ECMWF: Recent developments and plans

36th EWGLAM / 21st SRNWP

Meeting

DWD/Offenbach, 2014

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ECMWF

Outline

- Cycle 40r1 (November 2013)
- Migration IBM P7 → Cray XC30
- Cycle 40r3 (end 2014/early 2015)
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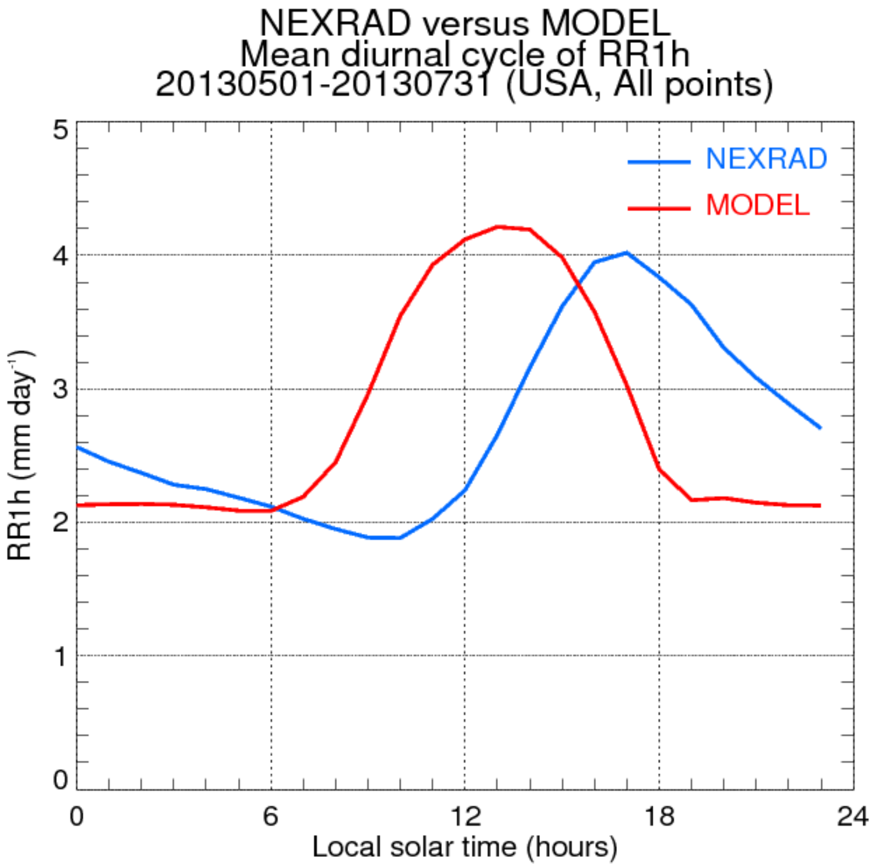
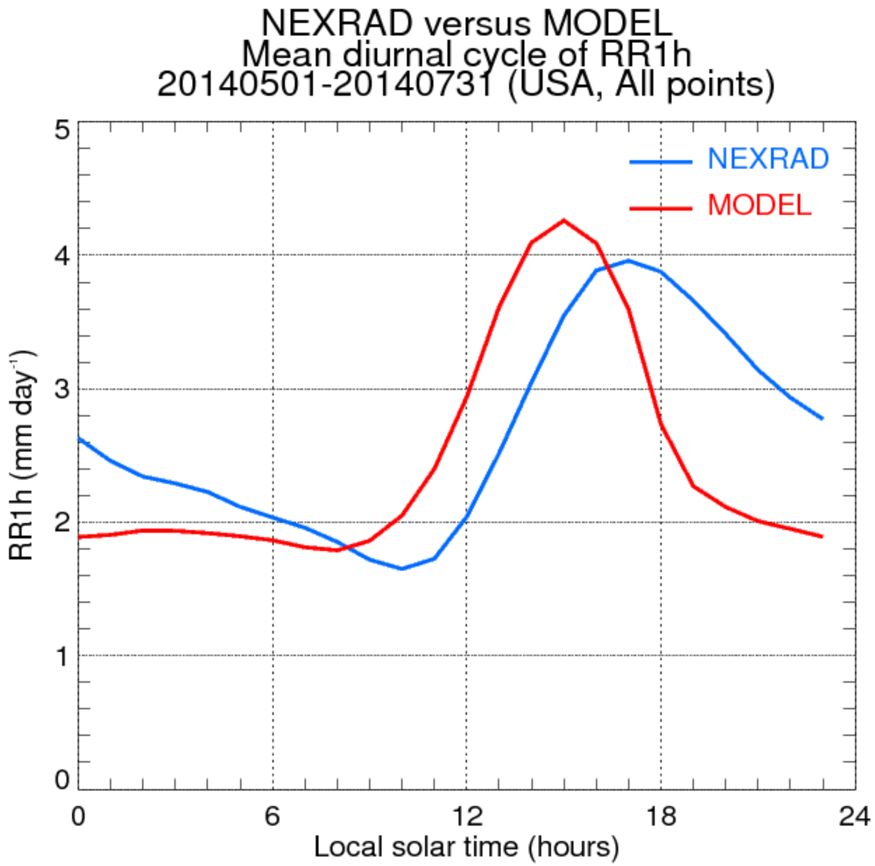
Cycle 40r1 (November 2013)

- ENS:
  - L91 with top at 1 Pa
  - coupling to ocean model from t=0
  - Land surface initial perturbations
- 25 EDA members + Online estimation of bg-err cov.
- Boundary layer diffusion and subgrid orography schemes
- Convection closure
- Regularized diffusion in simplified VDF (TL/AD model)
- Remote sensing:
  - SSMIS 183 GHz channels activated in all-sky microwave radiance assimilation
  - enhanced use of AMSU-A, AMSU-B and MHS data over sea ice,
  - situation-dependent observation errors and revised quality-control for AMVs.
- … see www.ecmwf.int/en/forecasts/documentation-and-support/changes-ecmwf-model/cy40r1-summary/cycle-40r1

Comparison of ECMWF precipitation forecasts against NCEP Stage IV (NEXRAD) rain composites over the U.S.A.





→ Improved timing after NL convection revision in CY40R1.

Changes implemented in 40R1 building on Sandu et al, 2013

Turbulence closure for stable conditions: $$K_{M,H} = \left|\frac{\partial U}{\partial Z}\right| l^2 f_{M,H}(R_i), \quad \frac{1}{l} = \frac{1}{kz} + \frac{1}{\lambda}$$

Up to 38R2

- long tails near surface, short tails above PBL
- λ =150m
- non-resolved shear term, with a maximum at 850hPa

→

From 40R1

- long tails everywhere
- λ = 10% PBL height in stable boundary layers
- λ = 30 m in free shear layers

\+

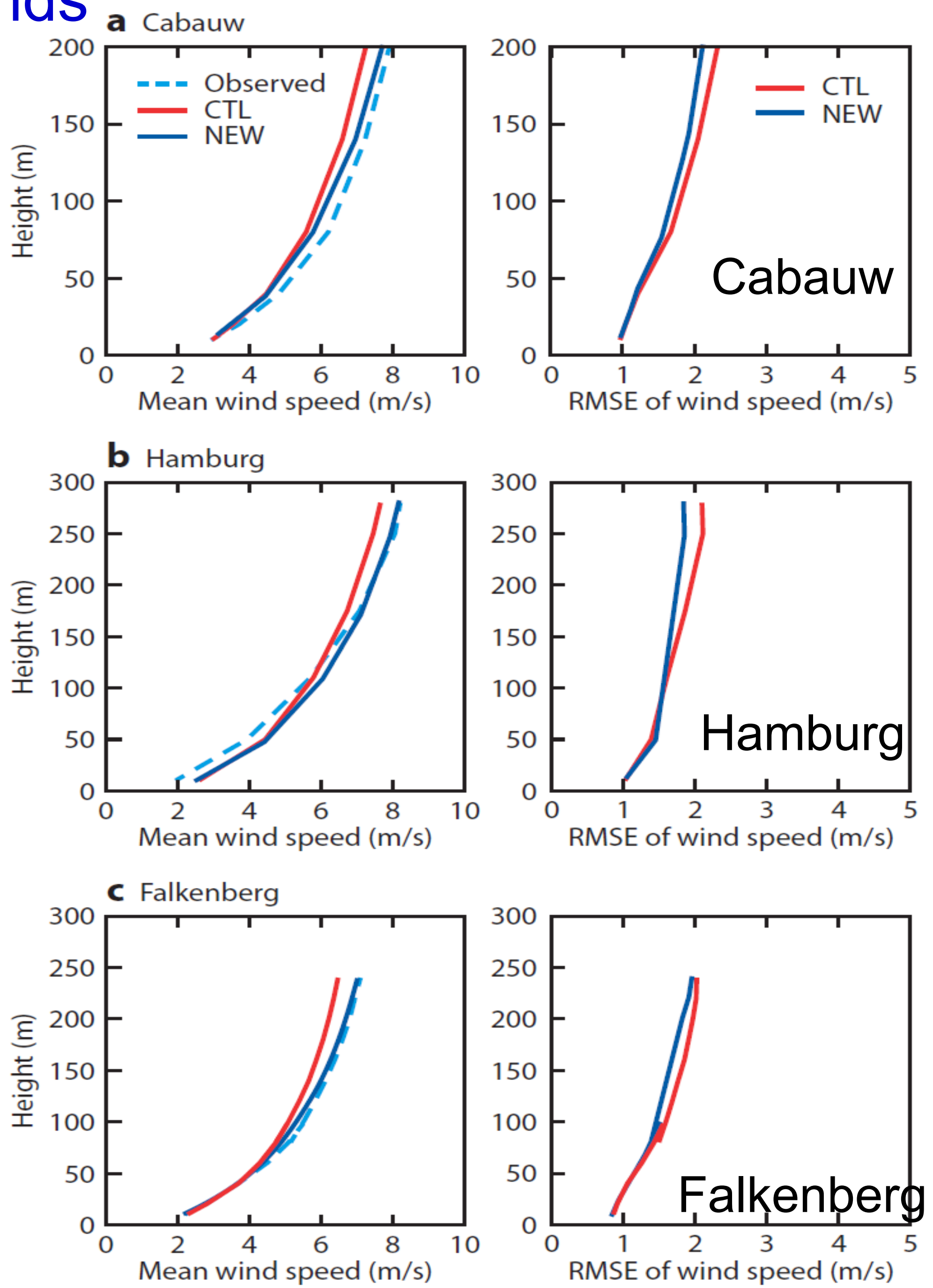
Increase in drag over orography
Increase in atm/surf coupling

Consequence: net reduction in diffusion in stable boundary layers, not much change in free-shear layers, except at 850 hPa

Improvement of low level winds

Comparison with tower data
T511L137 analysis runs
JJA 2012, 0 UTC, step 24h

Improvement in both mean and RMSE in the upper part of stable boundary layers



Sandu et al, ECMWF Newsletter 138

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Migration from IBM P7 to Cray XC30

	IBM	Cray
Processor	IBM Power7	Intel IvyBridge
Clock Speed	3.8 GHz	2.7 GHz
Switch	IBM HFI	Cray Aries
Nodes	762 *2	3500 *2
Cores	24384 *2	84000 *2
Cores per Node	32	24
Peak (Tflops)	370*2	907*2
Available Memory per Core (Gbytes)	48/32	60/24
Compiler	IBM XLF	Cray CCE
OS	AIX	CLE
Parallel File System	gpfs	lustre

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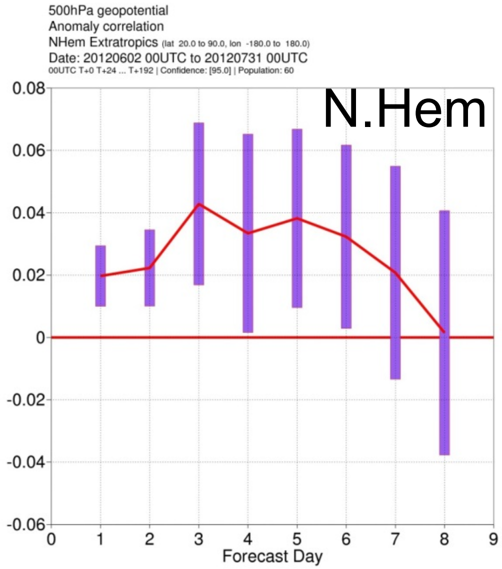
40r3 (end 2014/early 2015)

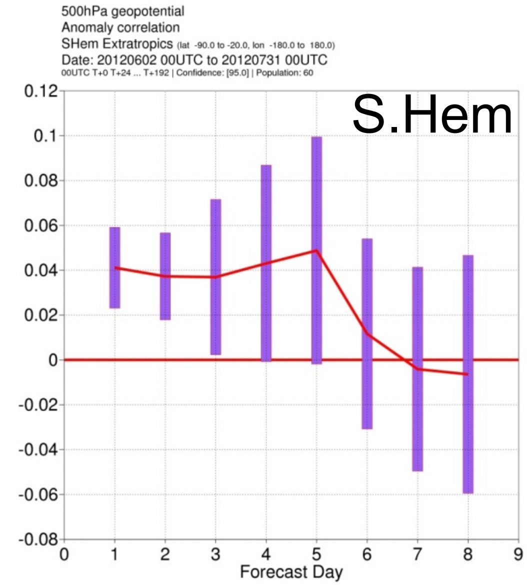
- 4D-Var inner loop
  - resolutions: 255Linear-255Linear-255Linear grid
  - 1st inner loop: iterations 70 → ~28, full TL/AD physics
- Improved EDA noise filtering based on 25 EDA members and B from using mixture of EDA perturbations from last cycle (1/3) and other times of year (2/3).
- Improved obs. errors in SEKF and use of ASCAT in SEKF
- High-resolution radiosondes from parts of Europe and ships
- Ability to assimilate ground based GPS and aircraft humidity
- First phase of COPE (Continuous Observation Processing Environment) implemented

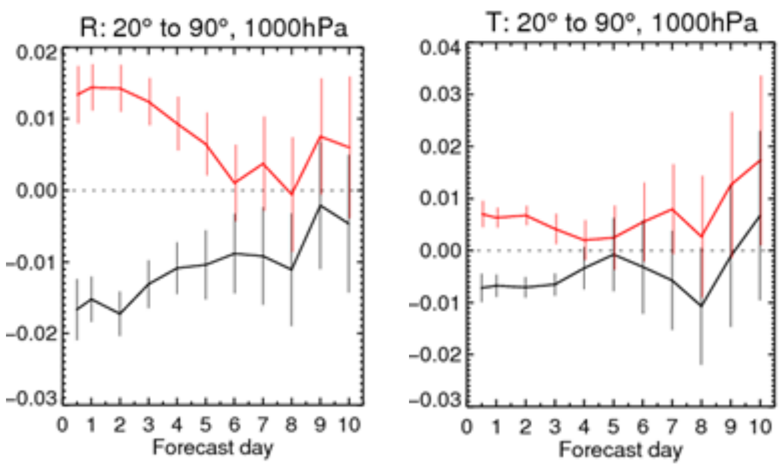
Forecast scores for Hybrid 4DVAR&EDA

versus

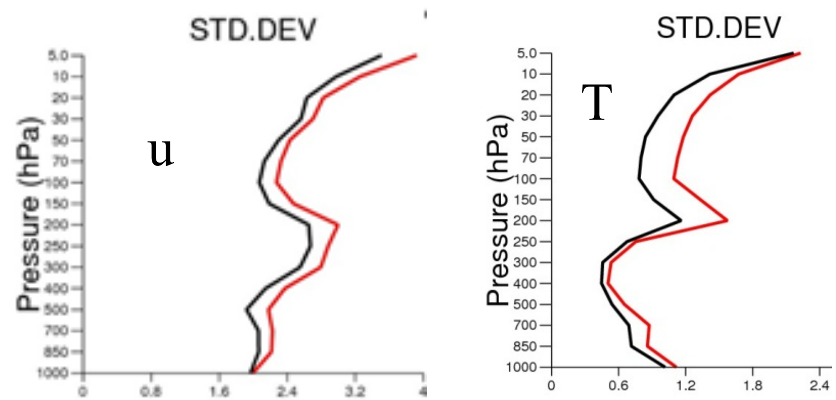
static **B** 4DVAR







Impact of the soil moisture analysis on the 1000hPa Humidity and Temperature forecast RMSE in %. Black line: revised cycle 40r3 SEKF compared to cycle 40r1. Red lines show the impact of switching off the SEKF



