Data Assimilation & OSSEs

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Acknowledgements: L. Isaksen, E. Andersson

Outline

- WGNE and Data Assimilation

- OSSEs

ECMWF

WGNE and Data Assimilation (I)

- **WGNE 28:**
  - http://www.wmo.int/pages/about/sec/rescrosscut/documents/WGNE_28_Final_Report.pdf
- **Data Assimilation and reanalysis:**
  - Critical elements are the importance of the assimilating models and the assimilation methods addressing reanalysis issues:
    - long window, coupling of the earth system, cycling of background and model error covariances, bias correction across various instruments
- **Impact of observations:**
  - general recognition that additional metrics are needed beyond the ACC and RMS error traditional scores
  - High impact weather and service delivery

WGNE and Data Assimilation (II)

Current trends in Data Assimilation:

- Variational analysis remains the most widely used technique operationally
- Ensemble techniques have much improved in maturity and most centres invest in ensemble data assimilations via various algorithms: ensemble of 4D-Vars, 4D ensemble Var, hybrid techniques, pure EnKF.
- One major concern: scalability
  - ensemble techniques are agreed to be better at tackling than traditional variational techniques.
- Most centres invest in improving their use of satellite observations:
  - advanced infrared sounders, in all sky conditions, and at increasingly high resolution, etc.

WGNE and Data Assimilation (III)

General discussions:

- WGNE and THORPEX DAOS
  - Substantial data assimilation expertise in THORPEX DAOS WG
  - This Working Group is likely to become part of the standing WWRP structures post THORPEX (after 2014)
  - To avoid duplicating efforts, links should be through membership overlap
    - DAOS ex-officio member in WGNE
- Research on reanalysis techniques should be promoted
- WDAC could task WGNE and DAOS to work together to assist in modeling of co-variances and coupling issues.
- WDAC should also oversee the general issue of OSSE infrastructure in support of observational design for climate applications.

OSEs and OSSEs

- There is a strong requirement for observing system impact assessments coming from both the WMO members (NMHSs), the space agencies and other managers of observing networks
- It is essential to keep a visionary outlook, appropriate for the long-term evolution of the GOS and the realisation of the Vision for the GOS in 2025. The observation impact work should not be driven exclusively by the current political and budgetary situation.
- OSEs remain the main tool to quantify impact assessment
- OSSE (or flavours of it) capability could be an important step toward quantifying the future constellation vision
- OSEs/OSSEs are widely used in NWP context: Are they fit to contribute to GCOS and others?

Internationally Collaborative Joint OSSEs Progress At NOAA

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@Cooperative Institute for Research in the Atmosphere (CIRA)/CSU, CO

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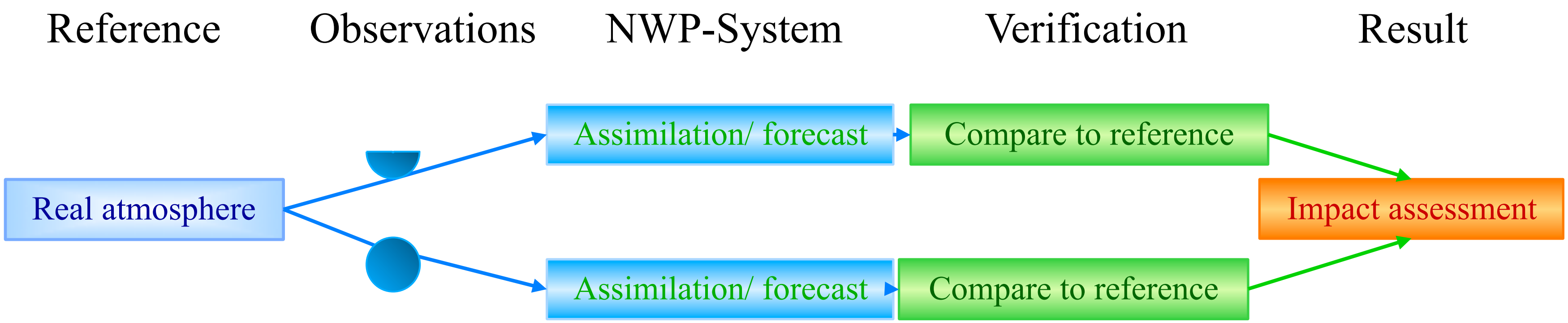
OSSE:Observing Systems Simulation Experiments
http://www.emc.ncep.noaa.gov/research/JointOSSEs/

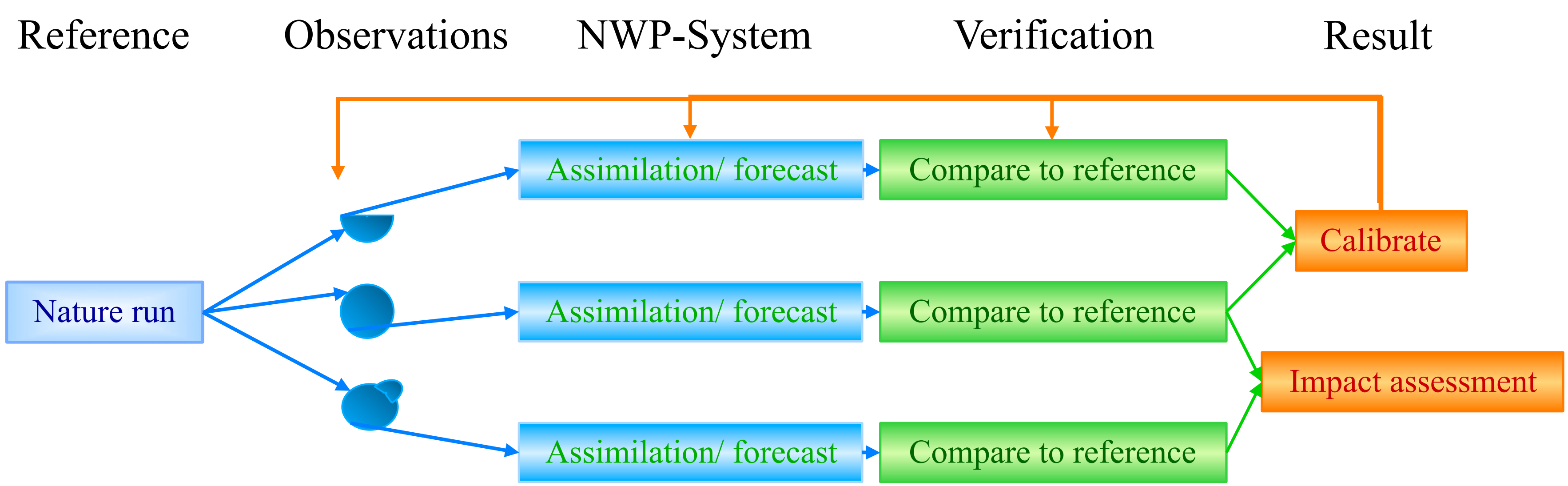
Contribution from an OSSE Infrastructure

