Evolution of the ARPEGE physics

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ALADIN/HIRLAM meeting
Marrakech, 7-11 may 2012

Outline

- Constraints : new computer
- Shallow convection
- PCMT
- Turbulence : Stable case and Dome C, BLLAST (Y. Seity talk)
- Conclusions

Constraints : New computer

- Summer 2013 :
  - new computer but no modifications in ARPEGE and AROME between summer 2013 and summer 2014 for two reasons : porting activities and no backup solution before 2014
  - Next update for the physics must be ready for Dec2012 for a operational use in summer 2013 (NEC)
- Objectives: summer 2014 ARPEGE at 7km with ~100 vertical levels and AROME at 1.3km with ~90 vertical levels

Preliminary test with the AROME shallow convection PMMC09 (Pergaud et al 2009, previously named EDKF) in ARPEGE

(for more details Y. Bouteloup)

- LEDKF : available since cy37t1
- Some instability and crash with the ARPEGE time step (600s) → Full implicit formulation → stable at 600s no more problem of instability or crash !

In AROME 2 implicit formulations = ED + MF

Eddy diffusivity resolved implicitly

$$\left(\frac{\partial \psi}{\partial t}\right)_{eddy} = -\frac{1}{\rho}\frac{\partial}{\partial z}\left(k\frac{\partial \psi}{\partial z}\right)$$

$$k = a_\psi l\sqrt{TKE}$$

+

Mass flux : implicit with zi=1 (AROME)

$$F_\psi = \rho\overline{w'\psi'} = M\left(\psi_u - \overline{\psi}\right)$$

$$F_\psi = \left(1 - z_i\right)F_\psi^- + z_i F_\psi^+$$

$$\left(\frac{\partial \psi}{\partial t}\right)_{MF} = \frac{1}{\rho}\frac{\partial}{\partial z}F_\psi = \frac{1}{\rho}\frac{\partial}{\partial z}\left(F_\psi^- - z_i M\left(\tilde{\psi}^+ - \tilde{\psi}^-\right)\right)$$

EDMF one full implicit formulation = ED and MF

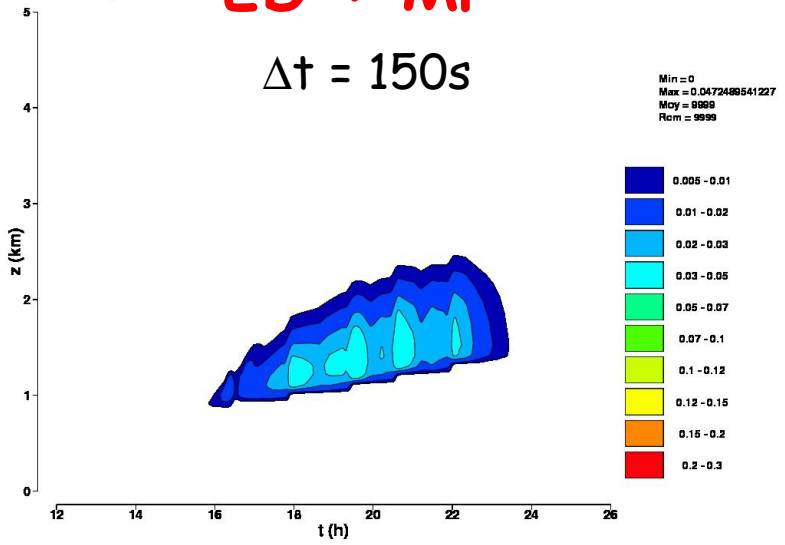
$$\left(\frac{\partial \psi}{\partial t}\right)_{edmf} = \frac{1}{\rho}\frac{\partial}{\partial z}\left(-k\frac{\partial \psi}{\partial z} + M\left(\psi_u - \overline{\psi}\right)\right)$$

Impact in 1D MUSC ARPEGE for ARM cumulus case

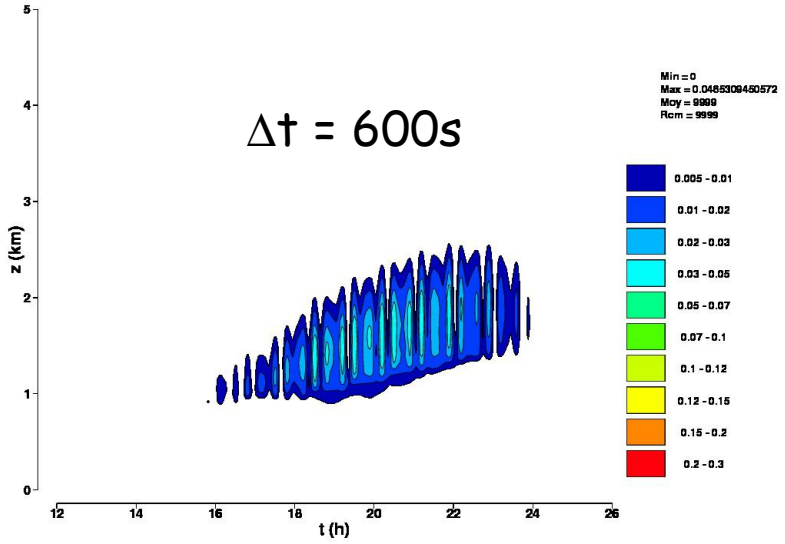
Cloud water g/kg

ED + MF

Δt = 150s

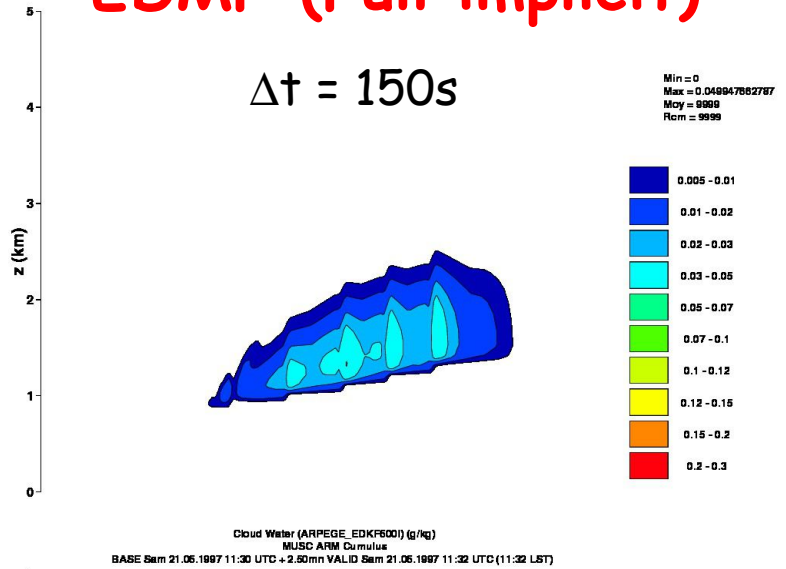


Δt = 600s

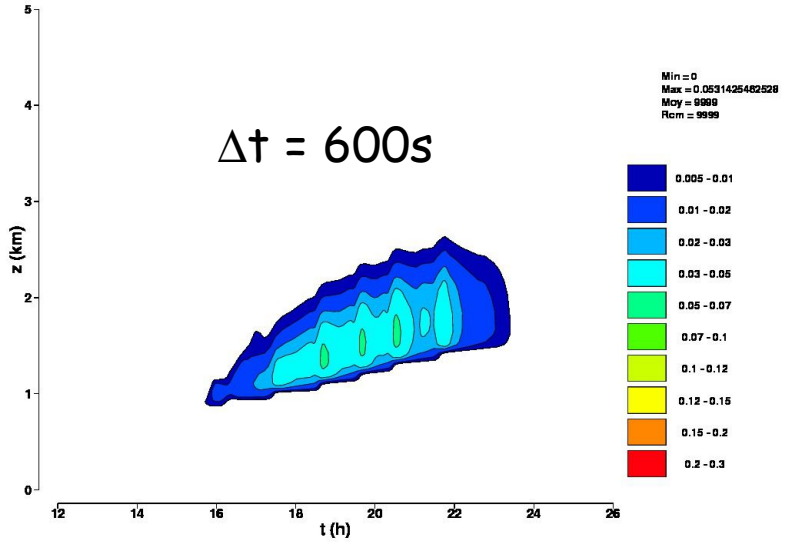


EDMF (Full implicit)

