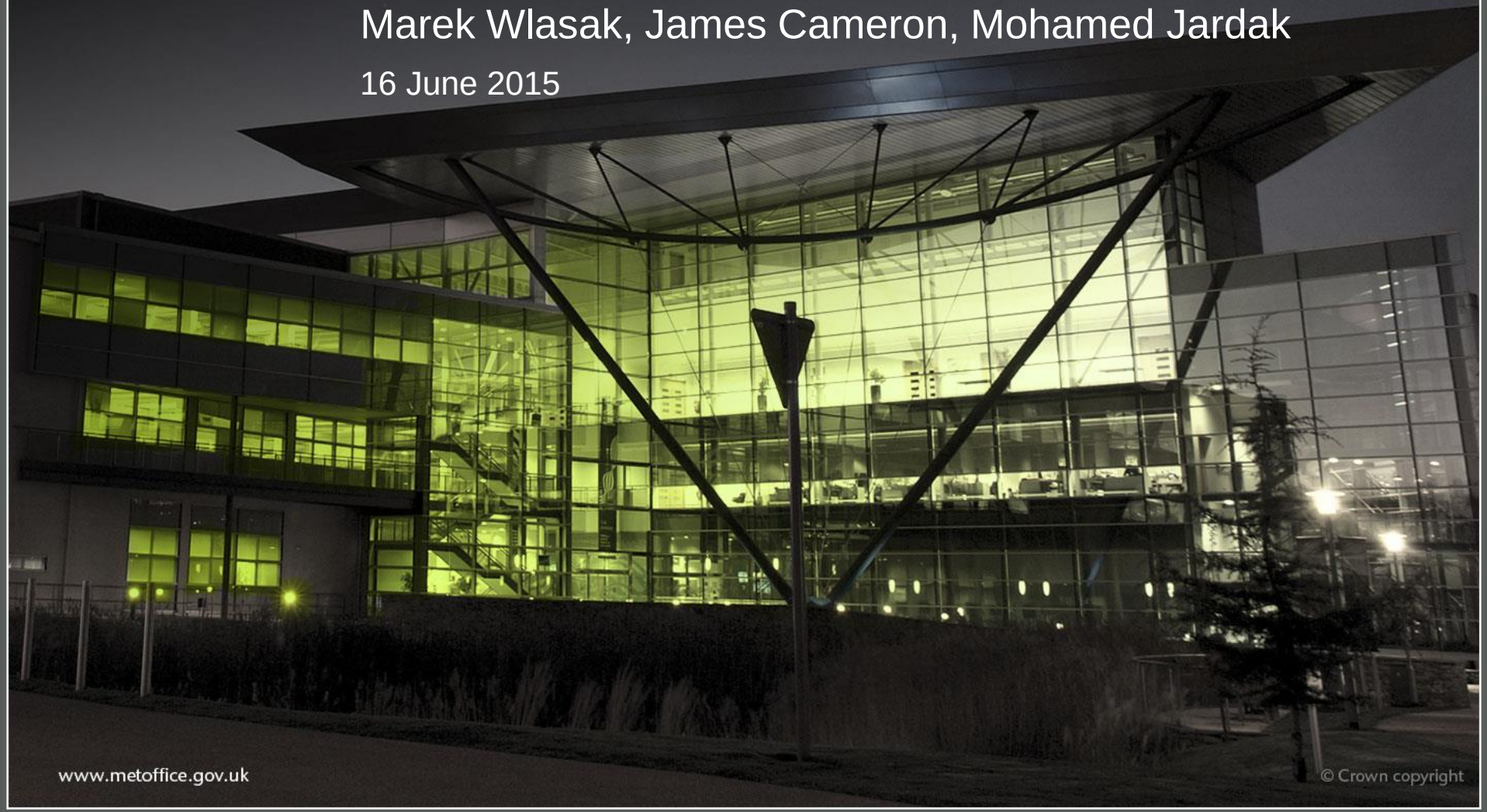
UKMO Data Assimilation Update

ICAP Barcelona. Yaswant Pradhan, Malcolm Brooks, Marek Wlasak, James Cameron, Mohamed Jardak

16 June 2015



Contents

1. Introduction
2. Assimilating more dust observations
    a) Extending MYDAOD
    b) Additional observation sources
3. Major upcoming DA changes
    a) VarBC
    b) CVT
    c) Ensemble DA
4. Conclusion

Introduction

Currently assimilating dust from

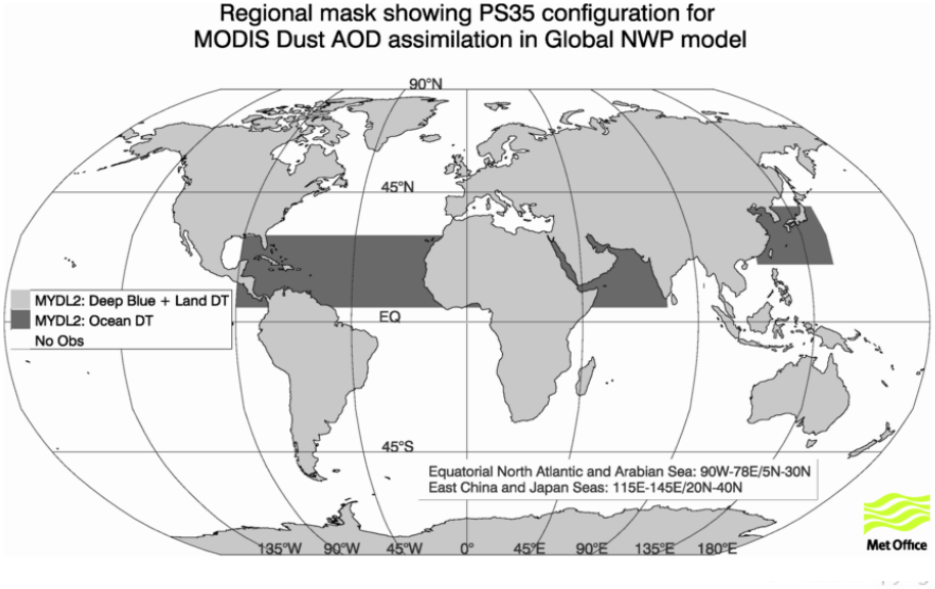
- MODIS Dust AOD Land:
  - Dark Target and Deep blue (Aqua only)
  - Operational since April 2013.
- MODIS AOD Ocean:
  - Dust only filter (see next slide)
  - Operational since March 2015.
- Prognostic dust is now radiatively active in the forecast model.

