Data Assimilation and Observing Systems Working Group report

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Two parts

- Promoting best practices for weather-climate prediction system development: a new WGNE activity [unrelated to DAOS]
- DAOS report [which I'll gloss over to get to discussion material]

Promoting “best practices” for model system development: a new WGNE activity?

Visit the main page

WIKIPEDIA
The Free Encyclopedia

Best practice

From Wikipedia, the free encyclopedia

A **best practice** is a method or technique that has consistently shown results superior to those achieved with other means, and that is used as a benchmark. In addition, a "best" practice can evolve to become better as improvements are discovered. Best practice is considered by some as a business buzzword, used to describe the process of developing and following a standard way of doing things that multiple organizations can use.

What are the best practices for weather and climate model system development?

Is there a need to define best practices for model development?

- It takes years 5-10 years of work to become really proficient in even one particular aspect of model development.
- Newcomers will:
  - boldly charge down blind alleys already groped by previous scientists.
  - will apply diagnostic tools that are out of date, or inappropriate.
  - will not compare their results against useful reference standards.

What might be some areas where best practices could be defined?

- **Define where to start** – for given aspect of the prediction problem, define the standard simple models to try your ideas out in before using WRF or GCMs.
- **Standardized diagnostics and benchmarks**
  - Define the most common, most helpful ways of displaying diagnostics that indicate whether you're getting a realistic result.
  - Makes published results more relevant and readable, as they can then be compared against prior work more readily.
- **Document the blind alleyways** - the ideas that have been explored, with negative results, but not extensively documented.
- **Software tools** that will make it easier to get started, that facilitate code maintenance, reusability.
  - single-column model physics (thanks Robert Pincus!) e.g., GASS, GCSS.
- **Define organizational best practices for model development**
  - How to set strategy and priorities, allocate resources.
  - How to manage the model development process.
  - How to use the review process to improve
  - Documentation standards (web, peer-reviewed articles)
- Your ideas.

Expected benefits

- Young scientists will become proficient more quickly.
- Established scientists that wish to switch from one area of expertise to another can do so more easily.
- Some mentors are better than others. Less accomplished mentors will have a new resource for their protégés.
- More rapid progress in weather and climate prediction development.

Some possible WGNE activities to promote best practices

- **Informal**: put together a wiki page, invite relevant scientists to add material.
- **More formal**:
  - Organize WMO or NCAR summer school, with invited speakers for data assimilation, dynamical core development, various parameterizations, etc.
  - Collect notes and publish a book. Subject-matter experts each responsible for their own chapter.
- **Formal**: a semi-permanent WGNE sub-group or WMO group to coordinate, conduct interviews, synthesize material.

Questions to consider

- Is it worth doing?
- How to engage the community.
- How to could such an activity evolve, as numerical weather and climate prediction evolves?
- How to fund, how to coordinate.

DAOS report

WWRP/DAOS terms of reference

The Data Assimilation and Observing Systems (DAOS) working group (WG) will provide guidance to the WWRP on international efforts to optimise the use of the current WMO Global Observing System (GOS). It will also provide guidance on which data assimilation methods may provide the highest-quality analysis products possible from the GOS. Through these activities, the DAOS-WG will facilitate the development of advanced numerical weather prediction (NWP) capabilities, especially to improve high-impact weather forecasts. DAOS will be primarily concerned with data assimilation and observing system issues from the convective scale to planetary scales and for forecasts with time ranges of hours to weeks.

To achieve its mission, the DAOS WG will:

- Provide community consensus guidance on data assimilation issues, including the development of advanced methods for data assimilation.
- Promote research activities that will lead to a better use of existing observations and that will objectively quantify the impact of current and future observation for NWP.
- Assist WWRP projects and other WMO working groups in achieving their scientific objectives by providing expert advice on the use of observations and data assimilation techniques (e.g. WGNE, IPET-OSDE, MWFR).
- To organize and provide the scientific steering committee for the WMO Data Assimilation Symposium, which is to be held approximately every 4 years.

Topics

- WMO DAOS meeting (Montreal, Aug 2014) notes and issues.
- Recent developments at several operational centres (4D-En-Var comparisons).
- A few highlights from the recent data assimilation literature that I found interesting.
- Discuss WMO/WWRP Science steering committee questions and actions for DAOS.

Notes from 2014 Montreal DAOS

- Roger Saunders retires as co-chair; Carla Cardinali (ECMWF) replaces Roger.
- WMO requested reduction of DAOS to 12 members. Retiring are Andrew Lorenc (Met Office), Ron Gelaro (NASA), Rolf Langland (US Navy), Tom Keenan (BOM).
- Current membership: Hamill, Cardinali, Buehner (Env Canada), Fourrié (Meteo France), Kleist (NCEP, U Maryland), Klink (DWD), Majumdar (U. Miami), Polavarapu (Env Canada), Tsyrulnikov (Roshydromet), Velden (U. Wisconsin), Wang (Chinese Academy of Sciences). Aim somewhat for gender and geographic balances.
- Cooperation on global OSSEs? DAOS role?
  - All recognize OSSE limitations (best it can do is provide upper bound on expected impact)
  - Possible global collaborations: sharing nature runs, facilitating comparisons between various centres' OSSEs, sharing forward operators?
  - Question for WGNE and reps from operational centres: what key questions about GOS would they like to see addressed with OSSEs? DAOS needed, or are existing collaborations working well?
  - List of more formal questions in supplementary slides, here.
- Discussions on whether other WMO projects (PPP, HIW, T-NAWDEX, HyMEX) can be helped in any particular ways by DAOS.
- "Forecast Sensitivity to Observations" (FSO)– an emerging technology for estimating observation impact. Both adjoint and ensemble-based methods have been developed. See supplementary slides here for a draft version of DAOS-suggested standardized terminology and notation.

Recent developments at several operational centres

(with apologies for omitting some)

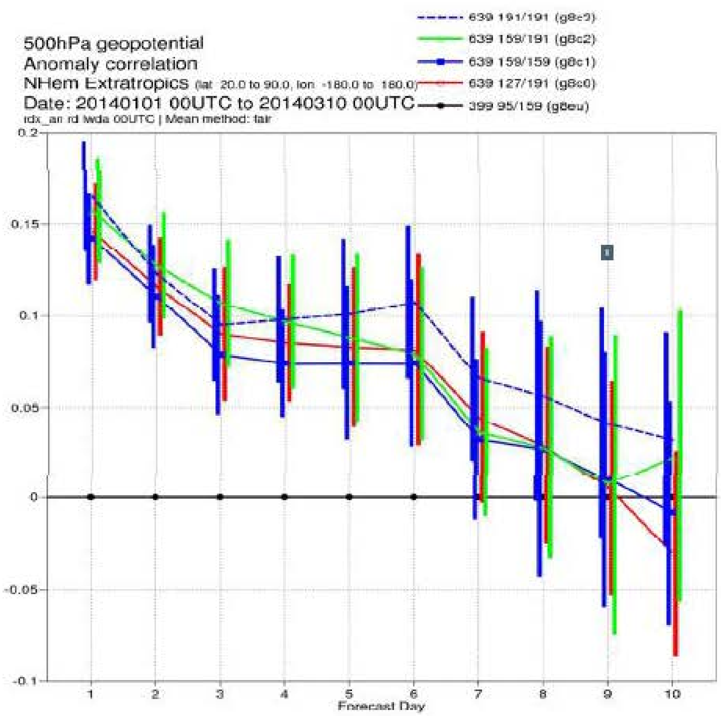
- ECMWF
- Canadian Meteorological Centre
- UK Met Office
- NOAA & NCEP

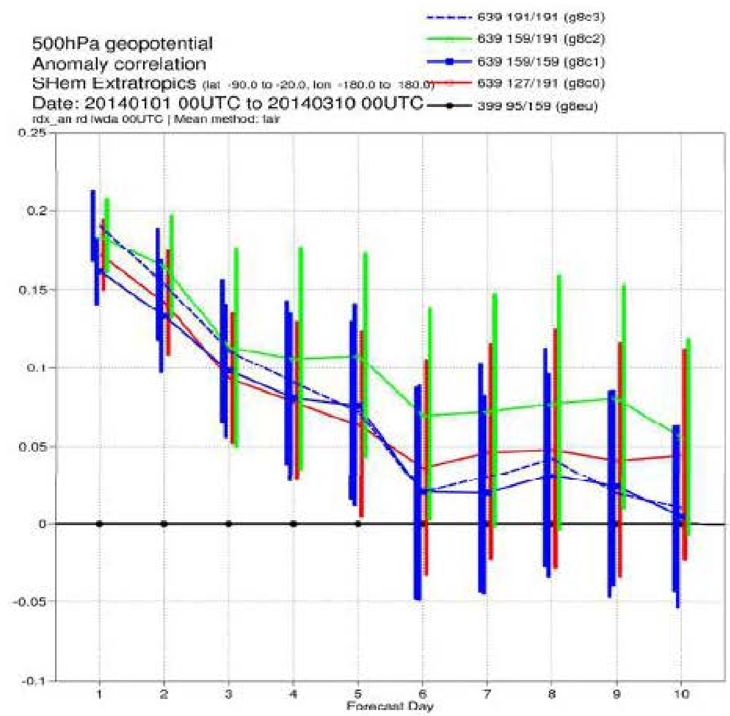
ECMWF: Increase in EDA control forecast skill for various resolution upgrades

Resolution upgrade

- TL399 (TL95/TL159) -> TL639 (TL159/TL159-TL191/TL191)

Measuring the improvement in the mean of forecasts initialized with EDA.

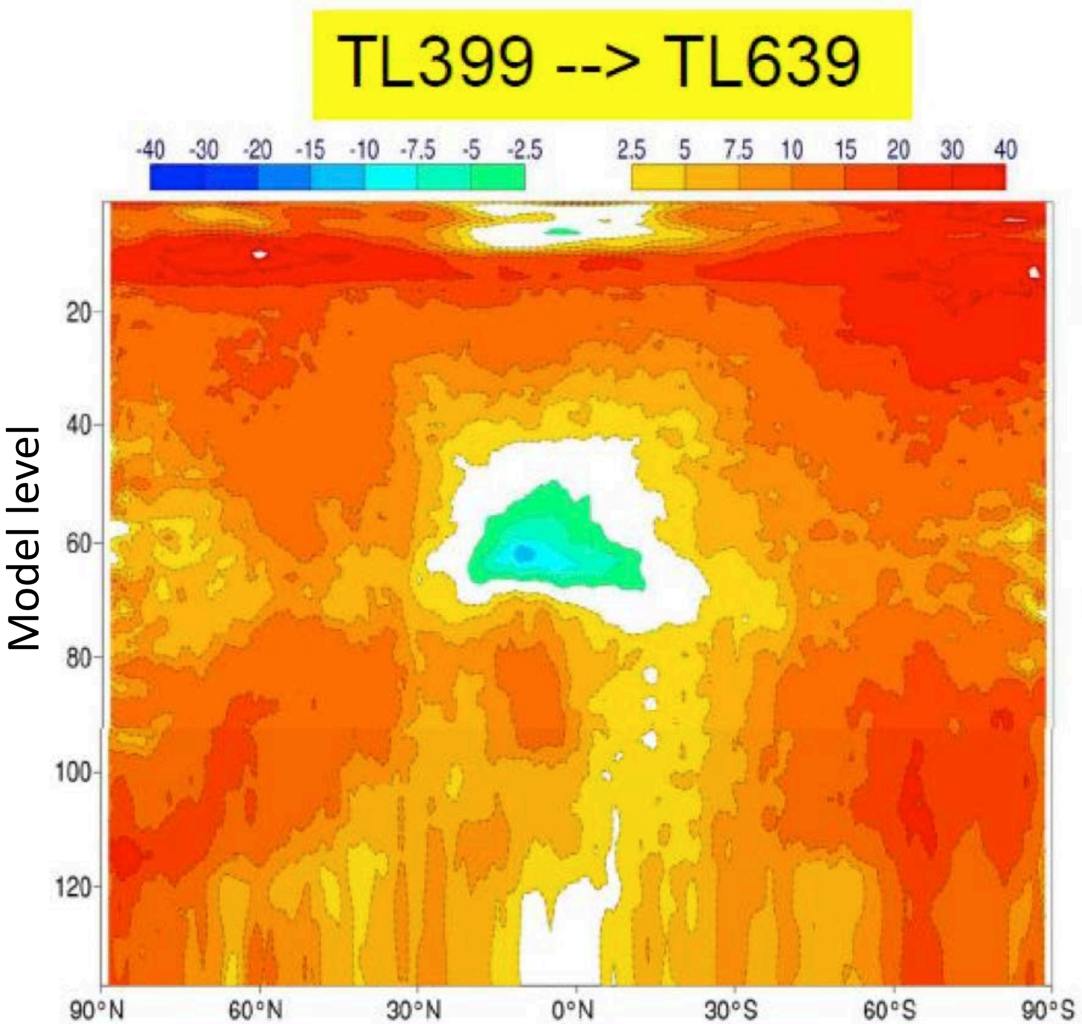




c/o Massimo Bonavita, ECMWF

more details on ECMWF DA improvements here

Increase in spread due to higher EDA outer-loop resolution



increase in spread (%) of meridional wind from increasing the EDA outer-loop resolution.

10% or more spread increase at most levels/latitudes

c/o Massimo Bonavita, ECMWF

Issues in DA and ensemble prediction

1) High-performance EnKF configuration.

The current operational EnKF continues scales well ~ 1000 cores. In future, O(10 000) cores. Not possible with the current code. Memory use in the EnKF is bottleneck, and we are starting to address this issue.

2) Length of the assimilation window.

With increasing spatial resolution, the predictability limit of the smallest dynamical features will become shorter than the length of the assimilation window. May be necessary to reduce the length of the assimilation window.

Current hypothesis: IAU and the recycling of additional variables from the background to the initial conditions of subsequent forecasts will reduce spin-up of the new system and permit a reduction of the assimilation window length.

3) Treatment of model error.

(i) use a multi-model approach; too much manpower?

(ii) use a well-tuned deterministic model and add stochastic perturbations to this with additional stochastic physics schemes. The approach is suboptimal for an ensemble context. Ad hoc fixes, such as putting a ramp near the surface, may also need to be implemented to stabilize the model integrations.

(iii) develop each parameterization to be stochastic from the outset.

There is no agreement on which of these three mutually exclusive approaches to follow.

(c/o Peter Houtekamer, CMC)

Issues in DA and ensemble prediction

4) Coupling with other forecasting systems.

An increasing range of earth modeling systems has to be supported by operational centers.

Unfortunately, the success of current systems is partly based on the adjustment of parameter values to obtain reasonable results. Thus an error may be introduced in a component system to partly compensate for an error of unknown origin.

It follows that an objective improvement in one system can actually degrade the performance of a system coupled to it. This seems to imply that R&D has to be performed in a big-science mode where various groups work tightly together to improve systems.

In Canada, we are tightly coupling the global deterministic and probabilistic assimilation systems. Regional systems are already coupled to these global systems. We intend to couple with land-surface, wave, and ocean prediction systems. The entire process is complex.