Δt = 150s



Δt = 600s

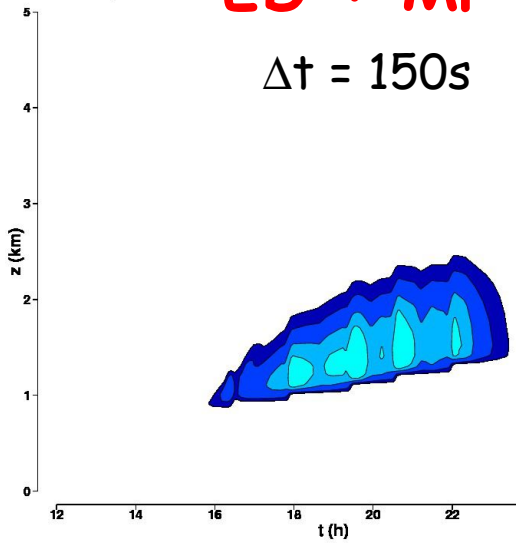


AM

Impact in 1D MUSC ARPEGE for ARM cumulus case

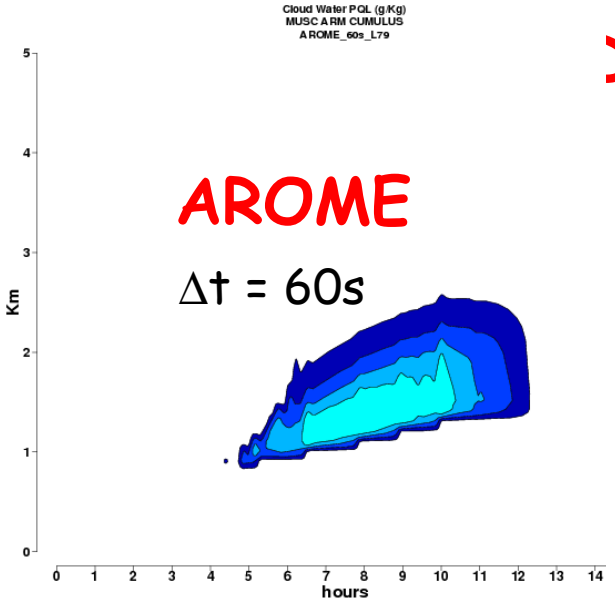
ED + MF

Δt = 150s



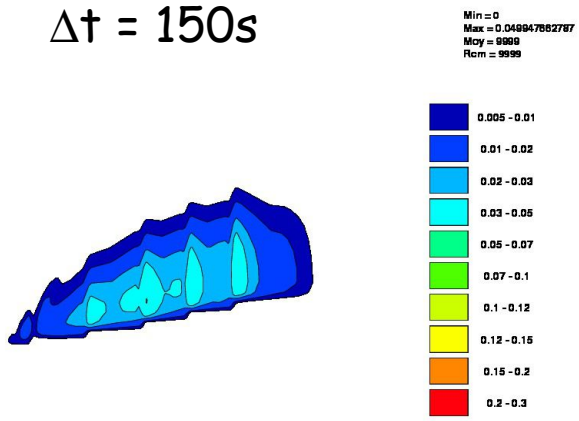
AROME

Δt = 60s

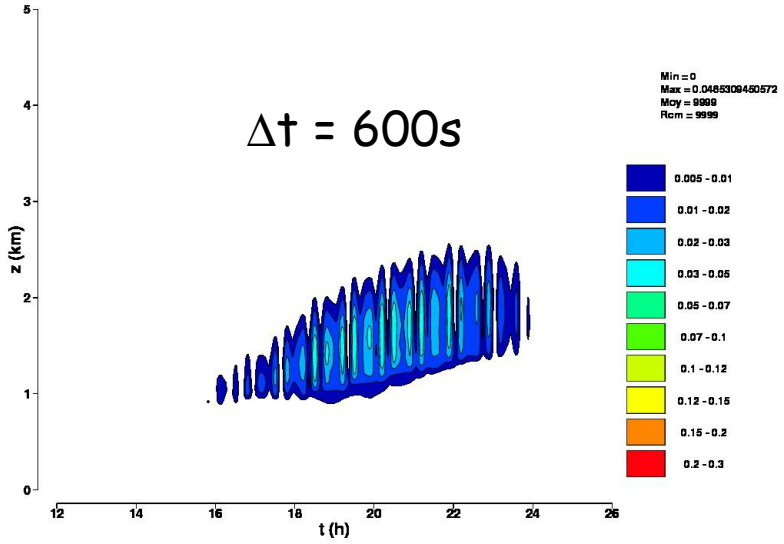


CMF (Full implicit)

