Snow scheme used in NWP and EURO4M : opportunities for snow climatology

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with acknowledgments to Y. Seity

MUSCATEN and NetIce Workshop

24-26 March Kuopio, Finland

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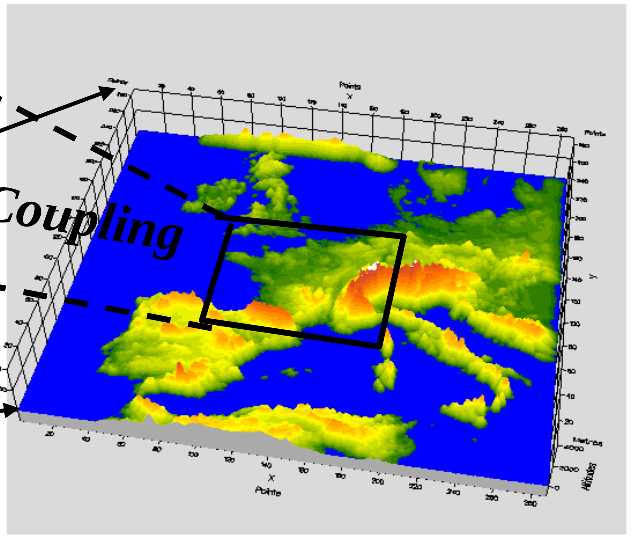
Outline

- NWP system in Meteo-France
- Snow analysis
- Snow in the NWP models at MF
- Some words about EURO4M

Operational Weather forecasting at Météo-France

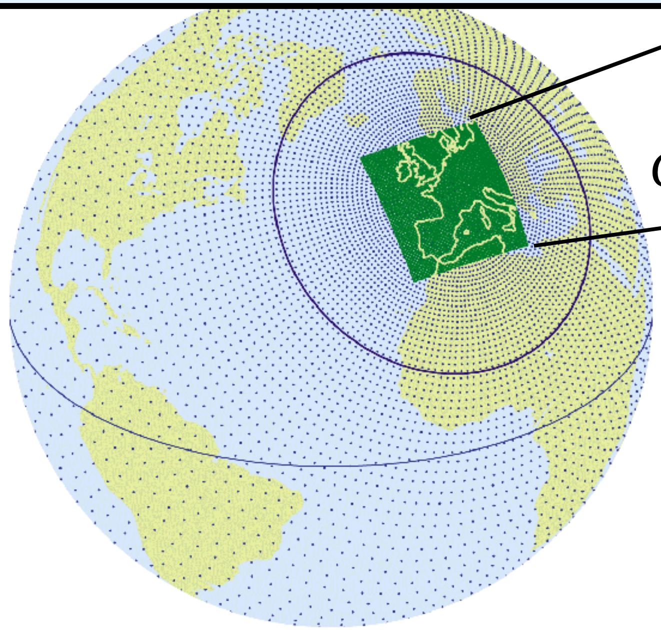
ARPEGE, ALADIN and AROME (until March 2010)

Cloud Resolving Model AROME 2009
Currently under development
1h to 30 h forecasts
dx=2.5 km over France
3DVar Data Assimilation system



Limited Area Model ALADIN
2-day forecasts every 6 hours
dx=10 km on Europe dt=7mn
3DVar Data Assimilation system

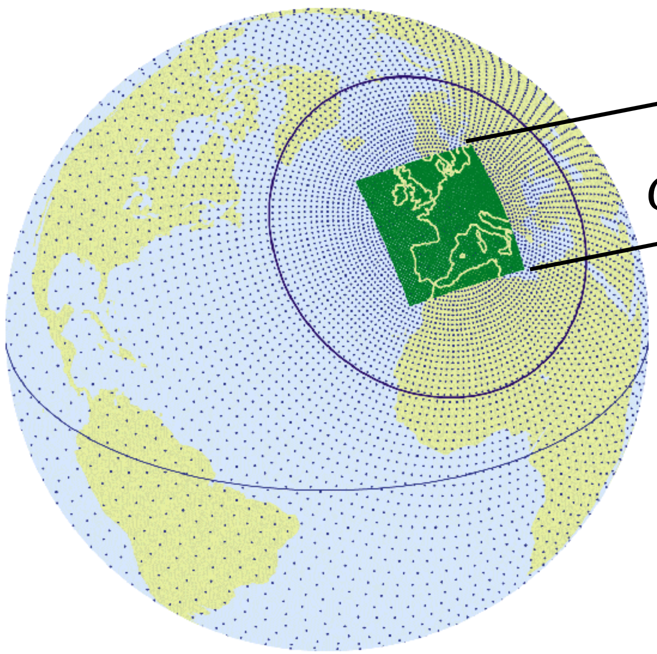
Coupling

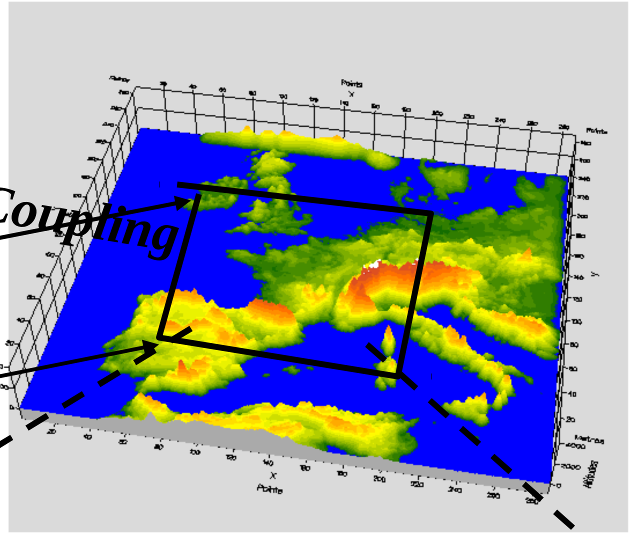


Global ARPEGE
4-day forecasts every 6 hours dx=15km on Europe, 80km on South Pacific dt=15mn
Stretching and turning of the pole over the zone of interest
Stretched vertical grid with 60 levels
4DVar Data Assimilation system

Operational Weather forecasting at Météo-France

ARPEGE and AROME (April 2010)





Cloud Resolving Model AROME 2009
Currently under development
1h to 30 h forecasts
dx=2.5 km over France
3DVar Data Assimilation system

Global ARPEGE
4-day forecasts every 6 hours dx=10km on Europe, 55km on South Pacific dt=10mn
Stretching and turning of the pole over the zone of interest
Stretched vertical grid with 70 levels
4DVar Data Assimilation system

SNOW ANALYSIS

- 3 prognostics variables= SWE, snow albedo and density (only used to diagnose the snow height in ARPEGE/ALADIN)
- SWE is only modified in the analysis if Tsurf > 0 → snowmelt. SWE is slightly restored toward climatology (around 22days)
- Snow albedo and density are initialized by the previous 6h forecast (ARPEGE/ALADIN)
- In fact, in ARPEGE/ALADIN, no “real” snow analysis with SYNOP observation or satellite information
- Snow analysis is under development and validation in CANARI: Mariken Homleid in HIRLAM/HARMONIE and Jure Cedelnik in ALADIN