Assimilating more dust observations

Extending MODIS Ocean AOD

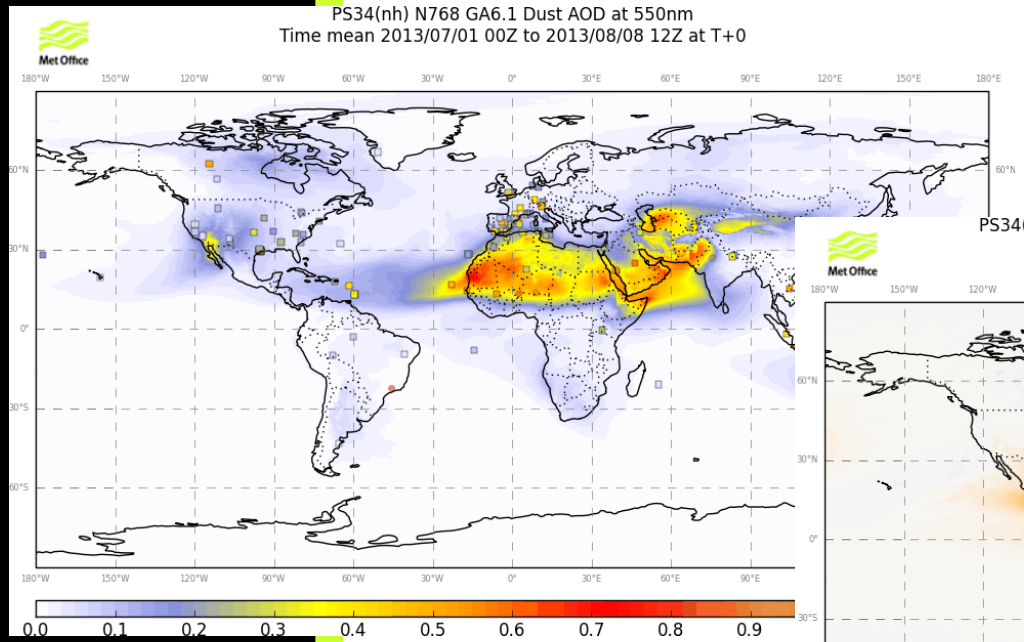
Dust qualifying criteria based on Bellouin et al(2005) and Jones & Christopher(2011):

- FMF <= 0.4•α<= 0.5, Effective radius > 1 μm
- AOD >= 0.1, Mass concentration >= 1.2e-4 kg/m2;
- Retrieval error < 0.4 and Confidence = 3 “best”
- Dust homogeneity test
- Regional mask over ocean

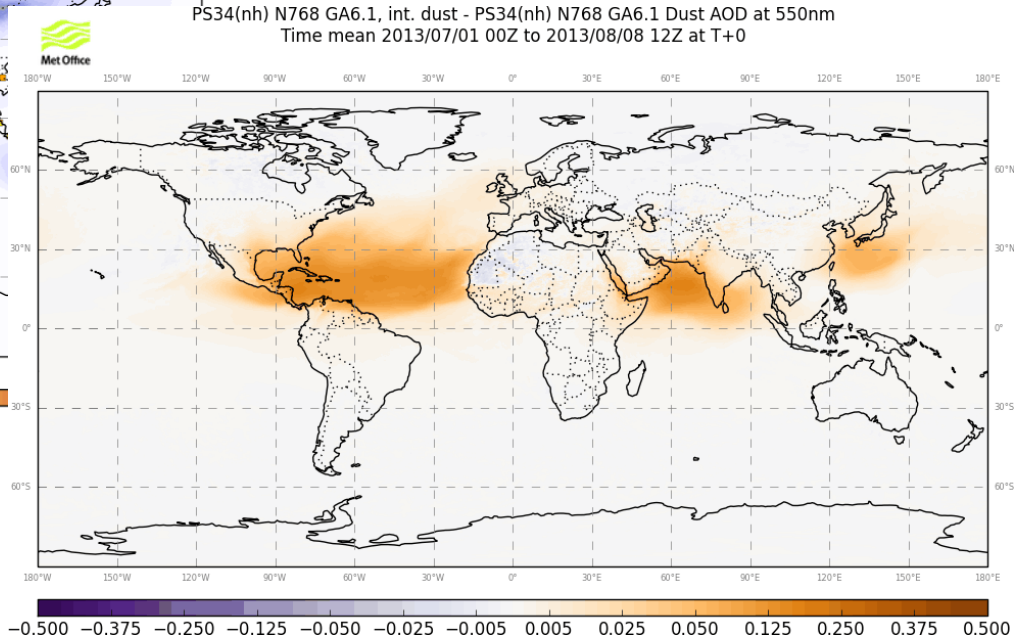


Extending MYDAOD

Removing AOD > 0.1 criteria allows obs of “no-dust” into assimilation.



Trial mean Dust AOD



MYDAOD impact:

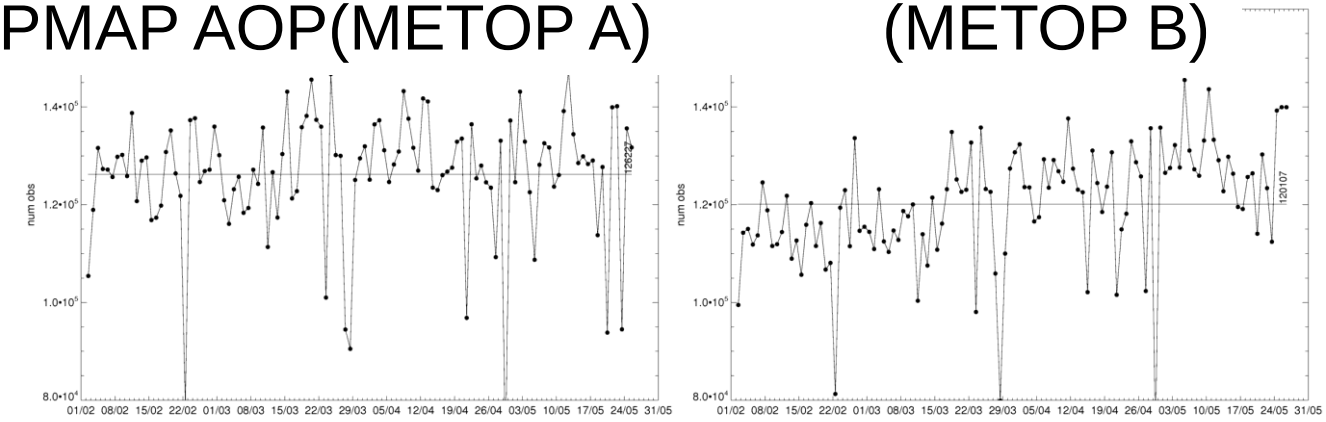
MYDAOD impact: (AOD<0.1):

Aiming for Autumn 2015 implementation.

Additional observation sources

- Preparation to include MODIS C6
- PMAP products are currently being monitored.
  - Real-time, received via EUMETCast
  - Planned comparison with MODIS/Terra and MetUM analysis (possibly MISR v2) + EUMETSAT final validation report
  - Fewer aerosol classes: Fine, DD, VA (but fits in our current plan)

PMAP AOP(METOP A) (METOP B)



- Use MISR v2 (when available , real-time?) for DA and/or validation

Major upcoming DA changes

VarBC: Variational bias correction (James Cameron)

Static scheme = what we do now.

- Collect a few weeks of O-B statistics.
- Calculate a new bias correction from the statistics.
- Leave it unmodified for many months.

VarBC = Variational bias correction.

- Apply bias correction in OPS.
- Analyse an increment to the bias correction in VAR.
- Bias correction is continually updated.
- Similar approach at most other centres!