Innovation statistics for July 2014 for 13 German radiosonde stations. Red curves are alpha numerical data and black curves are BUFR data

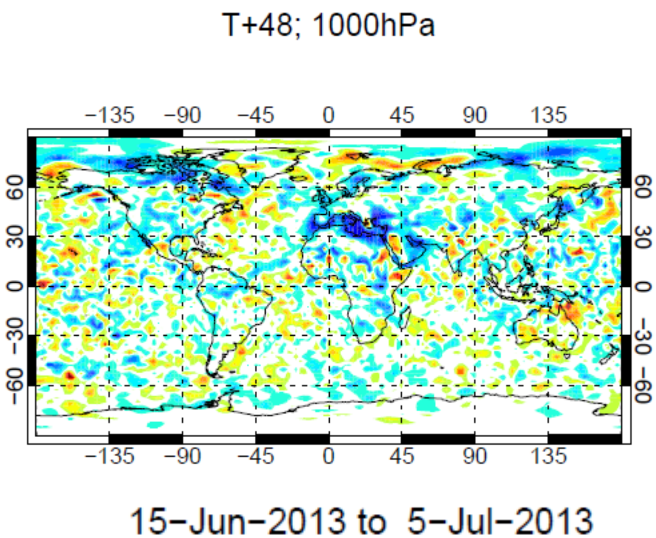
40r3 (end 2014/early 2015)

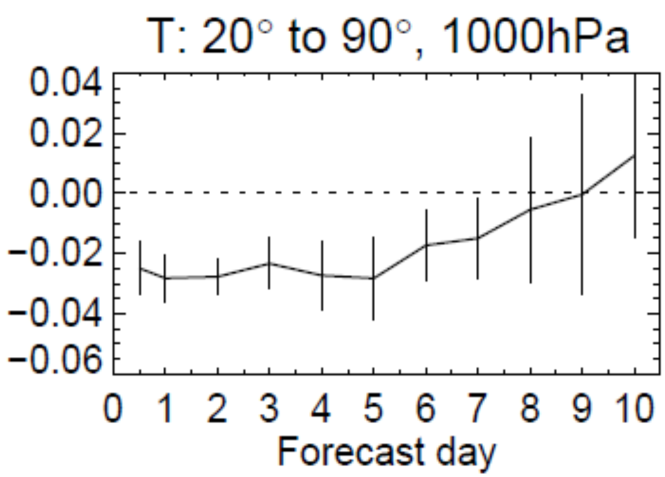
- 1st set of new sfc. climate fields (land-sea mask, sub-grid orogr.)
- Activation of lake model (FLAKE)
- Modified convective detrainment & closure of midlevel convection
- Large-scale cloud scheme revision
- Improved scheme for computing semi-Lagrangian trajectory departure points in the stratosphere
- 3D quasi-monotone limiter and consistent quasi-monotone interpolation of moist variables
- MACC-II CO2/O3/CH4 climatologies; bugfix CO2 increase
- RRTM upgrade; cloud min. effective radius change
- Active use of wave modified stress in coupled mode
- Revised sea-ice minimum threshold, sea-ice roughness length
- Revised consistency check between SST and sea ice conc.

Highlight: Impact of water bodies in the analysis cycles

Summer experiment

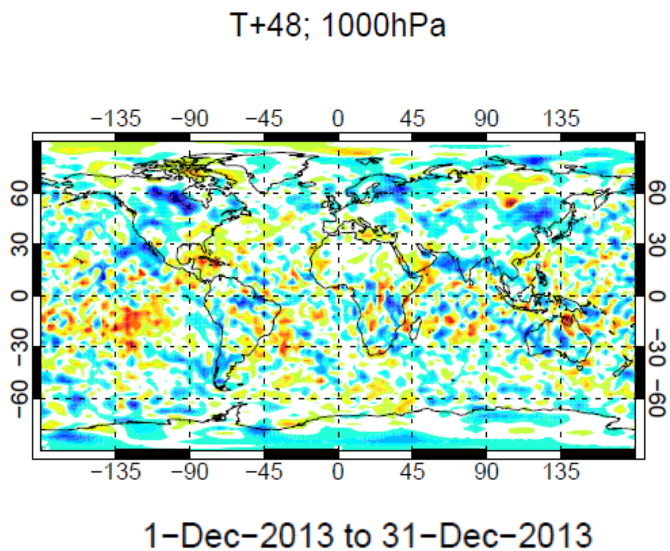
(Temperature scores)

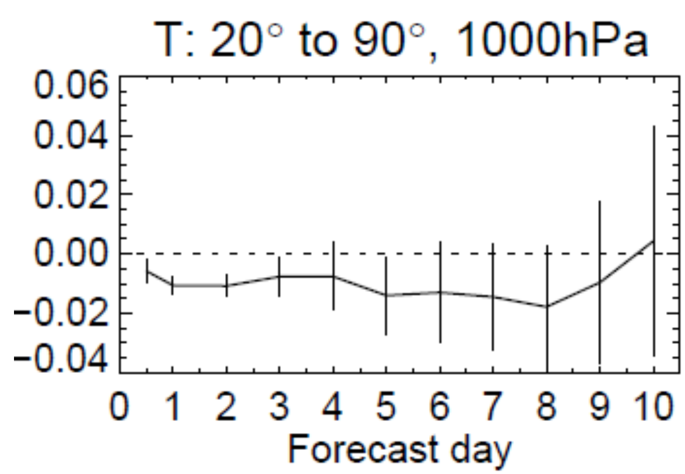




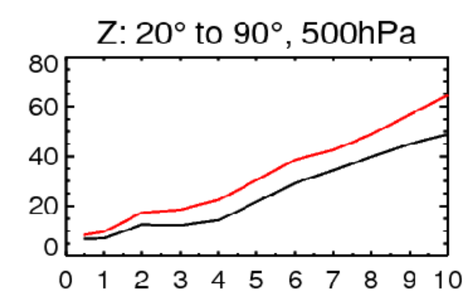
Winter experiment

(Temperature scores).



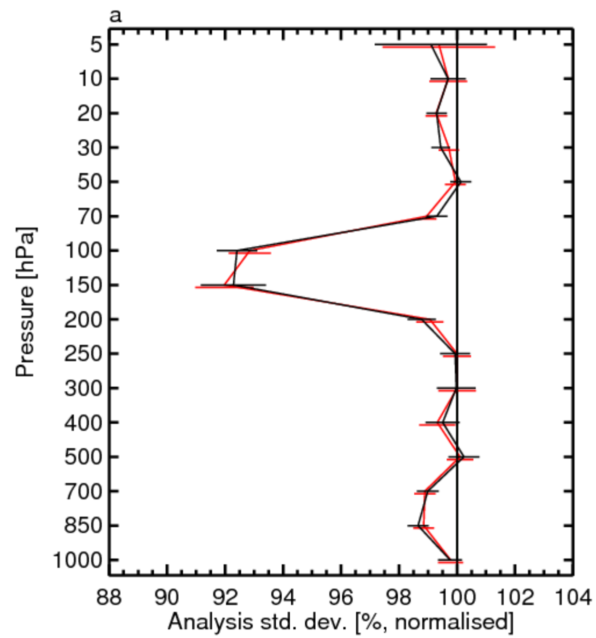


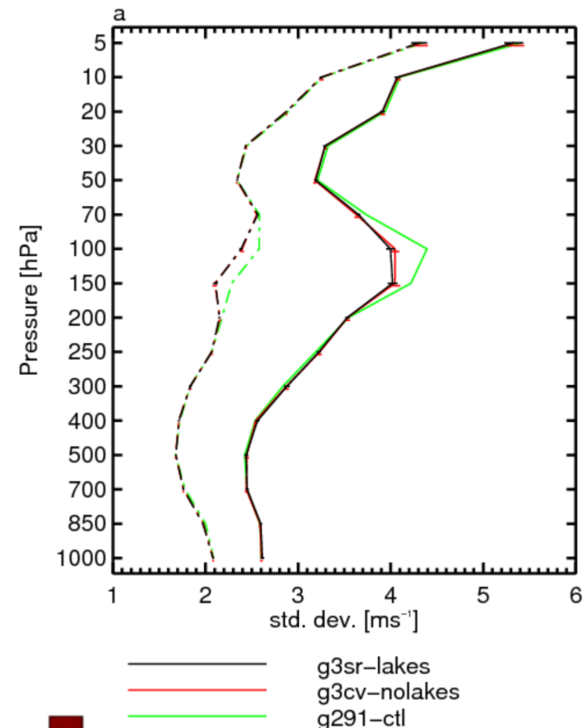
- In CY40R3 forecast of 2m temperature are improved in proximity of lakes and coastal areas
- Winter RMSE impact is positive as well but around 1% improvement
- In summer the impact is estimated in 2-3% relative improvement in RMSE of T1000hPa significant up to 7 days
- In summer also the Z500 mean error is reduced

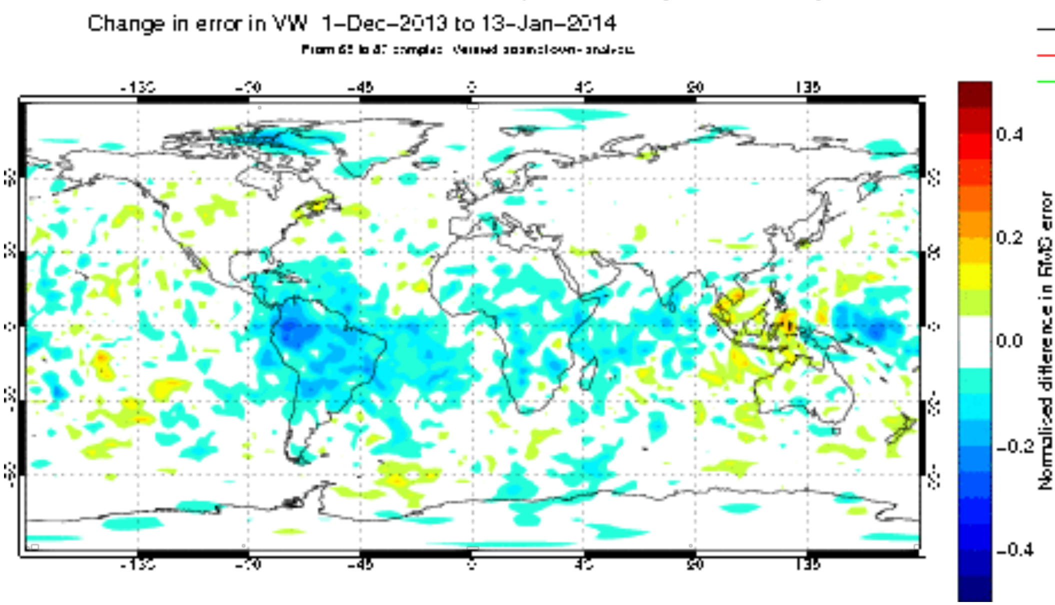


Organized detrainment and momentum transport: 40r3

Positive and complementary contribution by convection and cloud scheme on upper tropospheric wind, T.







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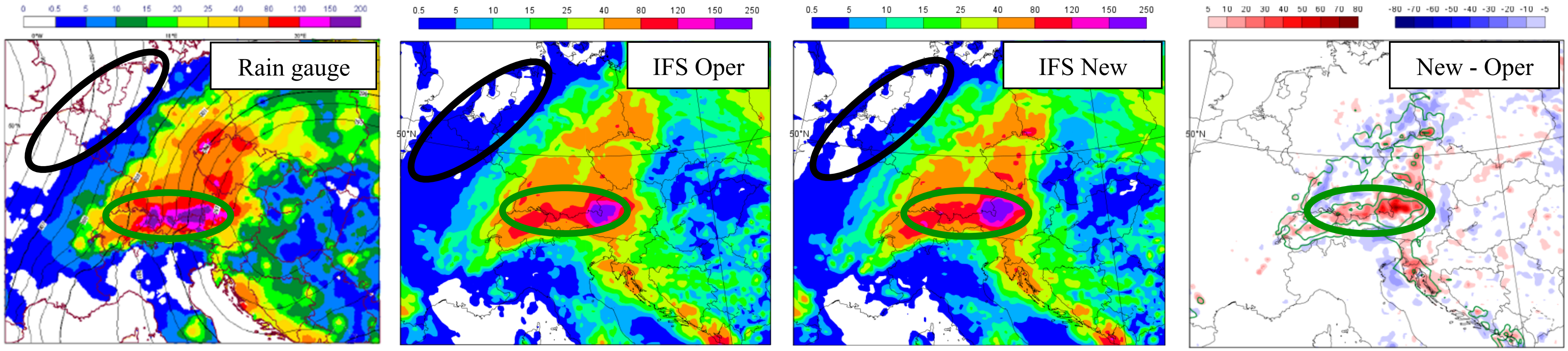
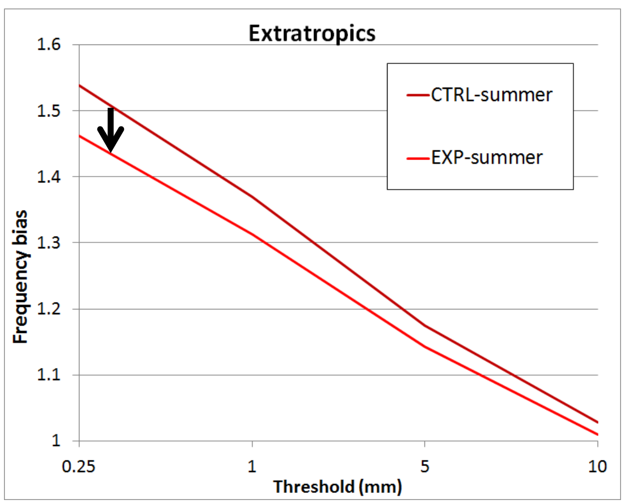
Improving the PDF of precipitation (40r3)