SNOW SCHEME USED IN NWP AT METEO-FRANCE

ARPEGE/ALADIN

(based on Douville et al, 1995,

Bazile et al 2002 for the snow fraction on the vegetation)

AROME (Douville et al, 1995)

No budget equation for snow → no Tsnow

- no melting: $\alpha_{sn}(t+\Delta t) = \alpha_{sn}(t) - \tau_{lin}\frac{\Delta t}{\tau} + \frac{P_n \Delta t}{W_{new}}$ with P_n: snow fall, $\tau_{lin} = 0.008$, $\tau = 86400s$ and $W_{new} = 10mm$.
- melting: $\alpha_{sn}(t+\Delta t) = (\alpha_n(t) - \alpha_{min})\exp\left(-\tau_{exp}\frac{\Delta t}{\tau}\right) + \alpha_{min} + \frac{P_n \Delta t}{W_{new}}$ with $\tau_{exp} = 0.24$.

$$\rho_{sn}(t+\Delta t) = \left(\rho_{sn}(t) - \rho_{\max}\right)\cdot \exp\left(-\tau_{\exp}\frac{\Delta t}{\tau}\right) + \rho_{\max}$$

After snow falls, the density is recalculated as the weighted average of the previous density and that of new snow. The albedo is put back to 0.85 if the snowfall exceeds 10mm

ARPEGE/ALADIN:

$\rho_{\min} = 0.1, \rho_{\max} = 0.3$

$\alpha_{\min} = 0.65, \alpha_{\max} = 0.85$

AROME:

$\rho_{\min} = 0.1, \rho_{\max} = 0.3$

$\alpha_{\min} = 0.50, \alpha_{\max} = 0.85$

$$\alpha = (1-veg)\cdot\left((1-P_{sn}^{bg})\alpha_{bg} + P_{sn}^{bg}\alpha_{sn}\right) + veg\cdot\left((1-P_{sn}^{veg})\alpha_{veg} + P_{sn}^{veg}\alpha_{sn}\right)$$

SNOW SCHEME USED IN NWP AT METEO-FRANCE

ARPEGE/ALADIN

(based on Douville et al, 1995, Bazile et al 2002 for the snow fraction on the vegetation)

$$P_{sn}^{bg} = \frac{SNW}{SNW + 10}$$

To take into account the snow on the leaves and the fall below the canopy, a function F was introduced. F is a decreasing function of both the LAI and the snow age through the snow albedo equation (Douville et al,95) which gives indirectly the snow age and takes into account the melting

$$P_{sn}^{veg} = P_{sn}^{bg} \cdot F(Lai, snow\_age)$$

$$F = 1 - \frac{Lai}{7} \cdot \frac{\alpha_1 - \max(\alpha_0, \alpha_{SN})}{\alpha_1 - \alpha_0}$$

$$\alpha_0 = 0.84$$
$$\alpha_1 = 0.87$$

$$LAI \leq 2.9 \Rightarrow F = 1$$

Snowmelt: $F_m = \frac{T_s^+ - T_t}{C_T \cdot L_f \Delta t}$

Thermal coefficient does not depend on Cn (Km*2/J)

AROME (Douville et al, 1995)

$$P_{sn}^{bg} = \frac{SNW}{SNW + 10 \cdot (1 + z_{0\_oro})}$$

$$P_{sn}^{veg} = \frac{h_n}{h_n + 5 \cdot z_{0\_veg}} \qquad h_n = \frac{SNW}{\rho_{sn}}$$

$$p_{nc} = \min(1, \frac{SNW}{70})$$

Snowmelt computed with an estimated snow temperature

$$T_{sn} = (1 - (1 - P_{sn}^{veg}) \cdot veg) \cdot T_s^+ + (1 - P_{sn}^{veg}) \cdot veg) \cdot T_p^-$$

$$F_m = p_{nc} \frac{T_{sn} - T_t}{C_n \cdot L_f \Delta t}$$

$$C_n = 2\sqrt{\frac{\pi \cdot \rho_i}{\lambda_i \cdot c_i \cdot \rho_{sn}^{2.885}}}$$

$$C_T = \left(\frac{(1 - veg)(1 - P_{nc})}{C_g} + \frac{(1 - veg) \cdot P_{nc}}{C_n} + \frac{veg}{C_{veg}} \right)^{-1}$$

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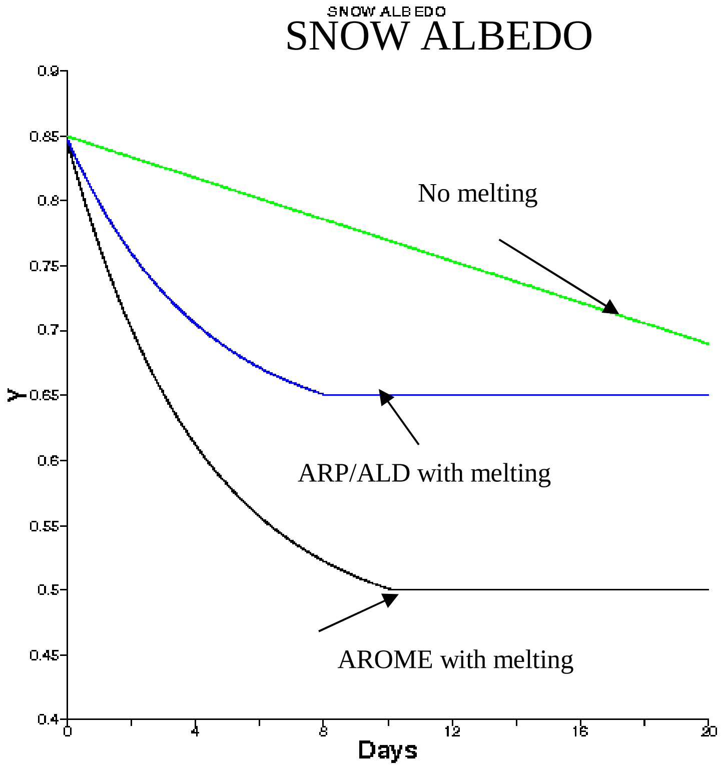
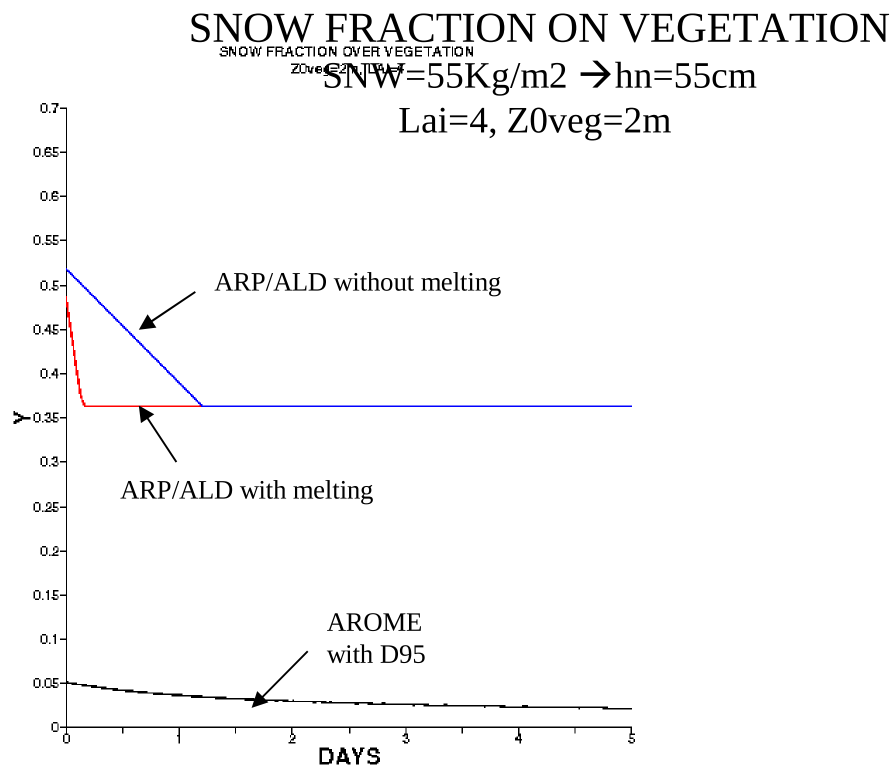
SNOW SCHEME USED IN NWP AT METEO-FRANCE