Outline of VarBC

The increments to the coefficients are derived from the control vector:

$$\beta' = \mathbf{U}_\beta \mathbf{v}^\beta$$

Observation penalty:

$$J_o = \frac{1}{2} \sum_k \left(\left(y_k + \sum_{i=1}^{I_k} \beta'_i p_{k,i} - y_k^o \right) R_k^{-1} \left(y_k + \sum_{j=1}^{I_k} \beta'_j p_{k,j} - y_k^o \right) \right)$$

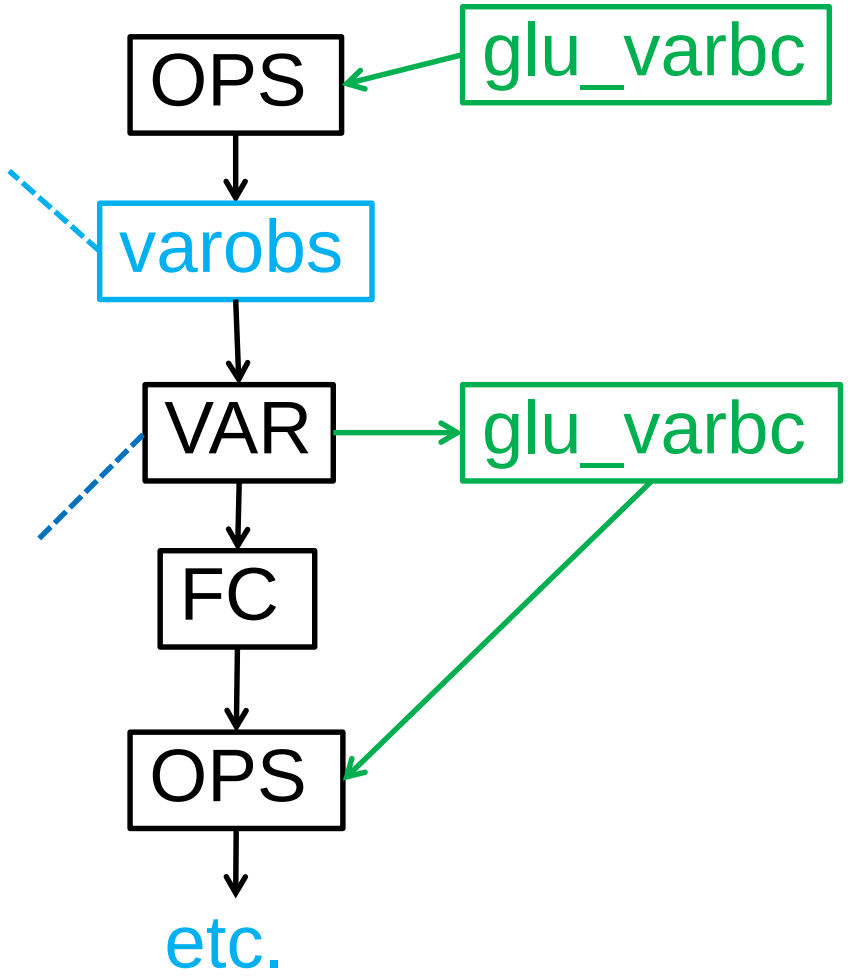
A background term limits how much the coefficients can change in each DA cycle:

$$J_\beta = \frac{1}{2} \beta'^T \mathbf{B}_{(\beta)}^{-1} \beta'$$

Outline of VarBC

varobs contain bias corrected observations and predictor values

VAR analyses increments to predictor coeffs

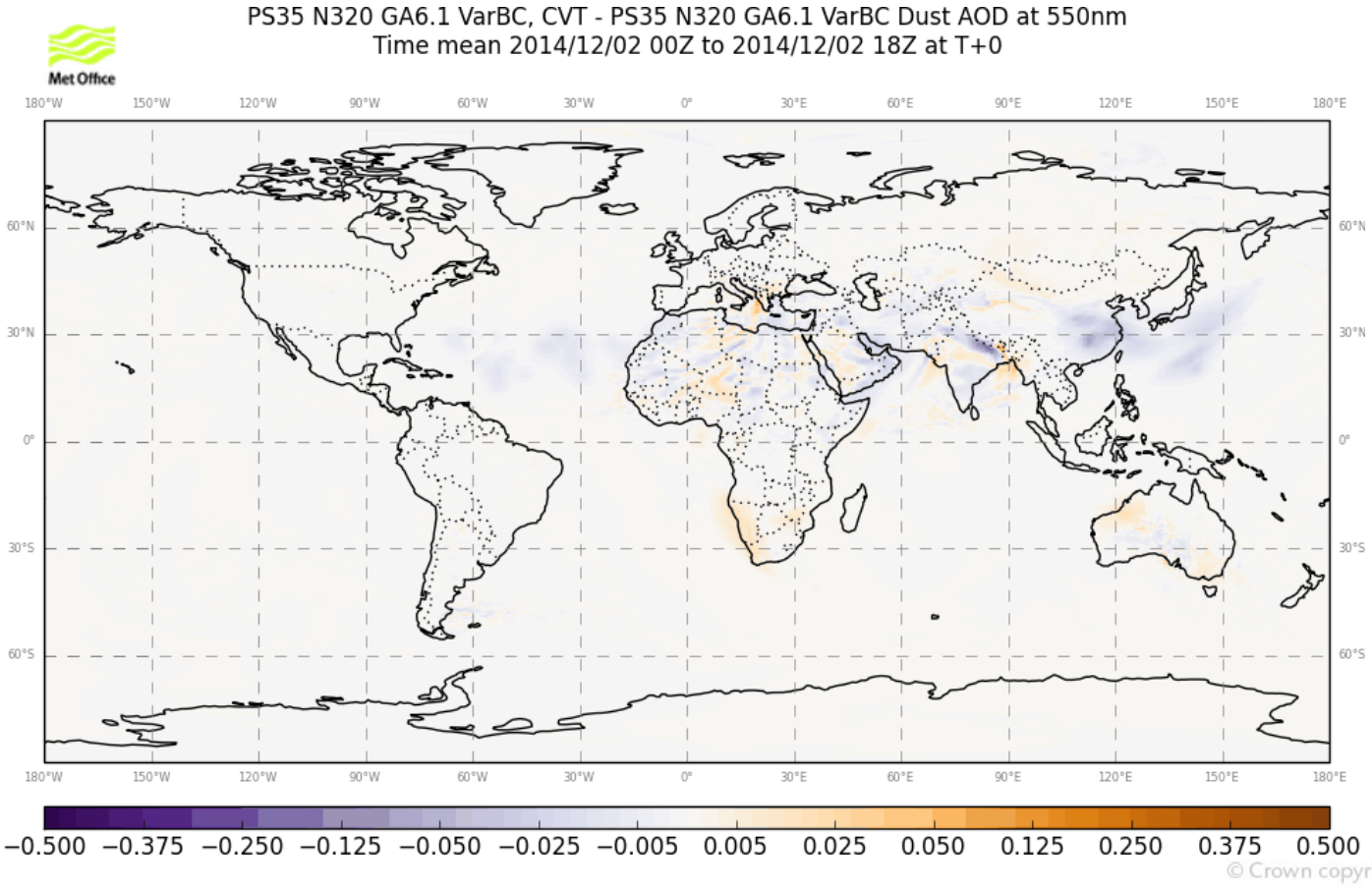


VarBC – a major change

General forecast: large improvements in long range PMSL!