Δt = 150s

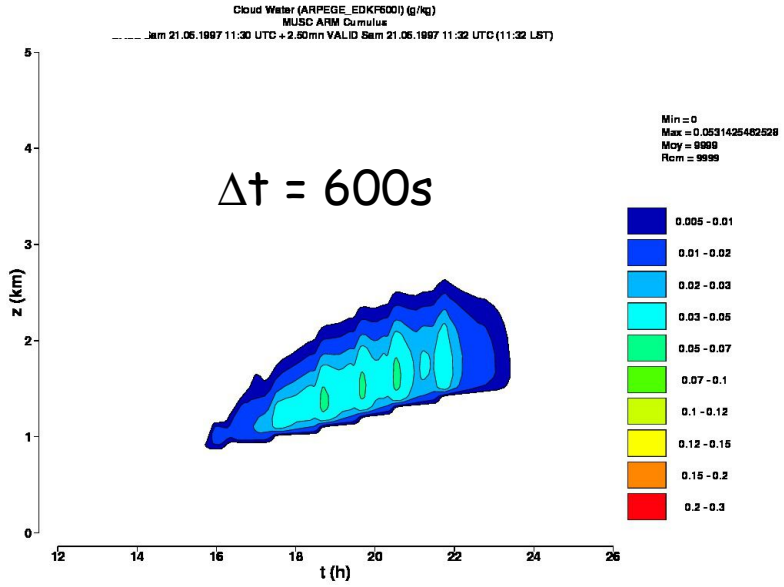


Δt = 600s



AM

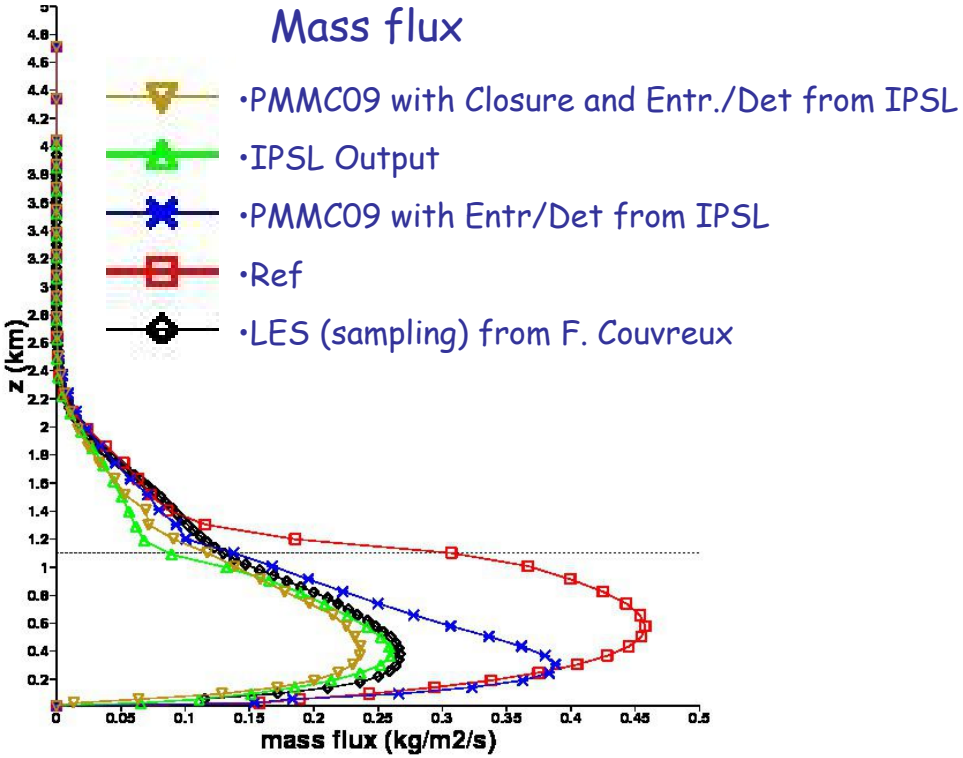
Δt = 600s



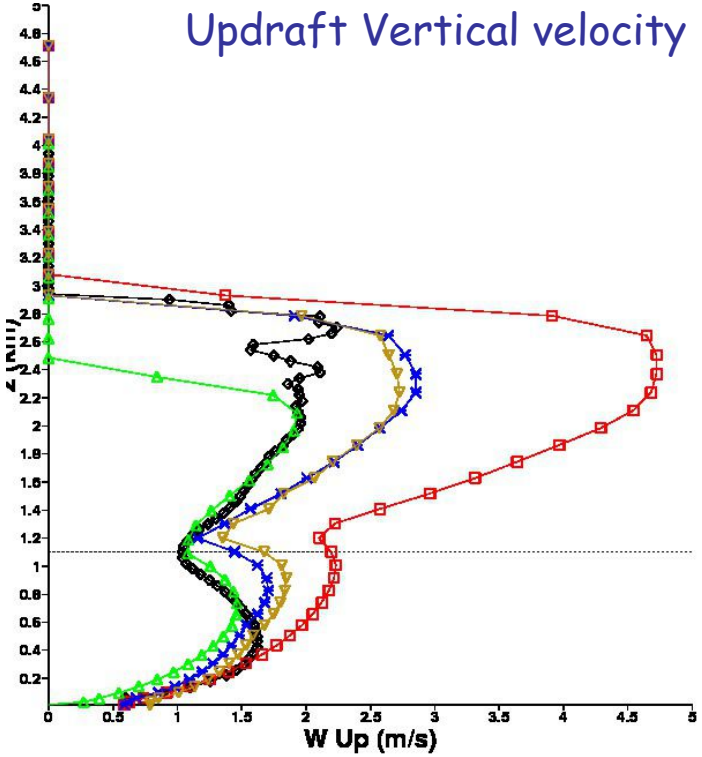
Impact in 1D model for ARM cumulus case scientific modifications (for more details Y. Bouteloup)

- Entrainment and detrainement from Rio et al (2010)
- Closure assumption from Rio and Hourdin (2008)

Mass flux



Updraft Vertical velocity



Also possible to use those options in AROME

Prognostic Condensates Microphysic and Transport: PCMT

For more details contact : JM Piriou and JF Gueremy

- 5 prognostic equations ql_sg, qi_sg, qr_sg, qs_sg, w_updraft (+15% CPU and +25% memory)
- Consistency with resolved part : the same microphysics is used for the resolved and the subgrid part.
- Entrainment-detrainment : symmetry convective <> resolved part (new).
- Separation microphysics – transport MT (Piriou JAS 2007).
- Ascent in dry and pseudo-adiabatic mode, transport flux as in (Guérémy Tellus 2011).
- Vertical transport of prognostic variables (cloudy, precipitation sedimentation) via a statistical algorithm from (Yves Bouteloup Tellus 2011) (new).
- Several closures and entrainment-detrainment are available.
- Preliminary Results : 1D EUROCS idealized humidity case, ARMCumulus, 3D vs CMORPH analysis, 3D zonal

Prognostic Condensates Microphysic and Transport: PCMT

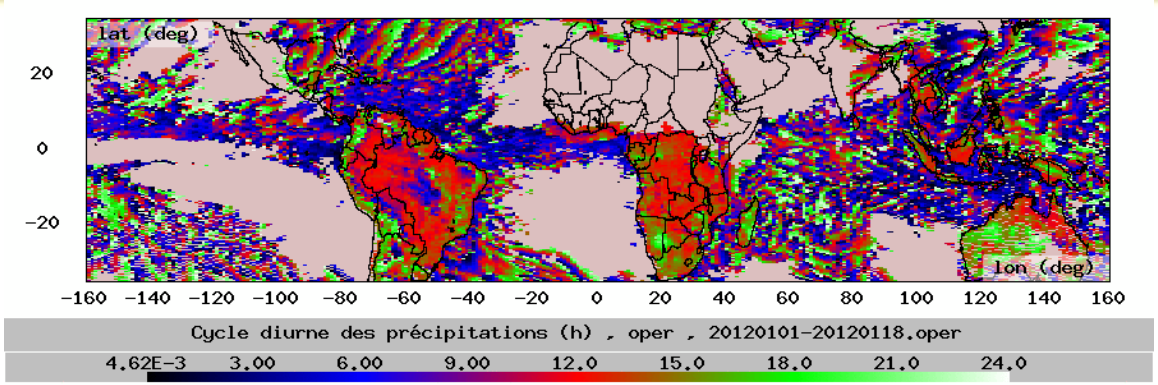
PCMT options used : CAPE closure and relaxation time function of W

Several options for testing:

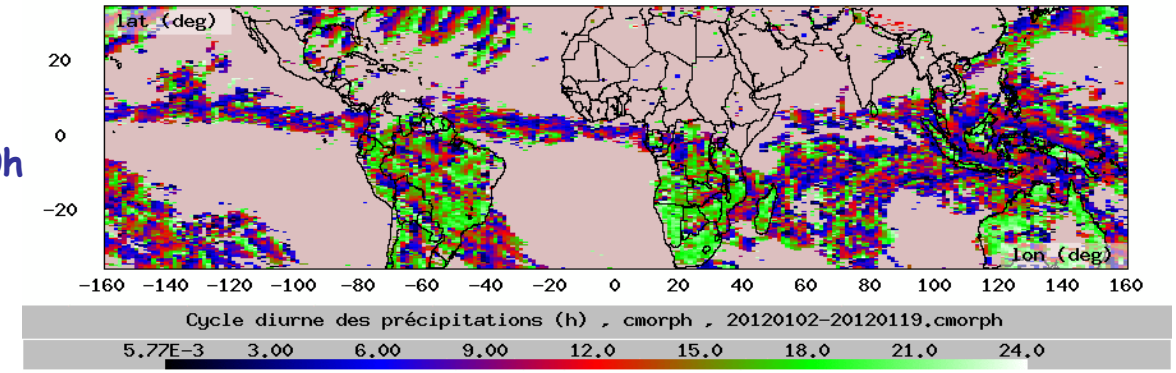
- - full PCMT = shallow (dry and moist) and deep → switch off KFB scheme → no direct link (inside the time step) between the TKE scheme and PCMT but better consistency (via prognostic variables) between shallow and deep convection
- - PCMT only the deep convection → 2 options:
  - KFB used in ARPEGE since Feb 2009 with the TKE scheme → stable scheme but no dry mixing in case of no condensation and no mixing on the wind
  - AROME shallow convection (PMMC09) used with the full implicit option (for long time step) : with the AROME tuning or with the entrainment from Rio et al 2010 and the closure from Rio & Hourdin 2008

PCMT Diurnal cycle (1-18 January 2012)

