Technical Documentationof of the Multiscale Model System M-SYS

(METRAS, MITRAS, MECTM, MICTM, MESIM)

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Preface

This documentation is based on earlier versions and is edited by the above authors. The previous version by Schlünzen et al. (2012) was used as basis, but that version is already based on earlier versions of the model documentation with many authors contributing different parts. The following contributors are gratefully acknowledged:

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The current model description corresponds mainly to the mesoscale model METRAS Version 5.0 and the microscale model MITRAS Version 2.0, as well as the LES version of METRAS.

1 Introduction

This report describes the structure and variable names of the M-SYS model system, which is developed in the mesoscale and microscale modelling group at the University of Hamburg. The single components are named “program” hereafter. The model theory is described in Schlünzen et al. (2018). The available programs and their use are listed in Table 1-1, their names are written in italics throughout the text.

The M-SYS model system is build-up in a way that shall ensure that variable names have the same meaning throughout the system. Therefore, the program name is only specifically mentioned, if the variables have a different meaning in different programs. In some cases the variable names used for physical variables were changed, when program code was translated from FORTRAN77 to FORTRAN90. These cases are specifically mentioned. It is also specifically mentioned if a variable name is used only in specific circumstances. The FORTRAN90 use is assumed as standard and not specifically mentioned.

Table 1-1: Available models, pre-processors and post-processors of the M-SYS modelling system with their programs and use. n/a means that a detailed documentation is currently not available.

Program	**Use**	**Type**	**Progr. Languag e**	**Documentatio n Reference**
MECTM	Mesoscale chemistry model	Model	f77	Schlünzen et al. (2018)
METRAS	Mesoscale meteorology model with passive tracer and pollen transport	Model	f90	Schlünzen et al. (2018)
METRAS-LES	LES version of model METRAS	Model	f90	n/a
METRAS-PCL	Mesoscale model including pre-processor m1tini to run on Linux PCs (for consultants)	Model	f90	n/a
MICTM	Microscale chemistry model	Model	f77	Schlünzen et al. (2018)
MITRAS	Microscale meteorology model with passive tracer transport	Model	f90	Schlünzen et al. (2018)
ECMWF	Interpolation of ECMWF re-analyses data on the metras grid	Pre-processor	f77	n/a
GRIGAU	Calculation of idealised topography	Pre-processor	f77	Linde et al. (2011)

Program	Use	Type	Progr. Language	Documentation Reference
GRITOP	Calculation of realistic topography	Pre-processor	f77	Spensberger and Schlünzen (2010)
M1TINI	1D model for calculation of balanced 3ort he3n3t be used for initialisation of 3D model	Model/ Pre-processor	f90	n/a
M3TM3T	Interpolation of METRAS or MECTM results on a higher resolving grid (used for nesting)	Pre-/Post-processor	f77	n/a
MASK	Creation of building mask	Pre-processor	f90	n/a
MEFOBS	Creation of analyses from observed data on the METRAS grid	Pre-processor	f90	n/a
STAR	Creation of photolysis rates	Pre-processor	f77	n/a
M3DIFF	Calculation of differences between model runs	Post-processor	f77	n/a
M3VALD	Validation of 3D model results with prescribed test cases	Post-processor	f77	n/a
MEMI_TOOLBOX	Import to Matlab, plot and other evaluation analysis	Post-processor	Matlab, C	Fock (2011)
P3ISOL	Plot program for cross sections and profiles based on NCAR-Graphics	Post-processor	f90	n/a
STATIO	Program to extract station data from model results to compare with point measurements	Post-processor	f90	n/a

Besides the models given in Table 1-1, some modules are available as extensions of the models (Table 1-2). For the naming of combined models and modules, the following convention is used:

- Combinations of different models should be combined with “/” (e.g. METRAS/MECTM).
- Combinations of different modules should be combined with “-“ (e.g. METRAS-LES, METRAS-MESIM).

Table 1-2: Available modules and their use in a corresponding model

Program	Use	Applied in model	Progr. Language	Documentation Reference
MESIM	Mesoscale sea ice model	METRAS	f90	Schlünzen et al. (2018)
SEMA	Sectional aerosol model	MECTM	f77	von Salzen (1997)

In Chapter 2 some more general information about the models and their use is given. Hints on processing of input data are given in Chapter 3, the record structure of the model output and hints about processing model output are given in Chapter 4. The implemented boundary conditions are listed in Chapter 5, names and species in the chemical module are listed in Chapter 6, values for specific parameters used internally in the model are tabled in Chapter 7, call trees for the models can be found in Chapter 8 and the main program variables are listed in Chapter 9 followed by a listing of the subroutine, function and module names in Chapter 10. Additionally, some references are given.

2 Managing the program code

As an example Figure 1 gives an overview on the programs needed for a concentration forecast using the model system. Control files are given including their names “TAPE” consistent with the use in the M-SYS modelling system.

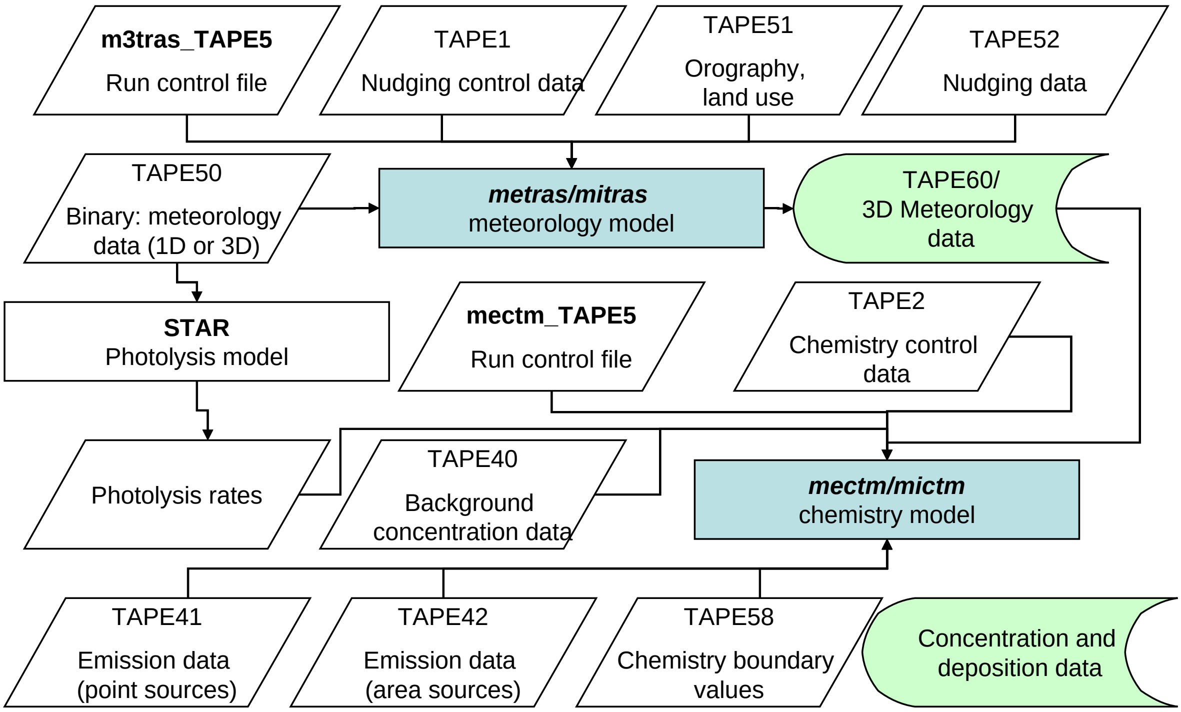

Figure 1: M-SYS modelling system with models (blue) metras/mitras and mectm/mictm for decoupled runs of meteorology and chemistry. Output files are marked in green.

2.1 Extraction of program code

All modules of the system are managed by using a UNIX-source code management system based on “rcs”. This source code management system, “PROTOOL”, is described in detail by Wosik et al. (1992).

The development of the model is done locally, and the code summarised in authorised versions. These can be found in the home directory of user u232015 in the sub-directory rcs and a text file (README_versions) lists the available versions and the main changes. The sub-directory *beta* includes versions that are still in test phase.

Alternatively the user can check out the model code from a subversion repository, which mirrors the authorized releases and is updated regularly. Access to the subversion repository is described in the group wiki to ensure restricted access. For further questions please contact the authors of this report directly.

2.2 Selection of M-SYS components

To allow shared source code for the different components of M-SYS conditional compilation based on pre-processor directives is implemented (Table 2-1). Additionall to switching between model components some special model configurations can also controlled via preporcessor directives (Table 2-2). These switches are controlled by #define / #undef switches in i_cprepro.h

Table 2-1: Control of M-SYS componen by preprocessor directives.

Directive switches	**M-SYS component**
kmetras	METRAS
kles	METRAS-LES
klpc	METRAS-PC[8]
kice	METARS-MESIM
kmitras	MITRAS[8]
kvegi	MITRAS[8] with explicit vegetation

Table 2-2: M-SYS run time settings by preprocessor directives

Directive switches	**Special run settings**
kfast	Modified model flow with different time steppings for some physical processes (e.g. recalculation of radiative and turbulent fluxes), model runs faster with accaptbly modified physics
kbpsep	Parameter to control BP writings: if defined write separate BP for every output time; if not defined collected to one single BP
kbin	Specify output format (unformatted)
kwtime	Estimate wall clock time needed for each openMP subroutine/function
ktree	Create dynamic call tree
kdebug	Control writings in debug mode
kibm	Settings for IBM AIX machine

[8] Additional to setting the directives it is necessary to check out the code differently from the version control system PROTOOL.

2.3 Compilation of program code

To compile the extracted code (Section 2.1), the source files (e.g. xyz.f90) are somewhat altered to ensure the model is running fast and program errors are traceable. The following steps are taken by an automatic procedure:

1. Line numbers are added to each line of code at its end (program pr_lnumber.c).
2. The gnu-preprocessor (cpp) is used
    - to restrict the code to the required part; this is controlled via gnu pre-compiler commands (#if – expressions; they can be found in i_cprepro.f90).
    - to expand the #define statements in the code.
3. Lines longer than 131 columns are broken into lines of 131 characters with continuation lines (&-command) (pr_lbreak.c).
4. The resulting files are stored with new names (e.g. i.xyz.f90).

The altered files are then compiled. If compiling is successful, the i.xyz.f90 files are moved to the directory LIB-3d, otherwise they remain in their original subdirectory.

3 Model control and input Data

The pre-processors (Table 1-1) create input data sets, which are necessary for model simulations.

3.1 Input files

The different sub-models of M-SYS have mandatory common input as well as mandatory individual and optional input files, which are only needed for certain model setups (Table 1-1).

Table 3-1: Input files and their meaning. Brackets mark optional input files.

Tape No.	**File-name**	**Content**	**Meteorology**			**Chemistry**	**Sea ice**
			1d	**3d**			
			m1tini	***metras***	***mitras***	***mectm / mictm***	***mesim***
1		nudging control data		(x)			
2		chemistry control data		(x)	(x)	x	
3		aircraft emission simulation control data		(x)			
4		tracer control data		(x)	(x)	x	
5	*_TAPE5	control of program specifics	x	x	x	x	x
10	*_TAPE10	control of sea ice model					x
31	BM*	obstacle information data			x		
32		leaf area density of vegetation			(x)		
34		Wind turbine characteristics		(x)	(x)		
40		background concentration data		(x)	(x)	x	

Tape No.	File-name	Content	Meteorology			Chemistry	Sea ice
			1d	3d			
			m1tini	*metras*	*mitras*	*mectm / mictm*	*mesim*
41	EP*	point source emission data		(x)	(x)	x	
42	EA*	area source emission data		(x)	(x)	x	
43		Aircraft emissions and influence		(x)	(x)		
44		Ship emissions		(x)	(x)		
50	BR*, Abin*	binary model result for restart or initialization		x	x	x	x
51	GA*	topography data	x	x	x	x	x
52	BF*	3d nudging data		(x)			
54		prescribed heat fluxes at the surface		(x)			
58	CF*	chemistry boundary values		(x)	(x)	(x)	
90	uiceini	initial ice drift					x
91	viceini	initial ice drift					x
92	*.nc (set in Tape10)	initial ice thickness, e.g. from satellite					x

3.2 Grid and topography generation

3.2.1 Creation of GIS input data needed for generation of topography files

Land cover and orography data can be prepared in geography information systems (GIS). These programs allow combination of different data sources most easily. The prepared dataset needs to be exported as standard ASCII grid format, which can be imported by the grid creation procedures.

3.2.2 Sub-grid-scale surface cover

Each grid cell in METRAS and MITRAS is composed of one or more sub-grid-scale surface cover classes. Currently, MECTM and MICTM do not consider sub-grid-scale surface cover. In METRAS and MITRAS, the surface energy budget and all surface-dependent fluxes are calculated with respect to the surface characteristics. The sea ice model MESIM does use sub-grid-scale surface classes but uses four surface classes to represent sea ice. Therefore, their meaning differs for MESIM applications of M-SYS.

3.2.3 Surface classes in MESIM

The well tested 10 surface cover classes from Schlünzen et al. 1996 have been replaced by the METRAS-50 classes, a predefined set of 56 surface cover classes with attributed physical parameters. Every METRAS-50 class is identified by a four digit number. During the simulation, only the METRAS-50 classes that occur within the model domain are considered; their identifiers are written by the GRITOP-preprocessor into the TAPE51. Using the switches sfcurb, sfcwat, and sfcice, a specific METRAS-50 class is defined as being a water class, an ice class, an urban class, or none of them. Hardcoded surface classes water (0) and urban (9) in the former version of the models have been removed. The switches act like a Kronecker delta function dependent on the surface cover class, for example (sfcurb):

$$\delta_{j,urb} = \begin{cases} 1, & if \;\; j \in \text{'urban'} \\ 0, & if \;\; j \notin \text{'urban'} \end{cases} \qquad (3.1)$$

where j is the surface cover class index and ‘urban’ generically refers to the user-defined interpretation of an urban surface. At present, the model has three surface cover classes automatically defined to function as an ‘urban’ surface (Table 3-2). Depending on the switch, different physical parameterizations are used (Schlünzen et al. 2018).

The values for the physical parameters and the switches are hard-coded in the subroutine iland.f90 that is called during the initialisation of the 1D-METRAS (se1_oiniti.f90). For MITRAS applications, the user is advised to ensure that $z_0 << z$ (lowest model level) for all surface cover classes used in the simulation.

Concerning the physical parameters, notably the concept of “urban” is different than in the former versions. In the well tested 10 surface cover classes the urban class consisted of buildings, streets, and urban vegetation. In the METRAS-50 classes “urban” contains only buildings and adjacent sealed surfaces. Streets and especially urban vegetation is not contained in the “urban” classes in the METRAS-50 classes.

In the chemical transport model the values for dry and wet deposition are calculated based on parameters for well tested 10 surface cover classes (see Section 7.1). Each parameter value (table entry) has a corresponding source (of precise values or of influence) labeled as superscripted characters. Entries with one or more numerical superscripts indicate values derived from sources containing an identical or nearly identical class name to that shown in column ‘Type’, and whose values are applied here accordingly. Where a clear nomenclature match was unavailable, entries with one or more alphabetical superscripts indicate a value derived from sources containing one or more classes which are believed to be related and which have influenced the value shown here. The values for QVCONT and QVDEEP are tuned to fit with the model’s physical parameterizations to get reasonable values for the simulated latent heat flux. The grid cell of each entry is shaded according to the relative strength of the value (i.e., confidence in its precision as a suitable average for this Type and in its applicability to other examples), based on the information available from sources. The shading scales from white (strong-confidence) to light gray (mixed-confidence) to dark gray (low-confidence). The user is advised caution when using a low-confidence class; careful evaluation of the properties of the modeling domain surface is strongly recommended.

Table 3-2: Surface characteristics for the METRAS-50 classes with albedo A_0 , thermal diffusivity k_s, thermal conductivity ν_s, soil water availability α_q (starting value), saturation value for water content W_k, roughness length z_0, urban / water / ice switch δ_i.

nm50sccl	Class	Type	A_0 ALBEDO	k_s THEDIF [m²/s]	ν_s THECON [W/mK]	α_q QVCONT	W_k QVDEEP [m]	z_0 YZ0CLS [m]	δ_i	
0	1000	Water	f(Z(t))[5]	1.50E-07[5]	100.00[5]	0.98[A]	100.0	f(u*)[5]	W	
1	1100	water, fresh, stationary	f(Z(t))[U]	1.50E-07[U]	100.00[U]	1.00	100.0	f(u*)[U]	W	
2	1222	water, fresh, dynamic	f(Z(t))[U]	1.50E-07[U]	100.00[U]	1.00	100.0	f(u*)[U]	W	
3	1300	salt water	f(Z(t))[U]	1.50E-07[U]	100.00[U]	0.98	100.0	f(u*)[U]	W	
4	1411	Mudflats	0.10[5]	7.40E-07[5]	2.20[5]	0.98	100.0	0.0002[5]		
5	1600	reserved for MESIM	-	-	-	-	-	-	I	
6	1710	reserved for MESIM	-	-	-	-	-	-	I	
	1711	sea ice, 0-10 cm thick	f(θ_z, $h_{i,c}$)[21]	1.50E-06[22]	2.035[22]	not used	not used	0.0010[21]	I	
	1712	sea ice, 10-40 cm thick	f(θ_z, $h_{i,c}$)[21]	1.50E-06[22]	2.035[22]	not used	not used	0.0010[21]	I	
	1713	sea ice, 40-100 cm thick	f(θ_z, $h_{i,c}$)[21]	1.50E-06[22]	2.035[22]	not used	not used	0.0010[21]	I	
	1714	sea ice, thicker than 100 cm	f(θ_z, $h_{i,c}$)[21]	1.50E-06[22]	2.035[22]	not used	not used	0.0010[21]	I	
	1715	reserved for MESIM	-	-	-	-	-	-	I	
	1716	reserved for MESIM	-	-	-	-	-	-	I	
	1717	reserved for MESIM	-	-	-	-	-	-	I	
	1718	reserved for MESIM	-	-	-	-	-	-	I	
	1719	reserved for MESIM	-	-	-	-	-	-	I	
	1720	reserved for MESIM	-	-	-	-	-	-	I	
	1721	reserved for MESIM	-	-	-	-	-	-	I	

nm50sccl	Class	Type	A_0 ALBEDO	k_s THEDIF [m²/s]	ν_s THECON [W/mK]	α_q QVCONT	W_k QVDEEP [m]	z_0 YZ0CLS [m]	δ_i	
	1810	reserved for MESIM	-	-	-	-	-	-	l	
	2105	bare ground	0.17[V]	3.80E-07[3]	1.18[3]	0.30	0.015	0.0012[4]		
	2106	sand	0.20[5]	5.70E-07[5]	1.05[5]	0.10	0.010	0.0003[5]		
	2107	gravel	0.12[7]	2.76E-07[14]	0.40[14]	0.10	0.010	0.0050[E]		
	2108	rock	0.10[M]	1.40E-07[3]	2.90[3]	0.05	0.010	0.0012[L]		
	2122	sand dune, with grass	0.20[F]	5.70E-07[F]	1.05[F]	0.15	0.035	0.0100[B]		
	2123	sand dune, spare vegetation	0.20[F]	5.70E-07[F]	1.05[F]	0.15	0.045	0.0500[T]		
	2220	asphalt	0.09[14,7,18]	2.30E-06[15]	1.35[14,9,7,12]	0.5	0.0015	0.0003[N]		
	2230	concrete	0.15[14,7]	2.30E-06[15]	1.81[9,10;7,18,13]	0.5	0.0015	0.0003[N]		
	2240	brick/pavers	0.30[1]	2.30E-06[15]	0.9[10]	0.02	100.0	0.0006[W]		
	2250	steel	0.30[11]	4.20E-06[19]	30[20]	0.5	0.0005	0.0003[N]		
	2712	Bushes, wet	0.20[D]	5.20E-07[D]	1.33[D]	0.65	100.0	0.1000[D]		
	2715	bare ground, wet	0.17[O]	7.40E-07[AC]	2.20[AC]	0.60	100.0	0.0012[F]		
	2911	salt pit	0.50[Q]	7.40E-07[AC]	2.20[AC]	0.98	100.0	0.0002[P]		
	3100	grass, short	0.20[B]	5.20E-07[B]	1.33[B]	0.35	0.050	0.0100[B]		
	3104	grass, short, wet	0.20[B]	5.20E-07[B]	1.33[B]	0.55	100.0	0.0100[B]		

nm50sc cl	Class	Type	A_0 ALBEDO	k_s THEDIF $[m^2/s]$	ν_s THECON [W/mK]	α_q QVCONT	W_k QVDEEP [m]	z_0 YZ0CLS [m]	δ_i	
	3138	grass, long	0.20[B]	5.20E-07[B]	1.33[B]	0.35	0.070	0.0200[X]		
	3148	grass, long, wet	0.20[B]	5.20E-07[B]	1.33[B]	0.55	100.0	0.0200[X]		
	3500	cropland	0.20[2]	5.20E-07[B]	1.33[B]	0.40	0.060	0.0400[2]		
	3830	cropland, irrigated	0.20[Y]	5.20E-07[B]	1.33[B]	0.65	100.0	0.0400[Y]		
	3863	Cropland, on sandy soil	0.20[Y]	5.20E-07[B]	1.33[B]	0.35	0.040	0.0400[Y]		
	4102	woody savannah	0.20[R]	5.70E-07[R]	1.05[R]	0.5	0.06	0.05[S]		
	4103	savannah	0.20[16]	5.70E-07[16]	1.05[16]	0.25	0.06	0.02[16]		
	4210	heath	0.15[5]	5.70E-07[AA]	1.05[AA]	0.15	0.423	0.0500[5]		
	4211	Heath, on sandy soil	0.15[Z]	5.70E-07[AB]	1.05[AB]	0.15	0.100	0.0500[Z]		
	4314	bushes, dry	0.20[D]	5.20E-07[D]	1.33[D]	0.15	0.060	0.1000[D]		
	4340	bushes, short	0.20[D]	5.20E-07[D]	1.33[D]	0.35	0.090	0.1000[D]		
	5100	forest, deciduous	0.17[2]	8.00E-07[C]	2.16[C]	0.60	0.120	1.0000[C]		
	5200	forest, coniferous	0.10[5]	8.00E-07[5]	2.16[5]	0.60	0.160	1.2000[5]		
	5213	forest coniferous, wet	0.10[G]	8.00E-07[G]	2.16[G]	0.70	100.000	1.2000[G]		
	5300	forest, mixed	0.15[5]	8.00E-07[5]	2.16[5]	0.60	0.120	1.0000[5]		

nm50sccl	Class	Type	A_0 ALBEDO	k_s THEDIF [m²/s]	ν_s THECON [W/mK]	α_q QVCONT	W_k QVDEEP [m]	z_0 YZ0CLS [m]	δ_i	
	5358	forest, mixed, dry	0.15[C]	8.00E-07[C]	2.16[C]	0.50	0.050	1.0000[C]		
	5656	forest, mixed, wet	0.15[C]	8.00E-07[C]	2.16[C]	0.70	100.000	1.0000[C]		
	5811	forest and bushes	0.20[D]	6.50E-07[AD]	1.75[AD]	0.45	0.100	0.2500[H]		
	6000	urban, sealed	0.18[I,]	1.22E-06[15]	3.03[9,15]	0.5	0.0015	0.9[I]		
	6005	urban, buildings < 11 m and surrounding sealed surfaces	0.18[J]	1.40E-06[15]	2.61[9,15]	0.5	0.0015	0.6[J]	U	
	6006	urban, buildings > 11 m and surrounding sealed surfaces	0.18[K]	2.30E-06[15]	3.44[9,15]	0.5	0.0015	1.2[K]	U	
	7010	mixed landuse	0.20[5]	5.20E-07[5]	1.33[5]	0.20	0.100	0.1000[5]		

The values for the physical parameters have been taken from Oke (1987) (1); Stull (1988) (2); Garratt (1992) (3); Wieringa (1993) (4); Schlünzen et al. (1996) (5); Grimmond and Oke (1999) (6); Kondo (2000) (7); Roth (2000) (8); Kusaka et al. (2001) (9); Ashrae (2005) (10); Prado and Ferreira (2005) (11); Dupont and Mestayer (2006) (12); Aschauer (2010) (13); Lee and Park (2008) (14); Fock (2011) (15); Kolusu (2012) (16); Masson (2000) (17); Masson et al. (2002) (18); http://en.wikipedia.org/wiki/Thermal_diffusivity, last access on 23.11.2011 (19); http://en.wikipedia.org/wiki/Thermal_conductivity, last access on 23.11.2011 (20); Birnbaum (1998) (21), Dierer (2002) (22)

Assumptions made during the definition of the parameters:

- A: Class 1000 is assumed to be salinated water.
- B: Assigned to the corresponding value of the class 'meadows' in (5).
- C: Assigned to the corresponding value of the class "mixed forest" in (5).
- D: Assigned to the corresponding value of the class 'bushes' in (5).
- E: Assumes the presence of large gravel stones, up to 5 cm in diameter.
- F: Assigned to the corresponding value of the class 'sand' in (5).
- G: Assigned to the corresponding value of the class "coniferous forest" in (5).
- H: Assigned according to 55 percent of the corresponding value of class 'bushes' in (5) and 45 percent of the corresponding value of class "mixed forest" in (5).
- I: Assumes mixed structural heights with a mean structural height of approximately 3.5 stories, 3.1 m per story. YZ0CLS value estimated from (2), (4), (6), (8) and (17), ALBEDO value estimated from (9), (14) and (15).
- J: Assumes mixed structural heights with a maximum height of 3.5 stories, approximately 3.1 m per story. Assumes a variable frequency, spacing and arrangement of structures typical of low density urbanization. YZ0CLS value estimated from (2), (4), (6), (8) and (17), ALBEDO value estimated from (9) and (15).
- K: Assumes mixed structural heights with a minimum height of 3.5 stories, approximately 3.1 m per story. Assumes a variable frequency, spacing and arrangement of structures typical of high density urbanization. YZ0CLS value estimated from (2), (4), (6), (8) and (17), ALBEDO value estimated from (9), (14) and (15).
- L: Assigned to the corresponding value of the class "bare ground" in (5).
- M: An estimate, assigned after comparison with classes 2105, 2106 and 2107.
- N: Assigned to the corresponding value of the classes 'runway tarmac' and 'concrete' in (4).