- **Impact assessment for future missions**
- **Objective way of establishing scientifically sound and technically realistic user requirements**
- **Tool for assessing performance impact of engineering decisions made throughout the development phases of a space program or system**
- **Preparation/early learning pre-launch tool for assimilation users of data from new sensors**

Observing System Experiment (OSE)



OSSE

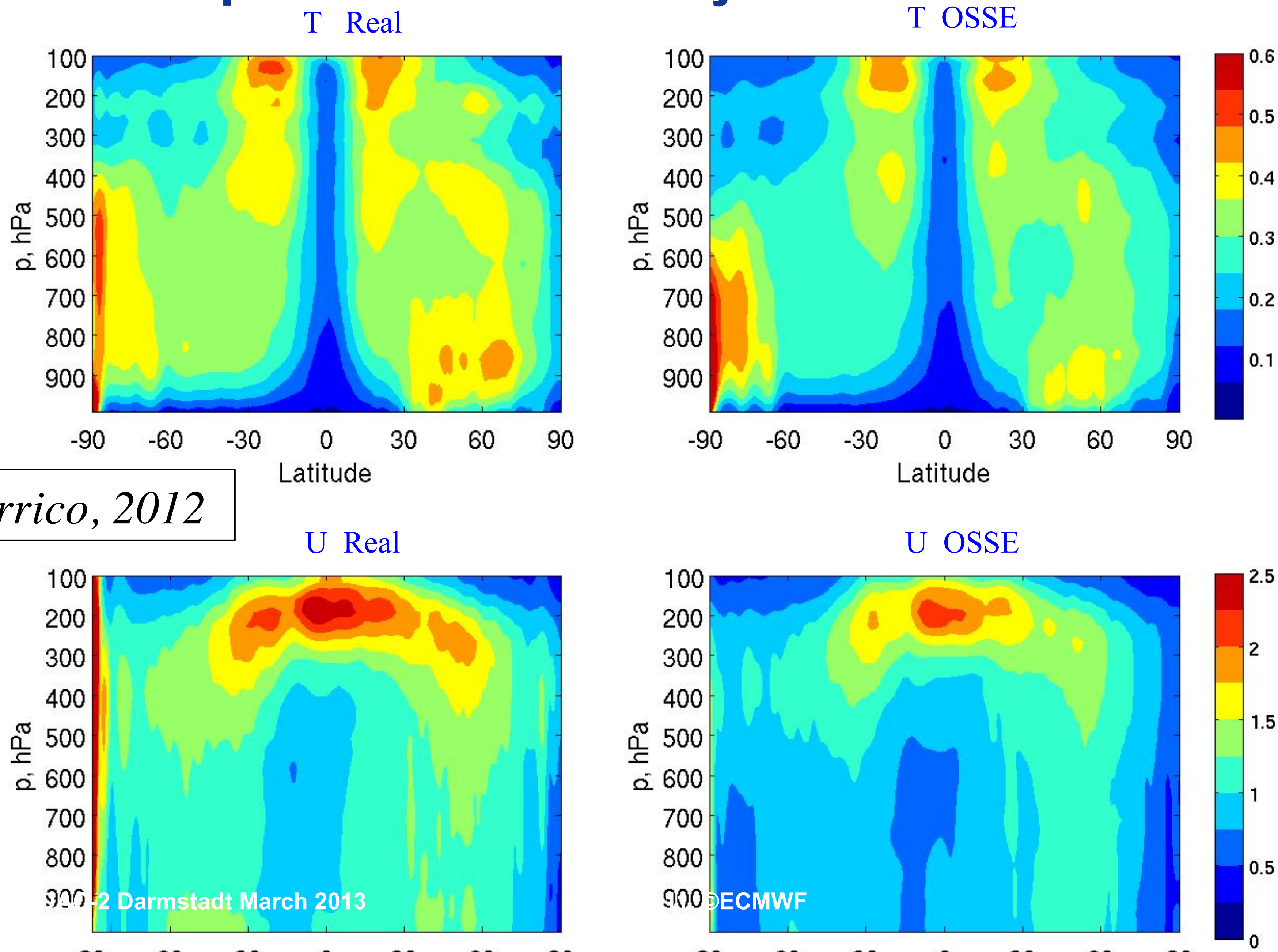


OSSE issues

- Realism of observations simulation
  - Data coverage
  - Observation error characteristics
- Realism of the nature run
  - Resolution
  - Cloud representation
  - Frequency of weather and/or climate events
- Realism of the scenarii
  - Simulation of tomorrow's (observation modelling and DA) systems with today's capabilities

