Regional climate modelling with the MAR model

```
M         M       AAAAAAA         RRRRRRR
MM       MM      A       A       R       R
M M     M M      A       A       R       R
M  M   M  M      A       A       R       R
M   MM   M       A AAAAA A       R RRRRR R
M        M       A       A       R R
(MODELE tridimensionnel ATMOSPHERIQUE a l'echelle REGIONALE)
M        M       A       A       R   R
M        M       A       A       R    R
M        M       A       A       R     R
M        M       A       A       R      R
```

by Hubert Gallée (LGGE, Grenoble, France)

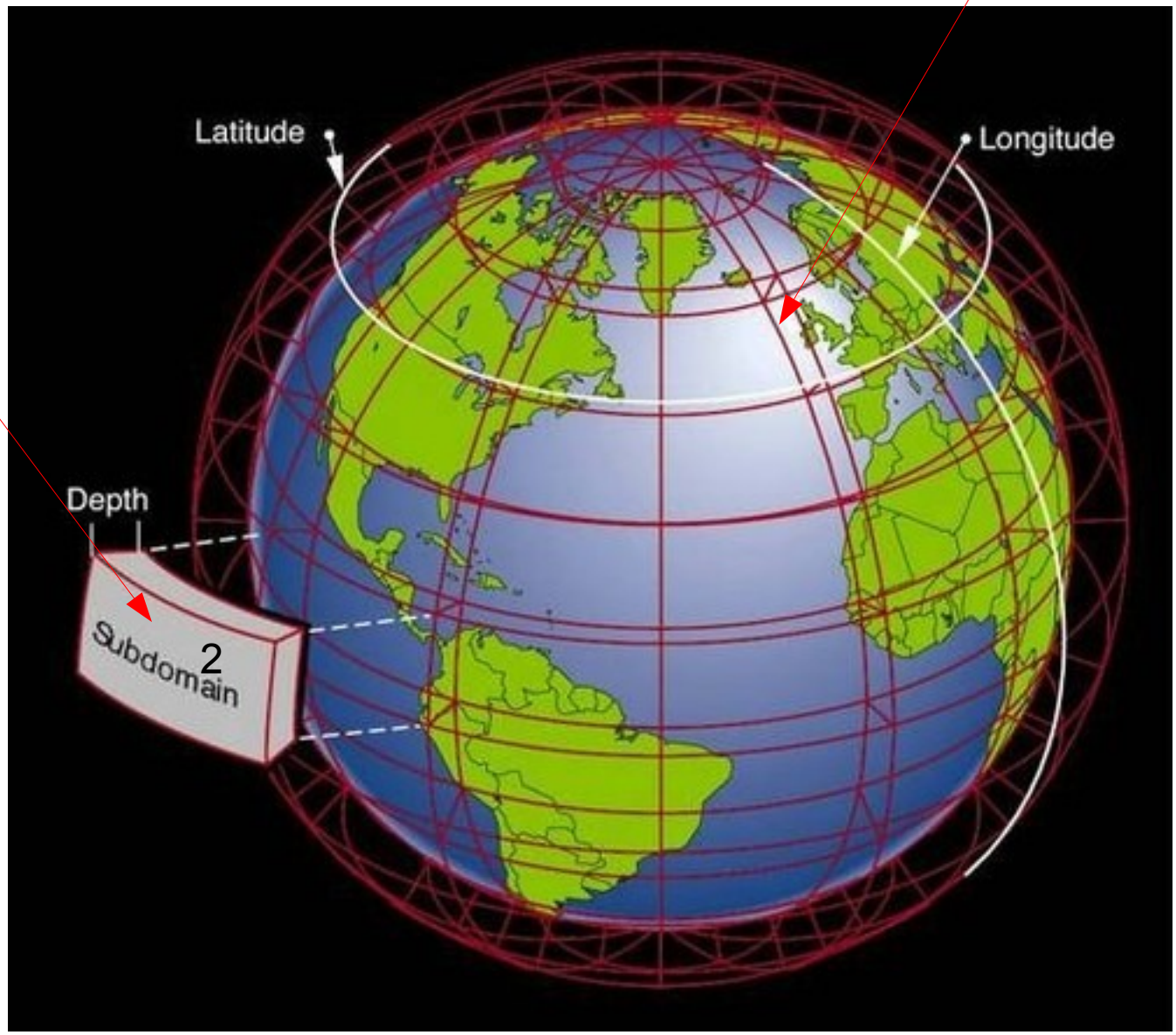
1. Regional modeling

Global circulation model (GCM)

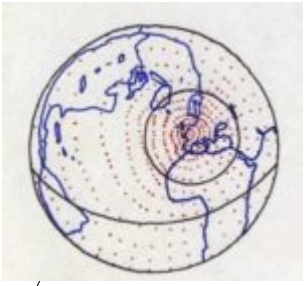
Regional climate model (RCM)

or

Limited area model (LAM)



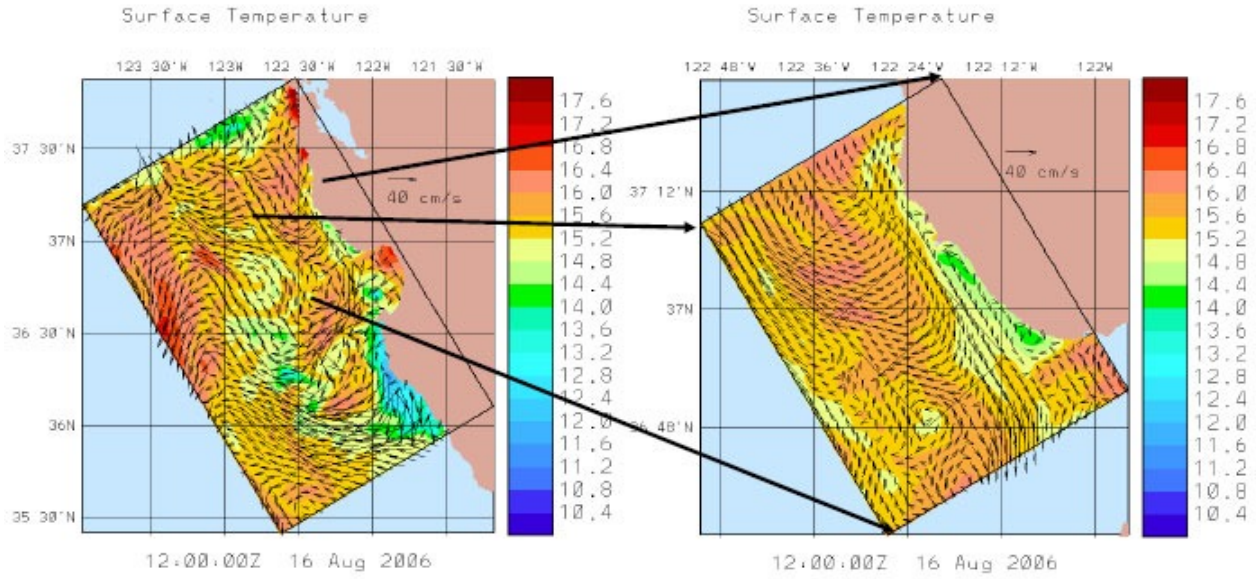
1. Regional modeling



+ The RCM have a **better spatial resolution** without an excess of computation times. This allows to have a more detailed topography to take into account the regional (or local) changes. (It is also the case for some variable resolution (zoomed) GCM).

+ The RCM have **more detailed parametrisations** (to take into the meso-scale phenomena) and are **tuned for the studied region**.