- O: An estimate, assigned to an approximate average of the classes “soils - dark, wet”, “soils - wet sandy” and “soils - wet clay” in (3).
- P: Assigned to the corresponding value of the class “mudflats” in (5).
- Q: An estimate, influenced by the ALBEDO corresponding to snow/ice surfaces of mixed age.
- R: Assigned to the corresponding value of class 4103.
- S: An estimate, assigned after comparison with class 4103, assuming a slightly higher mean vegetation height.
- T: An estimate, influenced by the YZ0CLS of both sand and vegetation types in (5).
- U: Assigned to the corresponding value of the class ‘water’ in (5).
- V: An estimate, based on dark soil types in the class set “soils” in (3).
- W: An estimate, influenced by the YZ0CLS of classes 2220 and 2230, with a presumed slight increase in roughness.
- X: An estimate, influenced by the YZOCLS of classes 3100 and 3104, with a presumed increase in roughness.
- Y: Assigned to the corresponding value of the class “cropland” in (2).
- Z: Assigned to the corresponding value of the class ‘heath’ in (5).
- AA: very low values for thermal diffusivity and thermal conductivity from (5) adjusted to more plausible values.
- AB: Same as heath.
- AC: Relatively high thermal diffusivity and thermal conductivity estimated due to the high soil moisture.
- AD: Somewhere between classes 5300 and 4340

3.2.4 Sea ice classes in MESIM

The surface classes 1 to 4 are differently used to the description above by the coupled atmosphere/seaice model METRAS/MESIM. These surface classes represent sea ice classes of different thicknesses. The roughness length is set to 0.001 m for all ice classes.

Table 3-3: Ice classes used in MESIM.

Class j	Ice thickness [cm]
1	0 – 10
2	10 – 40
3	40 – 100
4	>100

3.2.5 Topography generation for METRAS

The pre-processor GRITOP reads cadastre of topography data, creates a model grid and interpolates the data of land-use and surface heights to the model grid (Spensberger and Schlünzen, 2010). GRIGAU is very similar to GRITOP, but creates idealised orography (e.g. Gaussian hills) and random distributions of land-use (Linde et al., 2011). For details on the conversion of real data to model grid data, the implementation and application of these pre-processors, the reader is referred to Spensberger and Schlünzen (2010) and Linde et al. (2011). The unit of the topography input data is always metre.

3.2.6 Topography generation for MITRAS

For the small computational domain of MITRAS, the preprocessor GRIMASK (Salim, 2014) is used.

3.2.6.1 Orography height

Orography might also exisit in urban areas and is considered in MITRAS by terrain-following coordinates (Section 2.2 in Schlünzen et al., 2018). Both the aerodynamic as well as the radiative (shading) effects of the slopes are considered in MITRAS. For realistic applications, the orography data (terrain height above sea level) of the domain are introduced to GRIMASK in a standard ASCII grid format of a geographic information system (GIS). Usually these data are in much finer resolution (less than 0.25 m) compared to the computational domain horizontal resolution (~ 1 m). GRIMASK then aggregates these data to the surface grid cells to calculate the average orography height for each surface grid cell. This is done by splitting each grid cell into n sub-grids and calculating the orography height of each sub-grid. The eventual orography height, z_s, of a grid cell (i, j) is calculated from

$$z_s(i,j) = \frac{1}{n}\sum_{1}^{n} z_{sub}(x,y) \tag{47}$$

$z_{sub}(x,y)$ is the orography height of a sub-grid.

For idealized studies and test cases, GRIMASK can generate artificial orography heights according to the objective of the test case, e.g. a bell mouth hill or a Gaussian hill.

3.2.6.2 Surface Cover

It is essential to define the surface cover characteristics of the urban domain because they govern the surface energy budget (Section 5.2 of Schlünzen et al., 2018) and all surface dependent fluxes. The urban domain contains several surface cover types (water, sealed surfaces, vegetation, sand, ice, etc., see Table 3-2). The surface cover data are first introduced to GRIMASK in the GIS standard ASCII grid format. GRIMASK then integrates these data into the computational grid cells at the surface. Each grid cell is composed of at least one surface cover class, but subgrid scale surface covers are allowed (Section 3.2.2). GRIMASK calculates how many surface cover classes exist in the domain and the portion of each surface cover class in each grid cell. This is done following the approach used to calculate the orography heights (Section 3.2.6.1). Each grid cell at the surface is divided into sub-grids and the surface cover class of each sub-grid is defined. The data structure of the surface cover consists of two data sets: a) the portion of each surface cover class in each grid cell and b) a list of surface cover classes existing in the domain. Several classes are prepared in the surface cover class database also for the different vegetation types (coniferous trees, deciduous trees, bushes, etc. see Table 3-2). A database of several surface cover classes with attributed physical parameters (values in Table 3-2) is included in the 1-D MITRAS model.

For buildings, the explicit treatment is chosen. If the implicit consideration of obstacles is chosen, i.e. they are not explicitly resolved in the model grid, a much larger roughness length would be required which conflicts with a high vertical grid resolution. This is similarly true for trees. To distinguish surface cover classes, water, buildings and sea ice identifiers are incorporated for each surface cover class. These act as the Kronecker delta function to mark the particular class.

3.2.6.3 Building data

In the model MITRAS, detailed information on the building dimensions, shape, and location are needed for each building located in the domain to calculate the 3-D array *vol* and the building wall based markers described in Chapter 5 of Schlünzen et al. (2018). This is done in GRIMASK, which allocates the buildings to the computational grid. In the current version of MITRAS the 3-D field *vol* can be either 0 (building cell) or 1 (atmosphere cell). Therefore, the buildings are approximated to fit into the grid. Grid cells partially filled with buildings are determined to be a building or atmosphere cells in dependence on the volume fraction filled by the building. A grid cell filled with at least 50% of its volume by a building is denoted a building cell. Otherwise it is counted as an atmosphere cell. This approximation is computationally efficient to consider the effect of the buildings since the model equations only need to be multiplied by the 3-D field *vol*.

For realistic applications, the complex urban building geometry can be provided to GRIMASK in either the raster Digital Elevation Model (DEM) format, or in the ASCII 3-D Computer-Aided Design (CAD) format. GRIMASK integrates the high resolution DEM data, which is a grid of squares representing the elevation of each small grid, to the computational grid and calculates how much volume of the building is contained in each grid cell. When the building data are provided in the ASCII CAD format, GRIMASK uses an approach similar to z-buffering to integrate the building surfaces (usually triangles) to the computational grid and calculates the array *vol* and the face markers.

3.2.6.4 Vegetation

The vegetation input to MITRAS depends on the selected vegetation treatment in the model (Section 5.4. of Schlünzen et al., 2018). In the implicit mode, the vegetation is defined as a surface cover class. In the explicit mode, 3-D arrays of *LAD* and *LAI* are MITRAS input and prepared by GRIMASK. Two approaches are available in GRIMASK in order to calculate these arrays based on the available plant data. In the measurement approach, the following data for each plant in the model area are processed in GRIMASK: the measured 1-D vertical leaf area index profile $LAI(\dot{x}^3)$, the plant height, and the plant location. The following relation is used to relate *LAD* and *LAI*:

$$LAI\left(\dot{x}^3+\Delta z\right)=\int_z^{z+\Delta z} LAD\left(\dot{x}^3\right)dz \tag{49}$$

In the analytical approach, GRIMASK uses the following empirical relation proposed by Lalic and Mihailovic (2004) to describe LAD profile from plant parameters:

$$LAD\left(\dot{x}^3\right)=LAD_m\left(\frac{h-z_m}{h-\dot{x}^3}\right)^n exp\left[n\left(1-\frac{h-z_m}{h-\dot{x}^3}\right)\right] \tag{50}$$

LAD_m is the maximum *LAD*, h is the plant height above z_s, z_m is the corresponding height above z_s, and

$$n=\begin{cases} 6 & 0\le \dot{x}^3 < z_m \\ \frac{1}{2} & z_m \le \dot{x}^3 < h \end{cases} \tag{51}$$

The plant parameters used in these equations can be obtained from the forest phenology calendar.

3.3 Units of chemical species

The units of the species used for transport and reactions are different. As the reaction rates are given in m^3 s mol^{-1}, the unit of the calculation of reactions is mol m^{-3}. For the transport a conservative unit is necessary, mol kg^{-1} is used. Therefore the concentrations resulting from the chemical reactions are converted to mol kg^{-1}. The relation between mol kg^{-1} and mol m^{-3} is established by the air density ρ_0. The input and output unit of concentrations is ppb, for both – the background concentrations used as input data and the plotting data. The emission data has to be given in kg/h and needs to be converted to mol kg^{-1} s^{-1} in the model. For point sources, this is done in routine m3t_ctm_main for MECTM and in se_ctm for M3TRAS*;* for area sources of reactive tracers the conversion is done to ppmV min^{-1} in ochem_pvp (MECTM) and se_chem_pvp (METRAS), and for area sources of passive tracers to mol kg^{-1} s^{-1} in se_etrans_chem (METRAS only). The units used are:

- Model input concentrations [ppb]
- Emission data [kg/s] for EMIINI, [kg/h] for METRAS
- Transport (advection, diffusion, deposition) [mol kg^{-1}]
- Chemical reactions [mol m^{-3}]
- Model output concentrations [mol kg^{-1}]
- Plot output concentrations [ppb] (converted from mol kg^{-1})
- Model output deposition [mol m^{-2} s]
- Model output time series [ppb]
- Model output horizontal cross sections [mol kg^{-1}]

3.4 1-d model input

The one-dimensional version of METRAS/MITRAS requires two input tapes, respectively:

- TAPE5: control data for model run

- TAPE51: topography data file

TAPE51 is created by the pre-processors GRITOP or GRIGAU. It contains details on the location of the model area, grid structure, rotation of the model grid, topography heights at the grid points and the percentage of land-use classes at each grid point. It also includes details on the tide for simulations of coast lines with tidal flooding.

Instructions concerning the large-scale meteorological situation, integration time of the model, boundary conditions and other model control data have to be given in TAPE5. Since this file is well annotated and is continually adapted to new features of the model, it is not described in detail here. In case of problems with the meaning of variables or parameters to be set in TAPE5 please contact the authors.

3.5 3-d model input

For runs of the three-dimensional model version of METRAS the preparation of at least three input files is essential (see Figure 3). Again, TAPE5 contains control data of the model run. In contrast to the one-dimensional version no data about the meteorological situation is included in TAPE5. TAPE51 is identical to the TAPE51 used by the one-dimensional model version. TAPE50 is a binary file and contains the results of the one-dimensional model versions, which are necessary for initialising the three-dimensional model. For further restarts of the three-dimensional model this file is identical with binary output file (TAPE60) of each preceding three-dimensional run.

3.5.1 Input for nested model runs

For use of nested model version two additional input data files are needed. TAPE1 contains control data for the nesting. In particular the forcing coefficients and the variables to be forced are prescribed here. TAPE52 includes the forcing data. These can be produced by application by the pre-processor M3TM3T, which interpolates results given in a coarser resolution on the METRAS grid. Forcing data can also be provided by the pre-processors ECMWF and MEFOBS: The pre-processor ECMWF interpolates reanalyses from the ECMWF on the METRAS grid while the pre-processor MEFOBS generates analyses from observational data.

3.5.2 Input for simulations including tracer transport and chemistry

If a simulation with pollutant transport should be performed, additional input files have to be provided. Very similar to TAPE5, TAPE4 contains control data for tracer transport. The emission data file TAPE41 is created by the pre-processor EMIINI. Since this file has a formatted (FORTRAN) structure, a user can easily create own TAPE41 for test purposes. At the moment no pre-processor exists for creating a TAPE40, which includes concentration background data. The user has to edit this file and add concentration background data for the model run. If the transport close to sources have to be considered and thus a coupled model run for passive tracers have to be performed, the model requires an additional TAPE3, containing control data for the interactively coupled tracer run and, if the fully-coupled version is selected, point source data for up to 20 sources. This coupling considers only passive tracer transport but does not include chemistry. Model runs with pollutant transport including chemical reactions are controlled by TAPE2. In this file, among other details, the chemical reactions have to be prescribed. Since the input files are subject to continuous changes due to further model developments and are well annotated, they are not described in detail. In case of trouble with the meaning of variables or parameters in these files please contact the authors. TAPE52 is created with the pre-processor PRECHE. TAPE58 is a binary data file. It includes the boundary values for concentrations as a result of pre-processor M3TM3T, in case pollution transport has to be nested.

3.5.3 Input for microscale simulations

In addition for the tapes mentioned above, MITRAS needs a specification for building structures. These are included in TAPE31 and can be prepared with the program MASK. If vegetation shall be included the height of the trees has to be added into the topography data as a last column and the leaf area index (LAI) needs to be provided per tree type in TAPE32. The tree or bush type is encoded in the topography data by using the sub-grid-scale land-use characteristics.

3.5.4 Input sea ice simulations

In addition for the tapes mentioned above, the seaice model MESIM is controlled by the input in TAPE10. Balanced initial ice drift velocities need to be available as input files for prognostic runs. These initial velocities are stored component wise in the TAPE 90/91 and can be created by model prerun described in Section 3.7.

3.6 Creating METRAS output for METRAS

M3TM3T is a prepcocessor to interpolate the results of METRAS to another METRAS grid. It is used to calculate time dependent boundary conditions of species and for a nesting of METRAS into METRAS.

3.7 Running the sea ice model MESIM

a. The model MESIM uses sub-gridscale ice classes, therefore flux averaging needs to be used for surface layer fluxes. Five different modes are available for the ice model, which control which equations are solved. These modes are controlled in TAPE10 via the parameter IMCMETH. The meaning and the use of these modes are summarized in

Table 3-4. Some more details of the physical and technical details of these modes are listed in Table 3-5.

The initialisation of the METRAS/MESIM requires a chain of several model components:

2. Run 1d model to create meteorological input
3. Run ice model with IMCMETH=2 to calculate initial ice drift if needed
4. Use output of pre runs to start the final run:
    a. Use ice drift date from pre-run + 1d model results to start the model with IMCMETH = 3 or IMCMETH = 5 (start from restart file from pre-run with IMCMETH=2 should not work)
    b. Or run model with IMCMETH = 4 directly from 1d data

Table 3-4: Different modes of the ice model MESIM and their intended use

IMCMETH	Model	Use
-	Standart metras: no sea ice at all	Simulations over ice free sea
1	Fixed ice map coupled to atmospheric model	Investigate the influence of sea ice on the atmosphere
2	Initialize ice model: Find stationary initial ice velocity field (TAPE 90/91)	Pre-processor for sea ice forecasts using the dynamical ice model core (imcmeth 3 or 5)
3	Simplified ice model: dynamical ice model only	Simulation of sea ice conditions dominated by mechanical processes

4	Simplified ice model: thermodynamic ice model only	Simulation of sea ice conditions dominated by thermodynamical processes
5	Complete ice model including all physical processes	Forecasts of ice conditions which cannot handeled by the reduced ice model modes 3 or 4

Table 3-5: Properties of the different run modes of the atmosphere / sea ice model metras / mesim

IMCMETH		1	2	3	4	5
Properties	Normal METRAS	Fixed ice map	Stationary ice drift velocities	Dynamic ice model	Thermodynamic ice model	Full ice model
Time dependent atmospheric values	X	X	-	X	X	X
Changes of the surface temperature by sfc energy balance: Same as in standard metras (sfc class 1-9)	X	X[9]	-	X[9]		-
Changes of the surface temperature by sfc energy balance: Controlled by thermo. sea ice model for sfc classes 1-4; Same as in standard metras (sfc class 5-9)	-	-	-	-	X	X
Form drag of sea ice and special parameterization of z_0 over partial sea ice cover	-	X	X	X	X	X
Dynamic ice drift	-	-	X	X	-	X
Stationary solution of ice drift	-	-	X	-	-	-
Nested meteorology	(X)	(X)	-	(X)	(X)	(X)
Model restart	(X)	(X)	-	(X)	(X)	(X)
Output used as input for other ice model mode (IMCMETH)	-	1, 4,5	3, 5	3	4	5
Needed model results as input for initial run	1D	1D	1D	1D + results of 2	1D	1D + results of 2

[9] Simulated if surface energy balance selected (NTX3(1)=5)

4 Model output

Several programs for post-processing the model results exist. These programs all use the output files described in Section 4.1. The record structure of the binary data file output is described in Section 4.2.

4.1 Output files

Table 4-1 summarises the different output files. The file meanings in italics are always created by a model run. All other files are created only by in dependence of the model options.

Table 4-1: Output files and their meaning.

Tape Nr.	Common Name	Functional meaning	1D-Met.	3D-Met.	3D-Chem.	2D-Sea ice
6		report on model run	x (prints)	x (prints)		
7	AP	time series of residuum of BiCGSTAB pressure solver		x		
9	rpt.###	report for model run	x (writes)	x (writes)	x	
60	BP (3d) Abin (1d) AV (chem)	binary output	x[10]	x[11]	x[11]	
70-90	AL	time series at control grid point(s)	x	x		
62	AM	time series as model volume averaged values	x	x		
63	BR AR (chem)	binary output for restart		x	x	
64	AC	time series of the l^2-norm of the divergence before and after pressure solver		x		
65		time averaged surface (10 m and fluxes) values for forcing of ocean model		x		

[10] For restart

[11] For plotting

Tape Nr.	Common Name	Functional meaning	1D-Met.	3D-Met.	3D-Chem.	2D-Sea ice
67		time series of chemical species		x		
68	BC CC	Binary output (meteorology) binary output (chemistry)			x[12]	
69	out.69	chemistry tendencies			x	
99						
620	AI	Time series for sea ice				x

Error messages are written to standard output (TAPE6). Other control data of the run, are written to TAPE9. Time series of several meteorological variables at a selected grid point in the model domain are written to TAPE61. TAPE62 has the same file structure but includes model volume mean values and is used to control the accuracy of the model runs. TAPE67 is an output of a time series for all species in the case of a simulation with chemical reactions. This output can also be selected in the run control tape TAPE5 (Table 3-1).

The binary model output on TAPE60 contains grid structure data, large-scale fields and model results for different time steps. The output interval can be chosen in run control TAPE5. TAPE63 contains the same data but only for one time step. This file is written just before the model run exceeds the available CPU time. This file is used for a restart of the model.

If selected in TAPE5, two optional files are created by the three-dimensional version. TAPE65 and TAPE66 contain integrated meteorological, concentration and deposition fields at the surface and at the first grid level above the surface. The integration period is usually 10 minutes. TAPE65 has a special format for using these data further, e.g. in an ocean model.

4.2 Record Structure

Basically, four blocks of output record structures can be distinguished.

- The first block (Table 4-2) includes information on the model dimensions and is written only once.

[12] For plotting; file names different for online (BC) and offline (CC) chemistry model.

- The second block (Table 4-3) includes the so called A-structures. This is information on the grid and other control values of the model run. These data are written in the initialisation phase at least once and are always followed by the third block, the G-structures.

- The third block (Table 4-4) includes the so called G-structures. This is information on the basic state of the model, which corresponds to the large-scale variables. After the final orography is reached, these values are independent of time. These data are written in the initialisation phase at least once and always following the second block, the A-structures.

- The fourth block (Table 4-5) includes the so called M-structures. This is information on the time dependent mesoscale model results. These data are written with a frequency controlled by the user.

Table 4-2: Record structures for model output and control of plot program. All model output is written as REAL. Meanings of model output variables are also given in Section 0.

Rec. No	Variable name	Unit	Meaning	Variable name in program code	Physical variable
	ndim nx3 nx2 nx1	- - - -	Dimension of used model number of vector grid points in z-direction number of vector grid points in y-direction number of vector grid points in x-direction		

Table 4-3: A-record structures for model output and control of plot program. Each line 29ort h table corresponds to one record. All model output is written as REAL. Meanings of model output variables are also given in Section 0. “plot only” indicates a record only used in the plot program. Some records are currently not used, they are marked with “not used” in the column for variable names. Subroutines for reading are oinfa5x, oina50; subroutines for writing are outa60, se_outa60_sg.

A-Rec. No	Variable name	Unit	Meaning	Physical variable
	noreca		number of records in A-structure	
	nostra (1:noreca)		record numbers in A-structure	

A-Rec. No	Variable name	Unit	Meaning	Physical variable
0001	nend ndelta naus zeit dt ifilte delta	ddhh.mm ddhh.mm ddhh.mm s s s	NEND > 0: time steps till end of model run NEND < 0: time till end of model run model result output interval (time or time steps as NEND) time (step) of first model results time time step control value for filtering control value for filtering and absorbing layers	
0002	nte nbou ncor np1 npress nwind ntke ndis ypavmin (BR-file only)		control value for use of model equation for temperature control value for calculation of buoyancy control value for calculation of Coriolis force control value for calculation of pressure gradient fore (p1) control value for calculation of pressure gradient fore (p2) control value for calculation of wind control value for solving TKE-equation control value for solving equation for dissipation minimum of exchange coefficient	
0003	nqv nqlc nqlr nblhco nsfccl		control value for solving equation for specific humidity control value for solving equation for cloud water content control value for solving equation for rain water content control value for blending height concept (=1) or parameter averaging (=0) number of surface cover classes	
0004	nxyq ntrace nclyn lnudge		number of emission sources number of tracers control value for calculation with/without liquid water formation control value for nudging	

A-Rec. No	Variable name	Unit	Meaning	Physical variable
0005	resmax itmax ltyp htyp img		maximum residuum for elliptic pressure solver maximum number of iterations in pressure solver	
0006	timerad ecostz	s	time increment for calculation of radiation	
0007	ntsout		number of locations for time series output	
0008	nm50sccl		Total number of possible METRAS50 classes 68 (plus class with index 0)	
0009	not used			
0010	albedo thedif thecon thdeep qvdeep yz0cls urbsw	 m m	albedo thermal diffusivity in soil thermal conductivity in soil depth into which the daily temperature wave reaches in the ground water column depth in the ground roughness length for surface characteristics urban switch	
0011	yxmin ydx yta xvmet fxdxp1 fxp1dx mmi	m m m m	minimum coordinate in x-direction grid spacing in x-direction transformation constant for grid spacing in x-direction x-coordinate at vector grid points weighting factor in x-direction (05. For uniform grid), used for calculating averages (point/right hand neighbour) weighting factor in x-direction (05. For uniform grid), used for calculating averages (right hand neighbour/point) i-grid points for (ntsout) time series	

A-Rec. No	Variable name	Unit	Meaning	Physical variable
0012	yymin	m	minimum coordinate in y-direction	
	ydy	m	grid spacing in y-direction	
	ytb	m	transformation constant for grid spacing in y-direction	
	yvmet	m	y-coordinate at vector grid points	
	fydyp1		weighting factor in y-direction (05. For uniform grid), used for calculating averages (point/right hand neighbour)	
	fyp1dy		weighting factor in y-direction (05. For uniform grid), used for calculating averages (right hand neighbour/point)	
	zmmj		j-grid points for (ntsout) control time series	
0013	yztop	m	altitude of upper model boundary	
	ydz	m	vertical grid spacing (z-direction)	
	ytc	m	transformation constant of vertical grid spacing	
	zvmet	m	z-coordinate of vector grid point	
	fzdzp1		weighting factor in z-direction (05. For uniform grid), used for calculating averages (point above neighbour)	
	fzp1dz		weighting factor in z-direction (05. For uniform grid), used for calculating averages (above neighbour/point)	
	mmk		k-grid points for (ntsout) control time series	
0014	ytd	1	transformation constant for orography-slope in x-direction	
0015	yte	1	transformation constant for orography slope in y-direction	
0016	ytf		transformation constant in vertical direction (normalised vertical grid)	
	yeta	m	vertical coordinate at scalar grid point	
0017	ytg		transformation constant (vertical coordinate squeezing factor)	
	yzsurf		orography height at scalar grid point	
	yzssvv		orography height at u-,v-grid point	
0018	ephi		latitude (of x-,y-coordinate system origin)	
	elam		longitude (of x-,y-coordinate system origin)	
	edrewi		rotation angle of x,y-system against the N-E-system at the reference point of the topography	
	elon		longitude of each scalar grid point	
	elat		latitude of each scalar grid point	

A-Rec. No	Variable name	Unit	Meaning	Physical variable
0019	yz0 surfra		roughness length for momentum at scalar grid point fraction of sub-grid-scale land-use in a grid cell	
0020	nuvwxi		boundary values of wind vector (values in Chapter 5)	
0021	ydrewi ydrsin ydrcos		rotation angle of the x,y-system against the N-E-system for each grid point sin of rotation angle cos of rotation angle	
0022 - 0024	not used			
0025	lwest least lnorth lsouth		Control value for inflow (=1) or outflow (=0) western boundary Control value for inflow (=1) or outflow (=0) eastern boundary Control value for inflow (=1) or outflow (=0) northern boundary Control value for inflow (=1) or outflow (=0) southern boundary	
0026 - 0031	not used			
0032	np2xi		Boundary values of p2-pressure perturbation (values in Chapter 5)	
0033 - 0040	not used			
0041	imcmeth imcmask statvel		control parameters for the sea ice model (MESIM only)	
0042	hm, vm		land mask used in the sea ice model (MESIM only)	
0043 - 0049	not used			
0050	ntxi		boundary values of temperature (values in Chapter 5)	
0051	esecli elmin			
0052	not used			
0053	not used			

A-Rec. No	Variable name	Unit	Meaning	Physical variable
0054	lhflp nhflpf		control values for prescribing surface heat flux selection of corresponding time function	
0055 - 0058	not used			
0059	nxobst nyobst nzobst nsurfcount nsurftype nsurfdir		parameter for building surface cells: position of cell(nxobst/nyobst/nzobst) number of adjacient walls (nsurfcount) orientation of adjacient surface (nsurftype) direction of adjacient surface (nsurfdir)	
0060	not used			
0061	noahori		Control parameter for horizontal diffusions	
0062 - 0064	not used			
0065	ntkexi		boundary values of turbulent kinetic energy (values in Chapter 5)	
0066	ndisxi		boundary values of dissipation (values in Chapter 5)	
0067 - 0069	not used			
0070	nqvxi		boundary values of specific humidity (values in Chapter 5)	
0071	nqlcxi		boundary values of cloud water content (values in Chapter 5)	
0072	nqlrxi		boundary values of rain water content (values in Chapter 5)	
0073 - 0079	not used			
0080	nssxi		boundary values of tracer concentration (values in Chapter 5)	
0081	ntindx(ntrace)		function for assigning actually used tracer number (ntrace) to a fixed (and frozen) list of tracers	

A-Rec. No	Variable name	Unit	Meaning	Physical variable
0082	lacraft lship lbiog lpoll nemis_*		control value for aircraft emissions / influence control value for ship emissions control for emissions by biogeochemistry control for pollen emission number of active/passive point and area emitters	
0083 - 0099	not used			

Table 4-4: As Table 4-3, but for G-record structures. Subroutines for reading are oinfg5x, oing50; subroutines for writing are outg60, se_outg60_sg.