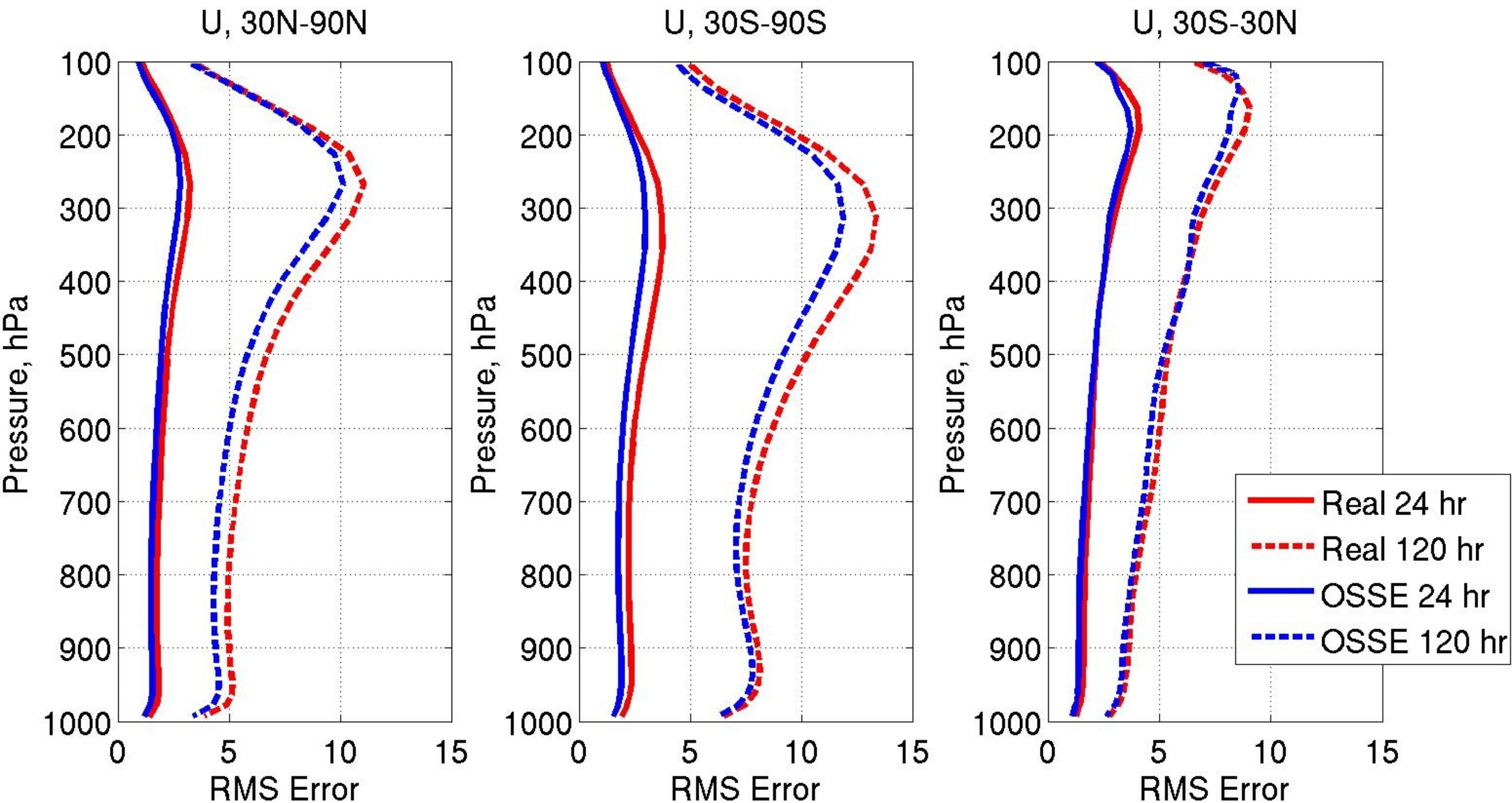
The credibility of an OSSE requires a careful assessment of a number of statistics that can be compared with a real system

Analysis metrics: Example: Square roots of zonal means of temporal variances of analysis increments



Errico, 2012

Forecast metrics: example: RMS fcst error (from Errico, 2012)



Solid lines: 24 hour RMS error vs analysis

Dashed lines: 120 hr forecast RMS error vs analysis

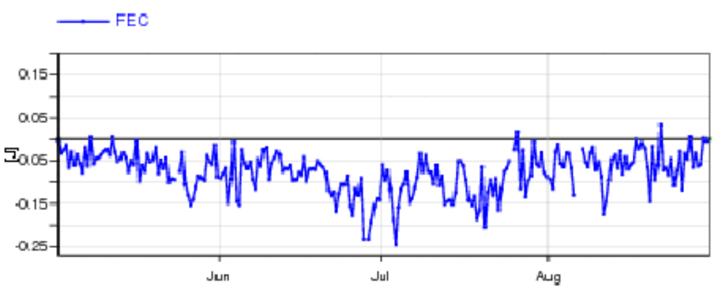
Real Control

OSSE Control

ECMWF

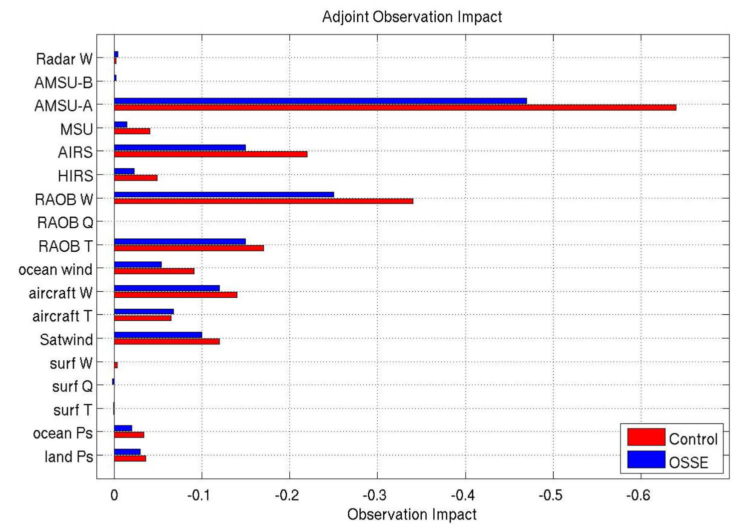
Other considerations

- **New techniques are maturing as complementary or as alternatives to brut force OSEs/OSSEs, aiming at assessing the information content of current or future observing systems**