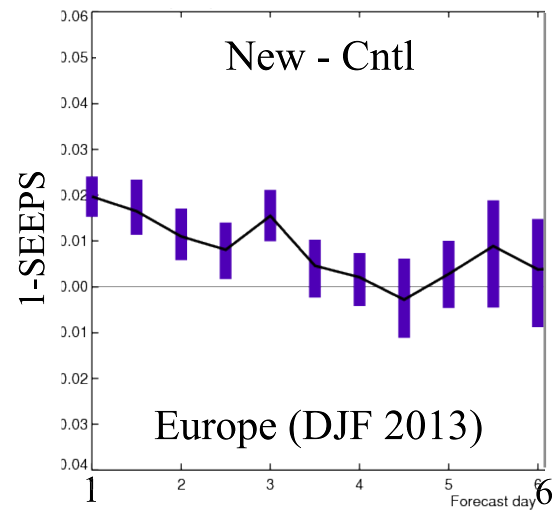
Central European floods 2013, 72 hour precipitation accumulation (mm) (31 May - 02 June)



- 10% decrease in light precipitation frequency bias
- 10% increase in orographic precipitation in flooding events (closer to observed)
- Improvement in precipitation skill (2%) in short-range over Europe

Precipitation frequency bias reduction (extratropics summer 2013)

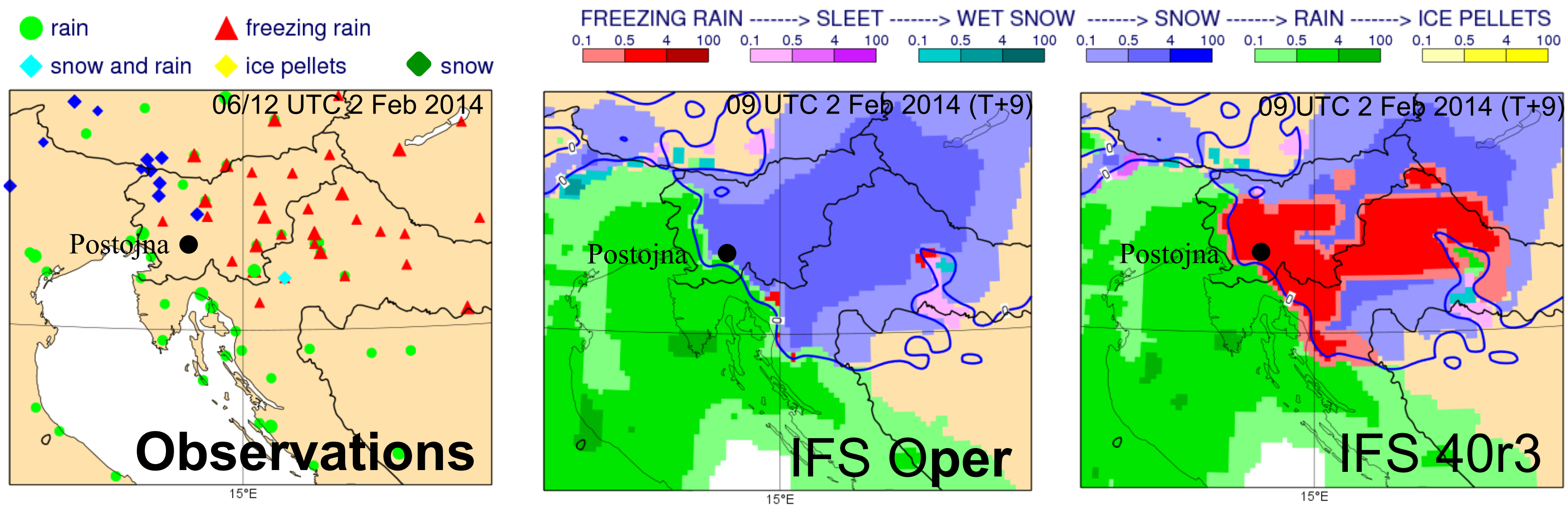




Increase in precipitation skill score in days 1-3

Towards predicting high-impact freezing rain events (40r3)

- Freezing rain can cause severe disruption and damage, tranports/power/forests…
- Case Study: Slovenia/Croatia early Feb 2014
- Current IFS physics not able to predict
- New physics in 40r3 allows prediction of freezing rain events
- Initial evaluation in HRES and ENS shows potential for useful forecasts
- Article in EC Newsletter Autumn 2014

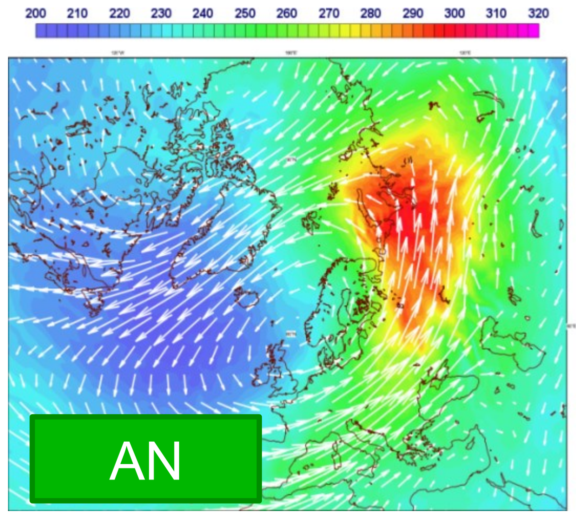


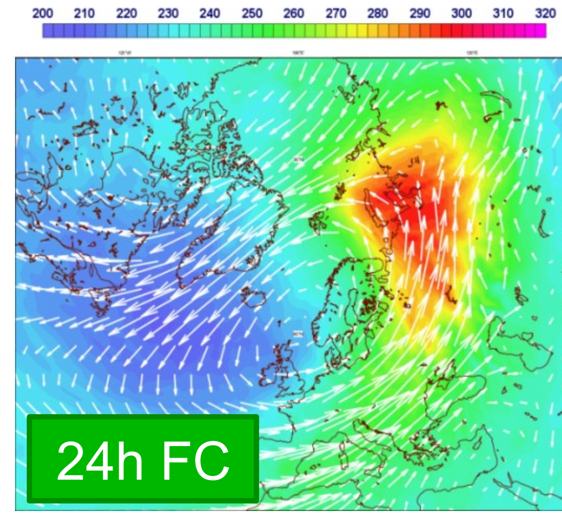
ECMWF

Sudden stratospheric warming: T at 5hPa

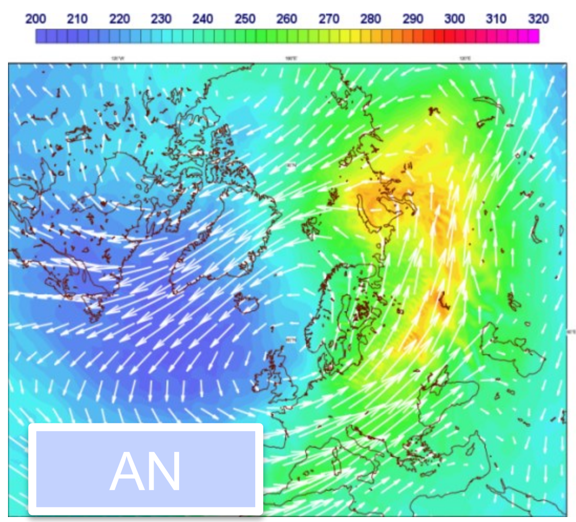
Revised SETTLS scheme:
1st order time limiter/filter

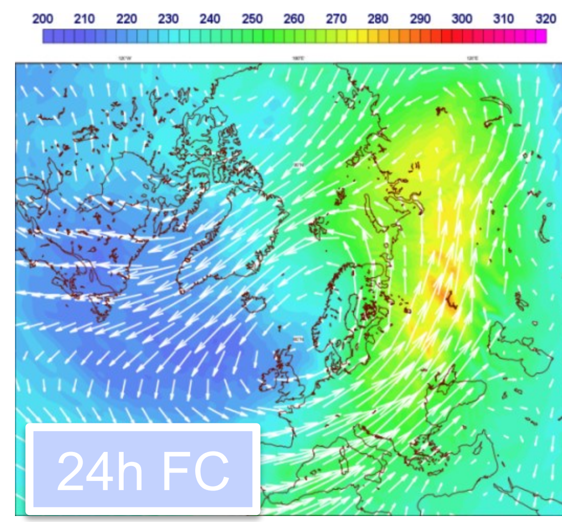
Reduces satellite data rejections





Standard SETTLS scheme





ECMWF

40r3 (end 2014/early 2015)

- Use of Altika and Cryosat altimeter wave height data
- RTTOV-11 (activated better vertical interpolation (mode 5); 54-level coefficient file for microwave sensors)
- All-sky assimilation upgrade (MHS clear to all-sky; SSMIS 183 GHz channels over land and sea-ice; AMSR2 activated and replaces SSMIS imager channels; azimuthal dependency of surface emissivity; GMI readiness)
- Assimilation of GPS-RO with 2D operator
- Assimilation of surface-sensitive ATMS channels over land; modified emissivity Kalman filter atlas
- Twice weekly 11-member reforecasts
- + . . . +bugfixes + techn. /passive changes for future upgrades

All-sky introduction

- **Microwave imagers used in clear-sky, cloud and precipitation**
  - Direct sensitivity to lower tropospheric water vapour, cloud, precipitation and ocean surface wind
  - Indirect sensitivity to winds and dynamics
  - Operational since 2009: currently assimilating SSMIS F17 and TMI
  - Operational candidates awaiting data ingestion: GMI, AMSR2
  - Biggest science issue is forecast model cloud biases
- **Microwave humidity sounders**
  - Direct sensitivity to low-to-upper tropospheric relative humidity, ice cloud and frozen precipitation; Indirect sensitivity to winds and dynamics
  - Preliminary operational implementation in 40r1 (SSMIS over oceans)
  - Full operational implementation in 40r3 (4×MHS, SSMIS over oceans, land and sea-ice)
  - Remaining 183 GHz channels to be transferred to all-sky soon (ATMS)

Impact of all-sky microwave humidity sounders and imagers -on top of the otherwise full observing system

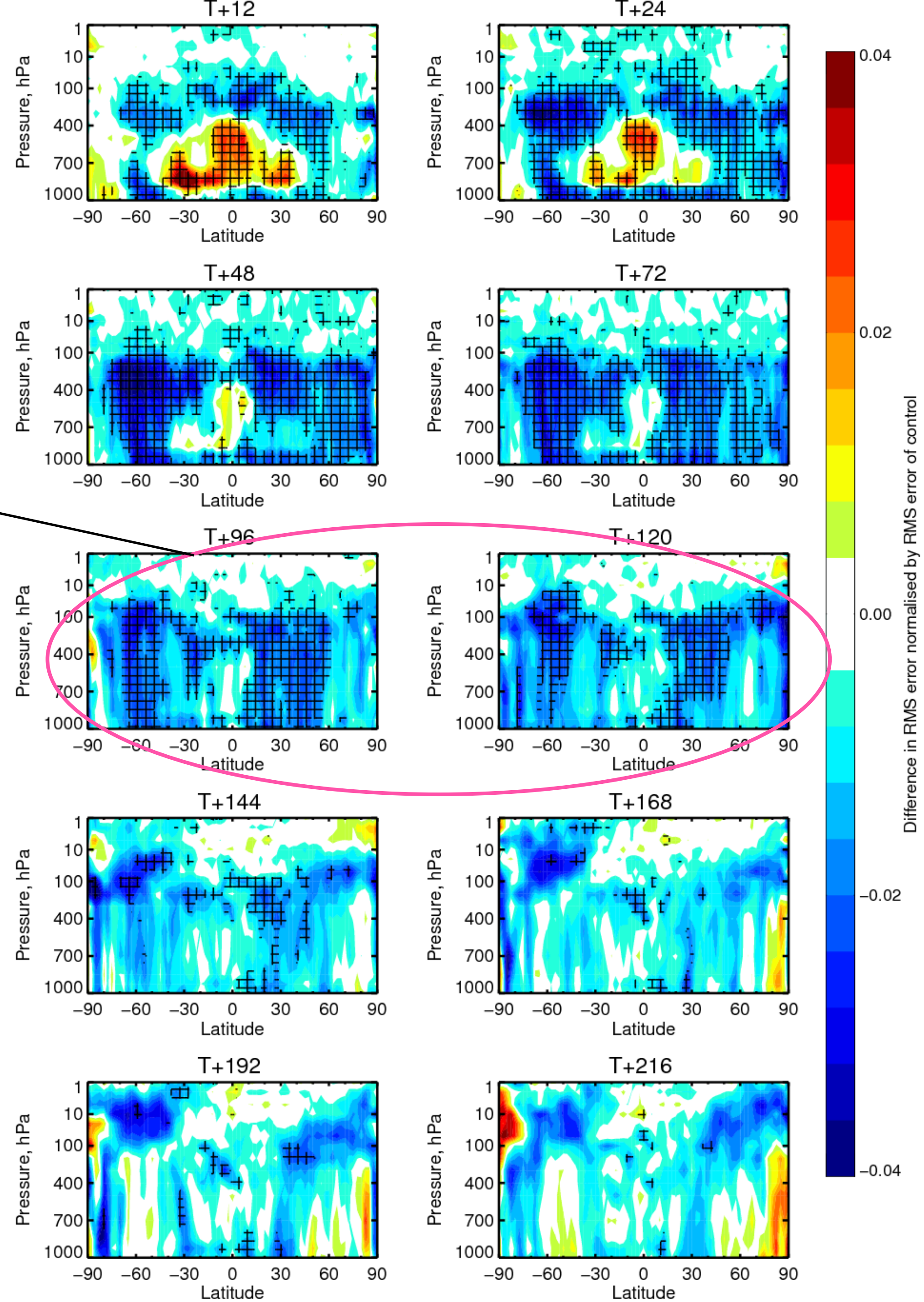
2-3% impact on day 4 and 5 dynamical forecasts

Change in RMS error of vector wind verified against own analysis

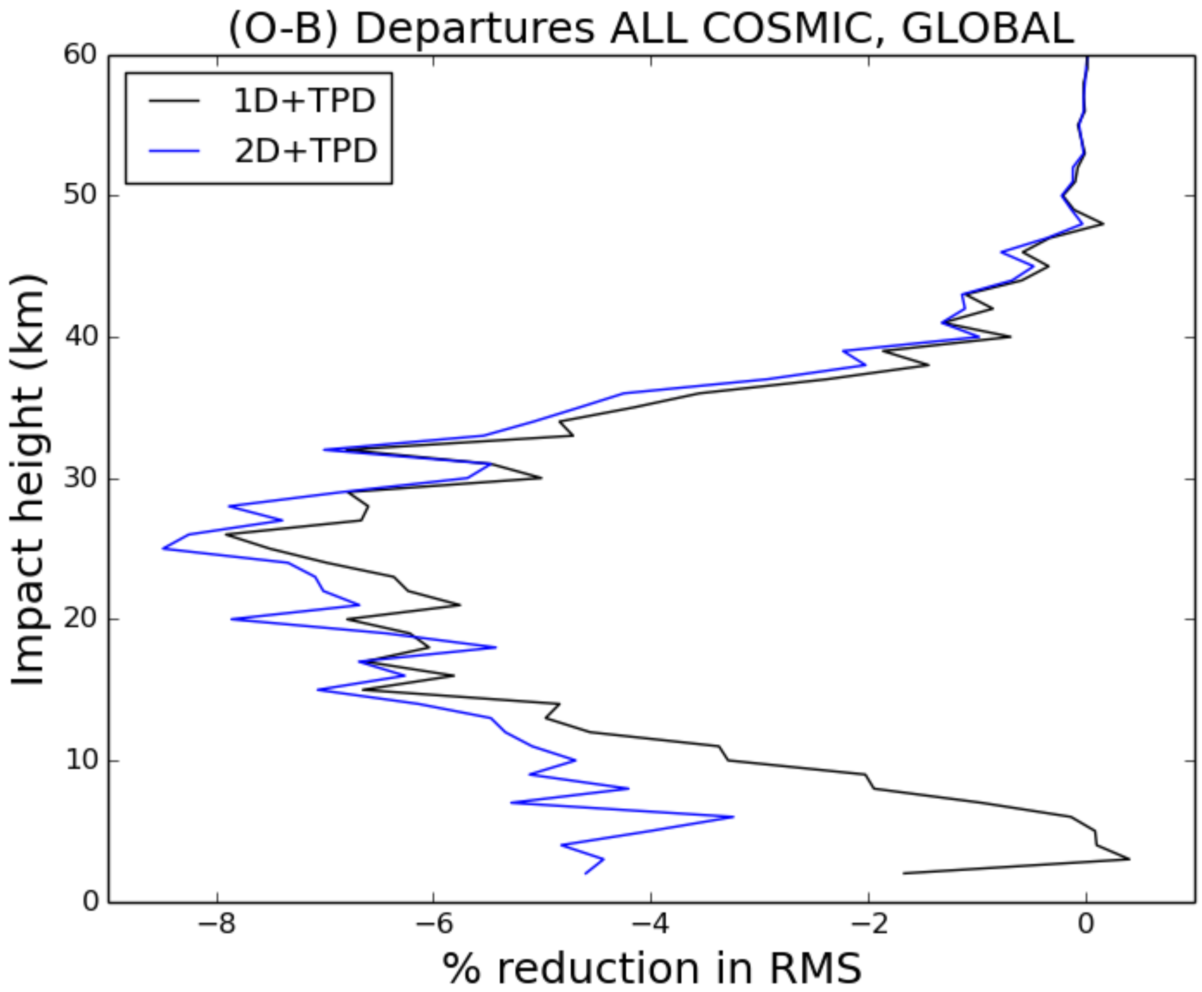
Blue = error reduction (good)

Based on 322 to 360 forecasts

Hatching indicates 95% conf.



