Summary of the ECMWF/EUMETSAT NWP SAF Workshop on the Treatment of Random and Systematic Errors in Satellite Data Assimilation of NWP

Virtual workshop, 2 – 5 November 2020

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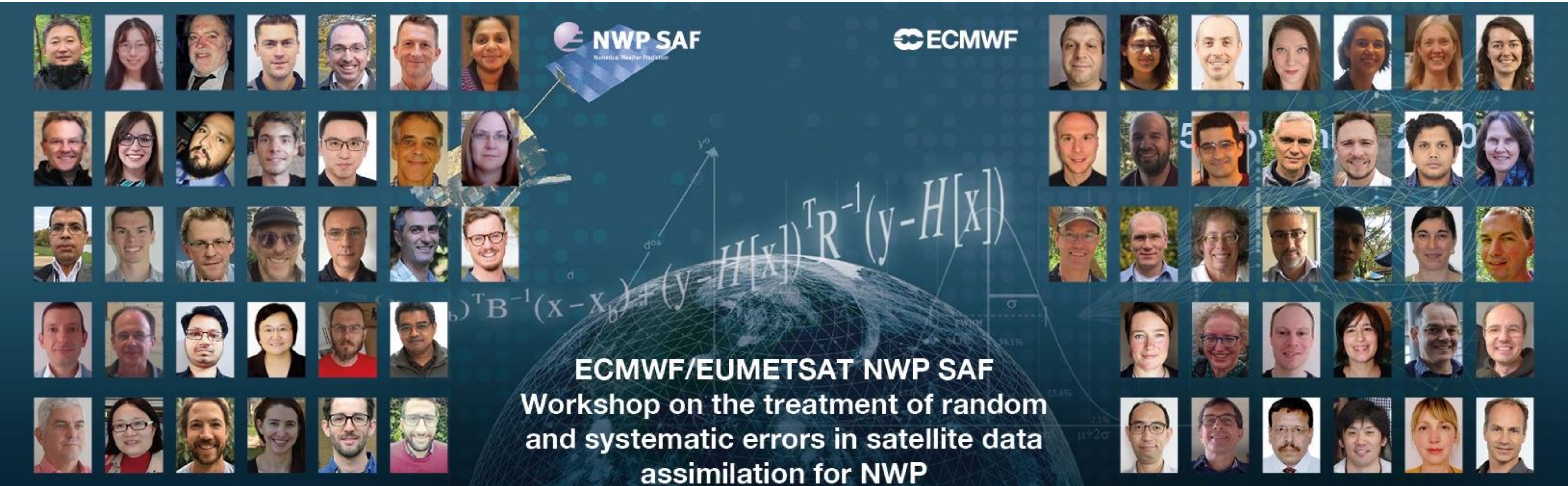


Context: Role of systematic and random errors in NWP

- **Systematic errors:**
  - Present in observations, observation operators (e.g., radiative transfer), forecast models, etc
  - Need to estimate/remove prior to or as part of the assimilation

- **Random errors:**
  - Estimates of random errors in background fields and observations are used to determine the weighting of both to produce an analysis
  - Observation-related random errors arise due to measurement errors, observation operators (e.g., radiative transfer), representativeness differences between observations/model fields, etc

Workshop overview

Three main themes, three sessions:

1. Estimating uncertainties
2. Correction of observational and model biases in data assimilation
3. Representing random observation errors in data assimilation

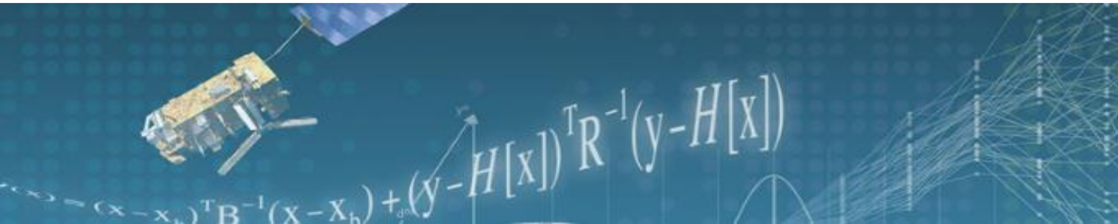
23 oral presentations; 12 posters

Panel discussions and **informal discussion groups** at the end of each day.

Working groups on treatment of systematic and random errors, respectively.

Almost **200 experts** from NWP centres, space agencies, and academia.