G-Rec. No	Variable name	Unit	Meaning	Physical variable
	norecg		number of records in G-structure	
	nostrg		structure numbers in G-structure (as given below)	
0100	zeit zeitg2 tgamma	ddhh.mmss	time time for new geostrophic values vertical temperature gradient (= environmental lapse rate)	
0101	iini jini		i-grid point for initialization j-grid point for initialisation	
0102 - 0117	not used			
0118	ini minirii mafrii		necessary for restart: in initialisation phase (=1) time or time steps for initialisation phase time or time steps for diastrophy phase	
0119	YZZ azshil tinsini twatini		vertical grid heights at vector grid points without orography orography height at time of restart temperature in soil for orography zero water temperature for orography zero	

G-Rec. No	Variable name	Unit	Meaning	Physical variable
0120	ugini		geostrophic wind (west-east component) for orography zero	
0121	vgini		geostrophic wind (south-north component) for orography zero	
0122	w0ini		vertical wind (basic state) for orography zero	
0123 - 0129	not used			
0130	p0ini		basic state pressure for orography zero	
0131 - 0149	not used			
0150	t0ini		basic state potential temperature for orography zero	
0151 - 0169	not used			
0170	qv0ini		basic state specific humidity for orography zero	
0171	qlc0ini		basic state cloud water content for orography zero	
0172	qlr0ini		basic state rain water content for orography zero	
0173 - 0199	not used			
0200	ug	m/s	geostrophic wind in W-E-direction (basic state)	U_g
0201 - 0209	not used			
0210	vg	m/s	geostrophic wind in S-N-direction (basic state)	V_g
0211 - 0219	not used			
0220	w0	m/s	large scale vertical wind (basic state)	W_0
0221 - 0230	not used			

G-Rec. No	Variable name	Unit	Meaning	Physical variable
0231	plot only	m/s	wind speed	*FF*
0232	plot only		wind direction	*DD*
0233 - 0299	not used			
0300	p0	Pa	basic state pressure	p_0
0301 - 0399	not used			
0400	rho0	kg/m^3	basic state density	ρ_0
0401 - 0409	not used			
0410	hiini		start value for ice thickness hi	
0411	hsini		start value for snow thickness hs	
0412	lifini		start value for length of ice floe lif	
0413	surfrathini		start value for surface fraction surfrath	
0414	uiceini	m/s	start value for ice west east drift (currently also used as inflow boundary condition)	
0415	viceini	m/s	start value for ice south north drift (currently also used as inflow boundary condition)	
0416 - 0499	not used			
0500	t0	K	basic state potential temperature	θ_0
0501	tinsoil	K	value for soil temperature in a depth of 10 cm to 2 m (value not time dependent during simulation but height dependent)	
0502	twater	K	water temperature for all water surfaces in the model area (value not time dependent during simulation but height dependent)	
0503	not used			
0504	not used			
0505	plot only		basic state virtual potential temperature	$\theta_0 (1+0.60789\ q_{v0})$
0506 -	not used			

G-Rec. No	Variable name	Unit	Meaning	Physical variable
0649				
0650	tke0	m^2/s^2	basic state turbulent kinetic energy	
0651 - 0653	not used			
0654	hflpa	W/m^2	Average values of prescribed heat flux	
0655 - 0659	not used			
0660	dis0	m^2/s^2	basic state dissipation	
0661 - 0699	not used			
0700	qvo	g/kg	Basic state specific humidity	q_{v0}
0701 - 0709	not used			
0710	qlc0	g/kg	Basic state cloud water content	q_{lc0}
0711 - 0719	not used			
0720	qlr0	g/kg	Basic state rain water content	q_{lr0}
0721 - 0799	not used			
0800	ss0	mol/kg	Basic state tracer concentration	C_0
0801 - 0889	plot only		basic state tracer concentration (tracer no. 1, …, 89)	$C_{1,0}$ … $C_{89,0}$
0890 - 0999	not used			

Table 4-5: As Table 4-3, but for M-record structures. Subroutines for reading are oinfm5x, oinm50; subroutines for writing are outm60, se_outm60_sg.

M-Rec No	Variable name	Unit	Meaning	Physical variable

M-Rec No	Variable name	Unit	Meaning	Physical variable
	norecm		number of records in M-structure	
	nostrm		Structure numbers in M-structure (as given below)	
1000	zeit jn dt dtold	ddhh. mmss s s	time time loop index (number of time step since start of model run) time step length time step length of previous time step	
1001	lresd lresh nliq ncnv		daily reset of precipitation and deposition values (lresd=1), else lresd=0 Hourly reset of deposition values (lresh=1), else lresh=0 existence of liquid water (nliq=1), else nliq=0 numerical scheme of vertical diffusion with Crank Nicolson (ncnv=1), centred differences (ncnv=0) or automated control (ncnv=-1)	
1002	mini nudcon nudpot		Time steps or time in initialisation	
1003	ihrold			
1004 - 1009	not used			
1010	vol (n3dobst)		Obstacle mask (=1 outside obstacle, =0 inside); only used in microscale model	
1011 - 1099	not used			
1100	qvcont	m	Integral water content in vegetation and soil	
1101 - 1799	not used			
1800	msurc		(not used)	
1801 - 1899	not used			

M-Rec No	Variable name	Unit	Meaning	Physical variable
1900	yz0 surfra	m	roughness length for momentum at scalar grid point[13] fraction of sub-grid-scale land-use in a grid cell	
1901	albedo_ice		albedo of sea ice (MESIM only)	
1902	yz0h2o	m	roughness length over water (time dependent)	
1903	yz0theta	m	Roughness length for heat	
1904 - 1945	not used			
1950			location of fine and coarse grid	
1951 - 1999	not used			
2000	ut[14]	m/s	velocity in x-direction	
2001	uf	m/s^2	time dependent changes of advection and diffusion terms for ut	
2002	(unnamed)	m/s	ut turned to east-west direction	
2003 - 2009	not used			
2010	puxw puxe	m/s	phase velocity c_1 for ut at the western boundary phase velocity c_1 for ut at the eastern boundary	
2011	puyw puye	m/s	phase velocity c_2 for ut at the western boundary phase velocity c_2 for ut at the eastern boundary	
2012	puzw puze	m/s	phase velocity c_3 for ut at the western boundary phase velocity c_3 for ut at the eastern boundary	

13 This is the same field as 19, but time dependent changes of z0 are considered. These especially take place for water surfaces.

14 Old variable name: UJN

M-Rec No	Variable name	Unit	Meaning	Physical variable
2013	puxs puxn	m/s	phase velocity c_1 for ut at the southern boundary phase velocity c_1 for ut at the northern boundary	
2014	puys puyn	m/s	phase velocity c_2 for ut at the southern boundary phase velocity c_2 for ut at the northern boundary	
2015	puzs puzn	m/s	phase velocity c_3 for ut at the southern boundary phase velocity c_3 for ut at the northern boundary	
2016 - 2019	not used			
2020	ut_init	m/s	Initial wind profile used for fixed boundary values (x-component)	
2021 - 2099	not used			
2100	vt[15]	m/s	velocity in y-direction	
2101	vf	m/s^2	Time dependent changes of advection and diffusion terms for v	
2102	(unnamed)	m/s	vt turned to north-south direction	
2103 - 2109	not used			
2110	pvxw pvxe	m/s	phase velocity c_1 for vt at the western boundary phase velocity c_1 for vt at the eastern boundary	
2111	pvyw pvye	m/s	phase velocity c_2 for vt at the western boundary phase velocity c_2 for vt at the eastern boundary	
2112	pvzw pvze	m/s	phase velocity c_3 for vt at the western boundary phase velocity c_3 for vt at the eastern boundary	

15 Old variable name: VJN

M-Rec No	Variable name	Unit	Meaning	Physical variable
2113	pvxs pvxn	m/s	phase velocity c_1 for vt at the southern boundary phase velocity c_1 for vt at the northern boundary	
2114	pvys pvyn	m/s	phase velocity c_2 for vt at the southern boundary phase velocity c_2 for vt at the northern boundary	
2115	pvzs pvzn	m/s	phase velocity c_3 for vt at the southern boundary phase velocity c_3 for vt at the northern boundary	
2116 - 2119	not used			
2120	vt_init	m/s	initial wind profile used for fixed boundary values (y-component)	
2121 - 2199	not used			
2200	wt[16]	m/s	vertical velocity	
2201	wf	m/s	time dependent changes of advection and diffusion terms for wt	
2202 - 2209	not used			
2210	pwxw pwxe	m/s	Phase velocity c_1 for wt at the western boundary phase velocity c_1 for wt at the eastern boundary	
2211	pwyw pwye	m/s	phase velocity c_2 for wt at the western boundary phase velocity c_2 for wt at the eastern boundary	
2212	pwzw pwze	m/s	phase velocity c_3 for wt at the western boundary phase velocity c_3 for wt at the eastern boundary	

16 Old variable name: WJN

M-Rec No	Variable name	Unit	Meaning	Physical variable
2213	pwxs pwxn	m/s	phase velocity c_1 for wt at the southern boundary phase velocity c_1 for wt at the northern boundary	
2214	pwys pwyn	m/s	phase velocity c_2 for wt at the southern boundary phase velocity c_2 for wt at the northern boundary	
2215	pwzs pwzn	m/s	phase velocity c_3 for wt at the southern boundary phase velocity c_3 for wt at the northern boundary	
2216 - 2219	not used			
2220	wt_init	m/s	initial wind profile used for fixed boundary values (vertical component)	
2221 - 2299	not used			
2300	plot only	m/s	wind speed based on horizontal wind components	$\|\vec{v}\|$
2301	plot only	m/s	wind speed based on all three components of the wind vector	$\|\vec{v}_{hori}\|$
2302	plot only	°	wind direction	*dd*
2303	plot only		wind vector	*vector*
2304	plot only		streamlines	*streamlines*
2305	plot only	1/s	divergence	*divergence*
2306	plot only		turned wind vectors (winds comp. parallel to east-west and north-south directions)	*vector*
2307	plot only		turned streamlines (winds comp. parallel to east-west and north-south directions)	*streamlines*
2308 - 2399	not used			
2400	womt	m/s	vertical velocity in boundary following coordinate system	
2401 - 3099	not used			

M-Rec No	Variable name	Unit	Meaning	Physical variable
3100	p1	Pa	mesoscale hydrostatic pressure perturbation	
3101 - 3199	not used			
3200	p2	Pa	mesoscale dynamic pressure perturbation	
3201 - 3299	not used			
3300	plot only	Pa	mesoscale pressure perturbation	$p_1 + p_2$
3301 - 3399	not used			
3400	plot only	Pa	total pressure	$p_0 + p_1 + p_2$
3401 - 3499	not used			
3500	plot only	Pa	surface pressure	p_s
3501 - 3999	not used			
4000	rhom	kg/m^3	mesoscale density perturbation	
4001 - 4099	not used			
4100	mold mnew		time indices (used in the sea ice model)	
4101	lold lnew		time indices (used in the sea ice model)	
4102	jndim		time loop index for the dynamic sea ice model (MESIM only)	
4103	statsiprof		control variable for the initial stationarity of the sea ice temperature profiles (MESIM only)	
4104	boutoiclp1		upper limit of the sea ice thickness in the surface classes 0, …, 4 (MESIM only)	
4105	dzstry		default values of vertical grid spacing in snow in the ice classes 1, …, 4 (MESIM only)	

M-Rec No	Variable name	Unit	Meaning	Physical variable
4106	dzitry		default values of vertical grid spacing in ice in the ice classes 1, …, 4 (MESIM only)	
4107 - 4109	not used			
4110	tim		real temperature in snow and ice (MESIM only)	T_i
4111	tw		temperature of the oceanic mixed layer (MESIM only)	T_w
4112 - 4119	not used			
4120	surfrath		fraction of surface classes 0.,…, 4 (MESIM only)	A_{icl}
4121	surfrathil		fraction of ice plus water of the surface classes 0,…, 4 (MESIM only)	
4122 - 4129	not used			
4130	nx3i		number of grid points in the ice in vertical direction (neglecting boundaries) (MESIM only)	
4131	nx3s		number of grid points in the snow in vertical direction (neglecting boundaries) (MESIM only)	
4132	nx3si		number of grid points in vertical direction in the sea ice (ice + snow); (neglecting boundaries) (MESIM only)	
4133	dzi		vertical grid spacing in ice in the ice classes 0,…, 4 (MESIM only)	
4134	dzs		vertical grid spacing in snow in the ice classes 0,…, 4 (MESIM only)	
4135 - 4139	not used			

M-Rec No	Variable name	Unit	Meaning	Physical variable
4140	hi		ice thickness in the ice classes 1,…, 4; (MESIM only)	$H_{i,icl}$
4141	hs		snow thickness in the ice classes 1,…, 4; (MESIM only)	$H_{s,icl}$
4142	hfb		freeboard height in the ice classes 1,…, 4; (MESIM only)	$H_{f,icl}$
4143	lif		length of ice floe in the classes 1,…, 4; (MESIM only)	$L_{i,icl}$
4144	wle		width of lead in the ice classes 1,…, 4; (MESIM only)	$L_{w,icl}$
4145 - 4149	not used			
4150	ethick		mean sea ice thickness; (volume per unit area); (MESIM only)	h
4151	ecomp		ice concentration, compactness (MESIM only)	A
4152 - 4159	not used			
4160	uice	m/s	drift-velocity in W-E-direction (MESIM only)	u_i
4161	vice	m/s	drift-velocity in S-N-direction (MESIM only)	v_i
4163 - 4169	not used			
4170	ustern0		friction velocity beneath the ice (MESIM only)	$u_{*,g,oc}$
4171 - 4179	not used			
4180	taxjnm1		temporary used variable for calculating the wind stress (MESIM only)	
4181	tayjnm1		temporary used variable for calculating the wind stress (MESIM only)	
4182 - 4189	not used			

M-Rec No	Variable name	Unit	Meaning	Physical variable
4190	imozint		time integration control variable for the dynamic sea ice model (MESIM only)	
4191	taxsto		temporary used variable for calculating the wind stress (MESIM only)	
4192	taysto		temporary used variable for calculating the wind stress (MESIM only)	
4193	taxtmp		temporary used variable for calculating the wind stress (MESIM only)	
4194	taytmp		temporary used variable for calculating the wind stress (MESIM only)	
4195 - 4999	not used			
5000	tetat	K	mesoscale potential temperature perturbation	$\tilde{\theta}$
5001	not used			
5002	plot only			$\theta' = \tilde{\theta} - \tilde{\theta}$ *(M3,M2,M1)*
5003	ztpsum[17]	K	total potential temperature	$\tilde{\theta} + \theta_0 = \bar{\theta}$
5004	plot only	K	mesoscale deviation of virtual potential temperature	$\tilde{\theta}(1+0.60789\tilde{q}_v)$
5005	plot only	K	total virtual potential temperature	$\bar{\theta}(1+0.60789\bar{q})$
5006	plot only	°C	real temperature	$\tilde{T} + T_0 = \bar{T}$
5007	tmean	K	horizontal mean of mesoscale temperature	
5008 - 5899	not used			
5900	tbuisurf	K	surface temperature (real) of building envelope	T_b
5910	sfcbnets	W/m^2	net short wave radiation at building surface	

17 Recommended: calculate in plot program to save storage for data to be stored.

M-Rec No	Variable name	Unit	Meaning	Physical variable
5911	sfcbnetl	W/m^2	net long wave radiation at building surface	
5912	sfcbinl	W/m^2	incoming long wave radiation at buildings	
5913	sfcbskyl	W/m^2	long wave 48ort he48n from sky onto buildings	
5914	sfcbgroul	W/m^2	long wave radiation from ground onto buildings	
5915	wturbu	W/m^2	sensible heat flux from atmosphere to building	
5916	wcondu	W/m^2	heat conduction through wall/roof (from inside to outside	
6000	averu	m^2/s	vertical exchange coefficient for momentum	K_{vert}
6001	ahoru	m^2/s	horizontal exchange coefficient for momentum	K_{hor}
6002 - 6009	not used			
6010	averphi	m^2/s	vertical exchange coefficient for scalar quantities	
6011	ahorphi	m^2/s	horizontal exchange coefficient for scalar quantities	
6012 - 6019	not used			
6020	wdev	m^2/s^2	autocorrelation of vertical wind fluctuations	$\overline{w'^2}$
6021	tcgam	K/m	counter gradient flux of temperature	Γ_θ
6022	qcgam	kg/ (kg m)	counter gradient flux of specific humidity	Γ_q
6023 - 6049	not used			
6050	tket	m^2/s^2	mesoscale portion of turbulent kinetic energy	$\mathrm{T\tilde{K}E}$
6051	rmixl	m	mixing length	l
6052 - 6059	not used			
6060	dist	m^2/s^2	mesoscale portion of dissipation	$\tilde{\varepsilon}$

M-Rec No	Variable name	Unit	Meaning	Physical variable
6061 - 6499	not used			
6500	ustern	m/s	friction velocity	u_*
6501	tstern	K	scaling value for temperature	θ_*
6502	fzdl	1	stability value with L: Monin-Obukhov length	z/L
6503	qvstern	kg/kg	scaling value for specific humidity	q_{v*}
6504 - 6549	not used			
6550	momfl	kg/m/s^2	momentum flux	$\rho_{0,surf}\ u_*^2$
6551	hfl	W/m^2	sensible heat flux	$-c_p\rho_{0,surf}\ u_*\theta_*$
6552	plot only	W/m^2	heat flux	
6553	vfl	W/m^2	latent heat flux	$-l_{21}\rho_{0,surf}\ u_*q_{v*}$
6554	hflpt	W/m^2	actual value of prescribed surface heat flux	*function x average prescribed heat flux*
6555 - 6599	not used			
6600	ujstern	m/s	subgrid-scale friction velocity for surface types j=0, …, 9	u_*^j
6601	tjstern	K	subgrid-scale value for temperature scaling value for surface types j = 0, …, 9	θ_*^j
6602	qvjstern	kg/kg	subgrid-scale value for specific humidity for surface type j = 0, …, 9	q_*^j
6603	surblh	m	blending height	l_b
6604	yzoi	m	Roughness length for momentum (per land use class)	z_{0i}
6604 - 6649	not used			
6650	tjjnb	K	subgrid-scale values for surface temperature of surface type j = 0, …, 9	$\bar{\theta}_s^j$

M-Rec No	Variable name	Unit	Meaning	Physical variable
6651	qvjjnb	kg/kg	subgrid-scale values for specific humidity at surface of surface type j = 0, …, 9	$\overline{q}_{1s}^{1j}$
6652 - 6699	not used			
6700	zinv	m	inversion height	z_i
6701 - 6709	not used			
6710	wstern	m/s	free convection velocity	w_s
6711 - 6999	not used			
7000	qvt[18]	kg/kg	mesoscale specific humidity perturbation	$\tilde{q}_v$
7001 - 7002	not used			
7003	zqvsum	kg/kg	internal function: total specific humidity	$\tilde{q}_v + q_{v,0} = \overline{q}_v$
7004 - 7005	not used			
7006	plot only	%	relative humidity	$\tilde{q}_v + q_{v,0} = \overline{q}_v$
7007	qvmean	g/kg	horizontal mean of mesoscale relative humidity	
7008 - 7099	not used			
7100	qlctt	g/kg	mesoscale specific cloud water content perturbation	$\tilde{q}_{lc}$
7101 - 7102	not used			
7103	plot only	g/kg	total specific cloud water content	$\tilde{q}_{lc} + q_{lc,0} = \overline{q}_{lc}$

18 Old variable name: QVJN

M-Rec No	Variable name	Unit	Meaning	Physical variable
7104 - 7106	not used			
7107	qlcmea	g/kg	horizontal mean of mesoscale specific cloud water content	
7108 - 7199	not used			
7200	qlrtt	g/kg	mesoscale specific rain water content perturbation	$\tilde{q}_{lr}$
7201 - 7202	not used			
7203	plot only	g/kg	total specific rain water content	$\tilde{q}_{lr} + q_{lr,0} = \bar{q}_{lr}$
7204 - 7206	not used			
7207	qlrmea	g/kg	horizontal mean of mesoscale specific rain water content	
7208 - 7209	not used			
7210	qlract	mm/h	rate of rain at surface	
7211	qlrdel	mm	sum of hourly rain	
7212	qlrint	mm	sum of daily rain	
7213 - 7299	not used			
7300	cool	K/d	cooling rate due to longwave radiation balance	
7301	heat	K/d	heating rate due to short wave radiation balance	
7302 - 7399	not used			
7400	sfcnetl	W/m^2	longwave radiation balance at the surface	
7401	sfcnets	W/m^2	shortwave radiation balance at the surface	
7402	swdo		(unused)	
7403	swup		(unused)	

M-Rec No	Variable name	Unit	Meaning	Physical variable
7404	sjnetl	W/m^2	longwave radiation balance at the surface at surface of surface type j = 0, …, 9	
7405	sjnets	W/m^2	shortwave radiation balance at the surface at surface of surface type j = 0, …, 9	
7406	sglob	W/m^2	total incoming short wave radiation	
7407	slbod	W/m^2	longwave radiation emitted from surface	
7408	slgeg	W/m^2	downward longwave radiation reaching the surface	
7409	ecostz		cos of zenith angle	
7505	t2m	°C	real temperature at 2 m	
7506	not used			
7507	qvrf2m	%	relative humidity at 2 m	
7508 - 7999	not used			
8000*	ssjn	mol/kg	mesoscale tracer concentration perturbation	$\tilde{C}$
8001 - 8089	ssjn		concentration of tracers 01, …, 89 (mesoscale part); written for plot only in BC/CC files, not used in restart	$\tilde{C}_{01}...\tilde{C}_{89}$
8090 - 8099	not used			
8100*	ssvd	m/s	deposition velocity	v_D
8101 - 8189	ssvd		deposition velocity of tracers 01, …, 89; written for plot only in BC/CC files, not used in restart	$v_{D,01}....v_{D,89}$
8190 - 8199	not used			
8200*	sssdel	mol/m^2	hourly dry deposited material	
8201 - 8289	sssdel	mol/m^2	hourly dry deposited material of tracer 01, …, 89; written for plot only in BC/CC files, not used in restart	
8290 - 8299	not used			
8300*	sssint	mol/m^2	daily dry deposited material	