Metop-A AMSUA ch 13 (5 hPa) STDV adjoint forecast error contribution

C. Cardinali



Errico, 2012

- **EDA-sensitivity based**

Observing System Design: Optimising the number of GNSS RO measurements with EDA technique

→ guidance for GNSS RO component of the future Global Observing System for NWP

(1) How does the impact of GNSS RO measurements scale with the observation number?

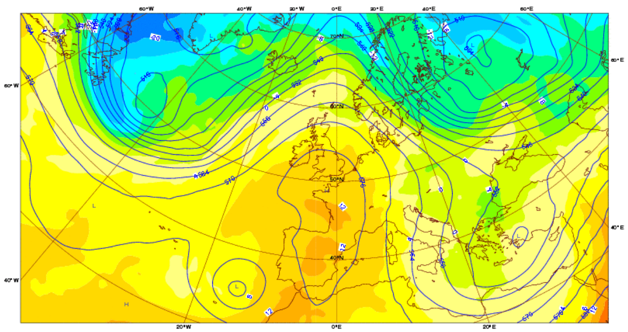
(2) Is an apparent saturation limit in the observation impact?

→ Using the Ensemble of data assimilations (EDA) technique to investigate the observation impact of simulated GNSS RO profiles (2000 to 128000 per day)

(Similar to *Tan et al (2007)* for ADM-AEOLUS)

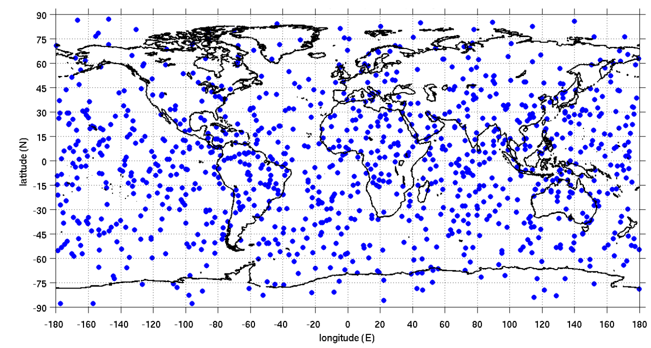
Generation of simulated GNSS RO data

ECMWF NWP analysis at T799 (~25 km) → proxy for the ‘truth’



interpolate

randomly distributed observation time and location



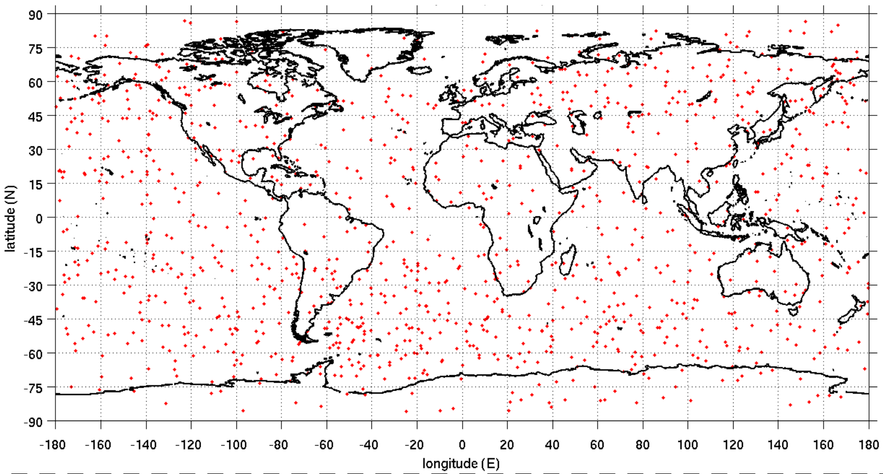
2D bending angle operator
(Healy et al. 2007)