GPS-RO: tangent point drift (37R2) and the 40R3 2D operator



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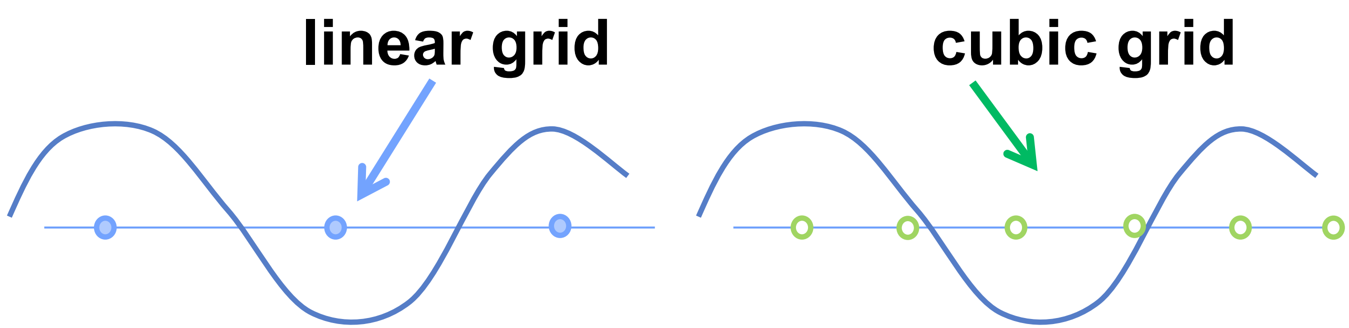
Options for resolution upgrade in 2015

- **HRES** Δx=16km (T_L1279) → Δx=8-10 km
- **AN 3 inner loops:**
  - In 40r3, T_L255-T_L255-T_L255 , i.e. Δx=80km
  - Upgrade: last inner loop Δx=40-50 km (T_L399 or T_C255)
- **EDA**
  - At present, T_L399 outer loop with T_L95-T_L159 inner loops.
  - Upgrade: T_L639 with T_L159-T_L159 inner loops

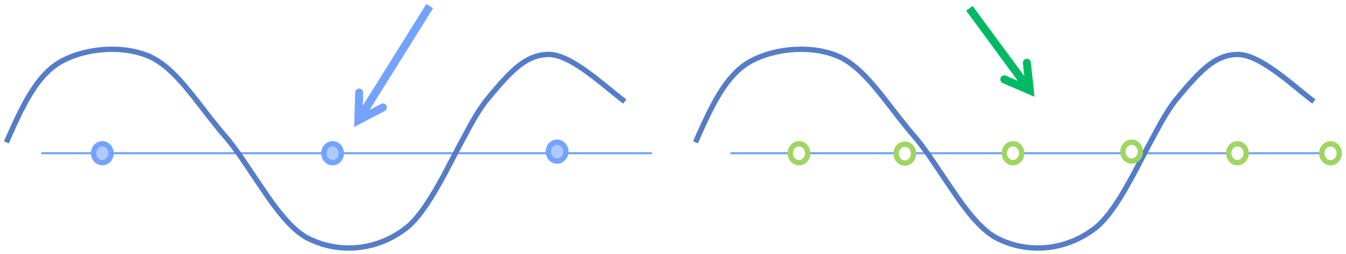


Options for IFS resolution in ENS

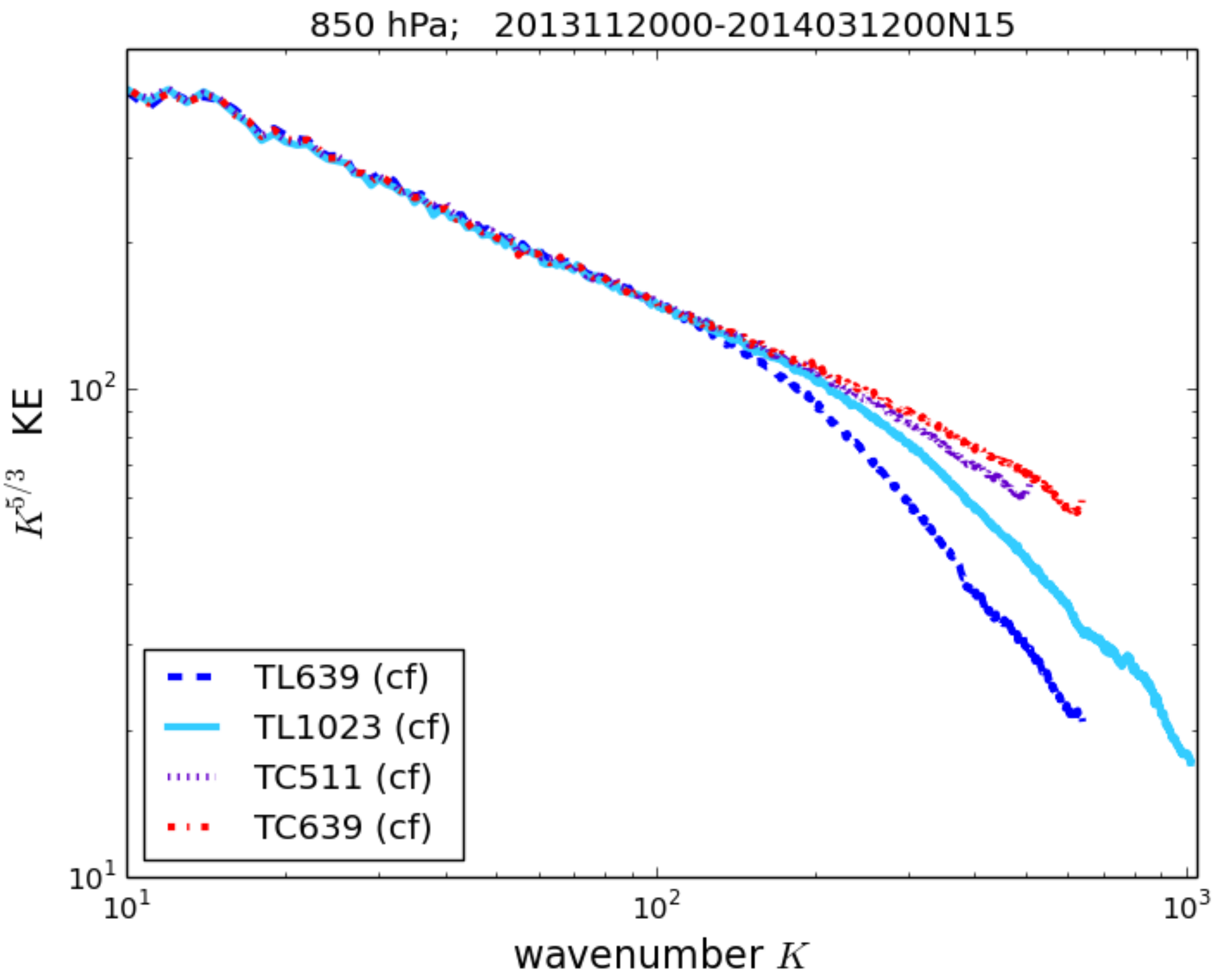
Currently, leg A: Δx=32km (T_L639), Δt=1200s

- For upgrade, Leg A consider configurations
  - T_L1023, Δx=20km, Δt=720s
  - T_C511, Δx=20km, Δt=900s
  - T_C639, Δx=16km, Δt=900s

Where T_L refers to linear grid and T_C to cubic grid, respectively



- Leg B → decision should be driven by extended-range forecast needs


850 hPa; 2013112000-2014031200N15
$K^{5/3}$ KE
10^2
10^1
10^1
10^2
10^3
wavenumber K
TL639 (cf)
TL1023 (cf)
TC511 (cf)
TC639 (cf)

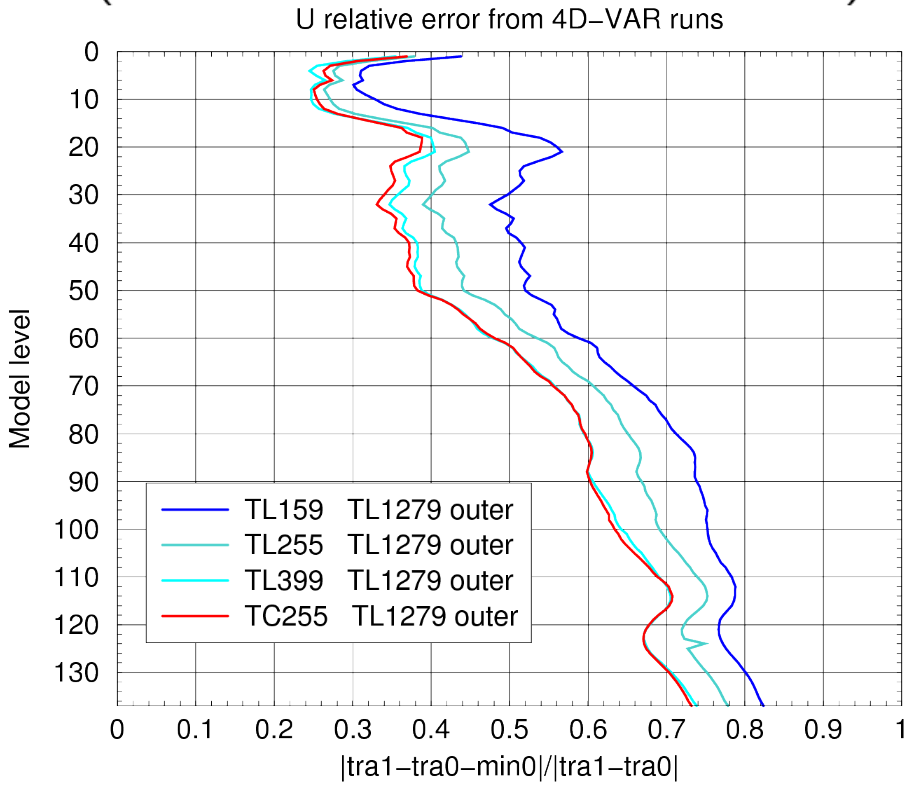
TL approx. error and inner loop resolution

- Direct measure of total analysis algorithm linearity/convergence is

$$4V{-}AN = \mathcal{M}(x^{n-1}+S^{-1}(\delta x^{n-1}))-\mathcal{M}(x^{n-1})-S^{-1}(M_{TL}(x^{n-1})\delta x^{n-1})$$

- TL tests of incremental 4D-VAR: constant outer loop, variable inner loop resolution. Higher resolution inner loops give more accurate TL approximation (see details in TM's 399 and 467).

Model level



Zonal wind: relative error of TL for the increment of first minimisation

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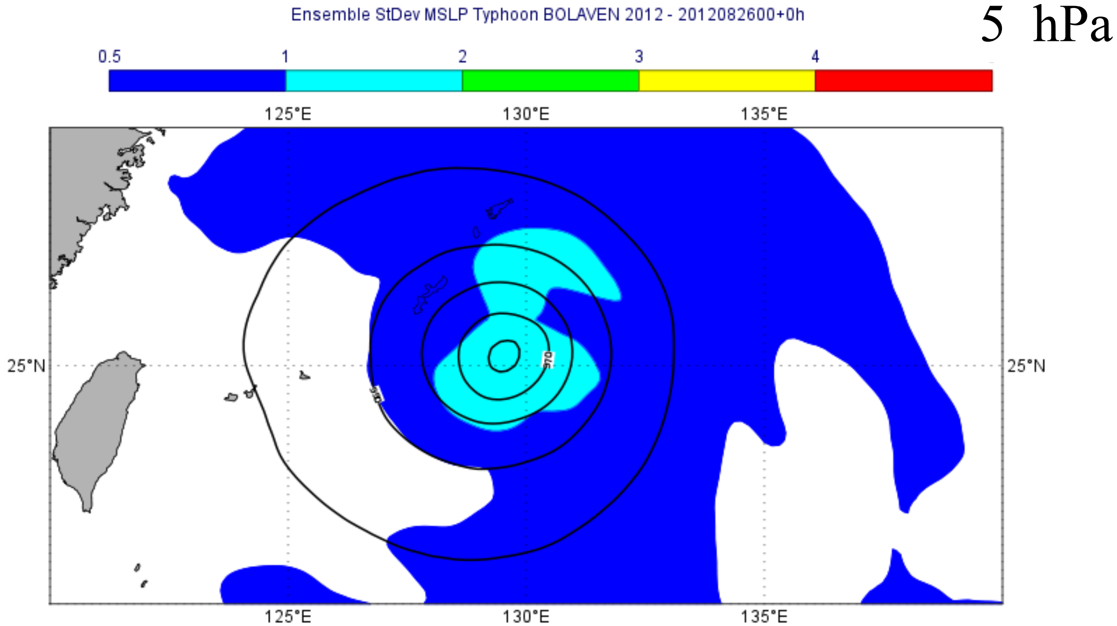
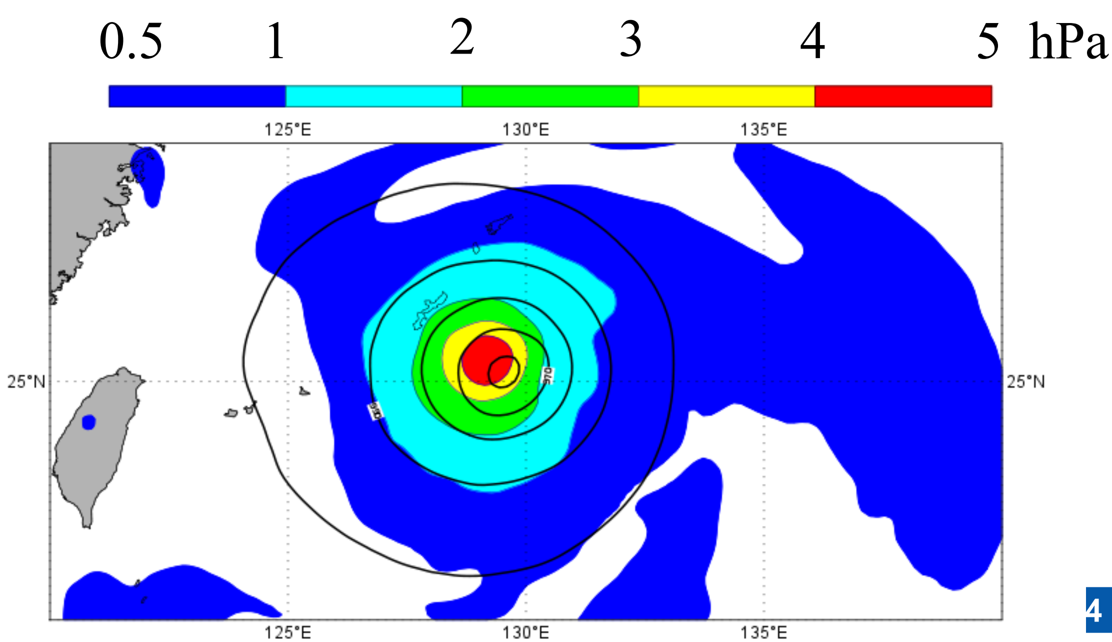
Typhoon BOLAVEN– MSLP ENS StDev at initial time