M-Rec No	Variable name	Unit	Meaning	Physical variable
8301 - 8389	sssint	mol/m^2	daily dry deposited material of tracers 01, …, 89; written for plot only in BC/CC files, not used in restart	
8390 - 8399	not used			
8400	sssedi	m/s	sedimentation velocity	
8401 - 8489	sssedi	m/s	sedimentation velocity tracers 1, …, tracer 89; written for plot only in BC/CC files, not used in restart	
8490 - 8599	not used			
8600*	sswdel	kg/m^2	hourly wet deposited material	
8601 - 8689	plot only		hourly wet deposited material of tracer 01, …, 89	
8690 - 8699	not used			
8700*	sswint	kg/m^2	daily wet deposited material	
8701 - 8789	plot only	kg/m^2	daily wet deposited material of tracer 01, …, 89	
8790 - 8799	not used			
8800*	plot only			
(8901)	plot only	kg/kg	Tracer 1: coarse and fine mesh grid	
(8902)	plot only	kg/m/m/h	hourly dry deposited material tracer 1: coarse and fine mesh grid	
(8903)	plot only	kg/m/m/T	Deposited material tracer 1: coarse and fine mesh grid	
8904	not used			
(8905)	plot only	kg/kg	$\tilde{C}_{01} + C_{0,01} = \bar{C}_{01}$ of tracer 1: coarse and fine mesh grid	$\tilde{C}_{01} + C_{0,01} = \bar{C}_{01}$
8906 - 8999	not used			
9000	ssq	10^3 pollen	pollen emission values	

M-Rec No	Variable name	Unit	Meaning	Physical variable
9001 - 9200	ssq		pollen emission values; written for plot only in BC/CC files, not used in restart	
9201		K	Surface temperature of bisgenic emissions	
9202 - 9399	not used			
9400	ema0	kg/s	area source emission at begin of current time interval	
9401 - 9499	not used			
9500	ema1	kg/s	area source emission at the end of current time interval	
9501 - 9599	not used			
9600	emp0	kg/s	point source emission at beginning of current time interval	
9601 - 9699	not used			
9700	emp1	kg/s	point source emission at end of current time interval	
9701 - 9809	not used			
10009	plot only	°	latitude from GA-file	
10010	plot only	°	longitude from GA-file	
10011 - 10018	not used			
10017	plot only		surface height (area plot)	
10018	plot only		land use (area plot)	
10019	plot only		2 cloud use types (area plot)	
10020	plot only		coastline (area plot)	
10021 - 10102	not used			

M-Rec No	Variable name	Unit	Meaning	Physical variable
10103	fymin fyymin zz(nnf3)			
10104 - 10116	not used			
10117	Fortop		forcing file's topography, initial and final values	
10118 - 10999	not used			
11000			time of forcing	
11001 - 11799	not used			
11700	Fnudge		forcing factor	
11701 - 11999	not used			
12000	u0no no feld	m/s →	u-component forcing U0NO*BNNTS + U0NN*BNOTS is written	
12001 - 12019	not used			
12020		m/s	UGNO*BNNTS + UGNN*BNOTS	
12021		m/s	VGNO*BNNTS + VGNN*BNOTS	
12022 - 12099	not used			
12100	v0no no feld	m/s →	v-component forcing V0NO*BNNTS + V0NN*BNOTS wird herausgeschrieben	
12101 - 12199	not used			
12200	w0no no field	m/s →	W-component forcing W0NO*BNNTS + W0NN*BNOTS is written	
12201 - 12404	not used			

M-Rec No	Variable name	Unit	Meaning	Physical variable
12305	plot only	kg/s	divergence of forcing field	
12306 - 12399	not used			
13400	p0no	Pa	pressure forcing, as wind field	
13401 - 15002	not used			
15003	t0no	L	temperature forcing, as wind field	
15004 - 17002	not used			
17003	qv0no	kg/kg	specific humidity forcing, as wind field	
17004 - 17102	not used			
17103	qlc0no	kg/kg	forcing data cloud liquid water content at old forcing time	
17104 - 17202	not used			
17203	qlr0no	kg/kg	forcing data rain liquid water content at old forcing time	
17204 - 18499	not used			
18500	ss0no	mol/kg	forcing data per tracer at old forcing time	
18501 - 98999	not used			
99000 - 99009	userfield0 - userfield9		generic user defined output fields (defined on scakar grid) intended for prototyping and debugging.	
99010 - 99999	not used			

5 Implemented Boundary Conditions

The boundary conditions used in the model are described in this section. For the difference form of the equations see Appendix B in Schlünzen et al. (1996). The values are prescribed for the model runs in TAPE5 or TAPE4.

5.1 List of possible boundary conditions types

All boundary conditions are directly implemented at the boundary which does not always correspond to a grid point for the selected variable. Therefore the values at the outermost grid point are calculated by use of the assumption that the value at the boundary $\chi(\text{boundary})$ is the average of the surrounding values:

$$\chi(\text{boundary}) = 0.5(\chi(\text{outer most grid point}) + \chi(\text{next inner grid point})) \qquad (5.1)$$

The boundary conditions (type) and their physical meaning are given in Table 5-1. Pressure boundary conditions are coupled with other boundary conditions and thus automatically prescribed. The other boundary conditions are more or less independent and can be individually selected. However, some combinations might give unrealistic results from a physical or chemical point of view.

Table 5-1: Types of boundary conditions.

Type	Meaning
0	periodic boundary conditions
1	zero gradient at the boundary
2	gradient at the boundary equal to gradient in the model
3	fixed values prescribed
4	large-scale values prescribed
5	budget equations or other model used at the boundary (e.g. surface energy budget)
6	zero flux
7	flux at the boundary equal to flux in the model
8	flux at the boundary calculated from deposition velocity
9	radiation boundary conditions at the outermost grid point of the selected variable

Type	Meaning	
10	direct calculation as far as possible	
11	flux at boundary prescribed	
12	at inflow boundary zero gradient (type 1)	at outflow boundary gradient at the boundary equal to gradient in the model (type 2)
13	at inflow boundary fixed values prescribed (type 3)	at outflow boundary radiation (type 27)
14	at inflow boundary fixed values prescribed (type 3)	at outflow boundary gradient at the boundary equal to gradient in the model (type 2)
15	at inflow boundary large-scale values prescribed (type 4)	at outflow boundary zero gradient (type 1)
16	at inflow boundary time depending values prescribed (only for species) (type 4)	at outflow boundary zero gradient (type 1)
23	boundary normal wind components large-scale values prescribed (type 4)	boundary parallel wind components zero gradient (type 1)
24	boundary normal wind components large-scale values prescribed (type 4)	boundary parallel wind components gradient at the boundary equal to gradient in the model (type 2)
25	boundary normal wind components radiation boundary conditions (type 9)	boundary parallel wind components zero gradient (type 1)
26	boundary normal wind components radiation boundary conditions (type 9)	boundary parallel wind components gradient at the boundary equal to gradient in the model (type 2)
27	boundary normal wind components: direct calculation as far as possible (type 10)	boundary parallel wind components zero gradient (type 1)
28	boundary normal wind components direct calculation as far as possible (type 10)	boundary parallel wind components gradient at the boundary equal to gradient in the model (type 2)

5.2 Lower Boundary

At the lower boundary the boundary conditions marked in Table 5-2 with “i” are implemented. For model runs under realistic meteorological conditions the boundary conditions marked with “me” are recommended for use in the mesoscale model, the ones marked with “mi” are recommended for use in the microscale model.

Table 5-2: Implemented boundary conditions at the lower boundary inclusive record number and variable to store the boundary condition.

Type	**Wind** (u,v,w) 20 nuvwx3(1)	**Temperature** θ 50 ntx3(1)	**Humidity** q 70 nqvx3(1)	**Cloud water content** q^c 71 nqlx3(1)	**Rain water content** q^R 72 nqrx3(1)	**Tracer** C_j 80 nssx3(1)
0	i	i	i	-	-	-
1	-	i	-	me	-	-
3	me,mi	mi	mi	i	-	-
5	-	me	me	-	-	-
7	-	-	-	i	me	-
8	-	-	-	-	-	me,mi
11	-	me	-	-	-	-
27	i	-	-	-	-	-
50		Like 5, but with buildings				

5.3 Upper Boundary

At the upper boundary the boundary conditions marked in Table 5-3 with “i” are implemented. For model runs under realistic meteorological conditions the boundary conditions marked with “me” are recommended for use in the mesoscale model, the ones marked with “mi” are recommended for use in the microscale model.

Table 5-3: As Table 5-2, but for the upper boundary boundary inclusive record number and variable to store the boundary condition.

Type	**Wind** (u,v,w) 20 nuvwx3(2)	**Temperature** θ 50 ntx3(2)	**Humidity** q 70 nqvx3(2)	**Cloud water content** q^c 71 nqlx3(2)	**Rain water content** q^R 72 nqrx3(2)	**Tracer** C_j 80 nssx3(2)
0	i	i	i	-	-	-
1	-	me,mi	me,mi	me,mi	me	me,mi
2	-	i	i	-	-	i
3	-	i	i	i	i	i
4	i	-	-	-	-	-

Type	Wind	Temperature	Humidity	Cloud water content	Rain water content	Tracer
23	me,mi	-	-	-	-	-
24	i	-	-	-	-	-

5.4 Lateral Boundaries

At the lateral boundaries the boundary conditions marked in Table 3 with an “i” are implemented. For model runs under realistic meteorological conditions the boundary conditions marked with “me” are recommended for use in the mesoscale model, the ones marked with “mi” are recommended for use in the microscale model.

Table 5-4: As Table 5-2, but for the lateral boundary boundary inclusive record number and variable to store the boundary condition.

Type	Wind (u,v,w) 20 nuvwx1/2	Temperature θ 50 ntx1/2	Humidity q 70 nqvx1/2	Cloud water content q^c 71 nqlx1/2	Rain water content q^R 72 nqrx1/2	Tracer C_j 80 nssx1/2
0	i	i	i	i	i	i
1	-	me,mi	me,mi	me	me	i
2	-	i	i	i	i	i
3	-	i	i	i	i	i
9	i	-	-	-	-	-
13	mi[19]	-	-	-	-	-
15	i	i	i	me	me	me,mi
16	-	-	-	-	-	i[20]
25	i	-	-	-	-	-
27	me[20]	-	-	-	-	-

[19] Recommended for use when comparing with wind tunnel data.

[20] Recommended for nesting

6 Names of Species and Reactions Systems

Details on the chemistry module of MECTM and MICTM are given in Meyer (2006).

6.1 Names of Species

Table 6-1: List of implemented chemical species.

Species number in METRAS	**Species number in MECTM MICTM**	**Model variable name**	**Name of (lumped) species**	**Compound / Formula**
1	1	no2	nitrogen dioxide	NO_2
2	2	no	nitric oxide	NO
3	3	o3	ozone	O_3
4	4	hono	nitrous acid	HNO_2
5	5	hno3 EMEP	nitric acid	HNO_3
6	6	hno4	pernitric acid	HNO_4
7	7	no3	nitrogen trioxide	NO_3
8	8	h2o2	hydrogen peroxide	H_2O_2
9	9	hcho	formaldehyde	HCHO
10	10	co	carbon monoxide	CO
11	11	ald	acetaldehyde	ALD
12	12	op1	methyl hydrogen peroxide	CH_3OOH
13	13	op2	higher organic peroxides	RO_2H
14	14	paa	peroxyacetric acid	$CH_3(CO)OOH$
15	15	ket	ketones	CH_3COCH_3, and others
16	16	gly	glyoxal	OHC – CHO
17	17	mgly	methylglygloxal and other α-carbonyl aldehydes	$CH_3COCCHO$
18	18	dcb	unsaturated dicarbonyls	$R–(CHO)_2$
19	19	onit	organic nitrate	$R–ONO_2$
20	20	n2o5	dinitrogen pentoxide	N_2O_5
21	21	so2	sulphur dioxide	SO_2
22	22	(sulf) EMEP	sulfuric acid	H_2SO_4
23	23	ch4	methane	CH_4
24	24	eth	ethane	C_2H_6

Species number in METRAS	Species number in MECTM MICTM	Model variable name	Name of (lumped) species	Compound / Formula
25	25	hc3	alkanes, alcohols, esters, and alkynes with HO rate constant (298 K, 1 atm) less than 3.4 × 10^{-12} cm^3 s^{-1}	e.g. C_3H_8
26	26	hc5	alkanes, alcohols, esters, and alkynes with HO rate constant (298 K , 1 atm) between 3.4 × 10^{-12} cm^3 s^{-1} and 6.8 × 10^{-12} cm^3 s^{-1}	e.g. C_7H_{16},
27	27	hc8	alkanes, alcohols, esters, and alkynes with HO rate constant (298 K, 1 atm) greater than 6.8 × 10^{-12} cm^3 s^{-1}	e.g. C_nH_{2n+2}
28	28	ol2	ethene	C_2H_4
29	29	olt	terminal alkenes	e.g. C_nH_{2n}
30	30	oli	internal alkenes	e.g. C_nH_{2n}
31	31	tol	tolune and less reactive aromatics	e.g. $C_6H_5CH_3$
32	32	csl	cresol and other hydroxy substituted	e.g. $HOC_6H_4CH_3$
33	33	xyl	xylene and more reactive aromatics	e.g. $C_6H_4(CH_3)_2$
34	34	pan	peroxyacetyl nitrate and higher saturated PANs	e.g. $CH_3C(O)O_2NO_2$
35	35	iso	isoprene	C_5H_8
36	36	tpan	unsaturted PANs	$CHOCH = CHC(O)O_2NO_2$
37	37	(ora1)	formic acid	HCOOH
38	38	(ora2)	acetic acid and higher acids	e.g. CH_3COOH
39	39	ho2	hydroperoxy radical	HO_2
40	40	mo2	methyl peroxide radicals	MO_2
41	41	oln	NO_3-alkene adduct radicals	OLN
42	42	aco3	acetyl peroxy and higher saturated acyl peroxy radicals	ACO_3
43	43	tco3	unsaturated acyl peroxy radicals	TCO_3
44	44	ho	hydroxy radical	HO
45	45	ethp	peroxy radical formed from ETH	ETHP

Species number in METRAS	Species number in MECTM MICTM	Model variable name	Name of (lumped) species	Compound / Formula
46	46	hc3p	peroxy radical formed from HC3	HC3P
47	47	hc5p	peroxy radical formed from HC5	
48	48	hc8p	peroxy radical formed from HC8	
49	49	ol2p	peroxy radical formed from OL2	
50	50	oltp	peroxy radical formed from OLT	
51	51	olip	peroxy radical formed from OLI	
52	52	tolp	peroxy radical formed from TOL	
53	53	xylp	peroxy radical formed from XYL	
54	54	ketp	peroxy radical formed from KET	
55	55	xno2	additional NO to NO_2 conversions	XNO_2
56	56	xo2	additional HO to HO_2 conversions	XO_2
57	57	(nh3) EMEP	ammonia	NH_3
58	58	(hcl)	hydrochloric acid	HCL
59	59	(h2so)	sulfuric acid	H_2SO
60	60	(nh4n) EMEP	ammonium nitrate	NH_4NO_3
61	61	(nh4s) EMEP	ammonium sulphate and ammonium hydrogen sulphate	$(NH_4)_{1.5}H_{0.5}SO_4$
62	n/a	ptra	oak pollen	
63	n/a	pass	passive tracer substance	
64	n/a	xe1m	xenon 131 meta-stable	^{131}Xe
65	n/a	xe3b	xenon 133 beta decay	^{133}Xe
66	n/a	xe3m	xenon 133 meta stable	^{133}Xe
67	n/a	xe5b	xenon 135 beta decay	^{135}Xe
68	n/a	kr85	krypton 85	^{85}Kr

6.2 Reaction system EMEP

Table 6-2: Reaction system EMEP

No	Reaction	D_5	D_6	Subroutine
1	$SO_2 \rightarrow SO_4^{2-}$	see below		
2	$NO + O_3 \rightarrow NO_2$	1.325E+06	1430.	
3	$NO_2 + hv \rightarrow NO + O_3$	1.450E-02	-4.0E-01	
4	$NO_2 + OH \rightarrow HNO_3$	6.625E+06		
5	$NO_2 + O_3 \rightarrow NO_3^-$	7.228E+04	2450.	
6	$HNO_3 \rightarrow NO_3^-$	1.000E-05		
7	$NO_3^- \rightarrow HNO_3$	0.500E-05		
8	$NO_2 + CH_3COO_2 \rightarrow PAN$	1.927E+06		
9	$PAN \rightarrow NO_2 + CH_3COO_2$	1.95E+16	13543.	
10	$NH_3 + SO_4^{2-} \rightarrow NH_4SO_4$			aero_ammonia
11	$NH_3 + HNO_3 \rightarrow NH_4NO_3$			aero_ammonia

The formation of sulphate (reaction 1 in Table 6-2) depends on the season and the reaction rate has to be calculated as:

$$k_1(\tau) = 3 \cdot 10^{-6} s^{-1} + (2 \cdot 10^{-6} s^{-1}) \sin\left(2\pi \frac{(\tau - \tau_o)}{T_j}\right). \quad (6.1)$$

T_j is the number of days of a year, τ the Julian day of the year for which the simulation is performed, and τ_0 corresponds to 80 days, which is the beginning of spring.

7 Parameter Values

7.1 Parameters for dry deposition model

The calculation of deposition velocity depends on how the variable cssvd is set. Table 7-1 lists possible values and their meaning.

Table 7-1: Meaning of cssvd in the model.

0	prescribed deposition velocity unchanged
1	deposition velocity calculated for SO_2
2	deposition velocity calculated for NO
3	deposition velocity calculated for NO_2
4	deposition velocity calculated for HNO_2
5	deposition velocity calculated for HNO_3
6	deposition velocity calculated for NH_3
7	deposition velocity calculated for O_3
8	deposition velocity calculated for H_2O_2
9	deposition velocity calculated for $HCHO$
10	deposition velocity calculated for ALD
11	deposition velocity calculated for ORA
12	deposition velocity calculated for RO_2
13	deposition velocity calculated for PAN
14	deposition velocity calculated for PAA
15	deposition velocity calculated for SO_4^{2-}
16	deposition velocity calculated for NH_4N
17	deposition velocity calculated for NH_4S
18	deposition velocity calculated for $N(5)$
19	deposition velocity calculated for $S(6)$
20	deposition velocity calculated for Pb
21	deposition velocity calculated for HCl

In this section the parameters $r_{s,min}$, $r_{s,max}$, and $r_{s,wet}$ for the calculations of surface resistance r_s (see section 4.1 of Schlünzen et al., 1996) as implemented into METRAS until now are listed. Table 7-3 gives the parameters $r_{s,min}$, $r_{s,max}$, and $r_{s,wet}$ for SO_2.

Table 7-2: Parameters $r_{s,min}$, $r_{s,max}$, and $r_{s,wet}$ for SO_2

Land-use type	**Season**	**Resistance parameters**			**Variable name**
		$r_{s,min}$ **[s/m]**	$r_{s,max}$ **[s/m]**	$r_{s,wet}$ **[s/m]**	
water	spring	0	0	0	depro
	summer	0	0	0	depro
	early autumn	0	0	0	depro
	late autumn	0	0	0	depro
	winter	0	0	0	depro
mudflat	spring	100	100	100	depos
	summer	100	100	100	depos
	early autumn	100	100	100	depos
	late autumn	100	100	100	depos
	winter	100	100	100	depos
sand	spring	1000	1000	1000	depos
	summer	1000	1000	1000	depos
	early autumn	1000	1000	1000	depos
	late autumn	1000	1000	1000	depos
	winter	1000	1000	1000	depos
mixed vegetation	spring	50	100	0	depos
	summer	70	500	0	depos
	early autumn	500	500	100	depos
	late autumn	50	50	50	depos
	winter	100	100	100	depos
wet grass	spring	100	400	0	depos
	summer	100	500	0	depos
	early autumn	500	500	100	depos
	late autumn	500	500	100	depos
	winter	100	100	100	depos
heath	spring	75	250	0	depos
	summer	100	500	0	depos
	early autumn	500	500	100	depos

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
	late autumn	200	200	100	depos
	winter	100	100	100	depos
bushes	spring	100	1000	0	depos
	summer	70	1000	0	depos
	early autumn	800	800	300	depos
	late autumn	800	1000	300	depos
	winter	800	800	800	depos
mixed forest	spring	100	1000	0	depos
	summer	60	1000	0	depos
	early autumn	1000	1000	500	depos
	late autumn	1000	1000	500	depos
	winter	1000	1000	1000	depos
coniferous	spring	150	1000	0	depos
forest	summer	150	1000	0	depos
	early autumn	800	800	100	depos
	late autumn	800	1000	100	depos
	winter	500	500	500	depos
urban areas	spring	1000	1000	1000	depos
	summer	1000	1000	0	depos
	early autumn	1000	1000	1000	depos
	late autumn	1000	1000	1000	depos
	winter	200	200	200	depos

The parameters of other gaseous species are obtained by multiplying those of SO_2 with the constant factors $\hat{r}_s$ given in Table 7-3 following a suggestion of Chang et al. (1987):

$$r_{s,min}^{species} = \hat{r}_s^{species} \cdot r_{s,min}^{SO_2} \qquad (a)$$

$$r_{s,max}^{species} = \hat{r}_s^{species} \cdot r_{s,max}^{SO_2} \qquad (b) \qquad (7.1)$$

$$r_{s,wet}^{species} = \hat{r}_s^{species} \cdot r_{s,wet}^{SO_2} \qquad (c)$$

The values of $r_{s,min}$, $r_{s,max}$, and $r_{s,wet}$ used for the aerosols SO_4^{2-} , NO_3^- and Pb are listed in

Table 7-4 and Table 7-5.

Table 7-3: Conversion factors $\hat{r}_s^{species}$ (eq. 4) and surface resistances r_s for gaseous species.

No	Species	Symbol	$\hat{r}_s^{species}$ [21]	**Parameters** [22] **over water:** $r_{s,min}=r_{s,max}=r_{s,wet}$ **[m/s]**
1	nitric oxide	NO	1.0	7000. 3)
2	nitrogen dioxide	NO_2	1.0	7000. 3)
3	nitric acid vapour	HNO_3	0.0	0.
4	ammonia	NH_3	0.2	0.
5	ozone	O_3	1.0	2000.
6	hydrogen peroxide	H_2O_2	0.1	0.
7	formaldehyde	HCHO	0.5	10. 3)
8	formic acid	ORA	1.0	0.
9	methyl hydro peroxide	OP	0.3	0.
10	peroxyacetic acid	PAA	0.3	180. 3)
11	acetaldehyde	MeCHO	2.0	6400.
12	peroxide			400.
13	sulphate	S(6)		0.
14	nitrate	NO_3		0.
15	lead	Pb		0.
16	ammonium sulphate	NH_3SO_4		0.
17	ammonium nitrate	NH_4NO_3		0.
18	peroxiacetyl nitrate	PAN		9999.
19	nitrous acid	HNO_2		0.

1) variable name in METRAS: DEPFAK

2) variable name in METRAS: depro

3) Wesley (1989) und Pahl (1990)

[21] Variable name: depfak

[22] Variable name depro

Table 7-4: Parameters $r_{s,min}$, $r_{s,max}$, and $r_{s,wet}$ for SO_4^{2-} .

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
Water	spring	0	0	0	depro
	summer	0	0	0	depro
	early autumn	0	0	0	depro
	late autumn	0	0	0	depro
	winter	0	0	0	depro
Mudflat	spring	300	400	0	depos
	summer	200	400	0	depos
	early autumn	200	400	0	depos
	late autumn	300	400	0	depos
	winter	1000	2500	0	depos
Sand	spring	600	1200	0	depos
	summer	200	400	0	depos
	early autumn	400	800	0	depos
	late autumn	600	1200	0	depos
	winter	2000	4000	0	depos
mixed vegetation	spring	500	1000	0	depos
	summer	300	600	0	depos
	early autumn	500	1000	0	depos
	late autumn	500	1000	0	depos
	winter	1000	2500	0	depos
wet grass	spring	400	600	0	depos
	summer	300	600	0	depos
	early autumn	300	600	0	depos
	late autumn	400	600	0	depos
	winter	1000	2500	0	depos
heath	spring	320	650	0	depos
	summer	220	450	0	depos
	early autumn	320	650	0	depos
	late autumn	320	650	0	depos
	winter	570	1400	0	depos
bushes	spring	400	800	0	depos

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
	summer	200	400	0	depos
	early autumn	350	700	0	depos
	late autumn	400	800	0	depos
	winter	1000	2250	0	depos
mixed forest	spring	300	600	0	depos
	summer	100	200	0	depos
	early autumn	200	400	0	depos
	late autumn	300	600	0	depos
	winter	1000	2000	0	depos
coniferous forest	spring	140	300	0	depos
	summer	140	300	0	depos
	early autumn	140	300	0	depos
	late autumn	140	300	0	depos
	winter	140	300	0	depos
urban areas	spring	600	1200	0	depos
	summer	200	400	0	depos
	early autumn	400	800	0	depos
	late autumn	600	1200	0	depos
	winter	2000	4000	0	depos

Table 7-5: Parameters $r_{s,min}$, $r_{s,max}$, and $r_{s,wet}$ for NO_3^-.