add realistic observation errors

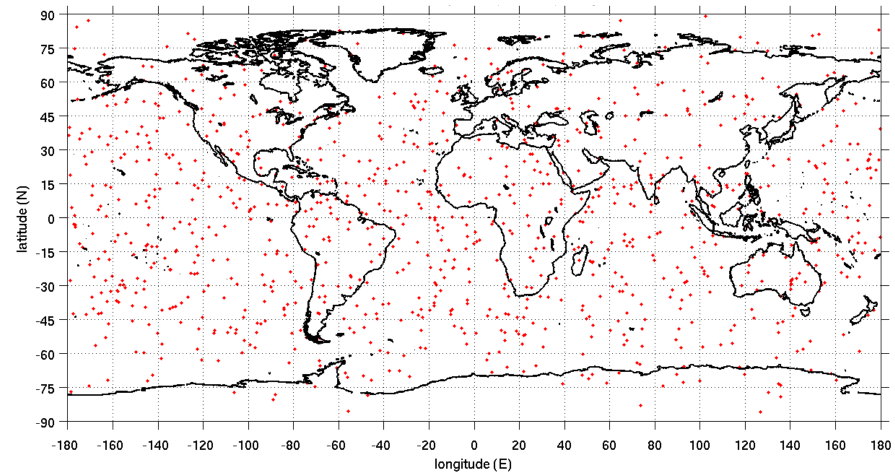
simulated bending angle profiles

12-hourly coverage of GNSS RO data

real data, N = 1157



simulated, N = 1000



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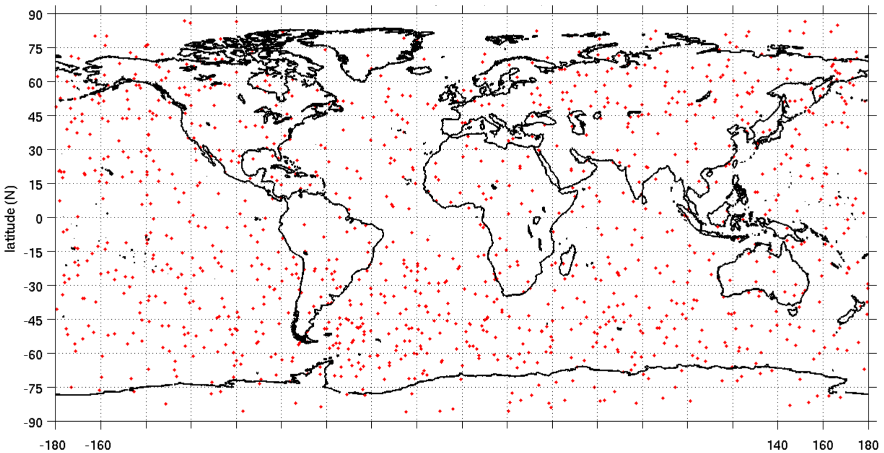
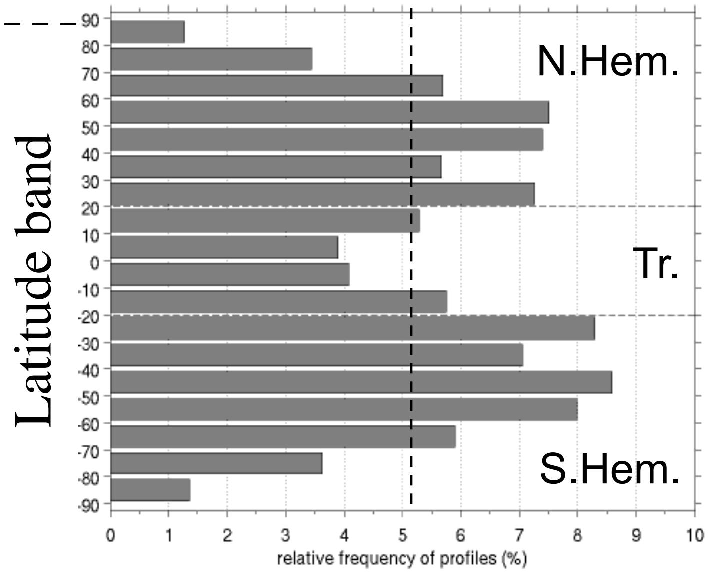
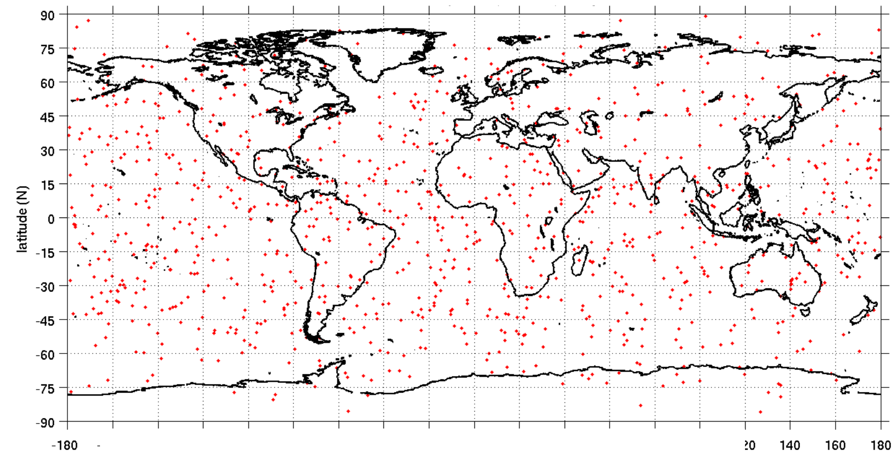
12-hourly coverage of GNSS RO data