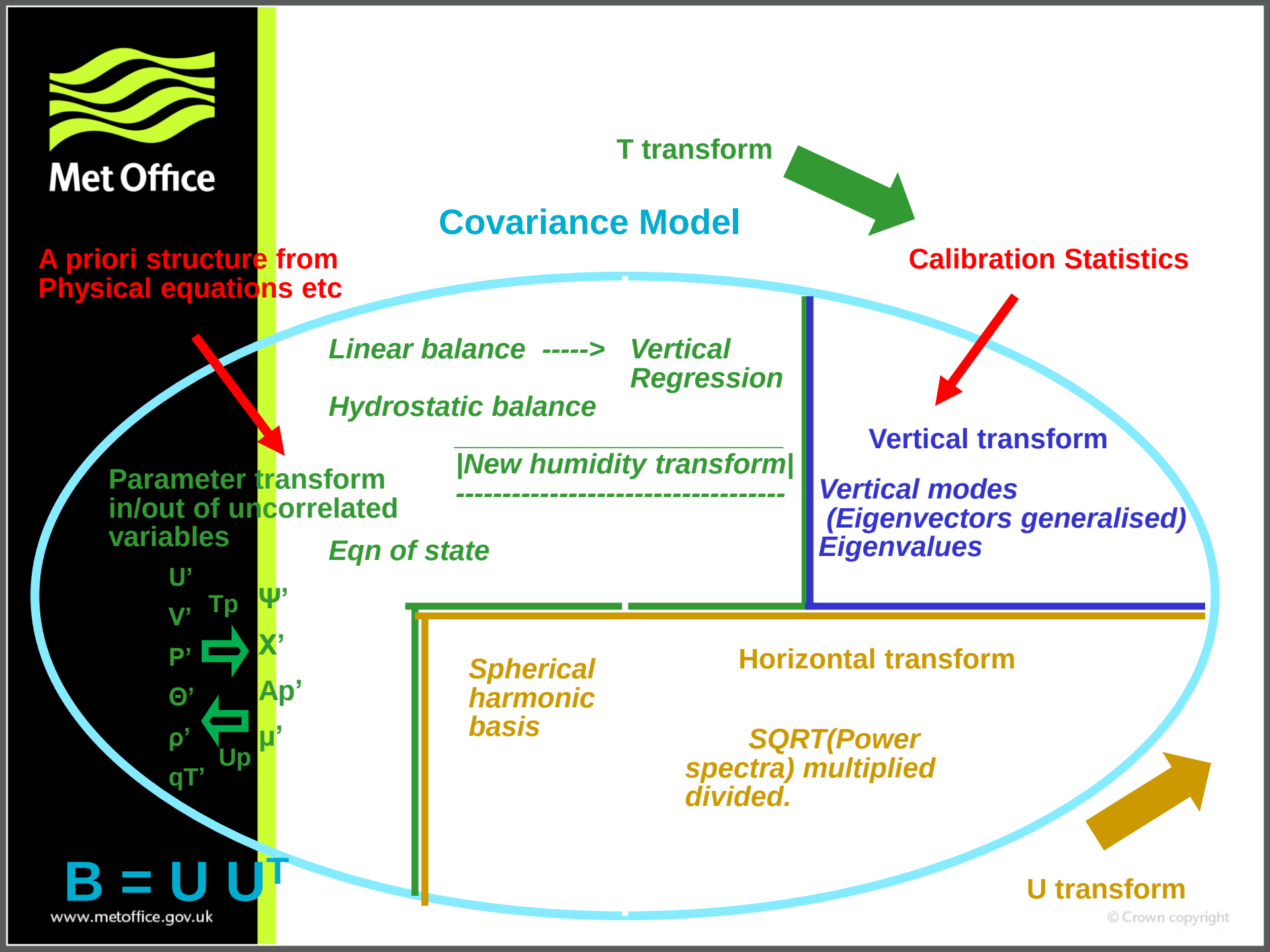
analysis changes to enhance H500 bias

Dust impact: Almost none:



Covariances and VAR transforms (CVT) changes
(Marek Wlasak)

- **Aid collaboration and general productivity**
  - **Simplified code for development**
- **Be flexible/easy to use**
  - **Made up of generic small programs**
- **More comutationally efficient**
  - **parallelism both at scripting level**
  - **Uses OpenMP within the data**
- **More portable**
  - **Major system changes in recent years**
- **Code is not just about static B**
  - **Also used to investigate ensemble data.**