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
water	spring	0	0	0	depro
	summer	0	0	0	depro
	early autumn	0	0	0	depro
	late autumn	0	0	0	depro
	winter	0	0	0	depro
mudflat	spring	300	400	0	depos
	summer	200	400	0	depos
	early autumn	200	400	0	depos

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
	late autumn	300	400	0	depos
	winter	1000	2500	0	depos
sand	spring	600	1200	0	depos
	summer	200	400	0	depos
	early autumn	400	800	0	depos
	late autumn	600	1200	0	depos
	winter	2000	4000	0	depos
mixed vegetation	spring	500	1000	0	depos
	summer	300	600	0	depos
	early autumn	500	1000	0	depos
	late autumn	500	1000	0	depos
	winter	1000	2500	0	depos
wet grass	spring	400	600	0	depos
	summer	300	600	0	depos
	early autumn	300	600	0	depos
	late autumn	400	600	0	depos
	winter	1000	2500	0	depos
heath	spring	320	650	0	depos
	summer	220	450	0	depos
	early autumn	320	650	0	depos
	late autumn	320	650	0	depos
	winter	570	1400	0	depos
bushes	spring	400	800	0	depos
	summer	200	400	0	depos
	early autumn	350	700	0	depos
	late autumn	400	800	0	depos
	winter	1000	2250[23]	0	depos
mixed forest	spring	300	600	0	depos
	summer	100	200	0	depos
	early autumn	200	400	0	depos

[23] Was wrong in old documentation (2550)

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
	late autumn	300	600	0	depos
	winter	1000	2000	0	depos
coniferous forest	spring	140	300	0	depos
	summer	140	300	0	depos
	early autumn	140	300	0	depos
	late autumn	140	300	0	depos
	winter	140	300	0	depos
urban areas	spring	600	1200	0	depos
	summer	200	400	0	depos
	early autumn	400	800	0	depos
	late autumn	600	1200	0	depos
	winter	2000	4000	0	depos

Table 7-6: Parameters $r_{s,min}$, $r_{s,max}$, and $r_{s,wet}$ for Pb.

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
water	spring	0	0	0	depro
	summer	0	0	0	depro
	early autumn	0	0	0	depro
	late autumn	0	0	0	depro
	winter	0	0	0	depro
mudflat	spring	300	400	0	depos
	summer	200	400	0	depos
	early autumn	200	400	0	depos
	late autumn	300	400	0	depos
	winter	1000	2500	0	depos
sand	spring	600	1200	0	depos
	summer	200	400	0	depos
	early autumn	400	800	0	depos
	late autumn	600	1200	0	depos
	winter	2000	4000	0	depos

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
mixed vegetation	spring	500	1000	0	depos
	summer	300	600	0	depos
	early autumn	500	1000	0	depos
	late autumn	500	1000	0	depos
	winter	1000	2500	0	depos
wet grass	spring	400	600	0	depos
	summer	300	600	0	depos
	early autumn	300	600	0	depos
	late autumn	400	600	0	depos
	winter	1000	2500	0	depos
heath	spring	320	650	0	depos
	summer	220	450	0	depos
	early autumn	320	650	0	depos
	late autumn	320	650	0	depos
	winter	570	1400	0	depos
bushes	spring	400	800	0	depos
	summer	200	400	0	depos
	early autumn	350	700	0	depos
	late autumn	400	800	0	depos
	winter	1000	2250	0	depos
mixed forest	spring	300	600	0	depos
	summer	100	200	0	depos
	early autumn	200	400	0	depos
	late autumn	300	600	0	depos
	winter	1000	2000	0	depos
coniferous forest	spring	140	300	0	depos
	summer	140	300	0	depos
	early autumn	140	300	0	depos
	late autumn	140	300	0	depos
	winter	140	300	0	depos
urban areas	spring	600	1200	0	depos
	summer	200	400	0	depos

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
	early autumn	400	800	0	depos
	late autumn	600	1200	0	depos
	winter	2000	4000	0	depos

Table 7-7: Parameters $r_{s,min}$, $r_{s,max}$, and $r_{s,wet}$ for PAA.

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
water	spring	0	0	0	depro
	summer	0	0	0	depro
	early autumn	0	0	0	depro
	late autumn	0	0	0	depro
	winter	0	0	0	depro
mudflat	spring	300	400	0	depos
	summer	200	400	0	depos
	early autumn	200	400	0	depos
	late autumn	300	400	0	depos
	winter	1000	2500	0	depos
sand	spring	600	1200	0	depos
	summer	200	400	0	depos
	early autumn	400	800	0	depos
	late autumn	600	1200	0	depos
	winter	2000	4000	0	depos
mixed vegetation	spring	500	1000	0	depos
	summer	300	600	0	depos
	early autumn	500	1000	0	depos
	late autumn	500	1000	0	depos
	winter	1000	2500	0	depos
wet grass	spring	400	600	0	depos
	summer	300	600	0	depos
	early autumn	300	600	0	depos
	late autumn	400	600	0	depos

Land-use type	Season	Resistance parameters			Variable name
		$r_{s,min}$ [s/m]	$r_{s,max}$ [s/m]	$r_{s,wet}$ [s/m]	
	winter	1000	2500	0	depos
heath	spring	320	650	0	depos
	summer	220	450	0	depos
	early autumn	320	650	0	depos
	late autumn	320	650	0	depos
	winter	570	1400	0	depos
bushes	spring	400	800	0	depos
	summer	200	400	0	depos
	early autumn	350	700	0	depos
	late autumn	400	800	0	depos
	winter	1000	2250	0	depos
mixed forest	spring	300	600	0	depos
	summer	100	200	0	depos
	early autumn	200	400	0	depos
	late autumn	300	600	0	depos
	winter	1000	2000	0	depos
coniferous forest	spring	140	300	0	depos
	summer	140	300	0	depos
	early autumn	140	300	0	depos
	late autumn	140	300	0	depos
	winter	140	300	0	depos
Urban areas	spring	600	1200	0	depos
	summer	200	400	0	depos
	early autumn	400	800	0	depos
	late autumn	600	1200	0	depos
	winter	2000	4000	0	depos

7.2 Parameters for Wet Deposition Model

Here the parameter values of a_s, b_s and c_s necessary 77ort he computation of washout coefficients (eq. 4.23 in Schlünzen et al., 1996). The values listed in Table 11 are taken from Martin (1984) and Tremblay and Leighton (1986).

Table 7-8: Parameters a_s and b_s for the calculation of washout coefficients.

Species	**Symbol**	**a_s [10^{-5} s^{-1}]**	**b_s[24] [10^{-5}]**	**c_S**
Sulphur dioxide	SO_2	0.	2.61	1
nitric oxide	NO	0.	0.99	1
nitrogen dioxide	NO_2	0.	2.18	1
Nitric acid	HNO_3	6.8	2.10	1
ammonia	NH_3	10.9	3.40	1
hydrogen peroxide	H_2O_2	7.5	2.30	1

24 Since (b_s) is an empirical formula the unit of b_s depends on the value of c_s

8 Call Tree

As an example of call trees for M-SYS a commented call tree of the atmosphere/sea-ice model METRAS/MESIM is shown in Table 8-1. The call tree of METRAS, being a subset of the slightly different but still similar call tree of MITRAS. Routines names are marked in bold font.

Table 8-1: METRAS-MESIM call tree.

M3TRAS					
	date_and_time				
	se_ikind Set kind values				
	se_iiedum Initialization variables for error messages				
	oinmet Initialization of model run				
		se_iall_par summaries call on several initializing subroutine			
			se_iphysc type and definition of physical parameters		
			se_ixcontr inizalization of control values		
			se_ixitpar initializationfor GMD-pressure-solver		
			se_ixtapnu initialization of input and output channel numbers		
		ochkra Check A output structure and complete NOSTRA array			
		ochkrg Check G output structure and complete NOSTRA array			
		ochkrm Check output M-structure and complete NOSTRM array			
		initialization run		restart run	
		oingaf read topographic (GA)-file		**se_imet** allocate and initialize basic arrays	
			se_imet initialize basic arrays	**se_iall_met**	
		okoeff coefficients for coordinate transformation		**se_iall_qv**	
		se_init_ctm chemistry model based on me-ctm		**se_ixtke**	
			se_intra read data for tracer control, background concentration and boundary concentration	**oingaf** read topographic (GA)-file	
					se_imet
					se_iall_met
					se_iall_qv
					se_ixboden
					se_ixblend

se_inche read emission data for point sources, area sources and control of output in report file	**se_ixpara**
	okoeff initialize transformation coefficients
	se_init_ctm initialize chemistry

se_inudge initializion parameters for nudging

se_ixnudge initializion fields for nudging

se_ixtke initializion fields for tke closure

se_ixdis initializion fields for tke-eps closure

se_iall_ice initializion fields sea ice model MESIM

initialization run		restart run
oi1a50 read 1d input		**oina50** read A structure
oi1g50 read G structure		**oing50** read G structure
	okoeff coefficients for coordinate transformation	
	se_inilscale extrapolate large scale background data from 1-d-results	
oi1m50 read M structure		**oinm50** read M structure

se_multini Allocation of working space for multigrid solver

se_readobst : read position of buildings, calculate boundary positions of the buildings

oinnud initialisation of forcing by nudging

se_dicht calculation of density

IGCG pressure solver	BiGSTAB pressure solver
se_p2lhs left hand side of poisson equation (pressure matrix)	**se_p2lhs_gs** left hand side of poisson equation (pressure matrix)
opilut	**se_multp2lhs**

se_stencil coefficients needed for modified upstream scalar advection

se_inice read and check of input tape m3tras_TAPE10

oifcpinit initialisation of ice floe configuration parameters

othermoiminit initialisation of thermodynamic sea ice model

se_wtransom calculation of w_omega from w, u and v

oinout definition of values for boundary condition fields

- **oshade** define minimum solor altitude for sunrise at every grid point (12 sectors).
- **onxisc** check of boundary conditions
- **se_ixintgr** initialization of time integrated 2d arrays at/above surface for output

ochkdi

se_outal Output of AL-files

out62 Output of AM-file

se_outa60_sg Output of BP-file

se_outg60_sg Output of BP-file

se_outm60_sg Output of BP-file

se_project Calculation of pressure perturbation (similar to se_p2) & vertical wind

Time integration loop

- **ozeit** Calculation of time and time-step
- Calculation of actual topography heights
  - **onudin** Initialization of forcing fields
    - **oinf52** Read of forcing data (f-structures)
  - **se_diast** Diastrophy of orography
    - **okoeff** Calculation of transformation coefficients
    - **ogeobe** Calculation of large-scale values (e.g. p0,t0,...)
    - **se_inttins** Interpolation of soil temperature depending on surface elevation
    - Adaptation of nonhydrostatic pressure solver matrix

oigcg-pressure solver	bicgstab pressure solver
se_p2lhs - Poisson equation left hand side	**se_p2lhs_gs** Matrix elements Poisson equation (left hand side)
opilut Incomplete LU decomposition of matrix B	

    - Adaptation of transformation of pressure solver matrices for multigrid methods
    - **se_multkoeff** Calculation of coordiate transformation coeficients for multigrid methods
    - **se_multp2lhs** Matrix elements for Poisson equation (left hand side) for multigrid methods
- **odynim** Calculation of seaice motion
  - **osurc_ice** Effective z0 + blending height + thermodynamic. b.c. for dynamic ice model
  - **oastar_ice** Scaling parameters (u* theta*,q*) for surface layer fluxes incl. form drag

- **otauice** Calculation of atmospheric drag used on B grid
- **odyniminit** Initialization of some variable (restart and first time step only)
- **owatvel** Geostrophic ocean current
- **odynimmcl** Main computational loop of dynamical sea ice model
  - **opressu** Calculation of ice pressure at scalar points
  - **oplast** Calculation of viscosities
    - **ostrain** Strain tensor at H grid points
  - **orelcon** Momentum equation terms not depending on previous time step u and v
    - **obcoef** Local grid point contribution to finite diff. approx. of viscous and advection
  - **orelax** Solve new velocities by over-relaxation
    - **oddy, oddx** Calculate derivatives
    - **omadv** Add in horizontal advection terms
    - **obcsv** Set ice drift velocity boundary conditions
  - **obcsv** Set ice drift velocity boundary conditions
  - EMDE advection scheme
  - **oadvecty, oadvectx** Solution of continuity equation
    - **osurfratempx, surfratempy** Advection of ice concentration
    - **ohitempx, ohitempy** Advection of ice thickness, snow thickness and ice floe length
    - **otsitempy, otsitempx** New temperature profiles in the sea ice after advection
      - **ocondovgpjjji** Normalized depth of vertical grid points
      - **ovgp** Calculation of vertical grid
      - **ocondovgpjjji** Normalized depth of vertical grid points
    - **oicezero** Fix small ice coverage
    - **oamax1** Fix ice coverage > 100%
  - **obcsh1** Calculation of scalar quantities at boundaries by upstream
  - **obcsh2** Boundary conditions for scalar quantities (SURFRATH,HI,HS,LIF)
  - **oicezero** Fix small ice coverage
  - **oamax1** Fix ice coverage > 100%
  - **obcsv** Set drift velocity boundary conditions
  - **oicezero** Fix small ice coverage
  - **oformopwa** Open water formation due to shearing deformation
  - **oicezero** Fix small ice coverage

- - **obcsh2** Boundary conditions for scalar quantities (SURFRATH,HI,HS,LIF)
    - **oicezero** Fix small ice coverage
    - **oamax1** Fix ice coverage > 100%
  - **oidynacouple** Sea ice atmosphere coupling
- **osurc_ice** Effective z0 + blending height + thermodynamic. b.c. for dynamic ice model
- **otqbsurm5** Sea ice + water surface temperatures + humidities for thermodynamic ice model
- **se_oastarfa** Scaling parameters (u* theta*,q*) for surface layer fluxes incl. form drag
  - **fe_formdr** Integral in form drag calculation
- Calculation of vertical diffusion coefficients
  - **oauber** Profile scheme of Schluenzen (1990), based on Dunst (1982)
  - **oauhol** Countergradient scheme of Luepkes, Schluenzen (1996)
  - **oaumix** Mixing-length approach
  - **oautro** Countergradient scheme of Troen, Mahrt (1986)
  - **se_exchange_tke** Turbulent kinetic energy equation
  - **oaudis** Turbulent kinetic energy equation and equation for TKE dissipation
  - **se_sgsm_deardo** Subgrid scale modell for LES
- **oahori** Calculation of horizontal diffusion coefficients
- **se_ewical** Calculation of wind
  - Advection and diffusion time step n-1
  - Calculation of advection
    - **oadvf** with 2nd order central scheme
    - **oadvf_eno** with eno and weno schemes
  - **odif** Calculation of diffusion
    - Implicit scheme
      - **odiuvi** u-component
      - **odivvi** v-component
      - **odiwvi** w-component
    - Explicit scheme
      - **odifve**
  - **oranfs** Calculation of boundary conditions, types 9, 15, 27
  - Advection and diffusion time step n
  - **se_p1f** Calculation of pressure gradient force (p1)
  - **se_corf** Calculation of Coriolis force
  - **se_bouf** Calculation of buoyancy force
  - **oranfp** Calculation of boundary conditions, type 27
  - Absorbing layers

- **onwind** Calculation of nudging for wind components
- **oranfe** Calculation of all boundary conditions, temporal values
- **ofilte** Filtering of values on !-surfaces
- Decision between hydrostatic/nonhydrostatic calculation
- **owhydr** Calculation of w (hydrostatic)
  - **oinout** Control of inflow/outflow boundaries
  - Calculation of vertical wind from hydrostatic assumption
- Pressure pertubation p2 calculated
  - no
    - **oinout** Control of inflow outflow bound-aries
  - yes
    - **se_p2** Calculation of pressure pertubation p2
    - **se_wtransom** surface normal wind component womega
    - **se_p2f** pressure gradient force (p2), time step n
    - **se_womcorr** rest divergency due to boundary effects
    - **se_div** Calculation of divergency
    - **oigcg** Iteration of elliptic equation
    - **obmul** Matrix multiplication
    - calculation of pressure change (solve poisson equation) with
      - **oigcg** IGCG solver
      - **se_multp2** BiCGSTAB solver
    - **se_p2f** Calculation of pressure gradient force (p2), time step n+1
    - **se_div** Calculation of divergency
    - **se_omtransw** new vertical velocity
- **ocuvw** Calculation of phase velocities

se_escalar Calculation of scalar quantities

- **ophid0** Tendencies for all scalar quantities zero
- **se_iced0** Preparations for the thermodynamic sea ice model
- **oansacp** Near surface temperature and specific humidity as well as cloud parameters
- **osalbedo** Calculation surface albedo
- **osuenba** Sfc. energy balance => temporary conductive heat flux at snow/ice surface
- **ostorb** Storing of boundary values for all solar quantities
- **ostlof** Calculation of surface fluxes for blending height concept
- **ouitra** Wind transformation to eta-system
- **se_phad** Advection and diffusion for each scalar quantity separately
- **odipcg** Countergradient (heat & mositure) fluxes for selected exchange coefficients

- - **odip** Calculation of diffusion
    - Calculation of horizontal diffusion
      - Implicit scheme: **odipvi**
      - Explicit scheme: **odipve**
  - **ouitra** Wind re-transformation
  - Calculation of sources/sinks
  - **ocloud** Calculation of cloud physical processes
    - **oauto** Autoconversion
    - **oakkr** Akkreszcenz
    - **oevap** Evaporation
    - **osedi** Sedimentation
    - **okond** Condensation
  - **se_tke_sources** Calculation of sources in tke equation for RANS model
  - **se_sgsm_source** Calculation of sgs tke sources for LES model
    odisqu Calculation of the dissipation equation (if specified)
  - **orad** Calculation of radiation budget in the atmosphere
    - **lwflux** Long wave radiation fluxes
    - **swflux** Short wave radiation fluxes
  - Calculation of temporal final values
  - **oliqad** Adjustment of liquid water
  - **onscal** Calculation of nudging for each scalar quantity separatly
  - **otbsur** Calculation of surface temperature (if bc. 5)
    - **se_tbsur_ice** Calculation of sgs ice coverages and sgs surface temperatures
  - **oqbsur** Calculation of surface humidity (if bc. 5)
    - **se_qbsur_ice** Calculation of surface humidity for water and ice surfaces
  - **ophhor** Lateral boundaries for each scalar quantity separately
  - **ophver** Vertical boundaries for each scalar quantity separately
  - **ofilte** Filtering of all scalar quantities on !-surface
- **se_dicht** Calculation of mesoscale density
- **se_p1** Calculation of pressure perturbation p1
- Calculation of final pressure, temperature and humidity
- **se_ctm** Chemistry model based on me-ctm
  - **se_cnest** Time dependent boundary conditions for species
    - **se_inf58** read data for time dependent tracer boundaries
    - **se_checkbc** check concentration range of boundary values

  - **se_check_conc** Checking concentrations
  - **se_emis** All sorts of emissions (point/area sources, ship, aircraft and pollen emissions)
    - **se_ptra_emis** Prescribes pollen emissions
    - **se_acinfl** Prescribes aircraft emissions
    - **se_shinfl** Prescribes ship emissions
  - **se_check_conc** Checking concentrations
  - **se_radio** Calculation of radioactive decay
  - **se_check_conc** Checking concentrations
  - **se_trans** Transport of chemical and tracer substances (including advection, sedimentation and deposition)
    - **se_part_sedi** calculate sedimentation
    - **se_vdepo** calculate deposition velocities
    - **ostorb** save boundary values
    - **ophhor** lateral boundary values
    - **ophver** top & bottom boundary values
      se_check_conc Checking concentrations
    - **ouitra** transformation of wind to eta-system
    - **se_phad** calculation of advection and diffusion
    - **se_check_conc** Checking concentrations
    - **ouitra** Back-transformation of wind from eta-system
  - **se_check_conc** Checking concentrations
- **se_outal** Write of time series data
- **out62** Write of time series data (area mean values)
  - **se_div** Calculation of divergency
  - **se_mmmsd** Min, max and mean 3D fields + std. deviations of all 2d-slices
- **outint** Write of integrated 2-d arrays
- **outchem** Write of chemistry data
- **se_outa60_sg / se_outaf60_sg** Write A-structure
- **se_outg60_sg / se_outgf60_sg** Write G-structure
- **se_outm60_sg / se_outmf60_sg** Write M-structure model results
- **se_outc68_sg** Chemistry output
- **se_structure** Initialize record numbers necessary for restart
- **outa60** Output restart data (BR-file)
- **outg60** Output restart data (BR-file)
- **outm60** Output restart data (BR-file)

		se_check Calculate checksums of the model results
	End of time integration loop	
End of model M3TRAS		

9 Main Program Variables of M-SYS Model System

Table 9-1: Global variable names in M-SYS model system. In consistency with the coding rules all variable names are given in small letters.

Variable	Module	Symbol	Explanation
		α	relation between exchange coefficients of scalar quantities and of momentum at neutral stratification
ahorphi	mo_xaust	$\hat{K}_{hor}$	horizontal exchange coefficient (scalar quantity)
ahoru	mo_xaust	K_{hor}	horizontal exchange coefficient (momentum)
ajdos	mo_ximatmo		downward sw-radiation at the surface
ajnetl	mo_ximatmo		net lw-radiation at the surface
ajnets	mo_ximatmo		net sw-radiation at the surface
albedo	mo_xboden	A	albedo
albedo_ice	mo_ximatmo		albedo of ice or ice with snowcover of each ice class
amas	mo_xamas		
aqphp1			local 1-d vector corresponding to 3-d local array PHIJNP1 (EQUIVALENCE instruction)
arsc	mo_siwconst		similarity constant
asy	mo_xasy		asy is the axymetrical term (coriolis + water drag) in over-relaxation of momentum equation to calculate ice drift
averphi	mo_xaust	$\hat{K}_{vert}$	vertical exchange coefficient (scalar quantity)
averu	mo_xaust	K_{vert}	vertical exchange coefficient (momentum)
b...	mo_xbrand		coefficients for pressure-solver at boundaries
b...	mo_xcilu		coefficients for pressure-solver
b...	mo_xcmatp		coefficients for pressure-solver
beta	mo_siwconst		constant for calculation of heat conductivity of saline ice
bnnts			weight of new time step for forcing data
bnots btflx	 mo_xtemp		weight of old time step for forcing data heat flux from buildings to atmosphere
boutoiclp1	mo_xbouto		

Variable	Module	Symbol	Explanation
brsc	mo_siwconst		similarity constant
bu	mo_xbubv		
bv	mo_xbubv		
cdswat	mo_siwconst		skin drag coefficient
cfile			name of file, containing start values
cgrid			position and grid size of each cell
cgrid(1,2,3).x vec(ji,jj,jk)			position (in m) of vector grid point (component u=1, v=2, w=3)
chiocg	mo_siwconst		heat transfer coefficient between the ice and the ocean
clbou	mo_ximatmo		Cloud boundary, lowest level with RH=100%
cln	mo_ximatmo		
cname			name of used program
cname_sp			name of species
cool	mo_xrad		cooling rate due to radiation
coswat	mo_xfrwat		
cpwat	mo_siwconst		heat capacity of sea water
cssvd	mo_xsspol		control value for deposition modelling (Table 7-1)
cstar	mo_xviscp	C_*	Ice strength reduction parameter for lead opening
ctaktu	mo_xchart		list of actually used tracers in model
ctlist	mo_xchart		list of potential chemicals in model (see CSSVd)
de	mo_xwork		array for pressure solver
delta	mo_xcontr	δ	control values for filtering and absorbing layers INT(delta): $>$ 1: filter after Pepper et al. (1979) INT(delta)*1000-INT(1000*delta): = 1: 3-point filter INT(delta)*1000-INT(1000*delta): = 2: 5-point filter INT(delta)*1000-INT(1000*delta): = 3: 7-point filter
depfak	mo_xdepos		coefficients for calculating, depending on kind of tracer
depos	mo_xdepos		coefficients for calculating, depending on kind of tracer
depro	mo_xdepos		coefficients for calculating, depending on kind of tracer