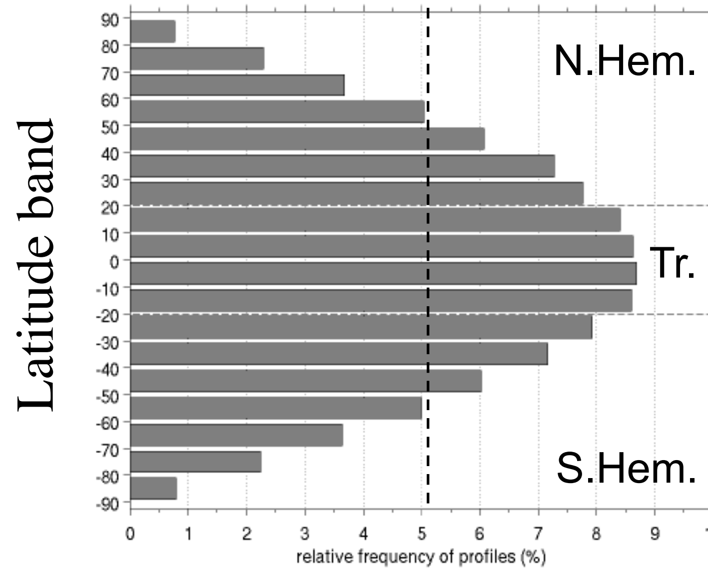
real data, N = 1157





simulated, N = 1000





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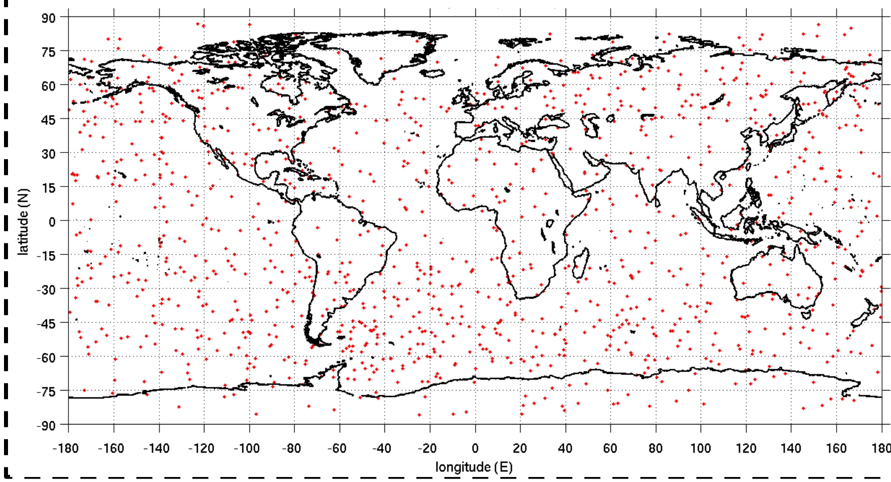
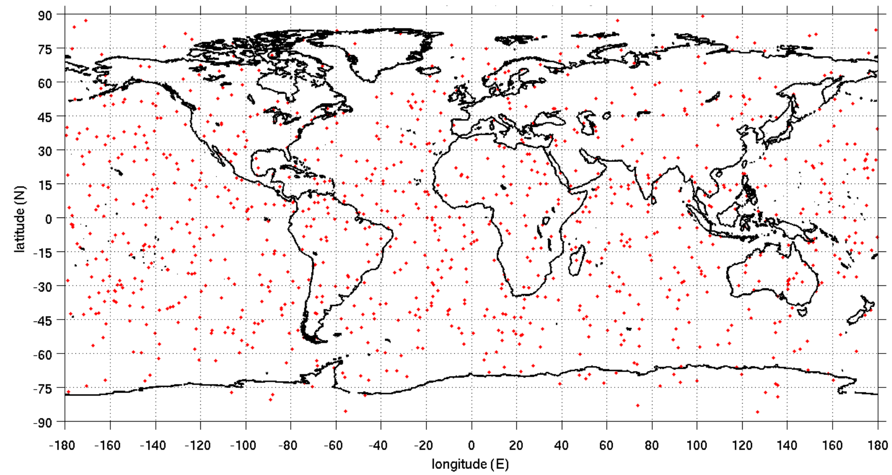
12-hourly coverage of GNSS RO data