26 August 2012, 0UTC

Ensemble with perturbations from T_L399 EDA



Ensemble with perturbations from T_L639 EDA

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Rewriting of moist boundary-layer: Rationale

- have a much simpler and maintainable code, have the same updraught in BL scheme and shallow convection

- avoid use of a 2nd cloud scheme (diagnostic and inconsistent)

- *avoid iterations and speed up performance (8% in total forecast time)*

- *possibly improve model performance (also for S5) and make long-term developments more feasible (mixed-phase, other moist turbulent developments, remove also iteration in callpar)*

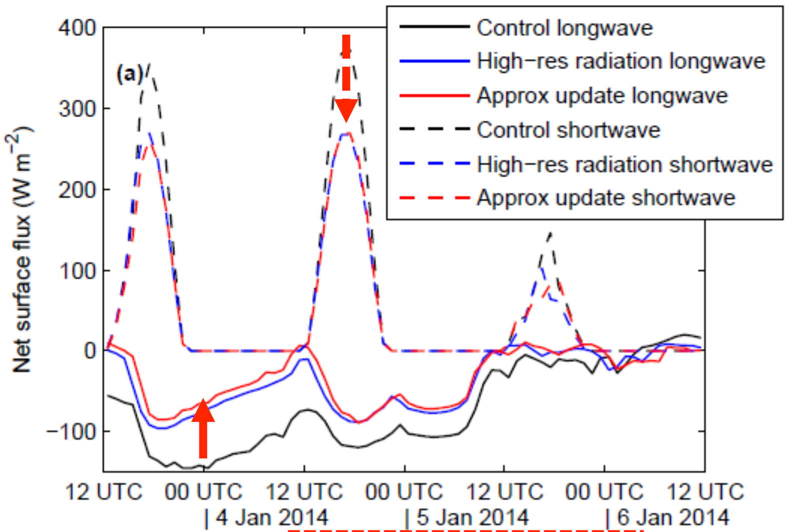
- *easier job for TL/AD physics*

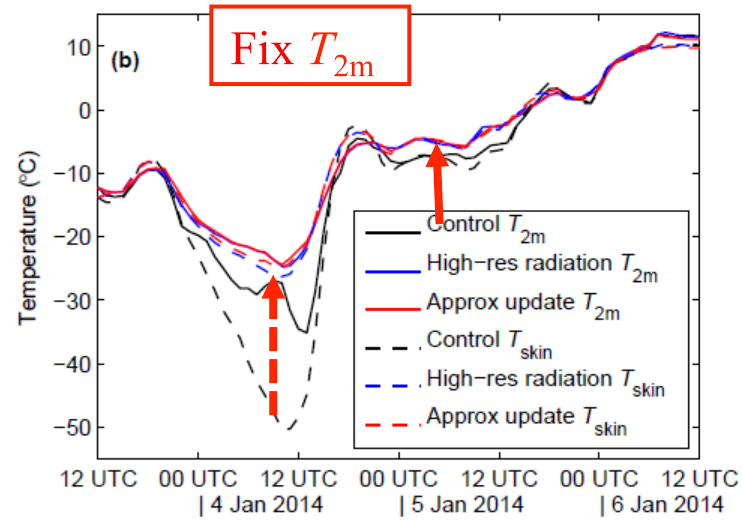
Approximate radiation updates

- **Problem – radiation called infrequently in time and space leading to coastal temperature errors due to:**
  - ***Longwave*** **– sea skin temperature applied to land: too cold at night**
  - ***Shortwave*** **– sea albedo applied to land: too warm in the day**
- **Solution – approximate radiation updates:**
  - ***Longwave*** **– compute $dL^{\uparrow}(z)/dL^{\uparrow}_{surf}$ exactly in radiation scheme, then use to update profile of longwave upwelling flux $L^{\uparrow}$ and heating rates every timestep and gridpoint according to local surface temperature.** ***Gives exactly what would be given by full scheme if atmospheric properties held constant.***
  - ***Shortwave*** **– use upwelling and downwelling fluxes at TOA and surface to compute atmospheric broadband** ***transmittance*** **and** ***reflectance*****, and use these to update surface up- & downwelling fluxes according to local albedo.** ***Doesn't just increase surface upwelling with increased albedo: accounts for extra back-reflection from the atmosphere.***

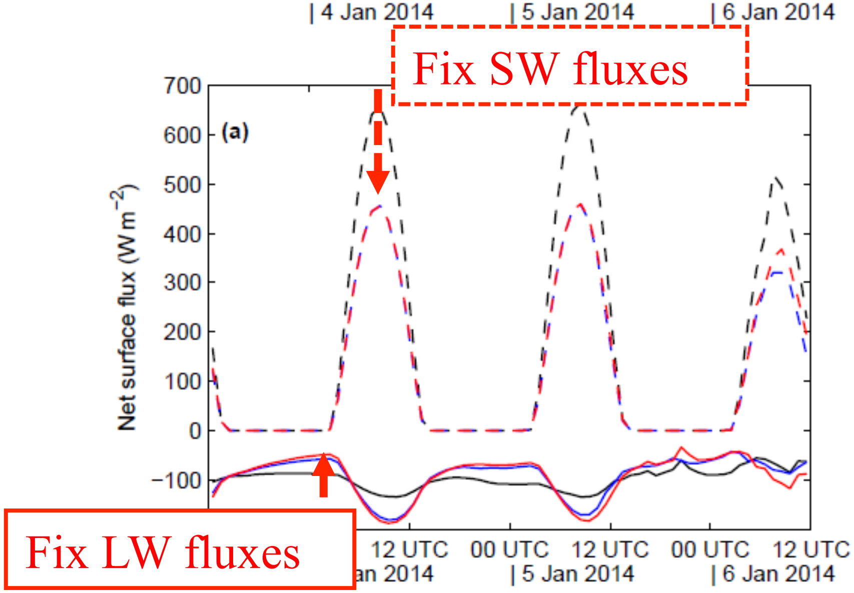
Net surface fluxes Temperature

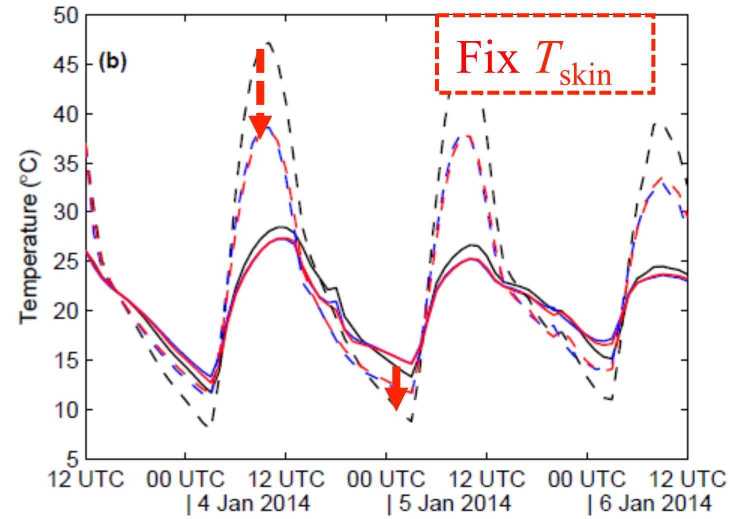
Long Island





Oman





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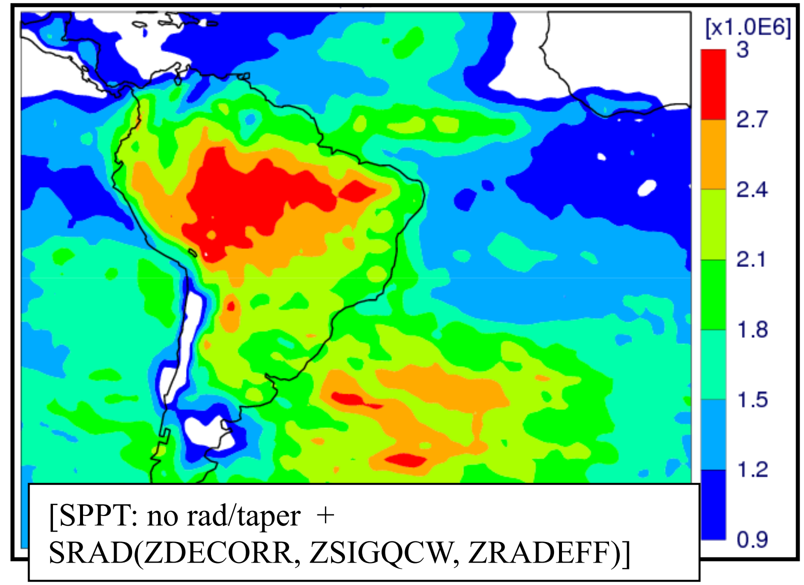
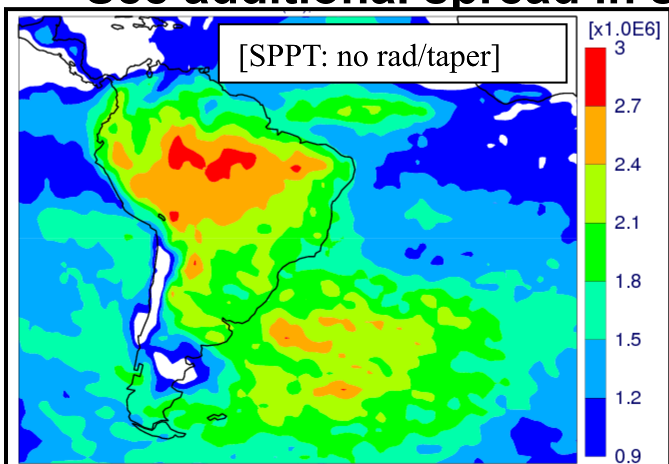
Effect of perturbed parameters in McICA

Impact of perturbing cloudy-skies parameters in McICA:

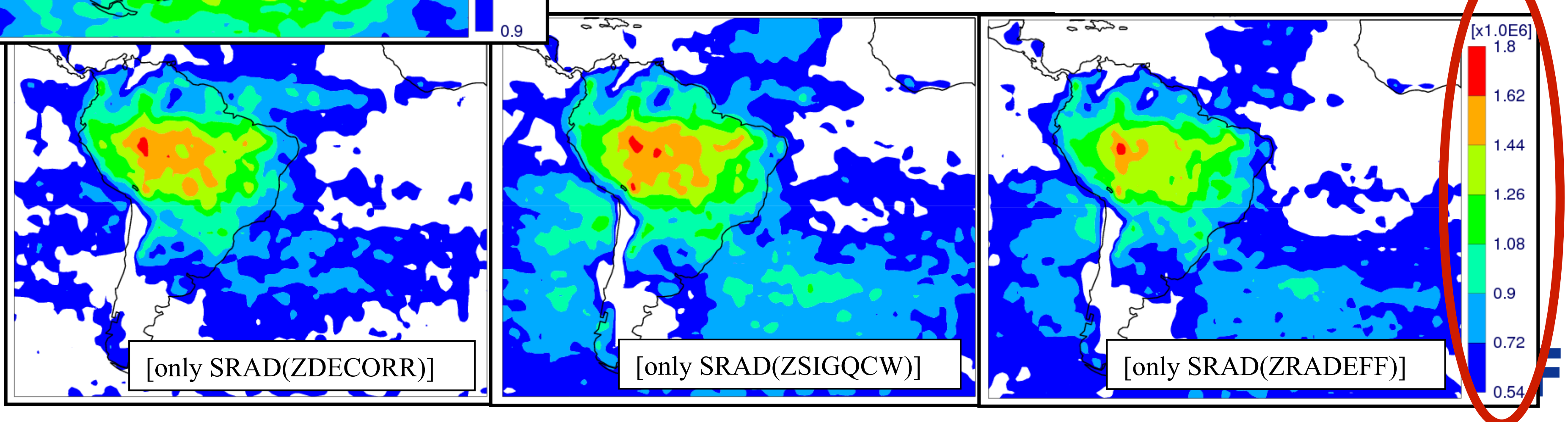
(From 30 boreal winter dates, 20 member ensembles:)

- **Standard upper-air variables: little significant effect over [SPPT: no rad/taper]**
- **See additional spread in surface fluxes**