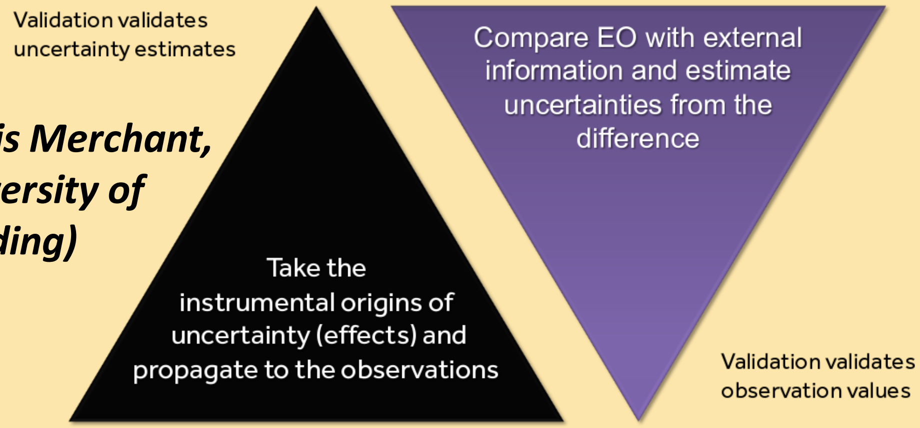
Recordings, posters, etc, see: https://events.ecmwf.int/event/170/



Estimating uncertainty: Main topics

- Uncertainty estimates from instrument characterisation
- Metrological approaches
- Estimation of radiative transfer and representation errors
- Uncertainty estimation and diagnosis in NWP
- Uncertainty estimation for historical datasets

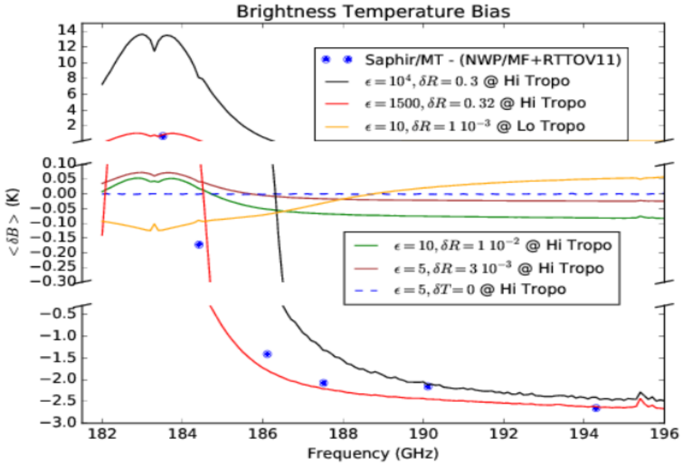
Top-down vs. bottom-up approach to uncertainty analysis



(Chris Merchant, University of Reading)