CMC: upgrade to global deterministic system

Changes from v3.0.0 → v4.0.0 to data assimilation system and initialization of GEM implemented in operations on 18 November, 2014:

- **4D-En-Var replaces 4D-Var**
- Horizontal grids:
  - Analysis increment: 50 km instead of 100 km grid spacing
  - Unchanged for background and analysis (GDPS: 25 km grid spacing)
- Satellite radiance observations:
  - Improved satellite radiance bias correction scheme
  - Additional AIRS/IASI channels assimilated
  - Upgrade RTTOV8 to RTTOV10
  - Modified obs error stddev for all radiance observations
- Improved treatment of radiosonde (4D), aircraft obs (bias correction)
- Assimilation of ground-based GPS data over N. America
- 4D Incremental Analysis Update replaces digital filter and now recycle several unanalyzed variables (GDPS only)
- Correction in GEM related to unit conversion for snow density and first layer thickness for shallow convection
- Use of new global sea ice concentration analysis

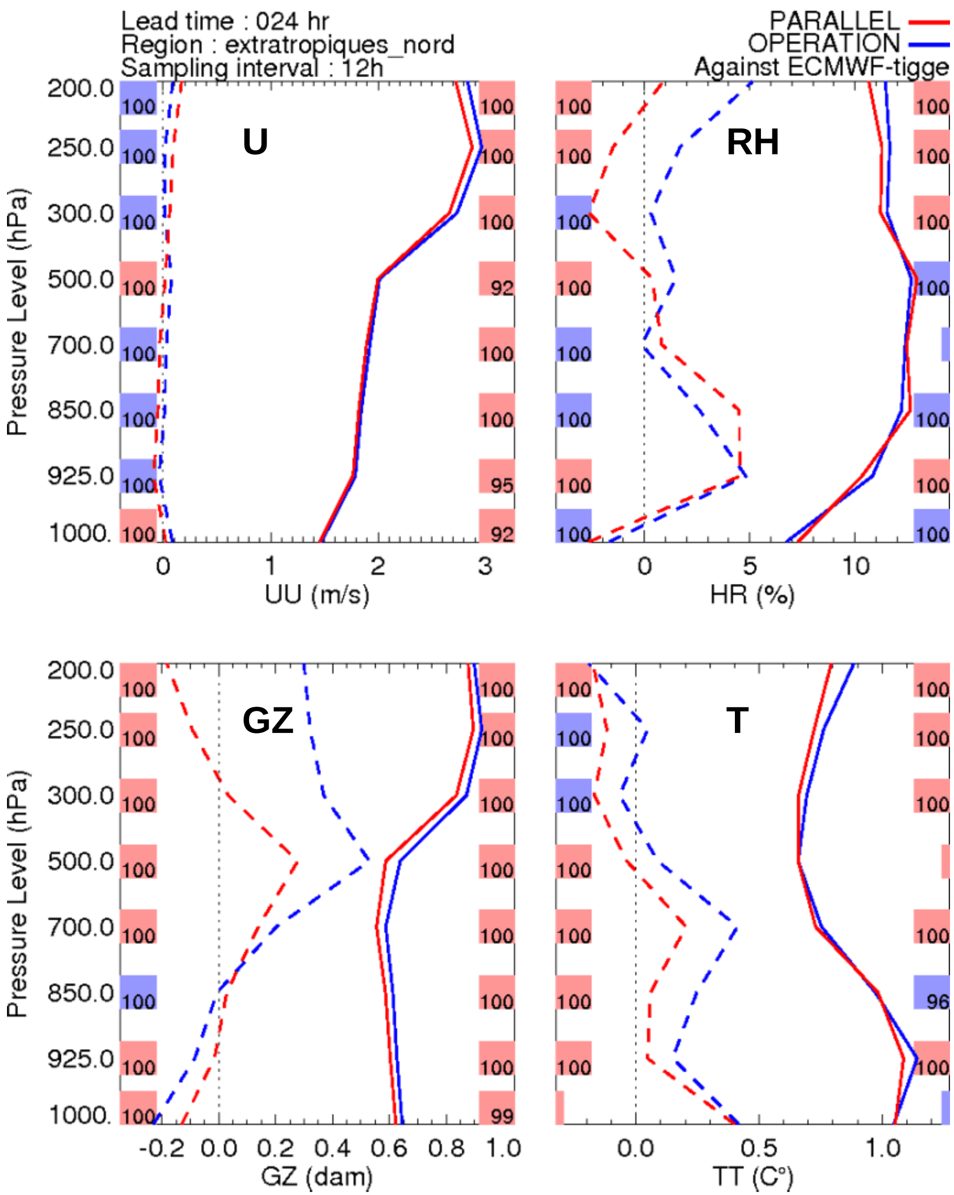
c/o Mark Buehner, CMC. More here.

(Good overview of 4D-En-Var by desRoziers et al, QJ, Oct 2014 **DOI:10.1002/qj.2325**)

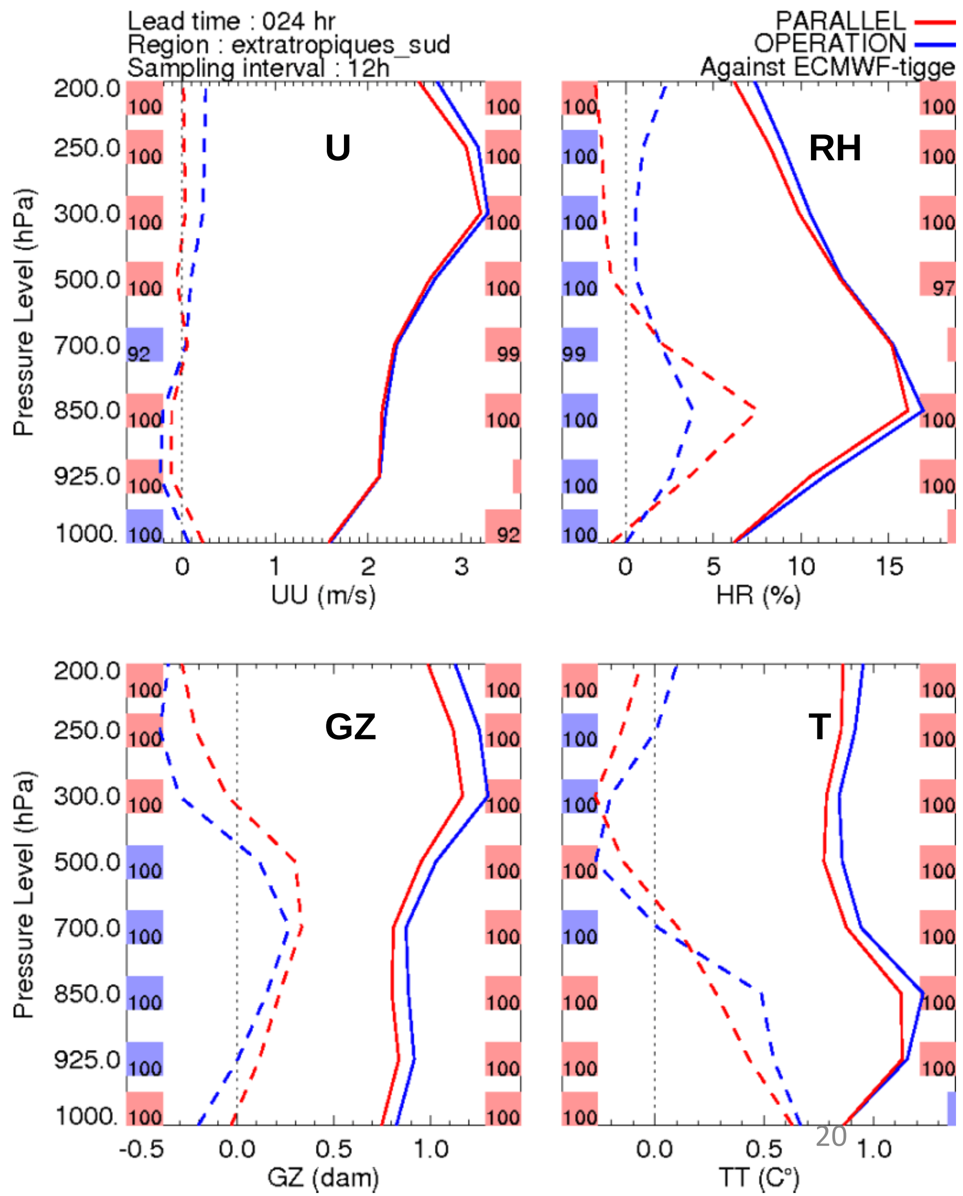
Evaluation of CMC forecasts: GDPS 4.0.0 vs GDPS 3.0.0

Verification vs. ECMWF analyses: 24-h forecasts

Northern extratropics



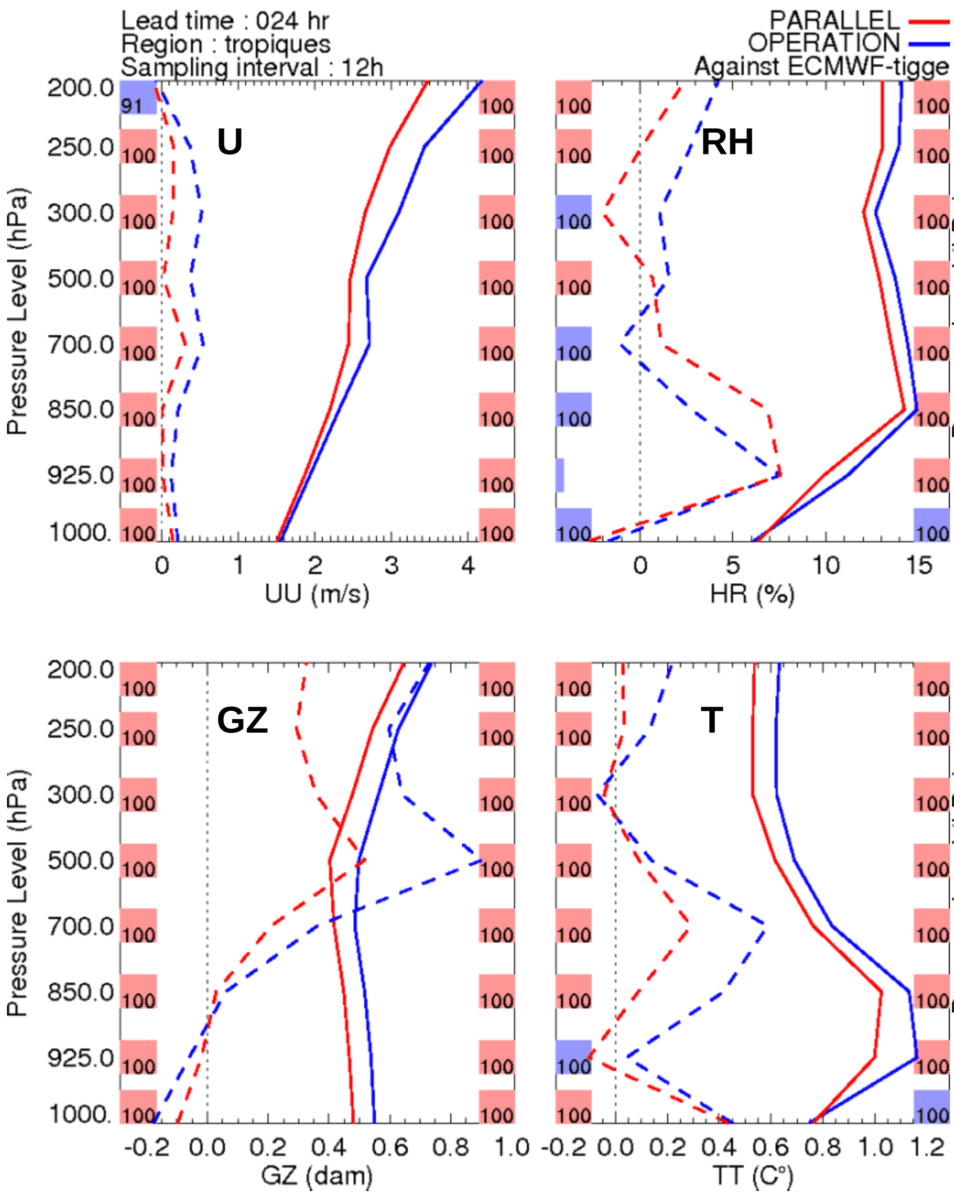
Southern extratropics



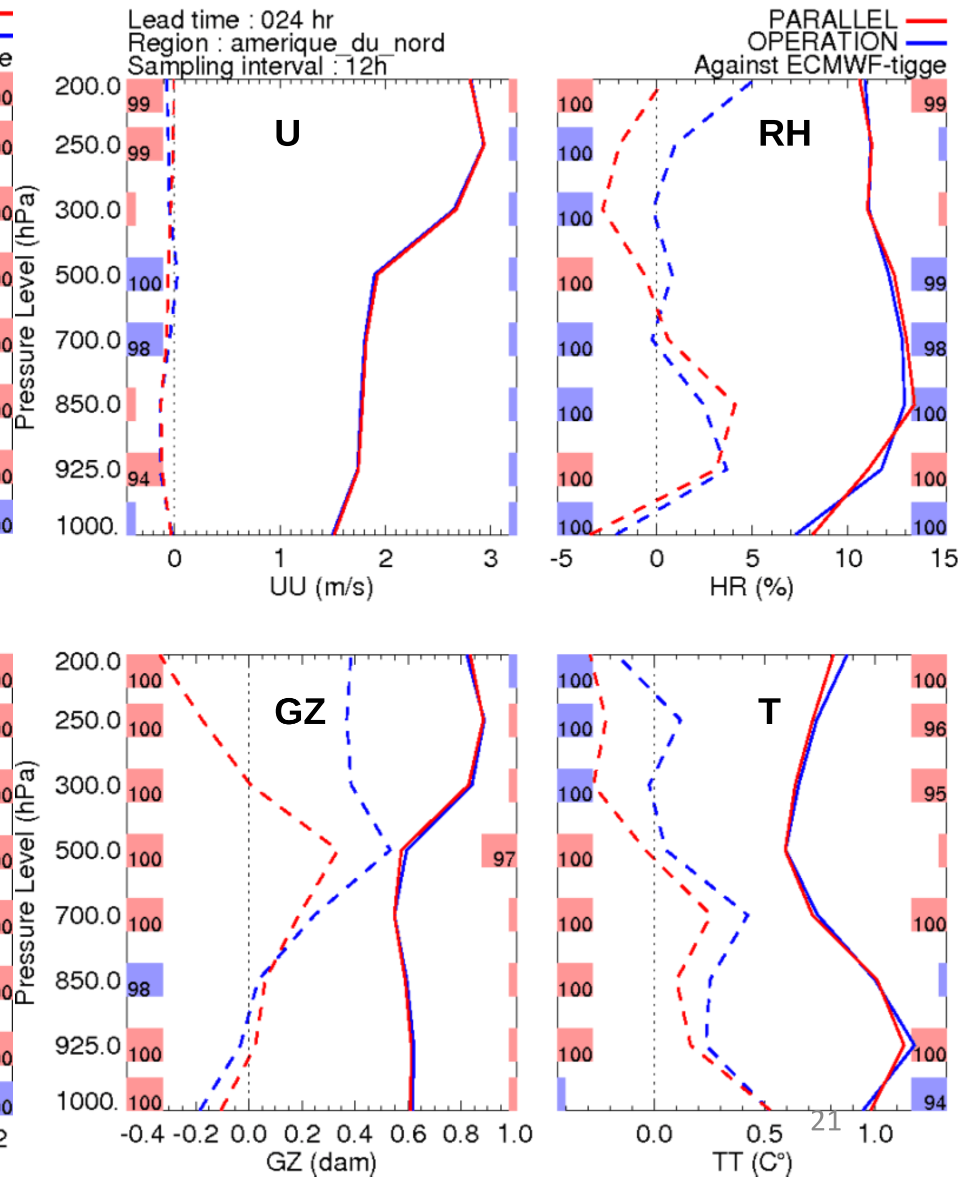
Evaluation of CMC forecasts: GDPS 4.0.0 vs GDPS 3.0.0