Variable	Module	Symbol	Explanation
der			reaction rate
dhibot	mo_xdhsi		ice thickness change at bottom
dhiflo	mo_xdhsi		ice thickness change due to flooding
dhitop	mo_xdhsi		ice thickness change at top
dhsflo	mo_xdhsi		snow thickness change due to flooding
dhstop	mo_xdhsi		snow thickness change at top
dml	mo_siwconst		depth of mixed layer of ocean
dobst			minimum distance to closest wall; within building = 0; scalar array
dqlcjn	mo_xqlic		change of cloud water content
dqlrjn	mo_xqlir		change of rain water content
dqvjn	mo_xqvap		change of specific humidity
dssjn	mo_xsspol		change of concentration
dt	mo_xcontr	Δt	time step
dtice	mo_xrun		time step in ice model
dtjn	mo_xtemp		change of temperature
dtold	mo_xcontr	Δt	time step of previous integration cycle (needed for Adams-Bashforth-scheme)
dttrased	mo_xcontr		time step for tracer sedimentation
dxsq	mo_xdrv	Δx^2	square of (equidistant) x grid spacing
dysq	mo_xdrv	Δy^2	square of (equidistant) y grid spacing
dzi	mo_ximg		vertical grid spacing in ice
dzitry	mo_xbouto		default vertical grid spacing in sea ice
dzs	mo_ximg		vertical grid spacing in snow
dzstry	mo_xbouto		default vertical grid spacing in snow
e11	mo_xe11e22e 12		strain rate sea ice
e12	mo_xe11e22e 12		strain rate sea ice
e22	mo_xe11e22e 12		strain rate sea ice
e2m	mo_ximatmo		vapour pressure at 2 m
ealmin	mo_xcontr	α_m	minimum sun altitude for no shading
eccen	mo_xviscp	e	cxcentricity of ellipse
ecm2	mo_xviscp	e^{-2}	parmeter based on cxcentricity of ellipse
ecomp	mo_xthck	A	ice concentration/compactness
ecostz	mo_xrad	$cos(\theta_z)$	cosine of zenith angle of sun
edd10	mo_xintgr	$dd(k=1)$	2-d array of time – integrated wind direction

Variable	Module	Symbol	Explanation
edelta	mo_xcontr	δ	declination of sun
edep	mo_xintgr	D	time – integrated dry deposition
edrewi	mo_xcontr		angle (from east) for rotation of coordinate system against N/E-direction
eff10	mo_xintgr	$\|v\|(k=1)$	2-d array of time – integrated wind velocity
eitime	mo_xintgr		integration time for special output on TAPE 65/66
elam	mo_xcontr	λ	longitude of reference point
elat	mo_xcontr	φ	latitude of grid points
elon	mo_xcontr	λ	longitude of grid points
ema0/1			area emissions at beginning / end of current time interval: created only for output
emisa	mo_xemiss	Q	area emission strength, array dimensions: (time interval, position, species)
emisa_idx	mo_xemiss		position of area emission, array dimensions: (time interval, position, dimension: y=1 x=2)
emisa_t	mo_xemiss	t	area emission times: beginning / end of time intervals
emisp	mo_xemiss	Q	point emission strength, array dimensions: (time interval, position, species)
emisp_idx	mo_xemiss		position of point emission, array dimensions: (time interval, position, dimension: z=1 y=2 x=3)
emisp_t	mo_xemiss	t	point emission times: beginning / end of time intervals
emp0/1			point emissions at beginning / end of current time interval: created only for output
epc	mo_siwconst		surface emissivities clouds
ephi	mo_xcontr	φ	latitude
epice	mo_siwconst		surface emissivities ice
eps	mo_siwconst		surface emissivities snow
epsur	mo_xintgr	p_{sur}	2-d array of time – integrated surface pressure
epw	mo_siwconst		surface emissivities water
eqr10	mo_xintgr	$f(k=1)$	2-d array of time – integrated relative humidity
eqstar	mo_xintgr	q_*	2-d array of time – integrated q_*

Variable	Module	Symbol	Explanation
erlw	mo_xintgr	R_L	2-d array of time – integrated long wave radiation balance
ersw	mo_xintgr	R_S	2-d array of time – integrated short wave radiation balance
esecli	mo_xcontr (MITRAS: mo_xrad)		limits (angle) of twelve sectors for calculation of shading
essj10	mo_xintgr	$C(k=1)$	time – integrated concentration
etai	mo_xzetaeta	η	shear viscosity of sea ice
ethick	mo_xthck	h	mean sea ice thickness
etr10	mo_xintgr	$T(k=1)$	2-d array of time – integrated real temperature
etrsur	mo_xintgr	T_{sur}	2-d array of time – integrated real surface temperature
etstar	mo_xintgr	θ_*	2-d array of time – integrated θ_*
eujn10	mo_xintgr	$u(k=1)$	2-d array of time – integrated wind
eustar	mo_xintgr	u_*	2-d array of time – integrated u_*
evd	mo_xintgr	v_d	time – integrated deposition velocity
evjn10	mo_xintgr	$v(k=1)$	2-d array of time – integrated wind
ewdep	mo_xintgr		time integrated wet deposition
f	mo_xcorr		Corriolis parmeter
faktra	mo_xdepos		factor for calculation of air resistance
faktrm	mo_xdepos		factor for calculation of molecular resistance
faktro	mo_xdepos		factor for calculation of surface resistance
fcos	mo_xpara	f'	secondary Coriolis parameter: $f'=2\Omega\cos(\varphi)$
fldo	mo_xrad		radiation flux (radiation model)
fldos	mo_xrad		radiation flux (radiation model)
fldosfc	mo_xrad		radiation flux (radiation model)
fludiv	mo_xrad		radiation flux (radiation model)
flup	mo_xrad		radiation flux (radiation model)
flups	mo_xrad		radiation flux (radiation model)
fnudg	mo_xnudge		forcing factors: =1: constant value, =2: tanh function
fortop	mo_xnudge		topography in forcing data file
fpres	mo_xrhsol		coefficients of r.h.s. of Poisson equation (divergence)
fsin	mo_xpara	f	primary Coriolis parameter: $f=2\Omega\sin(\varphi)$

Variable	**Module**	**Symbol**	**Explanation**
fx	mo_xfxfy		
fxdxp1			weighting coefficients
fxp1dx			weighting coefficients
fy	mo_xfxfy		
fydyp1			weighting coefficients
fyp1dy			weighting coefficients
fzdl	mo_xaust	z/L	stability value
fzdzp1			weighting coefficients
fzp1dz			weighting coefficients
gamma	mo_siwconst		constant for calculation of volumetric heat capacity of saline ice
heat	mo_xrad		heating rate due to radiation
hfb	mo_xifcp	$h_{f,c}$	mean heigh of freeboard for ice class c
hfl	mo_xaust		heat Flux
hflpf	mo_xaust		prescribed surface heat flux
hflpt	mo_xaust		value of prescribed heat flux [K m/s]
hi	mo_xifcp	$h_{i,c}$	mean sea ice thickness for ice class c
hiini	mo_iceini		initial value for ice thickness
hm	mo_xmask		land mask for scalar grid points calculated
hni	mo_xdhsi		
hs	mo_xifcp	$h_{s,c}$	mean snow thickness for ice class c
hsini	mo_iceini		
htyp	mo_xitpar		control value for multigrid-pressure-solver (GMd)
i0i	mo_ximatmo		fraction of shortwave-radiation penetrating into the ice without snow
icut			number of grid points influenced by a building
iday	mo_xcontr		number of day (model time)
ifilte	mo_xcontr		control value for filtering (each time step)
ihrold	mo_xcontr		last hour (model time)
ihrs	mo_xcontr		hours
iini	mo_xcontr		i-grid point for initialization
imcmask	mo_imc		control parameter for type of land-mask
imcmeth	mo_imc		control parameter for different ice model modi (compare Table 3-5, p. 26)
img	mo_xitpar		control value for GMd-pressure-solver
imin	mo_xcontr		minutes

Variable	Module	Symbol	Explanation
imorun	mo_xrun		control parameter for ice model
imozint	mo_xrun		
imsec	mo_xcontr		millisecond (model time)
ini	mo_xcontr		control variable for initialization
inni	mo_xcontr		j-grid point for initialization
intrep			control value for multigrid IGCG-pressure-solver
isec	mo_xcontr		seconds
itemp			number of species into a reaction
itlev	mo_xcontr		time level of scalar quantities (currently value is always =1; tetat, qlctt, qlrtt, qvt)
itmax	mo_xitpar		maximum number of IGCG-pressure-solver
itscal	mo_xcontr		actual time level for scalar quantity (currently value is always =1; implicit scheme not implemented; tetat, qvt, qlctt, qlrtt, tket, dist)
jahrzei	mo_xdepos		control value for time of the year
ji		i	loop index (east-west)
jj		j	loop index (south-north)
jk		k	loop index (vertical)
jn	mo_xcontr	n	loop index (time integration)
jndim	mo_xrun		control parameter for ice model
kipu	mo_siwconst		thermal conductivity of pure ice
kswi	mo_siwconst		shortwave bulk extinction coefficient of ice
lacraft	mo_xcontr		=true: Consider aircraft emissions / turbulence
lbiog	mo_xemiss		Controls calculation of biogenic emissions (not used up to now)
lcogra	mo_xcontr		control variable for calculation of counter gradient term
lcor	mo_xcontr		=true: Variable Coriolis force
lctm	mo_xcontr		=true: initialise chemistry
least	mo_xcontr		control variable for fixed inflow boundary
lhflp	mo_xcontr		=true: read of prescribed suface head flux (and use of it)
lif	mo_xifcp	$L_{i,c}$	mean length of ice floe for ice class c
lifini	mo_iceini		initial value for length of ice floe
lininor	mo_xcontr		=true: Consider grid point dependent north direction in Coriolis force, 1d-

Variable	**Module**	**Symbol**	**Explanation**
			initialization, nudging and radiation
lnew	mo_xrun		time level in ice model
lnnpre	mo_xnudge		control variable for pressure forcing
lnnql	mo_xnudge		control variable for liquid water forcing
lnnqv	mo_xnudge		control variable for humidity forcing
lnnte	mo_xnudge		control variable for temperature forcing
lnntra	mo_xnudge		control variable for tracer forcing, may differ for different tracers
lnnwin	mo_xnudge		control variable for wind forcing
lnorth	mo_xcontr		control variable for fixed inflow boundary
lnudge	mo_xcontr		general control variable for model forcing
lold	mo_xrun		time level in ice model
lpoll	mo_xemiss		Controls calculation of pollen emission and pollen transport
lrad	mo_xcontr		=true: radiation to be calculated
lradio	mo_xsspol		for each species =true: calculation of radioactive decay
lresd	mo_xcontr		control variable for daily reset of deposition arrays
lresh	mo_xcontr		control variable for hourly reset of deposition arrays
lship	mo_xcontr		=true: Consider ship emissions
lsouth	mo_xcontr		control variable for fixed inflow boundary
lsssedi	mo_xsspol		= true: modelling of sedimentation
lssvd	mo_xsspol		control value for calculation of deposition velocity
lt6566	mo_xcontr		control value for special output on TaPE65/66 (.true. = output, .false. = no output)
ltrace	mo_xcontr		= true: tracer transport (with or without chemistry)
ltrased	mo_xcontr		control value for sedimentation in general (=true if done)
ltyp	mo_xitpar		control value for multigrid-pressure-solver (GMd)
lwest	mo_xcontr		control variable for fixed inflow boundary
maf	mo_xcontr	$1/A_f$	number of time steps for diastrophy or time
mafrii	mo_xcontr		control variable for restart with incomplete init
mblock	mo_press		= NARE/NCOL

Variable	Module	Symbol	Explanation
mfemi	mo_xemiss		1= read of emission data
mini	mo_xcontr		time or time-step for initialization. Within the time MINI the number of pressure iterations is enlarged by a factor of 4.
minirii	mo_xcontr		control variable for restart with incomplete init
mmax	mo_xrelaxp		maximum iteration steps for over-relaxation of momentum equation to calculate ice drift
mmi	mo_xcontr		x1-grid-points to write AL time series
mmj	mo_xcontr		x2-grid-points to write AL time series
mmk	mo_xcontr		x3-grid-points to write AL time series
mnew	mo_xtind		time index in sea ice model
mold	mo_xtind		time index in sea ice model
momfl	mo_xaust		momentum flux
moute,n,s,w	mo_xwcal		control values for inflow (=0) – outflow (=1) (east,north,south,west)
msurc	mo_xboden		
mtisum	mo_xcontr		number of output-times
n3dobst			3D array for marking building cells defined at scalar grid point. =-1: in building =0: in atmosphere =#: number of boundaries with building walls connected to current grid point (but not in the building!)
naerosi	mo_chem		number of simple aerosol species
nare(m1)	mo_press		NX3P2 * NX2P2 (-1)
naus	mo_xcontr		number of time steps for first OUTPUT or time
nblhco	mo_xcontr		control value for run without (= 0) / with (=1) blending height concept
nblock	mo_press		= NVOL/NCOL
nbou	mo_xcontr		control value for ascending force
ncb0,1,2	parameter‾ met		=0,1 or 9, NX1, 2 depending on run without / with blending height concept
ncb0,1,2p1	parameter_me t		=1,0 or 10 NX1,2P1 depending on run without / with blending height concept
ncb1,2p2	parameter_me t		=1 or NX1,2P1+1 depending on run without / with blending height concept
ncblh	parameter_me t		control value for run without (= 0) / with (=1) blending height concept

Variable	**Module**	**Symbol**	**Explanation**
nchem	mo_xchem		=1: chemical reactions =0: no chemical reactions
nchesu	parameter_met		number of chemicals in chemistry module (summed up)
ncl1,2,3	parameter_met		= 1 or NX1,2,3 depending on run without/with clouds
ncl1,2,3p1	parameter_met		= 0 or NX1,2,3P1 depending on run without/with clouds
ncl1,2,3p2	parameter_met		= NCL1,2,3 + 2
nclyn	parameter_met		control value for run without (= 0)/with (= 1) clouds
ncnud	parameter_met		parameter to dimension nudging fields, (0: no nudging fields, 1: with nudging fields)
ncnv	mo_xcontr		control value for numerical scheme
ncol(m1)	mo_press		= NX3P2 (-1)
ncolst	mo_xchem		species number
ncor	mo_xcontr		control value for Coriolis force
ndelta	mo_xcontr		number of time steps for output interval or time
ndifco	mo_xcontr		control of applied exchange coefficient
ndim	mo_xcontr		dimension of used model
nemis_area	mo_xemiss		number of species in area emissions
nemis_area_a/p			number of active/passive species in area emissions
nemis_point	mo_xemiss		number of species in point emissions
nemis_point_a/p			number of active/passive species in point emissions
nend	mo_xcontr		number of time steps or time for model run
nevola/c	parameter_press		number of array elements for arrays of pressure solver
nhflpf	mo_xaust		control value for selecting factors for prescribed surface heat flux fields
njday	mo_xcontr		Julian day of date
nkat	mo_xchem		number of non-reactive species
nkemisa	mo_xemiss		mapping area emission species → species number in model run
nkemisp	mo_xemiss		mapping point emission species → species number in model run
nlev_scal	mo_xcontr		maximum time levels for scalar variables

Variable	Module	Symbol	Explanation
			(qlctt, qlrtt, qvt, tetat, womt, dist, tket) 1: explicit 3: implicit
nlev_wind	mo_xcontr		maximum time levels for wind (ut, vt, wt) 2: explicit 3: implicit
nliq	mo_xcontr		control value for existence of liquid water
nmeminnga	mo_xboden		Surface cover class METRAS-50 number from topography file
nm50sccl	mo_xboden		Total number of possible METRAS50 classes -1 (due to 0)
noahori	mo_xcontr		control value for kind of horizontal diffusion
nobstacle	mo_weight		number of grid cells that are (partly) covered by buildings
noreca	mo_xcontr		number of records in a-Input/output
norecar	mo_xcontr		number of records in restart file (A structure)
norecc	mo_xnudge		number of records in C-Input
norecf	mo_xnudge		number of records in F-Input
norecg	mo_xcontr		number of records in G-Input/output
norecm	mo_xcontr		number of records in M-Input/output
nostra	mo_xcontr		structure number in a-Input/output
nostrc	mo_xnudge		structure number in C-Input
nostrf	mo_xnudge		structure number in F-Input
nostrg	mo_xcontr		structure number in G-Input/output
nostrm	mo_xcontr		structure number in M-Input/output
np0f	mo_xnudge		forcing field dimensions pressure
np1	mo_xcontr	 *= -2* *= -1* *= 0* *= 1* *= 2*	control value for pressure deviation p_1 temporal hydrostatic model version temporal non-hydrostatic model version not calculated always non-hydrostatic model version always hydrostatic model version
np1x3(1)	mo_xdruck		(unused)
np1x3(2)	mo_xdruck		(unused)
np2x1,2(j)	mo_xdruck		control value for lateral boundaries of p_2
np2x3(1)	mo_xdruck		control value for surface boundary of p_2
np2x3(2)	mo_xdruck		control value for top boundary of p_2
nphi1,2(j)			control value for lateral boundaries of scalar quantity

Variable	Module	Symbol	Explanation
nphi3(2)			control value for top boundary of scalar quantity
npreak	parameter_chem		number of reactions
npress	mo_xcontr	*= 0* *= 1*	control value for pressure deviation p_2 p_2 not calculated (case ABS(NP1)=2, or always) non-hydrostatic model version
nprsmx	parameter_chem		max. number of terms
npspc	parameter_chem		maximum number of chemical species implemented at all
nqlc	mo_xcontr		control value for calculation of cloud water
nqlc0f	mo_xnudge		forcing field dimensions cloud liquid water
nqlcx1,2,3			control values for boundary conditions (cloud water)
nqlr	mo_xcontr		control value for calculation of rain water
nqlr0f	mo_xnudge		forcing field dimensions rain liquid water
nqlrx1,2,3			control values for boundary conditions (rain water)
nqv	mo_xcontr		control value for calculation of specific humidity
nqv0f	mo_xnudge		forcing field dimensions humidity
nqvx1,2,3(j)	mo_xqvap		control values for boundary conditions (specific humidity)
nreak(0,)	mo_xchem		active number of species on the left side of reaction
nreak(1,)	mo_xchem		species number
nreak(-1,)	mo_xchem		number of species on the left side of reaction
nreakp	mo_xchem		number of photolytic reactions
nreakt	mo_xchem		number of temperature dependent reactions
nreaku	mo_xchem		number of temperature independent reactions
nsclinm50(j)	mo_xboden		Number of surface class in the surface cover classes (all possible)
nshisub	mo_xshiemi		number of ship emitted species
nshitra	mo_xshiemi		number of ship tracks
nss0f	mo_xnudge		forcing field dimensions for different tracer

Variable	Module	Symbol	Explanation
nssx1,2,3(j)	mo_xsspol		control variable for boundary conditions (tracer)
nsurfcells	mo_xweight		number of cells in the atmosphere adjacent to buildings
nsurfcount	mo_xweight		
nsurfdir	mo_xweight		=1: when building at right hand side of the grid point = -1: when building at left hand side of the grid point
nsurftype	mo_xweight		type of building wall: 1: top 2: front and back (y-direction) 3: left and right (x-direction)
nt0f	mo_xnudge		forcing field dimensions temperature
nte	mo_xcontr		control variable for calculation of temperature
ntindx	mo_xsspol		transfer of actually used tracer index in model run to index of potential chemicals
ntke	mo_xcontr		turbulent kinetic energy equation
ntl2	mo_xcontr		1: explicit and implicit time level (implicit not implemented; tetat, qvt, qlctt, qlrtt, ut, vt, womt, wt) – “old” time level
ntl3	mo_xcontr		= 3; used in se_project for ut, vt, wt, womt
ntlev	mo_xcontr		time level for wind arrays (= 2 corresponds to not final but new wind values) 2: explicit and implicit (implicit currently not implemented)
ntr1,2,3	mo_met		= 1 or NX1,2,3 depending on run without/with tracer
ntr1,2,3p1	mo_met		= 0 or NX1,2,3P1 depending on run without/with tracer
ntr1,2,3p2	mo_met		= NTR1,2,3+2
ntrace	mo_met		number of tracers
ntramax	mo_xshiemi		maxmimum number of waypoints of all ships
ntrapt	mo_xshiemi		number of waypoints per ship
ntrasu	mo_xcontr		number of possible tracers (read from input)
ntrq	mo_met		= 1 or NXYQ depending on run without/with tracer
ntrt	mo_met		= 1 (for NTRACE = 0) or NTRACE (for

Variable	Module	Symbol	Explanation
			NTRACE ≥ 1)
ntryn	mo_met		control value for run without (= 0)/with (= 1) tracer
ntx1,2,3(j)	mo_xtemp		control variable for boundary conditions (temperature)
nu0f	mo_xnudge		forcing field dimensions u-component wind
nurban	mo_urban		1: calculate urban effects 0: do not calculate urban effects
nuvwx1,2,3(j)	mo_xwcal	*NXI(J)*	control variable for boundary conditions (velocity)
nv0f	mo_xnudge		forcing field dimensions v-component wind
nvol(m1)	mo_press		= Nx3P2 * Nx2P2 * Nx1P2 (-1)
nw0f	mo_xnudge		forcing field dimensions w-component wind
nwind	mo_xcontr		control variable for wind calculation
nx1	mo_met	$NI + 1$	number of vector grid points in x1-direction (neglecting boundaries)
nx2	mo_met	$NJ + 1$	number of vector grid points in x2-direction (neglecting boundaries)
nx3	mo_met	$NK + 1$	number of vector grid points in x3-direction (neglecting boundaries)
nx3i	mo_ximg		number of grid layers in the ice
nx3s	mo_ximg		number of grid layers in the snow
nx3si	mo_ximg		number of grid layers in ice+snow
nximj	mo_met		= Nxi – j
nxipj	mo_met		= NXi + j
nxyq	mo_met		number of possible sources
p	mo_xpress	P or P_p	ice pressure (in orelcon and oplast) or ice pressure for ideal plastic case (in opressu and oplast)
p0	mo_xgeos	p_o	pressure part (basic state)
p0ini	mo_xgini	p_o	initial field of basic state pressure
p0nn	mo_xnudge		forcing data pressure at new forcing time
p0no	mo_xnudge		forcing data pressure at old forcing time
p1	mo_xdruck	p_1	pressure part p_1 (mesoscale)
p2	mo_xdruck	p_2	pressure part p_2 (mesoscale)
phi0		Ψ_0	variable scalar quantity of large scale
phijn		Ψ^n	variable scalar quantity for time step *n*

Variable	Module	Symbol	Explanation
phijnp1		ψ^{n+1}	variable scalar quantity for time step *n+1*
pp	mo_xwork		array for pressure solver
pphixe,n,s,w		c_1	phase velocity c_1 of a scalar quantity at the east,north,south,west-boundary
pphiye,n,sw		c_2	phase velocity c_2 of a scalar quantity at the east,north,south,west –boundary
pphize,n,s,w		c_3	phase velocity c_3 of a scalar quantity at the east,north,south,west –boundary
pqcxw,e,n,s	mo_xqcran	c_1	phase velocity c_1 for q_1^{2c} at the west, east, north, south-boundary
pqcyw,e,n,s	mo_xqcran	c_2	phase velocity c_2 for q_1^{2c} at the west, east, north, south-boundary
pqczw,e,n,s	mo_xqcran	c_3	phase velocity c_3 for q_1^{2c} at the west, east, north, south-boundary
pqrxw,e,n,s	mo_xqrran	c_1	phase velocity c_1 for q_1^{2R} at the west, east, north, south-boundary
pqryw,e,n,s	mo_xqrran	c_2	phase velocity c_2 for q_1^{2R} at the west, east, north, south-boundary
pqrzw,e,n,s	mo_xqrran	c_3	phase velocity c_3 for q_1^{2R} at the west, east, north, south-boundary
pqvxw,e,n,s	mo_xqvran	c_1	phase velocity c_1 for q_1^{1} at the west, east, north, south boundary
pqvyw,e,n,s	mo_xqvran	c_2	phase velocity c_2 for q_1^{1} at the west, east, north, south boundary
pqvzw,e,n,s	mo_xqvran	c_3	phase velocity c_3 for q_1^{1} at the west, east, north, south boundary
prod			production rate
pssxe,n,s,w	mo_xssran	c_1	phase velocity c_1 for C at the east,north,south,west –boundary
pssye,n,s,w	mo_xssran	c_2	phase velocity c_2 for C at the east,north,south,west –boundary
pssze,n,s,w	mo_xssran	c_3	phase velocity c_3 for C at the east,north,south,west –boundary
pstar	mo_xviscp	P_*	Ice strength
ptemxe,n,s,w	mo_xtrand	c_1	phase velocity c_1 for θ at the east,north,south,west –boundary
ptemye,n,s,w	mo_xtrand	c_2	phase velocity c_2 for θ at the east,north,south,west –boundary