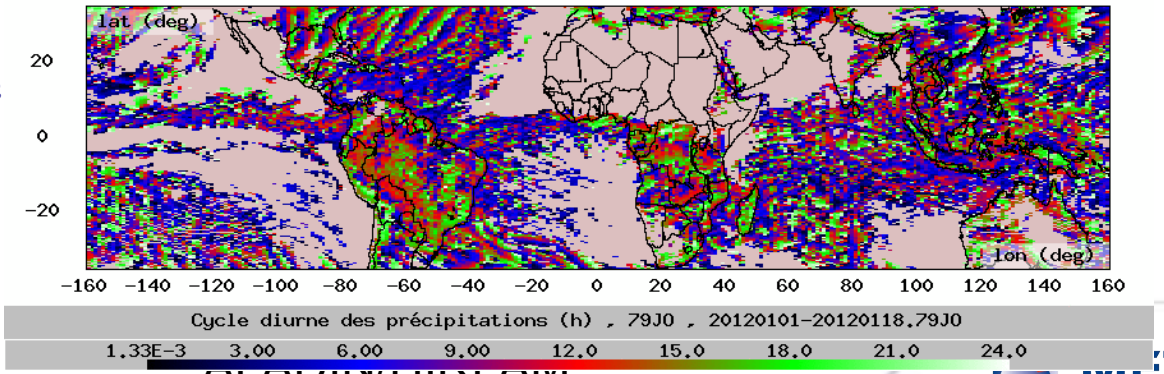
OPER
Max intensity at midday



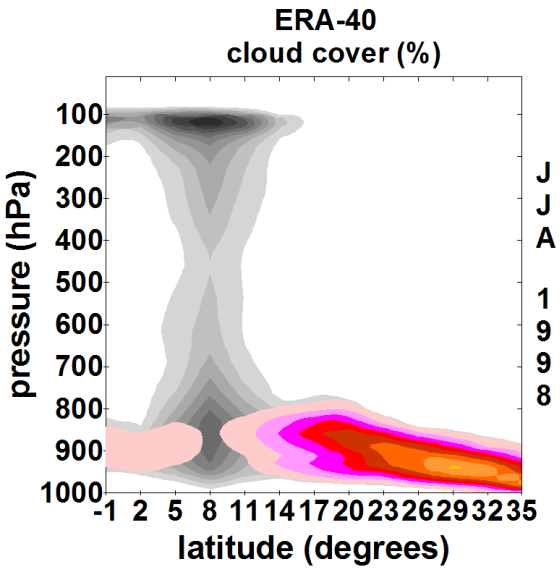
CMORPH
Max around 18h-20h



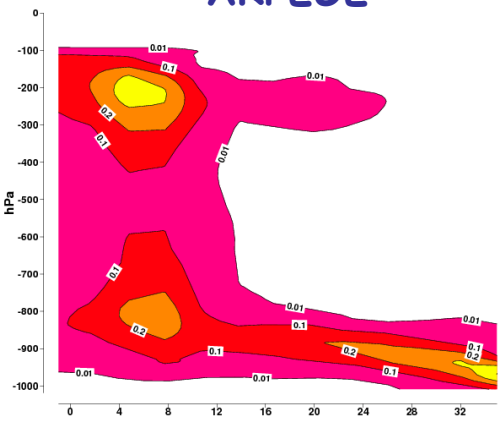
PCMT improves the diurnal cycle



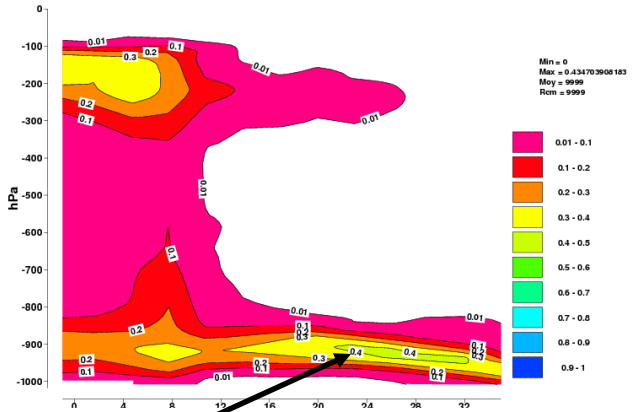
PCMT : GPCI Pacific vertical cross section



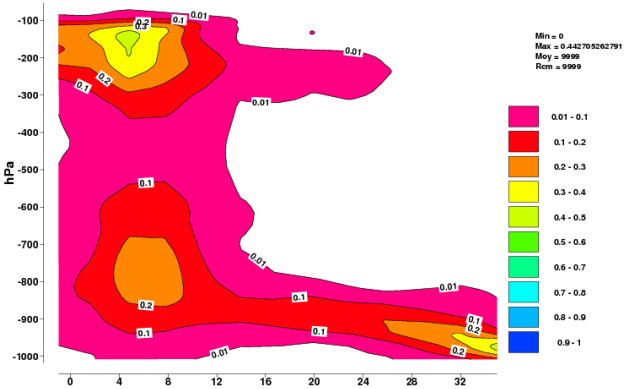
ARPEGE

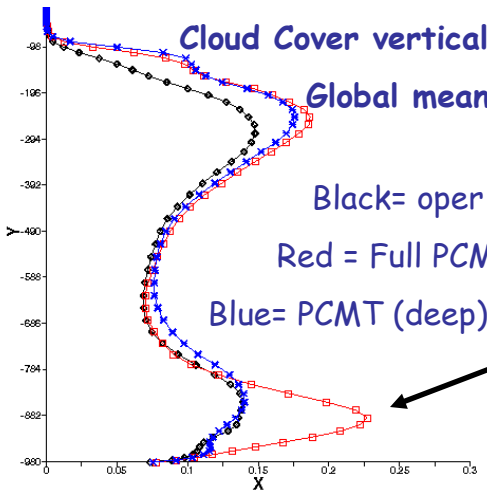


ARPEGE +PCMT (shal & deep)



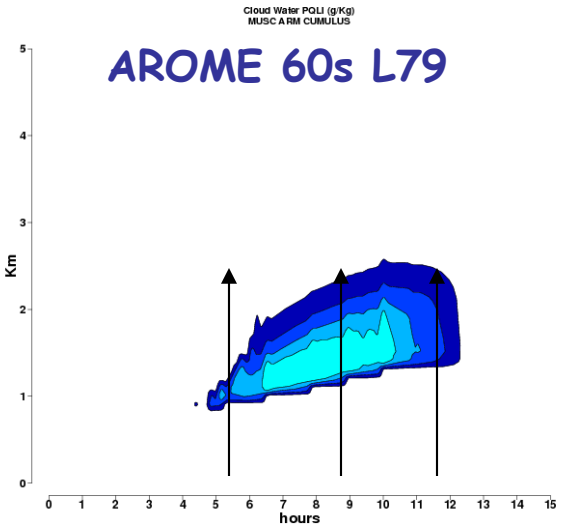
ARPEGE + PCMT (only deep) & KFB

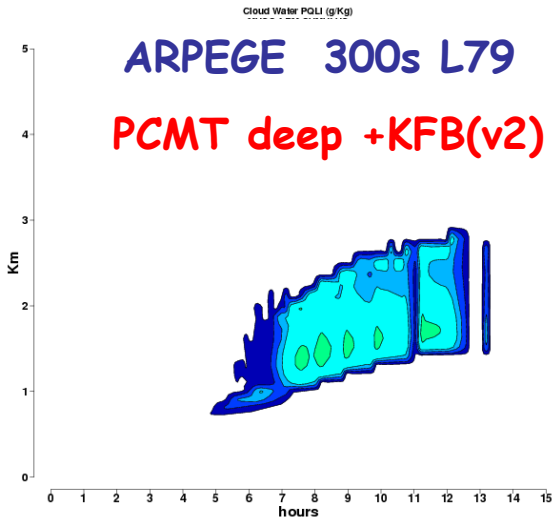


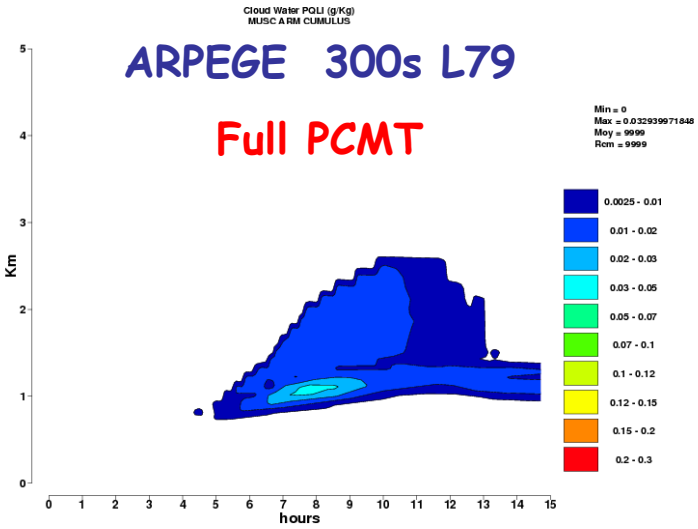


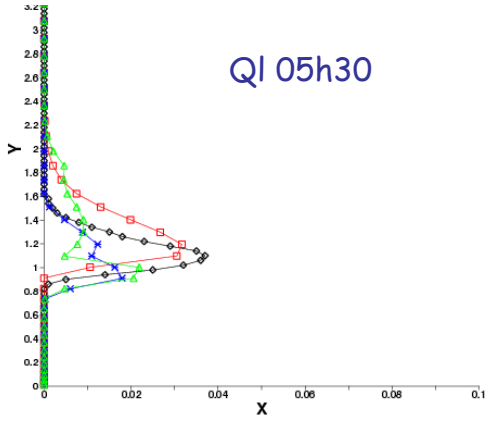
With PCMT full → too much low clouds over ocean probably due to a less active shallow part compared to KFB