Verification vs. ECMWF analyses: 24-h forecasts

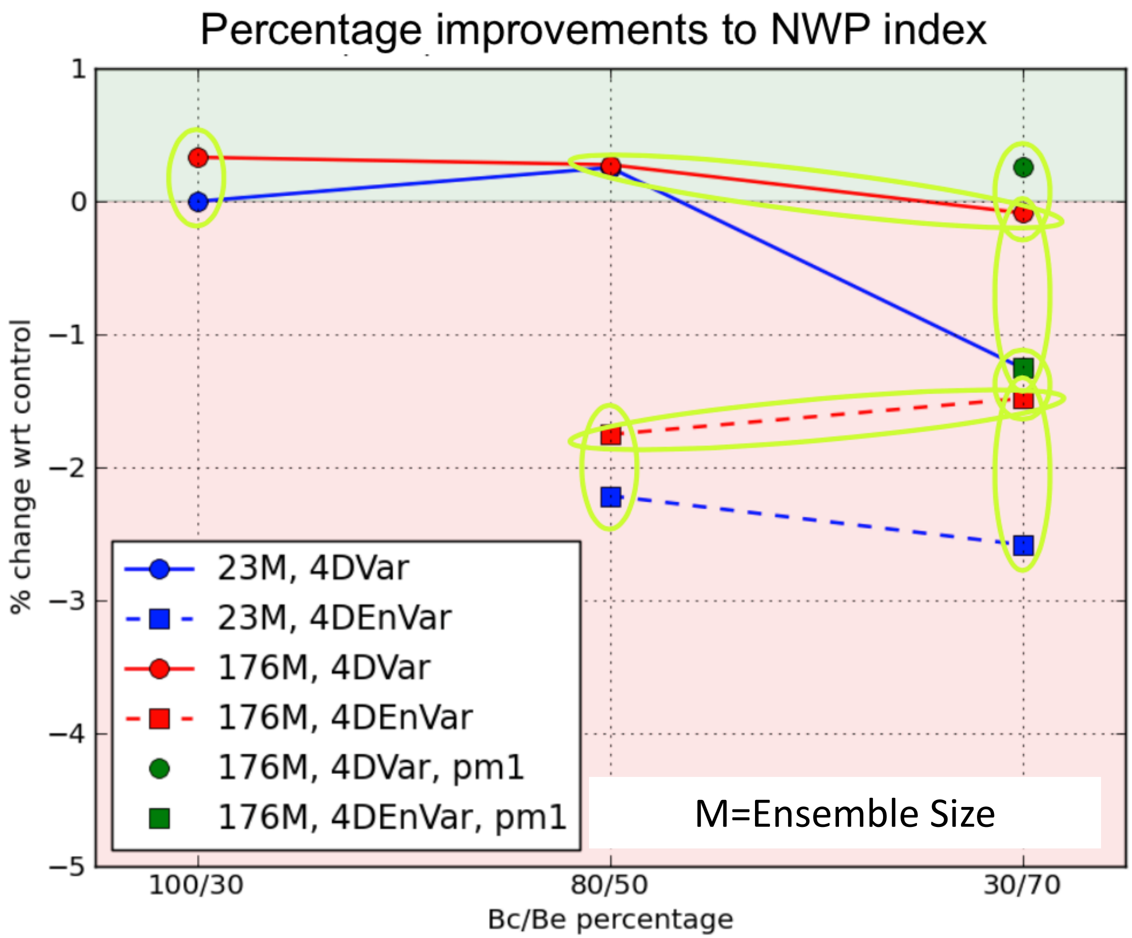
Tropics



N. America



UK Met Office:
4D-En-Var: impact of ensemble size, weight



Increasing Weight To Ensemble Covariance -->

Modest improvement when increasing the ensemble size

But much larger improvement when the ensemble weight is high

4DVar performs worse with high ensemble weight, 4DEnVar performs better

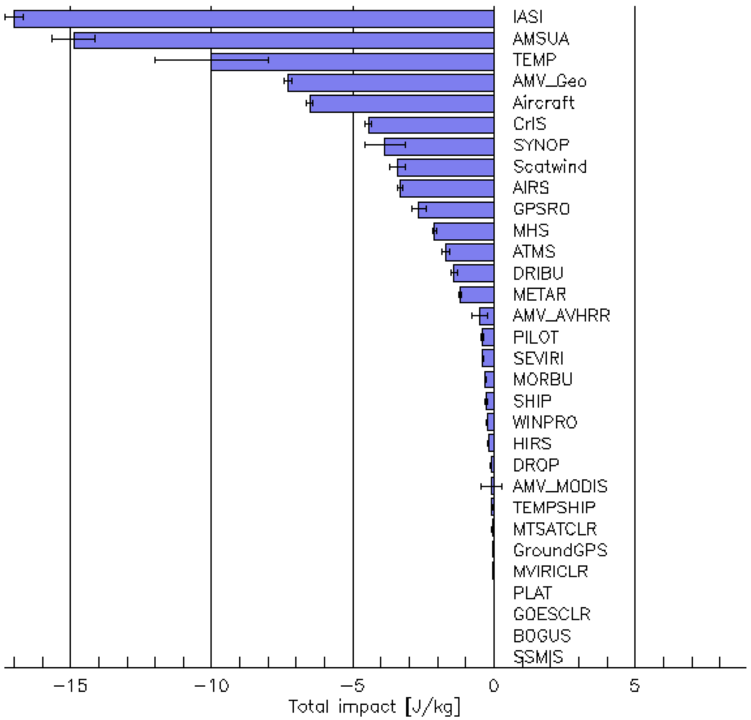
Using ensemble modes from the wrong time ("pm1": +/- 1hr) brings a small benefit

currently 4D-En-Var outperformed by 4D-Var. But Met Office has put less effort than CMC or NCEP into EnKF development. (Tom Hamill comments)

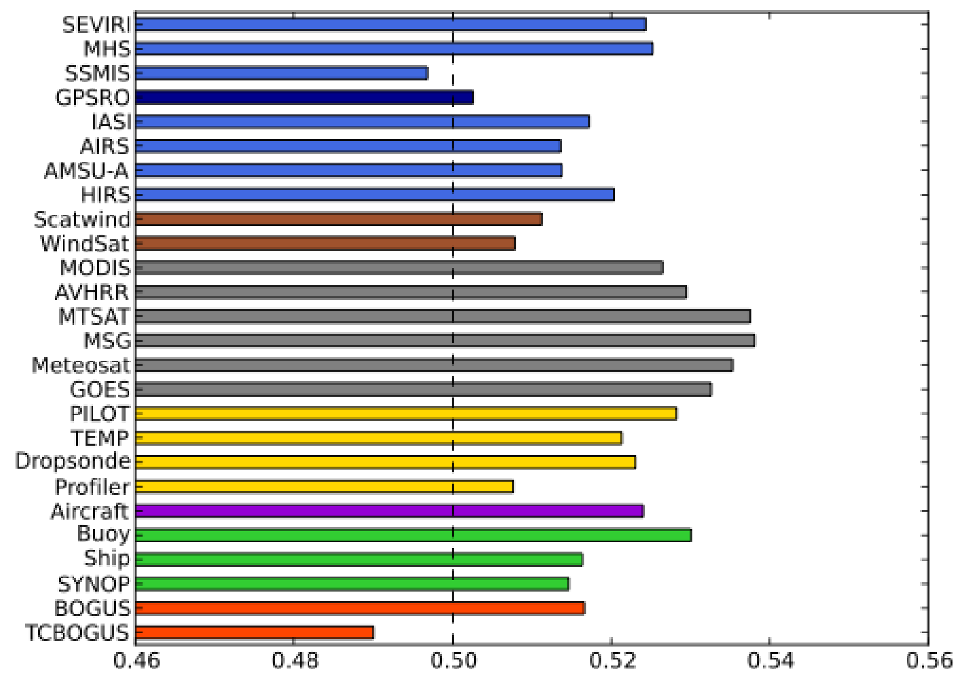
c/o Dale Barker

Forecast sensitivity to observations (FSO) in global NWP

Total observation impact (Aug 2014)



Fraction obs that improve forecast



- Infrared (IASI) and microwave (AMSUA) radiances now biggest impact.
- Barely > 50% of observations reduce forecast error.
- Estimate: need 6 months time series to assess impact for single observing system.

Met Office: global DAE strategy & plans

- Build world-class global DAE based on ensemble-variational DA and significant attention to optimal treatment of wide range of obs.
- Medium-term: Build on operational hybrid 4D-Var (implemented 2011) to
  - Investigate 4D-En-Var as alternative to hybrid 4D-Var.
  - Investigate ETKF replacement.
- Longer-term:
  - Consider rapidly updating (hourly?) global DA
  - LFRic DA: Initiate project in 2015 (LFRic is new dycore).

Met Office: summary

1. Significant upgrades to global DA in atmosphere, land surface continue.
2. Global 4D-En-Var getting close to hybrid 4D-Var skill.
3. Convective-scale 3D-Var still improving, adding significant value.
4. CS-scale strategy: Implement hourly 4D-Var, then consider EnDA.
5. Significant benefits of regional reanalysis.
6. LFRic (new dycore) DA effort to begin in 2015.

NOAA hybrid 4D-En-Var upgrade

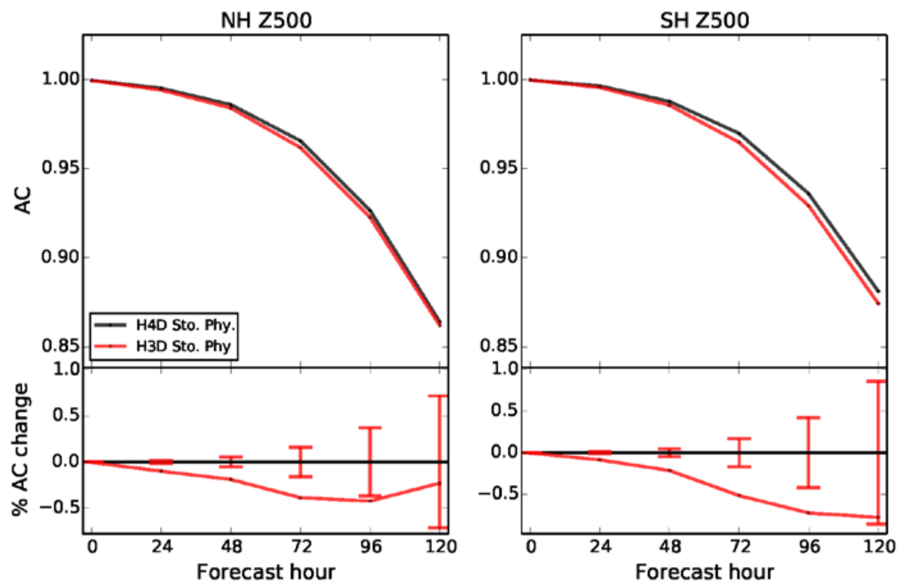
- Hybrid 3D-En-Var implemented May 2012.
- Upgrade to 4D-En-Var slated for Q1FY16 (for global model).
- Items that may be included:
  - 4-D covariances in hourly bins in a 6-h assimilation window.
  - 4-D incremental analysis update (for control forecast).
  - Static **B** contribution reduced from 25% to 12.5%
  - Localization length scales reduced in troposphere (from ~2000 km to ~1000 km).
  - Additive inflation eliminated, replaced by stochastic physics. Some retuning of stochastic physics parameters.
  - Multivariate ozone increment turned on (using ensemble-based cross-covariances to update ozone with non-ozone obs).

c/o Jeff Whitaker, ESRL/PSD

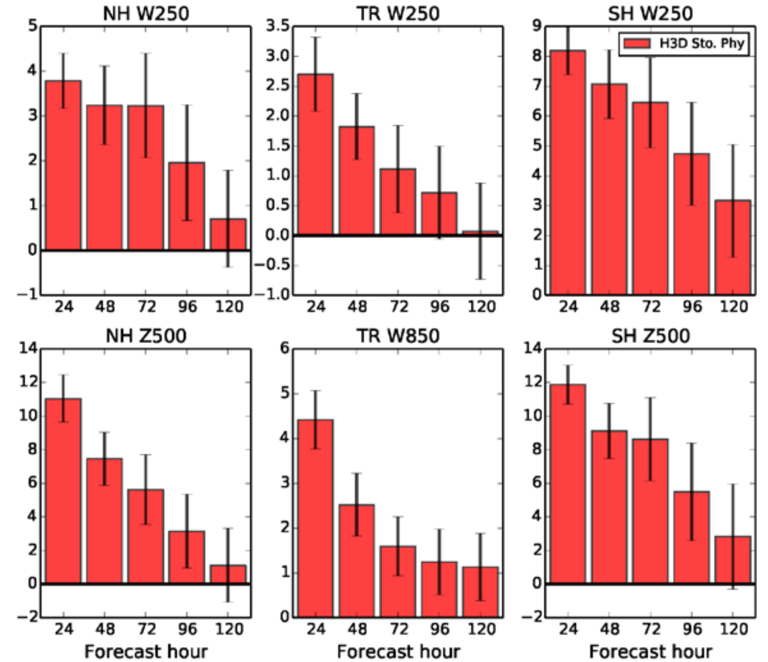
NOAA hybrid 4D-En-Var – ongoing work

- Static **B** component of increment is 3-D (does not vary through window).
  - Propagate with simple model, or eliminate static **B** entirely (larger ensemble size).
- Multi-scale localization/static **B** weighting.
  - Increasing static **B** contribution and/or reducing localization length scale improves (degrades) analysis at small (large) scales.
  - Both localization and static **B** weighting should be scale-dependent.
- Ensemble information not yet used in quality control.
- Exploring trade-offs between ensemble size and control forecast resolution. Currently 80-member T574 ensemble, and T1534 control forecast.

3-D v. 4-D hybrid in T670 SL GFS Tests
period: 10 July 2013 – 01 Oct 01 2013



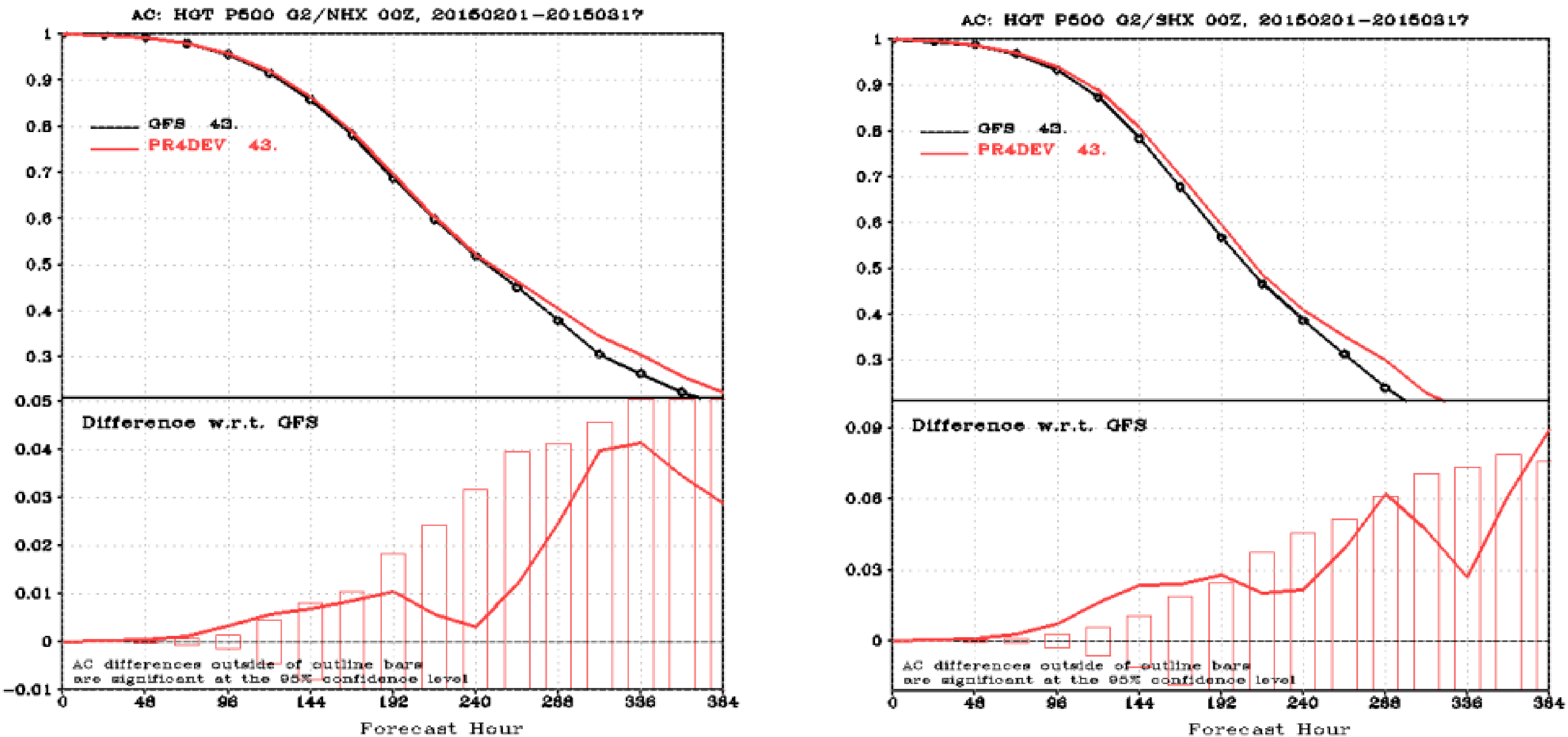
500 hPa AC (top) for 00 UTC forecasts for the entire experimental period for the 3D hybrid (red) and 4D hybrid (black) as well as the difference 3D minus 4D (bottom) for the NH (left) and SH (right)