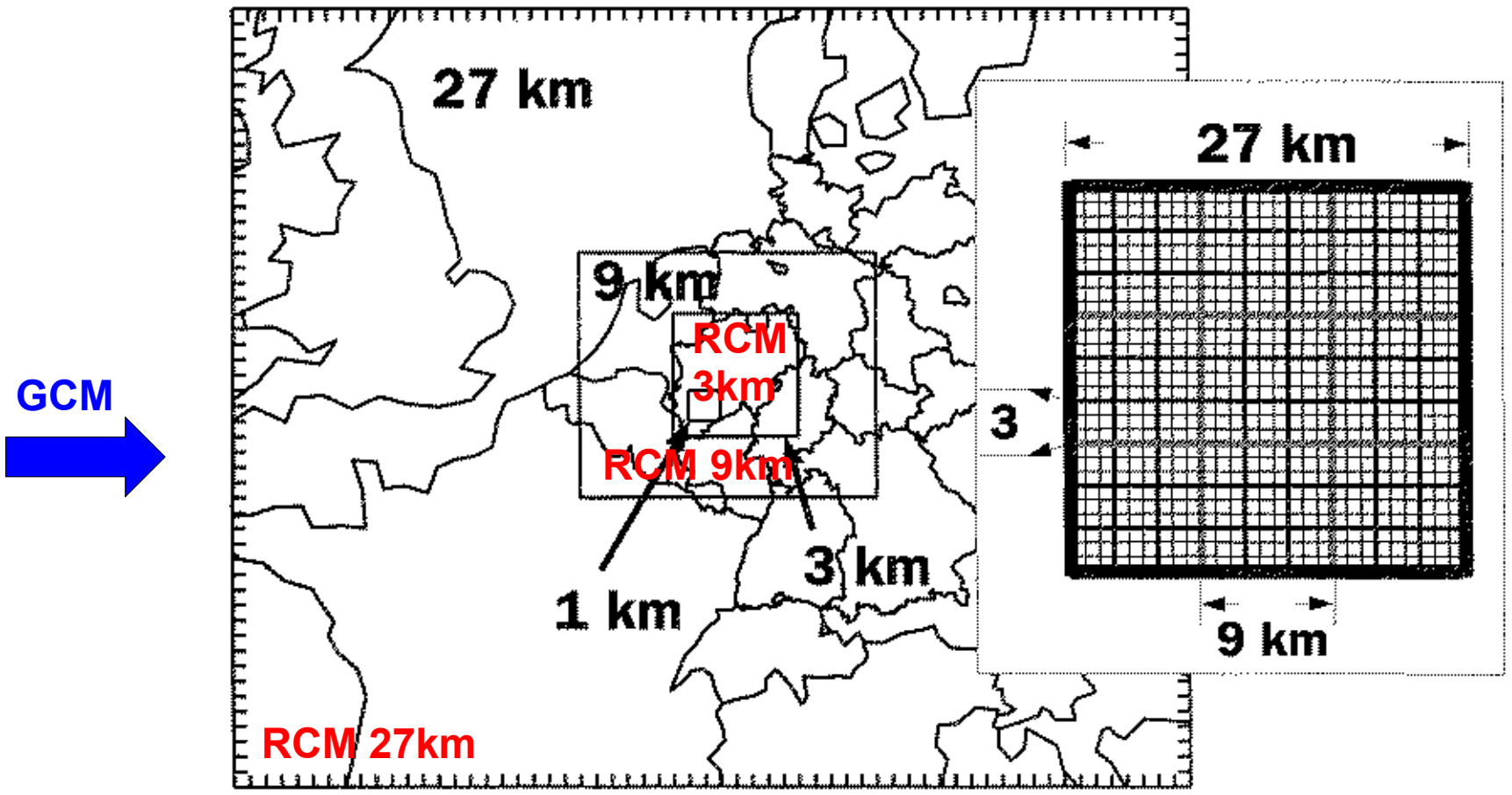
- The RCM **need to be forced at their boundaries** by results of a large-scale model, by observations or results with a lower resolution RCM. Unfortunately, the results of the RCM depend of the quality of the forcing fields.



1. Regional modeling

One way nesting

The low resolution fields are only used to force the higher resolution model.

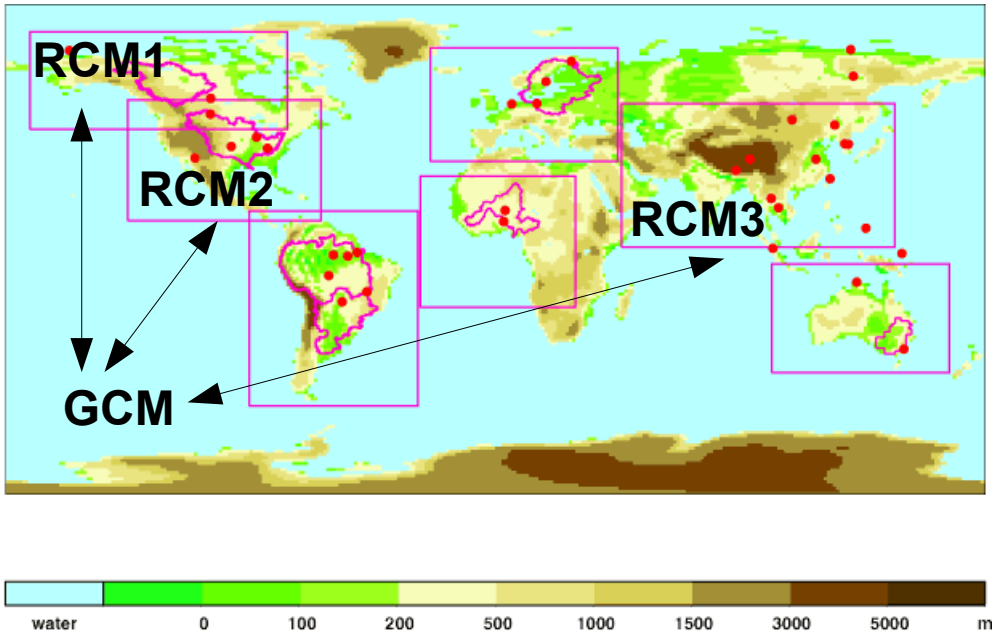


1. Regional modeling

Two way nesting

The results of the nested model are used in the LSC model.

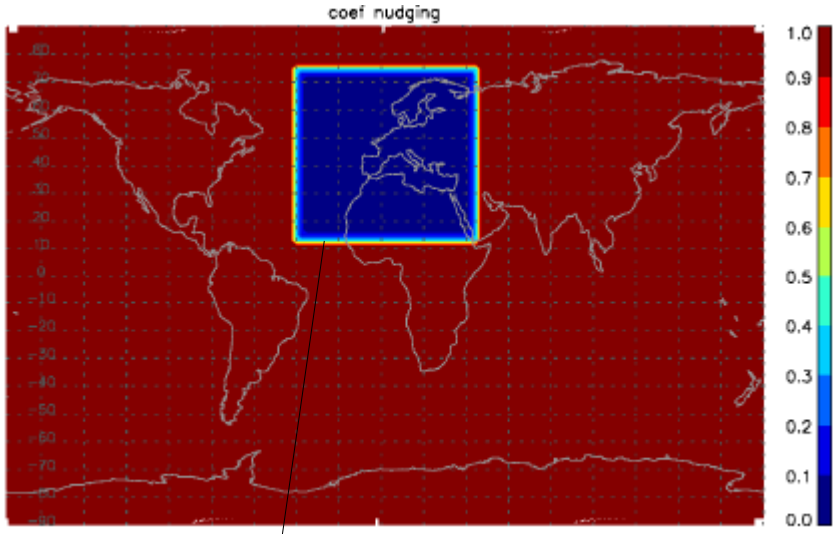
The dream for global modelling ... ;-)