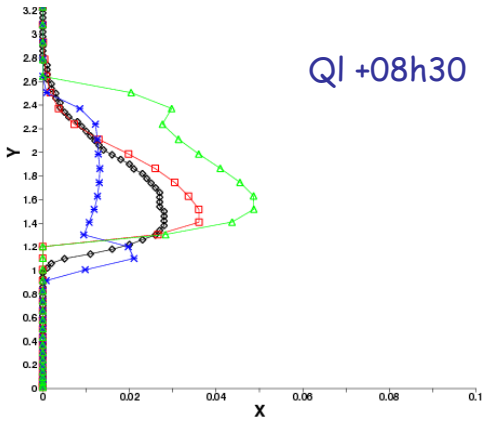
1D validation ARMCumulus
Cloud water (g/Kg)

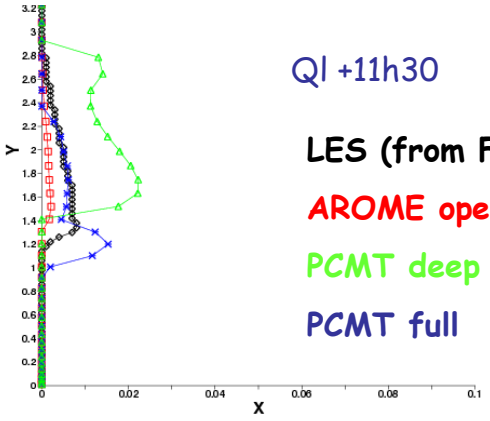












LES (from F. Couvreux)

AROME oper

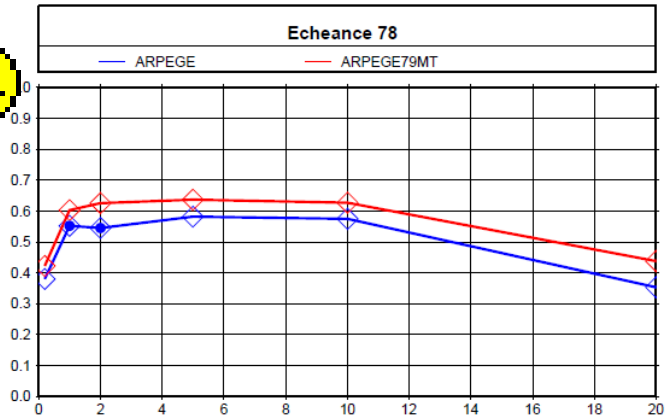
PCMT deep + KFB(v2)

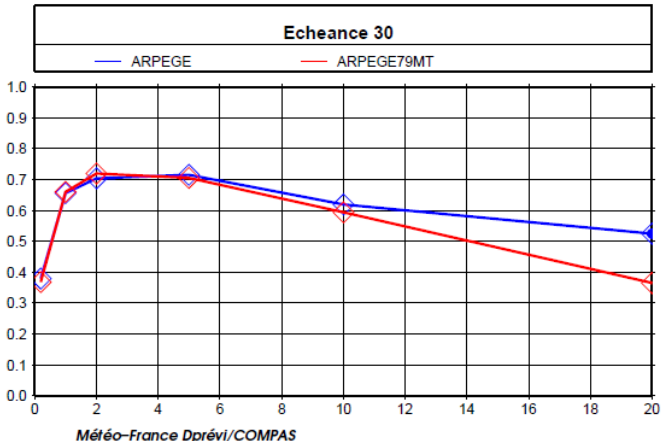
PCMT full

Full PCMT : better time evolution compared to KFB, nevertheless the cloud does not disappeared. Not enough mixing → PBL too moist ?

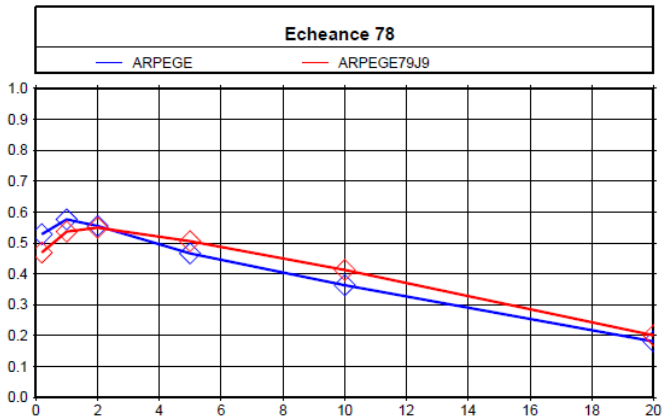
QPF over France (24h cumulated rain)

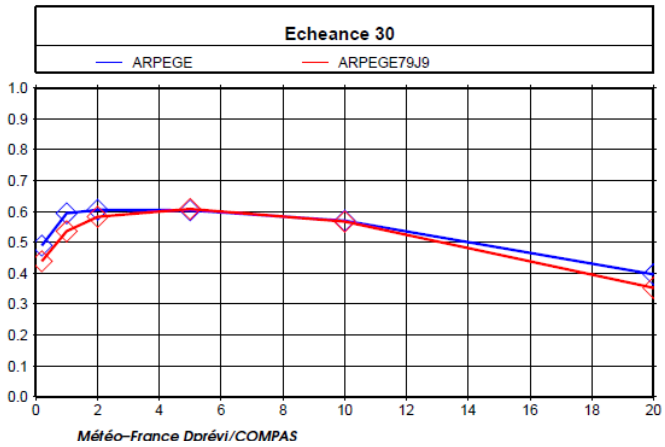
January 2012 BSS_NO 31km





July 2011 BSS_NO 31km





ARPEGE=Blue

PCMT(full)=Red

RR 78h-54h

RR 30h-06h

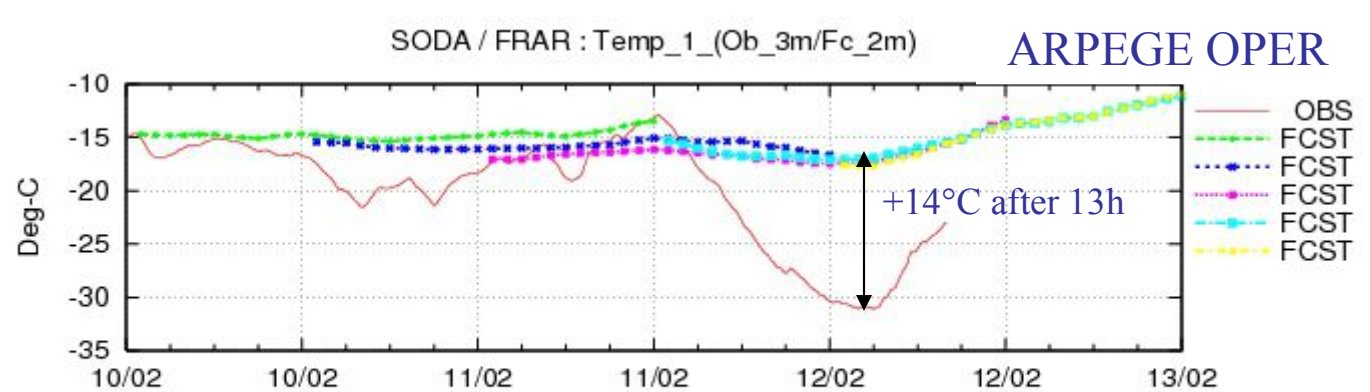
Probably spin up problem for the first day due to the analysis coming from the operational ARPEGE, nevertheless the results are encouraging for longer forecasts → requires 4DVAR experiment with PCMT.