Percent RMSE difference (3D minus 4D) for 250 hPa NH vector wind (upper left), 250 hPa tropical vector wind (upper middle), 250 hPa SH vector wind (upper right), 500 hPa NH geop. heights (lower left), 850 hPa tropical vector wind (lower middle), and 500 hPa hPa SH geop. heights (lower right).

c/o Daryl Kleist, U. Maryland

Near real-rime tests at operational resolution (T1534) – 01 Feb 2015 – 17 Mar 2015



500 hPa AC for 00 UTC forecasts from the operational GFS (black) and experimental system using hybrid 4D En-Var (red) as well as the difference (bottom panels) 4D (experimental) minus 3D for the NH (left) and SH (right)

Select highlights from recent literature

Changing AMSU-A error statistics

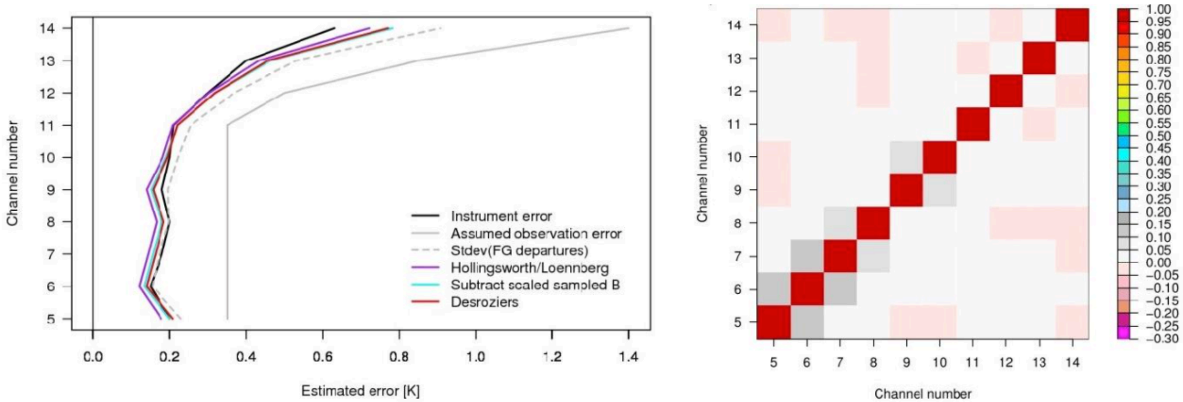


Figure 2: (left) Estimates of σ_o for AMSU-A on NOAA-18 from the Hollingsworth/Lönnberg (purple) and Desroziers (red) diagnostics, together with estimates of the instrument noise (black), the standard deviation of background departures (dashed grey), and the observation error assumed in 2008 (grey). (right) Estimates of observation error correlations obtained with the Desroziers diagnostic.

From ECMWF seminar proceedings: *"Progress towards better representation of observation and background errors in 4DVAR"* by Bormann, Bonavita and McNally

related conclusion based on FSO diagnosis in Cardinali and Healy, Oct 2014 QJ **DOI:10.1002/qj.2300**

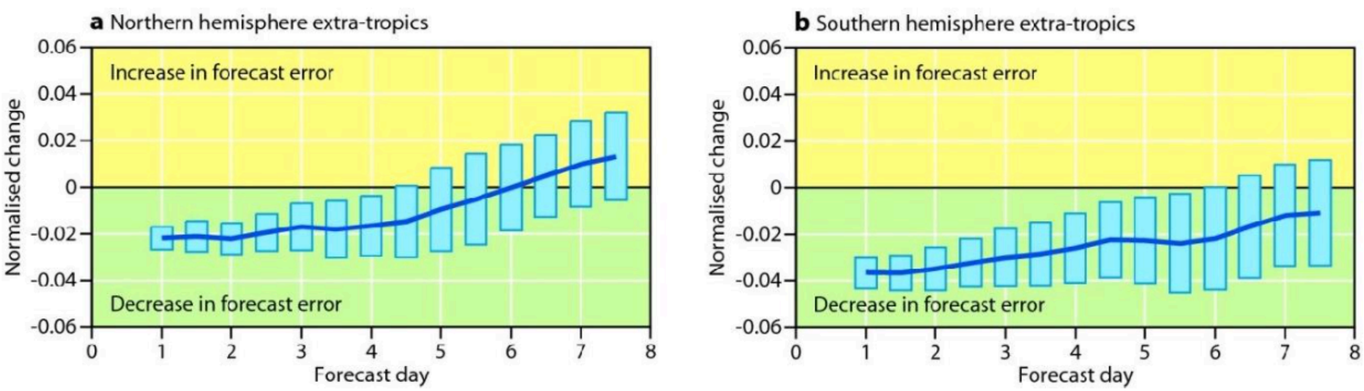


Figure 3: Forecast impact of reducing the AMSU-A observation errors in terms of the normalised difference in the root mean square error for the 500 hPa geopotential for the Northern Hemisphere (left) and Southern Hemisphere extra-tropics (right). Vertical bars indicate 95% significance intervals. The results are based on 120 forecasts obtained during December 2009–January 2010 and May–July 2010.

changed R from 0.35 K to 0.2 K

Forthcoming changes in the global satellite observing systems

- The polar constellation of hyper-spectral IR and microwave soundings are in relatively good shape.
- There are concerns on the constellation of microwave imagers.
- **Scatterometers are generally in poor shape** because all missions do not provide real-time access. EUMETSAT will have a follow-on to ASCAT for the mid-morning orbit. HY2 series provides early morning orbit data, but no real time access. CMA is planning for an early morning scatterometer. India's OceanSat2/3 will be in a noon orbit, but no plans by any agency for an early afternoon coverage in order to provide adequate temporal sampling.
- **GSP-RO is in precarious shape**. However, approval for a full COSMIC2 constellation of six equatorial and six high inclination orbits would solve most issues by providing about 16,000 soundings per day. Real-time access is very important.
- Again, real-time data access to secured data cannot be overstated. Low latency is critical and needs to be achieved by at last two polar ground stations.
- **Emerging satellite data**. Over the next decade that more of the following data types will be assimilated in models.
  - Lidar (winds, aerosols, clouds)
  - Salinity/Soil Moisture
  - Lightning mappers
  - Ocean Color
  - Atmospheric composition.
  - Altimetry

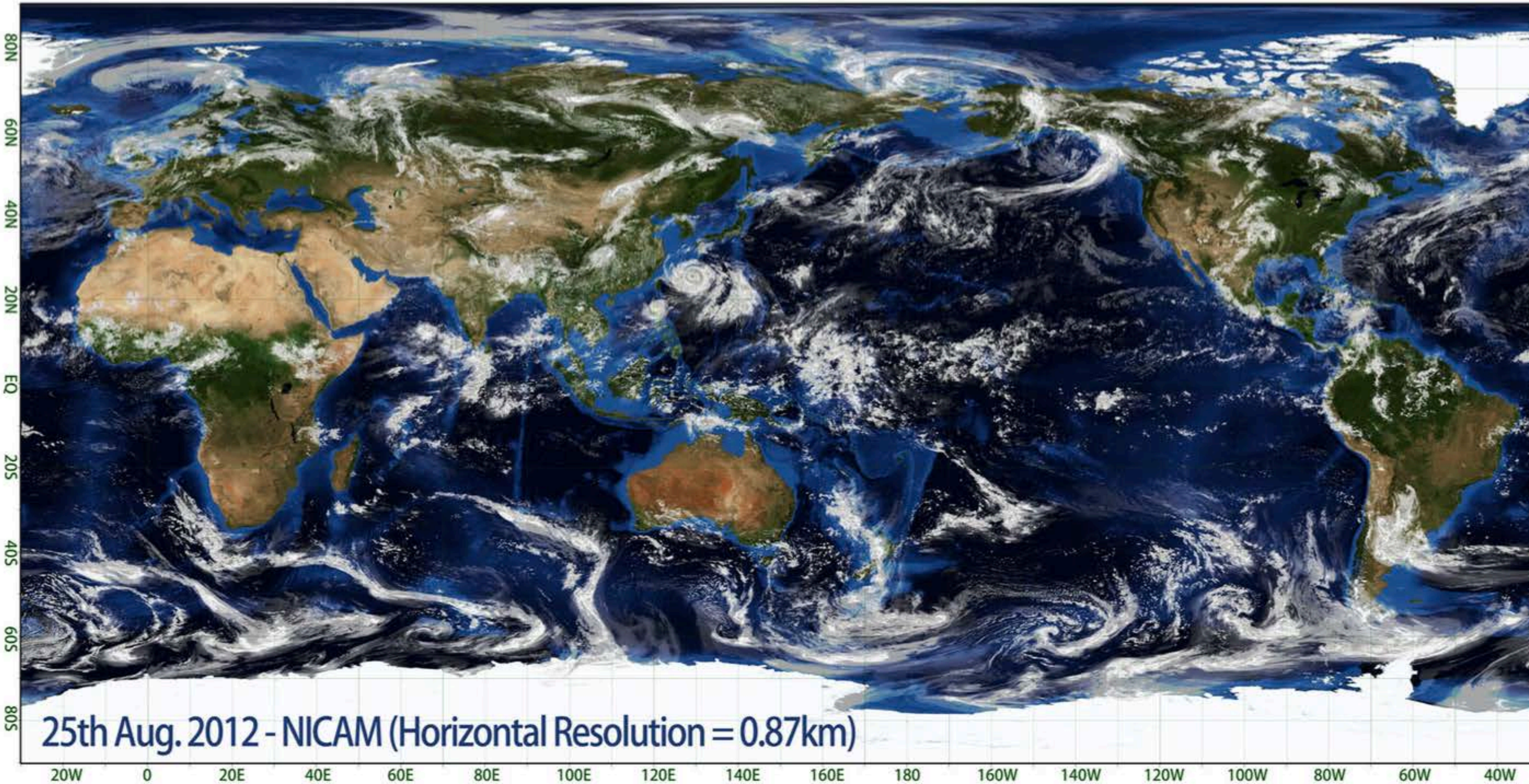
from Mitchell Goldberg, ECMWF Seminar on the Use of Satellite Observations in NWP, 8–12 September 2014

ADM-Eolus

European Space Agency Doppler wind lidar

- near sun-synchronous polar orbit
- expect ~ 72,000 wind obs. daily
- 3-year lifetime expected, launch ~ 2016
- measures winds perpendicular to satellite track.
- simulations with ECMWF EDA show on zonal winds impact similar to impact of raobs
  - largest impact for tropical oceans, near 200 hPa.
- haven’t measured impacts for anchoring/QC of other observations; could be significant for cloud-drift winds [Tom Hamill comment];

Global 870-m simulation (*Miyamoto et al. 2013*)



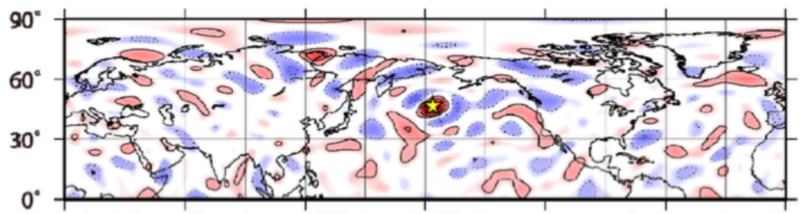
©JAMSTEC・AORI (SPIRE Field3), RIKEN/AICS
Visualized by Ryuji Yoshida

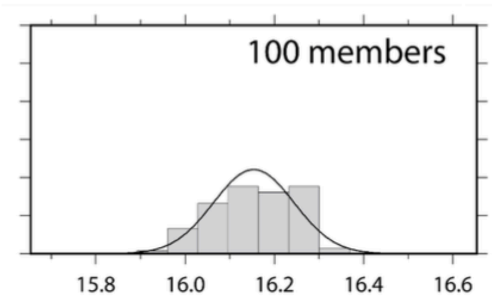
Our colleagues at Riken in Kobe Japan are pushing the frontiers of high-resolution modeling and data assimilation. From Miyoshi-sama presentation at ISDA2015.

Advantage of large ensemble

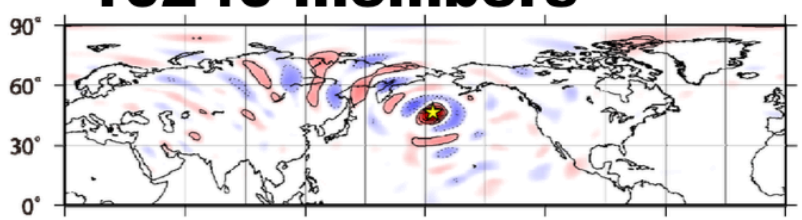
(Miyoshi, Kondo, Imamura 2014)

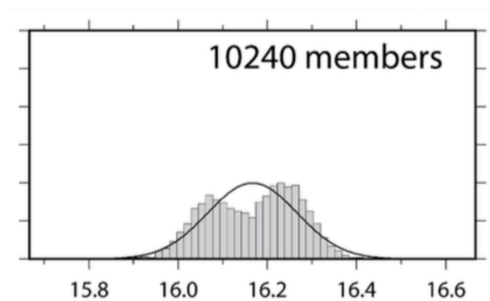
100 members





10240 members



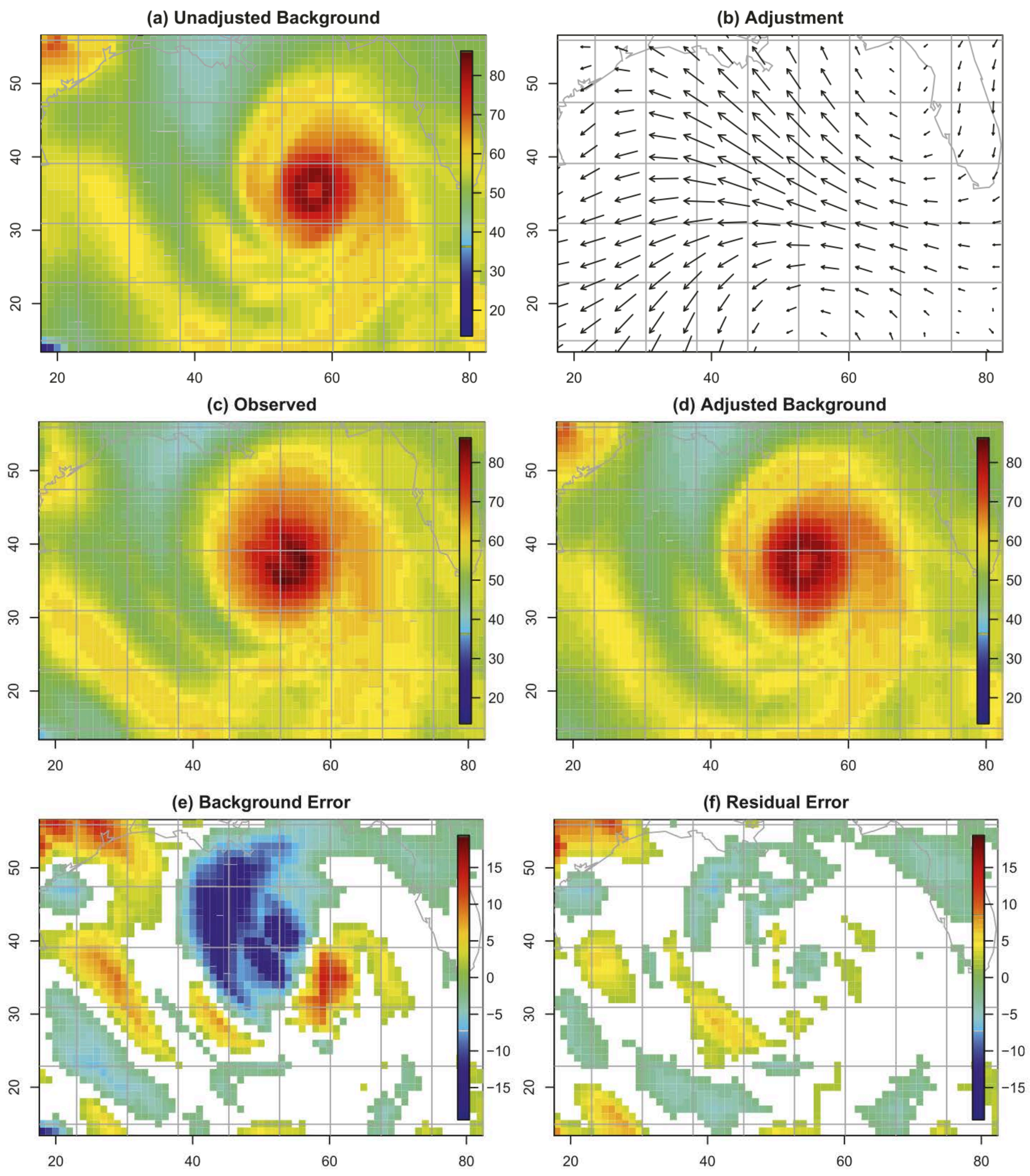


Sampling noise reduced

High-precision probabilistic representation

Cf. P-26 Kondo, Tue

Ref: ibid



"Feature calibration and alignment"

Nehrkorn et al. Feb 2014 *MWR*; as proposed in Sai Ravela's "field alignment" papers, before the regular assimilation of observations, performing a preliminary step of adjusting the background to account for position errors may significantly improve assimilation quality.