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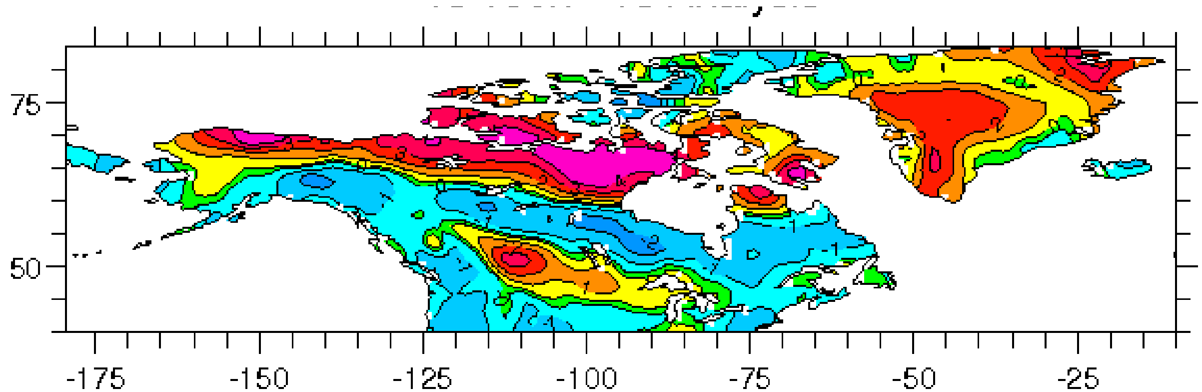
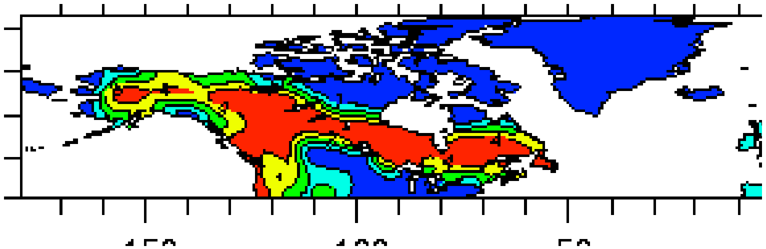
SNOW SCHEME USED IN NWP AT METEO-FRANCE