Turbulence : stable case and Dome C: Some weaknesses …

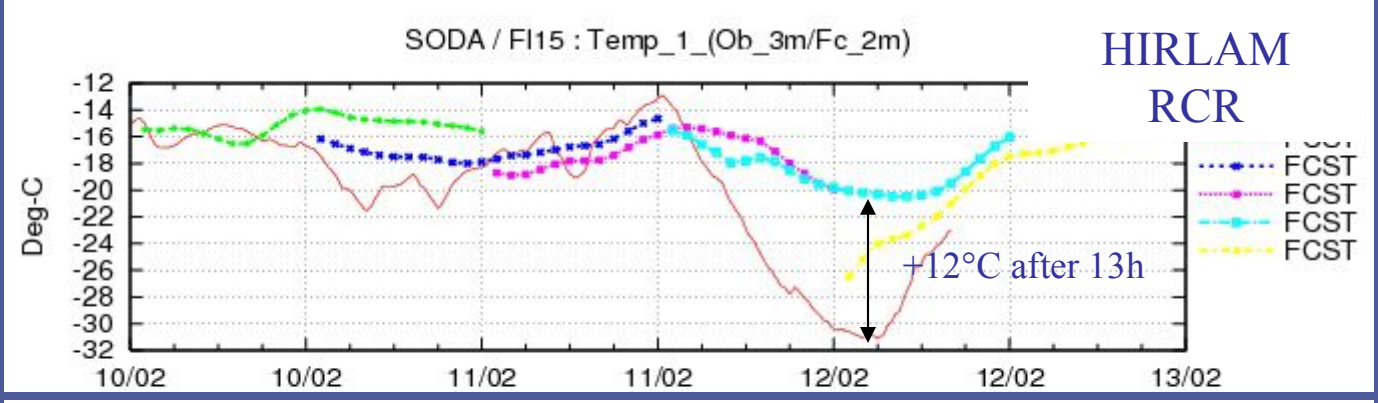
1. We still have warm bias over snow (Northern Europe, South and North Pole) → interaction with the surface and the snow scheme

Sodankyla T2m 20100211 starting at 12UTC

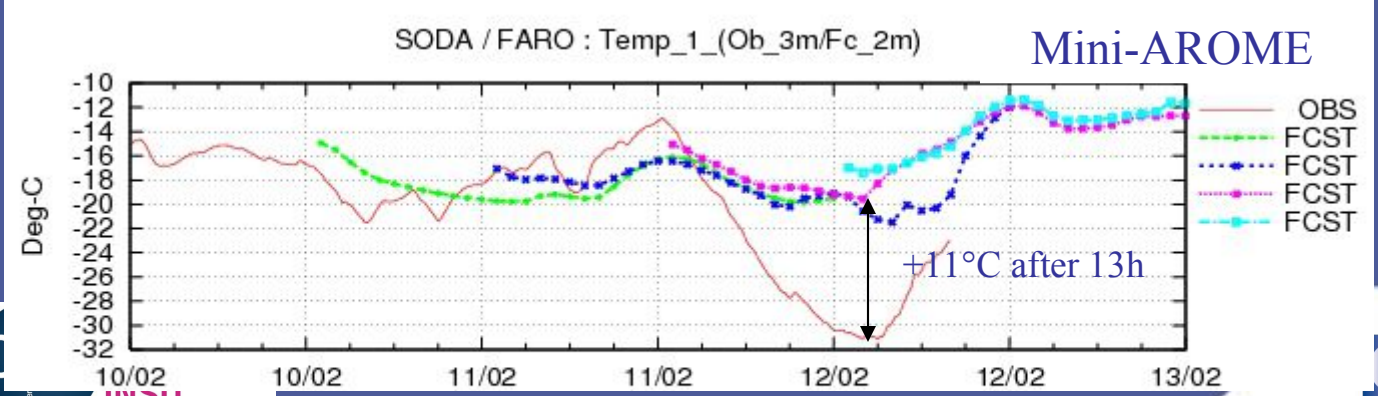
From http://fminwp.fmi.fi/mastverif/mastverif.html



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)



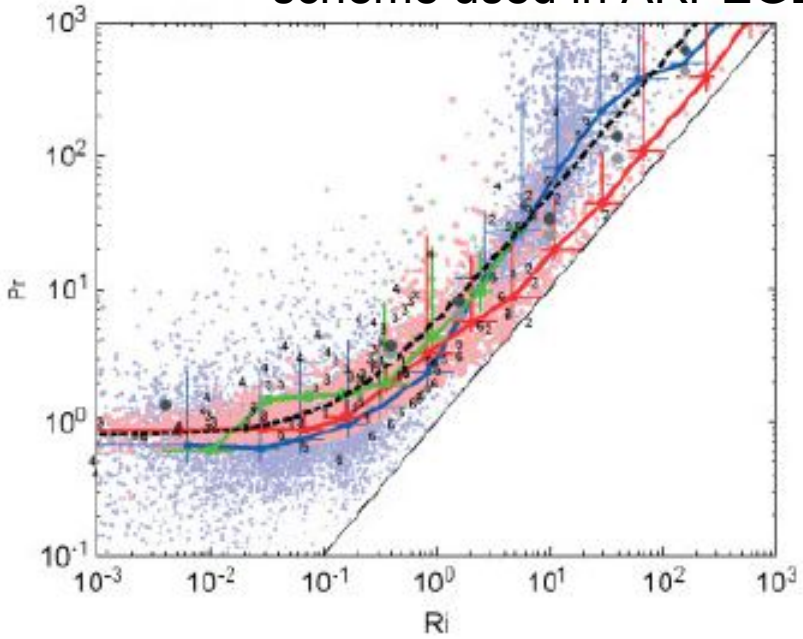
Mini-AROME : 30x30 pts dynamical adaptation from ARPEGE with SURFEX (snow scheme D95) → no specific analysis.

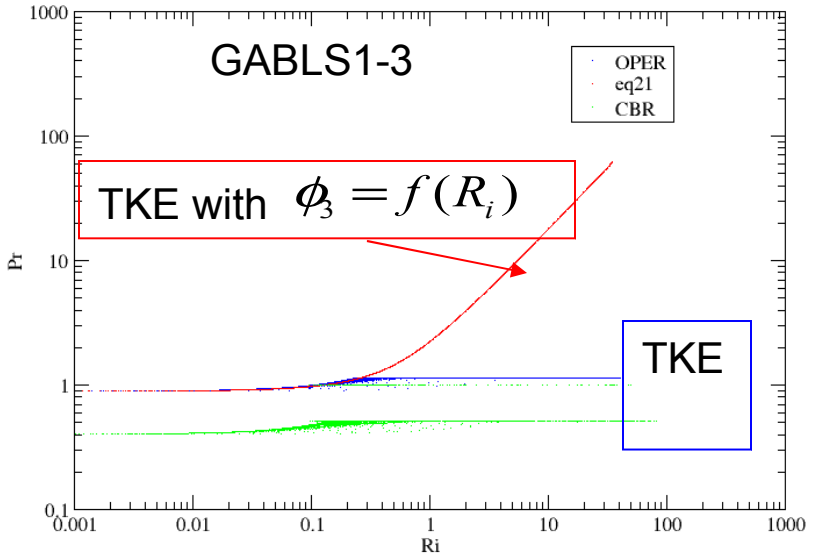
INSU Observer & comprendre

METEO FRANCE Toujours un temps d'avance

Turbulence : stable case and Dome C: Some weaknesses …

1. We still have warm bias over snow (Northern Europe, South and North Pole) → interaction with the surface and the snow scheme
2. Following Galperin et al 2007 and Zilitinkevich et al 2008 turbulence survives for Ri>>1. It is not the case with the TKE scheme used in ARPEGE/AROME…





From Zilitinkevich et al 2008 IIRLAM meeting

$$\Pr = \frac{K_m}{K_h} = \frac{1}{\alpha_\theta \phi_3}$$ with $\alpha_\theta = 1.13$

$0.78 \le \phi_3 \le 2.2$

Impact of Phi3=f(Ri)

$$(\overline{w'\theta_l'}) = -\alpha_\theta \alpha_u l \sqrt{\overline{e_T}} \cdot \frac{\partial \overline{\theta_l}}{\partial z} \cdot \phi_3 \qquad (\overline{w'q_t'}) = -\alpha_\theta \alpha_u l \sqrt{\overline{e_T}} \cdot \frac{\partial \overline{q_t}}{\partial z} \cdot \phi_3$$

$$\phi_3 = \frac{1}{1 + C \cdot \beta \frac{L_m^2}{\overline{e_T}} \frac{\partial \overline{\theta_l}}{\partial z}}$$