This may help reduce the amount of non-Gaussianity in DA, also.

WMO/WWRP Science Steering Committee: questions and actions for DAOS

- Organize a teleconference with WCRP key scientists to discuss common activities between WWRP and WCRP for DA.
  - see next slide on some details of reanalysis activities.
- How to prioritize coupling issues within PDEF and DAOS; suggest organize a teleconference between PDEF & DAOS co-chairs, C/WWRP.

Some notes on WWRP/DAOS and WCRP overlapping interests

Overlapping weather-climate interests with regards to data assimilation in the conduct of reanalyses.

(1) International coordination is largely informal, with the key players being the generators of the reanalyses (JMA & JAMSTEC, NASA, ECMWF, NOAA, NCAR, GFDL). Light WCRP presence. Are informal arrangements satisfactory.?

(2) Informal and semi-formal for collaboration.

- reanalyses.org.
- ACRE (Atmospheric Circulation Reconstruction over the Earth) -- Rob Allan is coordinating this as a grassroots umbrella organization for the collation of older data for supporting climate reanalyses. -
- WMO ET-DARE (Data Rescue), but not as active as ACRE.
- Australia has "Weather Detective" (http://www.weatherdetective.net.au/) that facilitates the rescue of old data, too.

(3) Common observational database, perhaps in the standard "ODB" format that ECMWF uses.

- easier to ensure that various reanalysis users are working with the same, or relatively similar observations.
- issues of shared ODB. For example, consider satellite data. What data goes into the ODB? Full radiances (immense data set), thinned radiances, super-obbed radiances? Raw data or data that has been QC'ed, possibly including corrections to assure common biases across different satellites?
- Different reanalysis providers would have different answers to these questions, and no one ODB may satisfy all.

My conversation with Gil Compo, CIRES

WWRP/WCRP connections, cont’d

- Constituent and coupled data assimilation: what groups/committees in WCRP include these topics? [Saroja Polavarapu].

Conclusions

- DAOS exploring whether it can facilitate collaboration on weather-climate issues like reanalyses, or on global interests like OSSEs.
  – if existing structures are working, we don't want to mess with them, though.
- DA methodology: lots of activity around 4D-En-Var at many centres, though with somewhat conflicting results.
  – personal opinion [Hamill] – DA results may be very sensitive to how one models the ensemble statistics for the background errors, including model uncertainty.
- Observations:
  – new Eolus wind lidar coming.
  – Scatterometer data scattered.
  – GPS radio occultations shown to be quite valuable, but existing network dying. COSMIC-2 a hoped-for replacement. RO data useful for anchoring as well as direct assimilation.

Supplementary material: OSSE questions to pose to operational centre representatives & others.

1) Is there an interest in quantifying the impact of future observational data, e.g. from a new satellite? If so, which observational platforms would be a priority?
2) Is there interest in assessing the benefits of new uses of current observations (e.g. varying the spatial and temporal density, error assignments etc)? If so, please list priorities for given observation platforms.
3) Would your center be able and willing to share components such as generalized forward operators? If so, please list some examples.
4) Is it feasible for your center to provide an OSSE framework that mimics an operational data assimilation and/or modeling framework, including synthetic observations provided either in-house or by other centers? If so, would staff within and outside the center be able to use it?
5) Is there the capability and interest to generate a global nature run that is used by the international OSSE community? The resolution of the nature run would need to be superior to that of operational models. The duration would be at least a full season for statistical robustness.
6) Is there interest in evaluating nature runs from other centers, in terms of their realism?
7) Is there interest in providing verification tools for OSSE analyses and forecasts?

thoughts/replies to Sharan Majumdar, smajumdar@rsmas.miami.edu

Supplementary material:
forecast sensitivity to observations terminology and notation

Proposed Terminology for Observation Impact and Related Quantities

Ron Gelaro, Carla Cardinali and Rolf Langland

Submitted for consideration by the DAOS-WG, 18 September 2014

Given the usual definitions in data assimilation for the gain matrix, $\mathbf{K}$, the observation error covariance matrix, $\mathbf{R}$, the observation operator, $\mathbf{h}$, the observation vector, $\mathbf{y}$, the analysis and background states, $\mathbf{x}_a$ and $\mathbf{x}_b$, and the tangent linear model, $\mathbf{M}_{(0,t)}$, and given a differentiable scalar measure, e, on the forecast, $\mathbf{x}_t$, at time t, the following terminology[1] is proposed:

1. Forecast Sensitivity to Observations (**FSO**):

$$\frac{\partial e}{\partial \mathbf{y}} = \mathbf{K}^{\mathrm{T}}\mathbf{M}^{\mathrm{T}}_{(t,0)}\frac{\partial e}{\partial \mathbf{x}_t} \qquad (1)$$

c/o Langland, Cardinali, and Gelaro

2. Forecast Sensitivity to Observation Error Covariance (**FSR**):

$$\frac{\partial e}{\partial \mathbf{R}} = \frac{\partial e}{\partial \mathbf{y}} \left[\mathbf{y} - \mathbf{h}(\mathbf{x}_a)\right]^{\mathrm{T}} \mathbf{R}^{-1} \tag{2}$$

3. Forecast Sensitivity Observation Impact (**FSOI**):

$$\delta e = \left[\mathbf{y} - \mathbf{h}(\mathbf{x}_b)\right]^{\mathrm{T}} \mathbf{K}^{\mathrm{T}} \mathbf{g} \tag{3}$$

where $\mathbf{g}$ is an order-n approximation in model space of the change in e due to changes in the initial conditions, $\mathbf{x}_0$.

Note 1: The most common applications of (3) in NWP involve a quadratic form of e and thus require a higher-than-first-order approximation of $\mathbf{g}$ for sufficient accuracy, e.g., as

[1] The expressions themselves have been derived in the literature.

in Langland and Baker (2004). In principle, however, $\mathbf{g}$ could take the form of a simple gradient.

Note 2: The use of an adjoint model is assumed in (1)–(3). For ensemble-based formulations of these quantities, the naming conventions can be appropriately modified, as in EFSOI or EnFSOI.

Supplementary slides:

more on ECMWF DA system developments (c/o Jean-Noel Thépaut)

Data Assimilation related upgrades available for implementation in March 2015

- Increased EDA resolution to TL639 outer loop and TL191/TL191 inner loop
- Implement new method for hybrid B: 70% static wavelet B and 30% error-of-the from latest EDA
- Increased inner loop resolution in 4DVAR from TL(255/255/255) to TL(255/319/399)
- Cycling flow-dependent errors and B in the EDA suite
- Optimisations OF EDA and reduced number of iterations for 1st minimization of EDA suite
- Assimilation of aircraft humidity
- Implementation of Sonntag saturation vapour equation for radiosonde and aircraft humidity departures
- Increased use of BUFR TEMP, BUFR SYNOP and BUFR drifter data
- Lapse rate correction for T2M SYNOP used in T2M analysis and in screen level assimilation
- Assimilation of BUFR SYNOP snow in land data assimilation system, more advanced blacklisting of snow data

Technical contributions

- Further optimisation of data assimilation suite and IFS
- Implementation of Aeolus L2B/C processing chain
- Implementation of more OOPS (Object Oriented Programming System) code
- OOPS 4DVAR with same inner/outer loop resolution available for research
- Restructured observation pre-processing and data screening tasks

Data Assimilation candidates for implementation later in 2015

- Implementation of HRES/4DVAR/EDA/ENS resolution upgrade
- Ability to bias correct and assimilate ground based GPS (GNSS)
- Ability to compute Land Data Assimilation SEKF Jacobians from flow-dependent EDA perturbations – this i a new more cost effective (and better) method
- Ability to assimilate SMOS data operationally
- Observation error retuning for conventional and satellite data
- Temperature bias correction of AIREP (old style aircraft data); introduce fix for ascend/descend bias correction
- Improve bias correction method for surface pressure data
- Reintroduce Jb balance in the stratosphere

Other ECMWF research activities in data assimilation

Reanalysis support and collaboration

Cloud Analysis activities

Ensemble of Data Assimilations (EDA) activities

Ensemble Kalman Filter activities

Weak-constraint 4D-Var and model error research

Aeolus Doppler Wind Lidar activities - L2B processor developments, integration and evaluation

Improved processing and improved assimilation of in-situ data

Land surface data assimilation activities

- Produce soil moisture reanalysis (1992-2016)
- Development of a SMOS soil moisture product based on a neural network training
- Further SMOS data assimilation development and experimentation
- Evaluate combined assimilation of ASCAT and SMOS data, preparation for assimilation of SMAP data

4DVAR inner loop resolution TL255-TL319-TL399

- Inner loop resolutions and timesteps changed:
  - TL255-255-255 → TL255-319-399
  - 1200-1200-1200s → 1200-1080-900s

- Improves tropospheric NH RMS ~2%, SH ~1% up to day 5 (vs oper/obs)

  - Wind RMS vs oper
  - Exp 255-319-399
  - Cntrl 255-255-255
  - ~70 days JAS
  - T/Z/R similar
- Cost 4DVAR +50%

New method for computing EDA based flow-dependent background errors

JB Computation

- 41R1: training dataset is (400 climatological EDA forecasts) + (200 latest EDA forecasts)

- 41R2: computation starts from static JB file which is updated with 200 latest EDA forecasts, using one pass incremental covariance computation algorithm:

$$\boldsymbol{C}_{n+1} = \frac{n}{n+1}\boldsymbol{C}_n + \frac{n}{(n+1)^2}(\boldsymbol{x}_{n+1} - \langle x \rangle_n)(\boldsymbol{y}_{n+1} - \langle y \rangle_n)^T$$

Relative weight (alpha_hybrid, namelist parameter) given to static – online component can be controlled through initial value given to n.

$$\boldsymbol{B}_{hybrid} = (1 - \alpha)\boldsymbol{B}_{static} + \alpha \boldsymbol{B}_{online}$$

alpha_hybrid depends on EDA size (current experiment. points to alpha_hybrid=0.3)

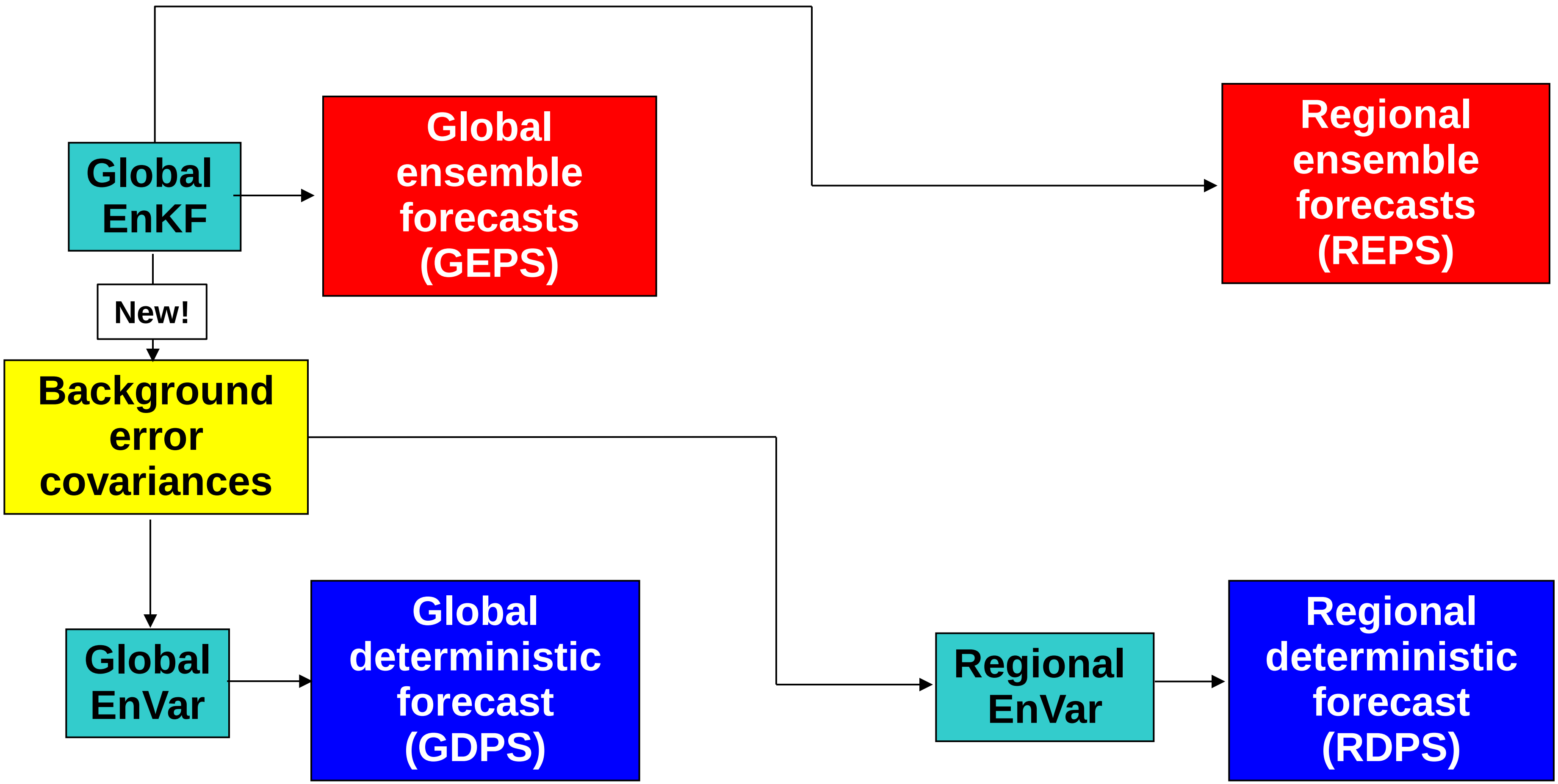
c/o Massimo Bonavita, ECMWF

Supplementary slides:

more on CMC DA system developments (c/o Mark Buehner)