Met Office
T transform
Covariance Model
A priori structure from
Physical equations etc
Calibration Statistics
Linear balance -----> Vertical
Regression
Hydrostatic balance
|New humidity transform|
Eqn of state
Parameter transform
in/out of uncorrelated
variables
U'
V'
P'
Θ'
ρ'
qT'
Tp
Up
ψ'
X'
Ap'
μ'
Vertical transform
Vertical modes
(Eigenvectors generalised)
Eigenvalues
Spherical
harmonic
basis
Horizontal transform
SQRT(Power
spectra) multiplied
divided.
U transform
B = U U^T
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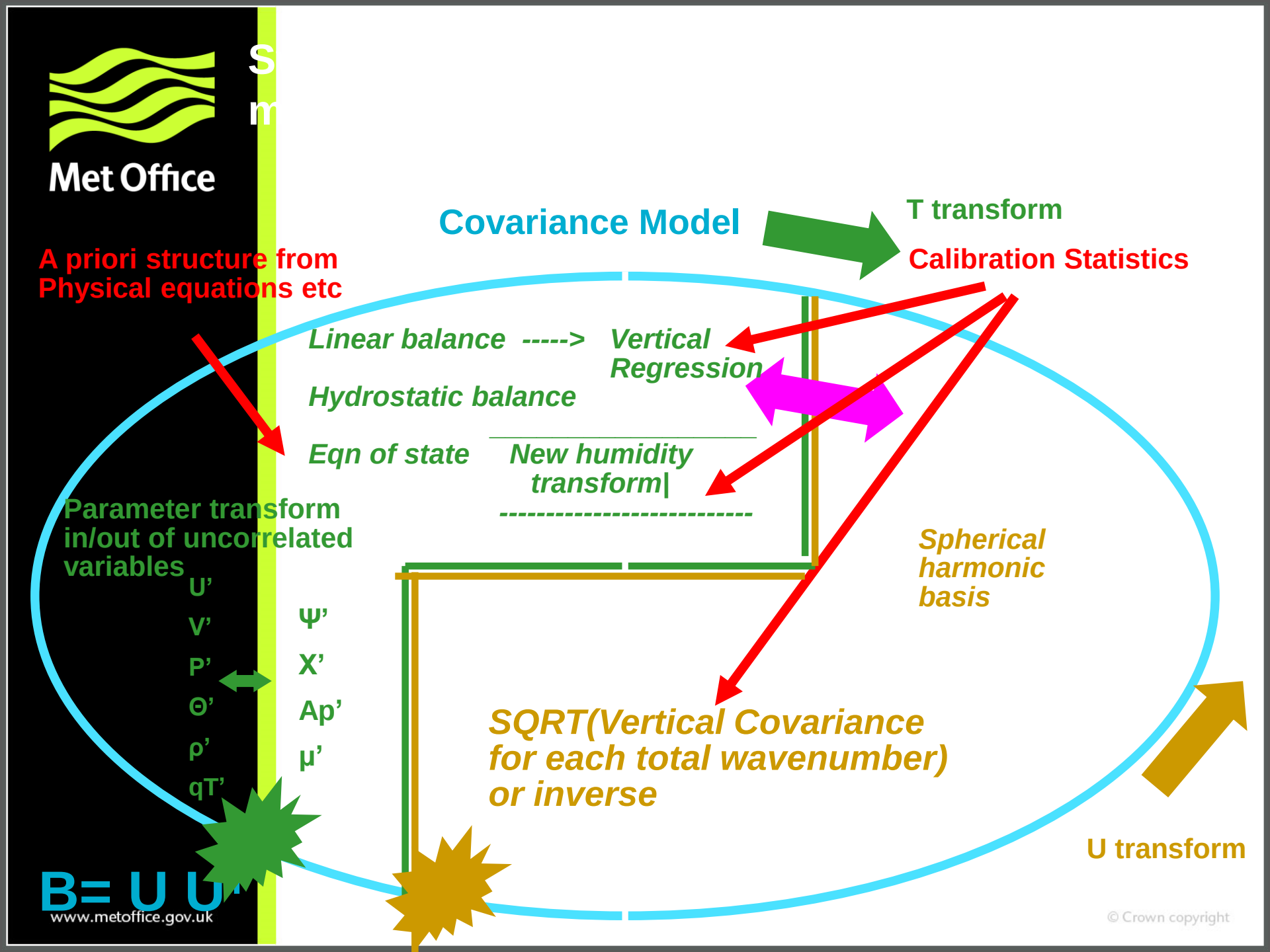
Met Office
S
m
Covariance Model
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A priori structure from
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Ap'
μ'
Spherical
harmonic
basis
SQRT(Vertical Covariance
for each total wavenumber)
or inverse
U transform
B= U U
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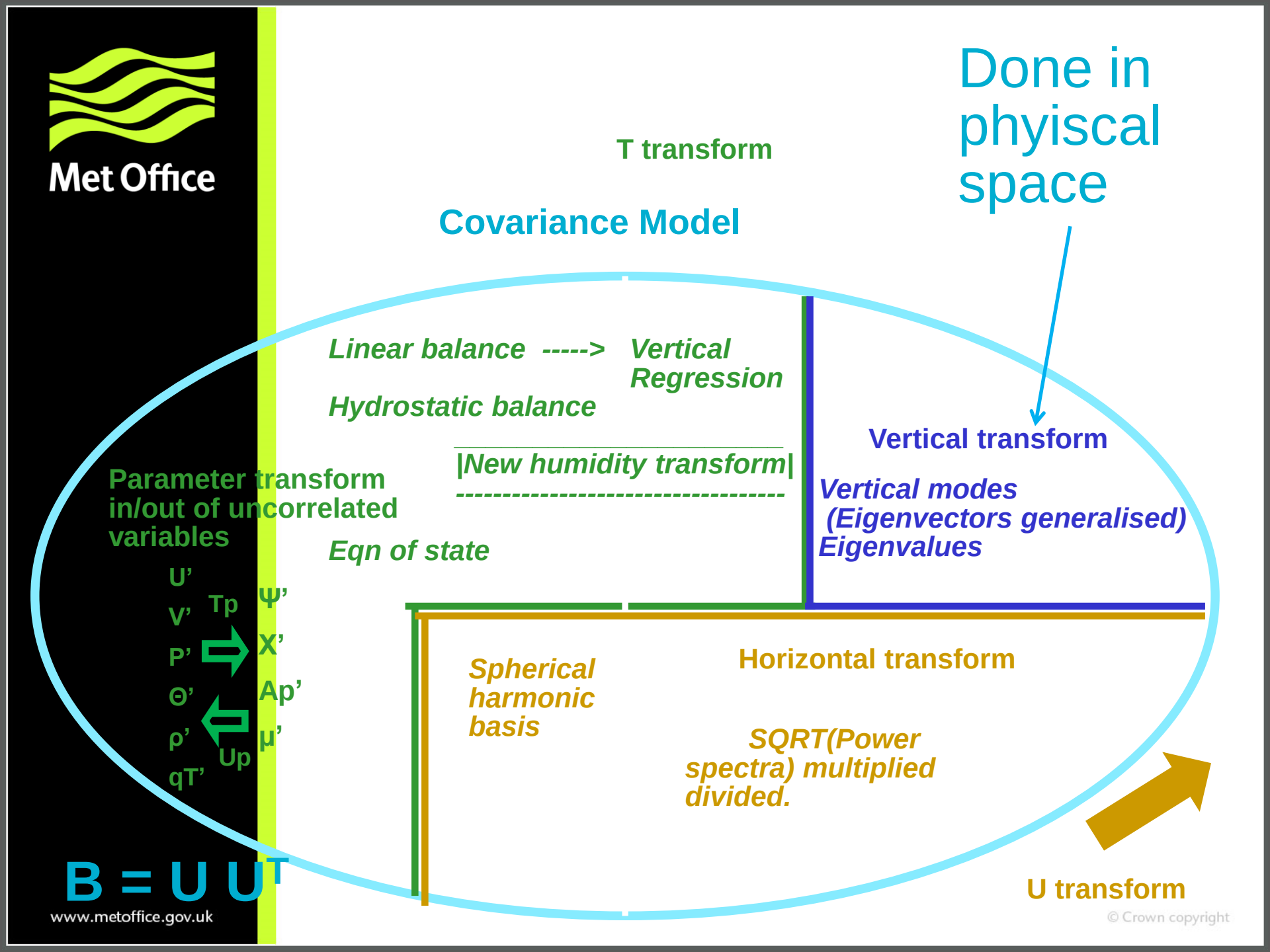
Met Office
Done in phyiscal space
T transform
Covariance Model
Linear balance -----> Vertical Regression
Hydrostatic balance
|New humidity transform|
Eqn of state
Vertical transform
Vertical modes (Eigenvectors generalised)
Eigenvalues
Parameter transform in/out of uncorrelated variables
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Tp
Up
ψ'
X'
Ap'
μ'
Spherical harmonic basis
Horizontal transform
SQRT(Power spectra) multiplied divided.
U transform
B = U U^T
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Purpose of swapped-transform order (1)

- **Need a background error covariance model that faithfully represents the key global characteristics of the training data.**

- **Want to make static background error covariances generated from our own ensemble. (Not ECMWF) – future proofing**

- **Need to retire old covariance model and remove its maintenance overhead.**

Purpose of swapped-transform order (2)

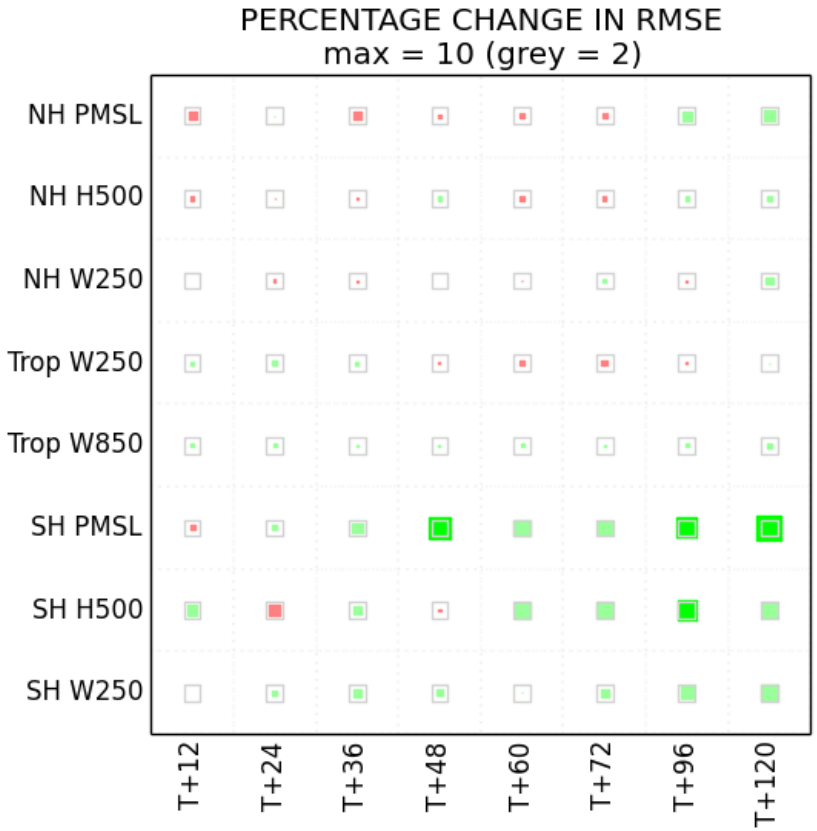
- **Scope for further scientific improvements:**
  - **improve latitudinal variability?**