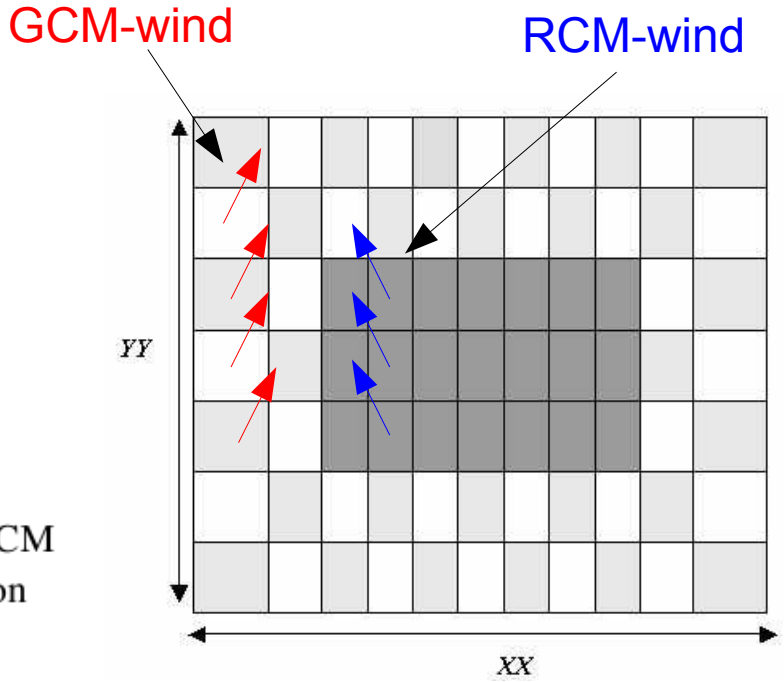


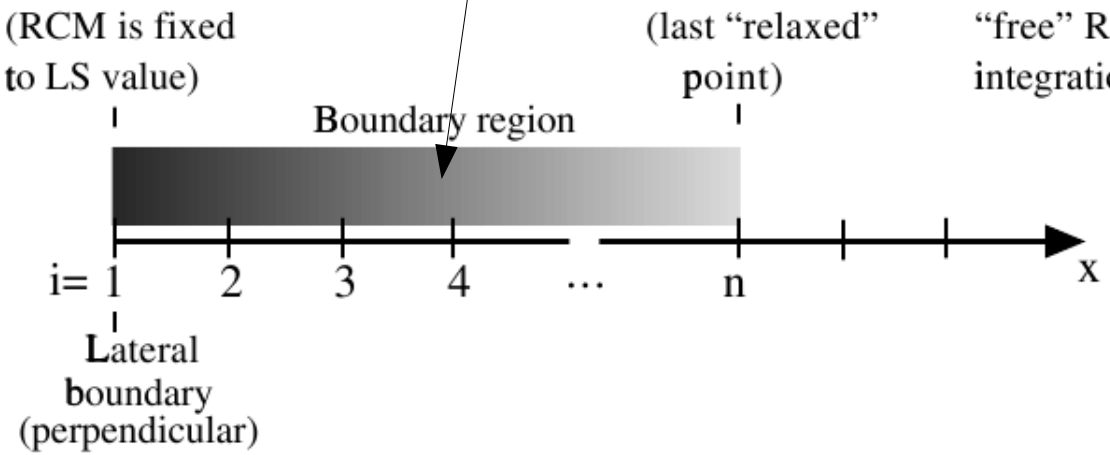
1. Regional modeling

Relaxation zone (1/3)

The boundary between the GCM and the RCM







1. Regional modeling

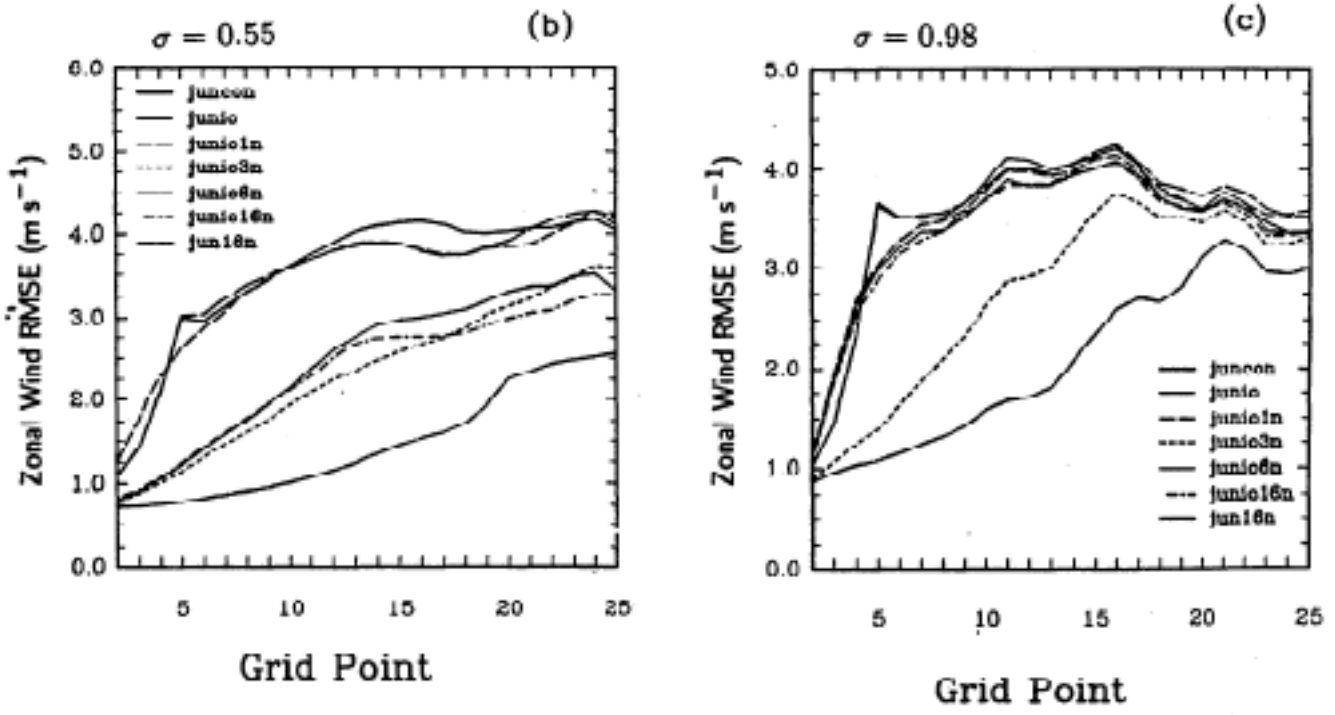


Figure 2. Root-mean-square errors between simulated and analyzed zonal wind speed at three atmospheric levels as a function of grid point distance from the lateral boundaries for a number of experiments by *Giorgi et al.* [1993b].

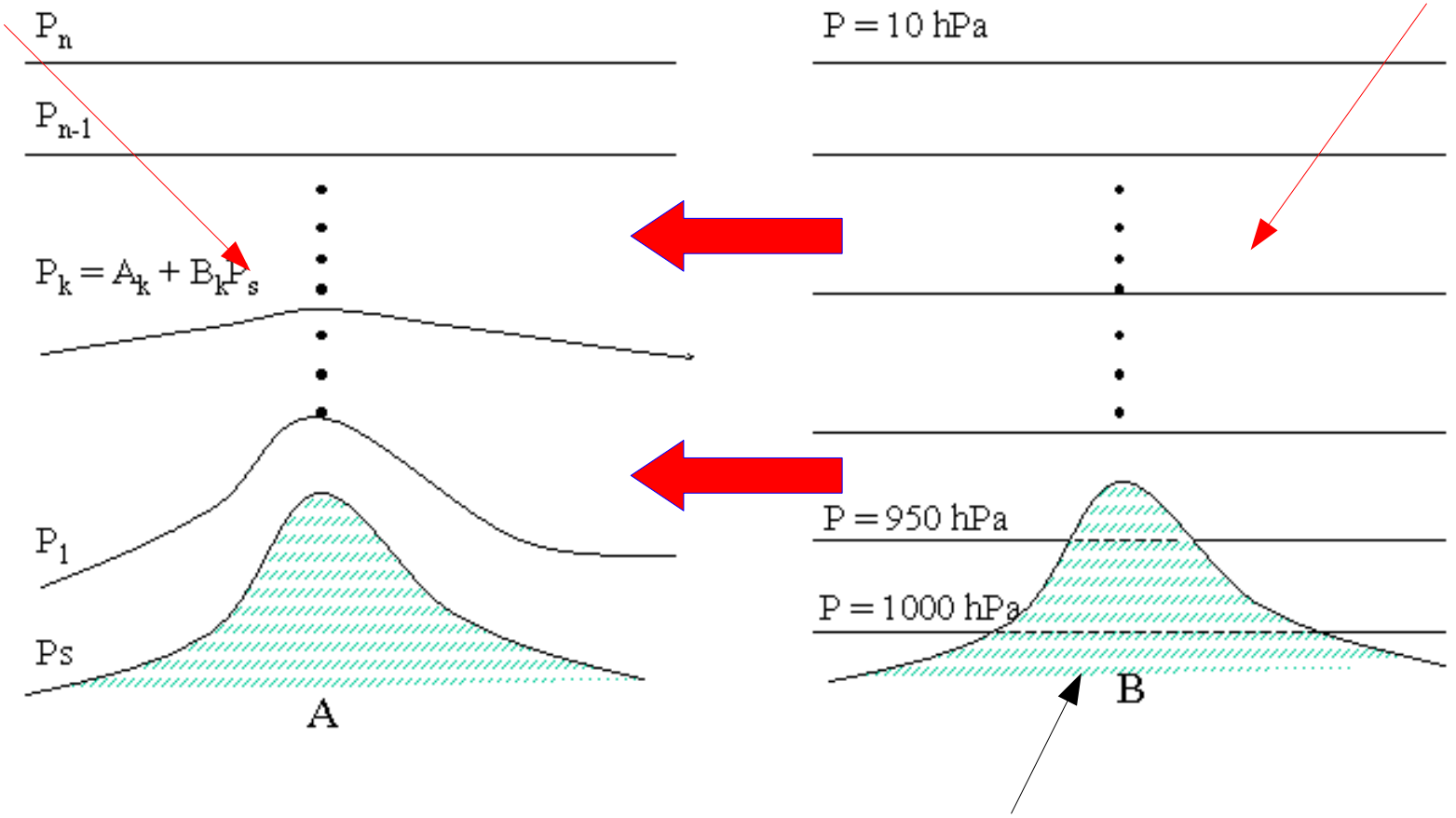
Ref: Giorgi, F., and L. O. Mearns (1999), Introduction to special section: Regional climate modeling revisited, J. Geophys. Res., 104(D6), 6335–6352.