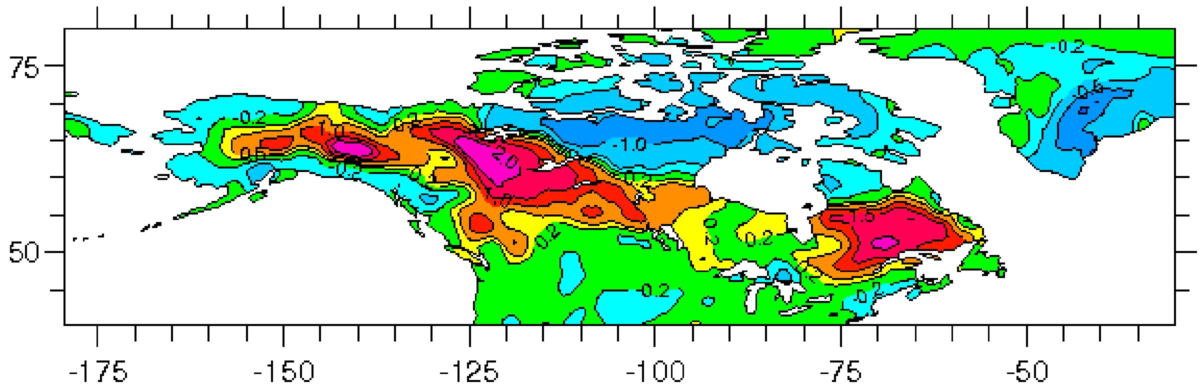
Bias March 2000
Ts



Leaf Area Index



Impact on Tsurf



SNOW SCHEME USED IN NWP AT METEO-FRANCE

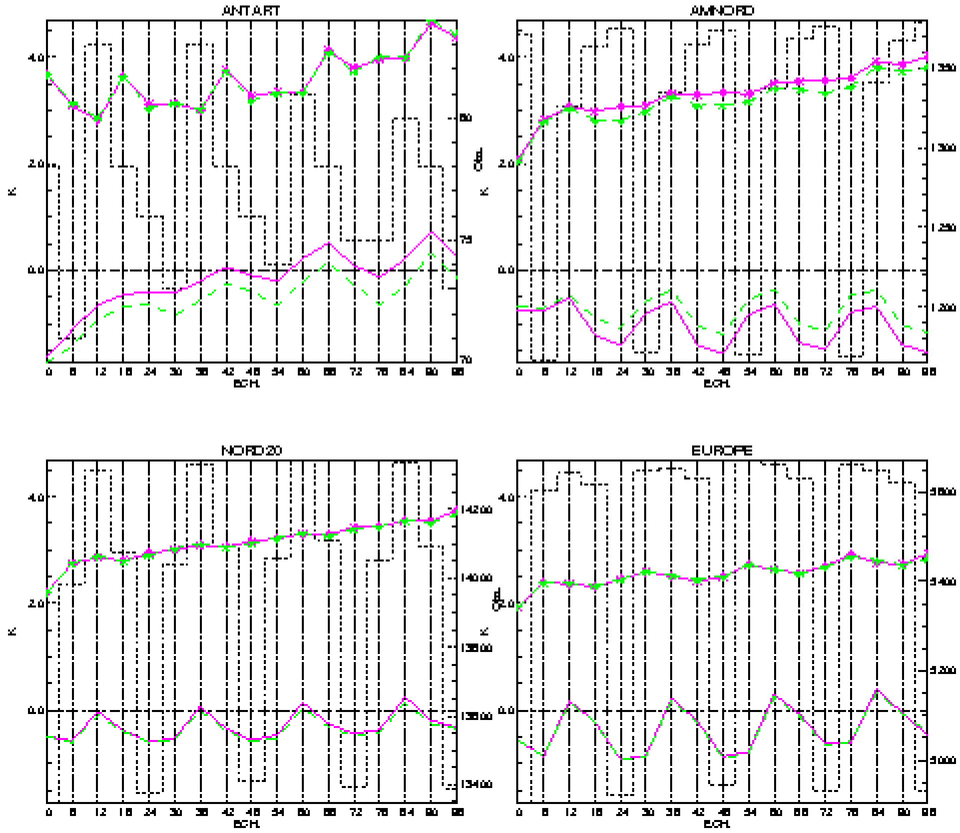
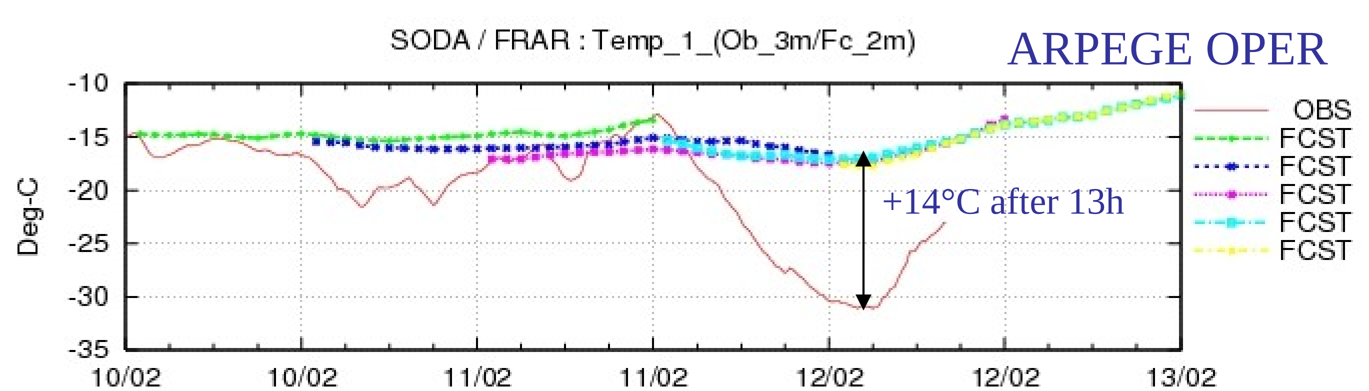


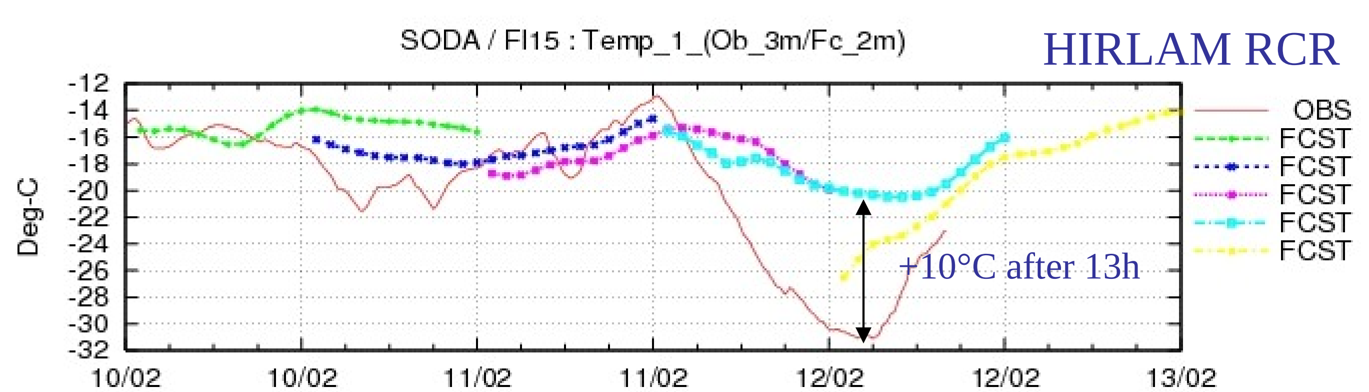
Figure 4: Difference between predicted and observed SYNOP values for T_{2m}. 4DVAR assimilation from 03/03/2001 to 18/03/2001. Averaged along 15 96h-forecasts over Antarctica, Northern America, North 20°, Europe. Full line: Reference. Dashed line: New scheme.

Sodankyla T2m 20100211 starting at 12UTC

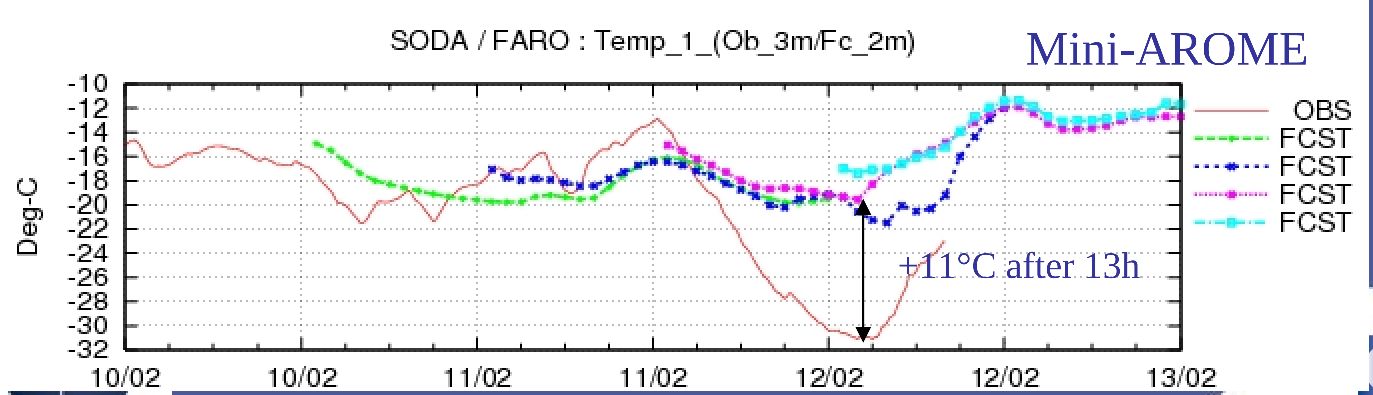
From http://fminwp.fmi.fi/mastverif/mastverif.html



ARPEGE: too warm
→surface analysis has rejected the T2m obs at 00UTC the 12th Feb. (yellow curve)



HIRLAM RCR : also too warm but less than ARPEGE → the surface analysis is able to capture the cooling (yellow curve)



Mini-AROME : 30x30 pts dynamical adaptation from ARPEGE with SURFEX (snow scheme D95) → no specific analysis.