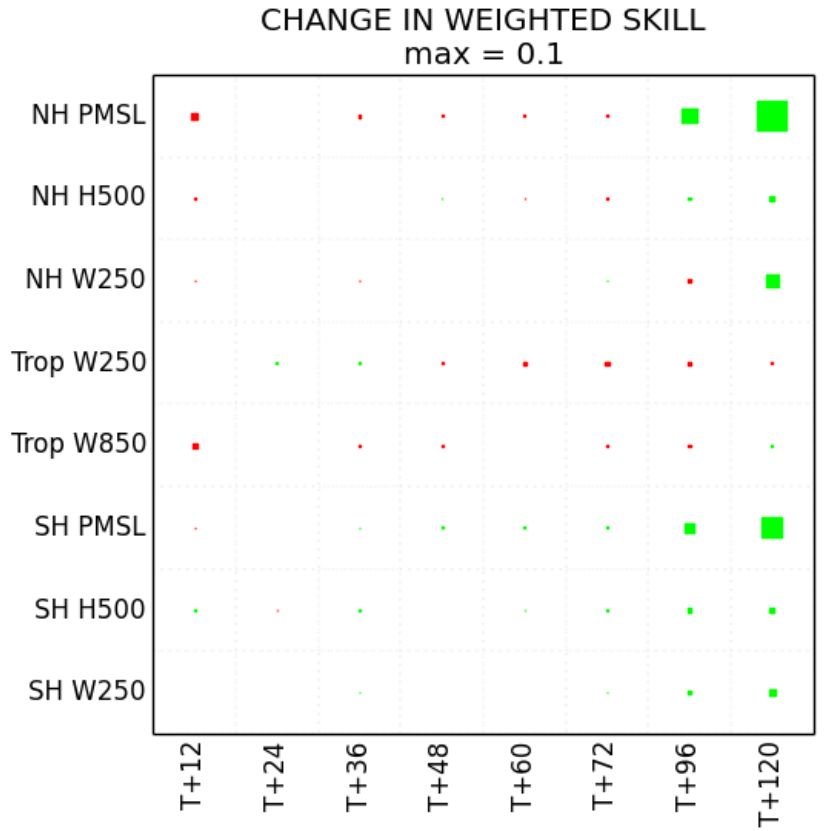
- **Currently we are using ECMWF training data including short forecasts from our current model.**
  - **Move to having all training data from our ensembles.**

Summer trial – forecast impact

VAR TRIAL: CVT vs non-CVT standard settings (Summer)
VERIFICATION VS OBSERVATIONS
FROM 20140619 TO 20140717
OVERALL CHANGE IN NWP INDEX = 0.326