New link between EnKF and GDPS/RDPS

2014 implementation: Increasing role of global ensembles

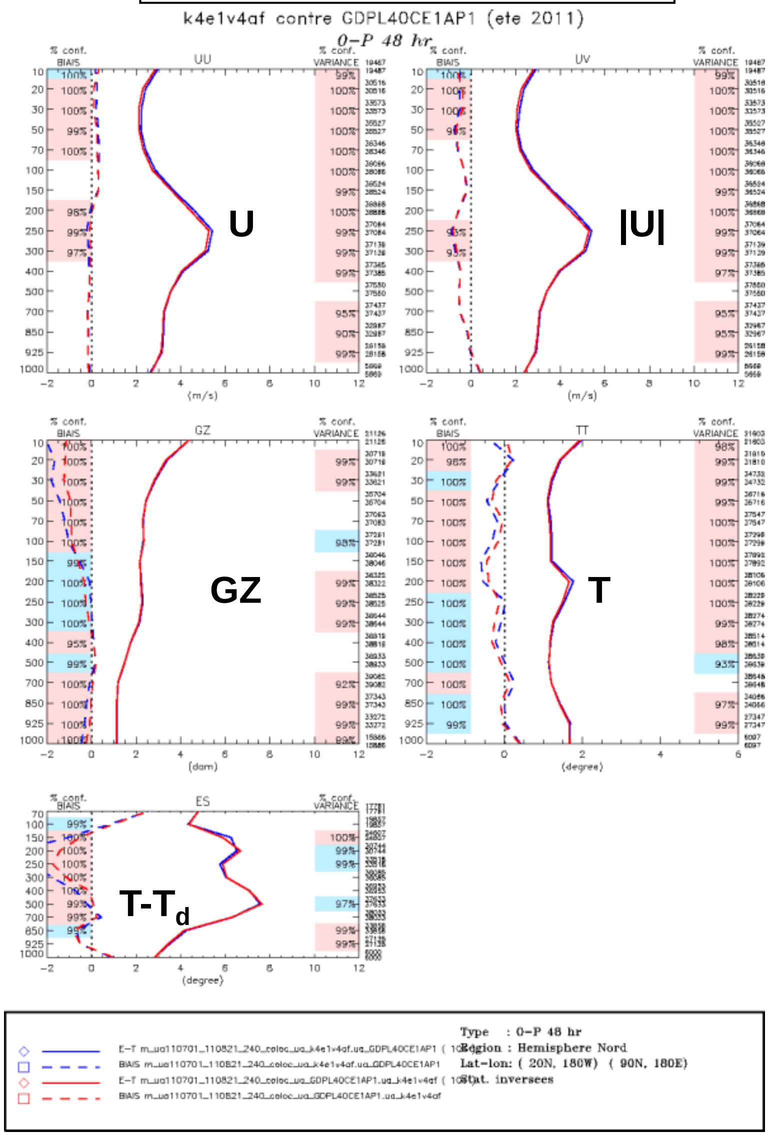


global system ***regional system***

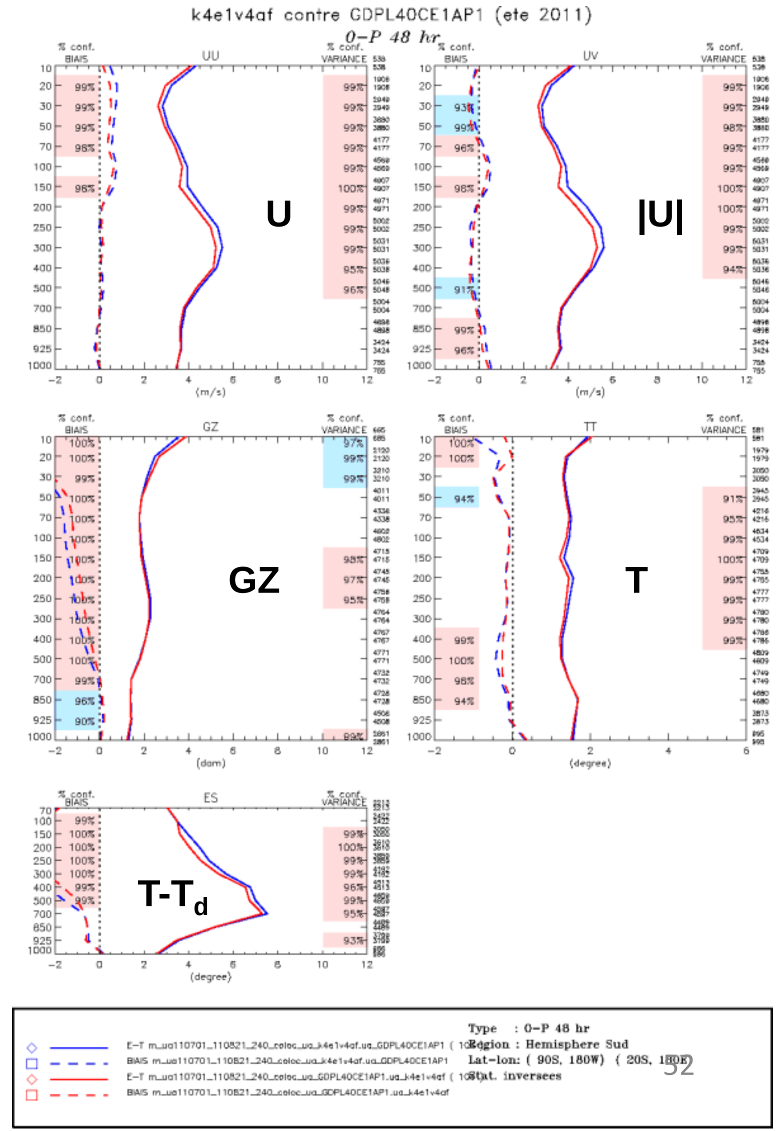
Forecast Results: GDPS 4.0.0 vs GDPS 3.0.0

Verification vs. Radiosondes – <u>48h forecasts</u>

Northern extratropics



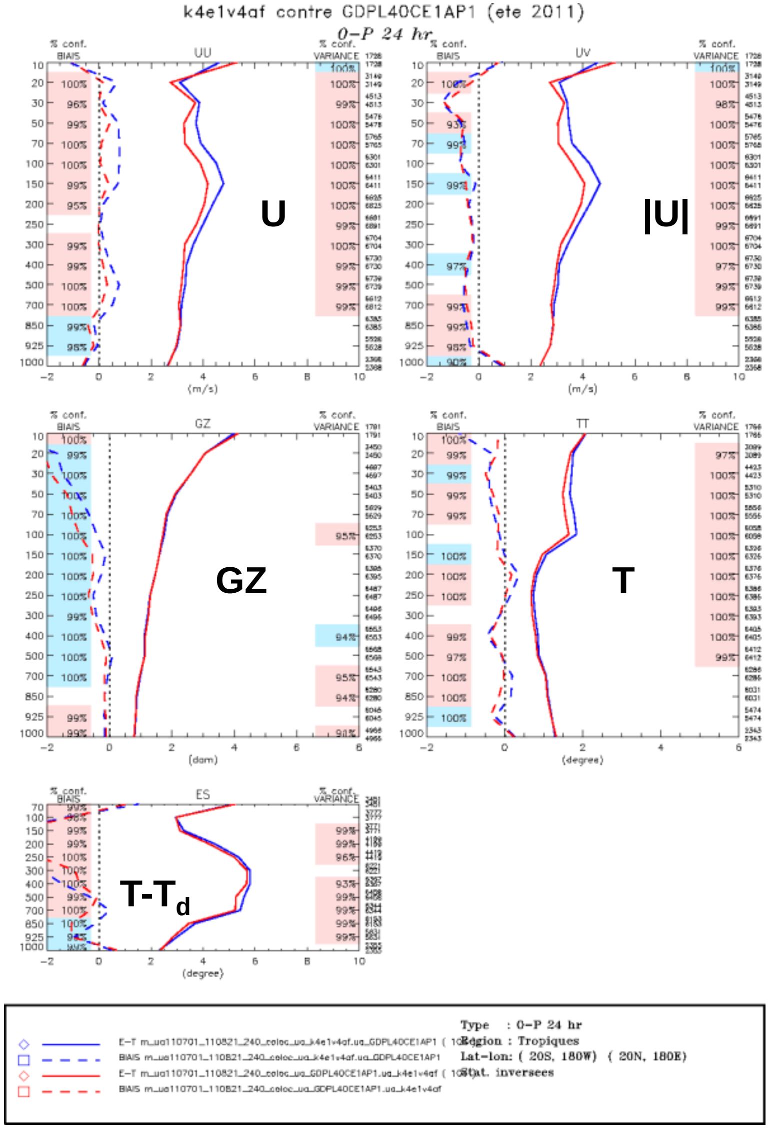
Southern extratropics



Forecast Results: GDPS 4.0.0 vs GDPS 3.0.0

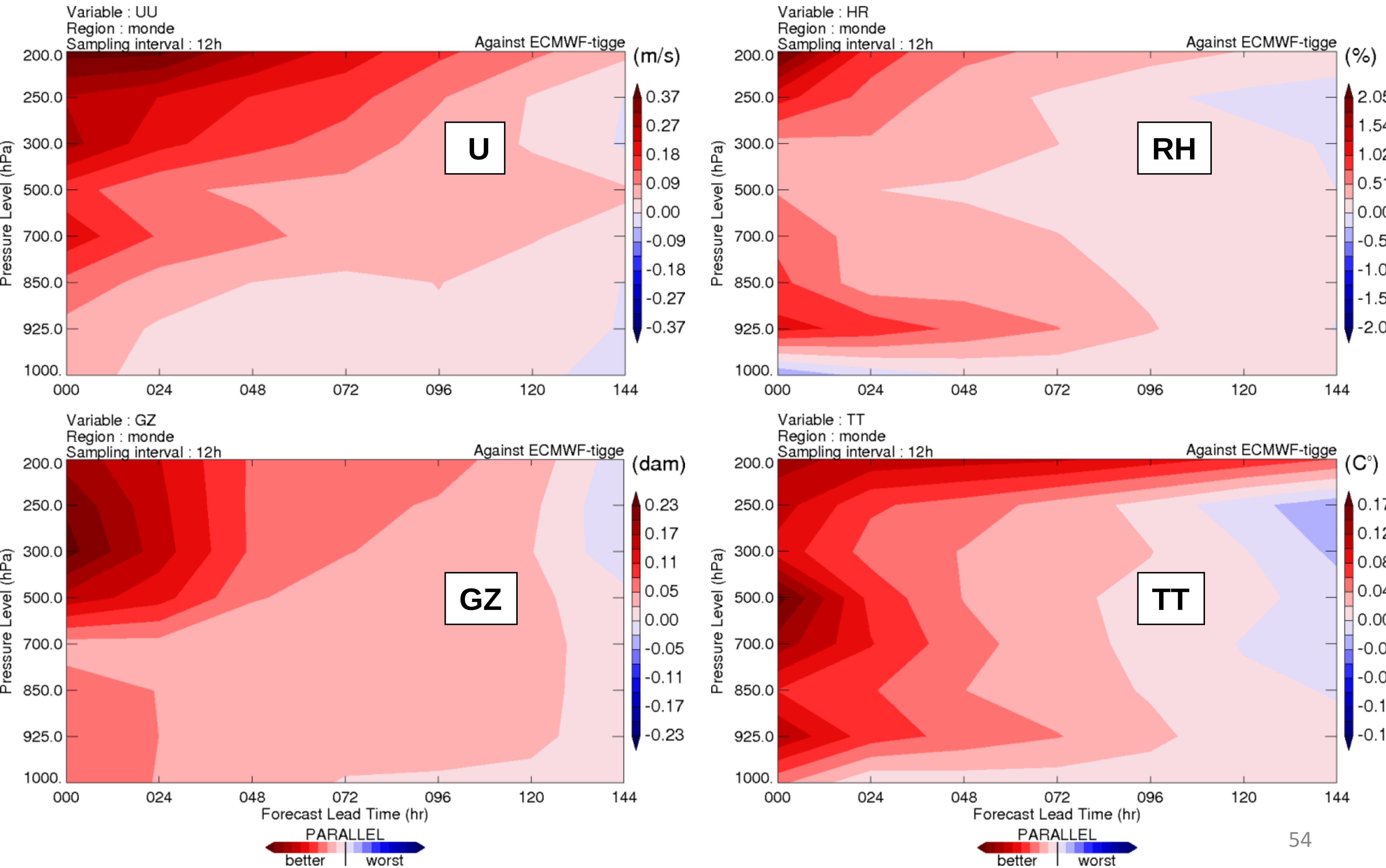
Verification vs. Radiosondes – 24h forecasts

Tropics



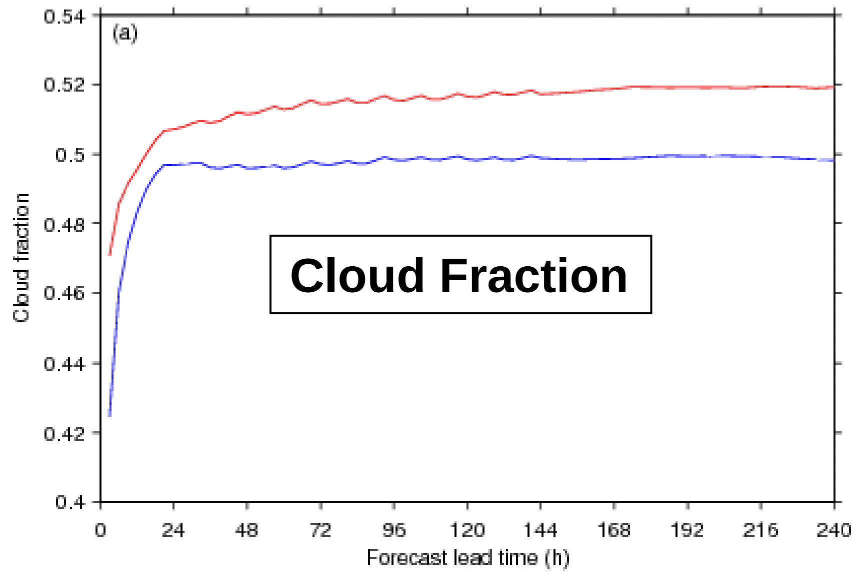
Evaluation of Forecasts: GDPS 4.0.0 vs GDPS 3.0.0

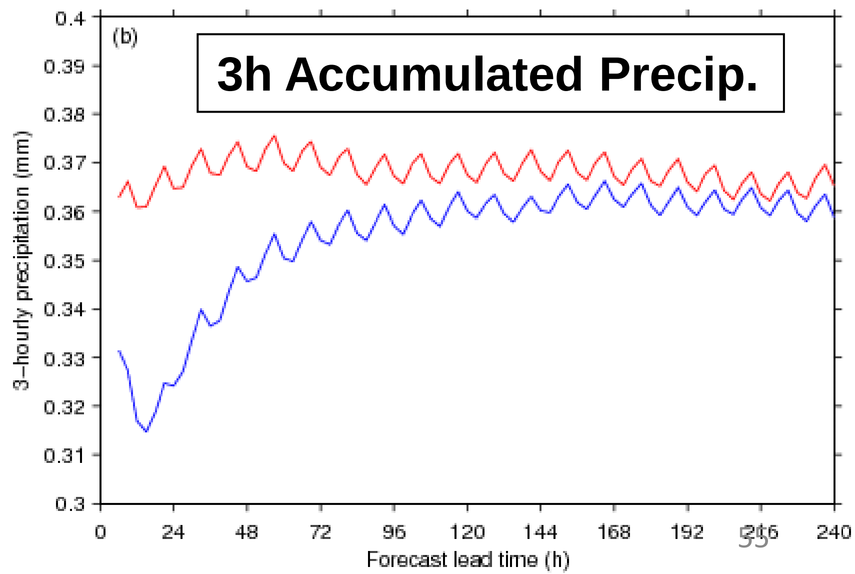
Verification vs. ECMWF analyses: Global Difference in std dev



Forecast Results: GDPS 4.0.0 vs GDPS 3.0.0

- Simple comparison of cloud and precip. spin-up from winter final cycle
- Several changes in new system affect the spin-up during model forecasts:
  - Recycling of several variables
  - 4DIAU instead of full-field digital filter
  - Elimination of uninitialized 3h forecast needed in 4DVar