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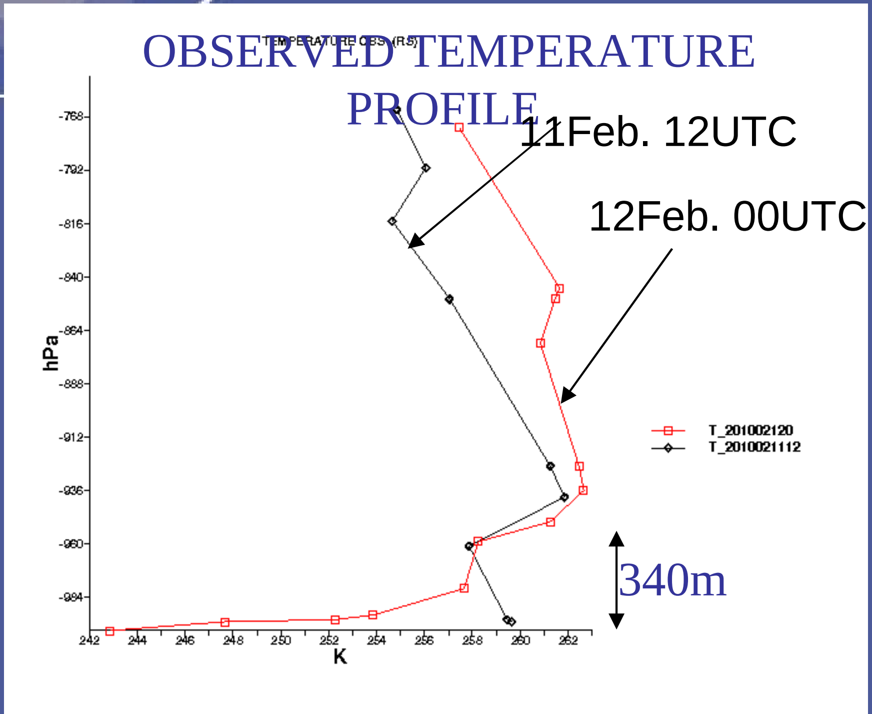
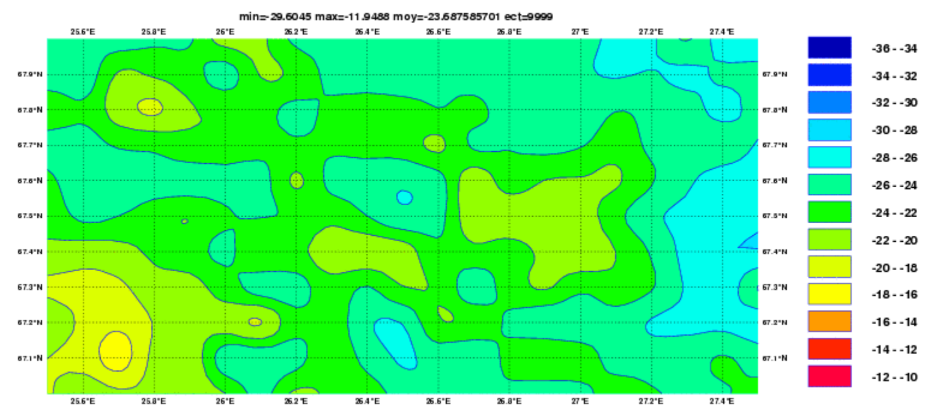
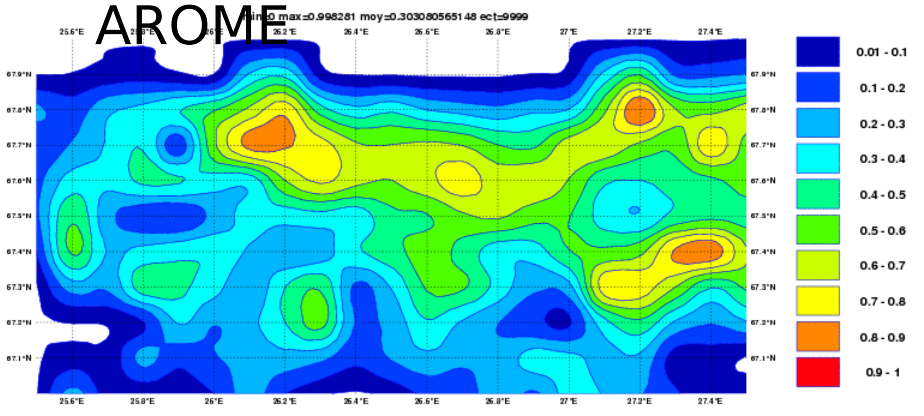


There are several possible reasons for this : surface and snow parameterization, « residual » vertical mixing, cloud cover ...