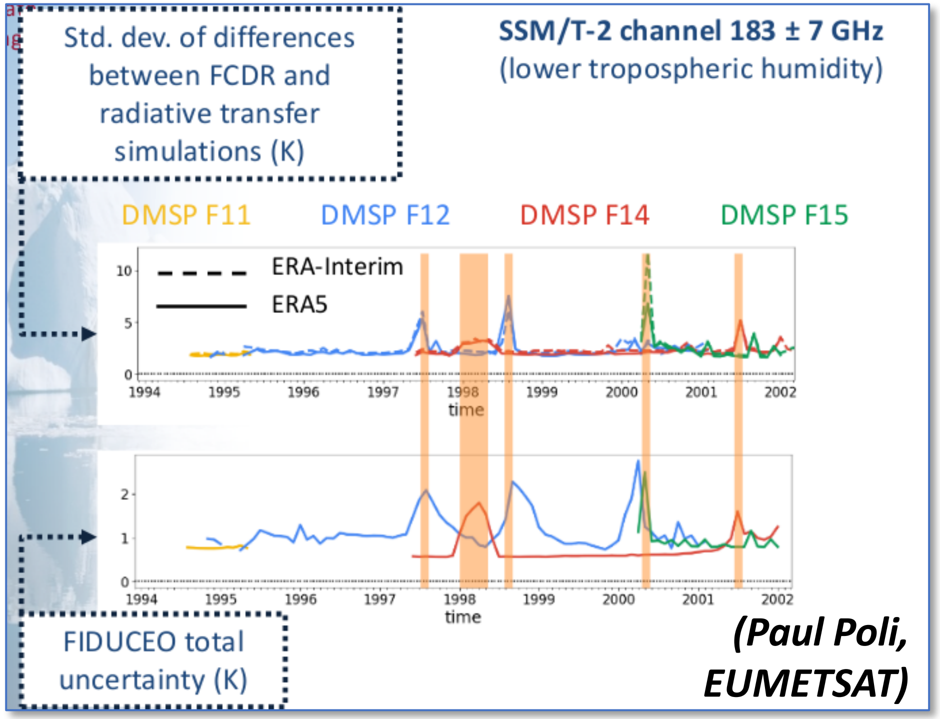
Effect of FOV inhomogeneity

Can turbulence (= inhomogeneity) within the field of view cause significant biases in radiative transfer modelling at the 183 GHz band?



(Xavier Calbet, AEMet)

Calbet et al., AMT, 2018



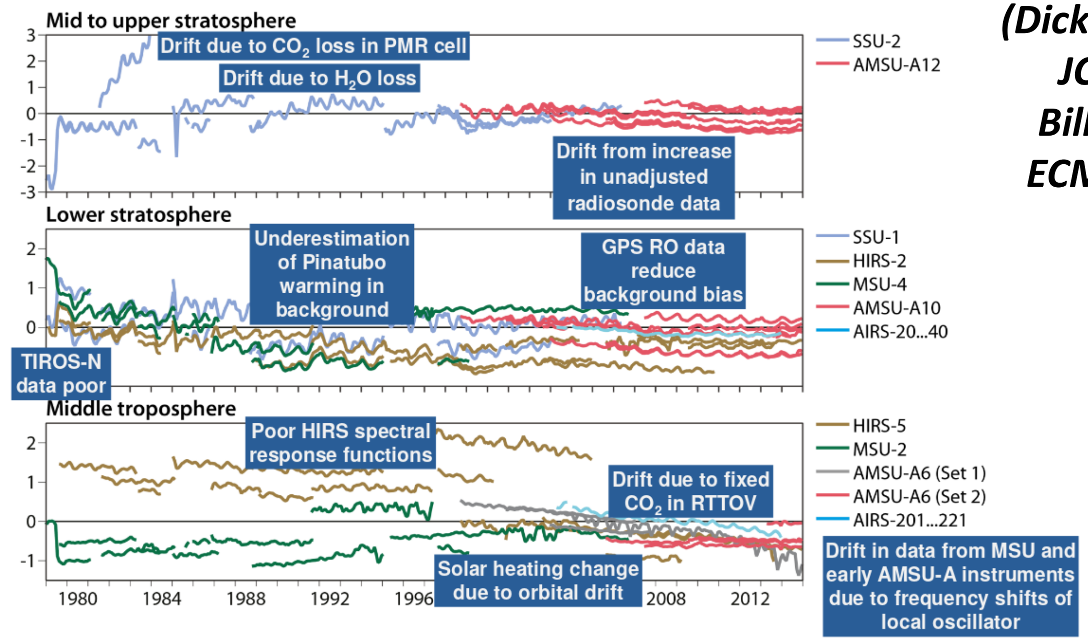
(Paul Poli, EUMETSAT)

Correction of observational and model biases in data assimilation: Main topics

- Treatment of observation biases in reanalyses
- How to estimate both model and observational biases in DA?
  - Variational bias correction; anchor analyses; weak-constraint 4D-Var
- The role of anchor observations and uncertainty constraints
- Machine Learning approaches to bias estimation