1. Regional modeling

Relaxation zone (3/3)

Vertical coordinates of the RCM model

Vertical coordinates of the LSC model



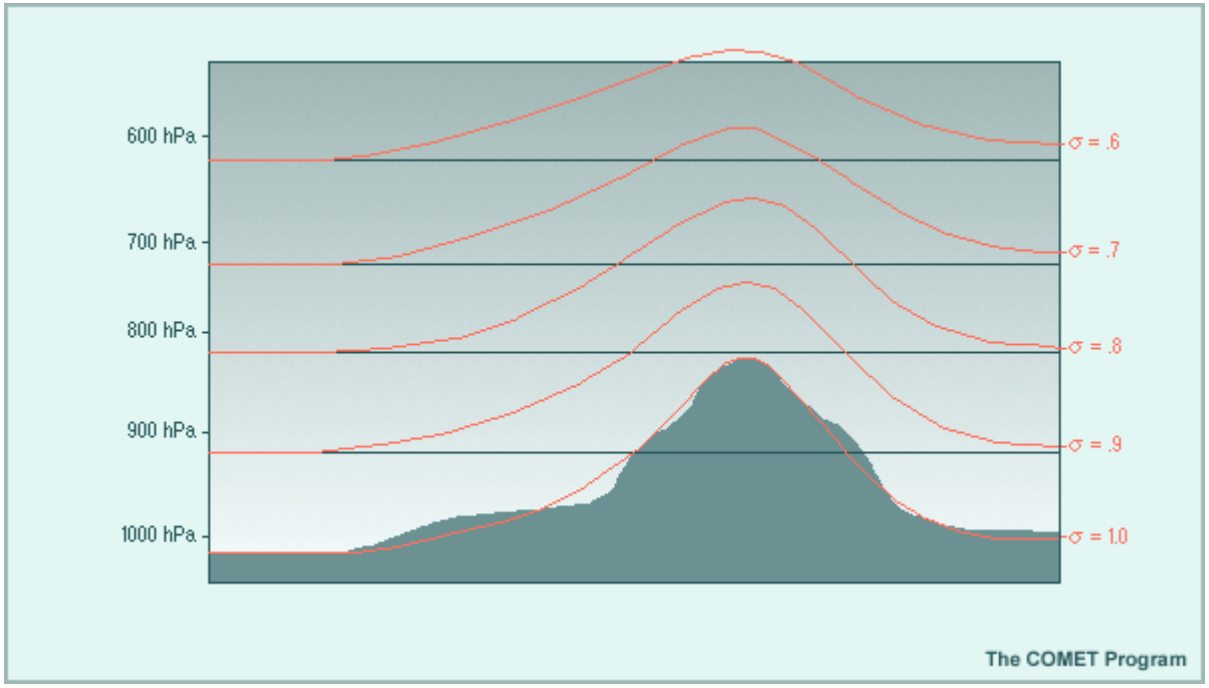
You should limit the topography in the relaxation zone

Topography not resolved by the GCM resolution

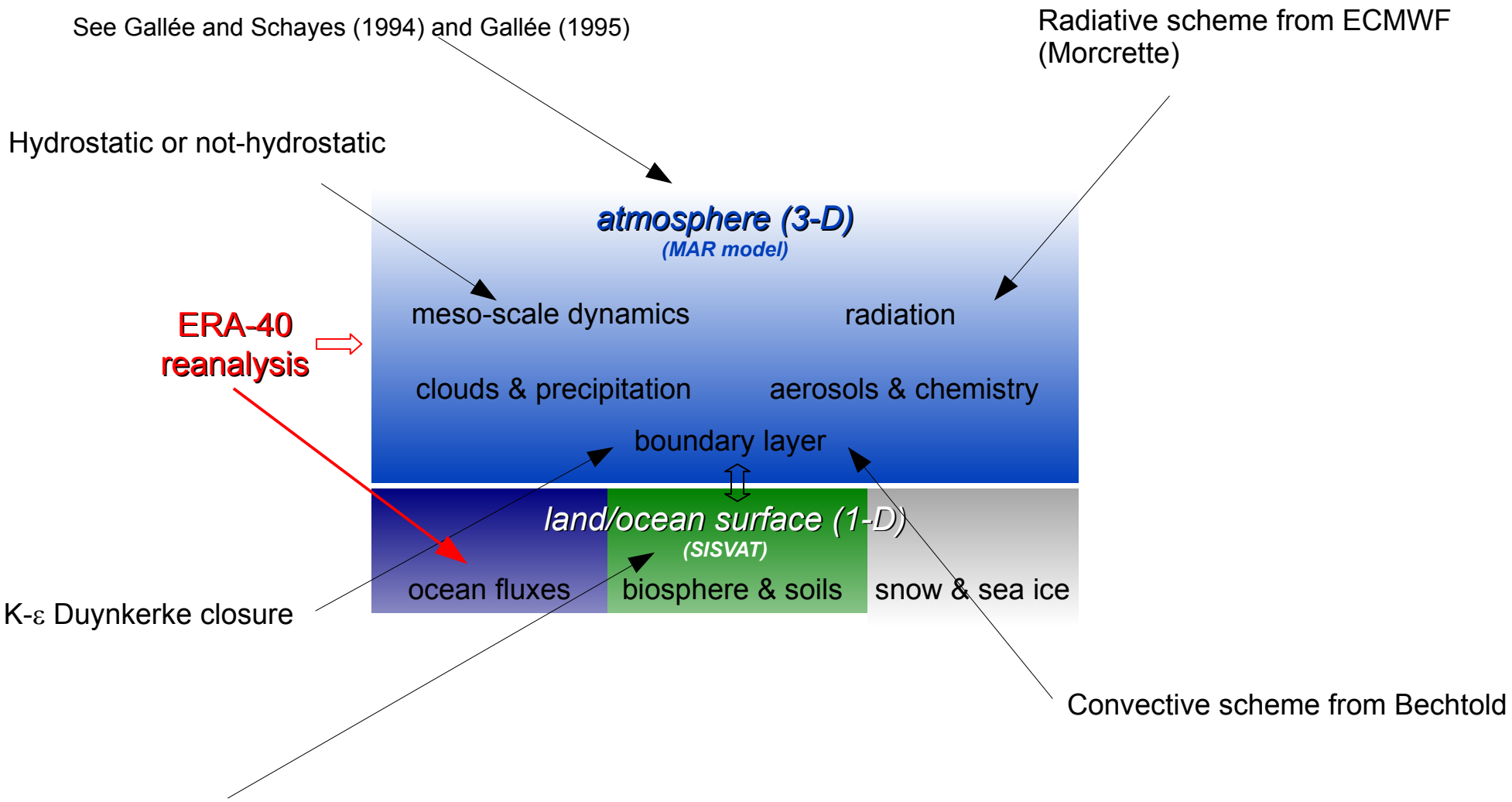
2. Introduction to MAR

- The MAR (Modèle Atmosphérique Régional) model was funded by Hubert Gallée (LGGE, France).
- It is (non-)hydrostatic primitive equation model.
- The vertical coordinate is the normalized pressure sigma:

$$\sigma(k) = \frac{p(k) - p_{top}}{p_{surface} - p_{top}}, k \in [1,40]$$

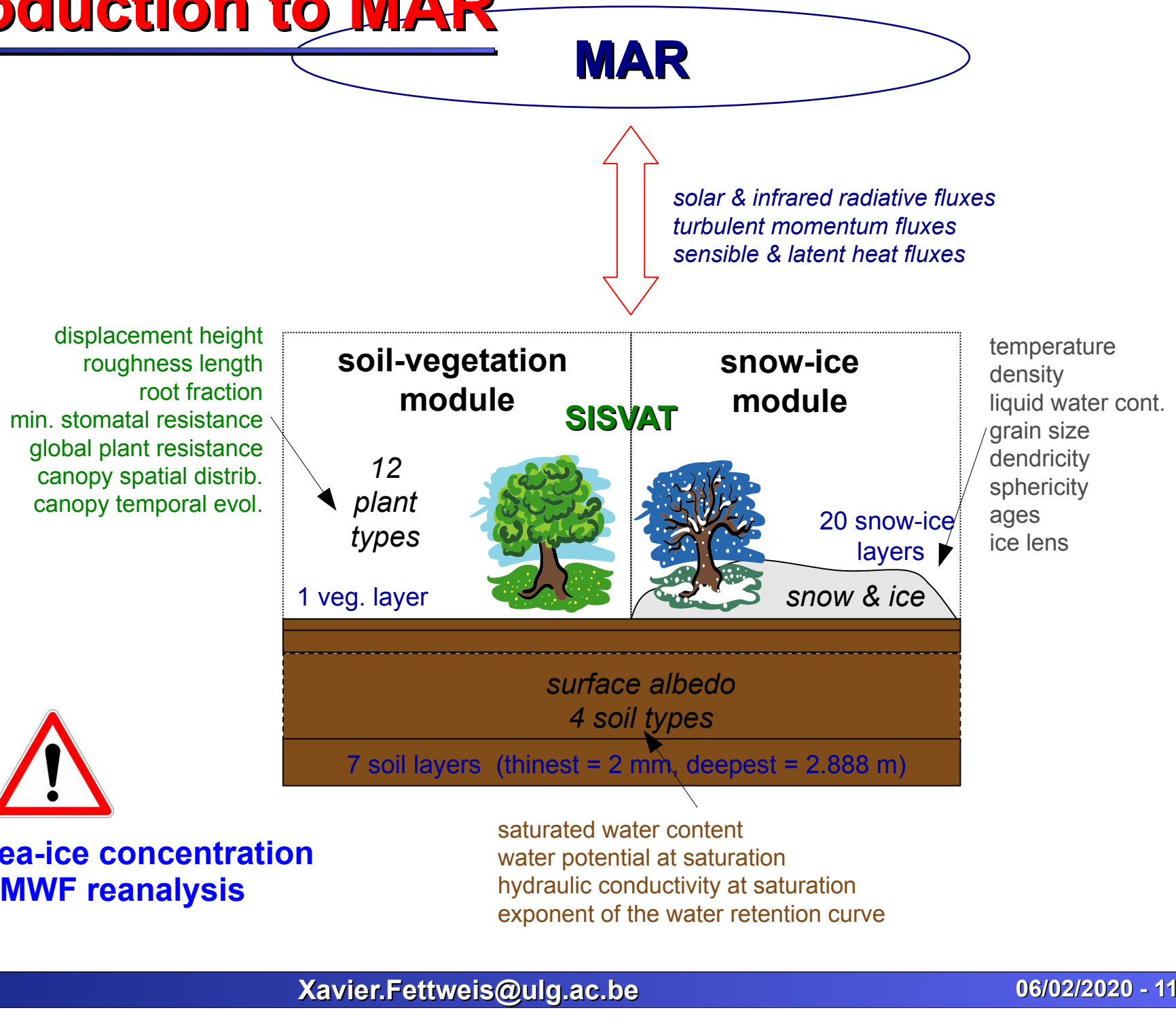


2. Introduction to MAR



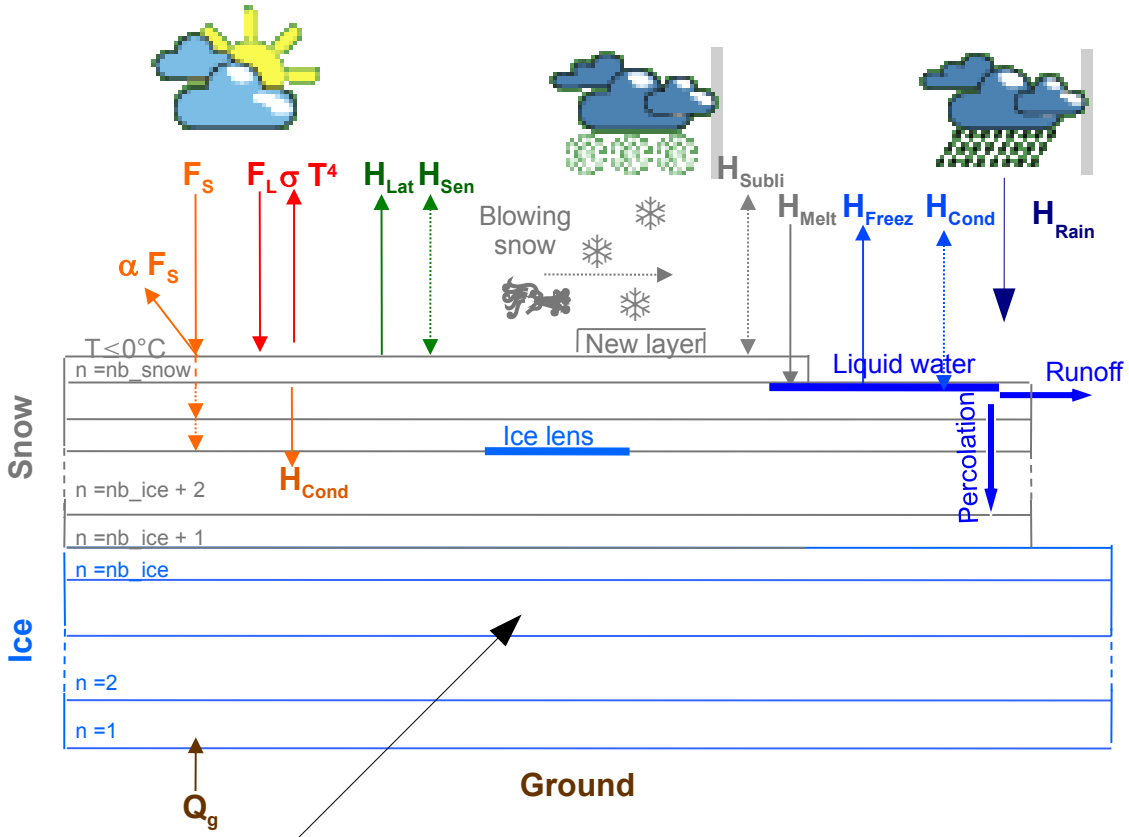
***SISVAT**: Soil Ice Snow Vegetation Atmosphere Transfer*
See De Ridder and Gallée (1998) and Gallée et al. (2001)