Tsurf Mini-AROME



Low level cloud Mini-AROME



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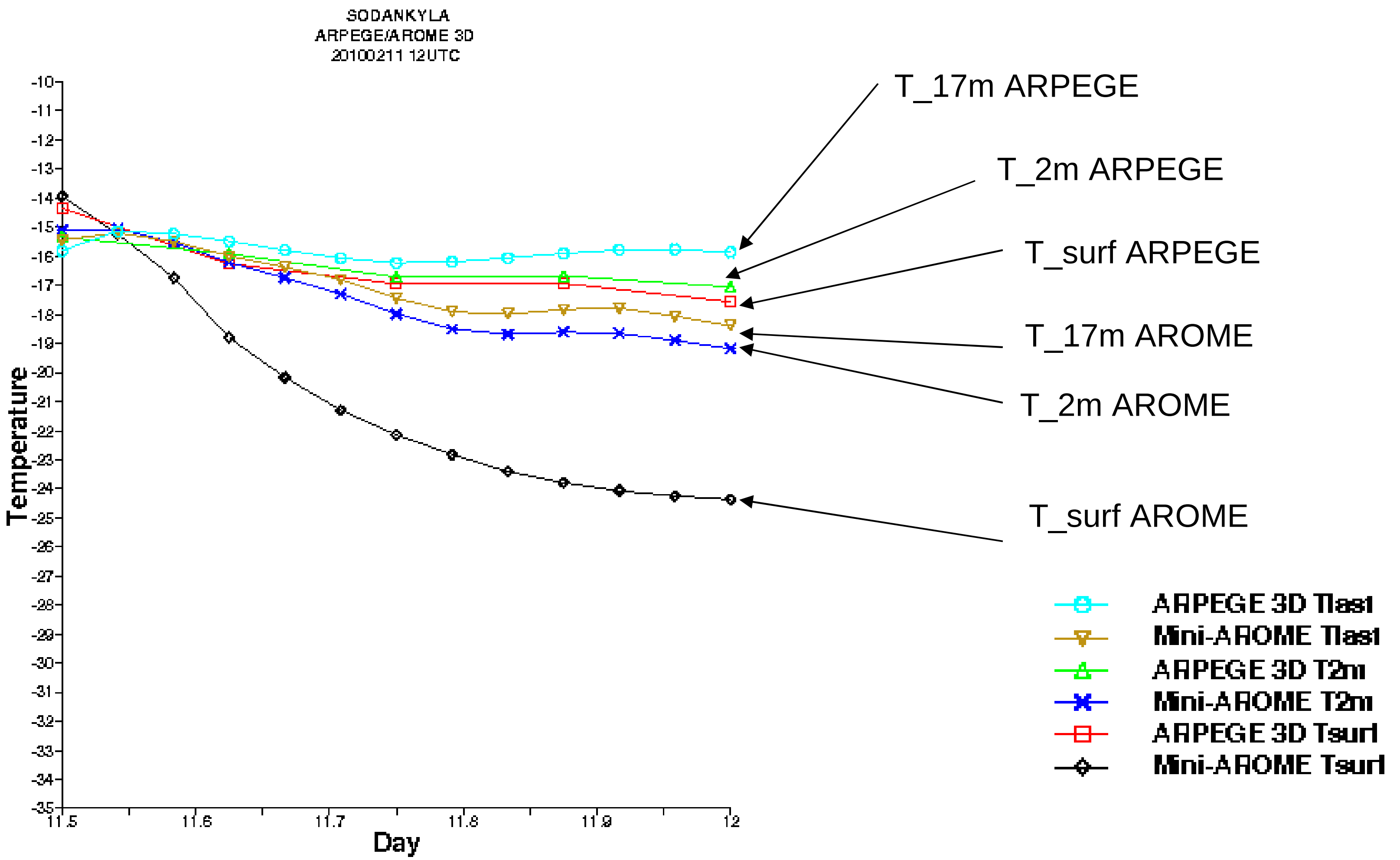
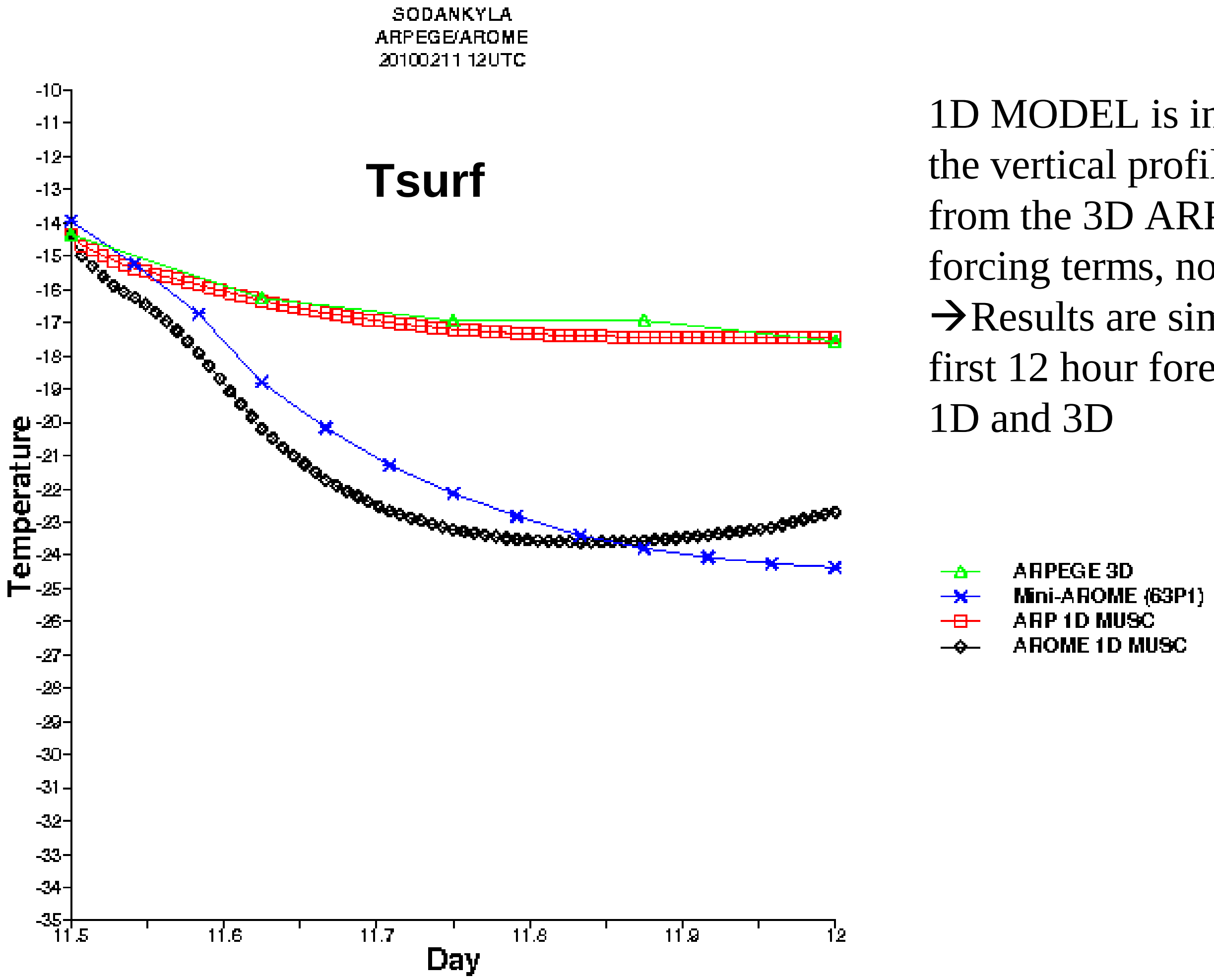
Tsurf, T2m, and T_17m SODANKYLA STARTING 20100211 at 12UTC