Variational bias corrections (K) in ERA-Interim

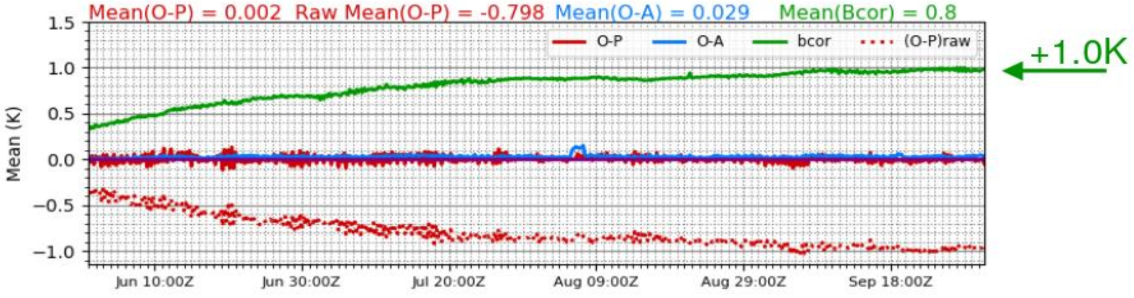
Simmons et al, 2014



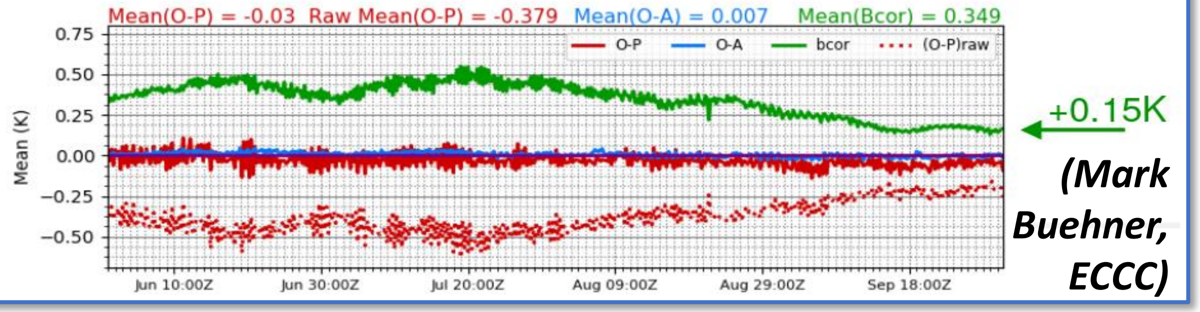
Drift in data from MSU and early AMSU-A instruments due to frequency shifts of local oscillator

(Dick Dee, JCSDA; Bill Bell, ECMWF)

Bias correction estimated using background state



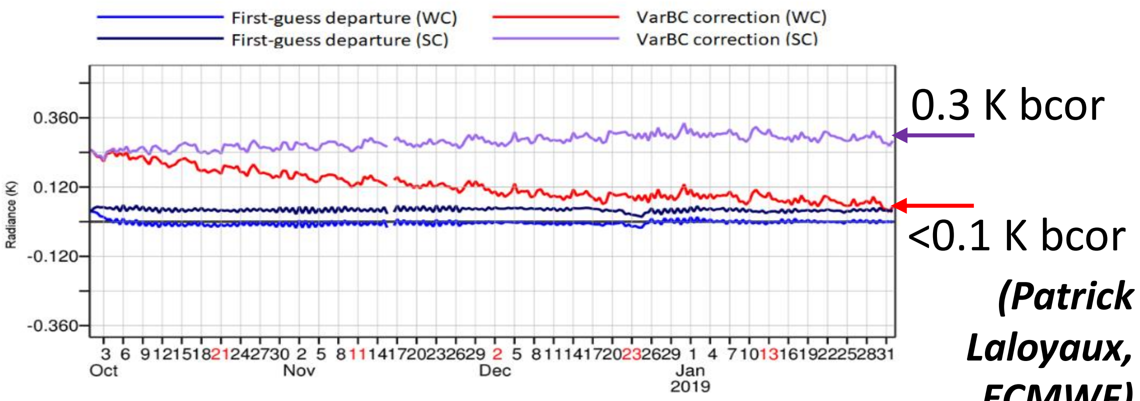
Bias correction estimated using 3D-Var with anchor obs



(Mark Buehner, ECCC)