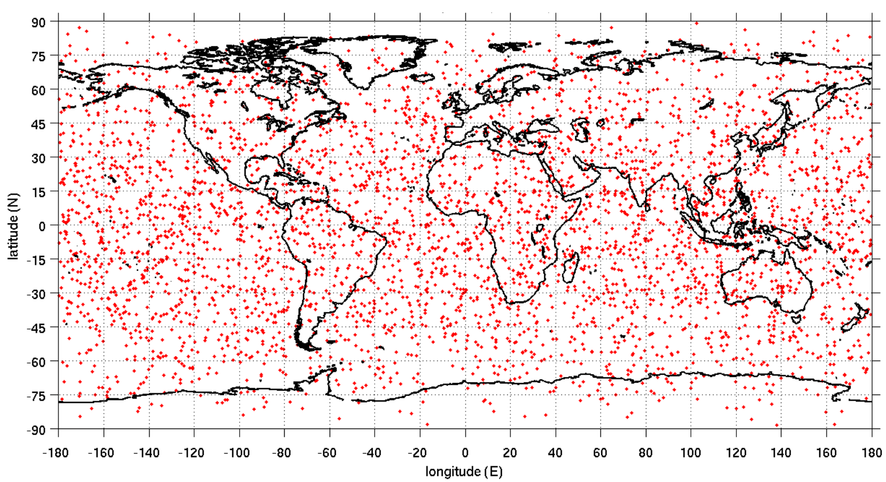
real data, N = 1157



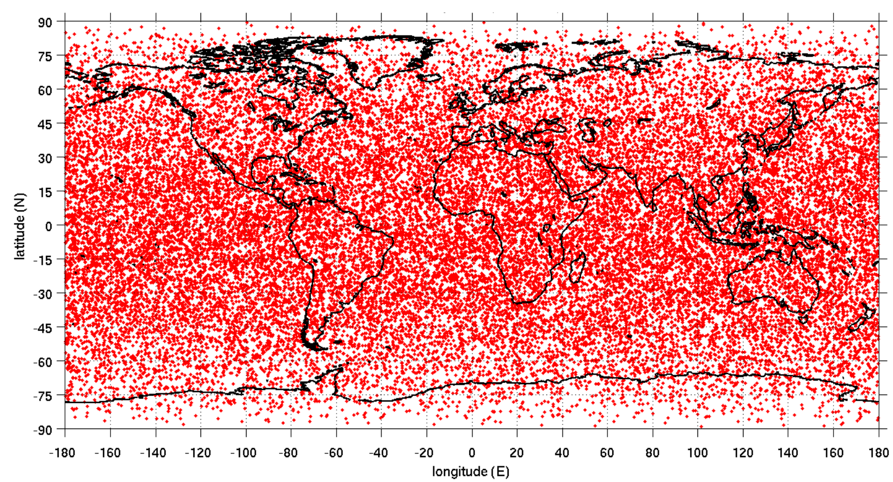
simulated, N = 1000



N = 4000



N = 32000



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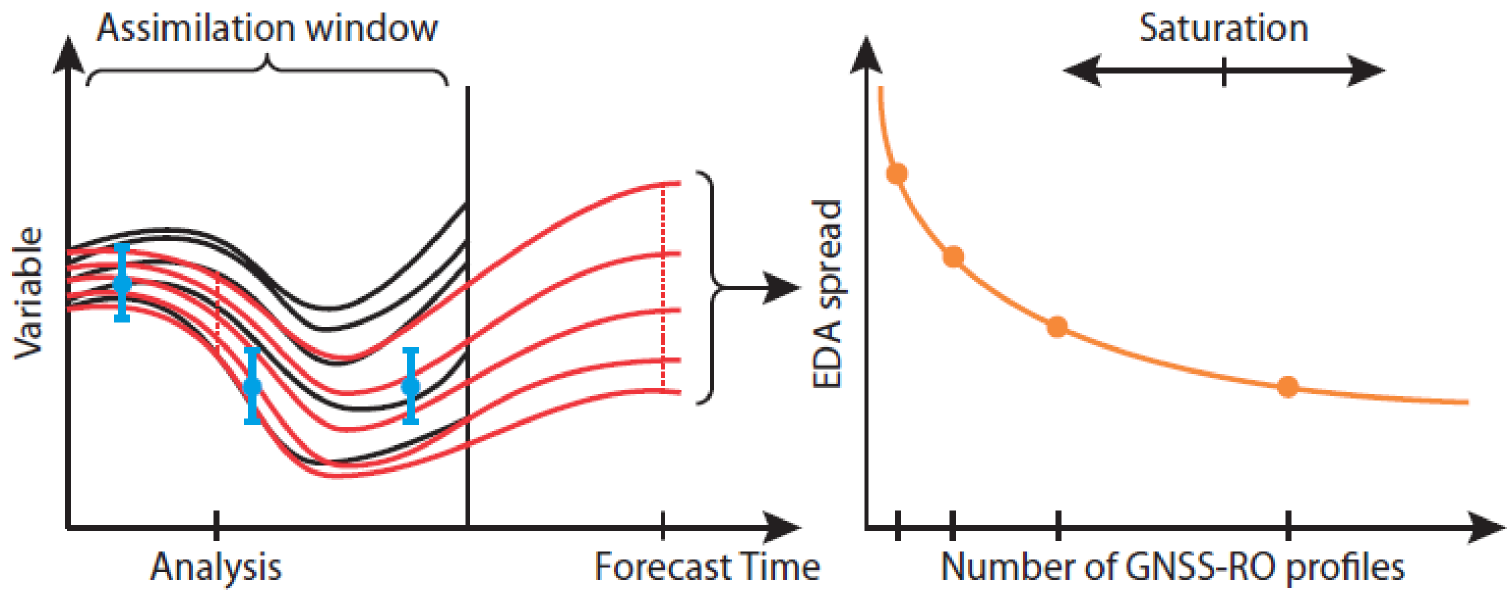
The EDA method – EDA spread