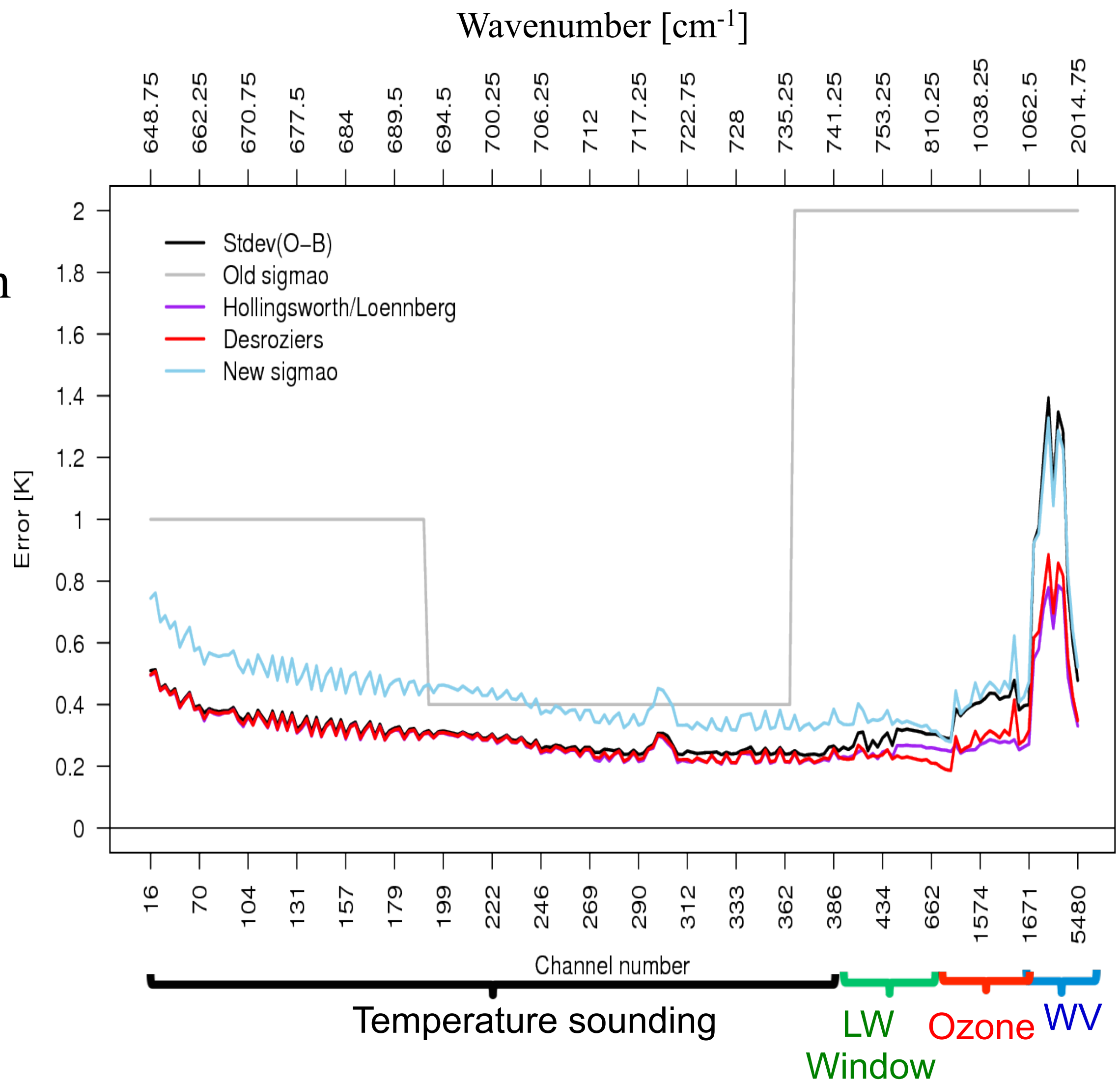
e.g. spread in surface dwnd solar radiation, t+36h to t+42h (J m^{-2})



Thank you for your attention!

IASI: σ_o

- **Rationale:** Use departure diagnostics to specify observation error covariance R



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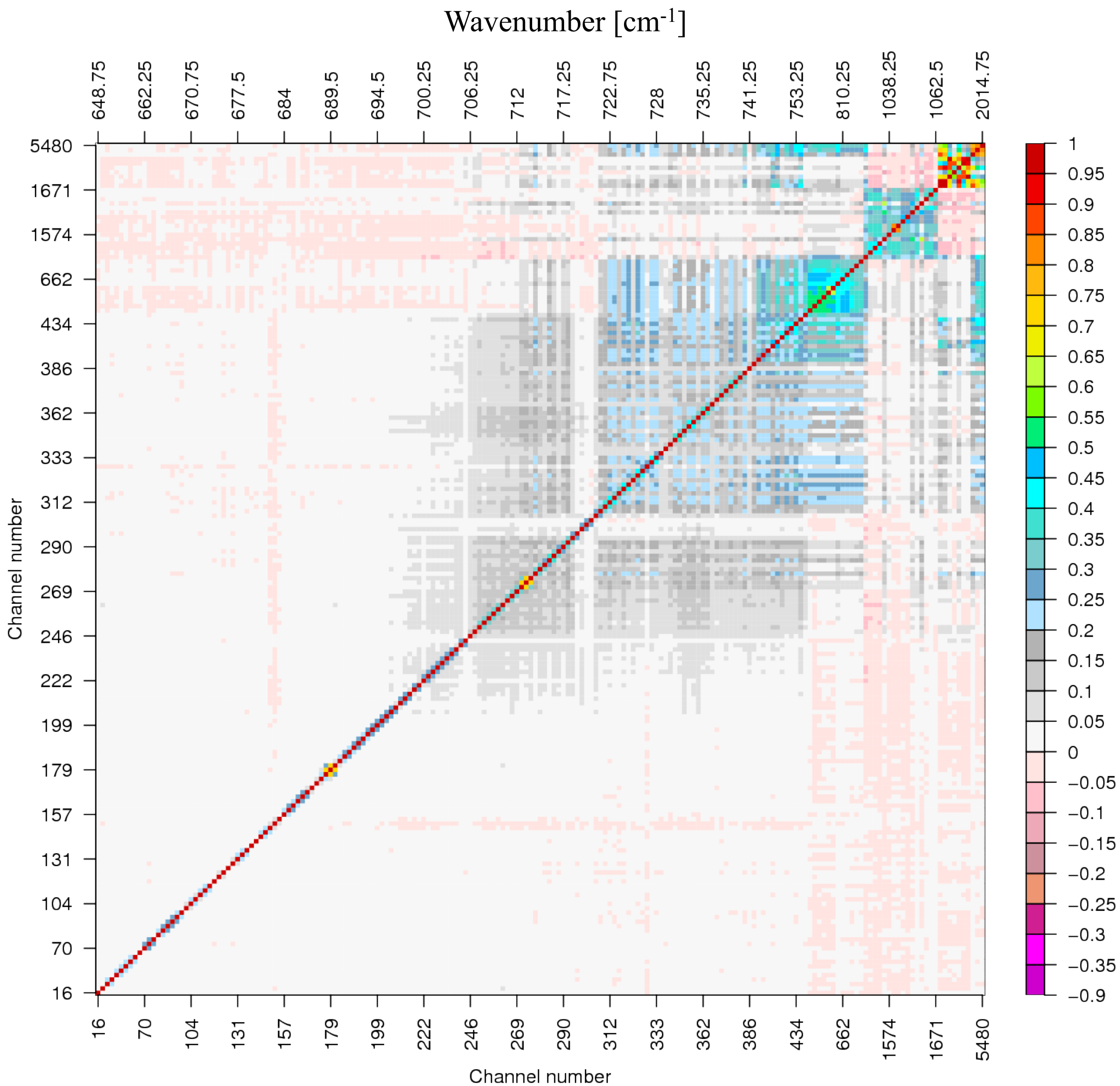
IASI: Inter-channel error correlations

- **Rationale:** Use departure diagnostics to specify observation error covariance R, including inter-channel error correlations



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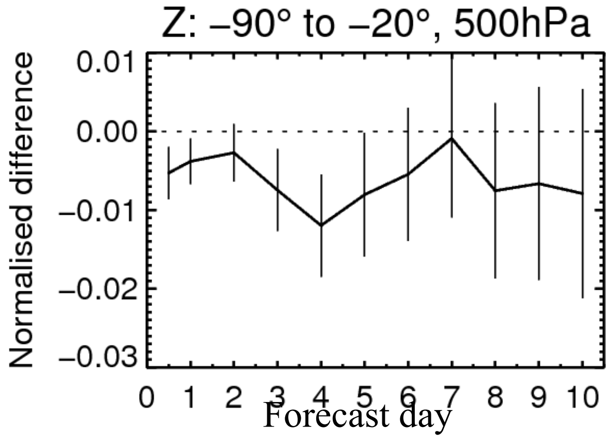
Forecast impact: Updated R for IASI and AIRS

(ie new σ_O + correlations vs operational σ_O without correlations)

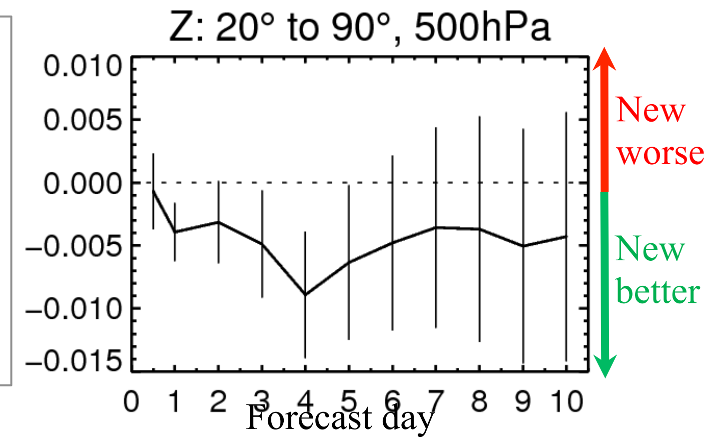
Significant positive forecast impact.

S.Hem.

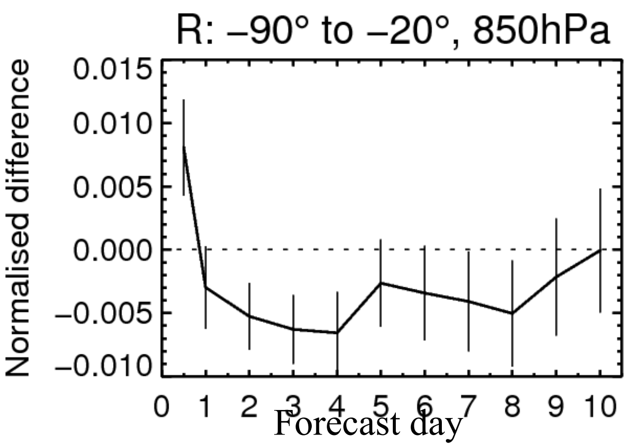
N.Hem.

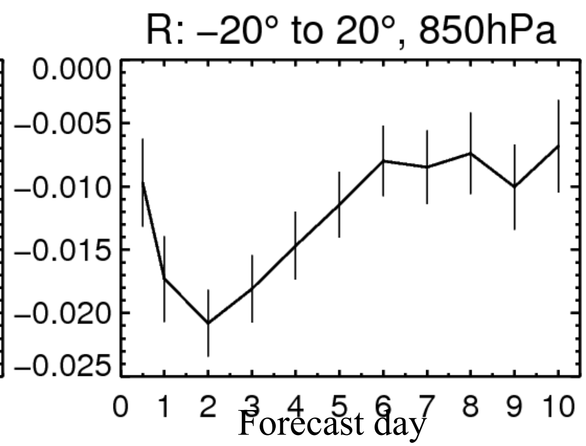


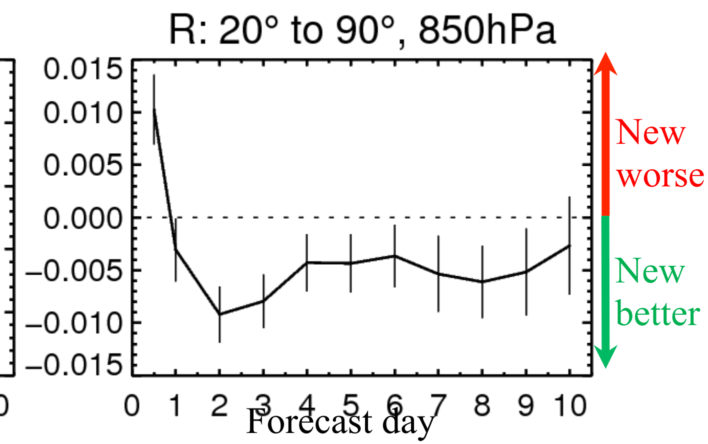
Normalised RMSE differences over 6 months: Aug-Oct 2013; Jan-Mar 2014, (vs own analysis)



Tropics

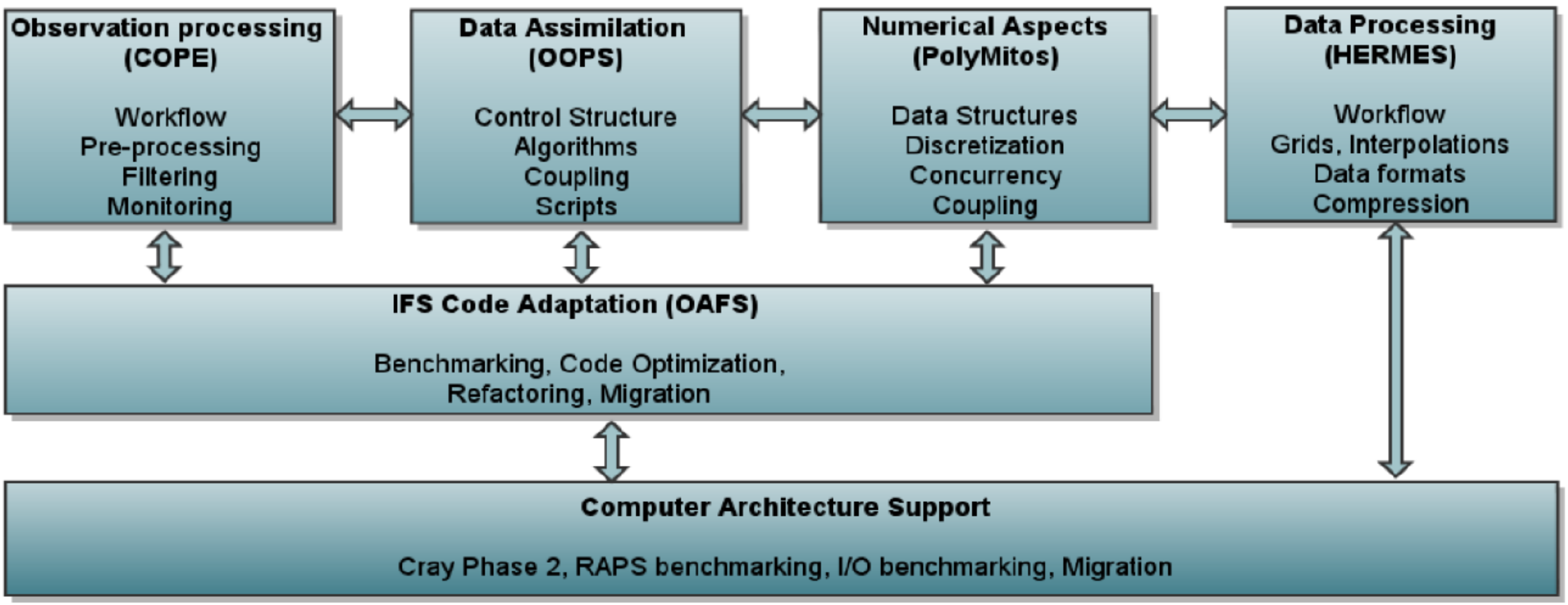






ECMWF

Scalability project



Goal: Implement a formal structure at ECMWF to coordinate science and software activities across departments for efficient exa-scale computing/archiving.