Interaction of weak-constraint 4D-Var with VarBC

First-guess departure and observation bias correction in AMSU-A channel 10

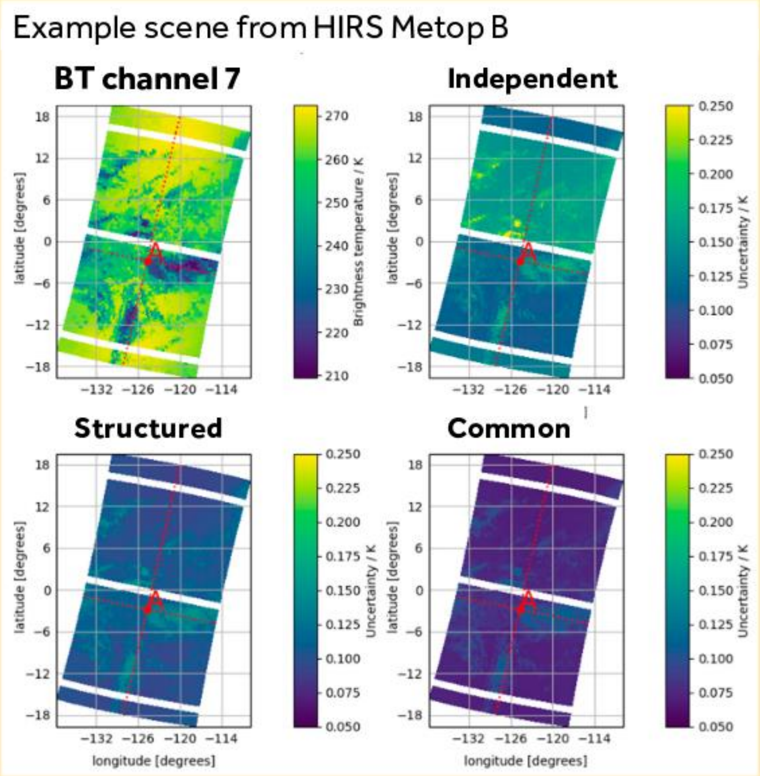


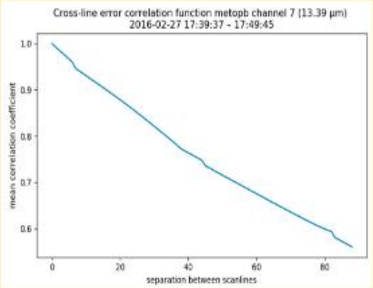
(Patrick Laloyaux, ECMWF)

→ Observation bias correction is large in SC4DVAR (part of model bias is absorbed in VARBC). VarBC is much smaller in WC4DVAR

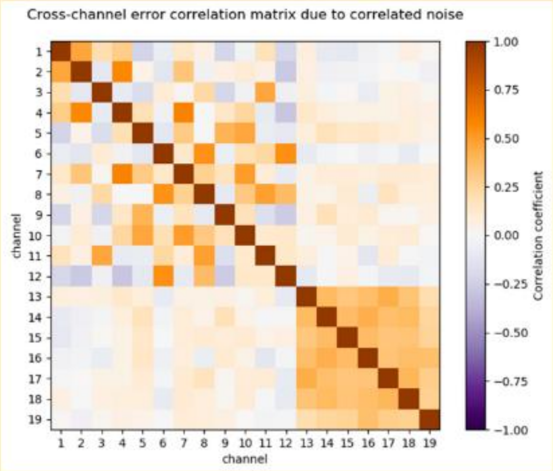
Representing random observation errors in data assimilation: Main topics

- Treatment of situation-dependent observational uncertainties
- Observation error correlations (incl from representation error):
    - Inter-channel, spatial
    - How to estimate them?
    - Accounting for them in the assimilation