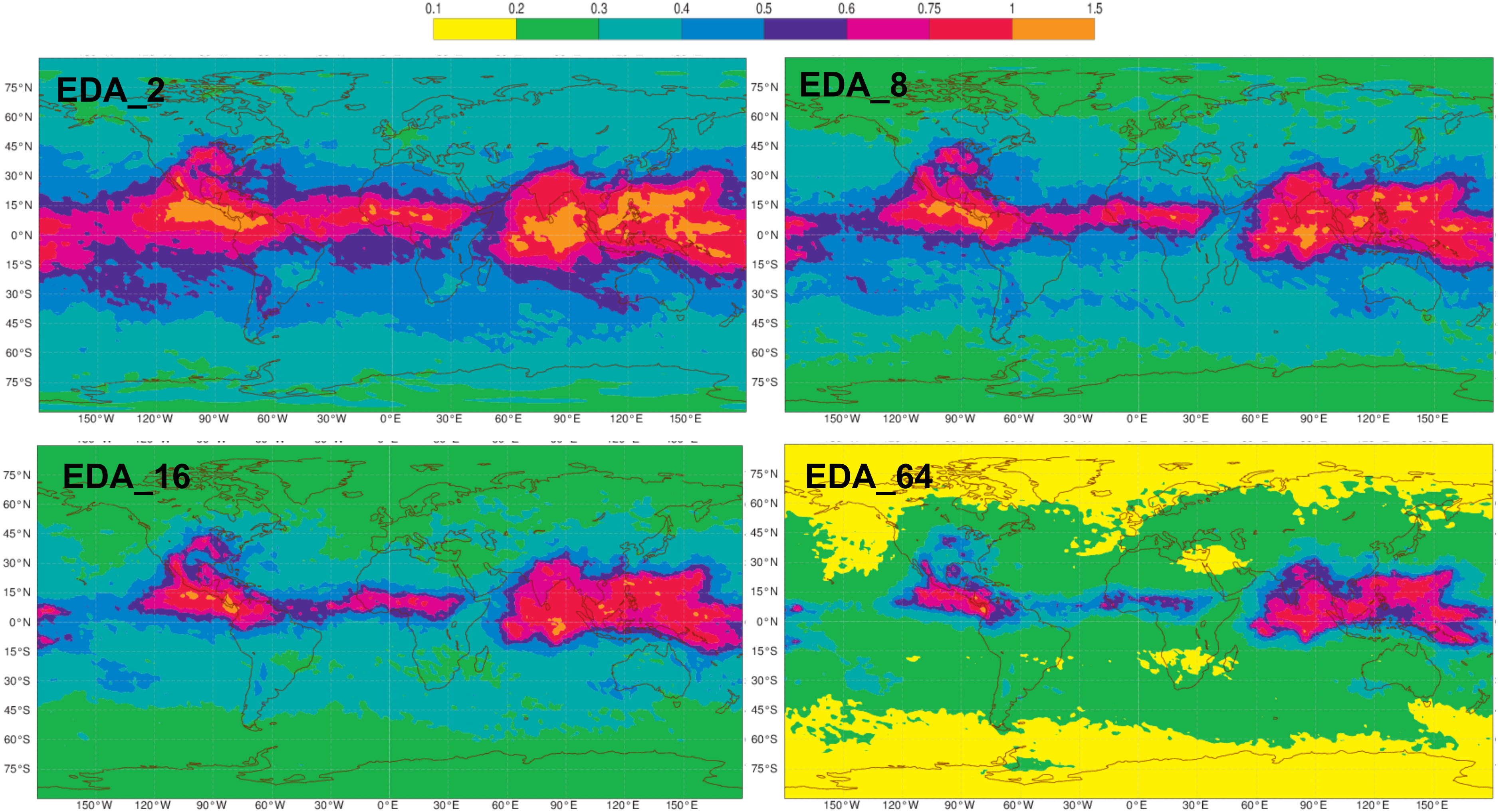


→ **Investigate how the EDA spread (the estimated analysis and forecast error variance) is changing when additional GNSS RO data are used → observation impact**

- **Study indicates 16000 GPSRO soundings as a guidance: feeback to WMO RRR**

Averaged EDA spread - Analysis

T (K) at 100 hPa: Analysis ensemble spread for June 8 - 27, 0 / 12 UTC



Growing demand: Atmospheric Composition OSSEs

Home > Newsevents > Meetings > Workshops > 2012 > Osse >

Workshop on "Atmospheric Composition Observation System Simulation Experiments" (OSSEs)

2012

- MACC-II
- Ocean Waves
- 15th HPC
- OSSE
- Parametrization

2011

- GABLS
- Model_uncertainty
- MOS13

2010

- MACC Gen Assembly
- Satellite Observations
- 14th HPC
- Non-Hydrostatic Modelling
- EGOWS
- SAFEWIND

The ***Atmospheric Composition Observation System Simulation Experiments (OSSE) Workshop*** will be held 22-24 October 2012

Supported by *CEOS Atmospheric Composition Constellation, NASA, MACC-II and ECMWF*

Organizers: *J. Al-Saadi (NASA, USA), D. Edwards (NCAR, USA), Y. Kasai (NICT, Japan), V.-H. Peuch (ECMWF, UK) and C. H. Song (GIST, Korea)*

Background

Observing System Simulation Experiments (OSSEs) have been extensively used by the numerical weather prediction community in order to help develop and optimize contemporary meteorological satellite instruments. Such numerical experiments are now also increasingly used in other fields of earth observation, in particular for oceanography and atmospheric composition applications.

With the evidence of growing and converging interests for Air Quality monitoring from the geostationary orbit (GEO) in America, Asia and Europe (see AC_Geo_Position_Paper_v4.pdf), the Committee on Earth Observation Satellites / Atmospheric Composition Constellation (CEOS/ACC) has recommended to organize a workshop dedicated to study the contribution of future GEO/Air Quality instruments to the global observing system of atmospheric composition using OSSEs.

The specific aims of the meeting hosted by ECMWF on 22-24/10 are:

- to take stock of the experience from NWP
- to review existing work worldwide on OSSEs for "chemical" satellite instruments
- to discuss best practices and to define the needed infrastructure in order to set up reliable OSSEs
- finally, to define a set of experiments intended to document the impact of GEO instruments (alone, together over different parts of the globe, as well as also in conjunction with Low Earth Orbit instruments). This is of particular relevance in Europe in the context of GMES (Global Monitoring for Environment and Security, GMES (Global Monitoring for Environment and Security) ,and of the setting up of operational air composition services MACC-II.

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OSSEs: Summary (I)

- Require substantial resources
- Outcome critically depends on proper specification of observation error statistics (*You get out what you put in*)
- Have in the past sometimes been too optimistic (*Models are more similar to each other than any of the models to reality*)
- Require careful calibration (*Does an OSE with simulated present day observation have the expected impact?*)
- As OSSEs deal with future impact, the performance of the then operational observing- and NWP-systems needs to be accounted for.

ECMWF

OSSEs: Summary (II)

- Substantial stable funding is required. Spanning a period of several years.
- Highest possible quality and resolution required for Nature Run. With option to regenerate it. More than one period.
- Simulation of observations should be flexible, and not tied to generation of N.R.
- Key to success lies in careful simulation of observations, and their errors. The expertise of several groups may be required for this
- Use one (preferably several) mature data assimilation systems. Not the one used for the N.R.
- Calibration of OSSE derived impact against actual impact (for main current observing systems) is essential.
- Careful evaluation, and critical assessment of results.

OSSEs: Summary (III): Elements of an OSSE toolkit

1) **Nature Run(s).** One short at highest resolution. One longer at lower resolution. To be packaged in standard format and archived. Available to users via web-interface. Definition after consultation with users to meet a range of requirements.

2) **Orbit simulators** and generator of realistic observation distributions for terrestrial data. Relatively straight forward.

3) **Observation simulator software.** A dozen or more codes to simulate observations and their errors with realism. For current (and some) future observing systems. Gross errors? Involve data providers. Document the simulators thoroughly.

4) **General interface between 1), 2), 3).** Read N.R., get observation locations, interpolate N.R. to those locations, apply observation simulators, standard format output.

Funding, coordination and management of such a concerted effort is required. Initiatives exist and should be consolidated.

ECMWF estimates to ~10 person-year the required effort to sustain such an activity.

OSSEs: Summary (IV)

- Full OSSEs are expensive and sharing Nature Runs and simulated observation saves costs
- OSSE-based decisions have international stakeholders and OSSEs should be developed as joint global projects
- Community ownership and oversight of OSSE capability is also important for maintaining credibility
- The EDA is an independent and simpler OSSE method that has been shown to be valuable, and complements traditional OSSEs

- OSEs (especially in the context of reanalyses) remain an invaluable resource to document information content of observations and provide future guidance

THE END