2. Introduction to MAR



Ocean and sea-ice concentration from ECMWF reanalysis

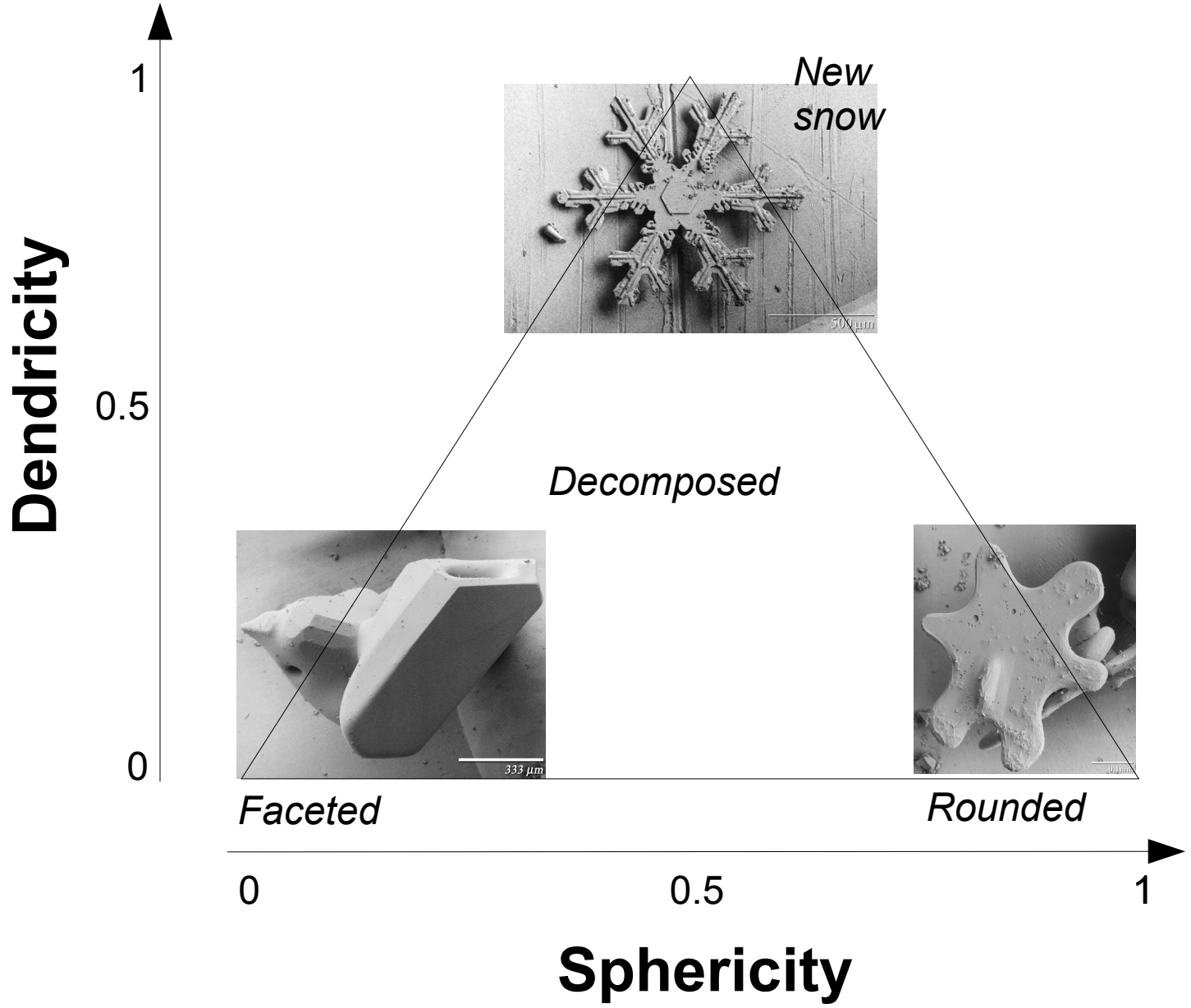
2. Introduction to MAR



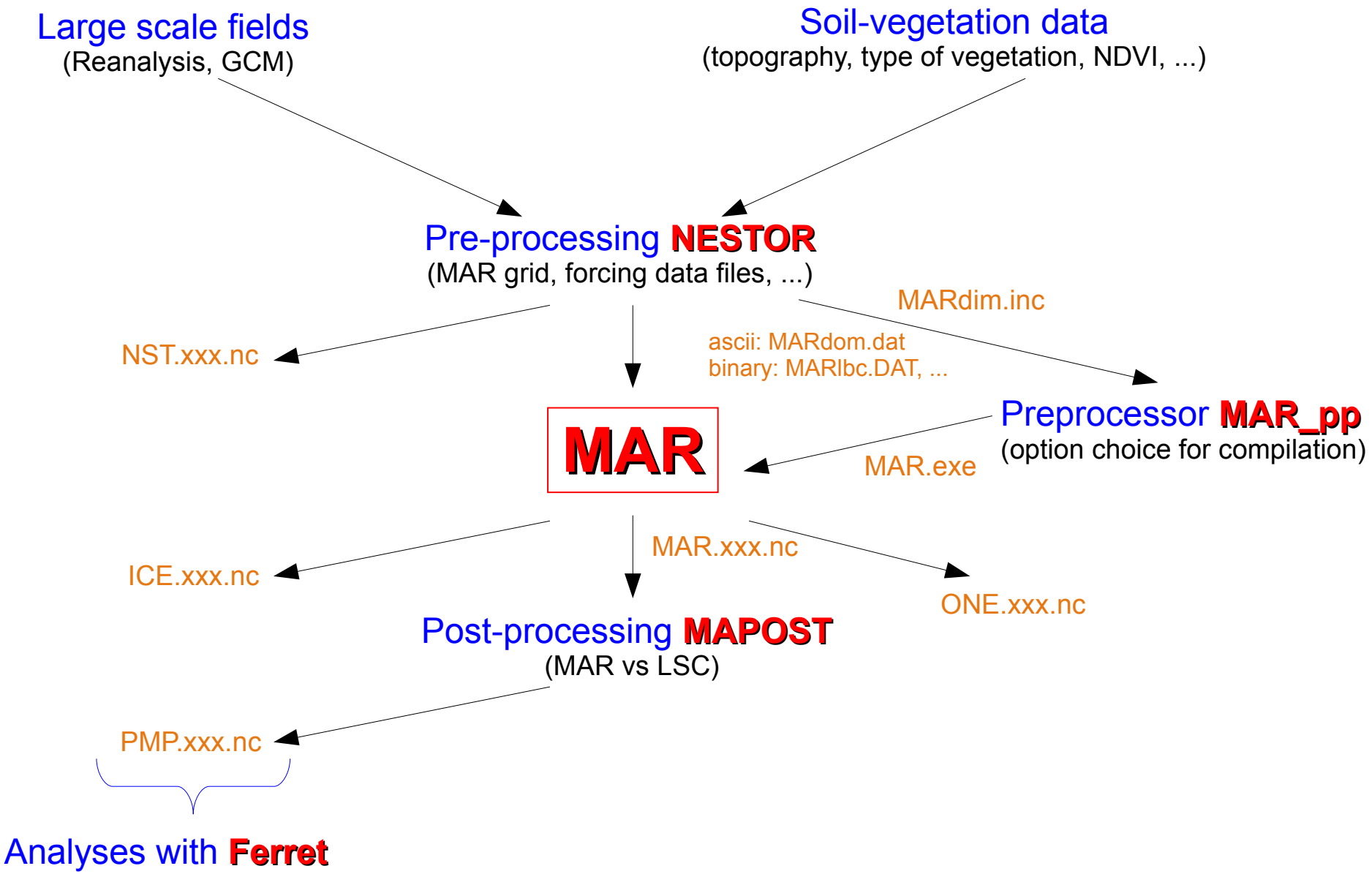
A snow layer is described by:

- density
- temperature
- height
- liquid water content
- age
- dendricity (% of original crystal shapes)
- sphericity (% of rounded versus angular shapes)
- grain size

2. Introduction to MAR



2. Introduction to MAR



3. Installation

Check after that your ssh key is working well.

On your main server, build the links:
cd ~/MAR
ln -sf $STKsrf in
ln -sf $STKmar out
ln -sf $WRKdir run
in fct of INI.ctr.