Land Data Assimilation System

LDAS exploits multi-sensors **satellite** remote sensing combined with ***in-situ*** for spatially integrated land water reservoirs monitoring & analyses (e.g. NWP/Climate applications)

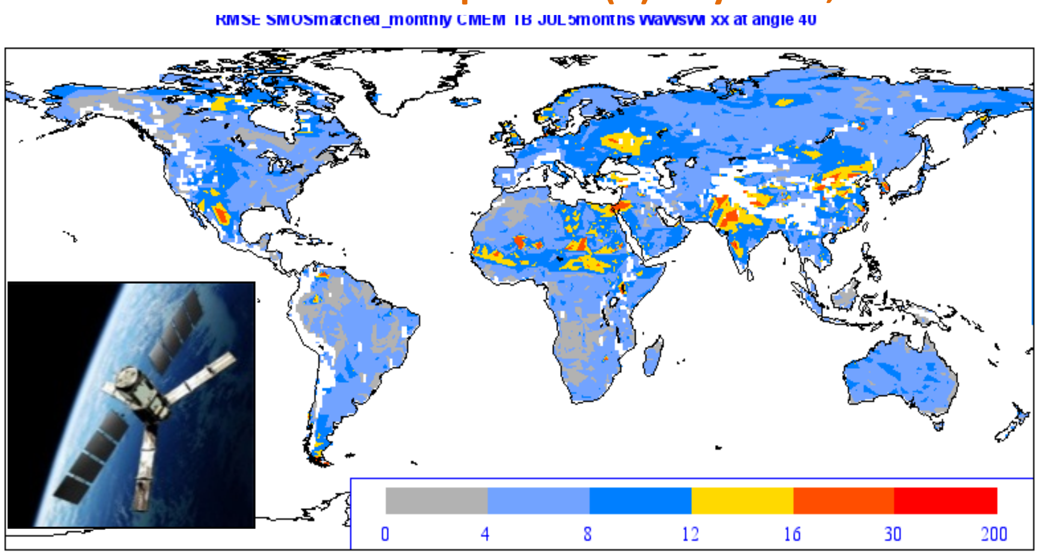
For soil moisture

- SYNOP *In-situ* T2m and RH2m; Satellite Scatterometer data (ERS/SCAT, MetOp/ASCAT), Passive microwave SMOS.

For snow

- SYNOP in-situ depth and multi-sensor NOAA NESDIS/IMS product on cover

SMOS TB First Guess Departure (K) July 2012, RMSD=6.7K



Future missions relevant for Land

Water cycle

- SMAP Active-passive MW (2014) and SWOT altimetry (NASA/CNES - 2020) highly relevant for Soil moisture and Sentinel-3 snow cover

Energy cycle

- METOP and MTG LSTs

Carbon cycle

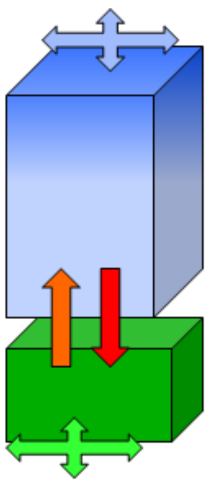
- Sentinel 2 (LAI/Albedo), BIOMASS

In-situ networks for snow, temperature, soil moisture, and fluxes important also for verification

Land Surface processes and error representation

Improving the realism of soil, snow, vegetation and lakes parameterisations has been subject of several recent research efforts at ECMWF. These Earth surface components work effectively as **energy and water storage** terms with **memory** considerably longer than the atmosphere counterpart.

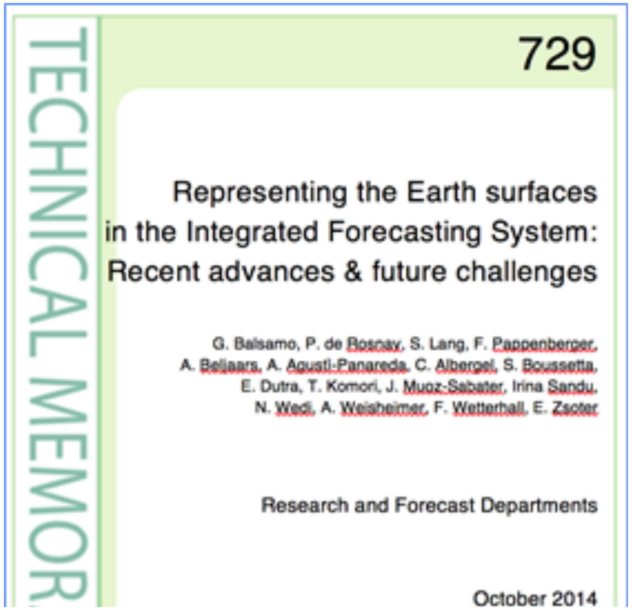
Their role regulating land-atmosphere **fluxes** is particularly relevant in presence of large weather and climate anomalies (i.e. extreme events)



$$(\rho C) D \frac{\partial T_s}{\partial t} = R_n + LE + H + G$$

$$\frac{\partial TWS}{\partial t} = P + E - R$$

$$\frac{\partial CO2^A}{\partial t} = GPP + \mathrm{Re} + A$$



TECHNICAL MEMOR

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Representing the Earth surfaces in the Integrated Forecasting System: Recent advances & future challenges

G. Balsamo, P. de Rosnay, S. Lang, F. Pappenberger, A. Beljaars, A. Agusti-Panareda, C. Albergel, S. Boussetta, E. Dutra, T. Komori, J. Muoz-Sabater, Irina Sandu, N. Wedi, A. Weisheimer, F. Wetterhall, E. Zsoter

Research and Forecast Departments

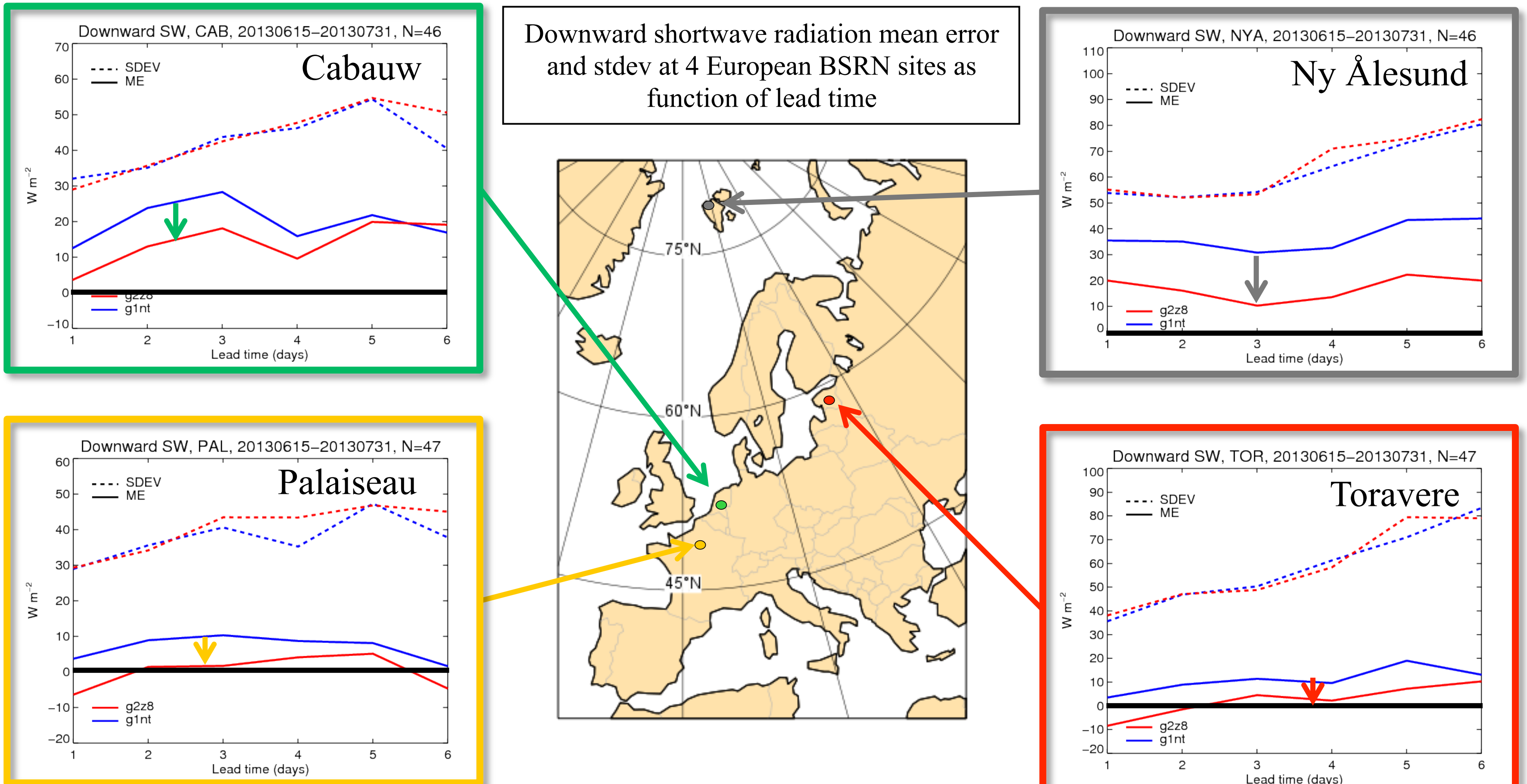
October 2014

Validity for H_2O / E / CO_2 cycles: surface R&D directed towards improved **storages** and **fluxes**

Reducing systematic errors in surface radiation (40r3)

- Long-term systematic errors in surface radiation (SWdown too high, LWdown too low)
- Part of this is due to too little cloud over land
- Changes to warm-rain processes in 40r3 increase liquid water path over land
- Evaluation at BSRN stations shows reduction in both SW and LW bias

Downward shortwave radiation mean error and stdev at 4 European BSRN sites as function of lead time

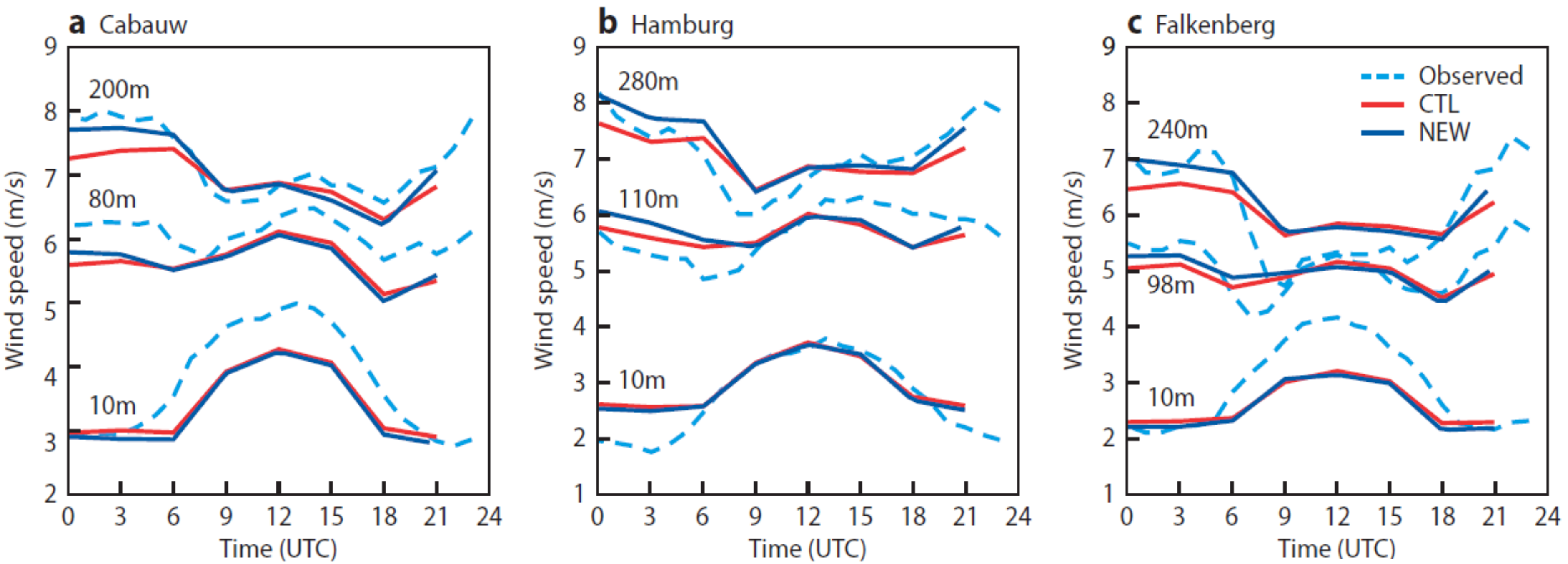


ECMWF

Improvement of low level winds

Comparison with tower data, T511L137 analysis runs, JJA 2012

Cabauw Hamburg Falkenberg



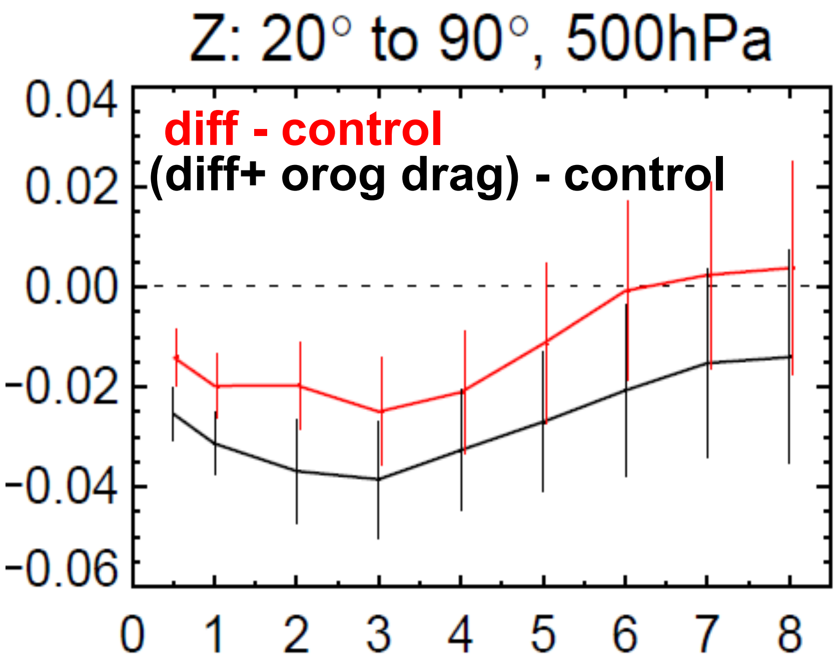
Sandu et al, ECMWF Newsletter 138

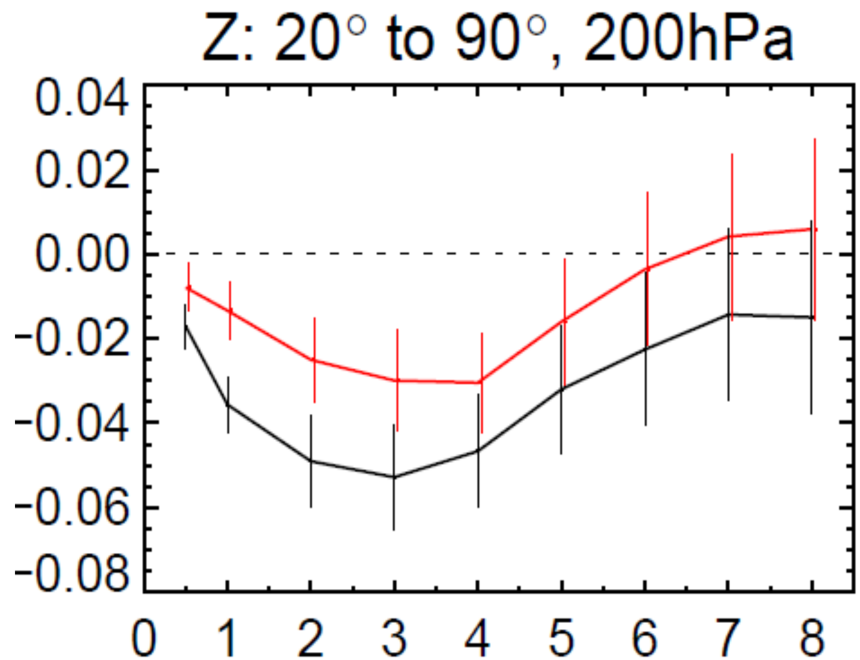
Improved low level jet and improved amplitude of the diurnal cycle at that level