Variable	Module	Symbol	Explanation
ptemze,n,s,w	mo_xtrand	c_3	phase velocity c_3 for θ at the east,north,south,west –boundary
puxe,n,s,w	mo_xwrand	c_1	phase velocity c_1 for u at the east,north,south,west –boundary
puye,n,s,w	mo_xwrand	c_2	phase velocity c_2 for u at the east,north,south,west –boundary
puze,n,s,w	mo_xwrand	c_3	phase velocity c_3 for u at the east,north,south,west –boundary
pvxe,n,s,w	mo_xwrand	c_1	phase velocity c_2 for v at the east,north,south,west –boundary
pvye,n,s,w	mo_xwrand	c_2	phase velocity c_2 for v at the east,north,south,west –boundary
pvze,n,s,w	mo_xwrand	c_3	phase velocity c_3 for v at the east,north,south,west –boundary
pwxe,n,s,w	mo_xwrand	c_1	phase velocity c_1 for v at the east,north,south,west –boundary
pwye,n,s,w	mo_xwrand	c_2	phase velocity c_2 for w at the east,north,south,west –boundary
pwze,n,s,w	mo_xwrand	c_3	phase velocity c_3 for w at the east,north,south,west –boundary
qbde	mo_xwork		array for pressure solver
qbpp	mo_xwork		array for pressure solver
qc	mo_xiwfluxes		preliminary conductive heat flux through ice and snow
qcgam	mo_xaust		counter gradient term for humidity
qdeoc	mo_siwconst		heat flux from deep ocean
ql	mo_ximatmo		latent heat flux
qlc0		q_{10}^{2C}	specific cloud water content (basic state)
qlc0ini	mo_xgini	q_{10}^{2c}	initial field of basic state for cloud water content
qlc0nn	mo_xnudge		forcing data cloud liquid water content at new forcing time
qlc0no	mo_xnudge		forcing data cloud liquid water content at old forcing time
qlcb,t	mo_xqlic	q_1^{2c}	cloud water content at surface/top
qlcflx	mo_xqlic		flux of cloud water at surface
qlcmea	mo_xqlic		horizontal mean specific cloud water content
qlct	mo_xqlic	q_1^{2c}	specific cloud water content (mesoscale)
qlcwe,s,n	mo_xqlic	q_1^{2c}	cloud water content at boundaries west/east/south/north

Variable	Module	Symbol	Explanation
qlr0	mo_xqlir	q_1^{2R}	specific rain water content (basic state)
qlr0ini	mo_xgini	q_{10}^{2R}	initial filed of basic state rain water content
qlr0nn	mo_xnudge		forcing data rain liquid water content at new forcing time
qlr0no	mo_xnudge		forcing data rain liquid water content at old forcing time
qlract	mo_xqlir		rate of rain at surface [mm/s]
qlrate	mo_xqlir	R	3d array of actual rain rate [mm/h]
qlrb,t	mo_xqlir	q_1^{2R}	rain water content at surface/top
qlrdel	mo_xqlir		rain [mm] per last full hour (e.g. at 12:30: rain from 11:00 to 12:00)
qlrflx	mo_xqlir		flux of rain water at surface
qlrint	mo_xqlir		rain [mm] since midnight
qlrmea	mo_xqlir		horizontal mean rainwater content
qlrt	mo_xqlir	q_1^{2R}	specific rainwater content (mesoscale)
qlrw,e,s,n,	mo_xqlir	q_1^{2R}	rain water content at boundaries west/east/south/north
qrh			relative humidity (basic state)
qs	mo_ximatmo		sensible heat flux
qs0		q_{1o}^{3}	ice (basic state) (still not calculated)
qsjn		q_1^3	ice (still not calculated)
qv0	mo_xqvap	q_{1o}^{1}	specific humidity (basic state)
qv0ini	mo_xgini	q_{1o}^{1}	initial field of basic state specific humidity
qv0nn	mo_xnudge		forcing data specific humidity at new forcing time
qv0no	mo_xnudge		forcing data specific humidity at old forcing time
qvcont	mo_xboden		water content in vegetation and soil
qvdeep	mo_xboden	h_q	scaling depth for humidity changes in the ground
qvflx	mo_xqvap		flux of specific humidity at surface
qvjflx	mo_xblend	$-u_*^j q_*^j$	subgrid scale flux of specific humidity at surface over surface type j(j=0,…,9)
qvjjnb	mo_xblend	q_{1s}^{1j}	subgrid scale specific humidity at surface of surface type j(j=0,…,9)
qvjnb,t	mo_xqvap	q_1^1	specific humidity at surface/top

Variable	Module	Symbol	Explanation
qvjnw,e,s,n	mo_xqvap	q_1^1	specific humidity at boundaries west/east/south/north
qvjstern	mo_xblend	q_*^j	subgrid scale scaling value for specific humidity for surface type j(j=0,…,9)
qvm	mo_xqvap		reference profile for relative humidity
qvmean	mo_xqvap		horizontal mean of mesoscale relative humidity
qvrf2m	mo_xqvap	RH	relative humidity 2m above ground
qvstern	mo_xaust	q_*	scaling value for specific humidity
qvt	mo_xqvap	q_1^1	specific humidity (mesoscale)
reacon	mo_xchem		values of reaction rate
resmax	mo_xitpar		residuum (pressure-solver)
rho0	mo_xdicht	ρ_o	density part (basic state)
rhocipu	mo_siwconst		volumetric heat capacity of pure ice at 273K
rhocw	mo_siwconst		volumetric heat capacity of water
rhoice	mo_siwconst		density of ice in "Archimedes"-calc.
rholibot	mo_siwcons		volumetric heat of fusion at bottom of ice
rholitop	mo_siwcons		volumetric heat of fusion at top of ice
rholstop	mo_siwcons		volumetric heat of fusion at top of snow
rhom	mo_xdicht	$\tilde{\rho}$	mesoscale density
rhosnow	mo_siwconst		density of snow in "Archimedes"-calc.
rhowat	mo_siwconst		density of sea water
rpsumm	mo_xpara		model control summand, dependent on computer accuracy
ru	mo_xrurv		term used for over-relaxation of momentum equation to calculate ice drift
rv	mo_xrurv		term used for over-relaxation of momentum equation to calculate ice drift
seka	mo_xrun		
seke	mo_xrun		
sfcbgroul	mo_xrad		long wave radiation from ground onto building
sfcbinl	mo_xrad		incoming long wave radiation to building
sfcbnetl	mo_xrad		net long wave radiation at building surface
sfcbnets	mo_xrad		net short wave radiation at building surface
sfcbskyl	mo_xrad		long wave radiation from sky onto

Variable	Module	Symbol	Explanation
			building
sfcnetl	mo_xrad		net long wave radiation at surface
sfcnets	mo_xrad		net short wave radiation at surface
ship_emi	mo_xshiemi	Q	Ship emission strength, array dimensions: (ship number, ship species number)
ship_gt	mo_xshiemi		Size of the ship as gross tonnage
ship_t	mo_xshiemi		Position of the ships in time
ship_x	mo_xshiemi		Position of the ships in x-direction
ship_y	mo_xshiemi		Position of the ships in y-direction
sig	mo_siwconst		Stefan-Boltzmann-constant
sinwat	mo_xfrwat		Ekman turning angle for ocean
sjnetl	mo_xblend	L^j	net subgrid-scale long wave radiation at surface for surface type $j(j=0,...,9)$
sjnets	mo_xblend	S^j	net subgrid-scale short wave radiation at surface for surface type $j(j=0,...,9)$
ss0	mo_xsspol	C_o	concentration (basic state)
ss0nn	mo_xnudge		forcing data per tracer at new forcing time
ss0no	mo_xnudge		forcing data per tracer at old forcing time
ssc			concentration of species in mol/m^3
ssflx	mo_xsspol	$V_D \cdot C$	concentration flux at surface
ssjn	mo_xsspol	C	concentration (mesoscale)
ssjnb,t	mo_xsspol	C	concentration at surface/top
ssjnw,e,s,n	mo_xsspol	C	concentration at boundaries west/east/south/north
ssq	mo_xsspol		array of emission conditions and coordinates 1st index: number of source 2nd index: jk,jj,ji,qs,start-endtime
sssdel	mo_xssdep		dry deposition $[kg/m^2]$ per last full hour (e.g. at 12:30 deposition from 11:00 to 12:00)
sssedi	mo_xsspol		sedimentation velocity [m/s]
sssint	mo_xssdep		dry deposition $[kg/m^2]$ since midnight (or start of model run)
ssvd	mo_xsspol		deposition velocity <0: fixed values >0: calculated (see CSSVd)

Variable	Module	Symbol	Explanation
sswdel	mo_xssdep	D^{wet}	wet deposition [kg/m ^{2}] per last full hour
sswfak	mo_xwdep	*a,b,c*	coefficients for calculation of washout coefficients
sswint	mo_xssdep	D^{wet}	wet deposition [kg/m ^{2}] since midnight
statsiprof	mo_xtind		control variable for initial stationarity of temperature profiles in ice
statvel	mo_imc		control parameter for sea ice drift velocities
stoe	mo_xchem		multiplication factor calculating Production and Loss
surblh	mo_xblend	l_b	blending height
surchl	mo_xblend	L_x	scale of horizontal extension of subgrid-scale surface elements
surfra	mo_xboden		control value for share of surface characteristics (0,…, 9)
surfrath	mo_xisurfra		fraction of surface classes
surfrathil	mo_xisurfra		fraction of ice plus water of the surface
surfrathini	mo_iceini		
surfrathni	mo_xisurfra		
surfrathnw	mo_xisurfra		
sx2	mo_xdrv	$1/(2\,\Delta x^2)$	
sxy	mo_xdrv	$1/(4\,\Delta x\,\Delta y)$	
sy2	mo_xdrv	$1/(2\,\Delta y^2)$	
t0	mo_xtemp	θ_0	temperature (basic state)
t0ini	mo_xgini	θ_0	initial field of basic state temperature
t0nn	mo_xnudge		forcing data temperature at new forcing time
t0no	mo_xnudge		forcing data temperature at old forcing time
t2m tbuisurf	mo_xtemp mo_xtemp	 T_b	temperature 2m above ground real temperature of building surface
taucl	mo_ximatmo		optical cloud thickness
tax	mo_xfrwnd		
taxcou	mo_xfrwnd		
taxjnm1	mo_xfrwnd		
taxsto	mo_xfrwnd		
taxtmp	mo_xfrwnd		
tay	mo_xfrwnd		

Variable	Module	Symbol	Explanation
taycou	mo_xfrwnd		
tayjnm1	mo_xfrwnd		
taysto	mo_xfrwnd		
taytmp	mo_xfrwnd		
tcgam	mo_xaust		counter gradient term for temperature
tetat	mo_xtemp		temperature
tgamma	mo_xcontr	γ	gradient of temperature
thdeep	mo_xboden	h_e	scaling depth for temperature changes in the ground
thecon	mo_xboden	v_s	thermal conductivity
thedif	mo_xboden	k_s	thermal diffusivity
tim	mo_xtim	T_c	temperature in ice and snow
timens	mo_xnudge		time of new forcing data
timeos	mo_xnudge		time of old forcing data
timeou	mo_xcontr		times model output
timerad	mo_xcontr		time for control of radiation calculation
timewns	mo_xfrwat		time of new forcing data of ocean current
timewos	mo_xfrwat		time of old forcing data of ocean current
tind	mo_xtind		
tinsini	mo_xtemp	$T(-h_\theta)$	temperature in the soil at initialisation grid point iini, jini
tinsoil	mo_xtemp	$T(-h_\theta)$	temperature in the soil (2-d array, real temperature)
tjflx	mo_xblend	$-u_*^j\theta_*^j$	subgrid-scale flux of temperature at surface over surface type j(j=0,…,9)
tjjnb	mo_xblend	θ_s^j	subgrid-scale surface temperature of surface type j(j=0,…,9)
tjnb,t	mo_xtemp	θ	temperature at surface/top
tjnw,e,s,n	mo_xtemp	θ	temperature at boundaries west/east/south/north
tjstern	mo_xblend	θ_*^j	subgrid-scale scaling value for temperature for surface type $j(j=0,...,9)$
tm	mo_xtemp		reference profile of mesoscale temperature
tmean	mo_xtemp		horizontal mean of mesoscale temperatures
tmelti	mo_siwconst		melting temperatures of ice
tmelts	mo_siwconst		melting temperatures of snow
tr2m	mo_ximatmo		real temperature at 2 m

Variable	Module	Symbol	Explanation
tstern	mo_xaust		scaling value for temperature
tw	mo_xtim		temperature of oceanic mixed layer
twater	mo_temp		water surface temperature
twfr	mo_siwconst		freezing temperature of oceanic water
u0nn	mo_xnudge		forcing data u-component at new forcing time
u0no	mo_xnudge		forcing data u-component at old forcing time
uf	mo_xwcal	f_1	component of advection and diffusion terms at
ug	mo_xgeos	U_g	geostrophic wind in west-east-direction
ugini	mo_xgini	U_g	initial field of geostrophic wind in west-east-direction
ugnn	mo_xnudge		forcing data u-component geostrophic wind at new forcing time
ugno	mo_xnudge		forcing data u-component geostrophic wind at old forcing time
uice	mo_xvel	u_i	ice drift speed in x-direction
uiceini	mo_xvel	u_i	initial sea ice drift in x-direction (TAPE90, compare Section 3.7 and Table 3-1)
ujn	mo_xwind		velocity in west-east-direction (same as ut, but f77 code)
ujstern	mo_xblend	u_*^j	subgrid-scale shear stress velocity for surface type $j(j = 0,...,9)$
userfield,j	mo_ userfield		empty fields (j = 0,…,9) for prototyping, written in plot and restart output if selected in control file
ustern	mo_xaust	u_*	shear stress velocity
ustern0	mo_xiwfluxes		friction velocity beneath the ice between ice and water
ut	mo_xwind		velocity in west-east-direction
uwat	mo_xfrwat		x component of geostrophic ocean current
uwatin	mo_xfrwat		
uwatn	mo_xfrwat		x component of ocean current forcing data at new forcing time
uwato	mo_xfrwat		x component of ocean current forcing data at old forcing time
v0nn	mo_xnudge		forcing data v-component at new forcing time
v0no	mo_xnudge		forcing data v-component at old forcing

Variable	Module	Symbol	Explanation
			time
vf	mo_xwcal	f_2	component of advection and diffusion term at
vfl	mo_xaust		vapour flux
vg	mo_xgeos	V_g	geostrophic wind in south-north-direction
vgini	mo_xgini	V_g	initial field of geostrophic wind in south-north-direction
vgnn	mo_xnudge		forcing data v-component geostrophic wind at new forcing time
vgno viewalfac	mo_xnudge mo_xrad		forcing data v-component geostrophic wind at old forcing time weighting factors for ground surface temperature needed for long wave radiation
vice	mo_xvel	v_i	ice drift speed in y-direction
viceini	mo_xvel	v_i	initial sea ice drift in x-direction (TAPE91, compare Section 3.7 and Table 3-1)
vm	mo_xmask		land mask for vector grid points
vol	mo_xweight		3D array in mask pre-processor, 1D array in model, defined at scalar grid point In mitras: 1: in atmosphere, 0: in building In mask: 1: in atmosphere, <1: in building
vrmax	mo_xrelaxp		
vt	mo_xwind		velocity in south-north-direction
vwat	mo_xfrwat		y component of geostrophic ocean curren
vwatin	mo_xfrwat		
vwatn	mo_xfrwat		y component of ocean current forcing data at new forcing tim
vwato	mo_xfrwat		y component of ocean current forcing data at old forcing time
w0	mo_xgeos	w_o	large-scale vertical wind
w0ini	mo_xini	W_o	initial field of large-scale vertical wind
w0nn	mo_xnudge		forcing data w-component at new forcing time
w0no wcondu	mo_xnudge mo_build_surf		forcing data w-component at old forcing time heat conduction through wall/roof of building
wdev	mo_xaust		

Variable	Module	Symbol	Explanation
weight_x,y,z	mo_xweight		fraction of grid cell in the atmosphere, defined at scalar grid point using n3dobst in model: =1: only atmosphere =0: in building of neighbouring wall all-in-all icut values in mask 3D-array at scalar grid point (fraction of cell face covered with building): =1: only atmosphere <1: with building _x: east, _y: north, _z: top
wf	mo_xwcal	f_2	component of advection and diffusion terms at
wl	mo_xwork		array for pressure solver
wle	mo_xifcp	$L_{w,c}$	mean width of lead / spacing between ice floe for ice class c
womt	mo_xwind	$\dot{u}^3$	transformed vertical velocity
wt	mo_xrelaxp		weighting parameter for over-relaxation of momentum equation to calculate ice drift
wt	mo_xwind		vertical velocity
wturbu	mo_build_surf		sensible heat flux towards building surface [W/m²]
wz0t	mo_build_surf		wall/roof roughness length for temperature
xpres	mo_xrhsol		coefficients for right side of Poisson-equation
xvmet	mo_xpara	x	x-coordinate of vector grid points
ycpair	mo_phys	c_p	specific heat for dry air at constant pressure
ycvair	mo_phys	c_V	specific heat for dry air at constant volume
ydrcos	mo_xcontr	d'	cos(ξ)
ydrewi	mo_phys	ξ	rotation angle (from east) for rotation of coordinate system against N/E-direction
ydrsin	mo_xcontr	d	sin(ξ)
ydx	mo_xpara	Δx	lateral grid-spacing
ydy	mo_xpara	Δy	longitudinal grid-spacing
ydz	mo_xpara	$\Delta \eta$	vertical grid-spacing
yeta	mo_xpara	η	transformed vertical coordinate (0:NX3P1)
ygrav	mo_phys	g	acceleration due to gravity

Variable	Module	Symbol	Explanation
yhyfak	mo_phys		factor to control validity of hydrostatic assumption
yk		k	$[s^{-1}]$ interval of auto conversion
ylat	mo_phys	R_{21}	latent heat of vaporization of water
ymolpr	mo_phys	Pr	Prandtl-number
ymolsc	mo_phys	Sc	Schmidt-number
yny	mo_phys	v	kinematic viscosity of air
ypahmax	mo_phys		maximum horizontal exchange coefficient
ypavmax	mo_phys		maximum vertical exchange coefficient
ypavmin	mo_phys		minimum vertical exchange coefficient
ypcappa	mo_phys	κ	von Karman constant (= 0.40)
ypomega	mo_phys	Ω	angle velocity of the earth
ypref	mo_phys	p_0	1000 hPa
yprefs	mo_phys	p_1^{*21}	reference pressure at saturation (6.107 hPa)
yqckri		q_{krit}^{21}	critical specific cloud water content
yrair	mo_phys	R_0	gas constant of dry air
yrdcp	mo_phys	R_0 / c_p	R_0 / c_p
yrh2o	mo_phys	$\rho(H_2O)$	density of water (= 1000. kg m^{-3})
yrhos	mo_phys	ρ_s	density at standard conditions (= 1.29 kg m^{-3})
yrvap	mo_phys	R_1	gas constant of water vapour
ysurco	mo_phys	c_1	constant for calculation of blending height
yta	mo_xpara	A	transformation constant of grid-spacing in west-east-direction
ytb	mo_xpara	B	transformation constant of grid-spacing in south-north-direction
ytc	mo_xpara	C	transformation constant of vertical grid-spacing
ytd	mo_xpara	D	transformation constant for surface-slope in east-west-direction
yte	mo_xpara	E	transformation constant for surface-slope in north-south-direction
ytf	mo_xpara	F	transformation constant
ytg	mo_xpara	G	transformation constant
ytref	mo_phys	T_0	=273.16 by WMO (reference temperature)
yvmet	mo_xpara	y	y-coordinate of vector grid-points

Variable	Module	Symbol	Explanation
yxmin	mo_xpara		minimum coordinate in west-east-direction (vector)
yymin	mo_xpara		minimum coordinate in south-north-direction (vector)
yz0	mo_xboden	z_0	roughness-length at grid point
yz0cls	mo_xboden	z_0	roughness-length for surface characteristics (0, …, 9)
yz0h2o	mo_xblend	z_0^0	roughness length for water surfaces
yz0jtemp			Roughness length for temperature
yzssvv	mo_xpara		surface height at u,v-grid point
yzsurf	mo_xpara	z_s	ground-altitude over main-sea-level
yztop	mo_xpara	z_t	altitude of the upper model boundary
yzz	mo_para		vertical wind grid points + 2 boundary values to construct the grid (-1:nx3p1)
z0ib	mo_siwconst		roughness lenght at the ice bottom
z0wat	mo_xfrwat		drag coefficient
zeit	mo_xcontr	t	model-time for I/O in ddhh.mmss
zeitbs	mo_xcontr		time (in sec) of model run
zeitg2	mo_xcontr		time for new geostrophic values
zeits	mo_xcontr		model-time [s] for internal time control
zesat0,s,x			internal functions: for saturation vapour pressure
zeta	mo_xzetaeta	ζ	bulk viscosity
zhel11	mo_xwork1		auxiliary arrays for scalar quantities
zhel12	mo_xwork1		auxiliary arrays for scalar quantities
zhel13	mo_xwork1		auxiliary arrays for scalar quantities
zhel2u	mo_xwork2		auxiliary array for u-component
zhel2v	mo_xwork2		auxiliary array for v-component
zhel2w	mo_xwork2		auxiliary array for w-component
zhel31	mo_xwork3		auxiliary array
zhel32	mo_xwork3		auxiliary array
zinv	mo_xaust		inversion height
zmaf	mo_xcontr		control variable for restart with incomplete init
zmafrii	mo_xcontr		control variable for restart with incomplete init
zmini	mo_xcontr		control variable for restart with incomplete init
zminirii	mo_xcontr		control variable for restart with incomplete init

Variable	Module	Symbol	Explanation
znudcon	mo_xcontr		
znudpot	mo_xcontr		
zppsum		p	internal function: total pressure
zqcsum		q_1^{2C}	internal function: total cloud water
zqr0,m,s,x			internal functions for conversion of specific humidity to relative humidity
zqrsum		q_1^{2R}	internal function: total rain water
zqs0,m,s,x			internal functions for conversion of relative humidity to specific humidity
zqsat0,s,x			internal functions for saturation specific humidity
zqvsum		q_1^1	internal function: total specific humidity
zrhsum		ρ	internal function: total density
ztp0,m,s,x			internal functions for conversion of real temperatures to potential temperatures
ztpsum		θ	internal function: total potential temperature
ztr0,m,s,x			internal functions for conversion of potential temperatures to real temperatures
zvmet	mo_xpara		3d-array of vertical coordinates at vector grid point

10 Main Modules, Subroutines and Functions

Table 10-1: Subroutines, modules and functions of the M-SYS model systems. Routines shared by the main meteorological core model METRAS/MITRAS are declared in the model column by M-SYS. Routines only used by special sub models are marked accordingly.