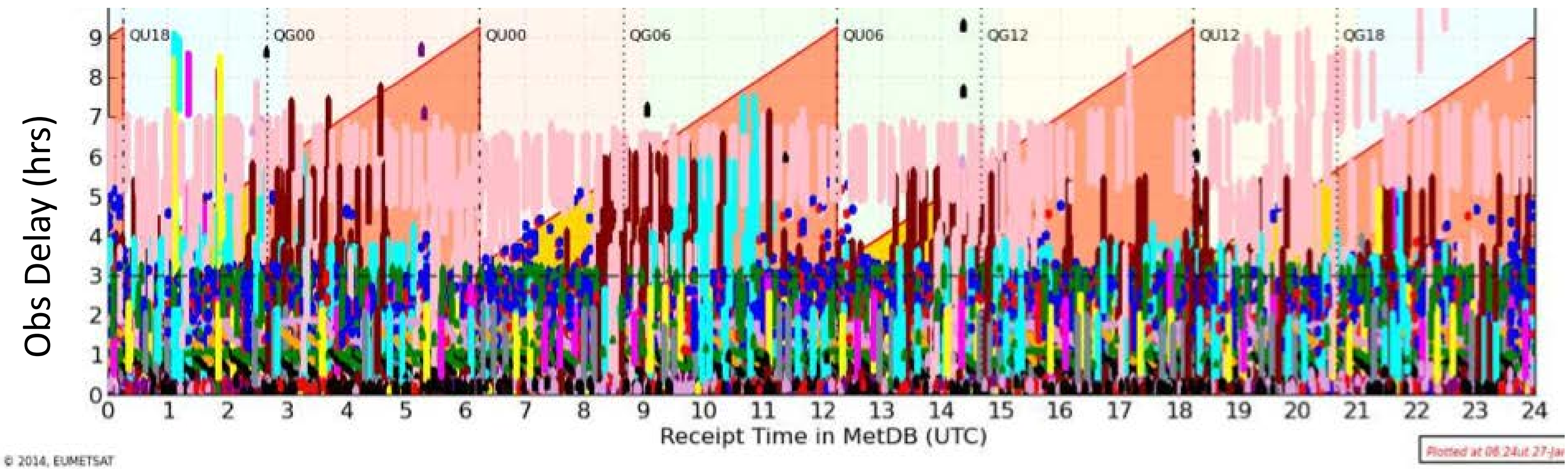


Conclusions: GDPS 4.0.0 vs GDPS 3.0.0

- Change from 4D-Var to 4DEnVar: Significant decrease in computational cost of global and regional systems
- Forecasts either improved or similar in quality vs. previous operational system
- Biggest improvements at short lead times and in the tropics and southern extratropics
- Mass bias significantly different in new system (due to: radiance BC, aircraft BC, recycling physics variables, 4D-IAU), better vs ECMWF, sometimes worse vs radiosonde
- Significant improvement expected for surface temperature and dewpoint during winter (snow density correction)

Supplementary slides:
more on Met Office DA system developments
(c/o Dale Barker)

Current Global DA Operational Scheduling (Example 00UTC analysis shown)



QG00 (2:40)

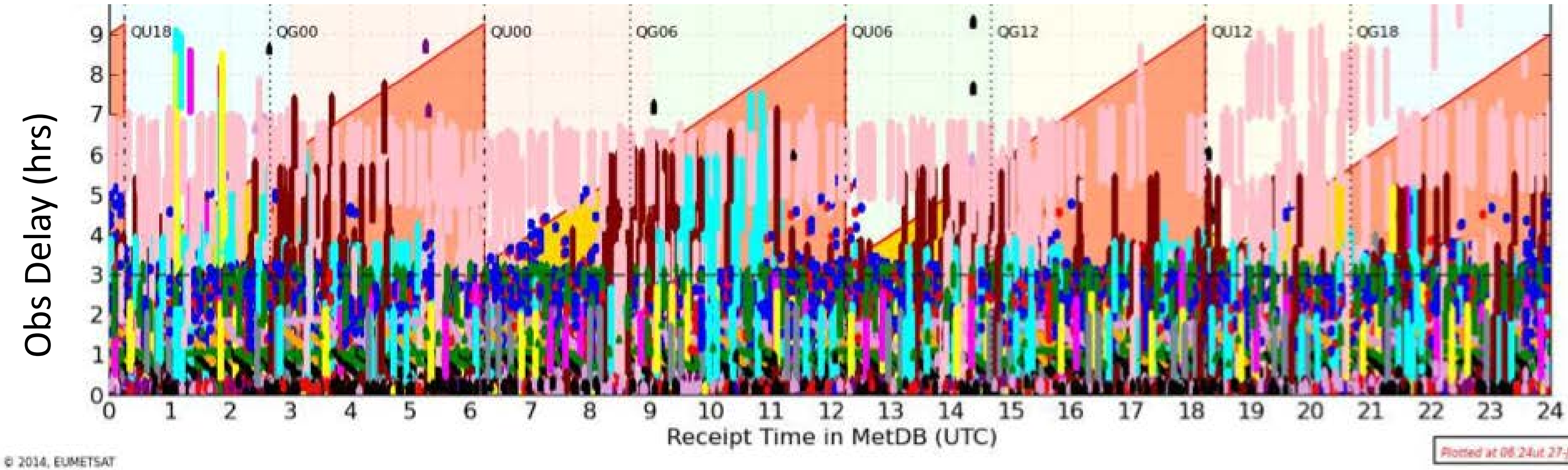
T+168

T+9 (update background for DA)

QU00 (6:15)

- Extended period forecast **does not** see late observations

'Prelim' Global DA Operational Scheduling (early upgrade on next HPC)

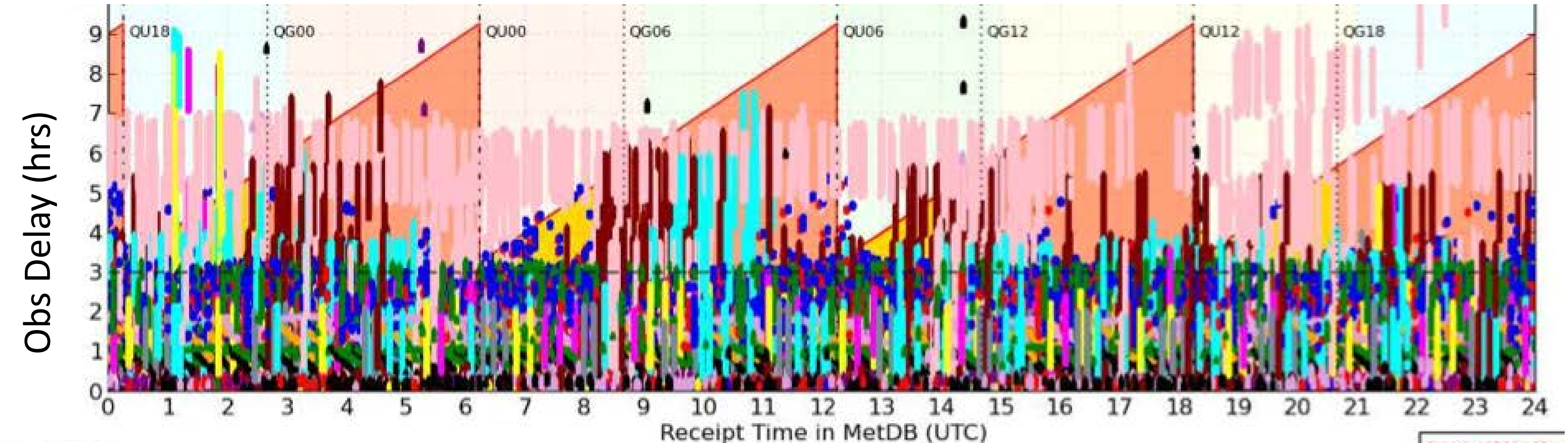


QP00 (2:40) → T+48

QG00 (6:15) → T+168

- Extended period forecast **does** see late observations
- Preliminary T+48hr forecast for customers needing early outlook

Global RUC DA Operational Scheduling (upgrade later on next HPC?)



T+?

QM00 (1:00)

T+?

QM01 (2:00)

etc….hourly updates?

- Complete flexibility to decide when to run global NWP.
- Smoother transition between subsequent analyses.
- DA benefits: Smaller increments, affordable via sensible preconditioning

Convective-Scale DA Strategy/Plans

- Short-term: Extract/optimize UK observing network for UKV 3DVar.

- Medium-term: Develop/implement UKV 4DVar for NWP-Nowcasting
  - Project initiated September 2014
  - Key deliverable:

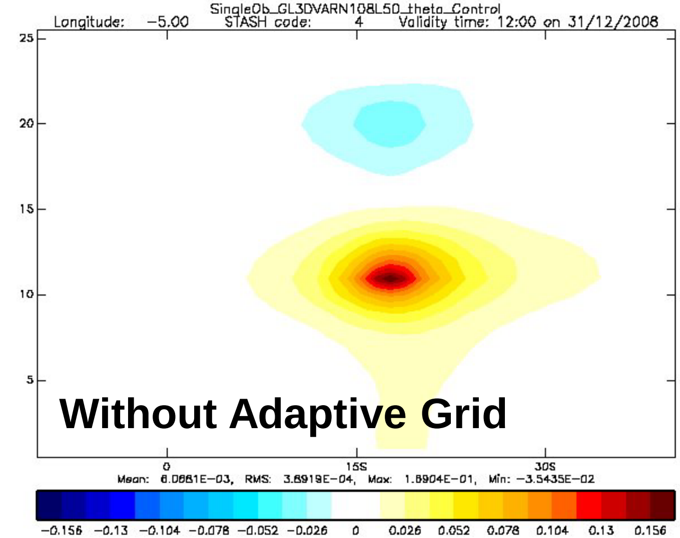
    Report on pre-operational trials of hourly 4DVAR system suitable for nowcasting (March 2016).

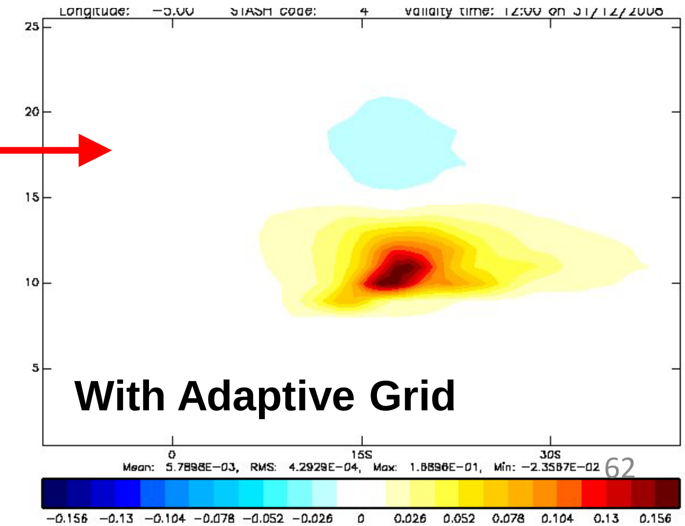
- Long-term: Investigate ensemble-based DA
  - Initial efforts focussed on EnKF
  - Preparations for larger MOGREPS-UK ensemble on next HPC
  - Feed in to LFRic DA design

1.5km UKV Data Assimilation

- Eight 3-hour assimilation cycles/day.
- Forecasts to T+36, every 3 hours.
- Observation cut-off = 75 minutes
- 3D Variational DA (3DVAR) for all obs. except radar rain rate (latent heat nudging)
- Adaptive vertical grid -> flow-dependent increments.
- Incremental Analysis Update (IAU) Initialization

Humidity Analysis Increment in presence of Sc band





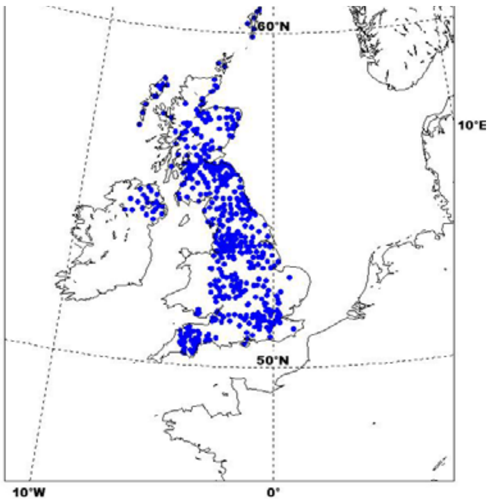
UKV DA Observations: July 2014

Observation group	Observation Sub-group	Items used	Daily extracted	% used in assimilation
Ground-based vertical profiles	TEMP PROFILER	T, V, RH processed to model layer average As TEMP, but V only	23 3000	95, 95, 92 15
Satellite radiances	METOP-A/B NOAA-18/19 Met-10 MSGRADUK	Radiances directly assimilated with channel selection dependent on surface type and cloudiness	MHS/AMSU-B: 30,000 MSG Ch5: 2,000,000 MSG Ch9: 2,000,000	10 0.7 0.1
Satellite-derived cloud	MSGRADUK* / GeoCloud	Cloud-top pressure	2,500,000	10
Aircraft	*Manual* AIREPS (incl. ADS) *Automated* AMDARS TAMDAR	T, V as reported, with duplicate checking and reject lists	 200 9,000 300	 90, 85 68, 68 0, 0
Satellite atmospheric motion vectors	Meteosat 10 BUFR UKWINDS	IR, WV	60,000	15
Satellite-based surface winds	METOP-A/B ASCATHR	KNMI retrievals	40,000	10
Ground-based surface	Land Synop Ship Fixed Buoy + Rigs Drifting Buoy METAR CDL * OPENROAD	P (processed to model sfc), V, T, RH, Vis*, Cloud* P, V, T, RH P, V, T, RH P P, V, T, RH, Vis V, T, RH T, RH	6,800 900 2,500 60 6,000 3,600 45,000	99, 96, 90, 65, 90, 100 80, 40, 70, 60 99, 99, 30, 15 99 15, 15, 15, 11, 2 92, 85, 55 20, 13
Ground-based radar *	RADRATE RADAR WINDS	Rain rate Doppler radial winds	2,000,000 Depends on ppn	0-5? …
Ground-based satellite	GPSIWV	ZTD	70,000	2

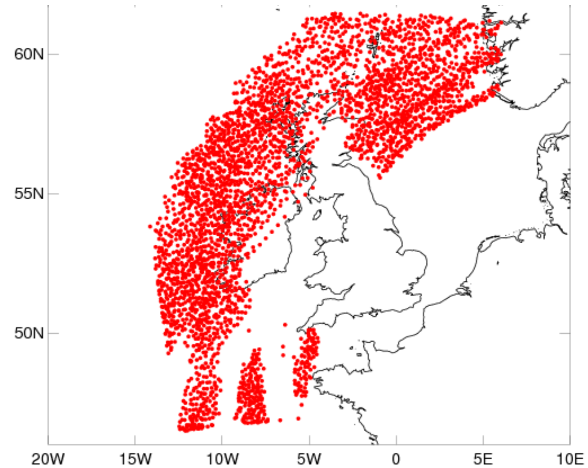
* Subset of data assimilated only in UK model