Changes implemented in 40R1: results

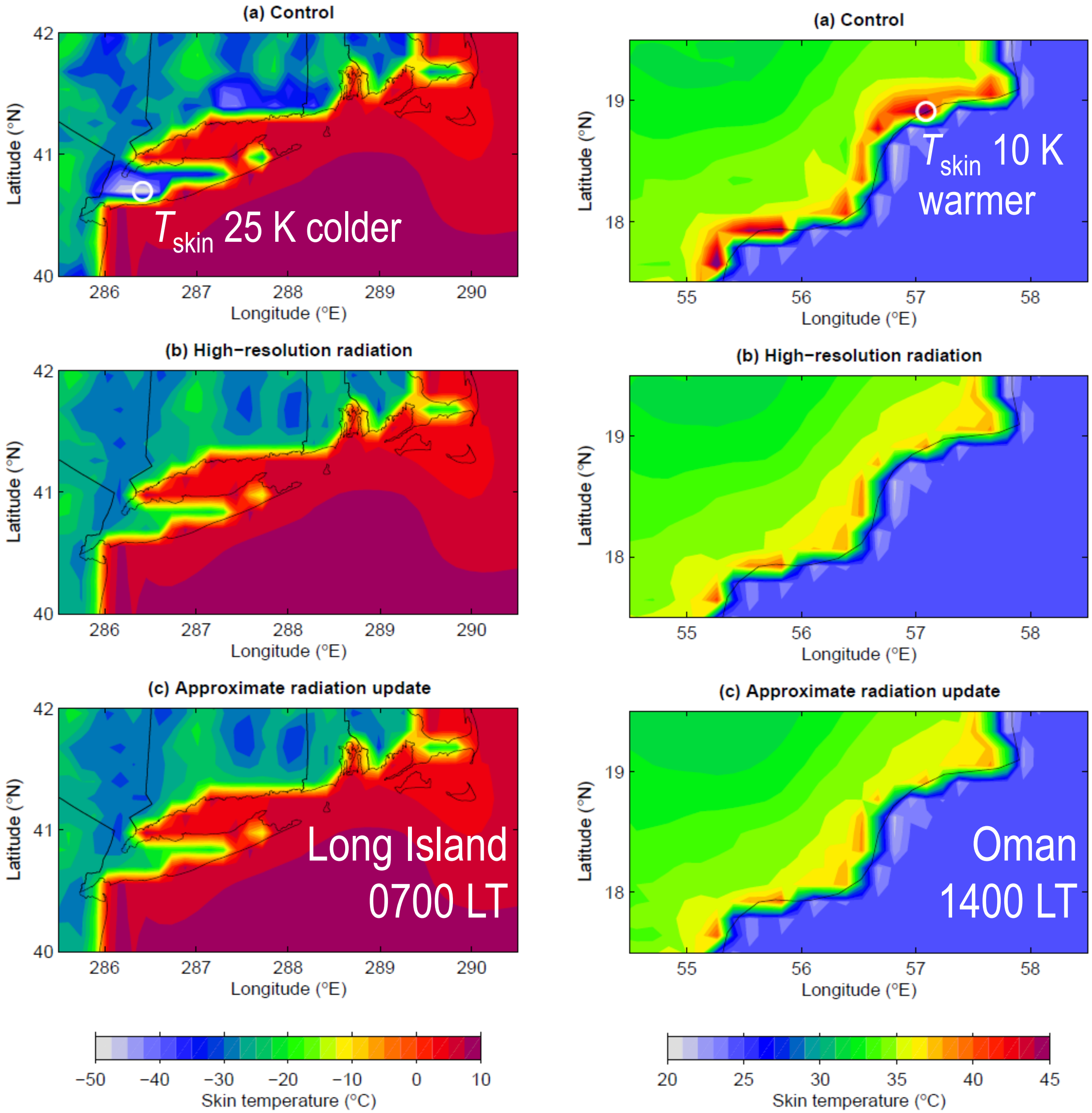
- small changes in 2m temperature during night time in winter (~0.1 K over Europe)
- Reduction of wind direction bias over Europe by 3° in winter, 1° in summer (out of 10°)
- Improvement in low level jets (next slides)
- Improvement of the large-scale performance of the model in winter N.Hemisphere
- Deterioration of tropical wind scores (against own analysis, not against observations!)

Change in RMSE of geopotential height (Jan-March 2012)





T1279 case study on 4 Jan 2014: T_{skin}

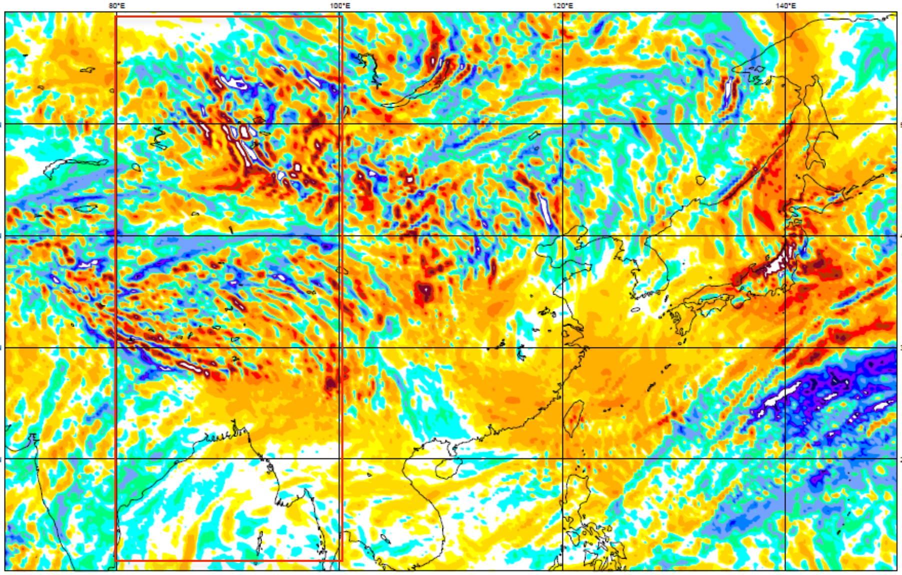


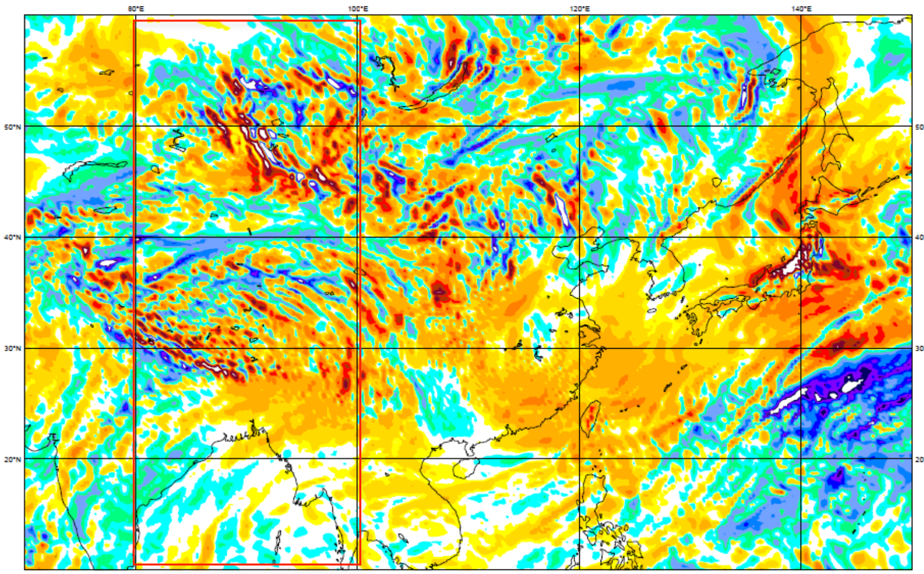
- **Control: radiation at T639/every 1-hr**
  - ***Radiation 12.5% of model time***
- **Radiation every timestep/ gridpoint**
  - ***Radiation 12 times more expensive***
- **New scheme**
  - ***Radiation 2% more expensive***

Grey zone is not only about convection!

w, T2047, Level 96

w, T1279, Level 96

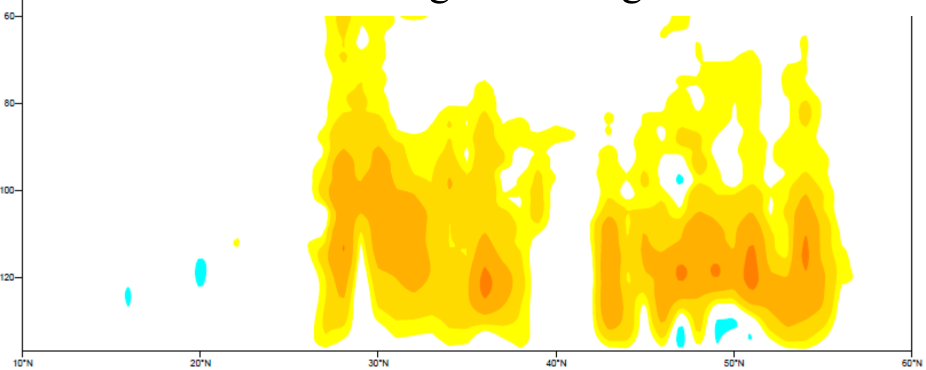


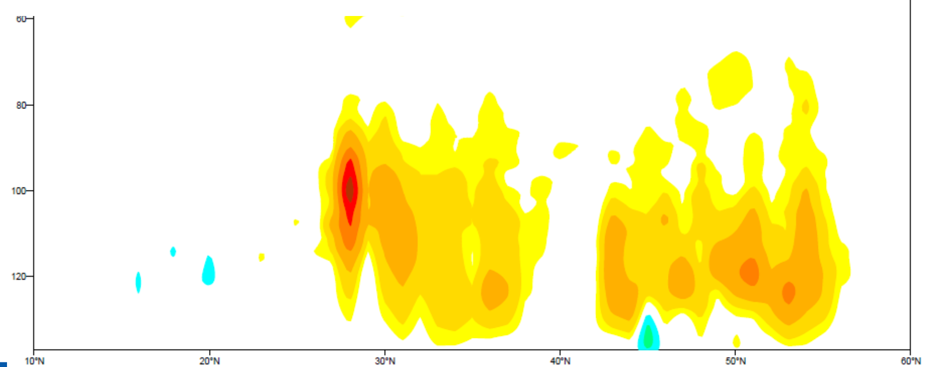


Momentum flux u'w' by scales smaller than T159, cross section 10^o-60^oN averaged over 80^o-100^oE

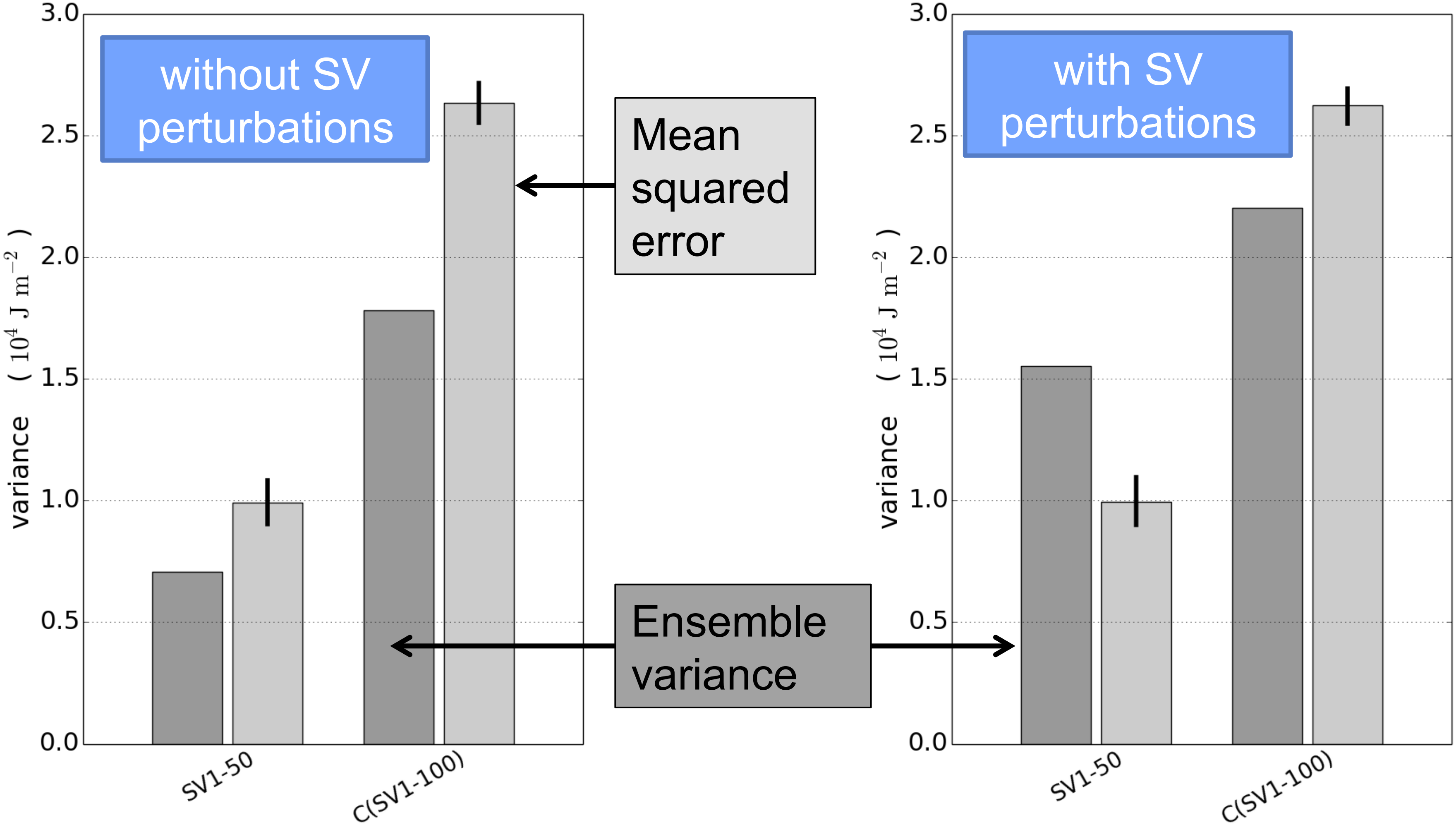
The increasingly resolved gravity waves at high resolution :

- affect 2T night time forecasts by introducing a resolution dependence in the parametrized turbulent diffusion
- exert drag on the large scale flow





Ensemble variance and singular vectors



Leutbecher, M. and Lang, S. T. K. (2014), On the reliability of ensemble variance in subspaces defined by singular vectors. *Q.J.R. Meteorol. Soc.*, **140,** 1453–1466.

ECMWF