Progress at ECMWF

+ more about the surface (J.F. Mafouf, surface session)
+ more about research in the dynamics (dynamic session)
+more about MACC (session “link with applications”)

Presented by Sylvie Malardel

Numerical Aspects, ECMWF

Forecasting system upgrades 2010-11

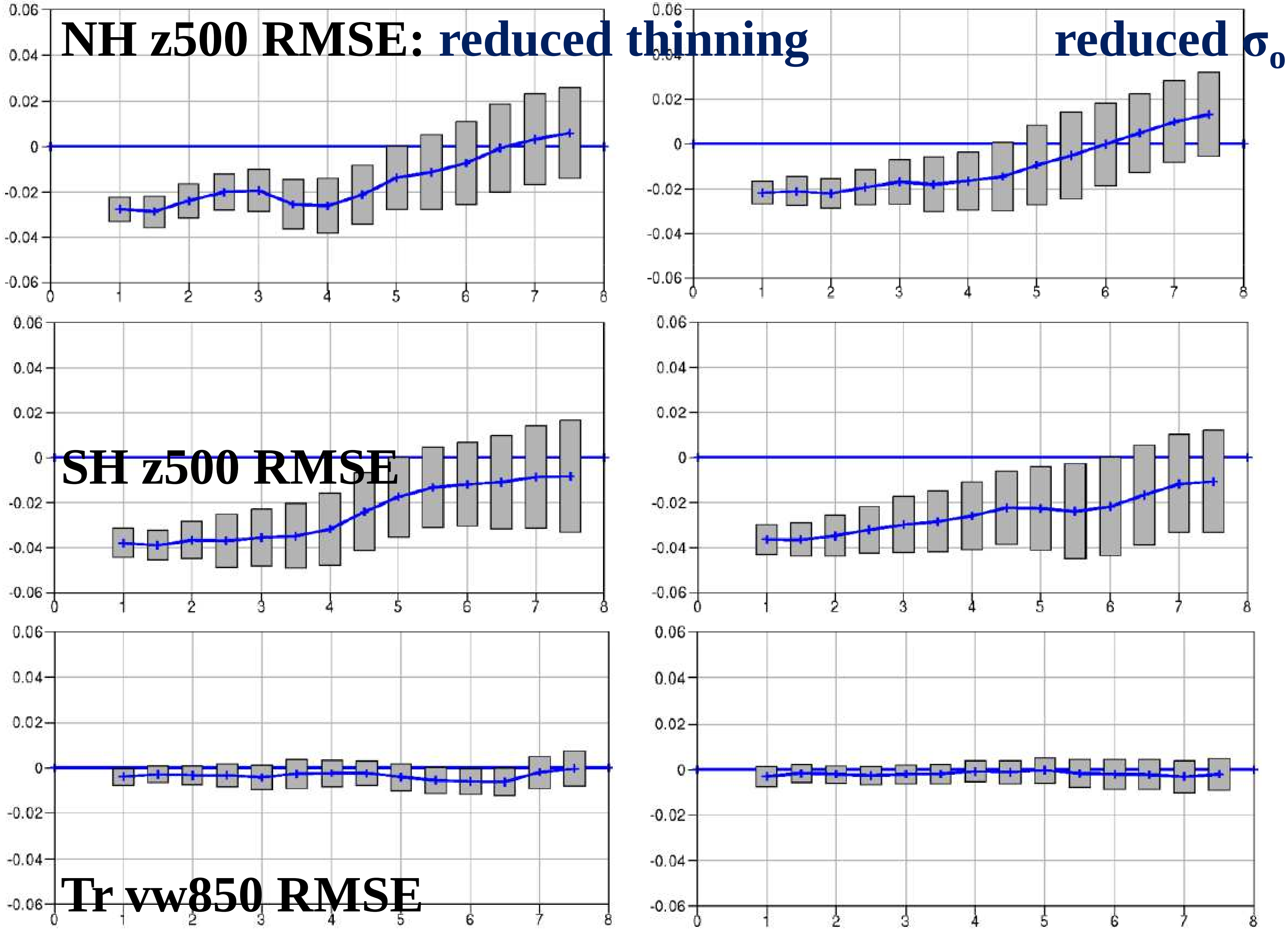
Cycle 36R4 – 11 November 2010:

- 5-species prognostic cloud scheme
- SEKF soil moisture and OI snow analysis
- Convection entrainment, all-sky assimilation refinement, 2 outer loops in early-delivery 4D-Var, etc.

Cycle 37R2 – 18 May 2011:

- Reduced AMSU-A radiance observation errors
- Use of EDA variances in 4D-Var background error formulation
- Cloud scheme modification, GPSRO observation operator improvement, etc.

CY37R2 highlights: AMSU-A data



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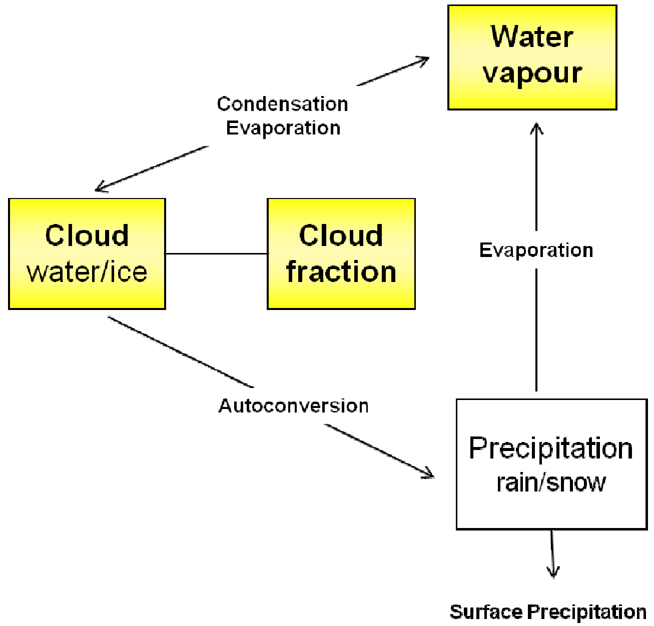
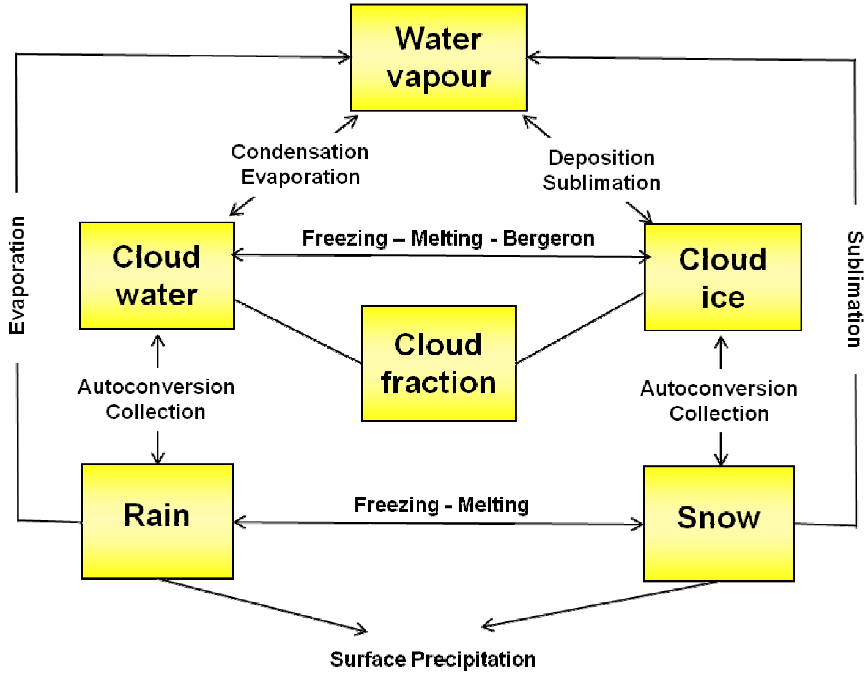
(1) New prognostic microphysics scheme
What has changed.....?

Previous Cloud Scheme
(Tiedtke scheme operational 1995-2010)



- 2 prognostic cloud variables + vapour
- Parametrized sources and sinks
- Includes convective detrainment
- Ice/water a diagnostic fn(temperature)
- Diagnostic precipitation

New Cloud Scheme
(operational from 9th Nov 2010, Cy36r4 onwards)



- 5 prognostic cloud variables + water vapour
- Ice and water now independent
- Snow/rain now advected with the wind
- Retains Tiedtke approach to sources and sinks
- More physically based, greater realism
- Significant change to degrees of freedom

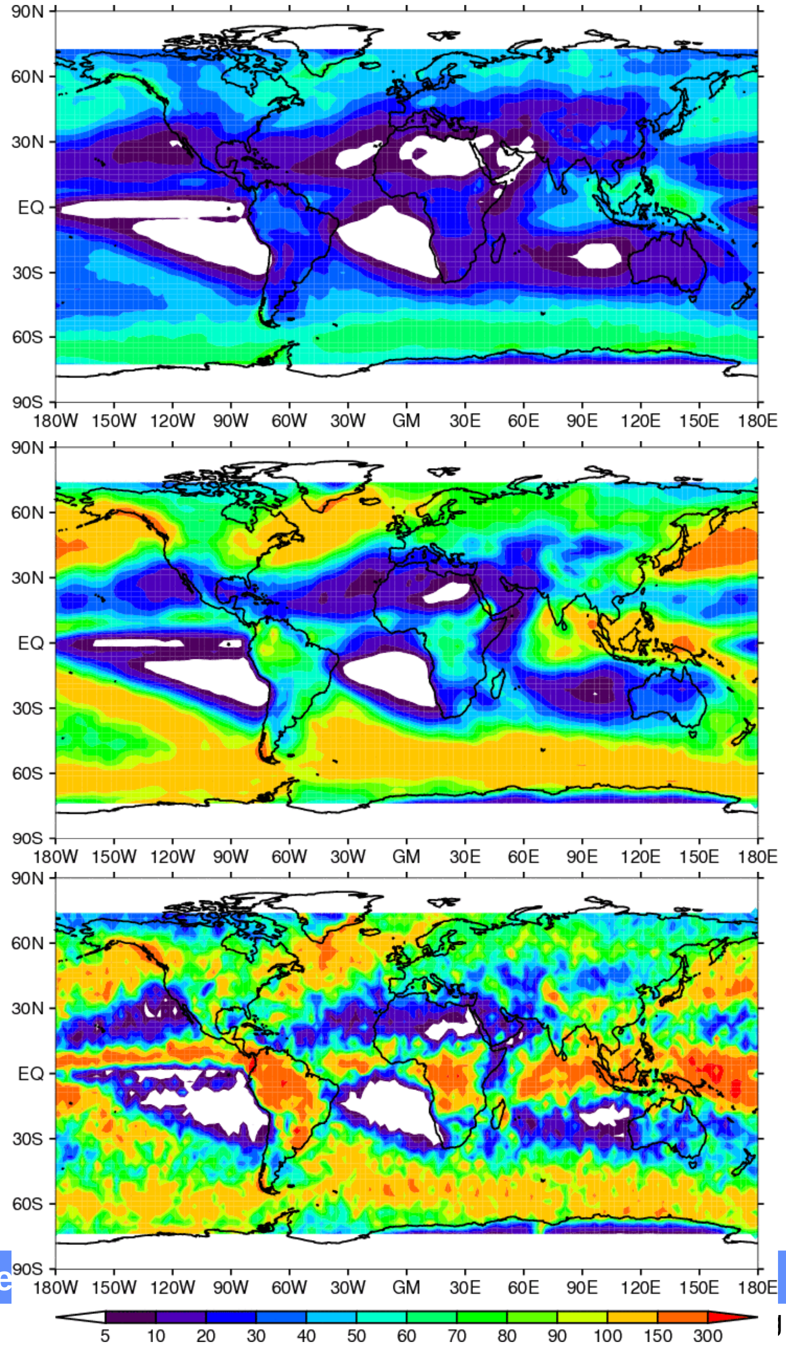
(2) Ice clouds and radiation

Ice water path interactive with radiation (1 year average)

Previous scheme (cloud ice only)

New scheme (ice + snow)

CloudSat (ice + snow)



- Significant amount of frozen water path is in precipitating snow particles
- New scheme agrees well with CloudSat dataset in extra-tropics
- Disagreement in tropics is due to model convective snow not included.

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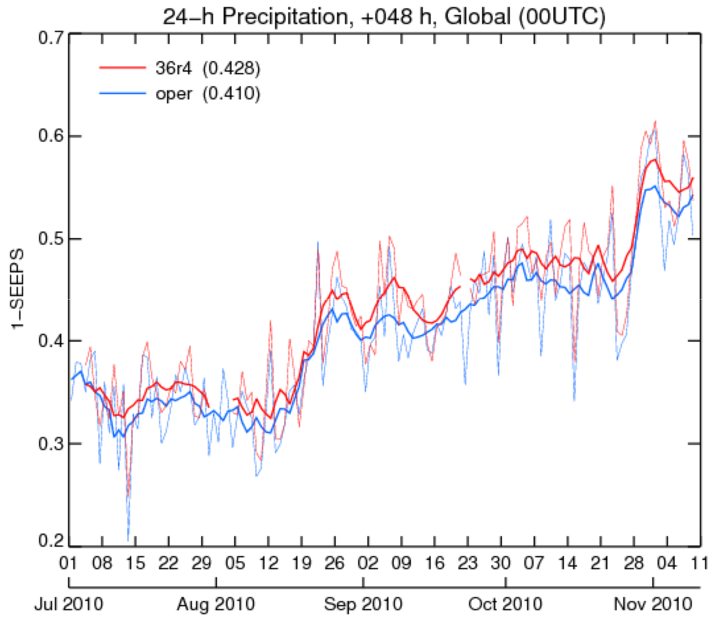
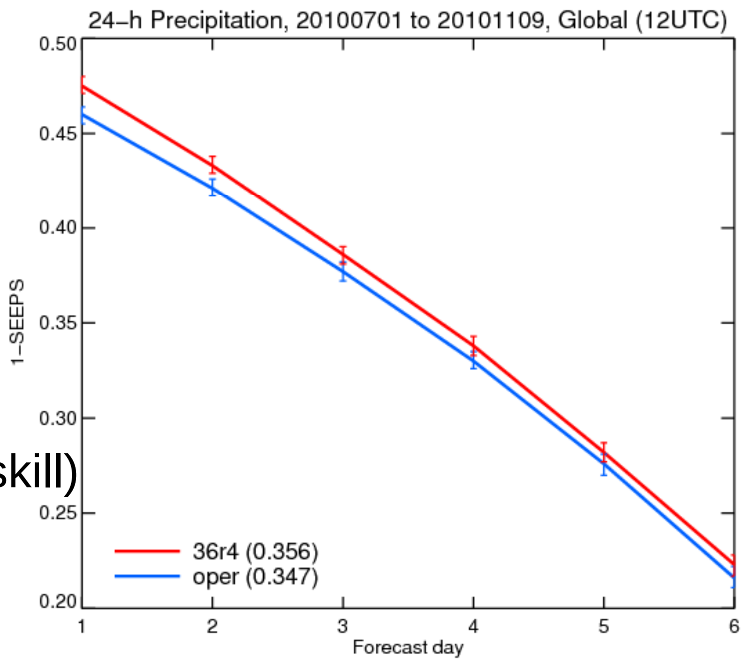
(3) Precipitation
Improved precipitation skill with new cloud scheme

Global 24-48 hr precip skill score (1-SEEPS) for Cy36r4 (red) versus Cy36r2 (blue) 1 July to 9 November



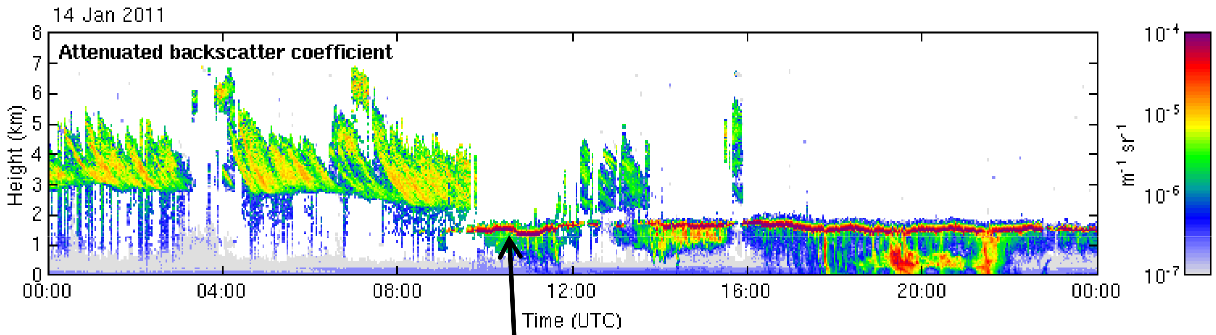
Global (1-SEEPS) score (as above) but as a function of lead time for Cy36r4 (red) versus Cy36r2 (blue)

(higher values = better skill)

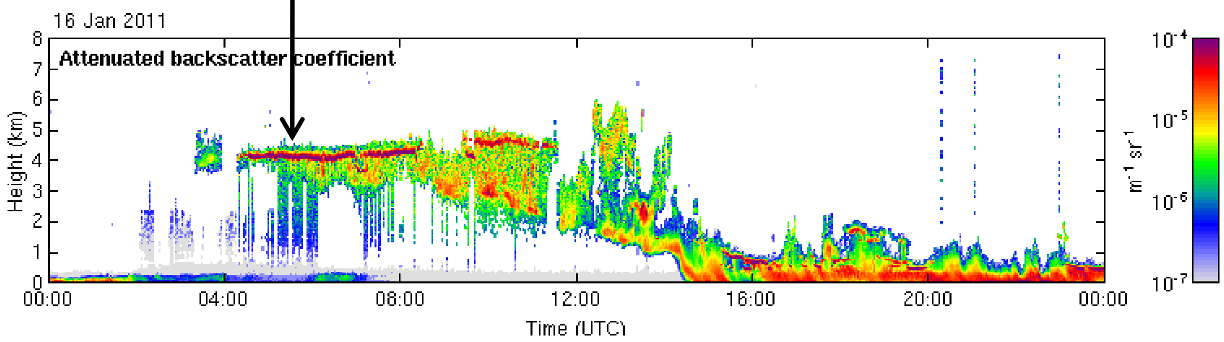


- Precipitation supplementary headline SEEPS score improved (due to new cloud scheme and convection changes at Cy36r4)
- Precipitation fields smoother due to prognostic variables.
- See small increase in precipitation downwind of orography (eg. Alps, Andes)

(4) Super-cooled liquid water
Commonly observed in the atmosphere



Example lidar backscatter timeseries at Sodankylä (Finland), **supercooled liquid water layers** often observed with ice falling out.



- Super-cooled liquid water (SLW) cloud frequently occurs in atmosphere as observed from aircraft & remote sensing.
- Observed with decreasing freq. down to around -35C (e.g. from ground-based and space-borne lidar, e.g. Hogan et al. 2003/2004).
- Supercooled liquid water is radiatively important and can increase cloud lifetime (liquid drops suspended, ice crystals grow and fall out)
- Fine balance between turbulent production of water droplets, nucleation of ice, deposition growth and fallout.

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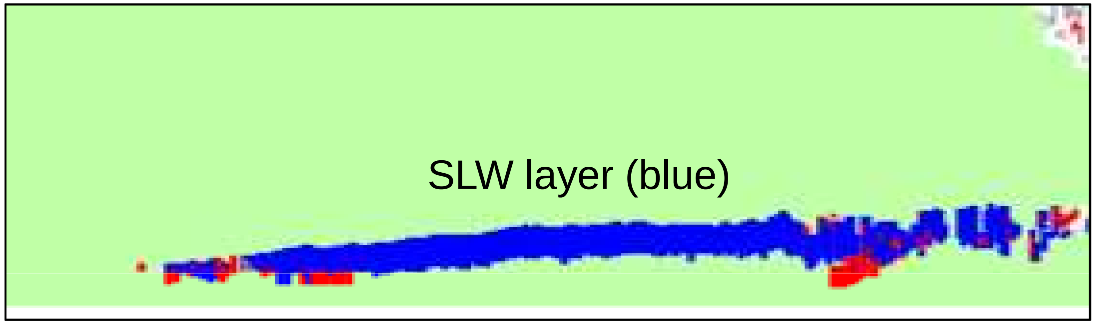
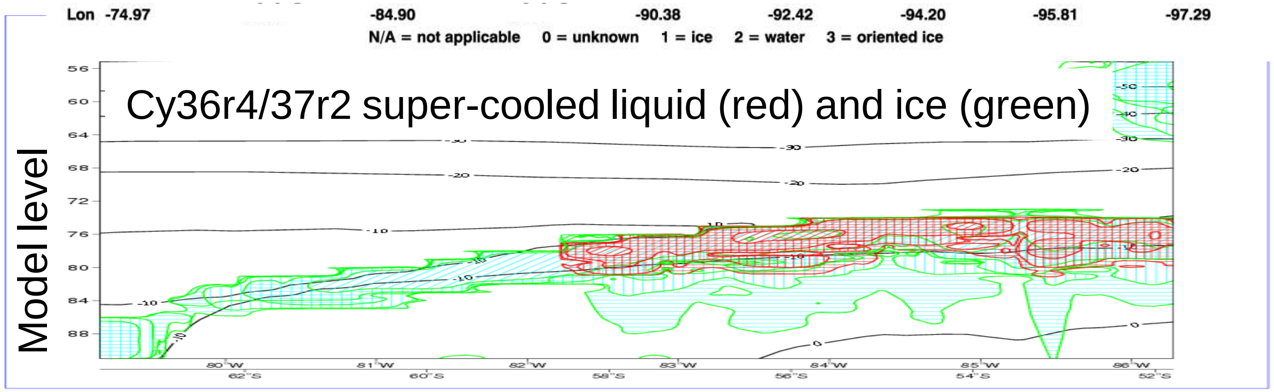
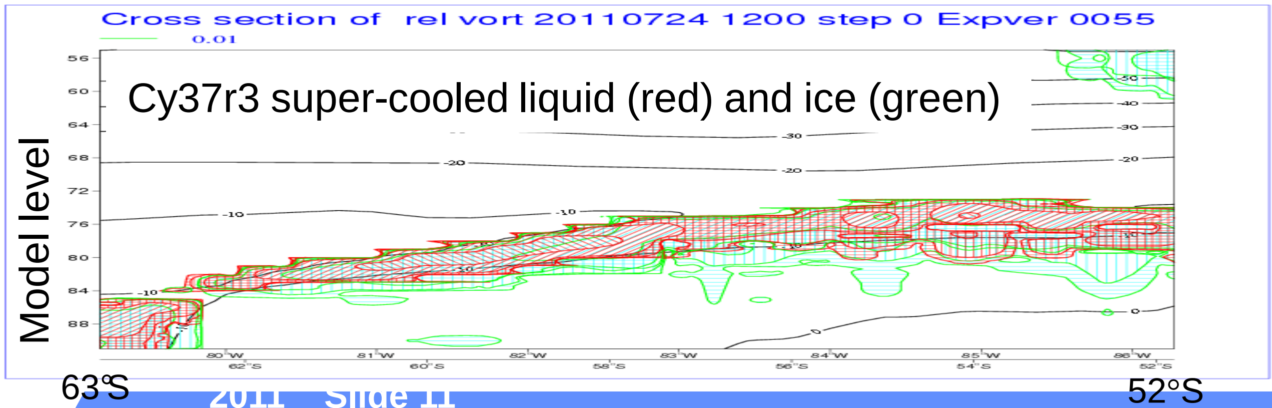
(4) Super-cooled liquid water
Southern Hemisphere cloud decks







- Over the Southern Hemisphere ocean, super-cooled liquid water (SLW) observed in low cloud decks over extensive areas (observed from lidar on board CALIPSO).
- New cloud scheme represents microphysical processes in mixed-phase cloud rather than a diagnostic function of T.
- Cy36r4/Cy37r2 had less SLW, Cy37r3 increases SLW, particularly at cloud top (as often observed).

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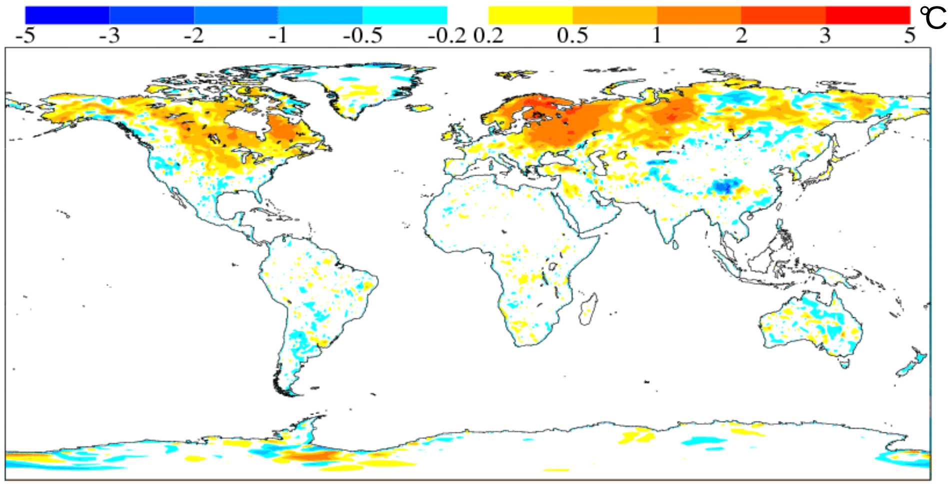
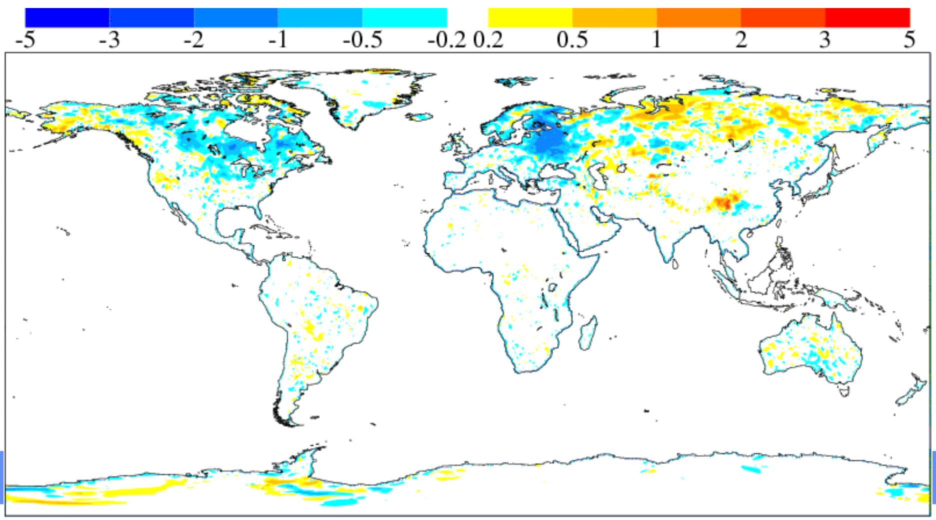
(4) Super-cooled liquid water
Radiative impact on low-level temperature over land

Mean T2m change (72hr forecast for Jan 2011) for Cy37r3 SLW cloud changes (red = warming)



As above, but change in mean absolute error (blue = good)



- Changes to representation of super-cooled liquid water in Cy37r3 positive impact.
- General increase in occurrence of super-cooled liquid water, particularly in weakly forced situations.
- Improved temperature bias and reduced errors in winter -time low cloud over land.

Clouds and precipitation
Summary

- The new prognostic cloud microphysics scheme was introduced in IFS Cy36r4 and operational on 9 Nov 2010.
- Updates to upper trop. cloud/humidity (Cy37r2) and super-cooled water (Cy37r3).
- Improved precipitation, ice cloud, super-cooled water and radiation interactions.
- New scheme allows a more physically based representation of microphysical processes and provides an appropriate framework for future cloud scheme development.

Highlights of upcoming cycles

Cycle 37R3 - 25 October 2011:

- Aircraft temperature bias correction
- Combined UV-IR ozone observation assimilation
- Cloud scheme and surface roughness modification, assimilation of Stage-IV, stratos. model error cycling , etc.

Cycle 38 – September 2012:

- Common cycle with Météo-France

Cycle 38R1 – spring 2012:

- Revised L91 background error covariance statistics
- Aliasing noise removal in spectral transforms
- Lagged 10+10 member EDA
- EDA mean instead of control as reference for EPS initial perturbations

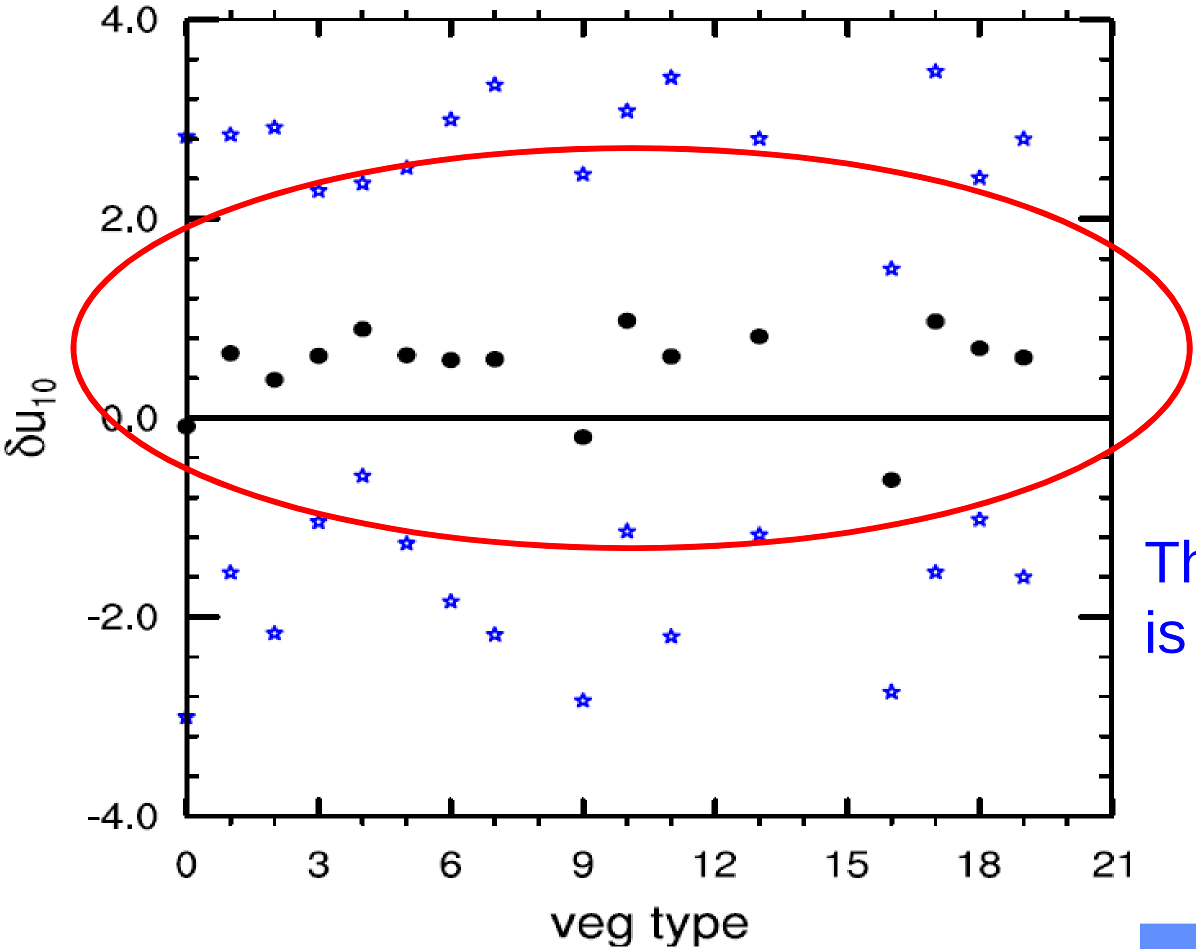
Cycle 38R2 – autumn 2012:

- Vertical resolution upgrade L91 → L137 for high-resolution forecast model and DA-system.

Derivation of a new roughness length table

The 10m winds are mainly controlled by the roughness length values and are generally overestimated by the model.

Forecast 10m winds error compared to synop obs.
(daytime – T511 L91 analysis run August 2010)



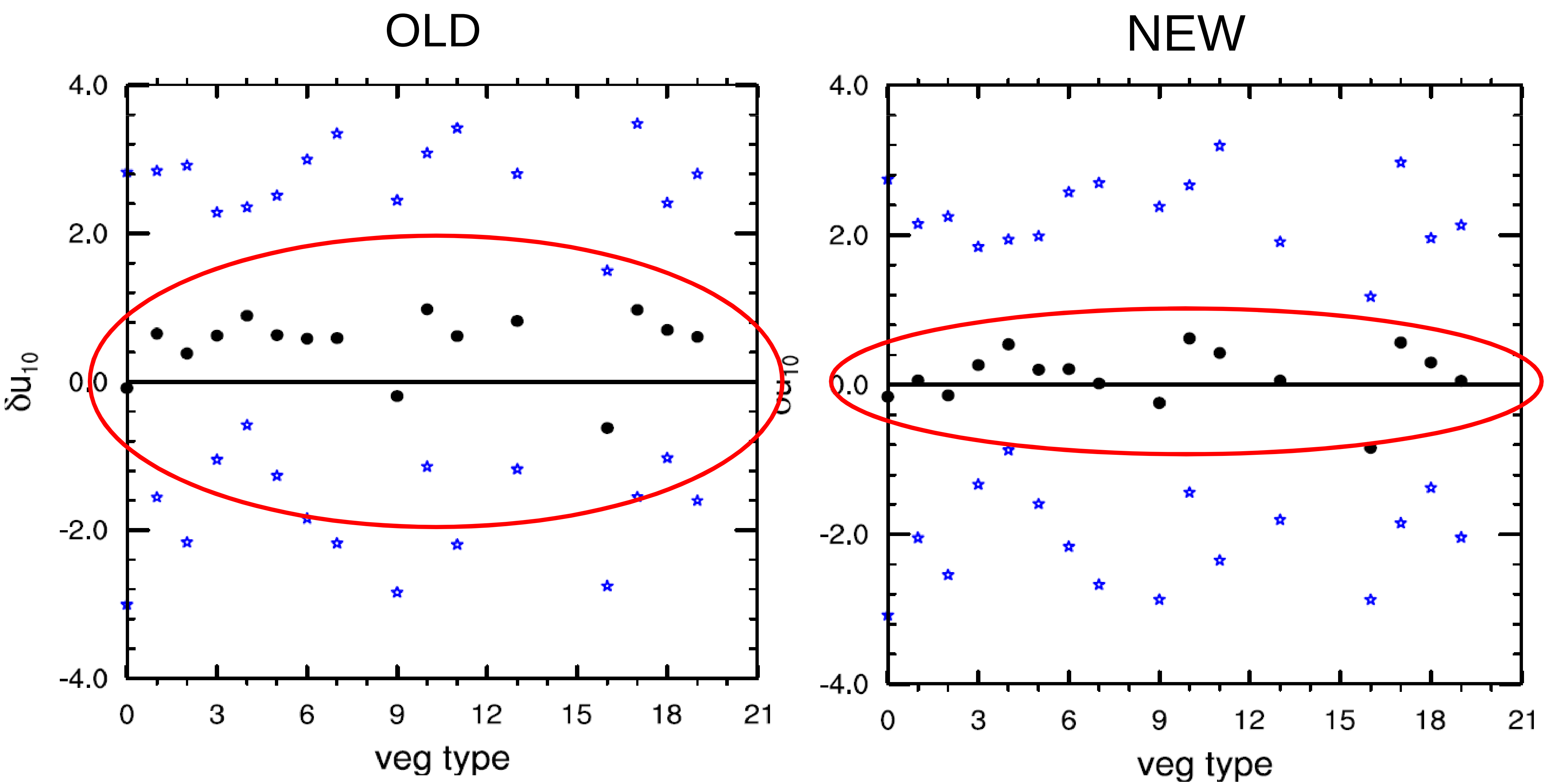
$$\frac{u_{100}}{u_{10}} = \frac{ln100/z_0^m}{ln10/z_0^m}$$

$$\frac{u_{100}}{u_{10}^{obs}} = \frac{ln100/z_0^{m*}}{ln10/z_0^{m*}}$$

The roughness length for momentum is increased for 10 vegetation types

Derivation of a new roughness length table

Forecast 10m winds error compared to synop obs.
(daytime – T511 L91 analysis runs August 2010)



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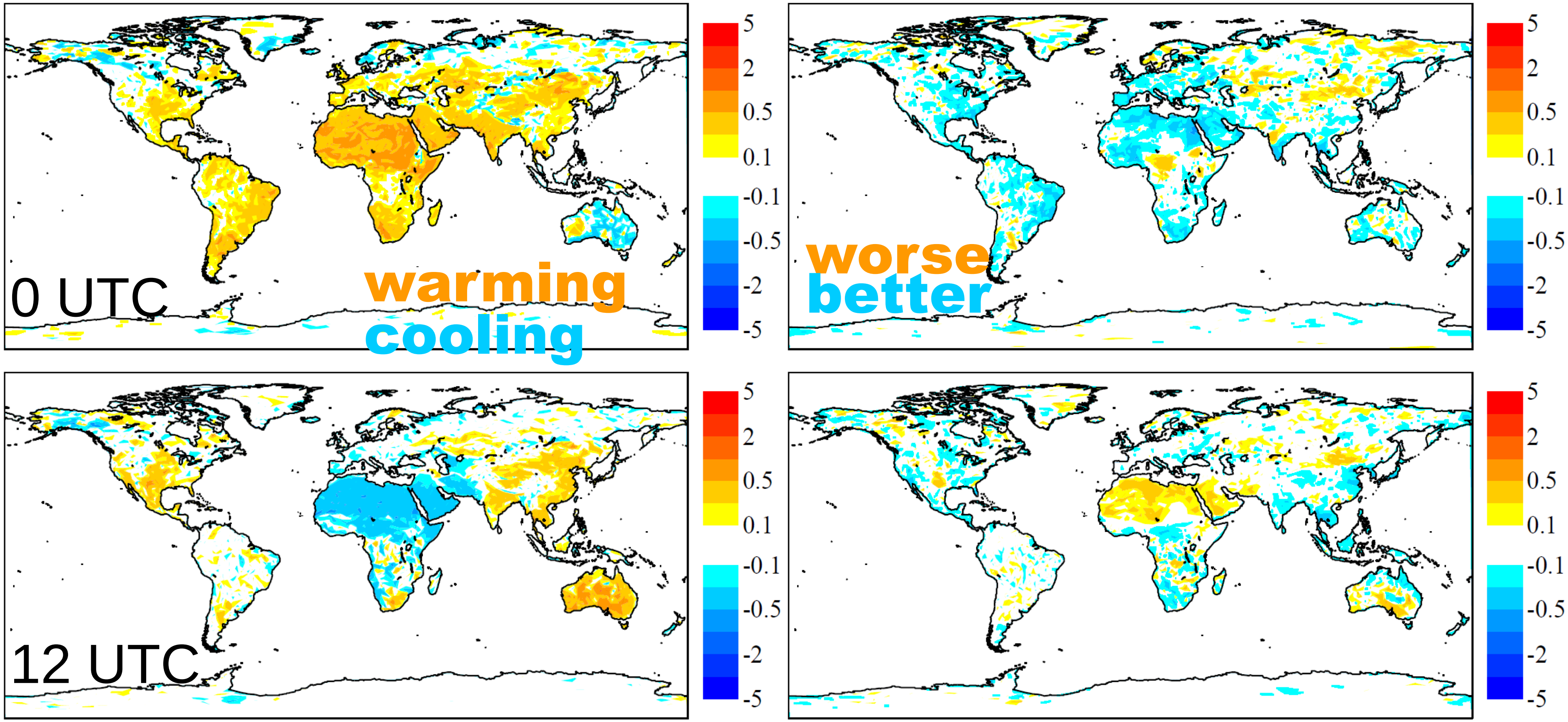
Derivation of a new roughness length table

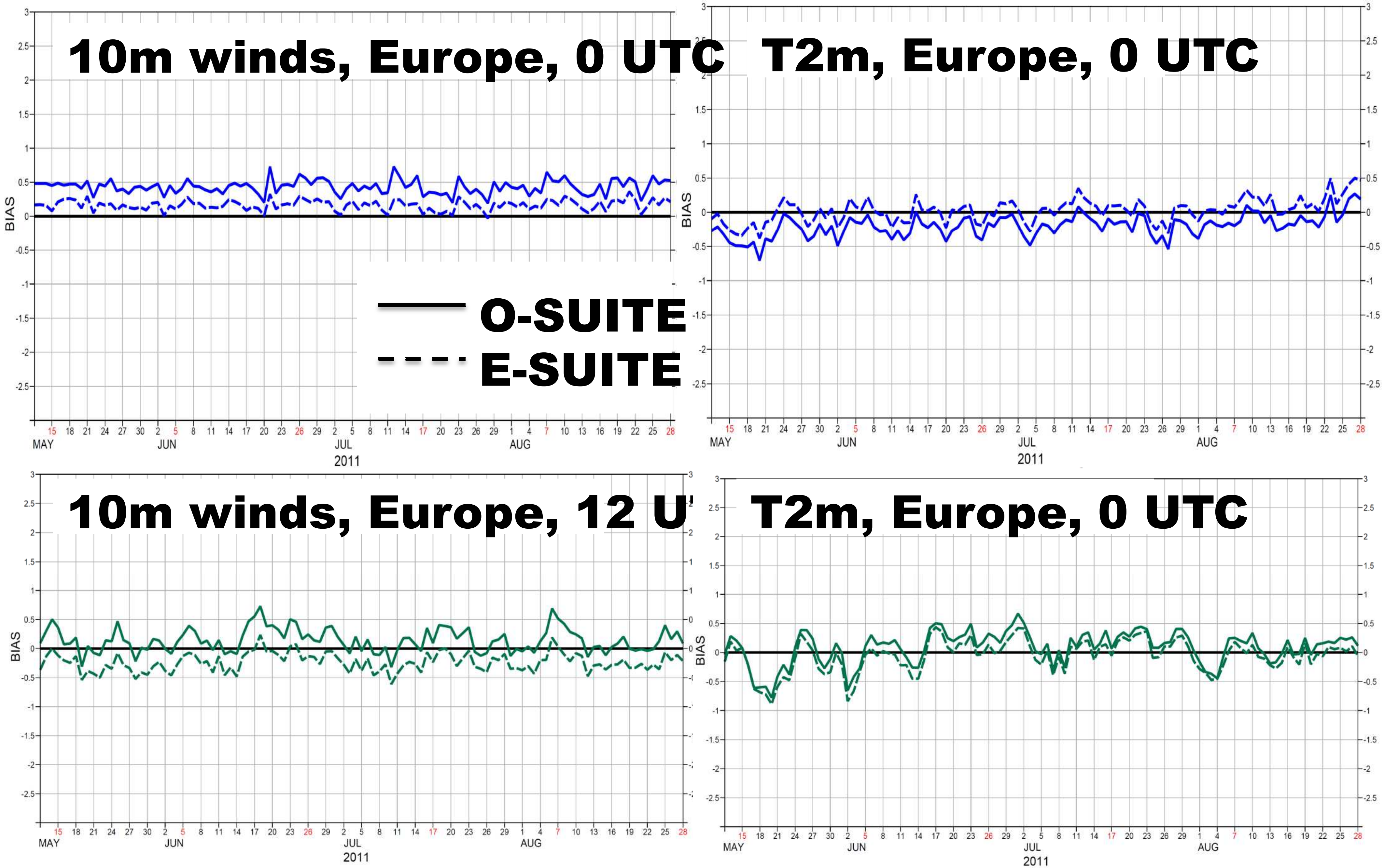
Heat roughness length = momentum roughness length/100 (instead of 10)

T511 L91 CY37R2 analysis runs for January 2011 :

T2m Z0 - CTRL | absolute error T2m Z0 - CTRL



Implementation of the new roughness length table in CY37R3



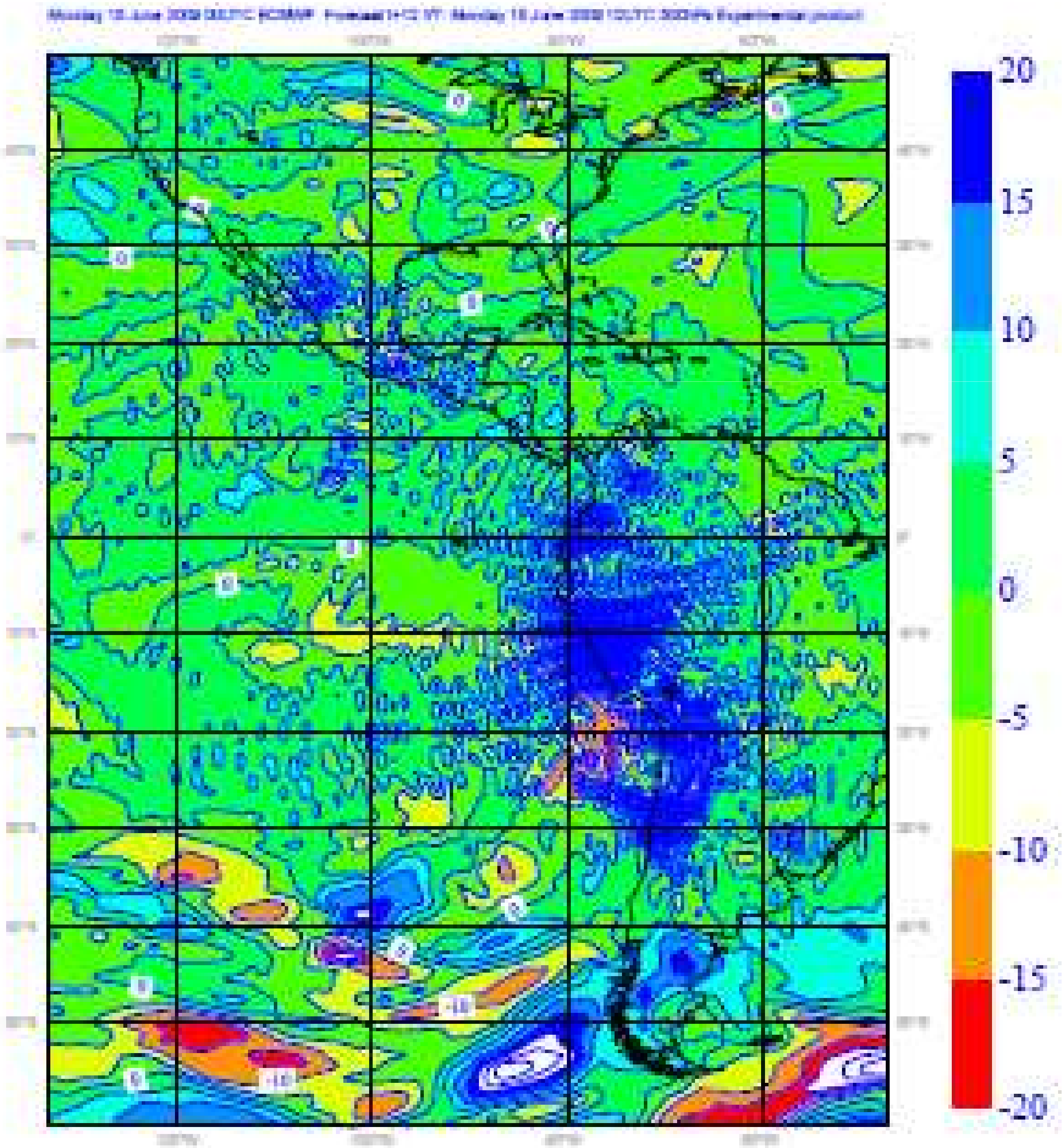
De-aliasing

- A feature of the linear grid (2N+1 gridpoints with N waves), where the product of two variables transformed to spectral space cannot be accurately represented with the available number of waves (as quadratic terms need a 3N+1 ratio).
- Absent outside the tropics in E-W direction due to the design of the reduced grid (obeying a 3N+1 ratio) but present everywhere (and all resolutions) in N-S direction.
- By subtracting the difference between a specially filtered and the unfiltered pressure gradient term at every time-step the stationary noise patterns can be removed at a cost of approx. 5% at T1279.
- Scores are positive (days 3-6) or neutral.

De-aliasing

E-W

500hPa adiabatic zonal wind tendencies (T159)



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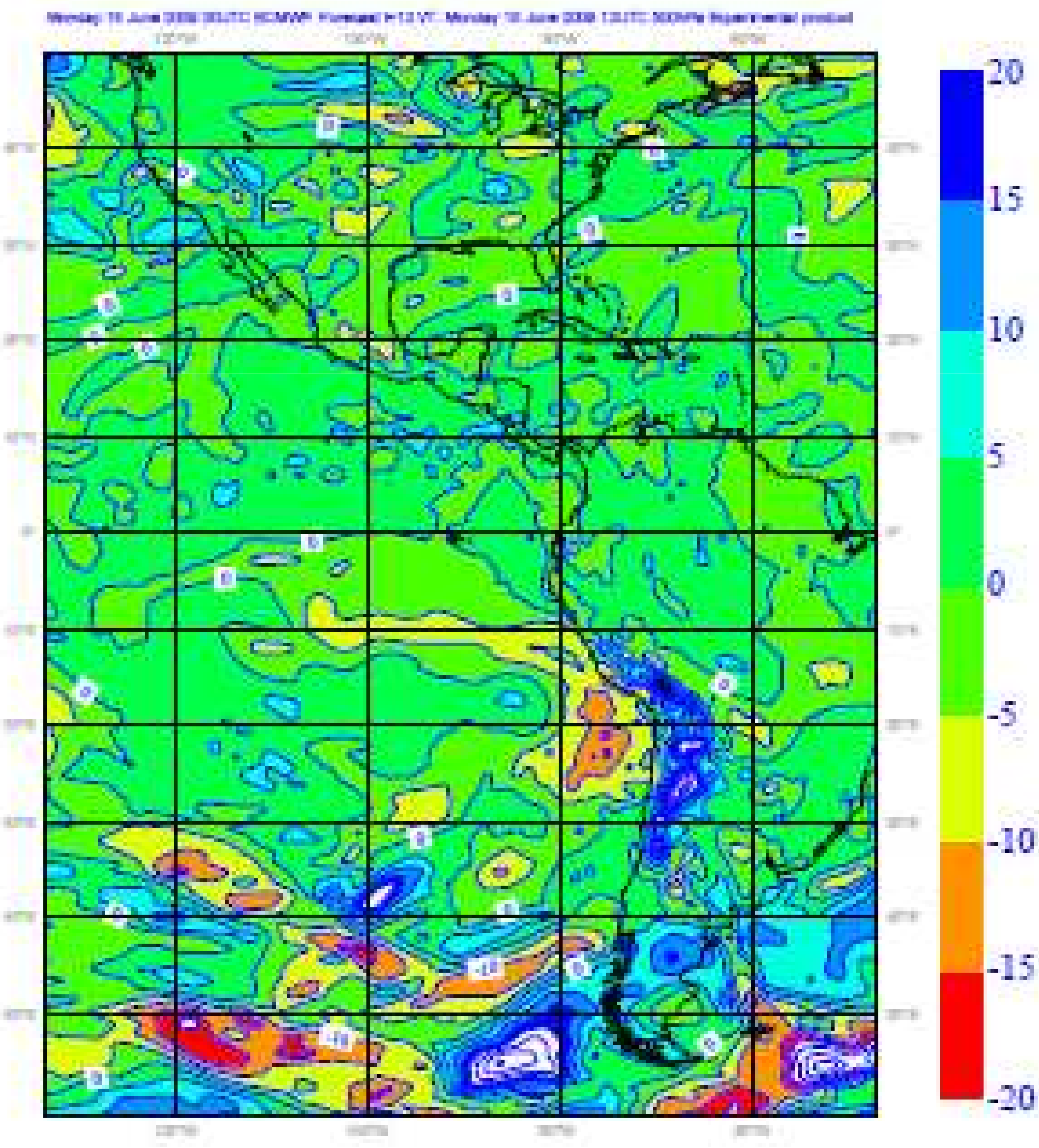
De-aliasing



ECMWF

Vertical resolution upgrade

Agathe Untch

Tomas Wilhelmsson, Elias Holm,

Peter Bechtold & Jean-Jacques Morcrette

A brief history of vertical resolution at ECMWF:

- Deterministic System
  - Oct 1999: **L60** , top 0.1hPa, new levels in stratosphere & mesosphere +PBL
  - Feb 2006: **L91** , top 0.01hPa (for non-orographic GWD)

    ~ doubled the resolution around the tropopause
- EPS
  - Oct 1999: **L40** , top 10hPa, identical to **L60** in the troposphere
  - Feb 2006: **L62** , top 5hPa, identical to **L91** in the troposphere

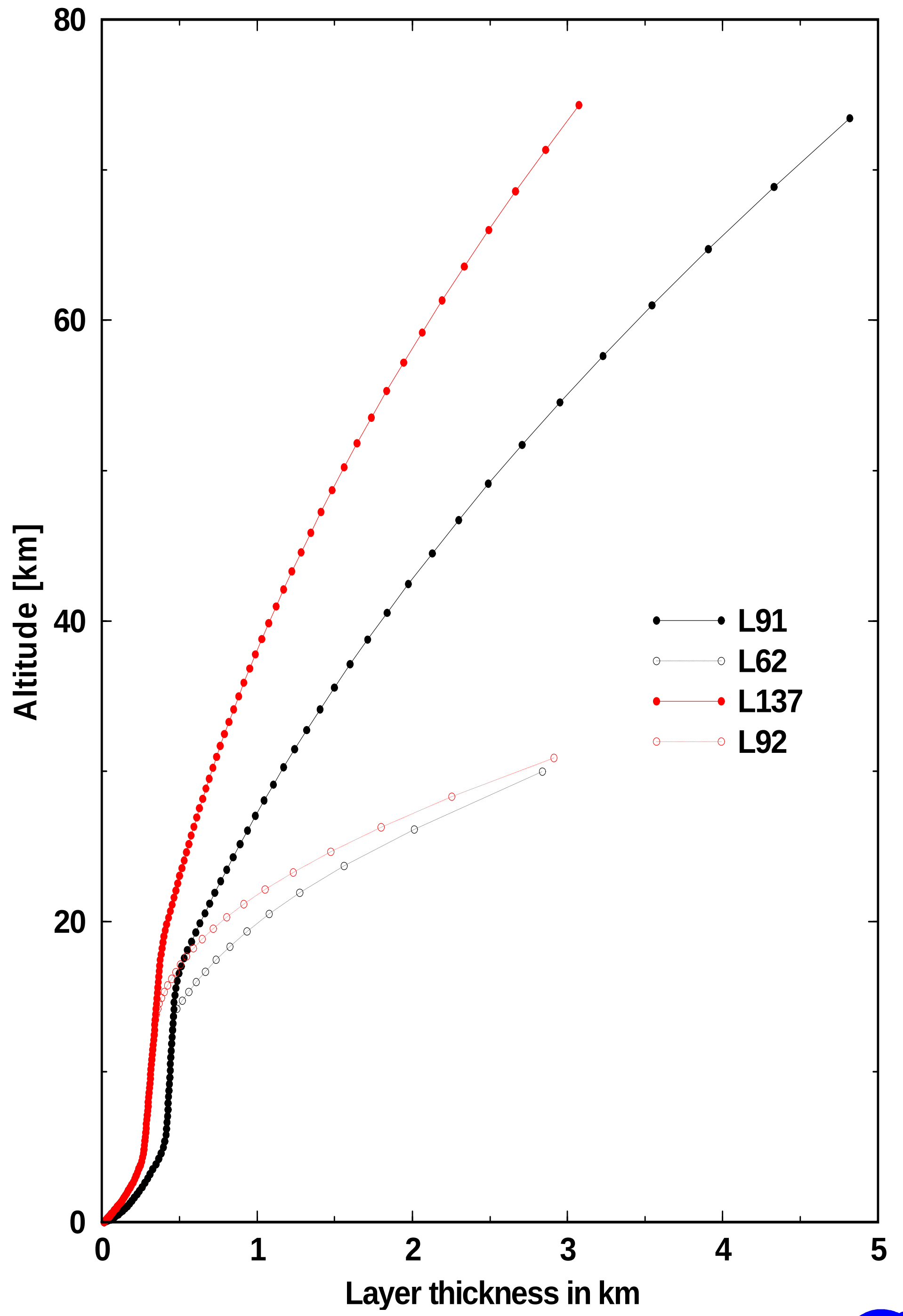
Upgrade

- **Deterministic system:**
  - **2012 ??: L137 , top 0.01hPa, improved resolution in the whole domain**

- **EPS:**
  - **2012?? : L92 , top ~5hPa, identical to L137 in the troposphere**

Deterministic system: upgrade from 91 to 137 levels

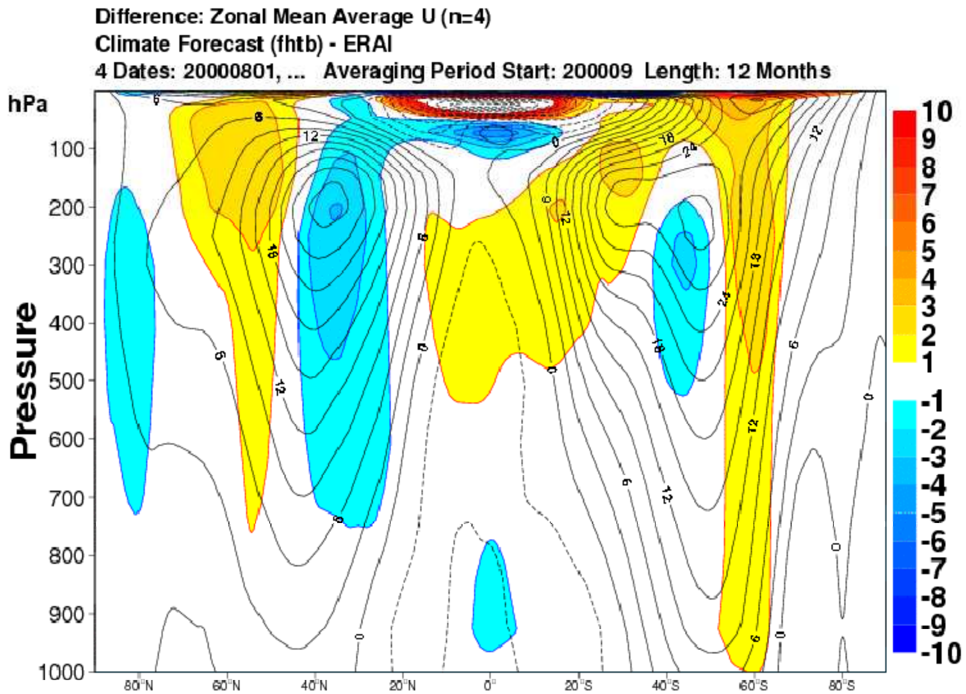
EPS: upgrade from 62 to 92 levels



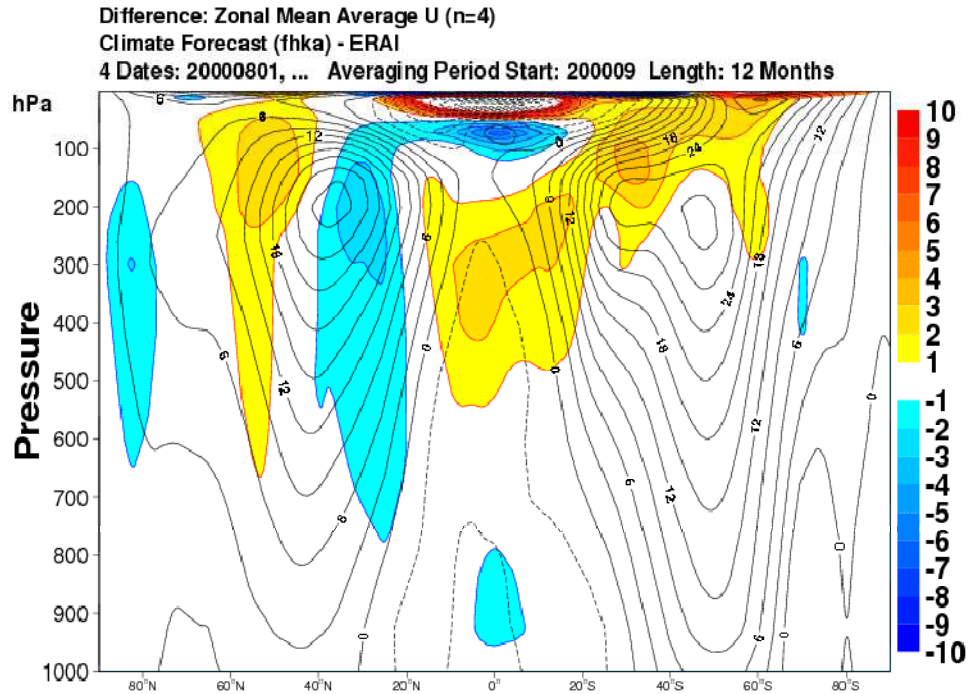
ECMWF

Model climate (37R2): u-wind

L91



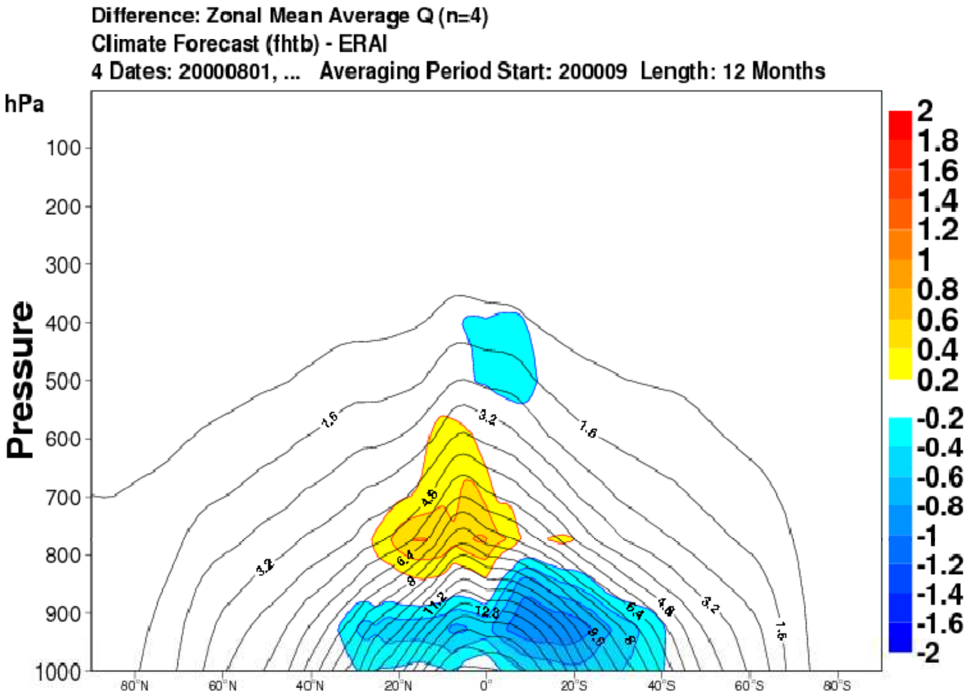
L137



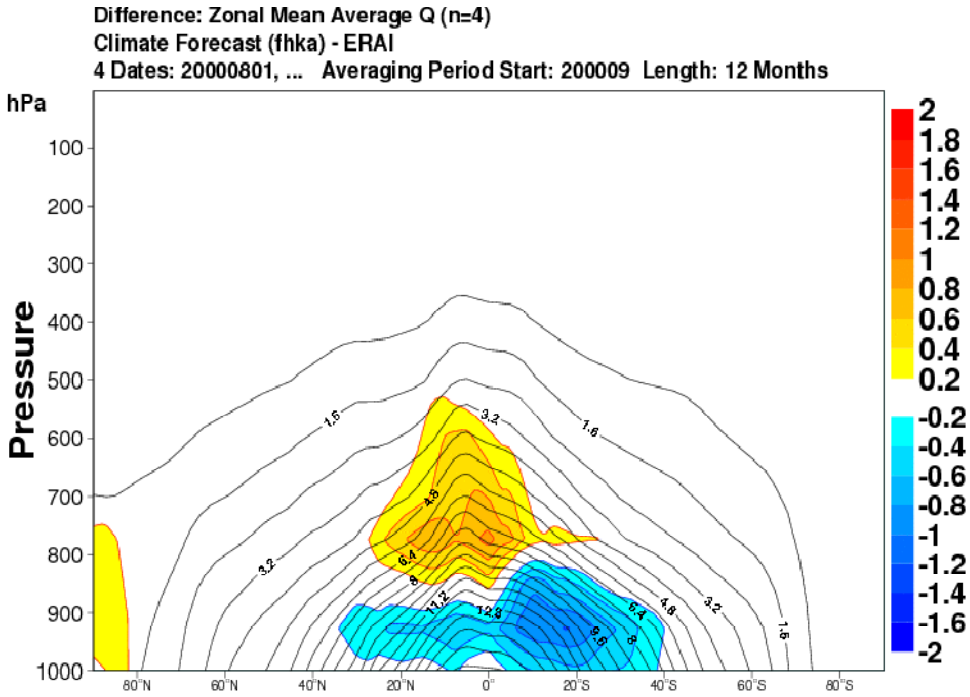
ECMWF

Model climate (37R2): humidity

L91



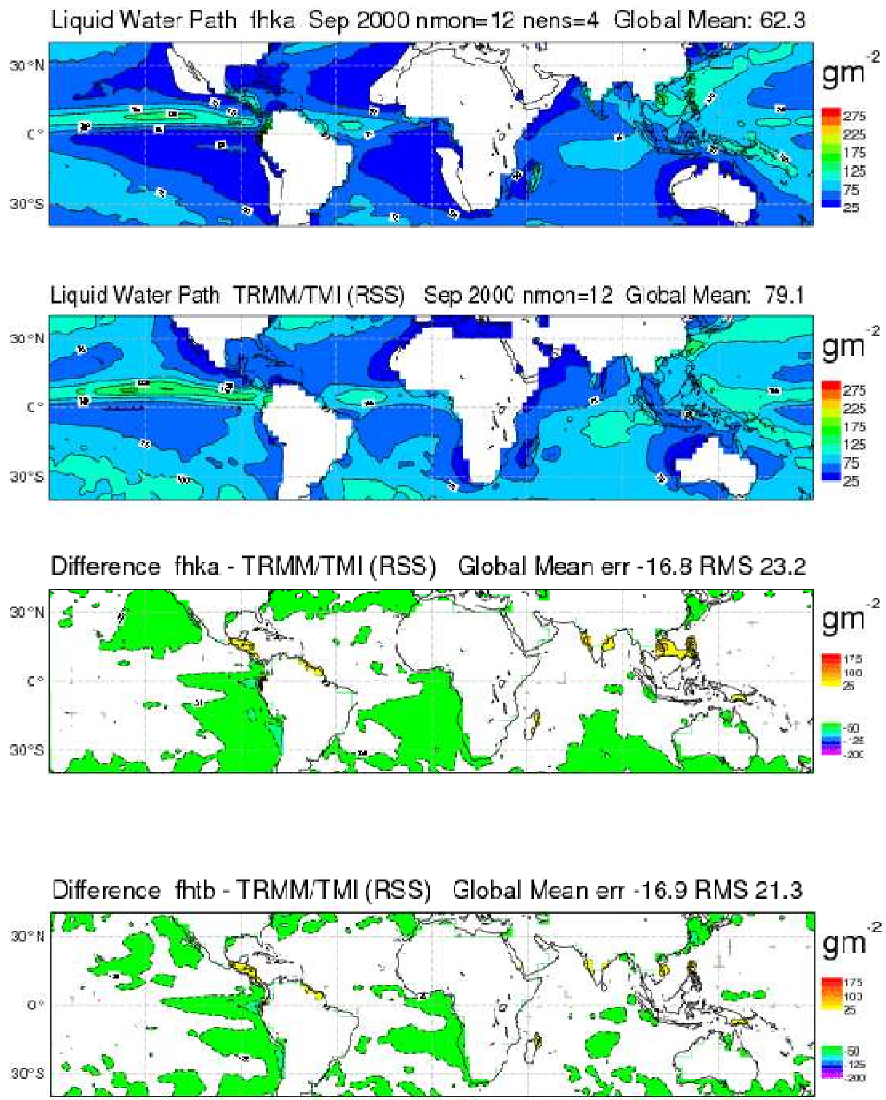
L137



ECMWF

Model climate (37R2): TCLW

L137



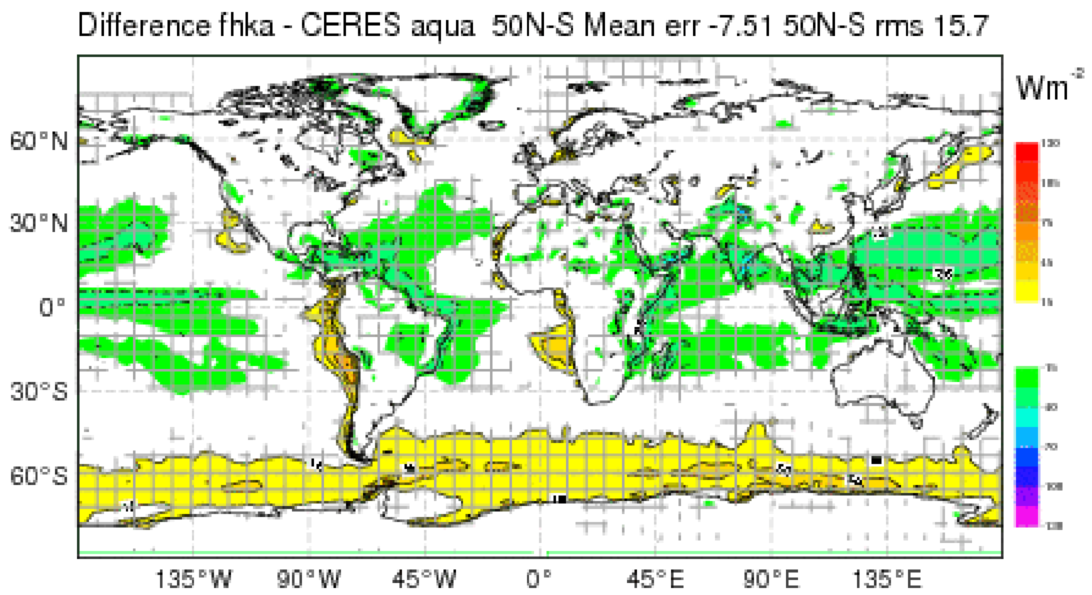
L91

Reduction in TCLW in stratocumulus areas

ECMWF

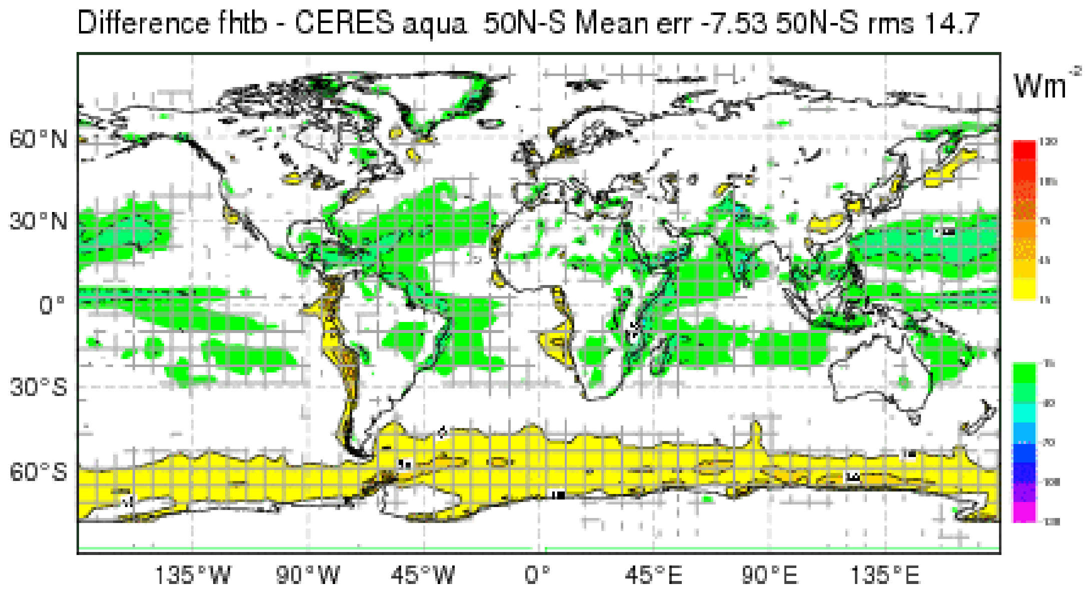
Model climate (37R2): TOA SW Radiation

L137



less stratocumulus

L91



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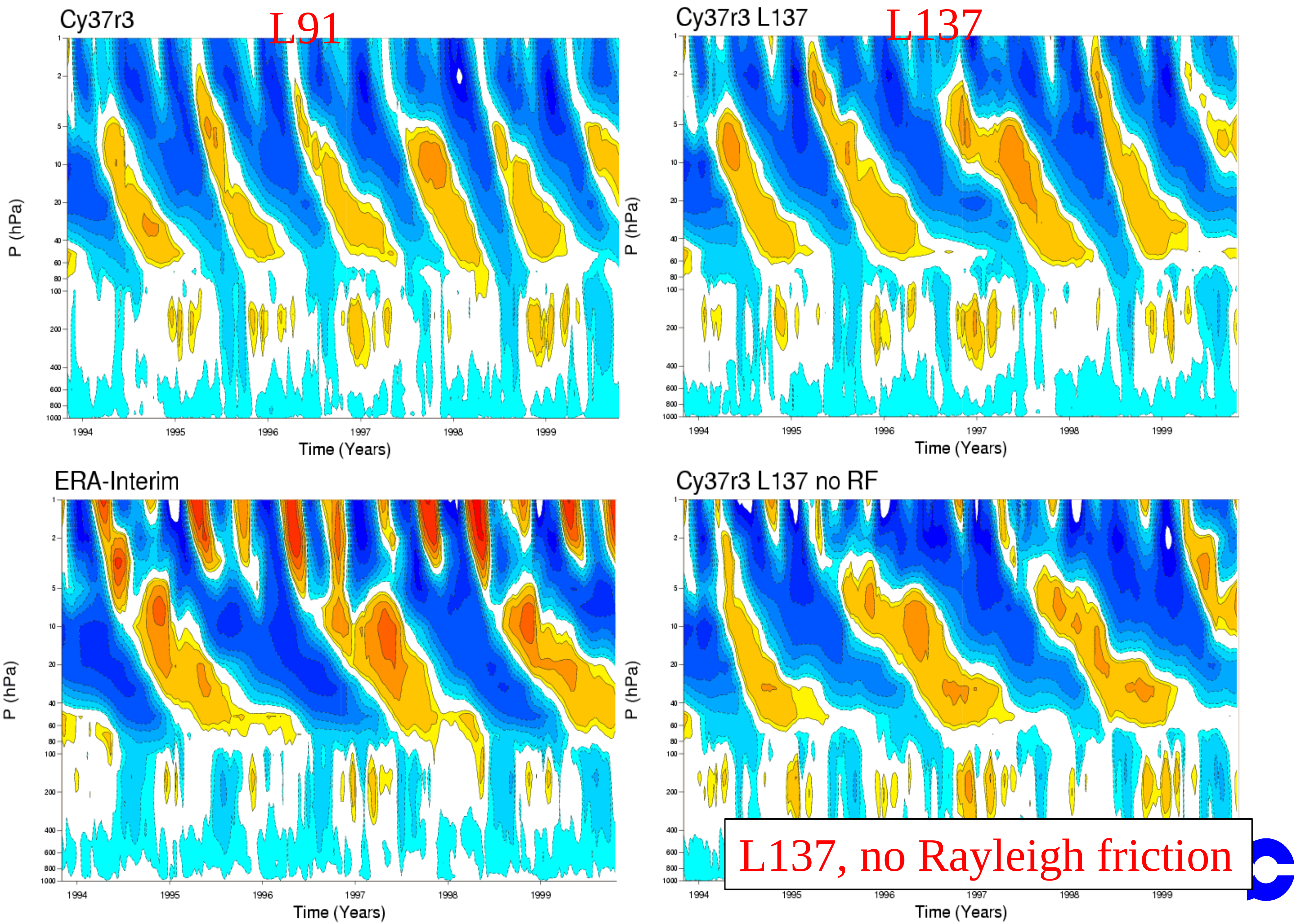
QBO & SAO (plots from Peter Bechtold)



Summary of L137 model results

- Model climate is mostly OK
- QBO substantially improved
- SAO improved a bit too
- (Tangent linear model error reduced in PBL and near the model top.   (Philippe Lopez))

  - Upgrade of resolution in the assimilation system
  - Objective : (end of) 2012

Some other research topics

- High resolution, non-hydrostatic and grey zone of convection
- Conservative advection
- Fast Legendre Transforms
- Physics: Convection, cloud, BL, radiation (+vert. res.)
- Weak Constraint 4DVAR
- OOPS (Object Oriented Prediction System)
- COPE (Continuous Observation Processing Environment)
- Cloud condensate background error
- System 4 (IFS-NEMO, NEMOVAR)
- Ice modelling
- ERA-Interim extended (79-89), ERA-CLIM started