routine/file	**description**	**(sub-)model**
fe_formdr	Numerical solution of an integral later used in the form drag calculation	MESIM only
fe_otchas	conversion of time to seconds	M-SYS
fe_ydecli	calculates suns declination [rad] for a given julian day	M-SYS
fe_ydeg	function for conversion [dd.mm ss] $\rightarrow$ [deg]	M-SYS
fe_yjdate	calculates the julian day for a given date	M-SYS
fe_ystrln	returns the string length	M-SYS
fe_ystrst	returns the string start	M-SYS
i.xyz.f90	all define expressions in source files xyz.f90 are extended; if specified when pre-compiling, line numbers of original source file are added at end of each line	M-SYS
mo_alias	aliases for species names	M-SYS
mo_build_surf	surface parameters for building faces	M-SYS
mo_chem	parameters for the tracer and chemistry module	M-SYS
mo_iceini	variables for ice model initialization	MESIM only
mo_iedum	variables for info/error messages	M-SYS
mo_imc	determination of basic icemodelcalculation control parameters	MESIM only
mo_kind	precision of real and integer values	M-SYS
mo_met	basic parameters for the meteorology module	M-SYS
mo_nudge	parameters for nudging	M-SYS
mo_phys	physical constants	M-SYS
mo_press	pressure variables	M-SYS
mo_siwconst	determination of basic snow, ice and water property constant	MESIM only
mo_stationarity	mean wind profiles to control stationarity of model results (mainly *mitras*)	M-SYS

routine/file	**description**	**(sub-)model**
mo_stencil	weighting functions and position parameters for *mitras*-obstacle mask	M-SYS
mo_tendencies	tendencies for tracer concentration	M-SYS
mo_userfield	empty user definabele fields for prototyping	M-SYS
mo_urban	arrays necessary to consider urban effects	M-SYS
mo_xacemi	information for aircraft emissions and induced mixing	M-SYS
mo_xamas		MESIM only
mo_xasy		MESIM only
mo_xaust	exchange coefficients	M-SYS
mo_xavs	varibles and arrays for AVS output	M-SYS
mo_xblend	sub grid-scale surface values and blending-height-parameters	M-SYS
mo_xboden	surface parameters	M-SYS
mo_xbouto		MESIM only
mo_xbrand	coefficients for IGCG pressure-solver	M-SYS
mo_xbubv		MESIM only
mo_xchart	species names	M-SYS
mo_xchem	boundary values for species concentration	M-SYS
mo_xcilu	values for IGCG pressure-solver	M-SYS
mo_xcmatp	values for IGCG- pressure-solver	M-SYS
mo_xcontr	control values for model-run	M-SYS
mo_xcorr		MESIM only
mo_xdepos	coefficients and control value for calculation of v_D	M-SYS
mo_xdhsi		MESIM only
mo_xdicht	density variables	M-SYS
mo_xdruck	mesoscale pressure variables and boundary values	M-SYS
mo_xdrv		MESIM only
mo_xe11e22e12		MESIM only
mo_xemiss	information for point and area emissions	M-SYS
mo_xeno	eno fields for ENO momentum advection	M-SYS
mo_xfrwat		MESIM only
mo_xfrwnd		MESIM only

routine/file	description	(sub-)model
mo_xfxfy		MESIM only
mo_xgeos	geostrophic values (wind, pressure)	M-SYS
mo_xgini	initial geostrophic values (wind, pressure, temperature)	M-SYS
mo_xifcp	main prognostic and diagnostic ice characteristics for dynamic sea ice model	MESIM only
mo_ximatmo		MESIM only
mo_ximg		MESIM only
mo_xintgr	time integrated 2-d arrays at/above surface for output on TAPE 65/66	M-SYS
mo_xintpr		M-SYS
mo_xisurfra	variables for ice concentrations	MESIM only
mo_xitpar	quantities for multigrid-pressure-solver	M-SYS
mo_xiwfluxes	variables for fluxes at ice boundaries	MESIM only
mo_xles	variables for LES mode	M-SYS
mo_xmask	land masks	MESIM only
mo_xmgrid	transformation coefficients, pressure solver matrix elements and obstacle weighting functions for a hierarchical multigrid domain	M-SYS
mo_xnudchem	information for nudging species concentration	M-SYS
mo_xnudge	nudging control variables and fields	M-SYS
mo_xpara	components of metric tensor, grid spacing, time values	M-SYS
mo_xqcran	boundary values for cloud water	M-SYS
mo_xqlic	cloud water variables	M-SYS
mo_xqlir	cloud water variables	M-SYS
mo_xqrran	boundary values for rain water	M-SYS
mo_xqvap	specific humidity values	M-SYS
mo_xqvran	boundary values for specific humidity	M-SYS
mo_xrad	radiation module variables	M-SYS
mo_xrelaxp		MESIM only
mo_xrhsol	values for pressure-solver	M-SYS
mo_xrun		MESIM only
mo_xrurv		MESIM only
mo_xshiemi	information for ship emissions	M-SYS

routine/file	description	(sub-)model
mo_xssdep	deposition values	M-SYS
mo_xsspol	concentration values	M-SYS
mo_xssran	boundary values for tracer	M-SYS
mo_xsurva	surface variables	M-SYS
mo_xtapnu	input and output tape numbers	M-SYS
mo_xtemp	temperature values	M-SYS
mo_xthck	variables for ice thickness and concentration	MESIM only
mo_xtim	tempartures for thermodynamic sea ice model	MESIM only
mo_xtind		MESIM only
mo_xtke	tke budget values	M-SYS
mo_xtname	input and output tape names (= filenames)	M-SYS
mo_xtrand	boundary values for temperature	M-SYS
mo_xvel	variables for ice drift velocities	MESIM only
mo_xviscp		MESIM only
mo_xwcal	special velocities and boundary conditions	M-SYS
mo_xwdep	coefficients for calculating wet deposition	M-SYS
mo_xweight	weighting functions and position parameters for MITRAS-obstacle mask	M-SYS
mo_xwind	velocities	M-SYS
mo_xwork	help-values for IGCG-pressure-solver	M-SYS
mo_xwork1	help-arrays for scalar quantities	M-SYS
mo_xwork2	help-arrays for wind fields	M-SYS
mo_xwork3	different help-arrays	M-SYS
mo_xwork4	help-arrays for chemistry and transport	M-SYS
mo_xwprov	meantime velocities	M-SYS
mo_xwrand	boundary values for velocities	M-SYS
mo_xzetaeta		MESIM only
oa1tp1	calculation of new temperature profiles	MESIM only
oa1tp2	calculation of new temperature profiles	MESIM only
oad0ph	advection for basic state scalar quantities	M-SYS
oaddrifticl1	additional drift of sea ice in ice class 1 in case of growing ice (resulting changes of vertical grid)	MESIM only
oaduph	calculation of advection Upwind-differences	M-SYS
oadvectx	solution of continuity equation (x-direction) by means of the emde-method	MESIM only

routine/file	description	(sub-)model
oadvecty	solution of continuity equation (y-direction) by means of the emde-method	MESIM only
oadvf	calculation of advection	M-SYS
oahori	resetting horizontal exchange coefficients	M-SYS
oamax1	fix ice coverage > 100%	MESIM only
oansacp	calculation of near surface temperature and specific humidity as well as cloud parameters	MESIM only
oashdef		MESIM only
oauber	calculation of vertical and horizontal exchange coefficients (after Dunst)	M-SYS
oaudis	calculation of vertical and horizontal exchange coefficients (via dissipation)	M-SYS
oauhol	calculation of vertical and horizontal exchange coefficients (after Holtslag)	M-SYS
oaumix	calculation of vertical and horizontal exchange coefficients (via mixing length)	M-SYS
oautro	calculation of vertical and horizontal exchange coef. (after Troen&Mahrt)	M-SYS
obchg	calculation of coefficients in Poisson equation	M-SYS
obcoef	this subroutine calculates the contributions from the local grid point, ie (i,j), to the finite difference approximation to the momentum equations for the viscous and advection terms. those contributions to from the local rate of change and from the oceanic drag term will be added afterwards in subroutine relcon.	MESIM only
obcsh1	calculation of scalar quantities (surfrath,hi,hs,lif) at 1,nx1,nx2 by upstream (not able to calculate by emde-scheme)	MESIM only
obcsh2	boundary conditions for scalar quantities (surfrath,hi,hs,lif)	MESIM only
obcshlw	set snow thickness hs, ice thickness hi, length of ice floe lif and width of lead wle on boundaries	MESIM only
obcsinit	initialisation of various masks	MESIM only

routine/file	**description**	**(sub-)model**
obcssurf	set surfrath on boundaries	MESIM only
obcsv	set drift velocity boundary conditions	MESIM only
obmul		M-SYS
ochbot	calculation of changes at the bottom of the ice	MESIM only
ochkdi	check of array dimension parameter	M-SYS
ochkra,m,g	control completeness of A,M,G output structures	M-SYS
ochsiwiw	calculation of final changes concerning snow, ice and water	MESIM only
ochsiwoi	calculation of final changes concerning snow, ice and water (case : only snow and ice)	MESIM only
ochsiwow	calculation of final changes concerning snow, ice and water (case : only water)	MESIM only
ochtop	calculation of changes at the top of the sea ice	MESIM only
ochvg	change of vertical grid due to melting, freezing and flooding	MESIM only
ocloud	calculation of clouds	M-SYS
ocondovgpicl	Calculation of normalized depth of vertical grid points (version for icl)	MESIM only
ocondovgpjjji	Calculation of normalized depht of vertical grid points (version for jj, ji)	MESIM only
ocooticl	calculation of old temperatures at the normalized dephts of new vertical grid points	MESIM only
ocphi	calculation of phase velocities for radiation boundary cond. (scalar quantities)	M-SYS
ocuvw	calculation of phase velocities for velocities	M-SYS
oddx	calculate d/dx (eta * du/dx)	MESIM only
odenst	calculation of mesoscale density deviation dependent on temperature	M-SYS
odif	calculation of diffusion (velocity equation)	M-SYS
odifhe	calculation of horizontal diffusion with explicit scheme (velocity equation)	M-SYS
odifve	calculation of vertical diffusion with explicit scheme (velocity equation)	M-SYS
odip	calculation of diffusion (scalar quantities)	M-SYS
odipve	calculation of vertical diffusion with explicit	M-SYS

routine/file	description	(sub-)model
	scheme (scalar quantities)	
odipvi	calculation of vertical diffusion with implicit scheme (scalar quantities)	M-SYS
odisqu	calculation of source terms of dissipation	M-SYS
odiuvi	calculation of vertical diffusion with implicit scheme (wind v)	M-SYS
odiv	calculation of velocity divergence	M-SYS
odivvi	calculation of vertical diffusion with implicit scheme (wind v)	M-SYS
odiwvi	calculation of vertical diffusion with implicit scheme (wind w)	M-SYS
odynim(d	control of dynamic sea ice calculations	MESIM only
odyniminit	define basic parameters for the dynamic sea ice model, set initial fields and conditions	MESIM only
odynimmcl	main computational loop of the dynamic sea ice model	MESIM only
odynimmclstatvel	calculation of a stationary initial drift velocity field (first part of the main computational loop of the dynamic sea ice model)	MESIM only
ofichinoicl	calculation of resulting changes in the old ice classes (not for ice class 1)	MESIM only
ofilte	calculation of filtered values	M-SYS
oformopwa	create open water due to shearing deformation	MESIM only
ogeobe	initialisation of large scale values	M-SYS
ohitemp	advection of ice thickness, snow thickness and ice floe length	MESIM only
oi1a/g/m50	reading 1-d-profiles, written by 1-d model	M-SYS
oiceincheck	reading in the ice variables, they are just non-zero in case of ice coverage	MESIM only
oicezero	cut off if ice coverage small	MESIM only
oidynacouple	sea ice to atmosphere coupling after dynamically induced changes	MESIM only
oifcpinit	ice floe configuration parameters	MESIM only
oigcg	calculation of pressure	M-SYS
oina/g/m50	reading 3-d fields, written by outa/g/m60	M-SYS

routine/file	description	(sub-)model
oinc/f52	read forcing data from tape 52	M-SYS
oingaf	reading topography file	M-SYS
oiniti	initialize model run	M-SYS
oinitrel	adjusts the initial velocities to be in approximate balance	MESIM only
oinmet	initialize meteorology module, reading TAPE 5	M-SYS
oinnud	initialization of forcing by nudging	M-SYS
oinout	check of inflow/outflow boundary	M-SYS
okoeff	calculation of coefficients for the coordinate transformation	M-SYS
olimul	calculation of the bottom triangular matrix	M-SYS
omadv	add in horizontal advection terms	MESIM only
omeso	initialization of mesoscale quantities (1d-model)	M-SYS
onscal	forcing of scalar values	M-SYS
onudin	update forcing arrays	M-SYS
onwind	forcing of wind components	M-SYS
onxisc	check of selected boundary conditions	M-SYS
ophhor	calculation of the lateral boundary values for scalar quantities	M-SYS
ophver	calculation of bottom and top boundary values for scalar quantities	M-SYS
opilut		M-SYS
oplast	calculates the viscosities	MESIM only
oprepconticl	preparation for calculation of new temperatures	MESIM only
opressu	calculation of the ice pressure p(h,a) at scalar grid points	MESIM only
oqbsur	calculation of specific humidity at surface	M-SYS
orad	calculation of radiation fluxes	M-SYS
oranfe	establish the final boundary value for the velocity	M-SYS
oranff	final boundary values for wind	M-SYS
oranfp	establish the top and bottom boundary values of the provisional velocities	M-SYS
oranfs	calculation of the boundary values at radiation conditions and b/c 8	M-SYS
oranp2	boundary conditions of p_2	M-SYS

routine/file	**description**	**(sub-)model**
orelax	calculates velocities at the next time step by first estimating the velocities using sequential overrelaxation with cheybeshev acceleration (see hockney and jesshope (1981), pg 334-341). In this case we are updating a checkerboard alterna colors, ie first red, then black.	MESIM only
orelcon	calculates those parts of the momentum equations for sea ice that do not depend on the u and v values at the previous time step, and the coefficients for the u and v values at the grid point (the diagonal terms). This subroutine sets up the equations to be solved by relax.	MESIM only
oreploficl	replacement of ice classes add new ice check old ice thicknesses: in case the old ice thickness in an ice class exceeds or falls below the ice thickness boundaries of this ice class, this ice is added to the ice of the class with the higher or the lower ice thickness.	MESIM only
osalbedo	surface albedo of snow, ice and water	MESIM only
oshade	calculating minimum sun altitude for no shading	M-SYS
oshdef	shearing deformation term for use in the open water creation term	MESIM only
osiprop	calculation of snow and ice properties	MESIM only
osohteq	solution of heat transfer equation	MESIM only
ostati	check the stationarity of a field	M-SYS
ostlof	calculation of sub grid-scale surface fluxes of scalar quantities	M-SYS
ostorb	storage of scalar boundary values	M-SYS
ostrain	strain tensor at the h grid point by first interpolating to 1/2 way between the h grid points, and then differentiating.	MESIM only
osuenba	calculation of surface energy balance temporary conductive heat flux at the snow/ice surface	MESIM only
osurc	calculation of surface characteristics	M-SYS
osurfratempx	adevection of ice concentration	MESIM only

routine/file	description	(sub-)model
osurfratempy	adevection of ice concentration	MESIM only
otauaice	calculation of the atm. drag (sea ice) used on the b-grid of the dynamic sea ice model	MESIM only
otbsur	calculation of temperature at surface	M-SYS
othermoiminit	initialisation of the thermodynamic sea ice model	MESIM only
otimnew	final solution of heat transfer equation for the multi layer case	MESIM only
otqbsurm5	calculation of surface temperature and humidity of open water and sea ice (only used in case of imcmeth = 5)	MESIM only
otsitempx	new temperature profiles in the sea ice after advection in x-direction	MESIM only
otsitempy	new temperature profiles in the sea ice after advection in y-direction	MESIM only
ouimul	calculation of the upper triangular matrix (filename: ouimul_vect)	M-SYS
ouitra	transformation/retransformation f wind	M-SYS
out62	print field mean values and position of maximum variance for each time step	M-SYS
outa/g/m06	print out the start/geostrophic/predicted values on tape 6	M-SYS
outa/g/m60	print out the start/geostrophic/predicted values on tape 60	M-SYS
outint	print out 10-min mean values on tape 65/66	M-SYS
ovgp	calculation of vertical grid	MESIM only
owatvel	determination of geostrophic ocean current field	MESIM only
owhydr	calculation of vertical wind from anelastic approximation	M-SYS
owtdep	calculation of wet deposition	M-SYS
ozeit	calculation of the time to the next time step	M-SYS
ozinv	calculation of inversion height	M-SYS
se_acinfl	calculation of aircraft emissions and induced mixing	M-SYS
se_adfluxcor	calculation of advection of scalar quantities with second-order upstream	M-SYS

routine/file	description	(sub-)model
se_bouf se_buildtemp	calculation of acceleration due to gravity calculation of building surface temperature	M-SYS
se_check_bc	check of boundary values for species concentration	M-SYS
se_check_conc	check of species concentrations	M-SYS
se_chem_pvp	calculation of chemical reactions	M-SYS
se_cnest	providing time dependent boundary conditions for species	M-SYS
se_corf	calculation of Coriolis force	M-SYS
se_cprof	interpolation of background concentration profiles to grid points	M-SYS
se_ctm	main routine for calculation of tracer transport and chemistry	M-SYS
se_diast	diastrophy of orography	M-SYS
se_disturb	Add disturbations in LES mode	M-SYS
se_dicht	calculation of mesoscale density deviation dependent on potential temperature	M-SYS
se_emis	calculation of all emissions of active and passive tracer substances	M-SYS
se_errmsg	handling of program errors and messages	M-SYS
se_escalar	numeric integration of balance equations of scalar quantities	M-SYS
se_ewical	calculation of the wind	M-SYS
se_exchange_tke	calculation of vertical and horizontal exchange coefficients (via TKE-Budget)	M-SYS
se_iall_ice	initialize ice variables	MESIM only
se_iced0	preparation of thermodynamic sea ice model	MESIM only
se_imc	initialize variables of mo_imc	MESIM only
se_inche	initialise chemical reaction module, mainly reading point and area emissions	M-SYS
se_inf58	read of time dependent boundary conditions for species	M-SYS
se_inhflp	read TAPE54	M-SYS
se_inice	read and check of seaice model input tape m3tras_tape10	MESIM only
se_iniice	read of TAPE10 (control data for sea ice model)	M-SYS
se_inilscale	extrapolation of 1-d results to 3-d fields	M-SYS
se_init_ctm	initialization of chemistry and transport module	M-SYS
se_intra se_lwviewfac	initialise tracer module, mainly reading TAPE4 calculation of weighting factors for LW radiation	M-SYS

routine/file	description	(sub-)model
	from ground to building	
se_inttins	interpolation of soil temperature depending on surface elevation	M-SYS
se_ini_random	initialisation of random seed for random generator	M-SYS
se_iphys	definition of physical parameters	M-SYS
se_iuserfield	initialize variables of mo_userfield	M-SYS
se_ixamas	initialize variables of mo_xamas	MESIM only
se_ixasy	initialize variables of mo_xasy	MESIM only
se_ixbouto	initialize variables of mo_xbouto	MESIM only
se_ixbubv	initialize variables of mo_xbubv	MESIM only
se_ixcorr	initialize variables of mo_xcorr	MESIM only
se_ixdhsi	initialize variables of mo_xdhsi	MESIM only
se_ixdrv	initialize variables of mo_xdrv	MESIM only
se_ixe11e22e12	initialize variables of mo_xe11e22e12	MESIM only
se_ixfrwat	initialize variables of mo_xfrwat	MESIM only
se_ixfrwnd	initialize variables of mo_xfrwnd	MESIM only
se_ixfxfy	initialize variables of mo_xfxfy	MESIM only
se_ixiceini	initialize variables of mo_iceini	MESIM only
se_ixifcpc	initialize variables of mo_xifcp	MESIM only
se_iximatmo	initialize variables of mo_ximatmo	MESIM only
se_iximg	initialize variables of mo_ximg	MESIM only
se_ixisurfra	initialize variables of mo_xisurfra	MESIM only
se_ixiwfluxes	initialize variables of mo_xiwfluxes	MESIM only
se_ixles	initialize variables of mo_xles	M-SYS
se_ixmask	initialize variables of mo_xmask	MESIM only
se_ixmet	initialize variables of mo_met	MESIM only
se_ixpressc	initialize variables of mo_xpress	MESIM only
se_ixrelaxp	initialize variables of mo_xrelaxp	MESIM only
se_ixrun	initialize variables of mo_xrun	MESIM only
se_ixrurv	initialize variables of mo_xrurv	MESIM only
se_ixthck	initialize variables of mo_xthck	MESIM only
se_ixtim	initialize variables of mo_xtim	MESIM only
se_ixtind	initialize variables of mo_xtind	MESIM only
se_ixvel	initialize variables of mo_xvel	MESIM only
se_ixviscp	initialize variables of mo_xviscp	MESIM only
se_ixzetaeta	initialize variables of mo_xzetaeta	MESIM only

routine/file	description	(sub-)model
se_ndweights	calculation of the nudging weigths	METRAS only
se_oastarfa	surface layer scaling parameters with flux averaging	M-SYS
se_oastarpa	surface layer scaling parameters with parameter averaging	M-SYS
se_oastarpf	surface layer scaling parameters with prescribed heat flux	M-SYS
se_outaf60_sg	write formatted output (A-structures)	M-SYS
se_outal	print time series, the values will be formatted after each time step	M-SYS
se_outgf60_sg	write formatted output (G-structures)	M-SYS
se_outmf60_sg	write formatted output (M-structures)	M-SYS
se_p1	calculation of the pressure part p_1	M-SYS
se_p1f	consideration of the pressure gradient force of p_1	M-SYS
se_p2	calculation of the pressure part p_2	M-SYS
se_p2f	consideration of the pressure gradient of p_2	M-SYS
se_p2lhs	for initialization of the coefficients of Poisson equation of p_2	M-SYS
se_phad	advection and diffusion of scalar quantities	M-SYS
se_phid0	reset of tendencies (scalar quantities)	M-SYS
se_print_version	print information about model version to	M-SYS
se_qbsur_ice	calculation of surface humidity	MESIM only
se_radio	calculation of radioactive decay of species	M-SYS
se_readhinc	read ice thickness data from NetCDF file	MESIM only
se_read_emis_dat	generalized read of area emissions	M-SYS
se_read_emisac_dat	read of aircraft properties	M-SYS
se_read_emiship_dat	read of ship properties and routes	M-SYS
se_read_emisp_dat	generalized read of point emissions	M-SYS
se_readobst	reading buildings, etc. from tape 31	M-SYS
se_set_hflp	calculate value of prescribed heat flux	M-SYS
se_shinfl	caculates ship emissions	M-SYS
se_sgsm_deardo	exchange coefficients for LES sgs turbulence closure	M-SYS

routine/file	description	(sub-)model
se_sgsm_source	calculation of source terms of the TKE budget (LES)	M-SYS
se_structure	initialization of record numbers necessary for restart	M-SYS
se_tbsur_ice	sgs surface coverages, sgs surface temperatures	MESIM only
se_tke_sources	calculation of source terms of the TKE budget (RANS)	M-SYS
se_trans	calculation of species transport	M-SYS
se_vdepo	calculation of deposition velocities for species	M-SYS
swflux	calculation of shortwave radiation fluxes	M-SYS

11 References

Aschauer, J. (2010): *Auswertung der Betriebsdaten von Erdwaermesonden und Ableitung des Waermeleitfaehigkeitskatasters Oberoesterreich.* Österreichische Wasser- und Abfallwirtschaft. 62, 86-93.

ASHRAE (2005): *ASHRAE handbook: 2005 fundamentals.* American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1022 pp.

Birnbaum, G. (1998): *Numerische Modellierung der Wechselwirkung zwischen Atmosphäre und Meereis in derarktischen Eisrandzone.* Berichte zur Polarforschung, 268, pp 160. Dissertation at University of Bremen,1997.

Brutsaert, W.H. (1982): *Evaporation into the Atmosphere.* D. Reidel: Dordrecht, 299 pp.

Dierer, S.C. (2002): *Untersuchung von groß- und mesoskaligen Einflüssen auf die Entwicklung polarer Mesozyklonen mit Hilfe des Modells METRAS.* Berichte aus dem Zentrum für Meeres- und Klimaforschung, ZMK Universität Hamburg, Meteorologisches Institut, Vol. 35, pp. 106.

Fock, B.H. (2011): *MeMi Matlab* Toolbox. Available on request from URL: https://code.zmaw.de/projects/memi-toolbox

Garrratt, J.R. (1992): *The atmospheric boundary layer.* Cambridge University Press: Cambridge, 316 pp.

Kanda, M, Kanega M., Kawai, T., Moriwaki, R. and Sugarawa, H. (2007): *Roughness Lengths for Momentum and Heat Derived from Outdoor Urban Scale Models.* J. Appl. Met. Clim., 46, 1067-1079.

Kondo, J. (2000): *Atmospheric Science near the Ground Surface* (in Japanese). University of Tokyo Press, 324 pp.

Kolusu, S. (2012): *Determination of halide emissions by mesoscale modeling.* Dissertation. Meteorologisches Institut, Universität Hamburg.

Lalic, B. and Mihailovic, D.T. (2004): *An Empirical Relation Describing Leaf-Area Density inside the Forest for Environmental Modeling*, Journal of Applied Meteorology 43 (4), 641–45,.

Lee, S.-H. and S.-U. Park. (2008): *A Vegetated Urban Canopy Model for Meteorological and Environmental Modelling.* Bound-Lay. Meteor. 126, 73-102.

Linde, M,, Spensberger, C. and Schlünzen K.H. (2011): *GRIGAU / GRIGAU_50 - Preprozessor zu Initialisierung idealisierter Topographien für das Modell METRAS.* Meteorologisches Institut, Universität Hamburg. METRAS Technical Report 9, 40.

Masson, V. (2000): *A physically-based scheme for the urban energy budget in atmospheric models.* Bound.-Lay. Meteor., 104,261-304.

Masson V., Grimmond, C.S.B. and Oke, T.R. (2002): *Evaluation of the Town Energy Balance (TEB) scheme with direct measurements from dry districts in two cities.* J. Appl. Meteor., 41, 1011-1026

Meyer, E. M. I. (2006): *Die Bedeutung atmosphärischer Prozesse für den Stickstoffeintrag in Küstengewässer.* Dissertation. Universität Hamburg. 121 p. URL: http://www.zmaw.de/fileadmin/Bib/ZMK_A.html

Oke, T.R. (1987): *Boundary Layer Climates.* 2nd ed. Routledge, 435 pp.

Roth, M. (2000): *Review of atmospheric turbulence over cities.* Q.J.R. Meteor. Soc., 126, 941-990.

von Salzen (1997): *Entwicklung und Anwendung eines Modells für die Dynamik und Zusammensetzung des sekundären und marinen Aerosols.* Dissertation. Zentrum für Meeres und Klimaforschung der Universität Hamburg. Nr. A30.

Schlünzen, K., H., Bigalke, K., Lüpkes, C., Niemeier, U. and von Salzen, K. (1996): *Hints for using the mesoscale transport and model 'METRAS'.* Meteorologisches Institut, Universitaet Hamburg.

Schlünzen, K.H., Bungert, U., Fock, B.H., Flagg, D., Gierisch A., Grawe D., Kirschner, P., Lüpkes, C., Reinhardt, V., Ries, H., Spensberger, C. and Uphoff, M. (2012): *Technical Documentation of the Multiscale Model System M-SYS (METRAS, MITRAS, MECTM, MICTM, MESIM)* Meteorologisches Institut, Universität Hamburg, MeMi Technical Report, 3, pp. 117.

Schlünzen, K. H., Boettcher M., Fock B.H., Gierisch A., Grawe D., Salim M. (2018): *Scientific Documentation of the Multicscale Model System M-SYS (METRAS, MITRAS, MECTM, MICTM, MESIM).* Meteorologisches Institut der Universität Hamburg. MEMI Technical Report 4., pp. 147.

Spensberger, C. and Schlünzen K.H. (2010): *GRITOP - Preprozessor zur Initialisierung von Topographiedaten für das Modell METRAS*. Meteorologisches Institut, Universität Hamburg. METRAS Technical Report 8, 31.

Wieringa, J. (1993): *Representative Roughness Parameters for Homogeneous Terrain.* Bound-Lay. Met., 63, 323-363.