Installation of MAR

```
tar xzf MARsrc_2009-01-23.tgz
cd ~/MAR/bin
```

Check ~/MAR/bin/**INI.ctr** and after

Update the $HOME/.bashrc for $PATH
+ build the ssh-key for no-password ssh connection

```
./INSTALL
Type "bash"
./INI $DOM
```

Domain name (ex. EUa, GRd, ...)

MAR

bin/	Main BASH scripts
in/	Input files (LSC,TOPO, ...) (It can be on a remote server!)
msg/	Batched message (log files)
out/	Output files (MAR.xxx.nc, ...) (It can be on a remote server!)
run/	Working directory (or scratch directory)
sim/	Simulations directories (NESTOR, MAPOST, run scripts, ...)
src/	Sources
tmp/	Temporary directory
usr/	User's files (Fortran, MARvou.dat, ...)

3. Installation

Directories of ~/MAR

MAR/sim/$DOM/

code/	Working directory to compile MAR for each simulation (the files are archived afterwards to the stock)
ctrl/	MAR.ctr for each simulation (initial date, time step, ...)
input/	Input ascii files directory
post/	MAPOST directory
run/	simulation directory (generated BACH scripts of each run of the simulation)

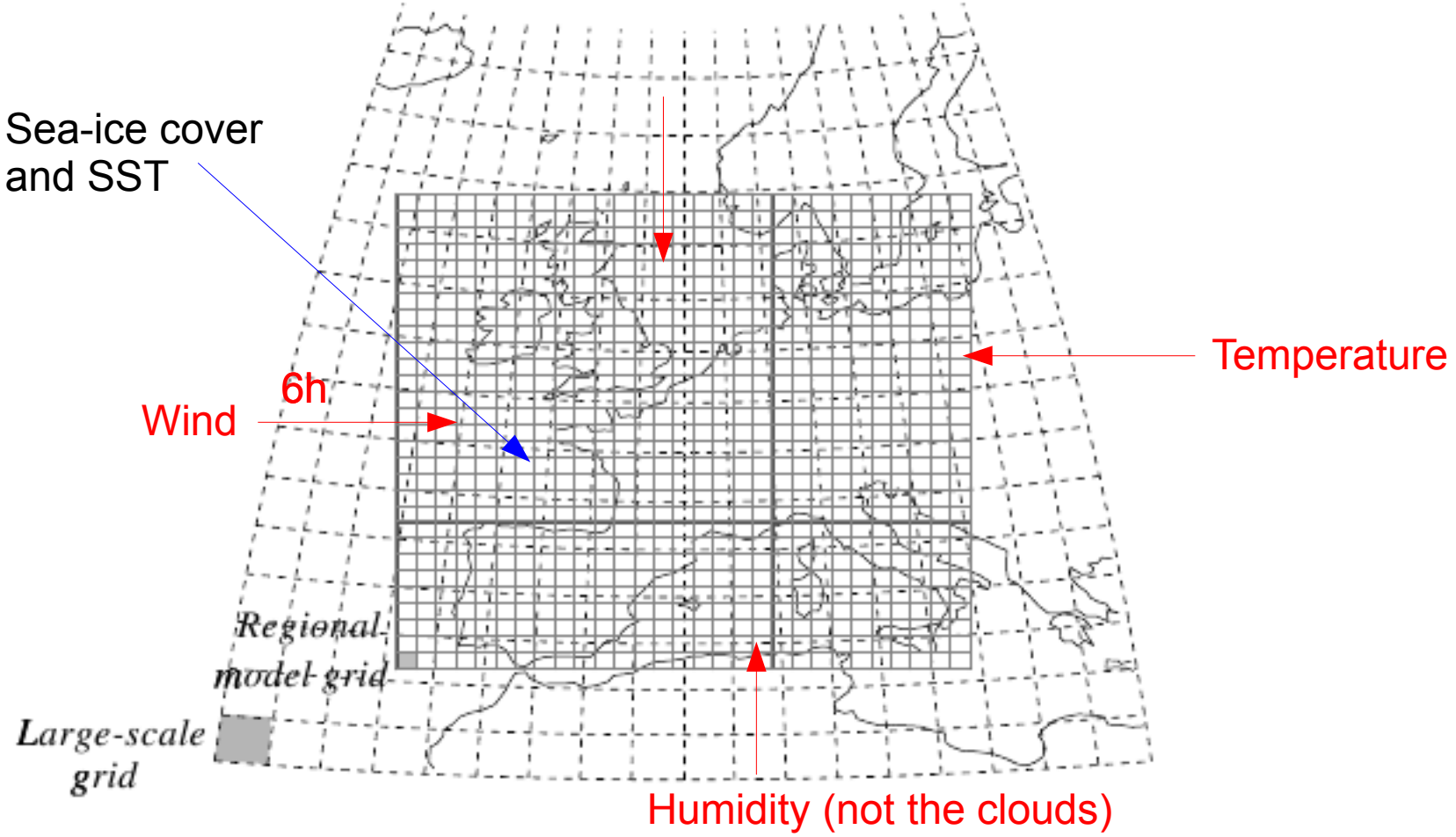
input/datMAR/	Constant ascii files used by MAR (MARvou.dat, ...)
input/MARctr/	Used MARctr.dat for each run of the simulation
input/MARdom/	MARdom.dat generated by NESTOR and used by the simulation
input/NESTOR/	NESTOR directory

4. NESTOR

They are linearly interpolated in MAR between each 6 hours.

NESTOR is used:

- to create the MAR grid.
- to initialize the MAR fields at the beginning of the simulation
- to make the needed forcing fields every 6h. The forcing fields are the temperature, wind, humidity at each MAR level as well as the SST and sea ice cover above the ocean.



4. NESTOR

First step with NESTOR

Check that n03=NC1, n24=T, n26=T in ~/MAR/bin/NST.ctr

NST $DOM 2003 07 set

and follow the instructions (check that your $SCRATCH is not in ~/MAR/run)
cd $SCRATCH/NST_$DOM_set-up

Compile.exe*	To compile NESTOR
input/	Input files
LSCfil.dat	Path of the large scale forcing files
MARgrd.ctr	Parameters of the MAR grid
NESTOR.exe*	NESTOR executable
NSTing.ctr	Parameters of NESTOR
NSTvou.dat	Selection of variables in the NetCDF output file
output/	Output files
src/	Source in Fortran

4. NESTOR

Some configurations (1/2)

NSTing.ctr:

See: **src/USRgrd.f**
(f.e.: use of a special
topography above Greenland)

To have a NetCDF file
of the output
(not used by MAR)

See **src/NSTdim.inc**
for the **dimension**
of the relaxation zone
the dimension
of the LSC files
and your domain!

Input files are
needed.

For using SISVAT

SST from ERA

```
...
GRD                     | Region .e.g. GRD,ANT,EUR,GRD                (a3)
...
T                       | - graphic check file     (NST*.nc)         (F/T)
...
F                       | - border of constant topography at boundaries |
F                       | - imposed LSC topography in the const. border |
F                       | - imposed LSC topography in the whole domain  |
F                       | - zero topography        in the const. border |
T                       | - filtering of topography                     |
------------------------| CORRECTION APPLIED TO METEO. FIELDS :
F                       | - 600-hPa geopotential height               (F/T)
T                       | - mixed surface layer                       (F/T)
...
F                       | - Correction with NDVI index (res. 1 km)    (T/F)
F                       | - Correction with NDVI index (res. 8 km)    (T/F)
...
T                       | De Ridder and Schayes (1997) soil model     (T/F)
40.                     | Imposed soil wetness in all layers (0 to 100 %)
T                       | Soil wetness from ECMWF fields              (T/F)
...
F                       | Imposed Reynolds sea surface temperature    (T/F)
```

4. NESTOR

The dimensions of the grid are: mx x my x mz

Some configurations (2/2)

MARgrd.ctr:

Latitude and longitude of the grid centre

Coordinates (i,j) of the centre

```
-40                     | MAR domain center longitude
41                      | MAR domain center longitude (grid point = imez)
70.50                   | MAR domain center latitude
70                      | MAR domain center latitude  (grid point = jmez)
------------------------|-------------------------------------------
25.0                    | MAR mesh size (km)
```

Resolution used

Max a factor 10 between the LSC model and MAR

See **src/NSTdim.inc** for the dimensions (mx, my) of the grid

```
...

0.01                    | Pressure at top (kPa)

...
```

For the sigma vertical grid

First level

```
2.                      | zzmin= STD NEW (0=>OK) Vertical discretisation
0                       | aavu=  STD NEW (0=>OK) "
0                       | bbvu=  STD NEW (0=>OK) "
0                       | ccvu=  STD NEW (0=>OK) "
```

Form of the vertical grid

The number of vertical levels (mz) should be 19, 30, 40, 60. Otherwise, aavu, bbvu and ccvu must be specified.