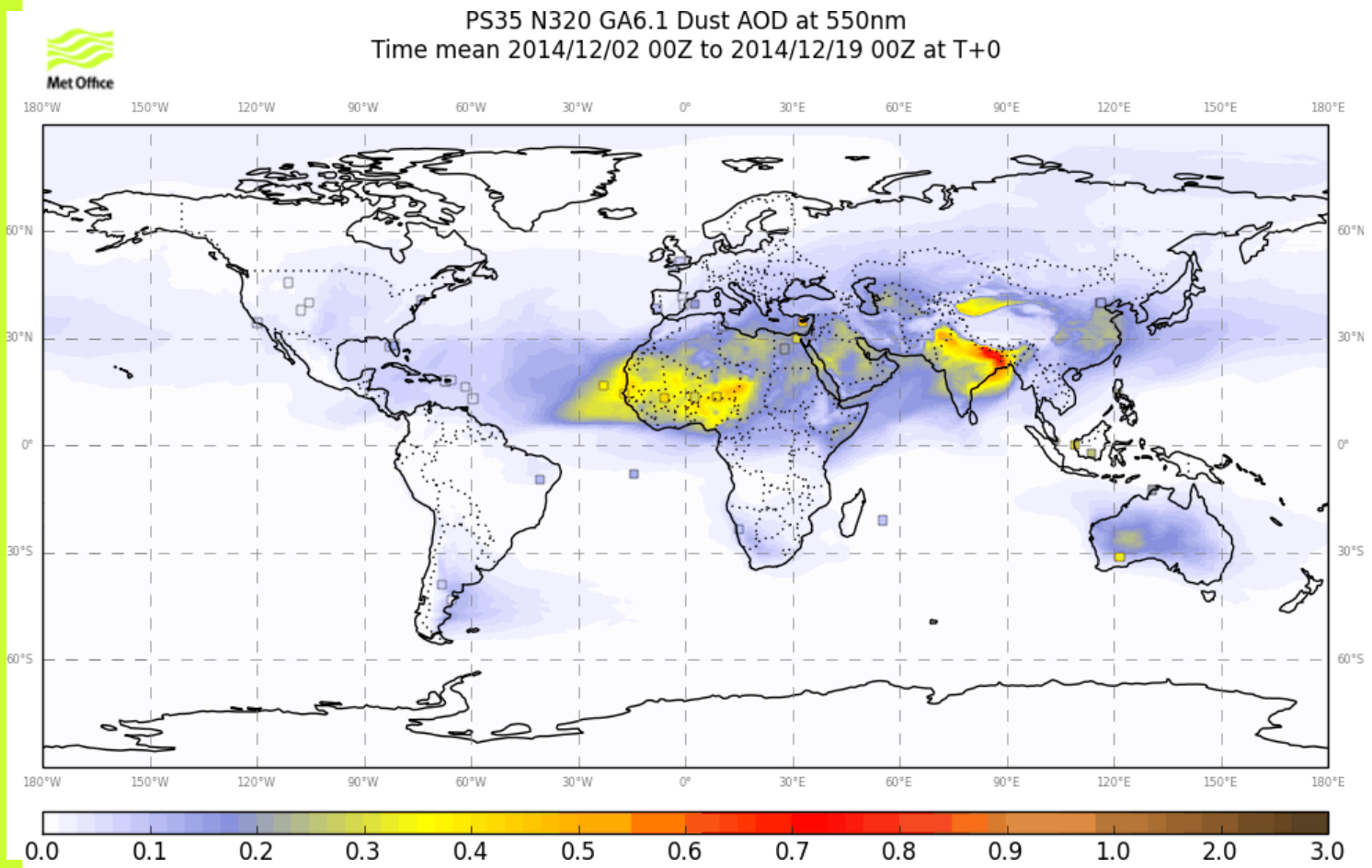
+ve good!
+0.3, small



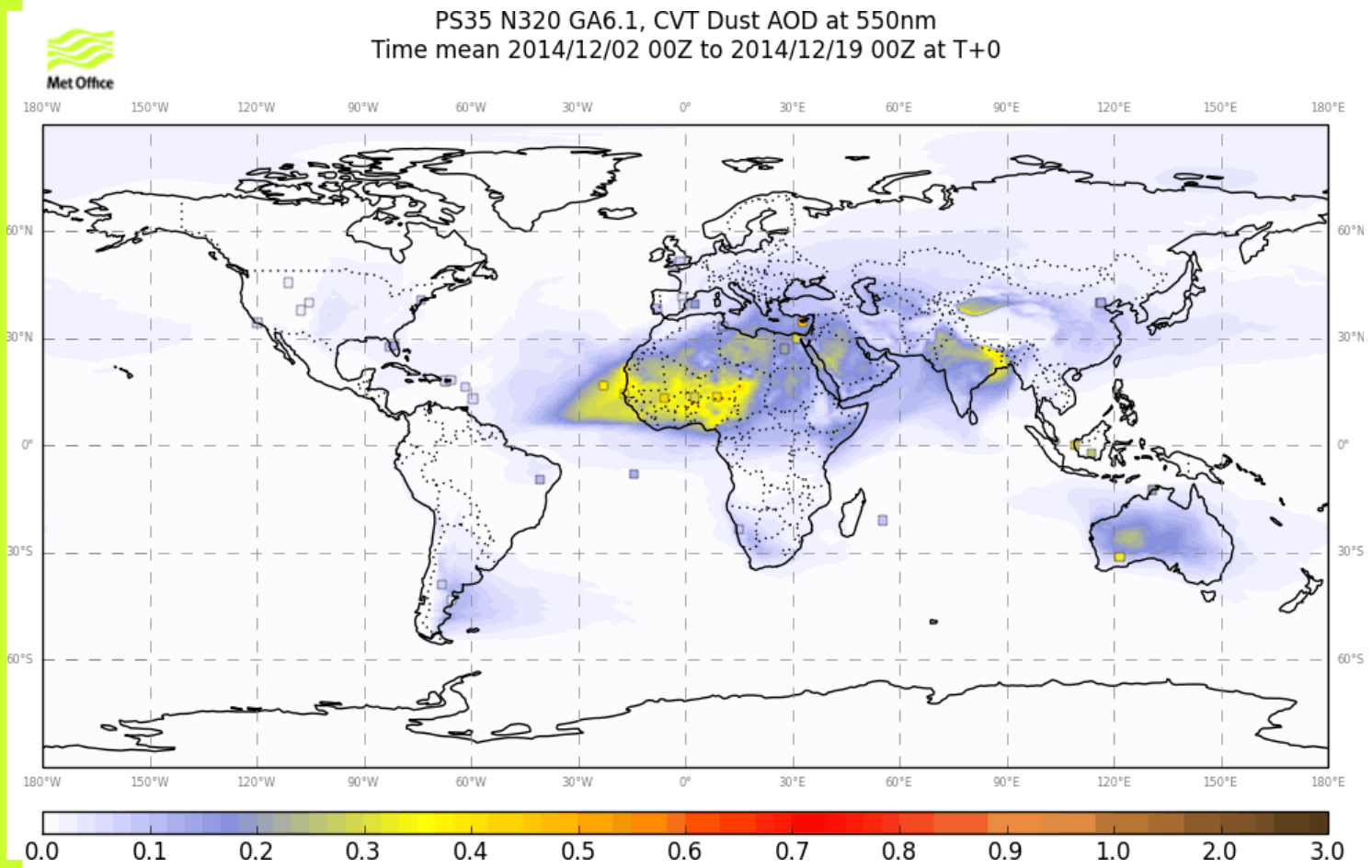


- **Aside: Analysis increments are bigger (except for winds at surface)**

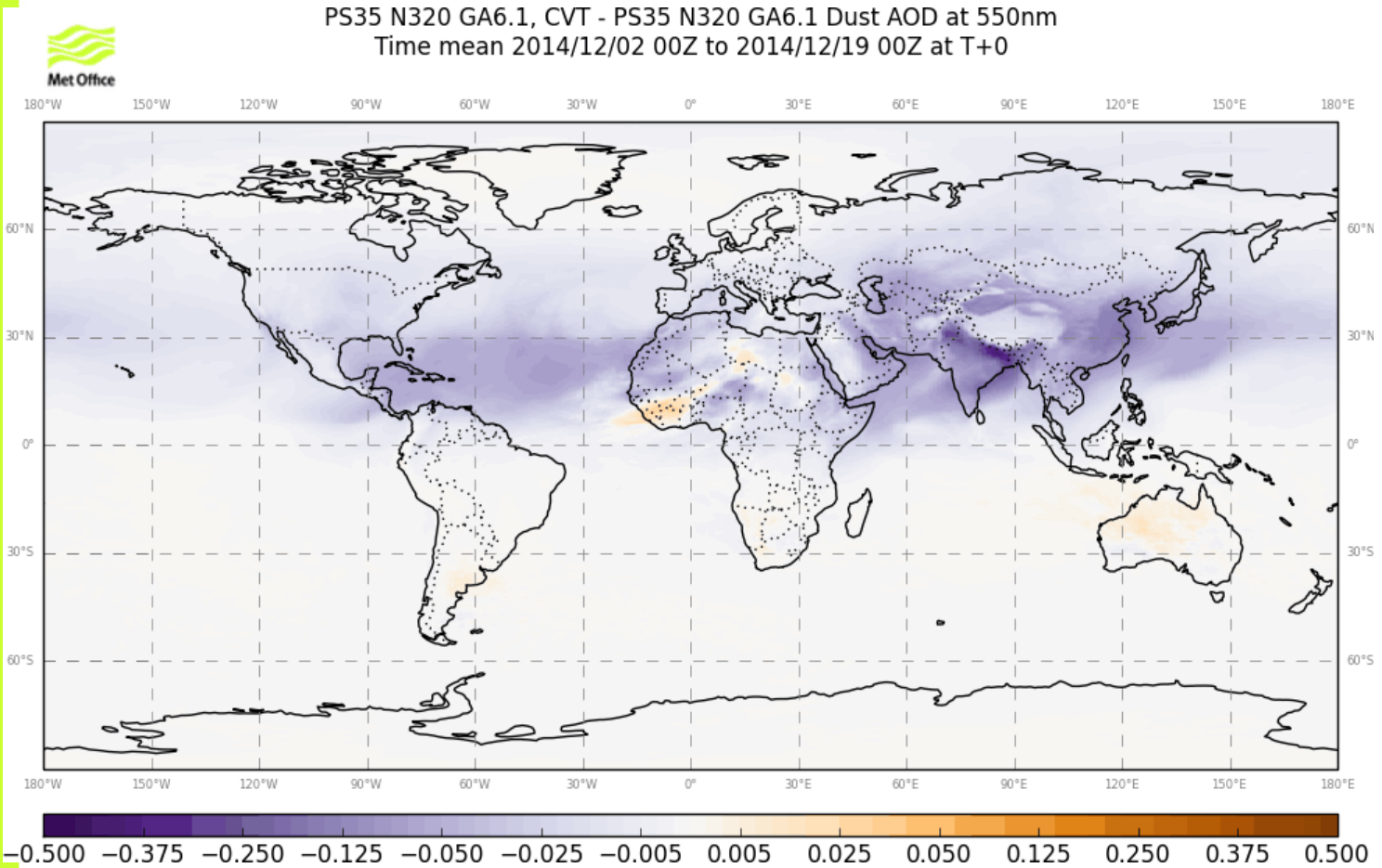