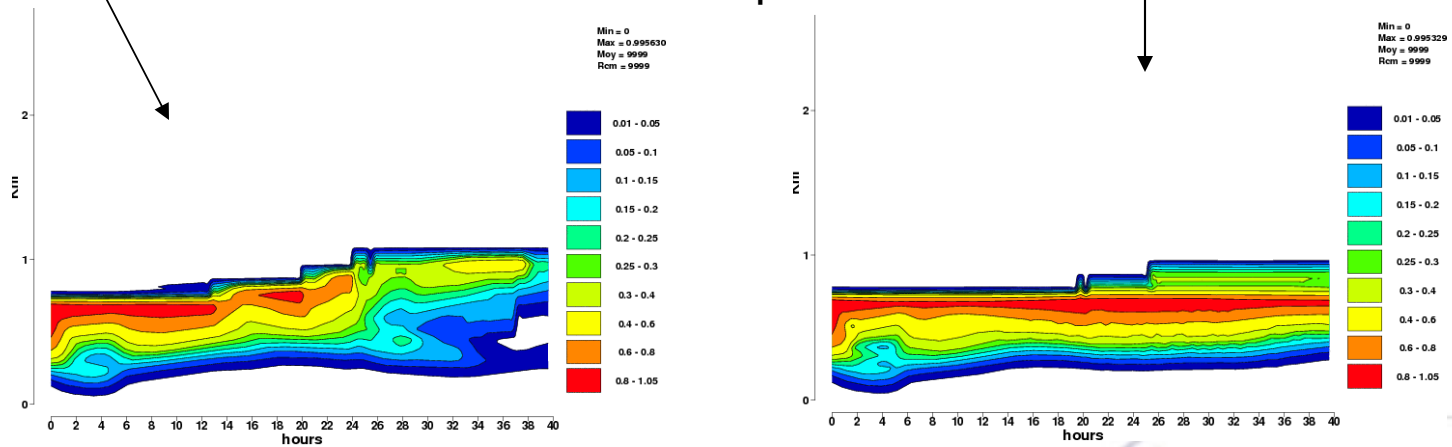
Default formulae from
(Cuxart (2000) eq19)

or in a stationary equilibrium of TKE
(Cuxart (2000) eq21)

$$\phi_3 = \frac{1}{1 + C_4 R_i / f(R_i)}$$

$$f(R_i) = 0.5\left(1 - (C_3 + C_4)Ri + \left((1 - (C_3 + C_4)Ri)^2 + 4C_4 Ri\right)^{0.5}\right)$$

Cloud Cover ASTEX Lagrangian Case (Euclipse)
Cloud Cover : impact of Phi3



Impact of Phi3=f(Ri)

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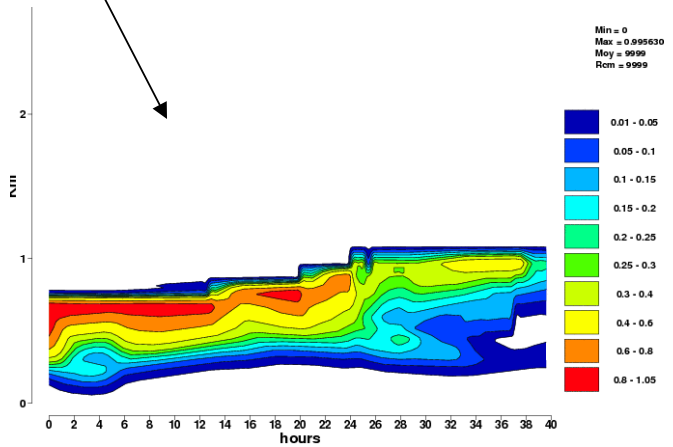
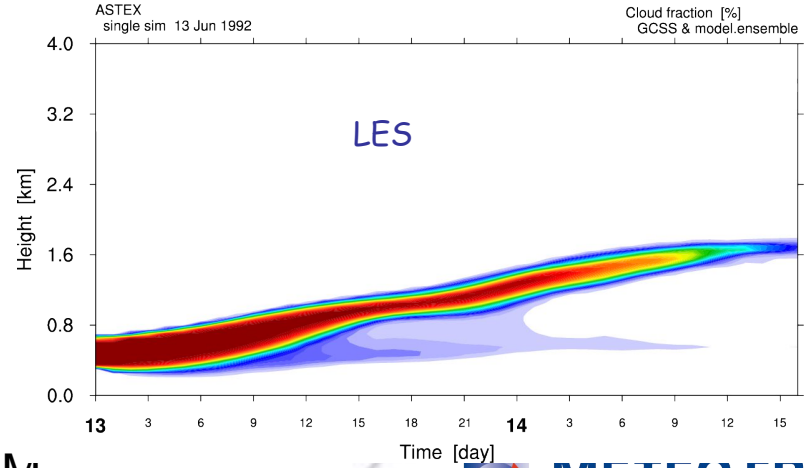
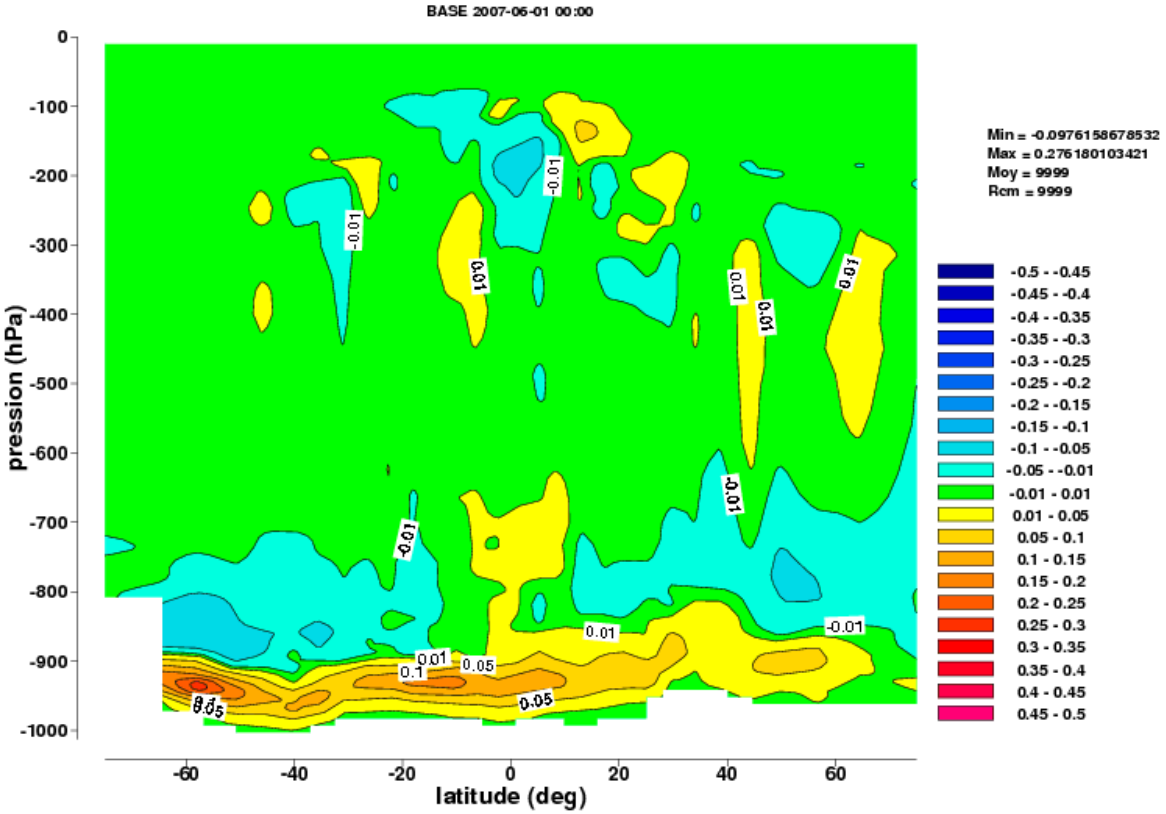