4. NESTOR

Don't forget to check the output
NetCDF file with ferret !
cancel data/all ; use NST.2003.08.01.00.EUa.nc ; shade sh,lon,lat ; go land

Launch of NESTOR

- After configuring NESTOR (mainly **src/NSTdim.inc and MARgrd.ctr**):

```
./Compile.exe
./NESTOR.exe
```

- If all is Ok, you have to copy your configuration files (*MARgrd.ctr*) as well as *src/NSTdim.inc* and *NESTOR.exe* to

```
~/MAR/sim/$DOM/input/NESTOR
```

by using the *dont_forget_to_copy_files_after.bash*.

and don't forget to change **~/MAR/bin/NST.ctr**

- Afterwards

```
qsub ~/MAR/sim/$DOM/input/NESTOR/run/NST_$DOM.07.01.01-31.cmd
```

4. NESTOR

~/MARsim/out/$DOM/input/NESTOR/19XX/

Outputs of NESTOR (1/2)

MARdim.inc
MAR_SV.inc

Dimension of the MAR grid and the nbr of snow/soil layers in SISVAT **for the MAR compilation**

ascii

MARdom.dat: **Input files for MAR**: label, date of the start, grid properties latitude, longitude, sigma, ...

MARdyn.DAT
MARsol.DAT
MARsvt.DAT

Initialisation files for the date of the start of the simulation. These files are made after by MAR to restart the simulation.

binary

MARglf.DAT
MARlbc.DAT
MARsic.DAT
MARubc.DAT

Lateral boundaries files for each 6h of the NESTOR period.

NST.2008.12.01.00.GRa.nc : Outputs in NETCDF only for checking

4. NESTOR

Outputs of NESTOR (2/2)

Only use at the initialisation

MARdyn.DAT: temp., X and Y-wind, humidity, pressure, ... at each levels.

MARsol.DAT: surf. Temp., albedo, Z0, R0, flux, ... at the surface

MARsvt.DAT: idem but in each mosaics in SISVAT

Use every 6 hours

MARglf.DAT: green leaf fraction for SISVAT

MARlbc.DAT: lateral boundaries conditions: temp., X and Y-wind, humidity, pressure, ... at each levels of the boundaries + SST

MARsic.DAT: sea-ice concentration

MARubc.DAT: upper boundaries conditions: idem but at top of the atmosphere

4. NESTOR

Some specificities about NESTOR:

1. *Over the Greenland ice sheet, we use our own ice sheet mask and topography.*
   - *Use the default one for building your grid.*
   - *Interpolate the GIMP based 1 km DEM over your grid.*
   - *Read you new topo/ice sheet mask in **USRgrd.f***

2. *WARNING WARNING about **TOPcor.f** which imposes the LSC topo at your boundaries.*

   - *run NESTOR with ERA5*
   - *keep an output netcdf file with SH*
   - *read this file when ERA40 is used*
   - *be careful that the filtering will be applied 2 times if NST_SH is not read at the end of TOPcor.f*

3. *EU domain => vegetation and not permanent ice (mw=3)*
   GR domain => not vegetation but permanent ice (mw=2)
   (with some handmade changes, it is possible to have permanent ice, LAI (read by MAR) and vegetation if n24=T in NST.ctr

4. *mzabso > 4 is needed for large domains.*

5. MAR

Compilation of MAR (1/4)

Includes: ~/MAR/src/forMAR/forMAR/*.inc
~/MAR/usr/*.inc
~/MAR/out/$DOM/input/NESTOR/19XX/MARdcl_$DOM.tar

Main code: ~/MAR/src/forMAR/forMAR/***.f**

External subroutines:
~/MAR/src/forMAR/forMAR/*.f90
~/MAR/usr/SBCnew.f
~/MAR/src/libMAR/*.f

MAR preprocessing: ***MAR_pp (via BASH)***

f90 *.f90 *.f *.mod ← libnetcdf.a

MAR.exe

5. MAR

Compilation of MAR (2/4): MAR_pp

- The choice of the MAR options has been a lot simplified in

  ~/MAR/bin/CODE.ctr

  from MARv3.10 and is fixed in CODE following the domain used.

- To recompile MAR:

```
cd ~/MAR/out/Eua/a01/code
rm -f MAR_a01.exe
mkdir src
tar xzf compilink.tar.gz -C src
cd src
./COMPILE
ln -sf src/MAR_a01.exe .
```

The MAR executable is located in

```
~/MAR/out/EUa/a01/code/MAR_a01.exe
```

~/MAR/out/$DOM/input/NESTOR/19XX/MARdcl_$DOM.tar

Compilation of MAR (3/4): *.inc and sbcnew.f

MAR is parallelised on my or mz

mx, **my** and **mz** are the X, Y and Z dimensions.
klon=1 if NO vectorization (it is the case here).
n6 et n7 determine a relaxation zone towards lateral boundaries.
mw is the nbr of mosaics (2 or 3) in SISVAT

MARdim.inc

Klonv=1 if OpenMP is turned on
nsol is the nbr of soil layers in SISVAT
nsno is the nbr of snow layers

MAR_SV.inc

• **SBCnew.f** is called at the end of every time step.
It contains the code developed by the users for specific use.
By default, ~/MAR/bin/CODE use
`~/MARsim/src/forMAR/forMAR/sbcnew.f`
or
`~/MAR/usr/SBCnew.f`

5. MAR

Some specificities about MAR:

- Be careful about the used version of SBCnew!!

- Don't forget to define your domain in SBCnew if you want to use the MARinisnow files.
  - we have f90 programs to interpolate and build these files from previous low resolution simulations.
  - this allows to decrease the spin-up time of 10 years.

- Be careful of the mzhyd value in MARdim.inc which needs to be manually changes for some large domains (Arctic, Antarctica, ...).

5. MAR

Launch of MAR (the first time)

dt should be a divisor of 1800 (30min)
e.g.: dt=150s for 25km
dt=240s for 40km
dt=360s for 50km

dt is now adapted by the model itself.

Edition of

`~/MAR/bin/MAR.ctr`

and after

Initial and final date
Nbr of CPUs
Time step **dt**

```
MAR a01 2003 01 a
qsub ~/MAR/sim/EUa/run/a01/MAR_$DOM01.03.01.01-15.cmd
```

Restart of MAR to continue simulations

```
cd ~/MAR/sim/EUa/run/a01/
MAR -again ../../ctrl/a01/MAR.ctr.030101-031231 a01 2003 01 b
qsub MAR_EUa01.03.01.16-31.cmd
```

This step is normally automatic

5. MAR

Inputs:

Radiative scheme

MARs01.dat
MARs02.dat
MARinf.dat

~/MAR/sim/$DOM/input/datMAR

files read by SBCnew.f

MAR_GRa.dat
….

Boundaries forcing files as well
as the files need to relaunch MAR

MARdyn.DAT
MARsvt.DAT
MARlbc.DAT
MARxxx.DAT

from NESTOR/MAR

~/MAR/usr/

Domain, run name, date, ...

MARdom.dat

from NESTOR

MAR.exe

Parameters, time step; ...

MARctr.dat

~/MAR/sim/$DOM/ctrl/a01/MAR.ctr

Files to chose the output
variables in the NetCDF files

MARvou.dat,
ICEvou.dat, ...

~/MAR/sim/$DOM/input/datMAR

~/MAR/usr/

5. MAR

Outputs: