Model Physics

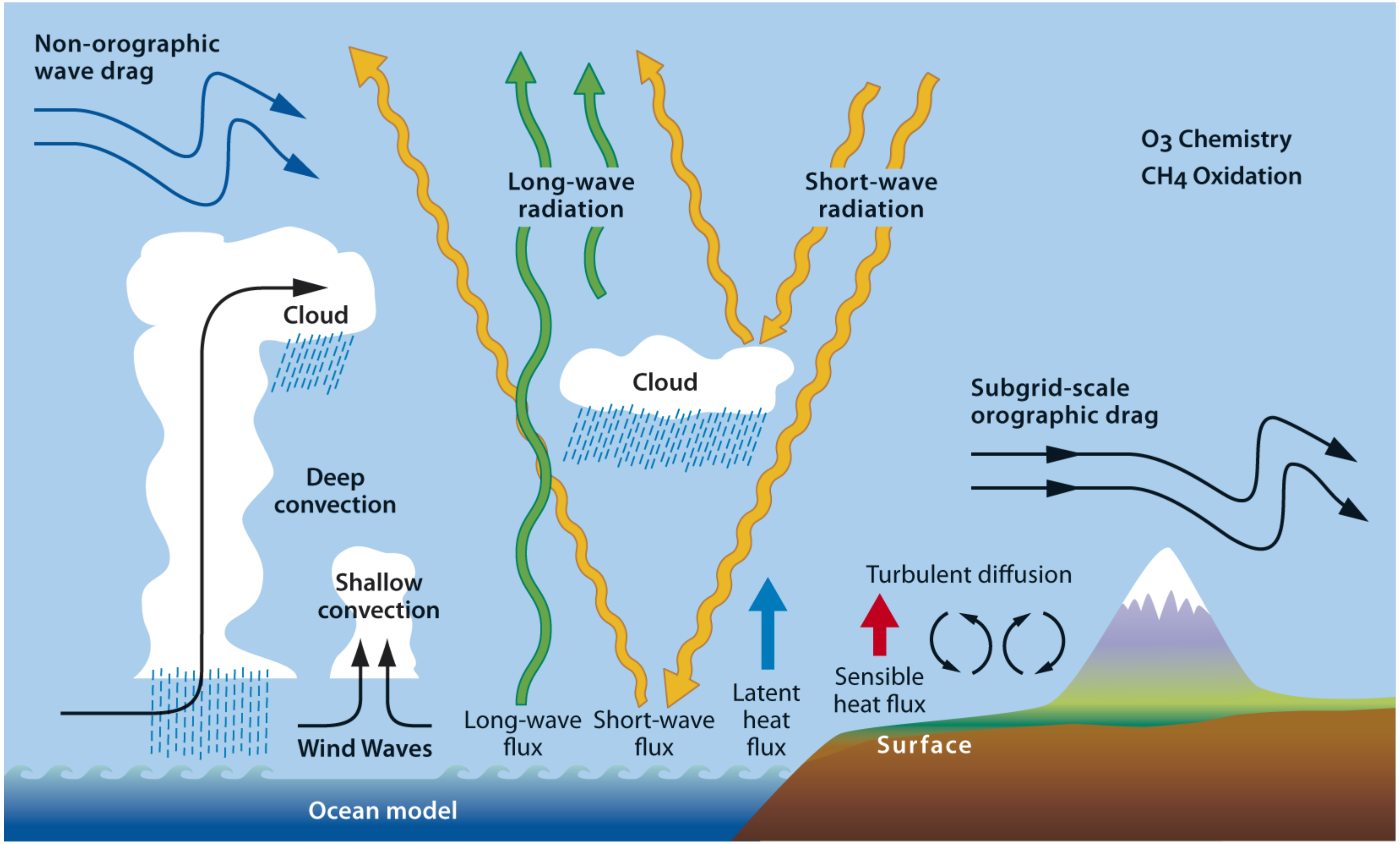
- A few basics
- High resolution
- A few problems
- A few products

for the Model Section: Peter Bechtold

http://www.ecmwf.int/en/learning/education-material/introductory-lectures-nwp

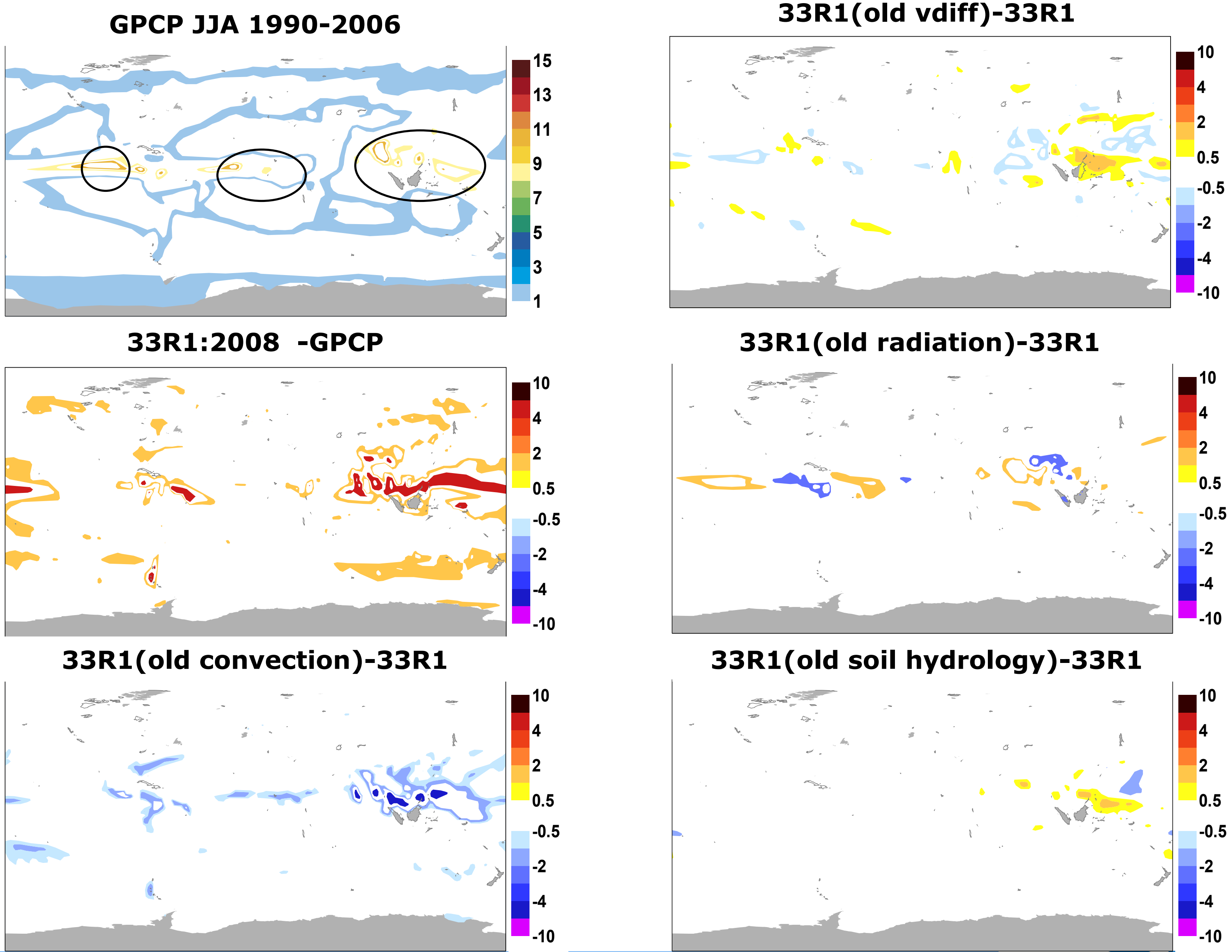
Parameterized processes in the ECMWF model

from the surface to the stratosphere

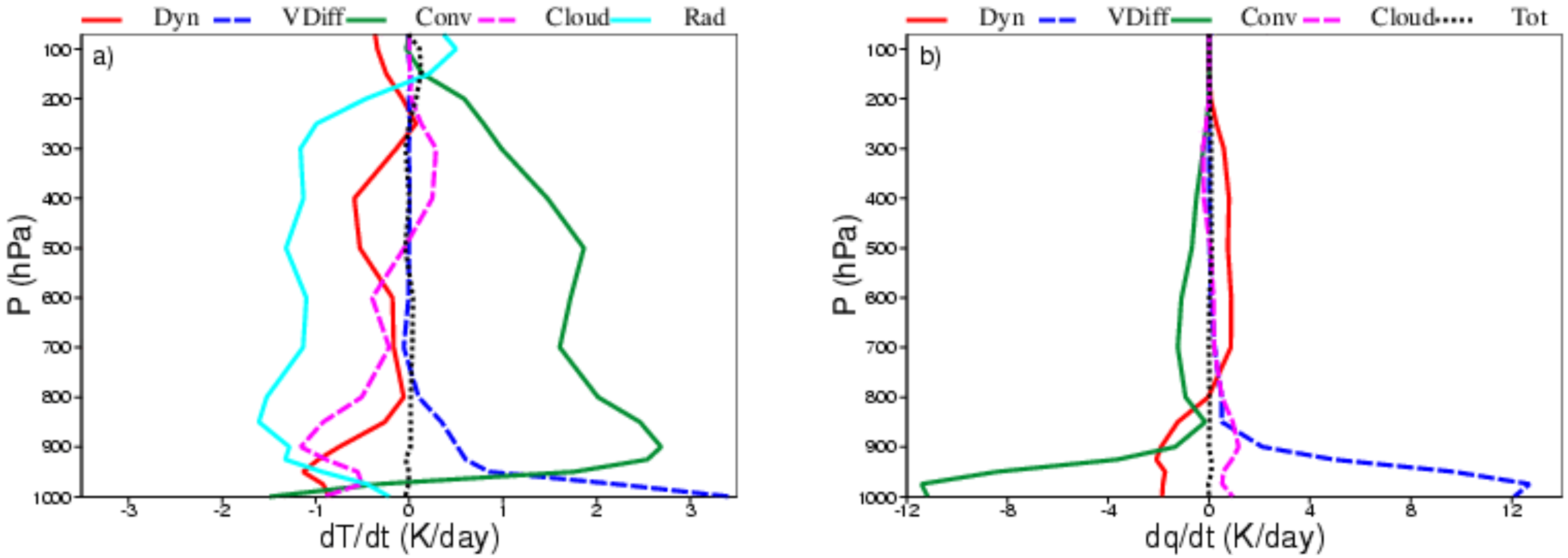


ECMWF

Precipitation JJA: Sensitivity to Model Formulation
Seasonal integrations



Model Tendencies - Tropics



For Temperature, above the boundary layer, there is roughly an equilibrium Radiation-Convection, but Dynamics and Clouds also important, whereas for moisture there is roughly an equilibrium between dynamical transport (moistening) and convective drying. - *Global Budgets are very* similar

All processes are important, nevertheless the driving force for atmospheric dynamics and convection is the radiation

The weather and thermal equilibria: exercises

- Suppose we have a series of fine day with an anticyclone, the temperature above the boundary-layer barely changes, Why?

$$\frac{d\theta}{dt} \approx 0 \quad \Rightarrow w\frac{d\theta}{dz} = \frac{d\theta}{dt}\Big|_{rad} = -\frac{2K}{86400s} \Rightarrow$$

w ~ -0.5 cm/s subsidence

~0.5 K/100 m

- But what happens when it is raining 100 mm/day ?

$$\int_{surf}^{10km} Cp\frac{dT}{dt}\rho_{air}\, dz = L_v \rho_{water}\, Pr(m/s)$$

$$c_p = 1005\, J/kg/K; \quad \rho_{water} = 1000\, kg/m3; \quad L_v = 2.5x10^6 \text{ J/kg}$$

$$\mathrm{Pr} = 100\frac{mm}{day} = 1.147\, m/s\, x10^{-6}$$

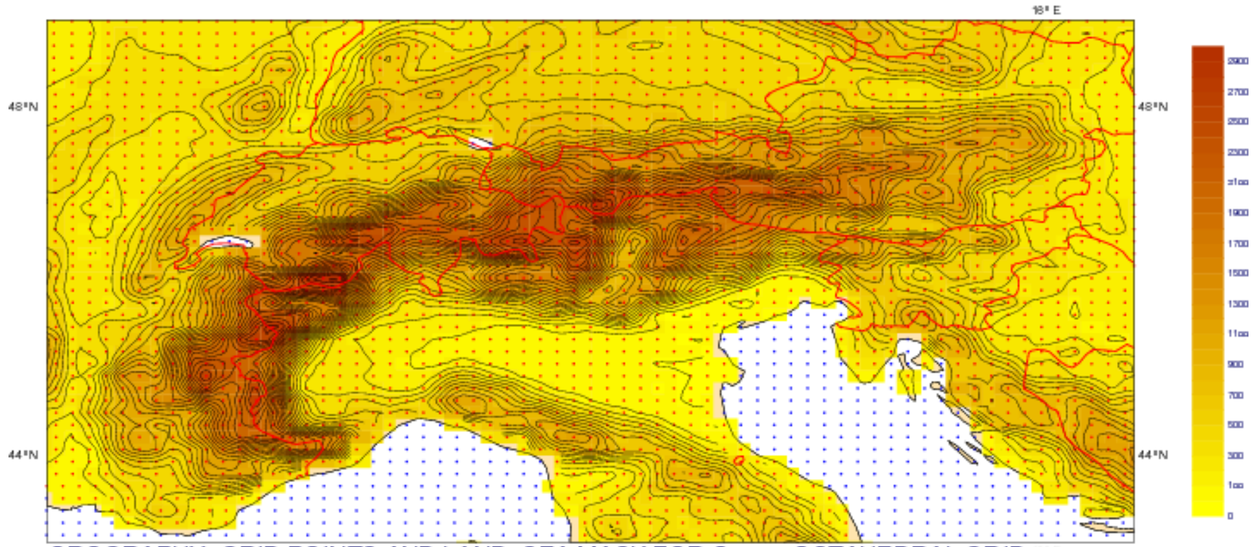
100 mm/day precipitation heats the atmospheric column by 2867 W/m2 or by 25 K/day on average. This heating must be compensated by uplifting of w ~ 10 cm/s ➔ heavy precip/convection requires large-scale perturbation.

The 2016 horizontal resolution upgrade:

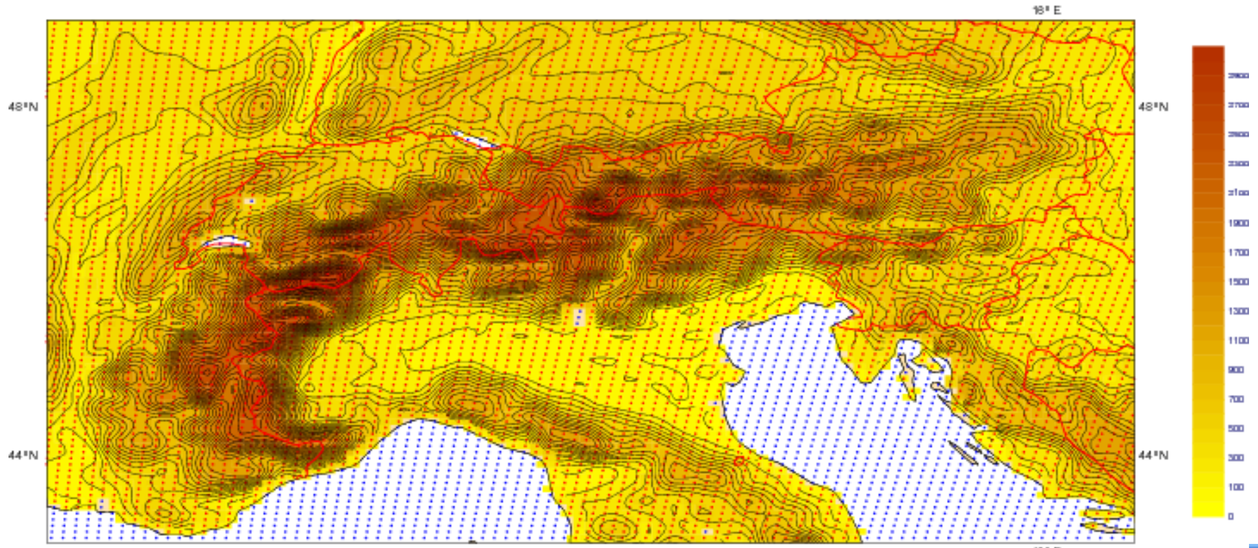
The Grids and effects from improved Numerics

From Tl1279 (16 km) to TCo1279 (9 km)

OROGRAPHY, GRID POINTS AND LAND_SEA MASK FOR N640 ORIGINAL GRID
orography shaded (height in m), land grid points (red), sea grid points (blue)



OROGRAPHY, GRID POINTS AND LAND_SEA MASK FOR O1280 OCTAHEDRAL GRID
orography shaded (height in m), land grid points (red), sea grid points (blue)



- Same max number of waves on the sphere=1279
- Less spectral smoothing applied to TC1279 orography than in Tl1279

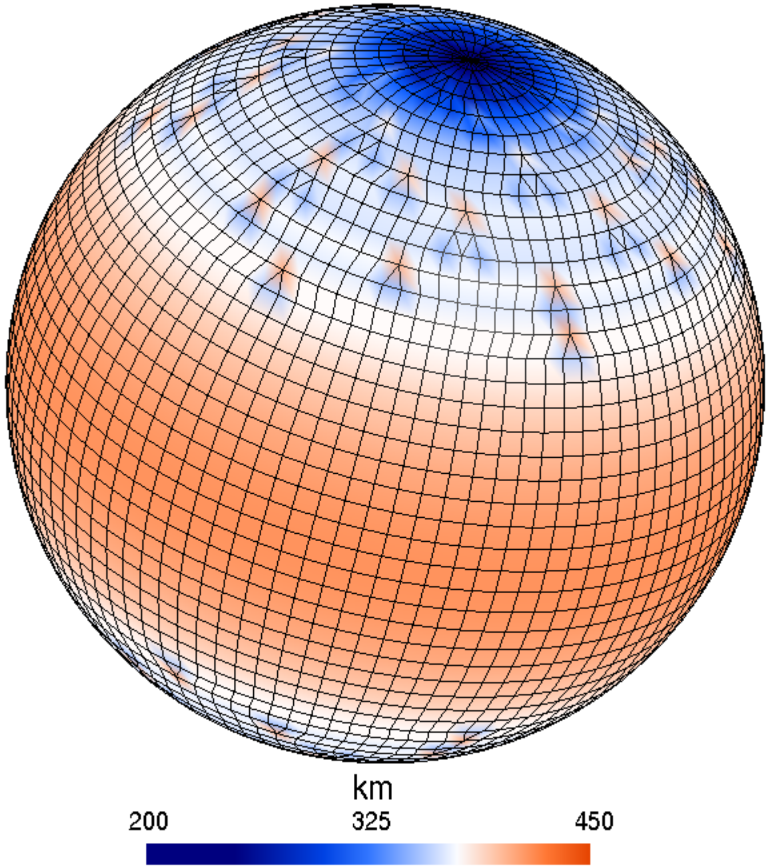
- In the linear=Tl grid 2 grid-points represent one wave, while in the cubic=TC grid, a wave is represented by 4 grid-points =>much more accurate

- note that most computations are done in grid-point space

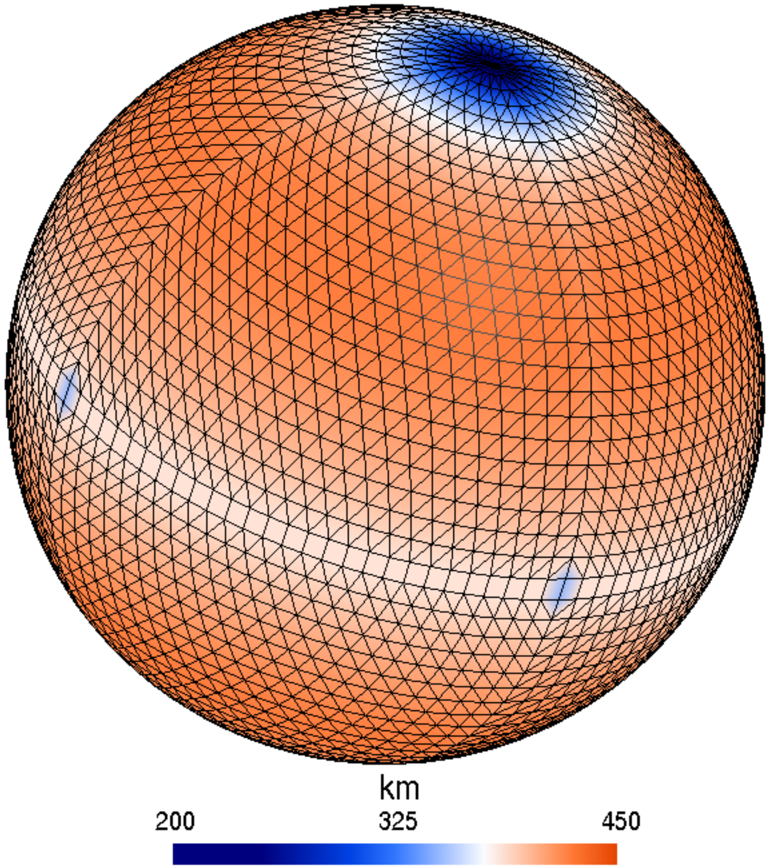
- The TC Gaussian grid is further reduced to a TC octahedral to save grid points

ECMWF

A new grid ....
and a more uniform resolution, ~9 km over Europe



N24 reduced Gaussian grid

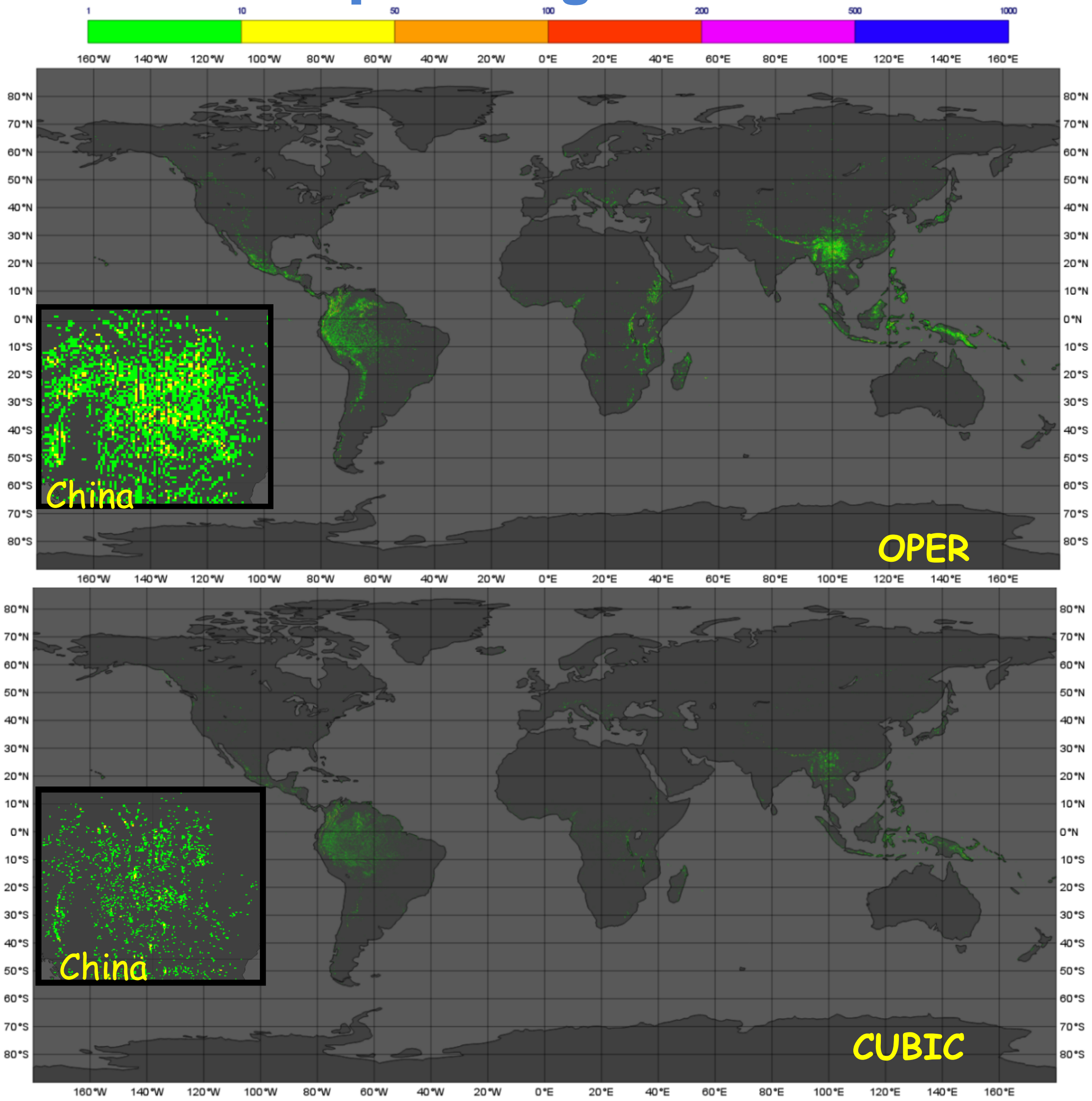


N24 octahedral Gaussian grid

Improvements: ….

Strong reduction of spurious grid-scale rainfall events (LSP)

Frequency of rain events >20mm/6h

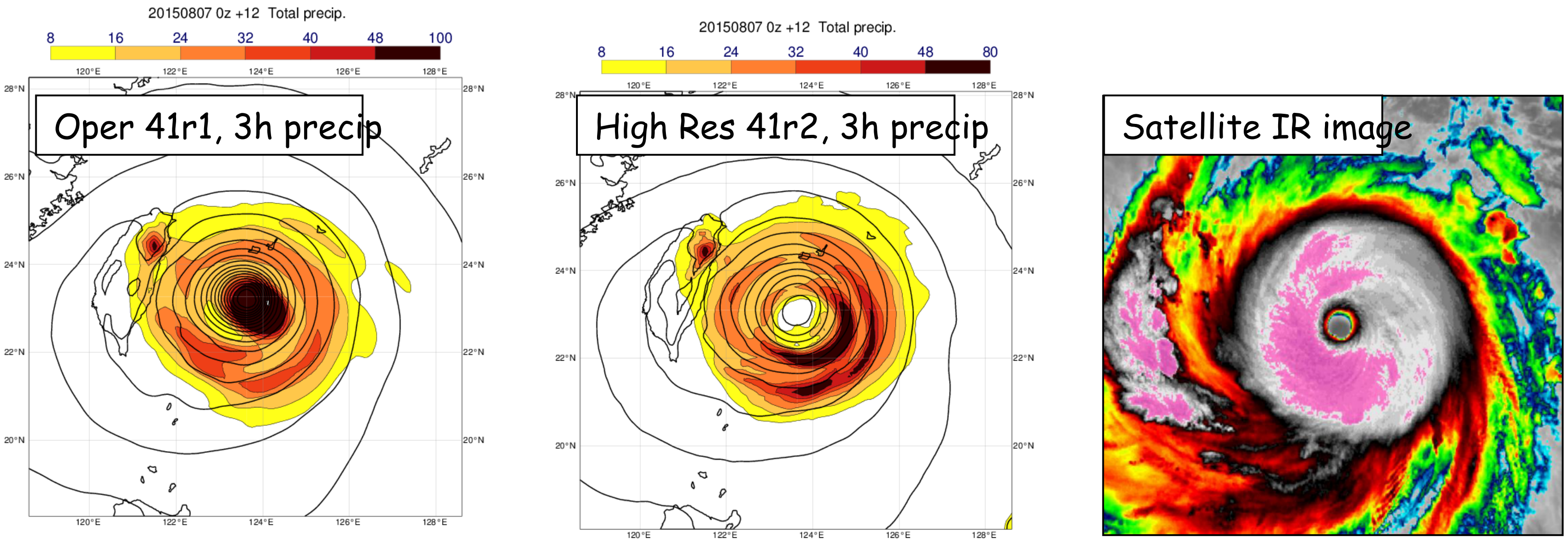


ECMWF

Improvements: Numerics

- Instability in Numerics due to departure point calculation in the semi-Lagrangian advection, leading to unrealistic tropical cyclone structures

Tropical Cyclone Soudelor
Aug 2015



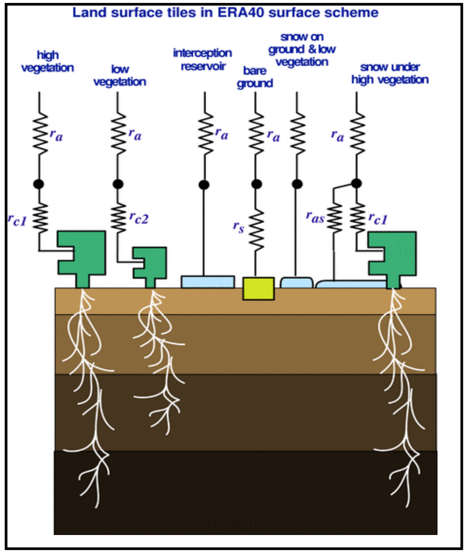
ECMWF

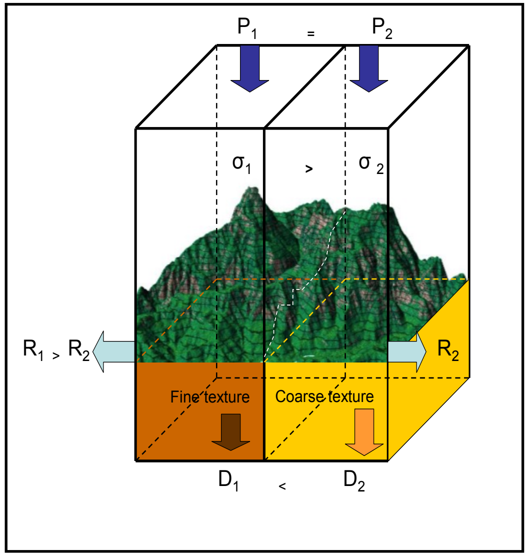
Physical processes: Surface temperatures wind and snow

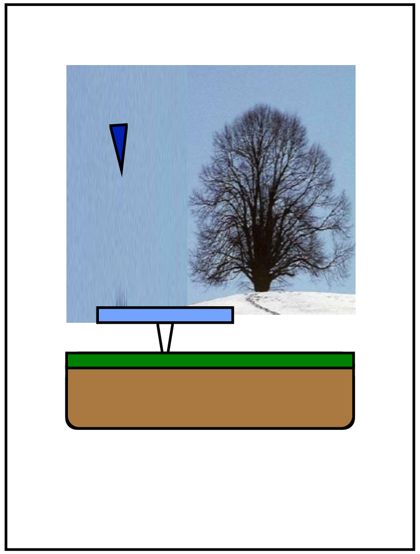
Land surface model evolution

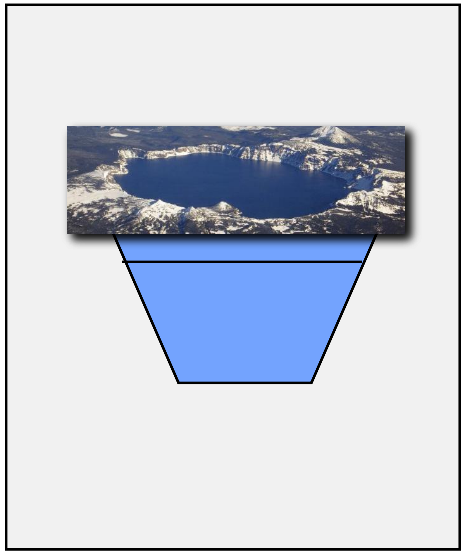
2000/06	2007/11	2009/03	2009 & 2010	2015

- TESSEL
- Hydrology-TESSEL
- new SNOW
- FLAKE









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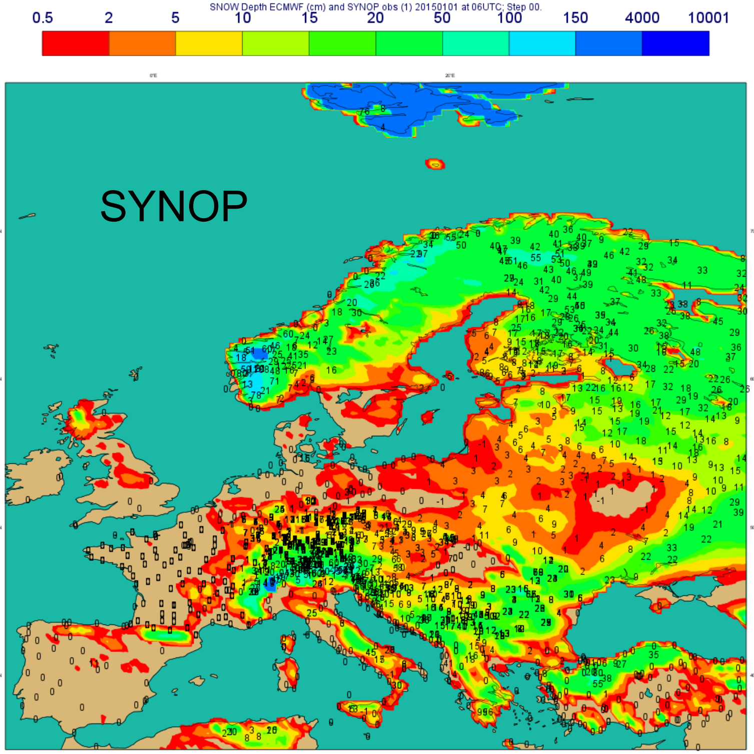
Snow Observations

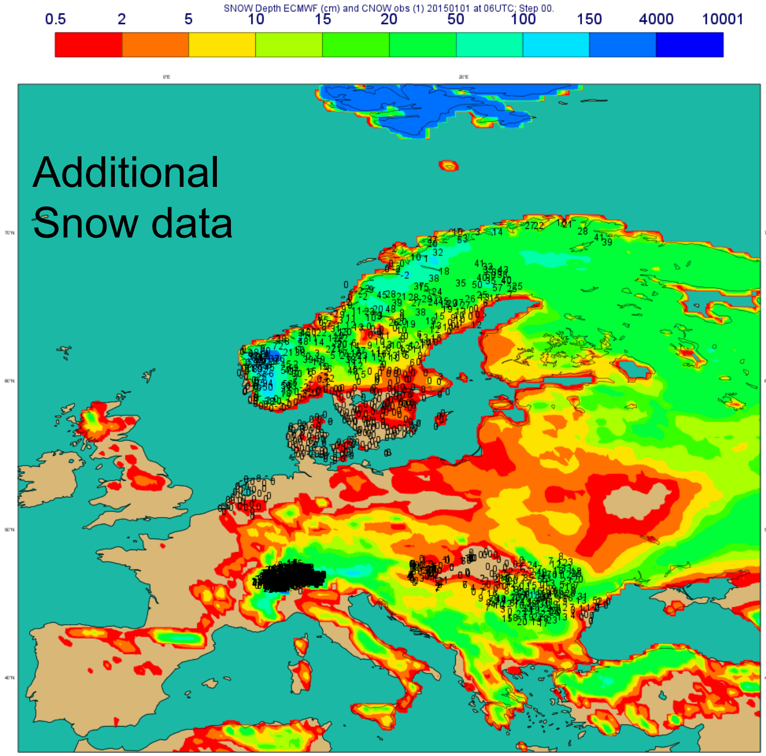
Snow SYNOP and National Network data

Snow Depth (cm)



Available on the GTS (Global Telecommunication System)

2015 01 01 at 06UTC



Additional data from national networks (7 countries):

Sweden (>300), Romania(78), The Netherlands (33), Denmark (43), Hungary (61), Norway (183), Switzerland (332).

→ **Dedicated BUFR (2011)**

(de Rosnay et al. ECMWF Res. Memo, R48.3/PdR/1139, 2011)

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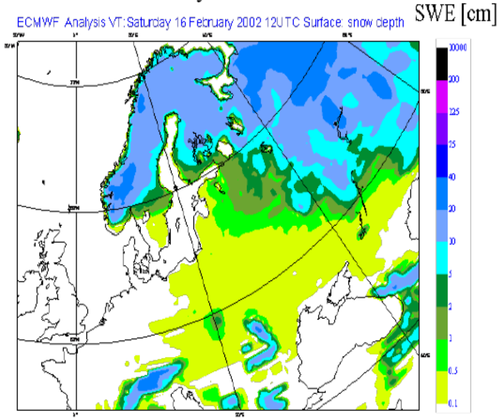
Snow analysis uses Synop and Satellite Obs

MODIS 16/02/2002

Analysis based on SYNOP



Snow extent is overestimated in the analysis when it is based on SYNOP data only

However, satellite only gives snow cover!
And the big change in 2014 was the way satellite data is used, i.e it is assimilated with large observation error, also if
FG =no snow, Sat=snow => Sat snow≈5 cm

Fc errors (scores) very sensitive to snow (analysis)

See also ECMWF Newsletter no 143, article pp 26-31, Spring 2015

Archived prognostic snow related quantities

- **Snow depth (water equivalent), Sd => actual depth=Sd*(Rl=1000)/Rsn**

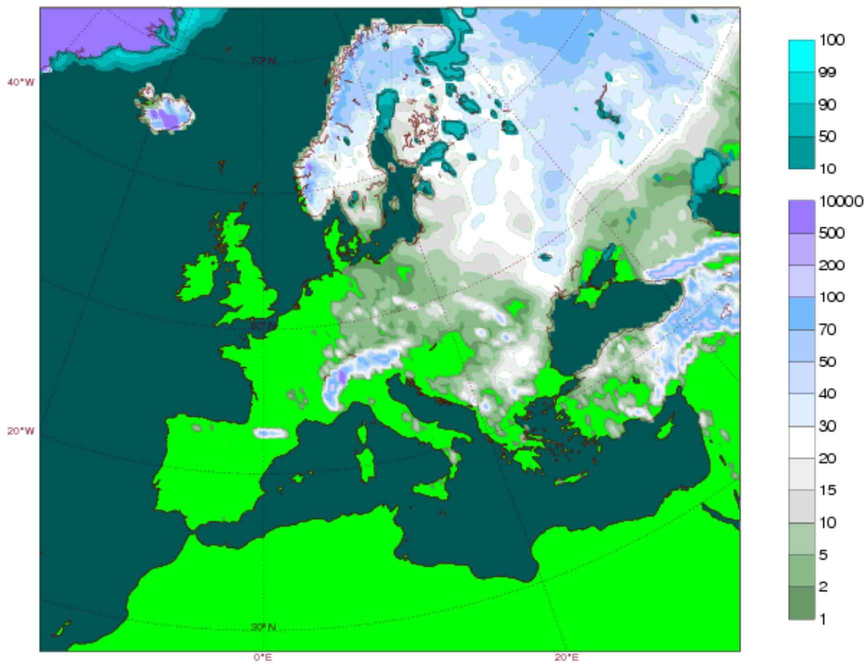
  below 10 cm snow depth snow cover becomes fractional

- **Snow density (typically factor 10 lower than water-> 1 mm precip~1 cm snow), Rsn** (mixture old/new snow, wind compression)

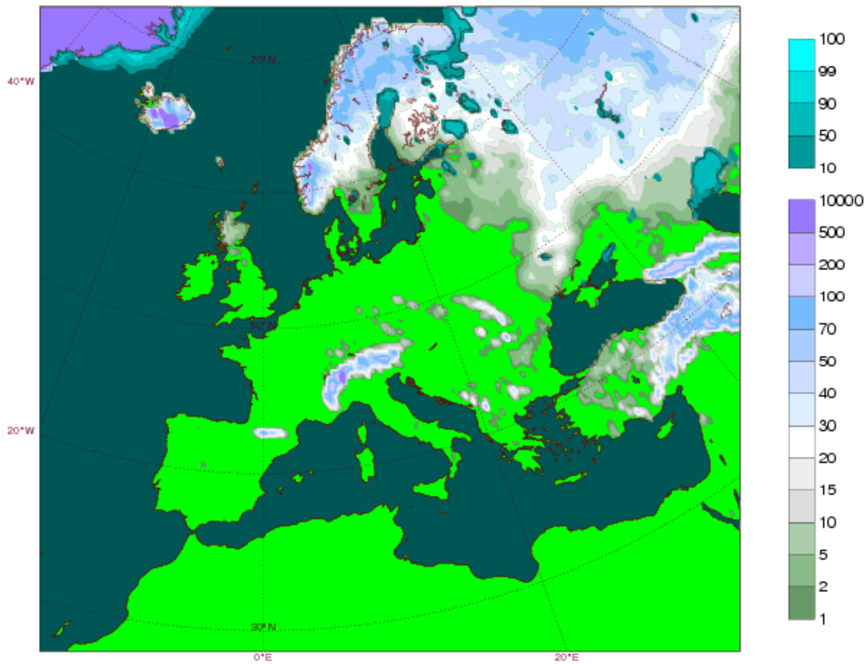
- **Snow temperature, Tsn**

- **Snow albedo, Asn**

Tuesday 26 January 2016 0000 UTC ECMWF t+0 VT:Tuesday 26 January 2016 0000 UTC
Snow depth in cm (using varying snow density). Sea ice fraction in %.



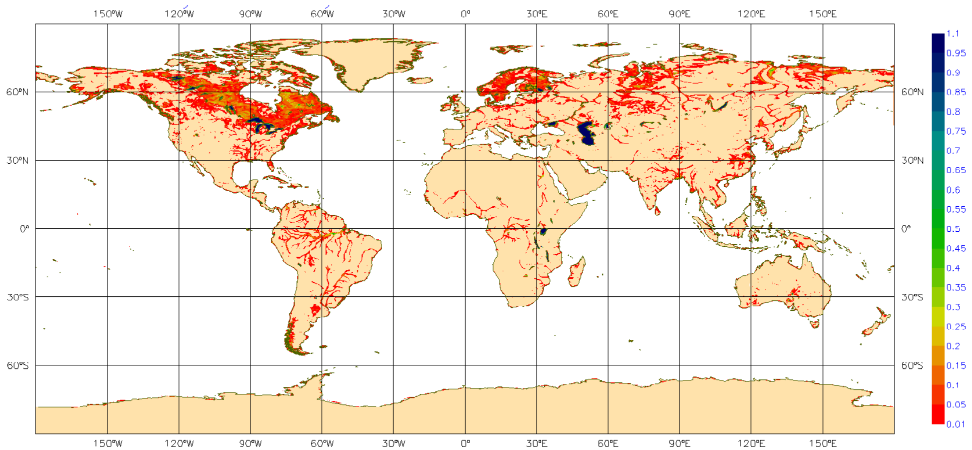
Monday 01 February 2016 0000 UTC ECMWF t+0 VT:Monday 01 February 2016 0000 UTC
Snow depth in cm (using varying snow density). Sea ice fraction in %.



http://www.ecmwf.int/en/forecasts/charts/medium/snow-depth-and-sea-ice

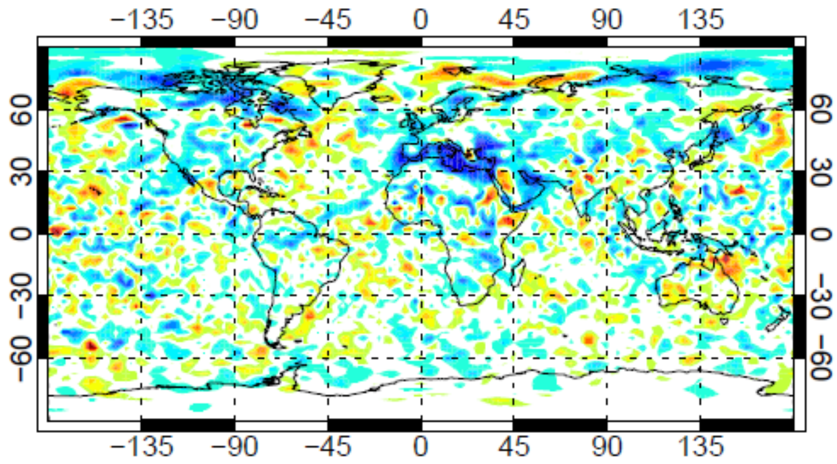
Impact of water bodies in IFS version June 2015

LAKE COVER FRACTION



T+48; 1000hPa

Summer experiment 15−Jun−2013 to 5−Jul−2013



Forecast of 2m temperature are improved in proximity of lakes and coastal areas

Why also coastal areas, these are not Lakes ?!...... cause before if land-sea mask>0.5 then only land point……… but doesn't solve T2m coastal problem for Norway

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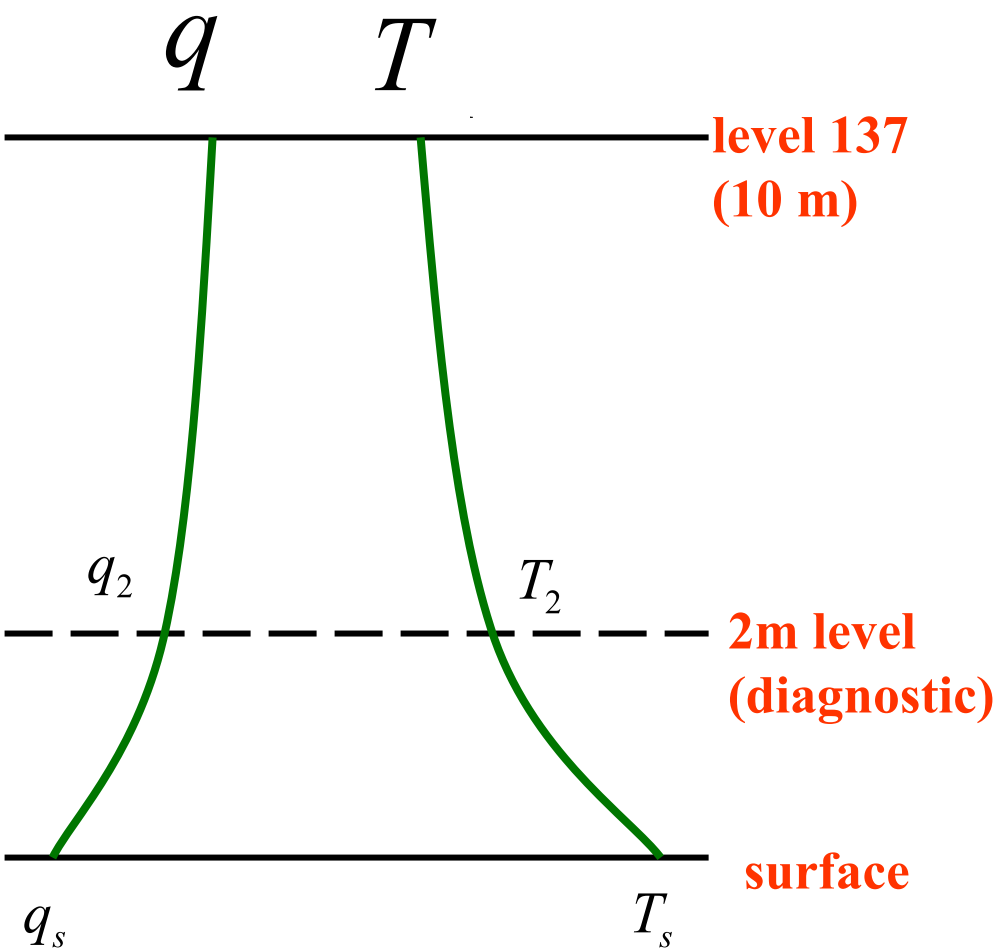
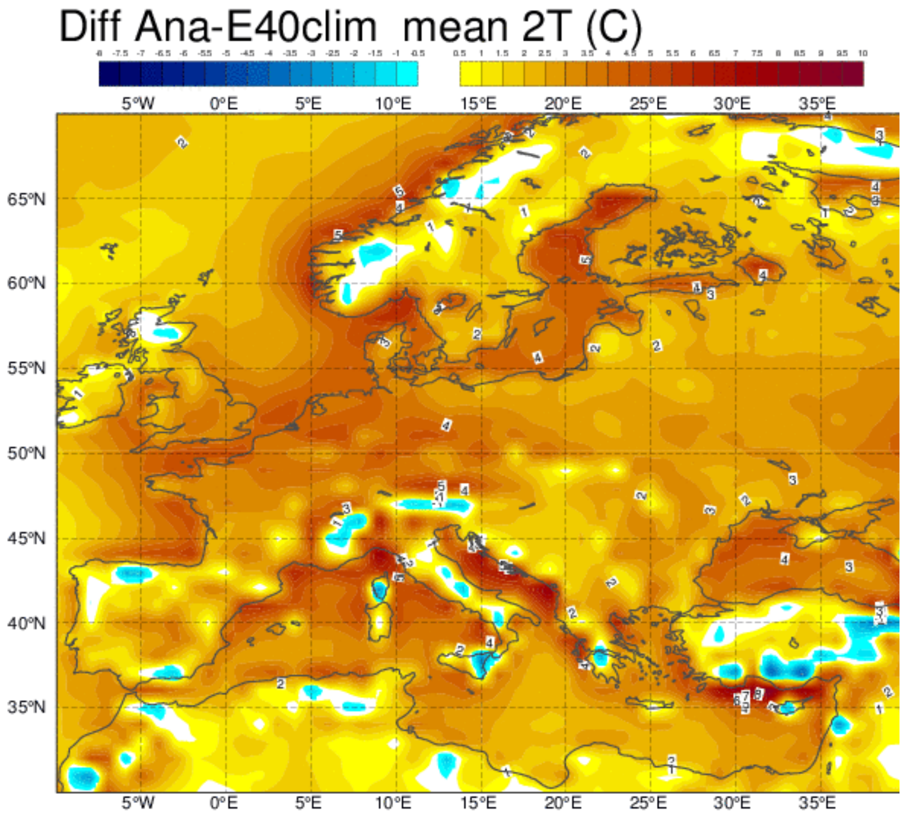
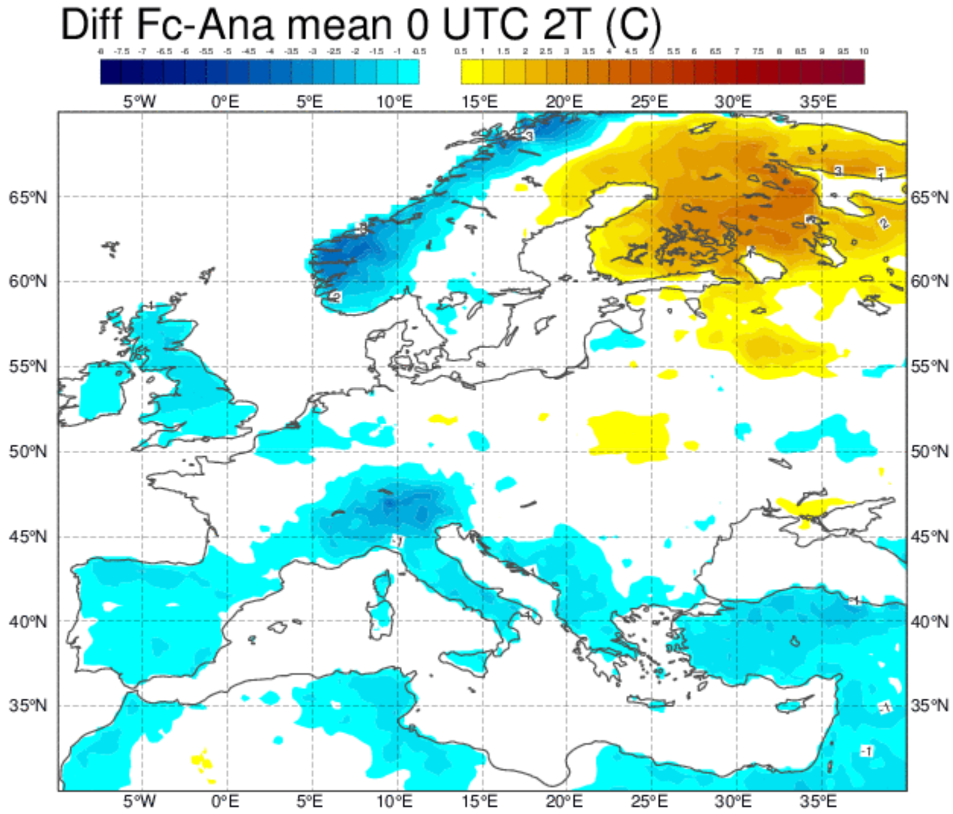
T and q interpolation to the 2m level



- q_s and T_s are determined by the land surface scheme or by SST.
- Main purpose of land surface scheme is to provide correct area averaged fluxes of heat and moisture.
- Land surface scheme considers different sub-areas (tiles) but effect on screen level variables is not accounted for yet.

T2m mean errors (K) 1.Nov 2015- 20.Jan 2016 00 UTC





But for 1-20 January 2016

land mask applied (contour interval 0.5 K, start at +- 0.5 K)

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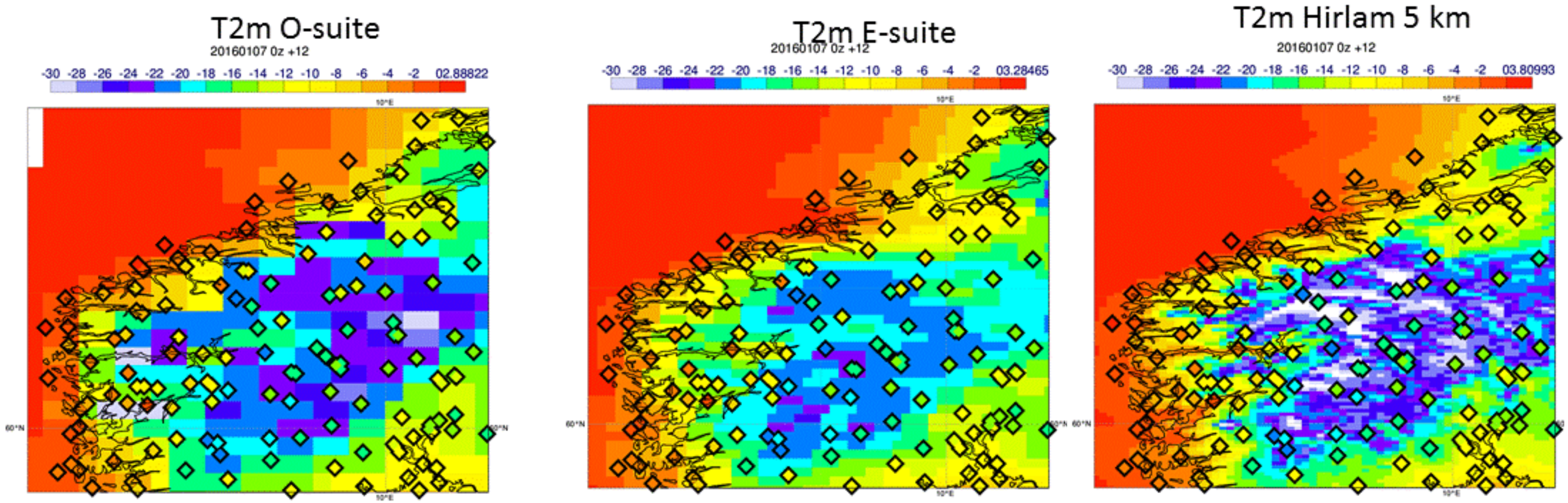
Temperature negative error reduction in 41r2 resolution upgrade:

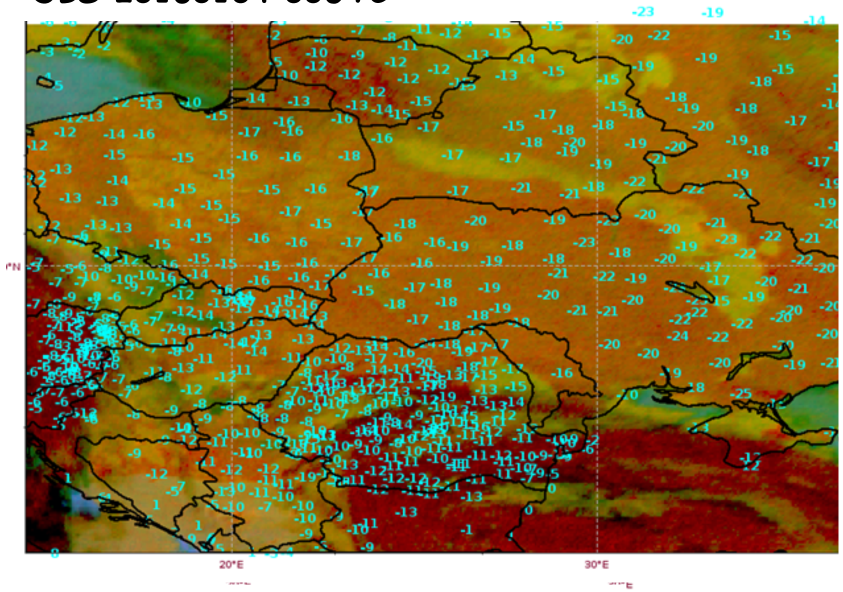
Coastal T-errors reduced through approximate radiation updates in space and time



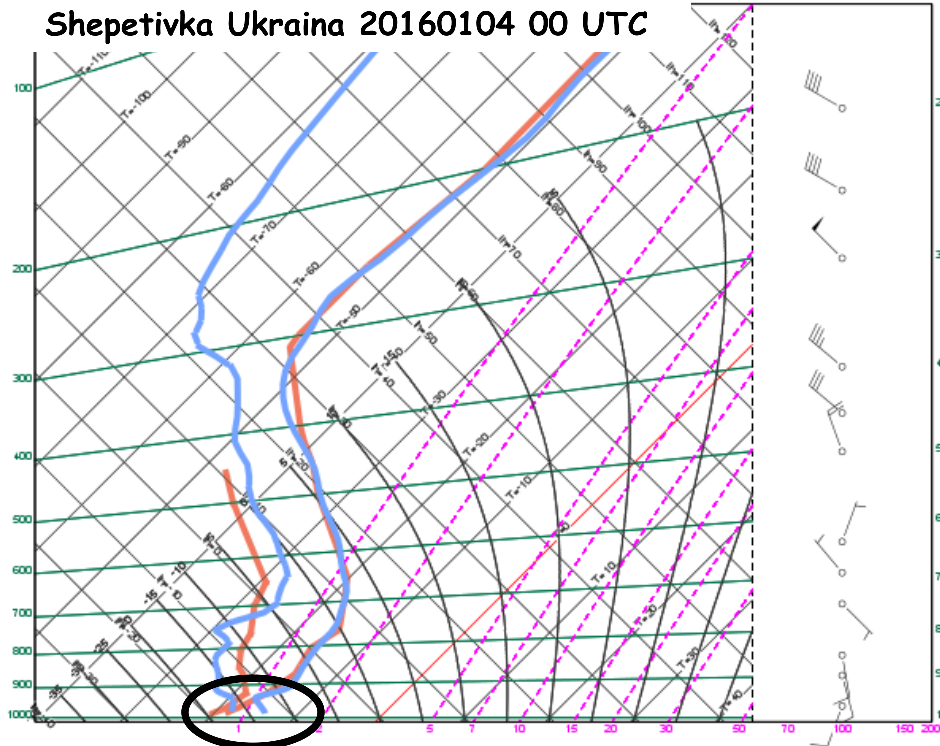
ECMWF

Example of night-time positive Temperature errors

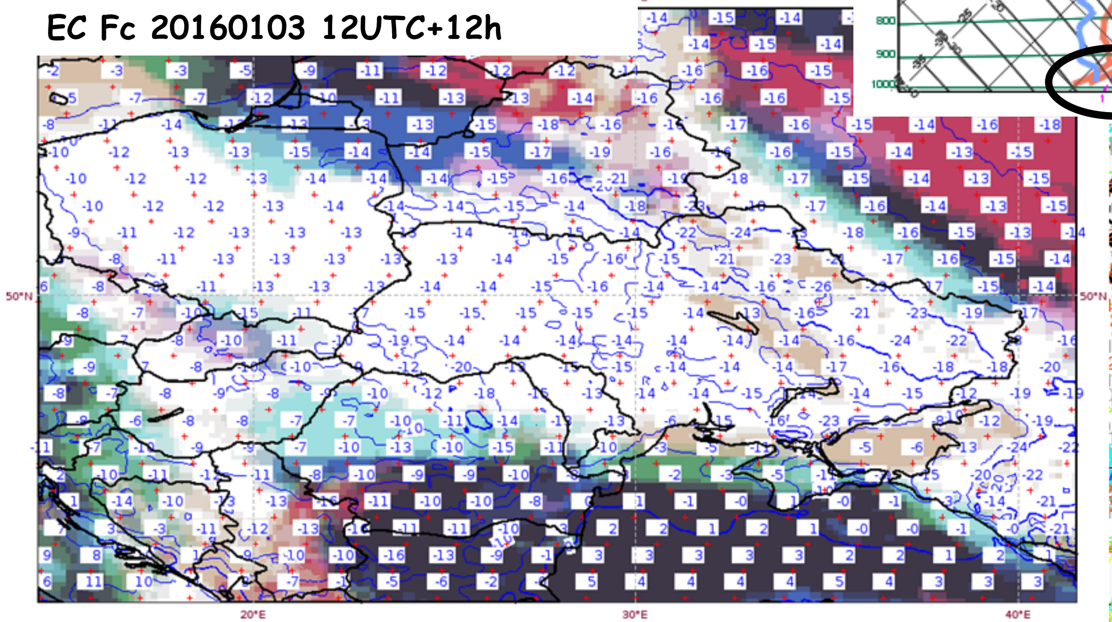
OBS 20160104 00UTC

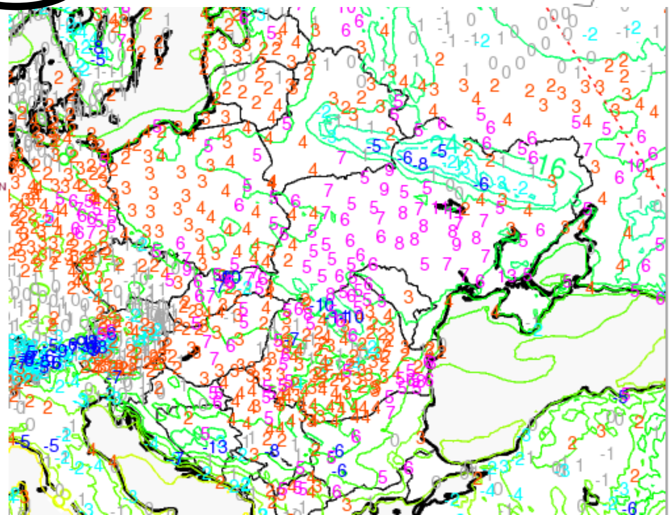


Shepetivka Ukraina 20160104 00 UTC



EC Fc 20160103 12UTC+12h





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Summary of wintertime 2m T errors

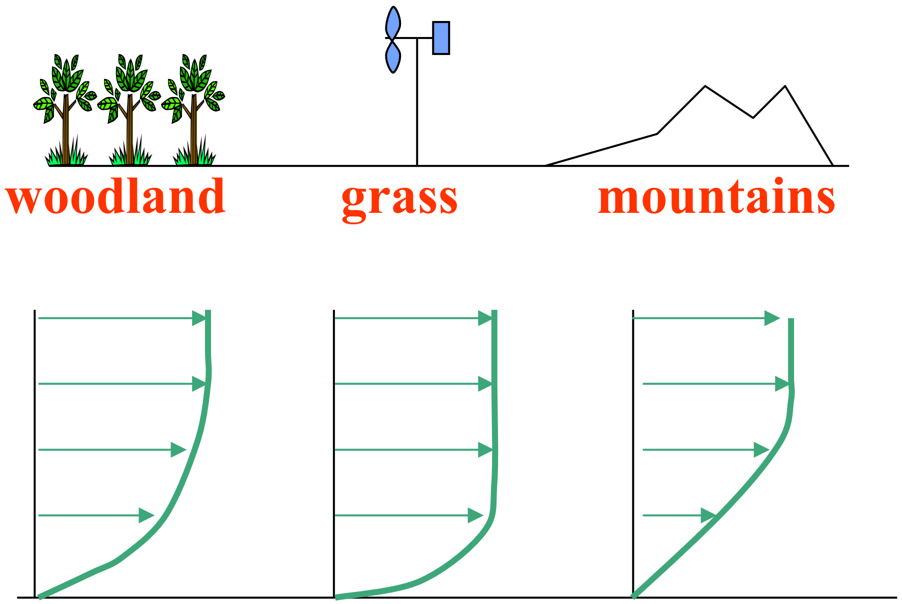
Overall not bad, mean error < 0.5 K, improved over 2010/11 but still

- Too warm, particular night-time problem, but apparent too cold over orography

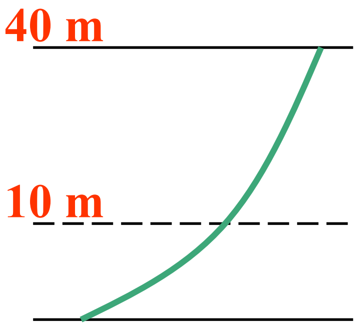
Various possible reasons: coupling (coefficient) with ground heat flux, error in lake temperatures (not frozen), stable boundary-layer mixing, low-level clouds, snow

- Overestimation of summertime night temperatures (not shown) … to be addressed 2nd half of 2016

10 m wind



- Local wind depends strongly on local exposure.
- ECMWF model has roughness length parametrisation to obtain realistic "area averaged" surface drag.
- Resulting wind is low over land because rough elements dominate.

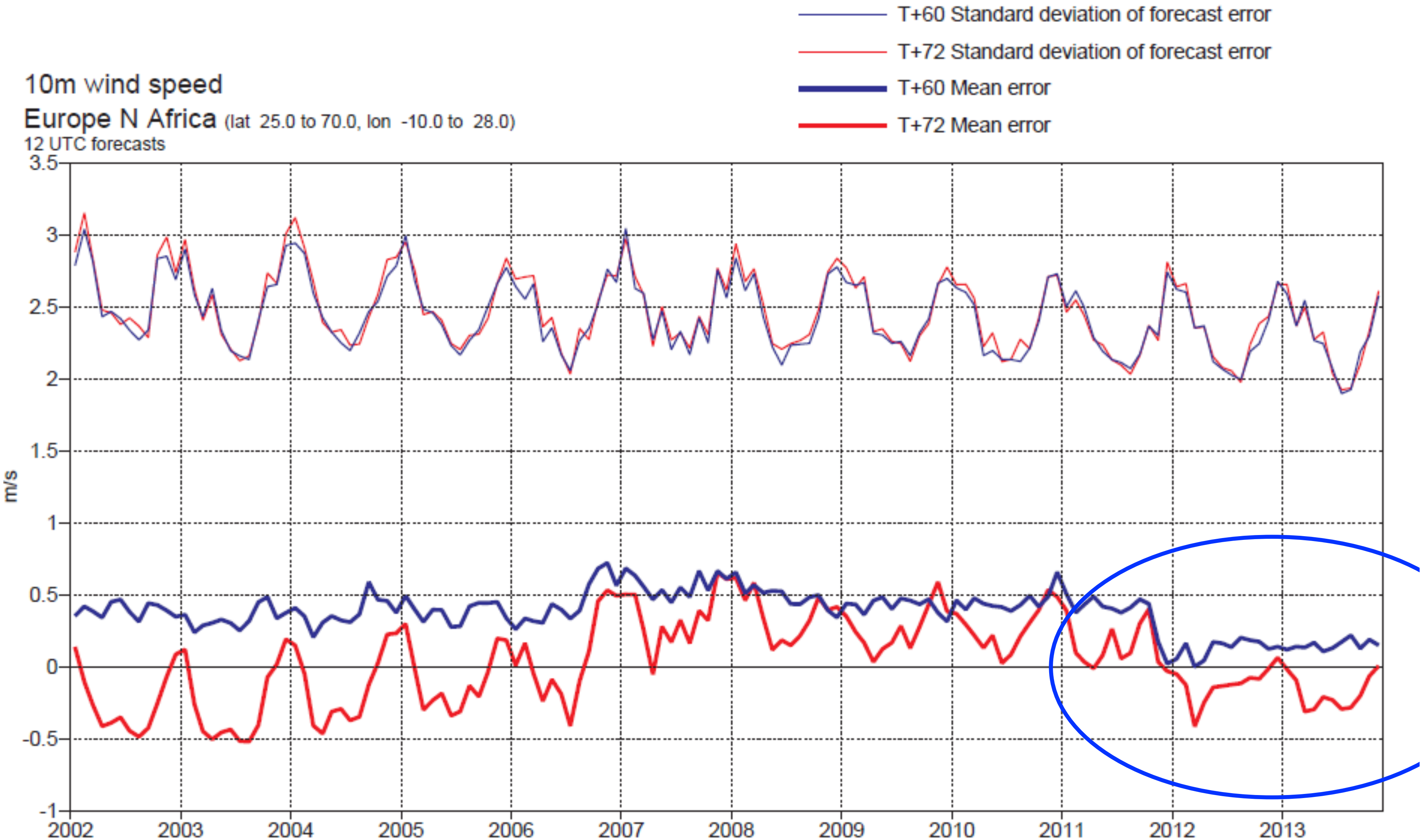


Post-processing of wind at 10 m

- Post-processed 10 m wind interpolates wind from 40 m (was 75 m before Nov. 2011)) assuming roughness length for grassland.
- Note: this exposure correction is only a partial correction to account for local effects (which tend to be more complex).

ECMWF

Changes to the roughness length table (Nov 2011)



ECMWF

Wind Gusts: what is it ?

WMO definition:

Gusts are defined as wind extremes observed by anemometer. A 3 second running average is applied to the data. The report practice is such that gusts are reported as extremes over the previous hour, or the previous 3 or 6 hours.

The mean wind is reported as a 10 min average which is the last 10-minute interval of the hour; it should be comparable with instant output of the model 10 m wind, as it can be interpreted as some space and/or time average.

ECMWF

Wind Gusts in the IFS

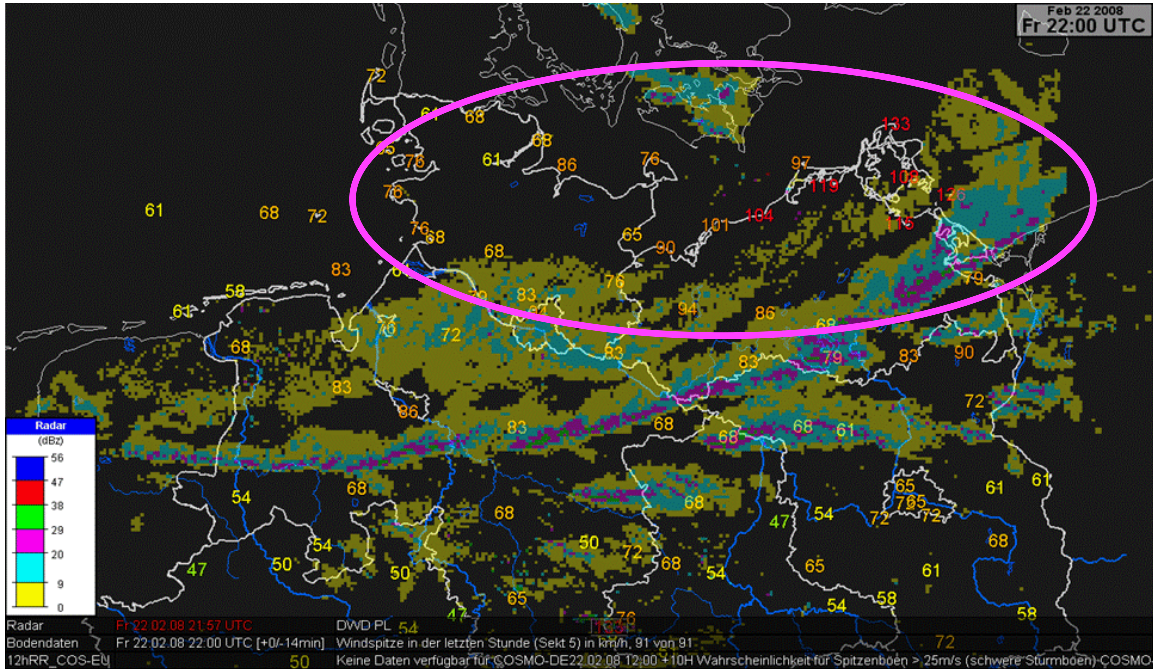
Gusts are computed by adding a turbulence component and a convective component to the mean wind:

$$U_{gust} = U_{10} + 7.71\, U_* \, f(z/L) + \underbrace{0.6 \max(0, U_{850} - U_{925})}_{deep \quad convection}$$

where $\mathbf{U_{10}}$ is the 10m wind speed (obtained as wind speed at first model level, or interpolated down from 40m level), $\mathbf{U_*}$ is the friction velocity – itself obtained from the wind speed at the first model level, and **L** is a stability parameter.

The convective contribution is set proport. to the wind shear between model levels corresponding to 850 hPa and 950hpa, respectively.

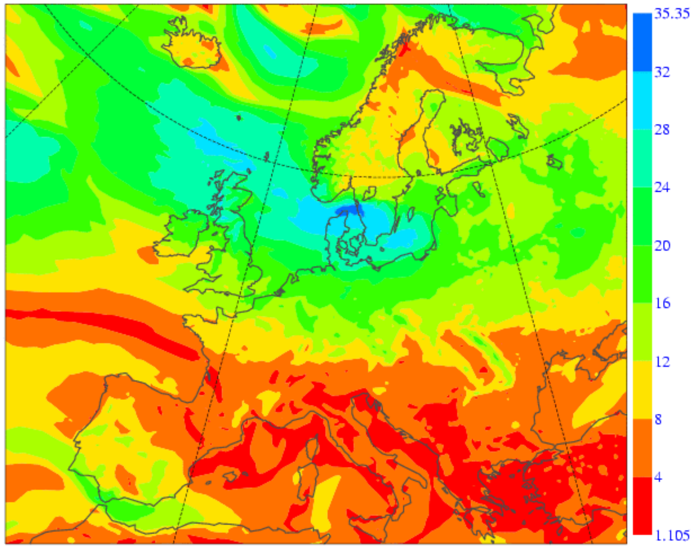
Convective Gusts



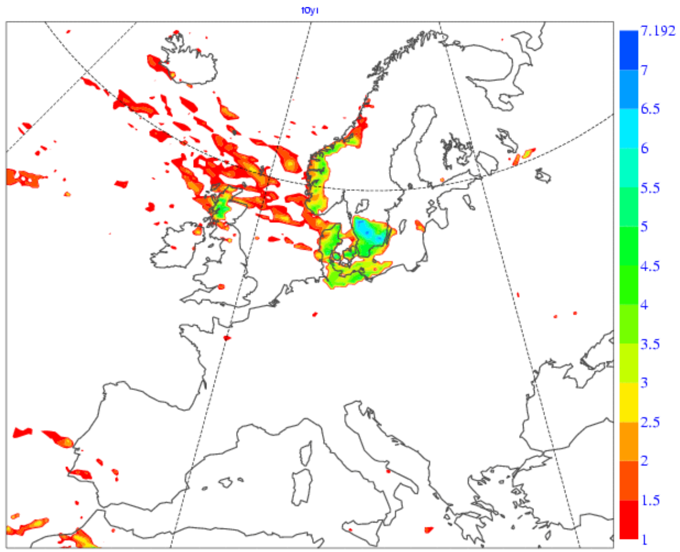
Motivation: report about gust front by DWD

22 February 2008

Oper



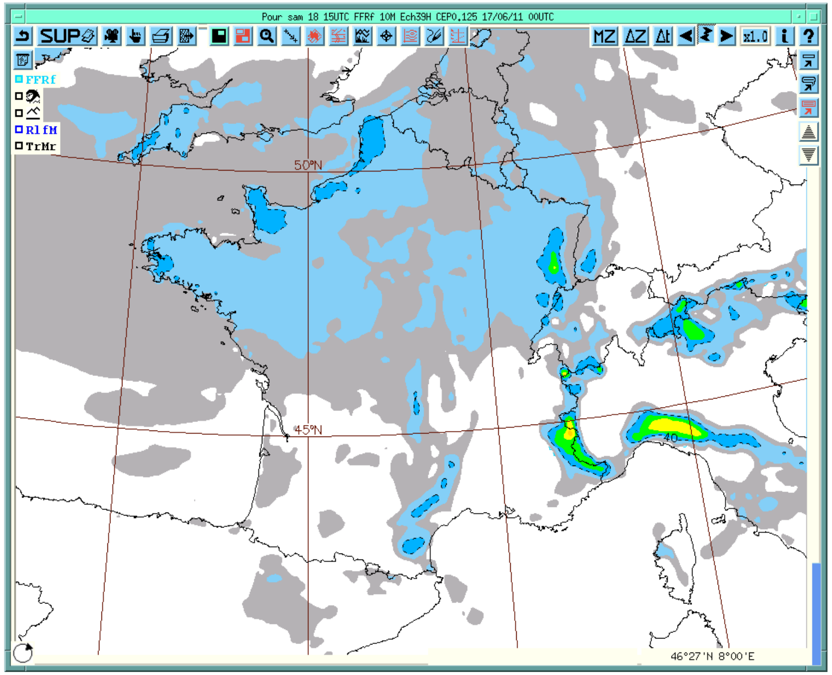
Conv



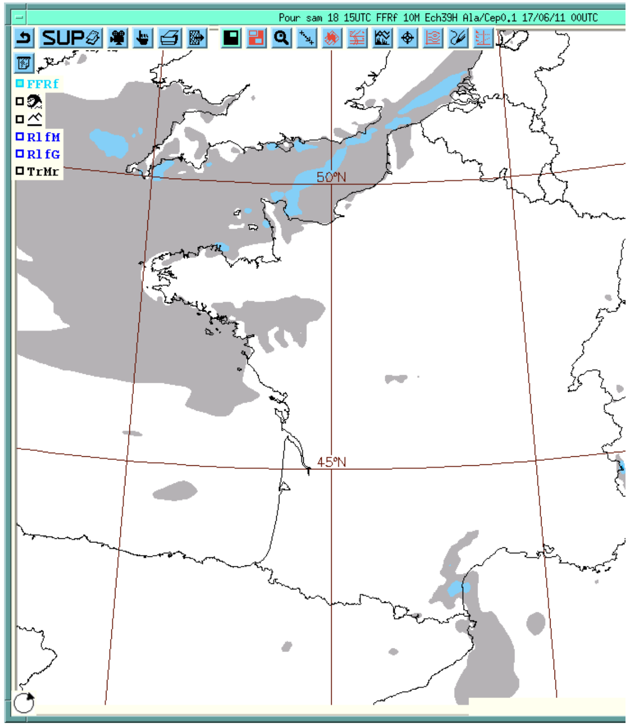
Wind gusts 18 June 2011

- Wind gust forecast for 18 June 15 UTC base 17 June 0 UTC
- ECMWF wind gust maxima are located over land, other models have maxima over the sea
- “It seems really unrealistic” to the Meteo-France chief forecaster

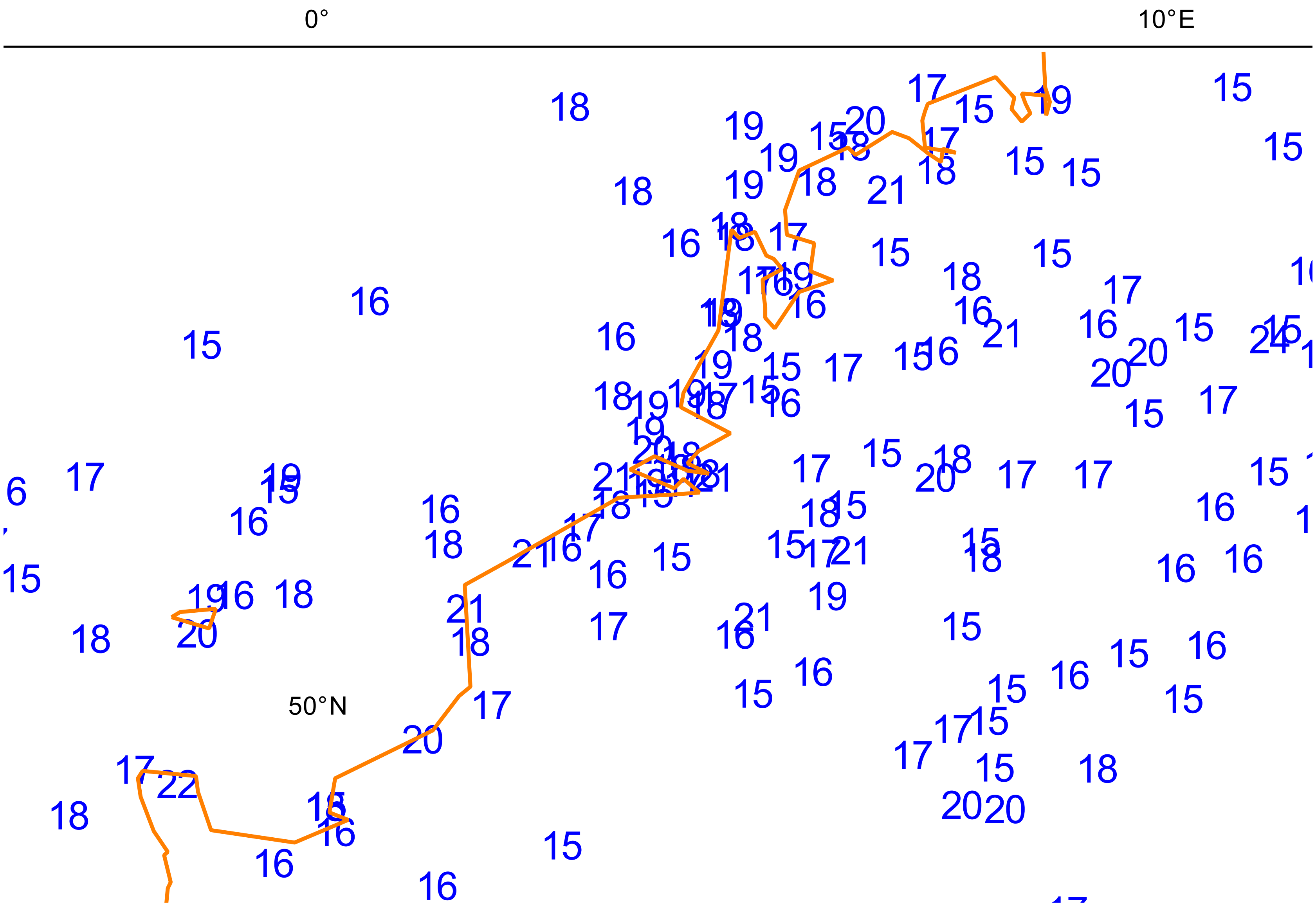
ECMWF



Aladin

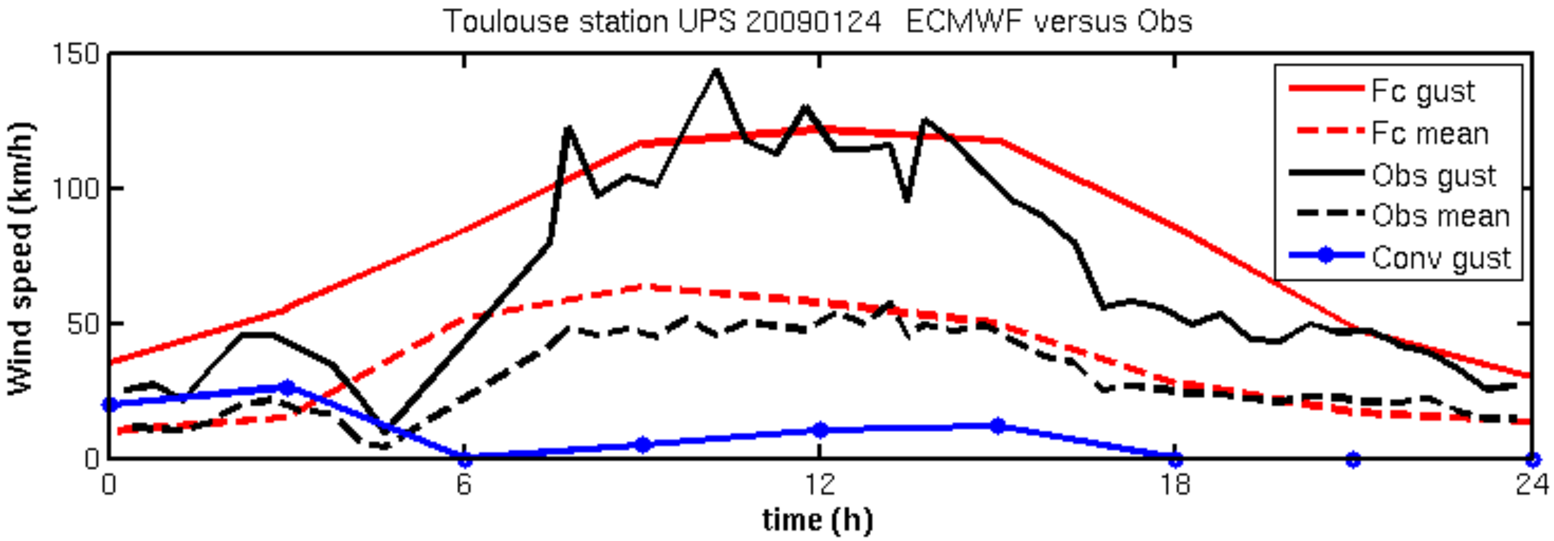


Wind gusts 18 June 2011



Wind gusts

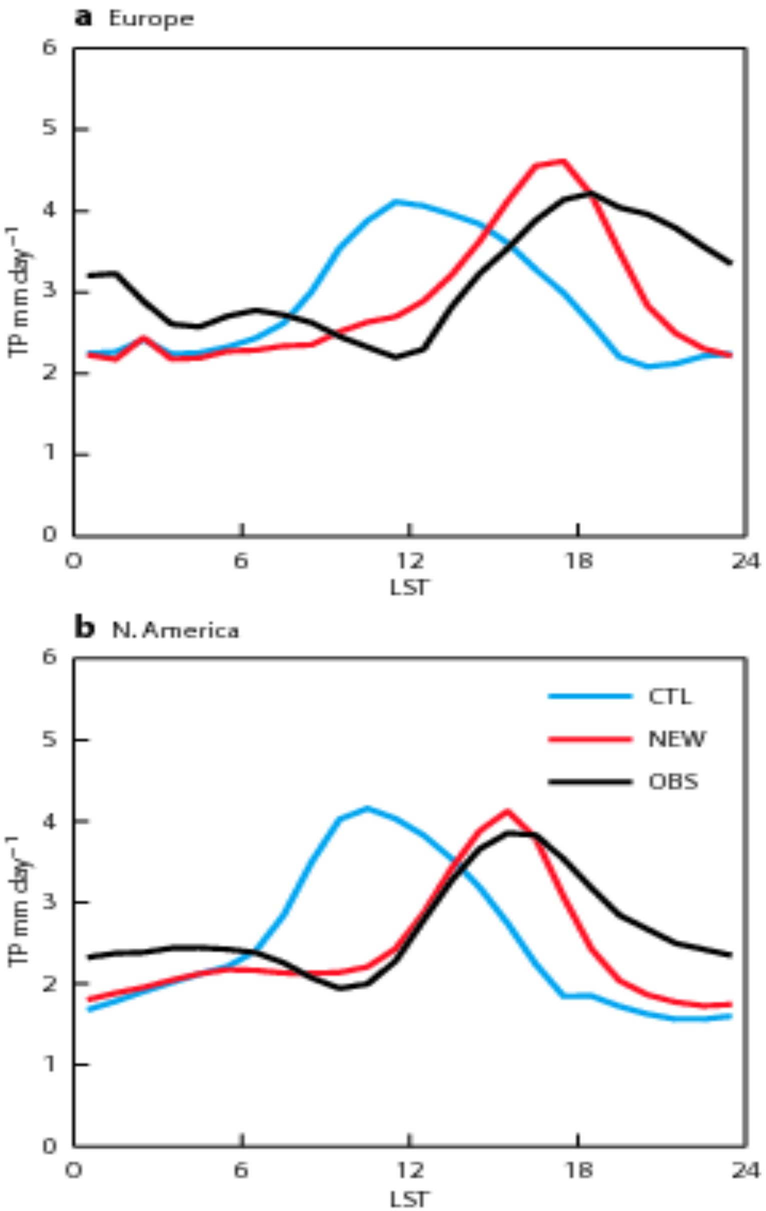
Time series against anemometer 24 January 2009 (storm Klaus)



Observed mean wind speed (dashed black line) and maximum wind speed (solid black line) for 24 January 2009 at a meteorological station at Toulouse University, France (courtesy Jean-Luc Attié and Pierre Durand), together with corresponding 3-hourly forecast values (red lines) from the operational deterministic forecast from 23 January 12 UTC. The blue line denotes the convective contribution to the gusts.

Physical processes: Summer and winter convection

Diurnal cycle: realistic since Nov 2013

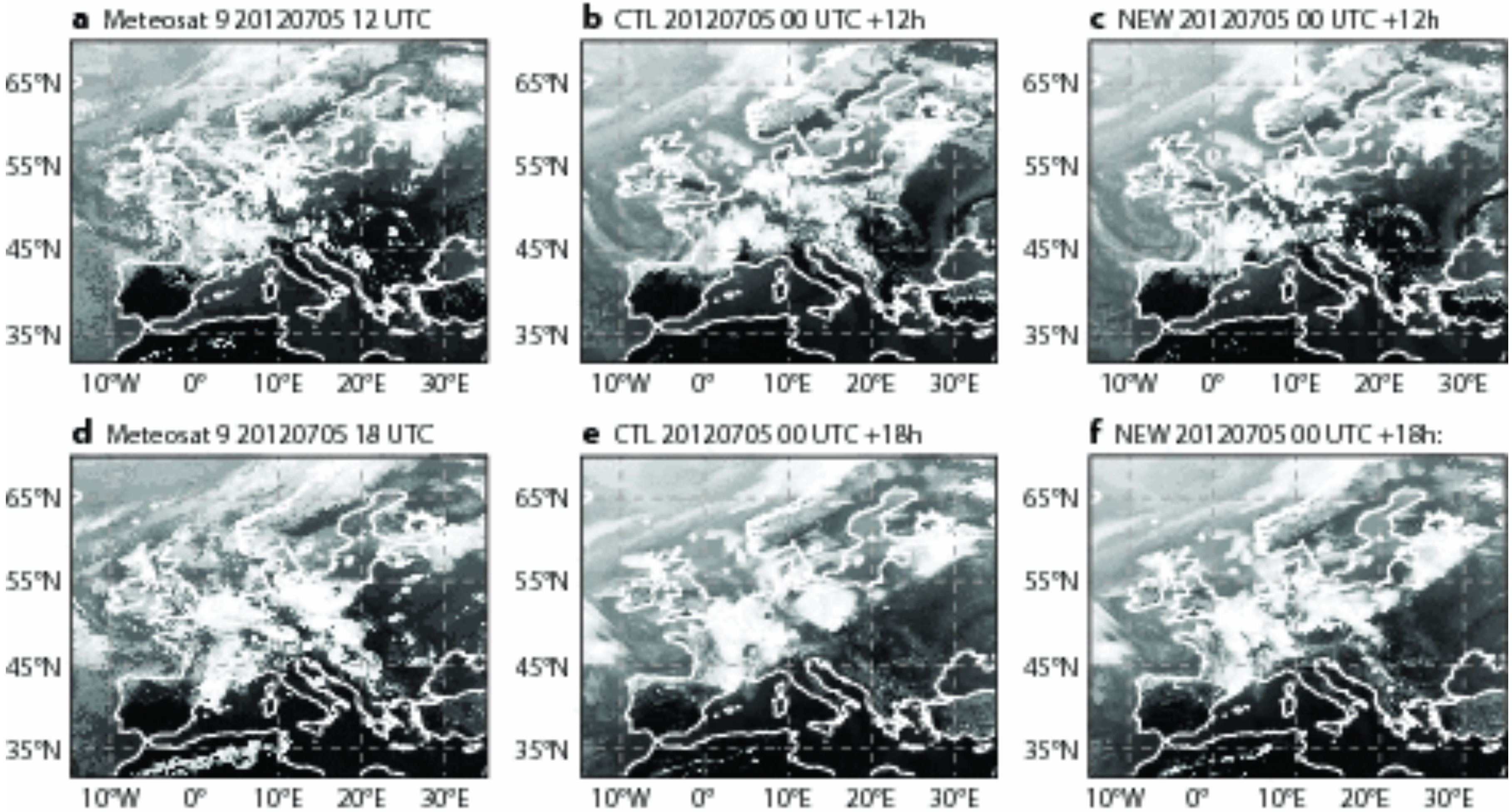


JJA 2011-2012 hourly rainfall composite against Radar

See ECMWF Newsletter No 136 Summer 2013
Bechtold et al., 2014, J. Atmos. Sci.

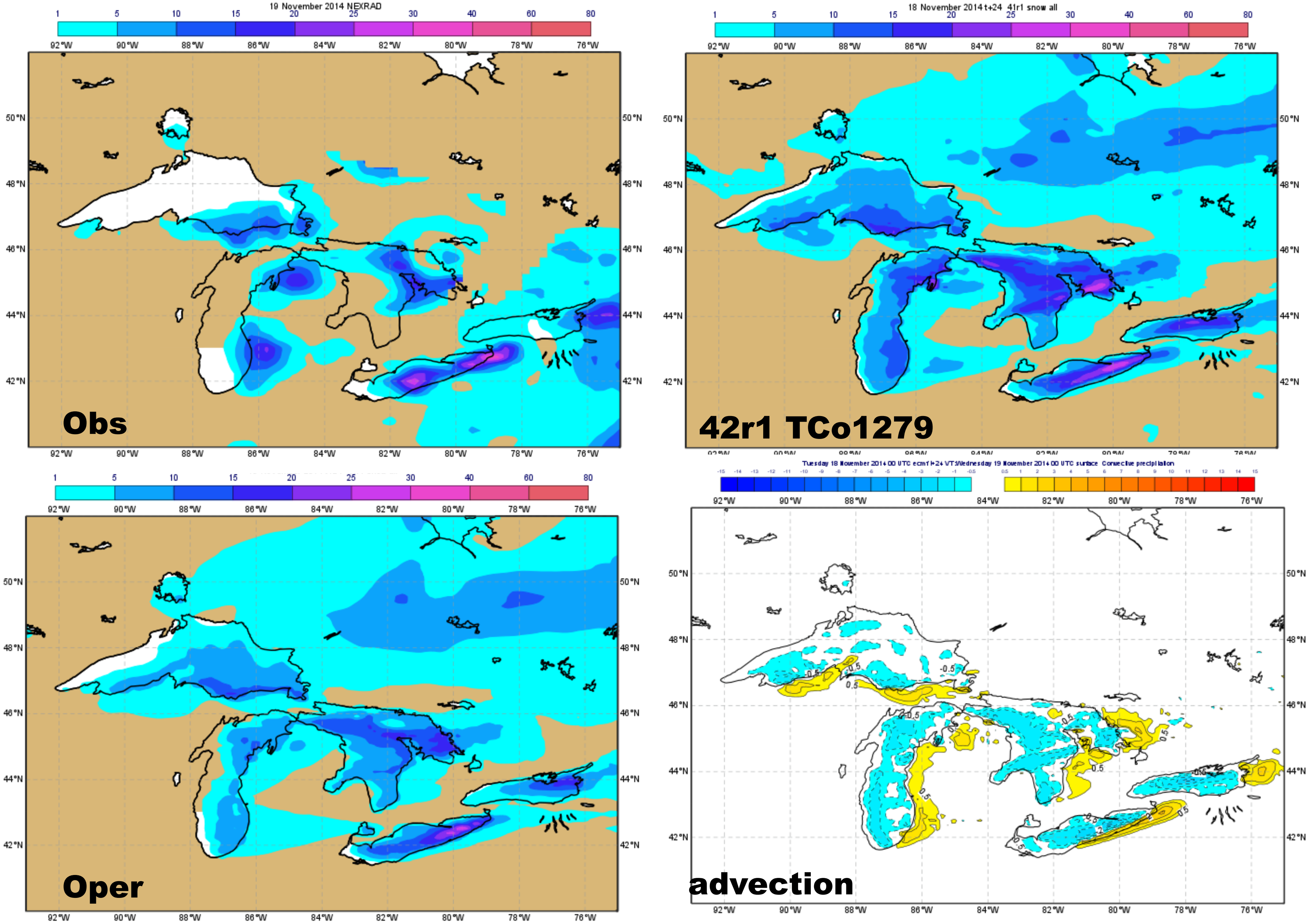
ECMWF

Diurnal cycle: Impact on weather forecasts



ECMWF

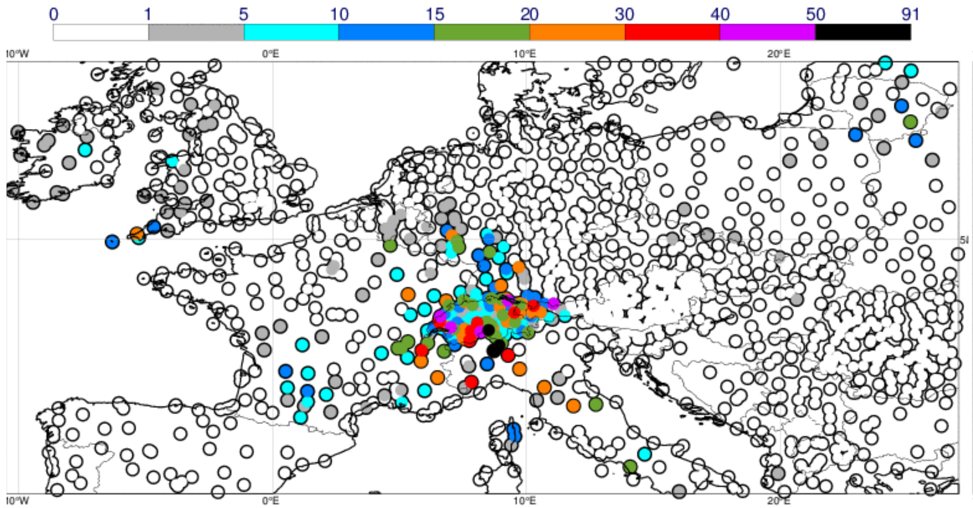
Winter convection: snow showers



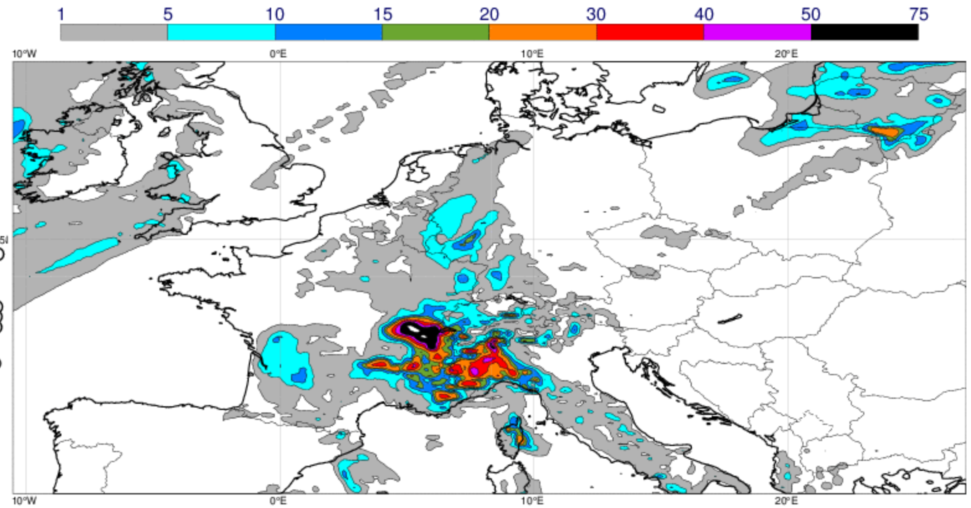
ECMWF

Example of (convective) precipitation forecast and resolution

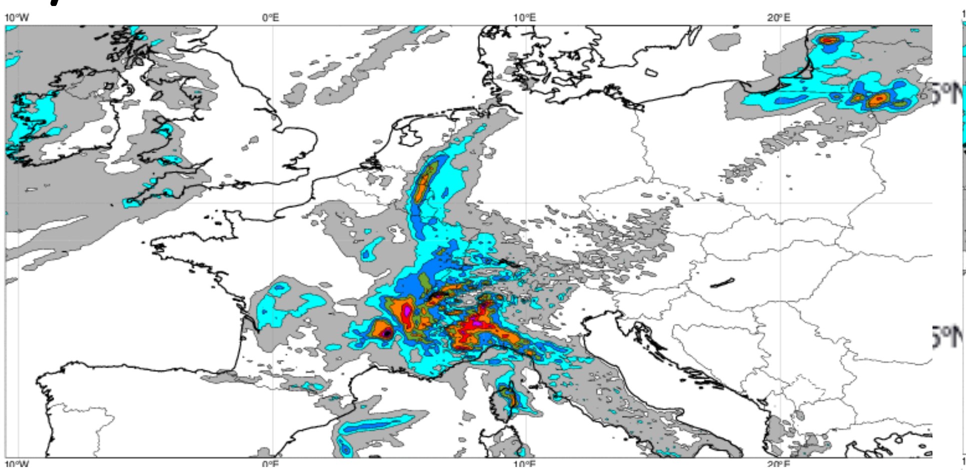
Obs 9 Aug 2015



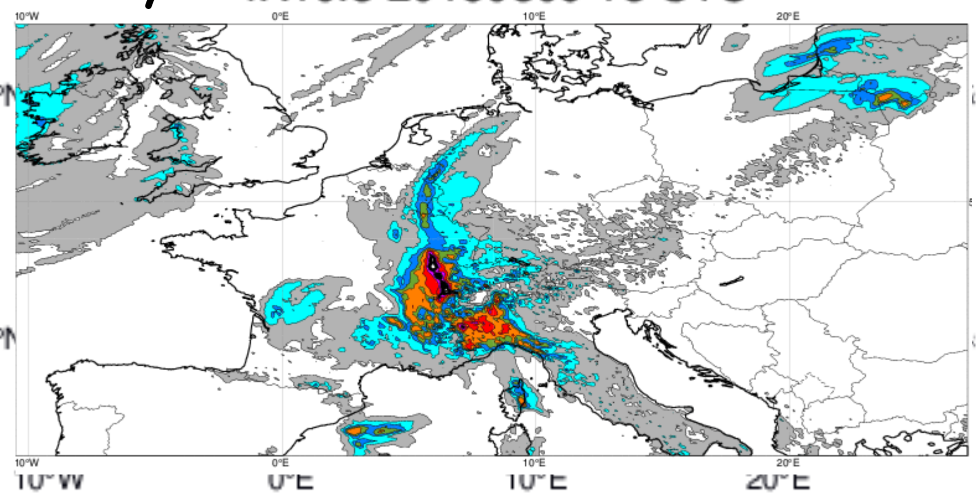
Oper Cy41r1 Tl1279 16 km



Cy42r1 TCo1279 9 km



Cy42r1 TCo1999 5 km scaled Mfl



ECMWF

Summary: issues for improvement

- T2m winter can still be difficult: stable boundary-layer, coupling with surface (ground, lakes) and low-level clouds
- Still some overestimation of light precipitation (drizzle)
- Melting of fresh snow on ground somewhat too slow
- Inland penetration of (convective) showers and convective organisation improved but can still be improved
- Too strong Indian and SE Asian Summer Monsoon (to be addressed in 2nd half of 2016 through new aerosol climatology)

A few things coming up in 2nd half of 2016

- New Aerosol climatology -> improved (reduced precipitation) Indian summer monsoon
- Revised Ozone climatology -> improved (cooling > 5K) upper stratospheric temperatures
- New products: Ceiling (m), convective cloud top height (m), height of 0 and 1 Deg C wet bulb temperature, direct beam surface radiation