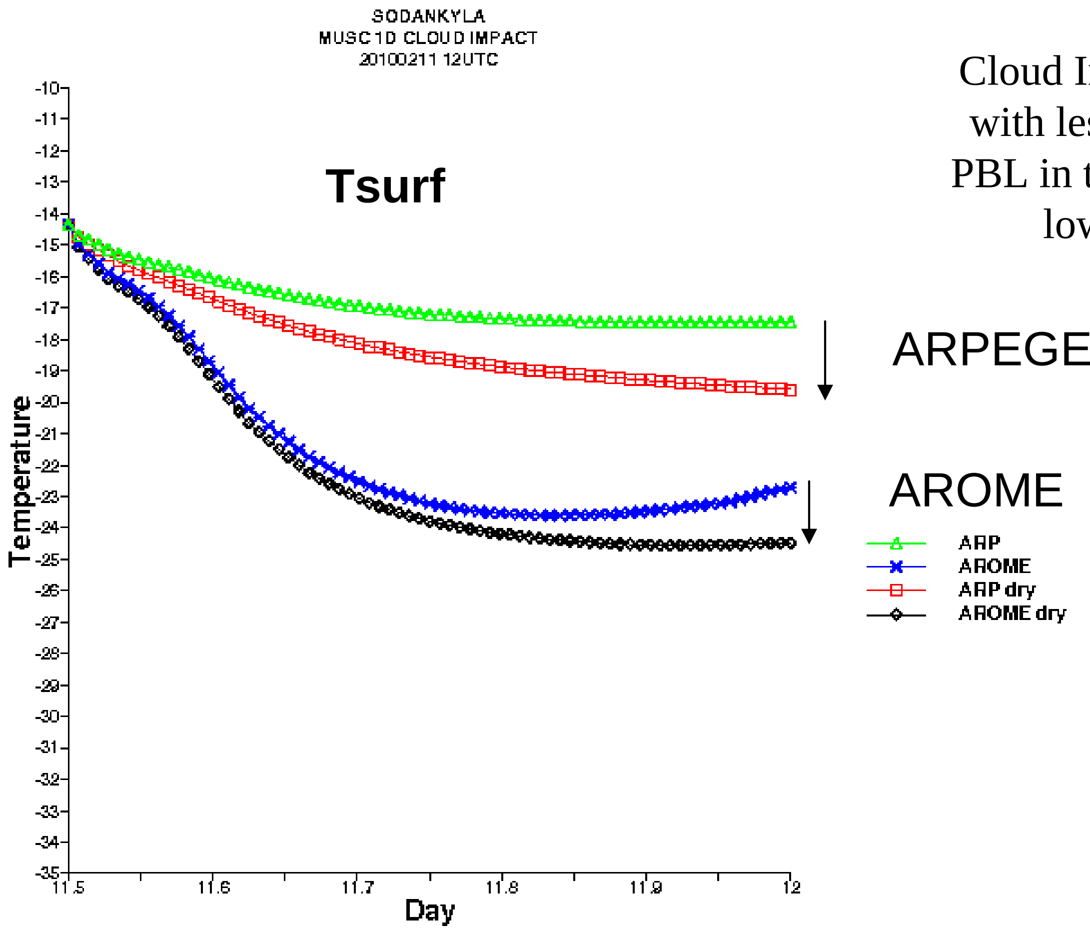


1D MODEL MUSC SODANKYLA STARTING 20100211 at 12UTC



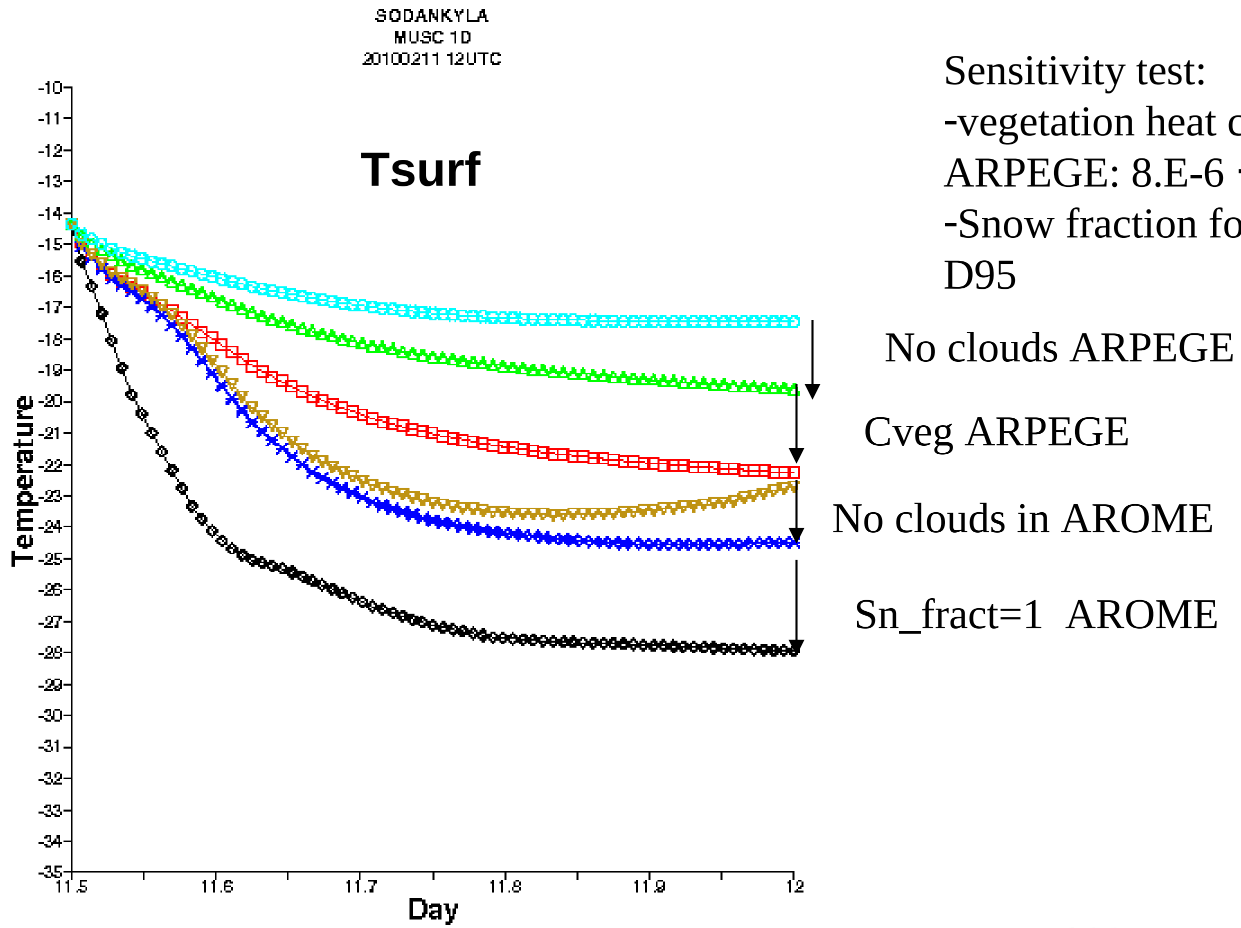
1D MODEL is initialized from the vertical profile extracted from the 3D ARPEGE no forcing terms, no advection
→Results are similar for the first 12 hour forecast between 1D and 3D

1D MODEL MUSC SODANKYLA
STARTING 20100211 at 12UTC



Cloud Impact: 1D forecast with less humidity in the PBL in the initial file → no low level cloud

1D MUSC SODANKYLA
STARTING 20100211 at 12UTC



Sensitivity test:
-vegetation heat capacity for ARPEGE: 8.E-6 → 2E-5 Km2/J
-Snow fraction forced to one in D95

To conclude …

1. Sodankyla is a very useful site to study snow/vegetation/atmosphere interaction. SURFEX offers the possibility to evaluate several and sophisticated snow scheme (ISBA-ES and ISBA-ES+) in the 1D model MUSC and in 3D with AROME with full interaction with the PBL →all the tools to understand and solve this warm bias !
2. How many snow fraction do we need ? For the bareground and for the vegetation to compute the total albedo, + another one for the soil budget equation ? This parameter has a strong impact but in general in the models the formulae is very simple. Snow fraction should depend on the snow depth, snow age, z0, wind speed, LAI , T_canopy etc …
3. Snow analysis is important to avoid strong bias especially if the snow precipitations computed by the models are not representative of the reality !