UKV Observation Activities

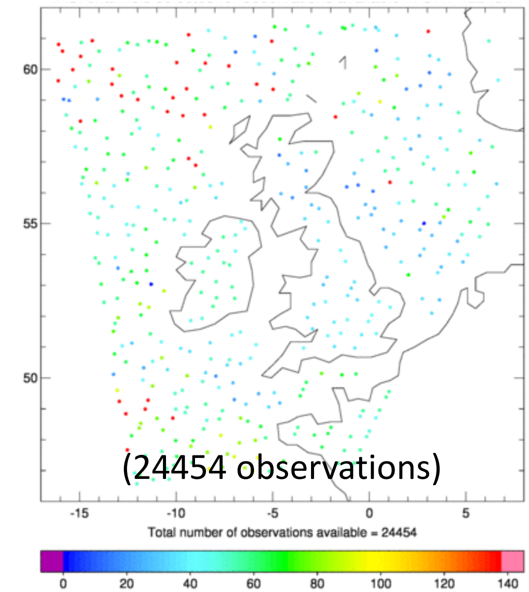
80→ ~600 OpenRoad stations

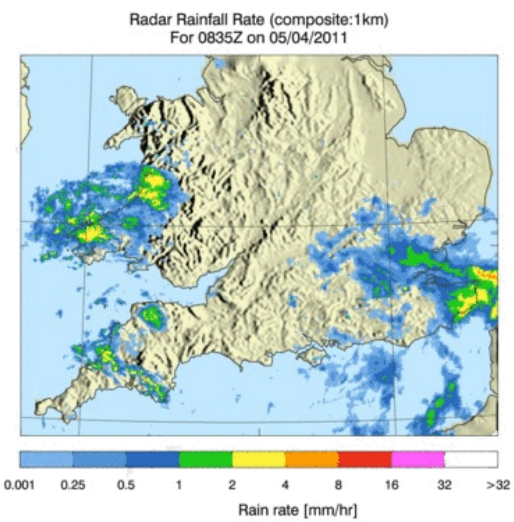


High-Res Meteosat 10 Winds

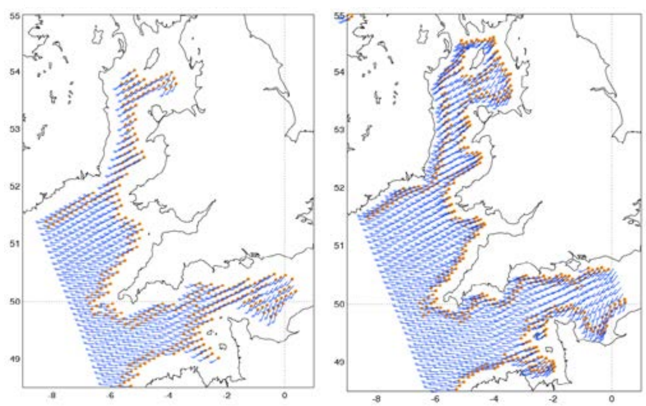


IASI Infra-Red Radiances





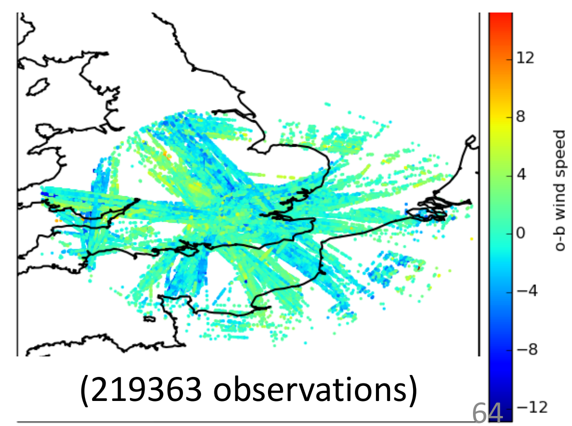
MetOp-A/B + Coastal Winds



Standard **Coastal**

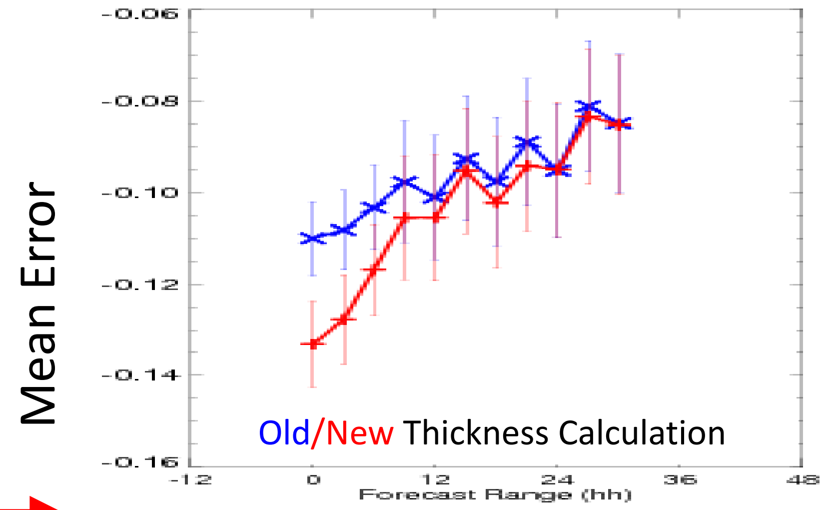
2

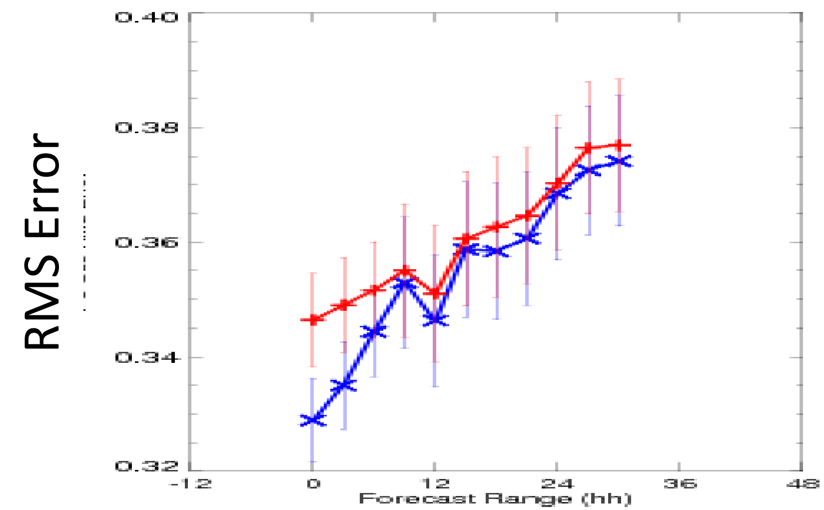
ModeS Aircraft Observations (initial monitoring only)



GEOCLOUD Cloud Assimilation

- Convert cloud top pressure/fraction to vertical profile.
- Compare model/ob cloud -> increment humidity.
- Improved cloud layer thickness via climatology.
- Significantly improved verification against surface cloud reports.
- Temperature/rainfall results mixed.
- Future: Use Visible/IR radiances to better estimate cloud thickness.



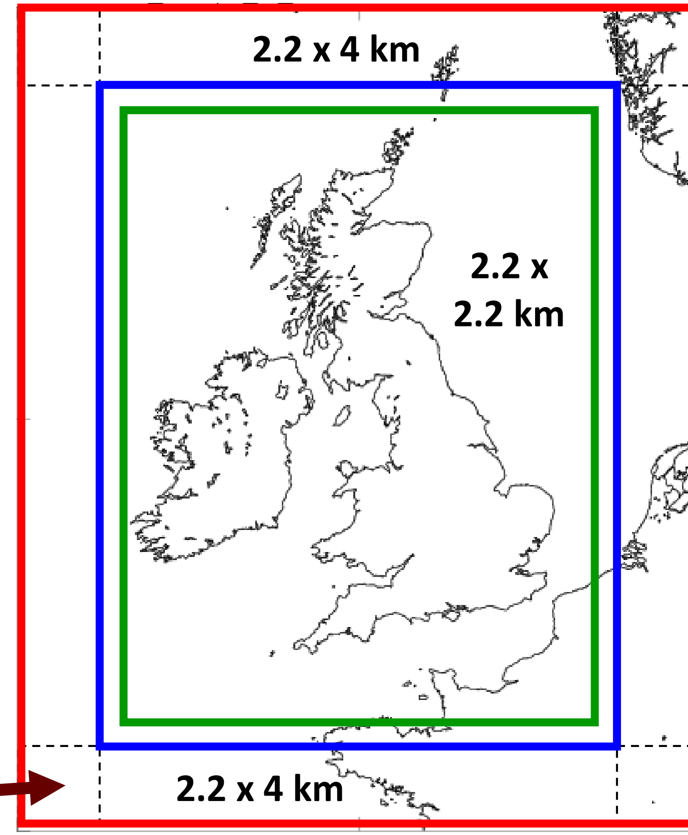


Peter Francis

MOGREPS-UK

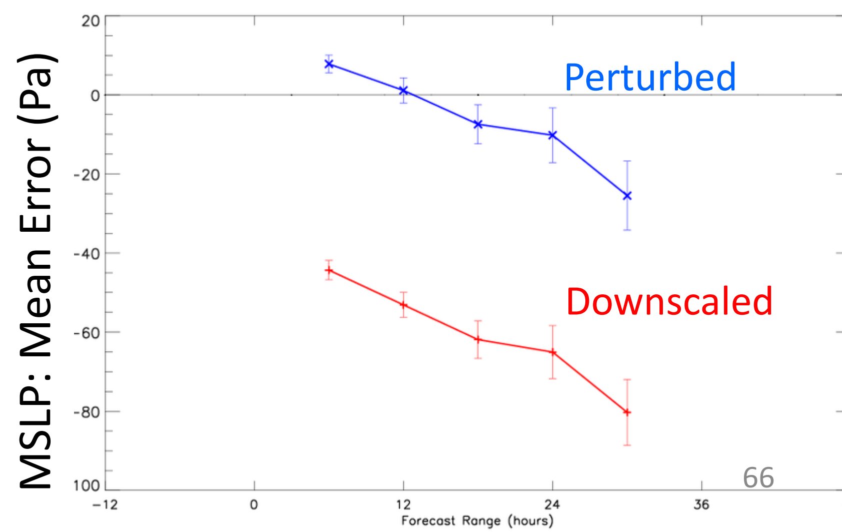
Current System: Downscaler

- Initial, boundary conditions:
  - From MOGREPS-G (T+3)
- Model physics as 1.5km UKV
  - No stochastic physics



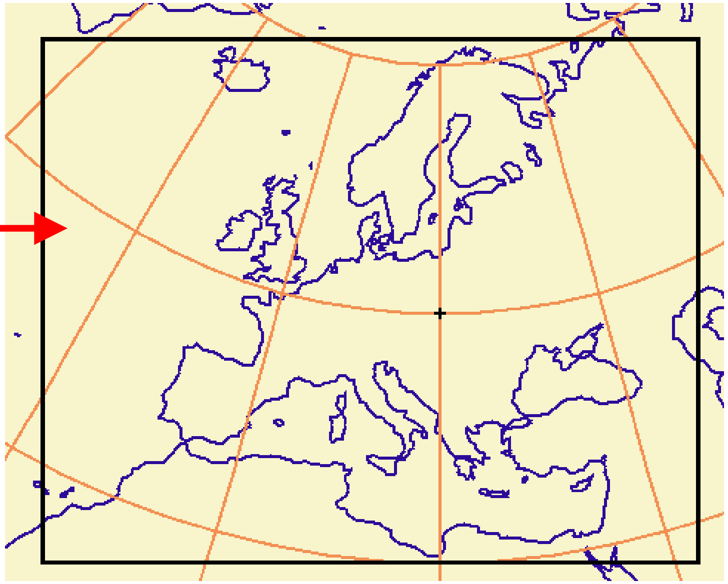
Planned Upgrades:

- Centre MOGREPS-UK on UKV DA analysis (using global perturbations)
- Develop stochastic physics scheme
- Large ensemble for Ensemble DA



Regional Reanalysis: Status and Plans

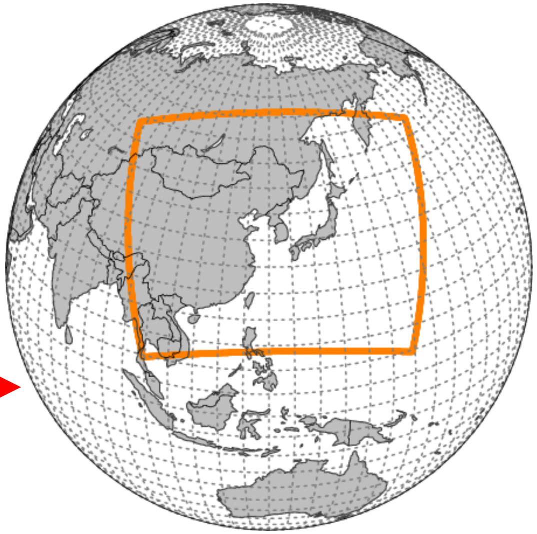
- EURO4M project (2010-2014): 2-year pilot reanalysis (2008-2009) – see MOSAC 2013 paper.



- Uncertainty Estimation for Regional ReAnalysis (UERRA: 2014-2018): multidecadal, ensemble reanalysis of the satellite era (1978-present).

- Indian Monsoon DA and Analysis (IMDAA: 2014 - 2018): Satellite-era reanalysis of South Asian Monsoon.

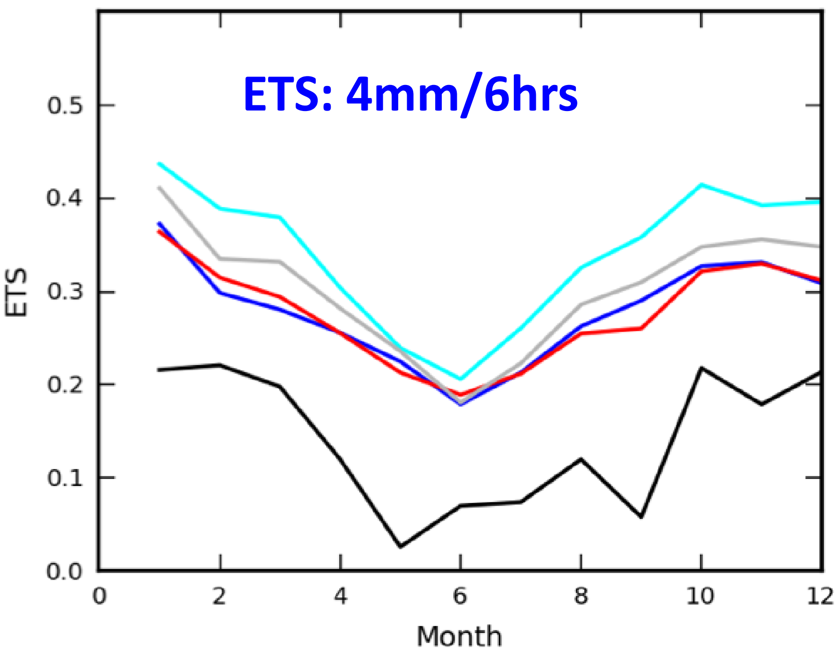
- East Asia Regional Reanalysis: KMA, Met Office, CMA(?).



Impact of Model/DA on Precip Skill

(no direct reanalysis precipitation assimilation as yet)

2008 ETS for Europe area



UM 4DVar Regional Reanalysis

UM Downscaler (ECMWF BCs)

HIRLAM 3DVar Regional Reanalysis

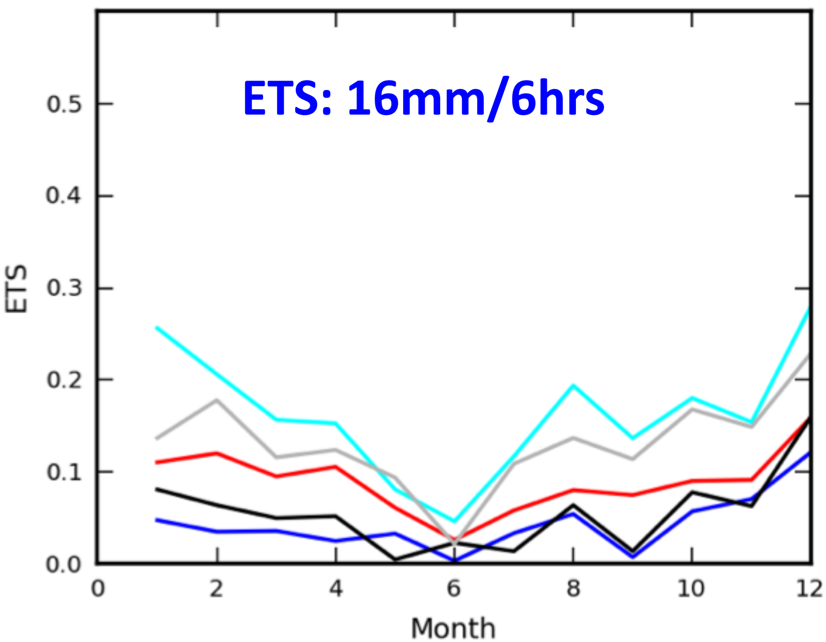
ERA-INTERIM Global Reanalysis

UM Climate Run (No analysis)

Impact of Model/DA on Precip Skill

(no direct reanalysis precipitation assimilation as yet)

2008 ETS for Europe area



UM 4DVar Regional Reanalysis

UM Downscaler (ECMWF BCs)

HIRLAM 3DVar Regional Reanalysis

ERA-INTERIM Global Reanalysis

UM Climate Run (No analysis)

Regional Improvement Over Global Reanalysis

	1mm	4mm	8mm	16mm
Regional Model	1%	9%	50%	300%
Regional Assimilation	8%	13%	14%	30%