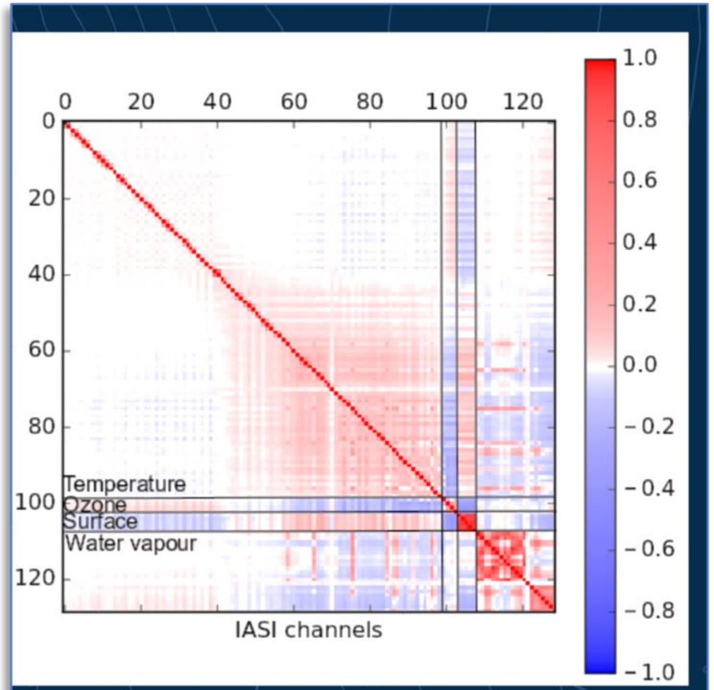
Correlation function along-track

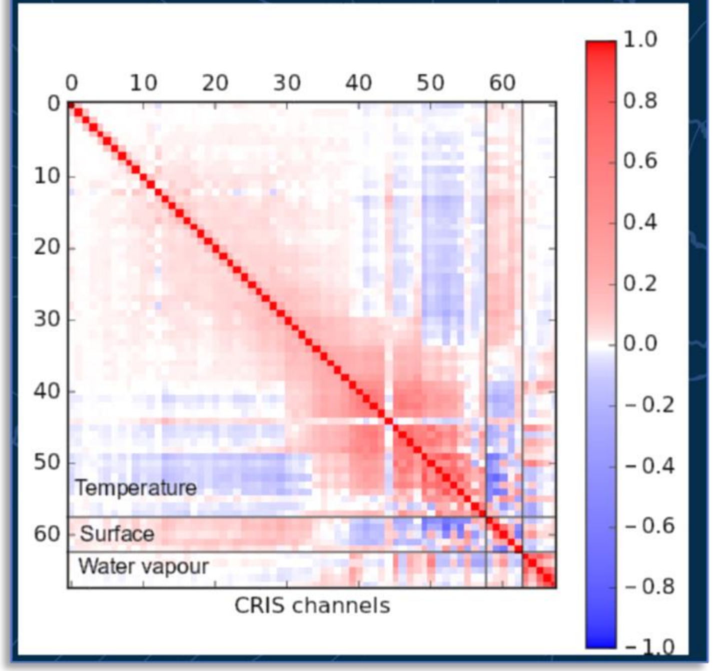


Cross-channel correlation function

(Chris Merchant, University of Reading)

Merchant et al., 2019, Rem. Sens., doi.org/10.3390/rs11050474

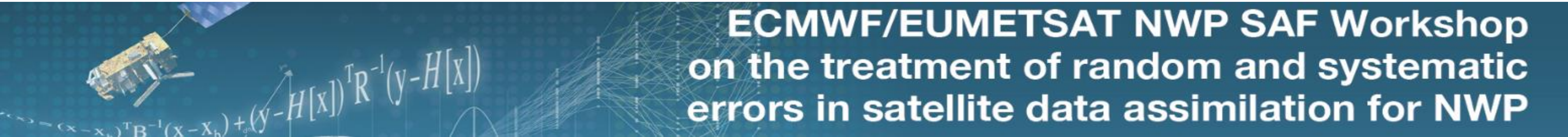




(Fiona Smith, BoM)

Main outcomes: Overarching points

- **More work needed regarding metrological/physical understanding of systematic as well as random observation-related errors.**
    - Includes instrument-related errors, as well as representation errors, arising, for instance from observation operators (e.g., radiative transfer) or spatial representation errors (e.g., linked to turbulent scales).
    - Seen as fundamental in informing the treatment of random and systematic errors in data assimilation.
    - Particularly relevant in the context of increasing diversity of observations (incl. emergence of data from constellations of small satellites).
- **More effort is also needed to utilize available information from metrological/ physical error analysis in the treatment of random and systematic errors in data assimilation.**
- **Support cross-community efforts, aimed at identifying errors/biases at source:**
    - E.g., inter-comparison of bias corrections from different centres (incl. bias models used)
    - Dialogue between instrument experts, NWP centres, GSICS, etc.



Main outcomes: treatment of systematic errors

- **Need for better reference observations or fuller error characterization of observations:**
  - to anchor bias corrections (for observations and models),
  - to better identify model biases, particularly for tropospheric humidity, high-altitude (mesosphere) and higher-depth (deep ocean).
  - Could hyperspectral IR become an anchor?
  - Establish traceable uncertainties for GNSSRO and hyperspectral IR?
- **Recommend NWP centres to revisit bias models used in adaptive observation-bias corrections to reflect advances in reducing systematic errors.**
  - Potential to aid disentangling estimating observation bias and model bias.
- **Possibilities for better characterization of uncertainties in climate reanalyses:**
  - E.g., observation denials, model parameter perturbations, ensemble approaches
  - Producing unbiased analyses is a higher priority for reanalyses compared to NWP, calling for dedicated developments in certain areas (e.g., more extensive use of CVarBC).

Main outcomes: treatment of random errors

- **Assignment of random errors is often based on diagnostic or ad-hoc methods.**
  - Recommendation to better understand these diagnostic uncertainty estimations.
  - Cross-comparison of results from different methods is recommended, as well as comparison to metrological/physical estimates.
- **Benefits expected from further refinements in the treatment of situation-dependent (representation) errors in observations.**
- **Recommend to NWP centres to increase efforts to overcome the technical challenges that currently limit taking into account horizontal observation error correlations.**