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EURO4M

European Reanalysis and Observations for Monitoring

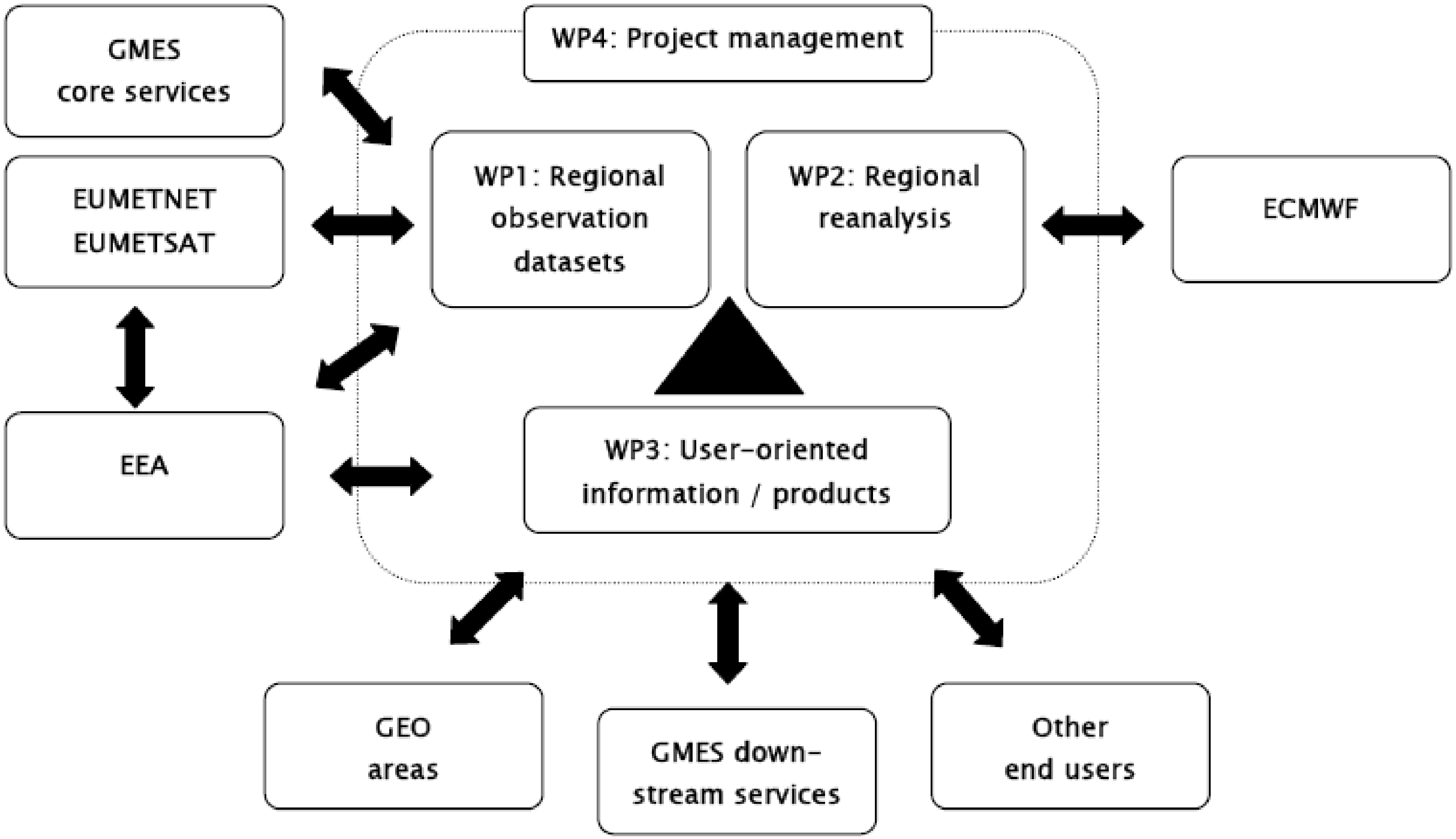
www.euro4m.eu

Albert Klein Tank, KNMI

- 4 Years to develop the capacity for, and deliver the best possible and most complete (gridded) climate change time series and monitoring services covering all of Europe.

No.	Participant organisation name	Short	Country
1	Royal Netherlands Meteorological Institute	KNMI	Netherlands
2	Met Office	MO	United Kingdom
3	University Rovira i Virgili	URV	Spain
4	National Meteorological Administration	NMA-RO	Romania
5	Meteo Swiss	MS	Switzerland
6	Deutscher Wetterdienst	DWD	Germany
7	Swedish Meteorological and Hydrological Institute	SMHI	Sweden
8	University of East Anglia (Climatic Research Unit)	UEA	United Kingdom
9	Météo France	MF	France

External links and user involvement



Thanks to Albert Klein Tank, KNMI

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EURO4M

- Essential Climate Variables: 6 surfaces, 5 atmos. + SST
  - Surface: temperature , precipitation(day), Pressure, radiative budget, wind (speed, dir), humidity
  - Atmo: radiative fluxes, T, wind, humidity, clouds properties (?)
  - Sea surface temperature
- 4 WP:
  - WP1: Regional observation datasets
  - WP2: regional analysis
  - WP3 user oriented information/products
  - WP4 project management

EURO4M

- WP1: Regional observation datasets (UEA: 1-48 avec 235pm)
  - WP1.1 Gridded datasets-stations (MS: 1-48) ← MF
  - WP1.2 Gridded datasets-remote sensing (DWD: 1-48)
  - WP1.3 Data coordination (URV: 1-36)
- WP2: Regional Analysis (MO : 1-48 avec 281pm)
  - WP2.1 Advanced regional data assimilation (MO: 1-48) : 4Dvar 15-25km
  - WP2.2 Dynamical downscaling of ERA (SMHI: 1-48) 3dVar 25km longer period than WP2.1
  - WP2.3 2D-mesoscale downscaling (MF: 13-48) with SMHI 2-3 km
  - WP2.4 Evaluation (MS: 25-48) ← MF. Possible comparison between ERAMESAN and SIM over Sweden ? And/or other Alps with SAFRAN-NIVO. Comparison with site measurement with long time series like Cabauw, Lindenberg, Sodankyla
- WP3: user oriented information/products (NMA: 1-48)
- WP4 : project management (KNMI: 1-48)

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EURO4M

• WP1.1 : **MF** will provide some of its own regional datasets in support to the project and apply its own quality control procedures to the collected data. Notably, MF will extend the different controls as thresholds, inter parameter consistency, time evolution and spatial consistency to the collected data.

•WP2.3 : **MF** will downscale (2.5/3Km) the 3D reanalysis from WP2.2 using low-level datasets, 2D analysis techniques, and land surface modelling. This will provide added value through additional observations and over orography. MF will also improve the 2D downscaling software, in particular the data QC and interface with the 3D reanalysis.

- snow analysis using the classical observations and satellite pictures will be investigated.
- The new system MESAN-SAFRAN will be able to also use the long time series of observations that are not used in NWP, including minimum and maximum temperature, etc. The datasets for this activity will come from WP1.
- Finally, the new system will be coupled with a surface and hydrological scheme in order to improved surface variables and in particular the climatology of snow cover.

Post-doctoral position

•24 months post-doctoral position starting probably in September 2010 to develop a new system based on the experiences of the MESAN and SAFRAN software for the 2D downscaling analysis.

•**Work description:**

• Firstly comparison between SAFRAN and MESAN, advantages, weaknesses, software portability and efficiency

•Develop the new system for the project. Provide the re-analyse forced by 3D analysis. Coupling with Surfex and evaluation of several snow scheme. The snow albedo, computed by the snow scheme, will be compared with Land-SAF data (WP2). A comparison of the surface fluxes (latent and sensible heat) with in-situ measurement available in Europe (Cabauw, Sodankyla, Lindenberg) will demonstrate the "physical" realism of the system.