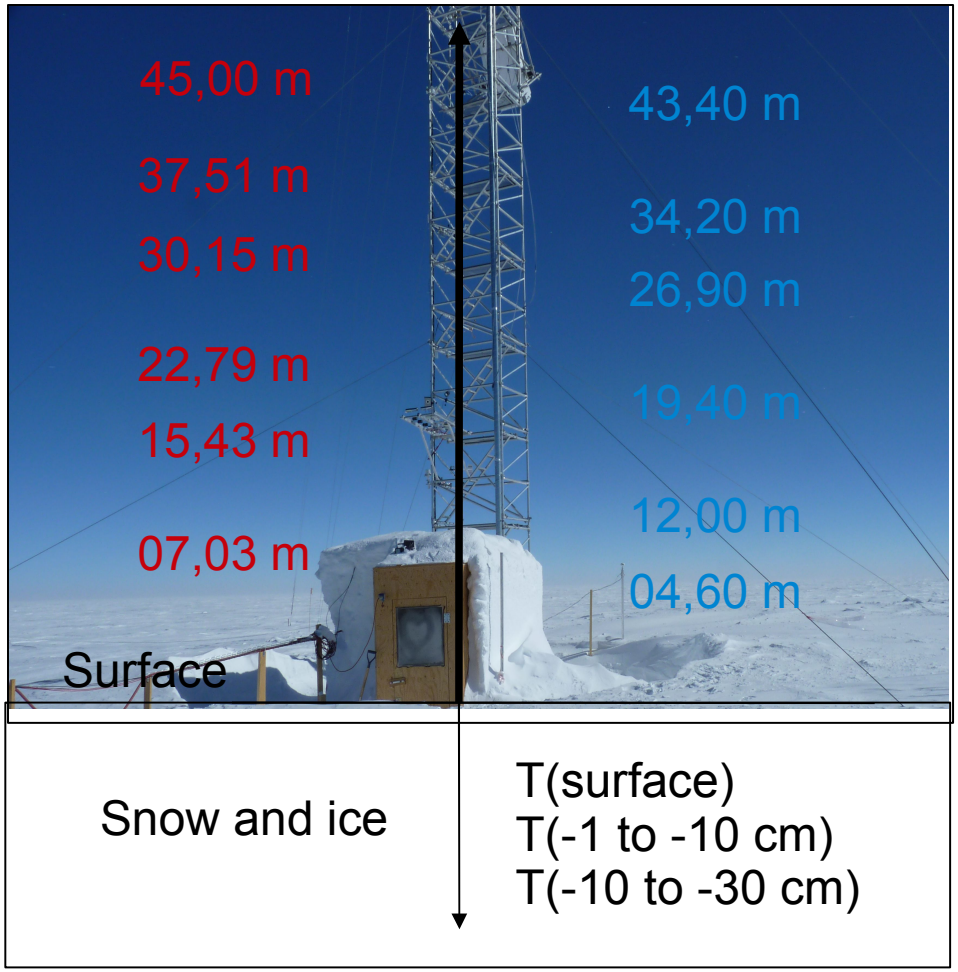
Impact of Phi3=f(Ri) in ARPEGE 3D

Cloud Cover (Zonal mean) : Phi3=f(Ri) – Ref



Phi3=f(Ri) increases the humidity in the PBL → more low cloud

Dome C / Concordia : a very convenient site to study snow-atmosphere interactions : GABLS (3 + n) ?

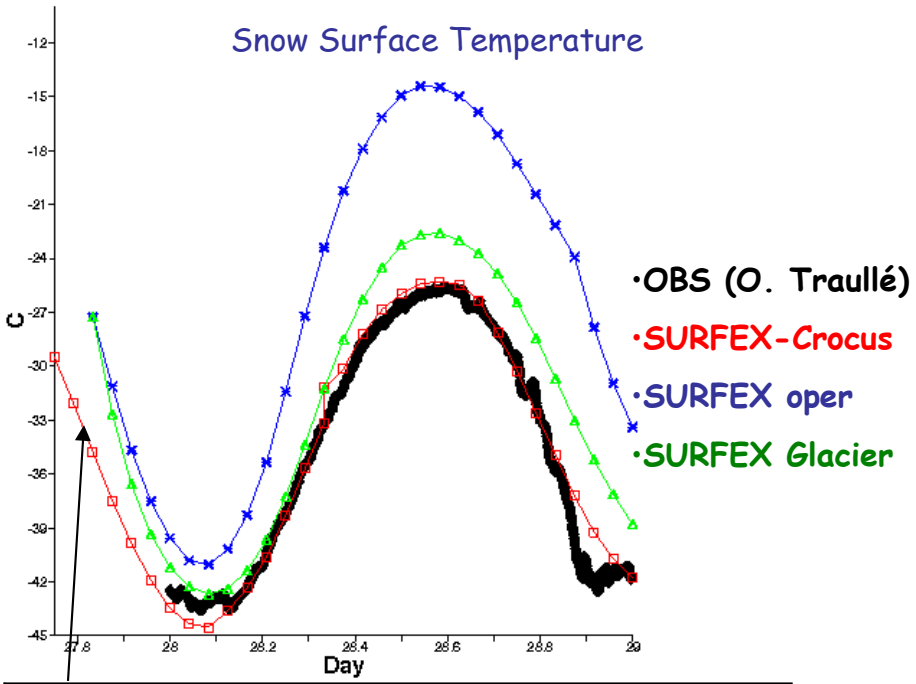


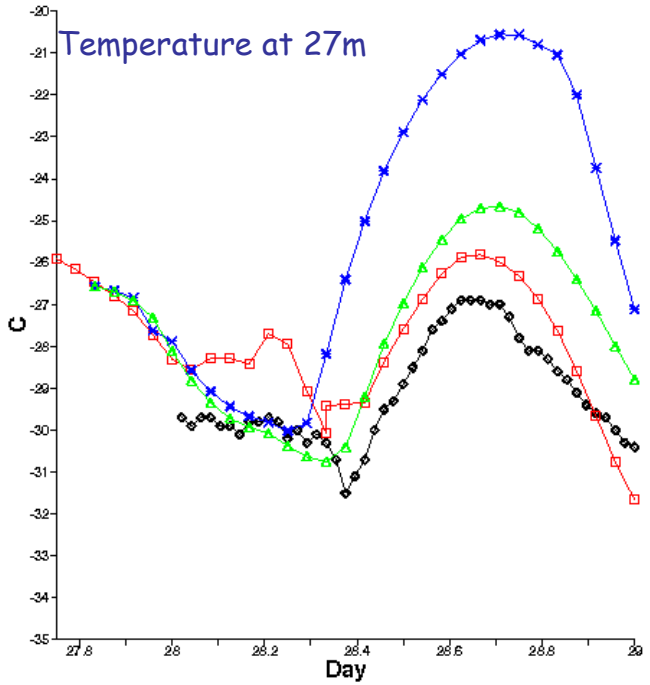
- High frequency parameters (10 Hz) from 6 ultra-sonic anemometers : 3D Wind components and sonic temperature
- Low frequency parameters (30 min) : air temperature (ventilated and not ventilated), relative humidity, wind speed and direction (**Young**)
- 1 minute solar radiation components
- Sub and surface temperatures

Thanks to O. Traullé (MF), Gert König Langlo (AWI for PMR, Bremerhaven, De) Christian Lanconelli (ISAC, Bologna, It), Andrea Pellegrini (ENEA, Roma, It), Eric Fossat (LUAN, Nice, Fr), Christophe Genthon (LGGE, Grenoble, Fr)

« American » ALADIN/HIRLAM meeting

Mini-AROME (100x100pts) L60 with LBC from ARPEGE analysis (Dome C) 20100128





AROME with SURFEX-Crocus snow scheme
E. Brun et al (2011) Journal of Glaciology (vol52)

Topic: create a 1D case (forcing term computed from AROME) to study the impact of the snow scheme and its interaction with the surface and the boundary layer.
Sensitivity to the snow scheme, vertical resolution, experiment with a prescribed Ts, evaluation of the Total Turbulent Energy (TTE) scheme

Conclusions

- PCMT:
  - **Positive impact : diurnal cycle, horizontal structure of precipitation, finer ITCZ**
  - **Nevertheless PCMT requires some tunings:**
    - **for the cloud cover**
    - **to reduce the precipitation over Asia (Himalaya, Indian)**
    - **to reduce cold bias of T at 200Hpa before 4Dvar experiment,**
    - **more test with MUSC (Bomex, Euclipse Case : Astex Lagrangian , Composite, Fire 1 etc …)**
  - **Necessity to choose this year between :**
    - **Full PCMT**
    - **PCMT(deep) +KFB**
    - **PCMT(deep)+PMMC09 with or without Ent/det and closure from IPSL**

- Turbulence : test of TTE in AROME/ARPEGE TKE scheme, possible cooperation with FMI (C. Fortelius and S. Zilitinkevich…), 1D experiment at Dome C with several snow scheme (available in SURFEX) to study interaction between surface and turbulence with MUSC.

LGGE tower 45m

meeting

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