Summer trial – dust impact



Summer trial – dust impact

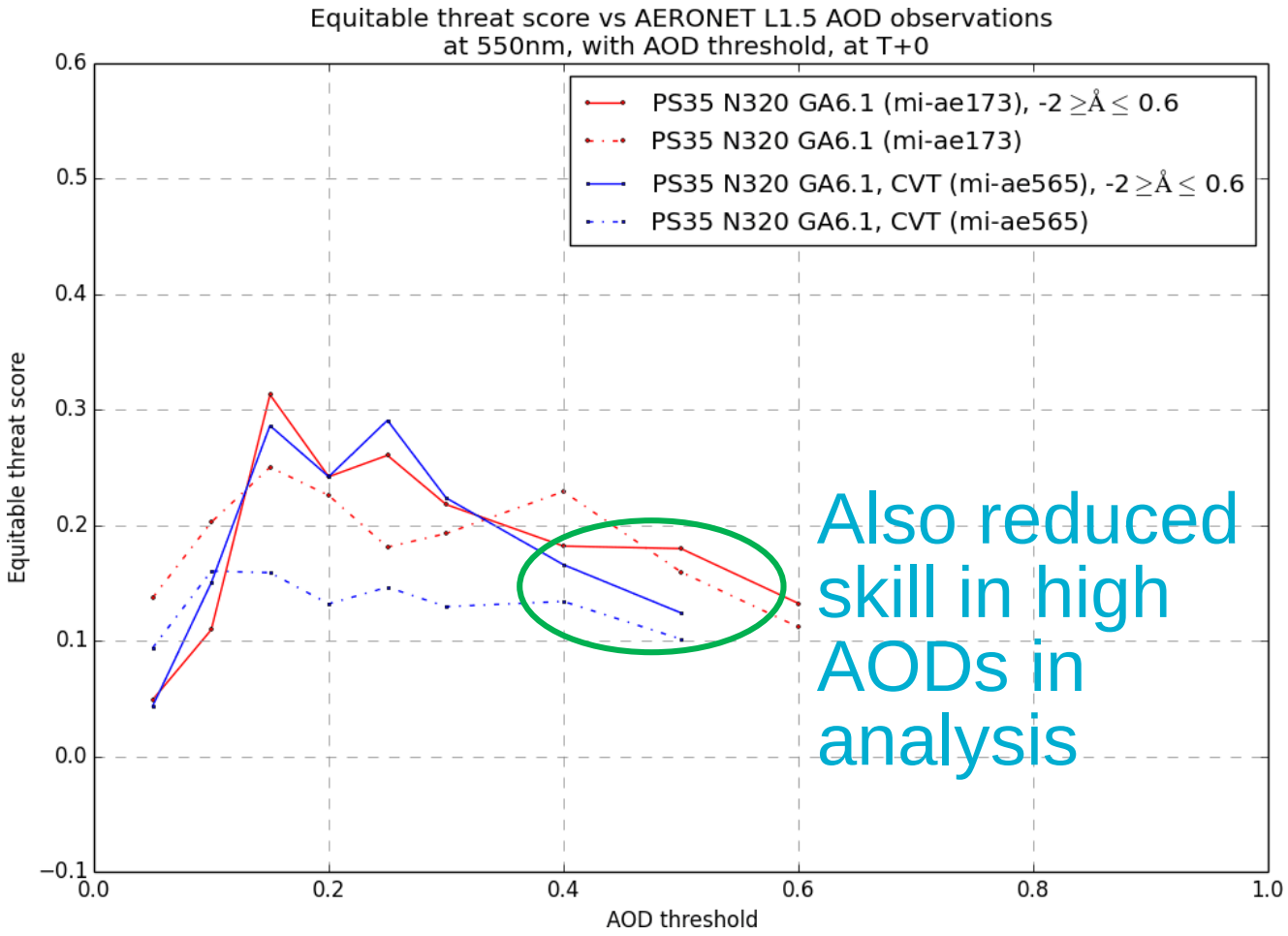


Summer trial – dust impact



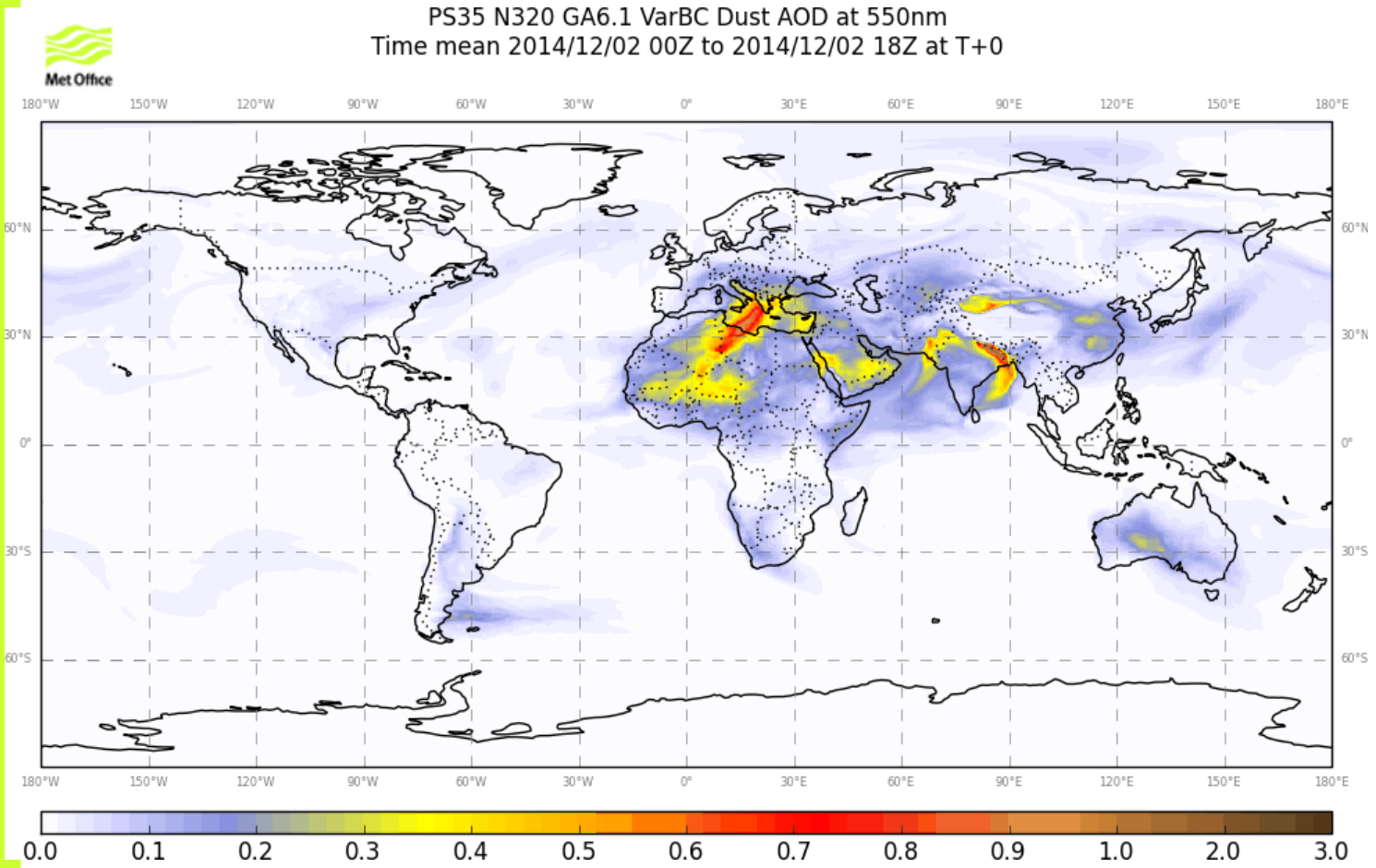
Removes ~1/2 dust added by MYDAOD

Summer trial – dust impact

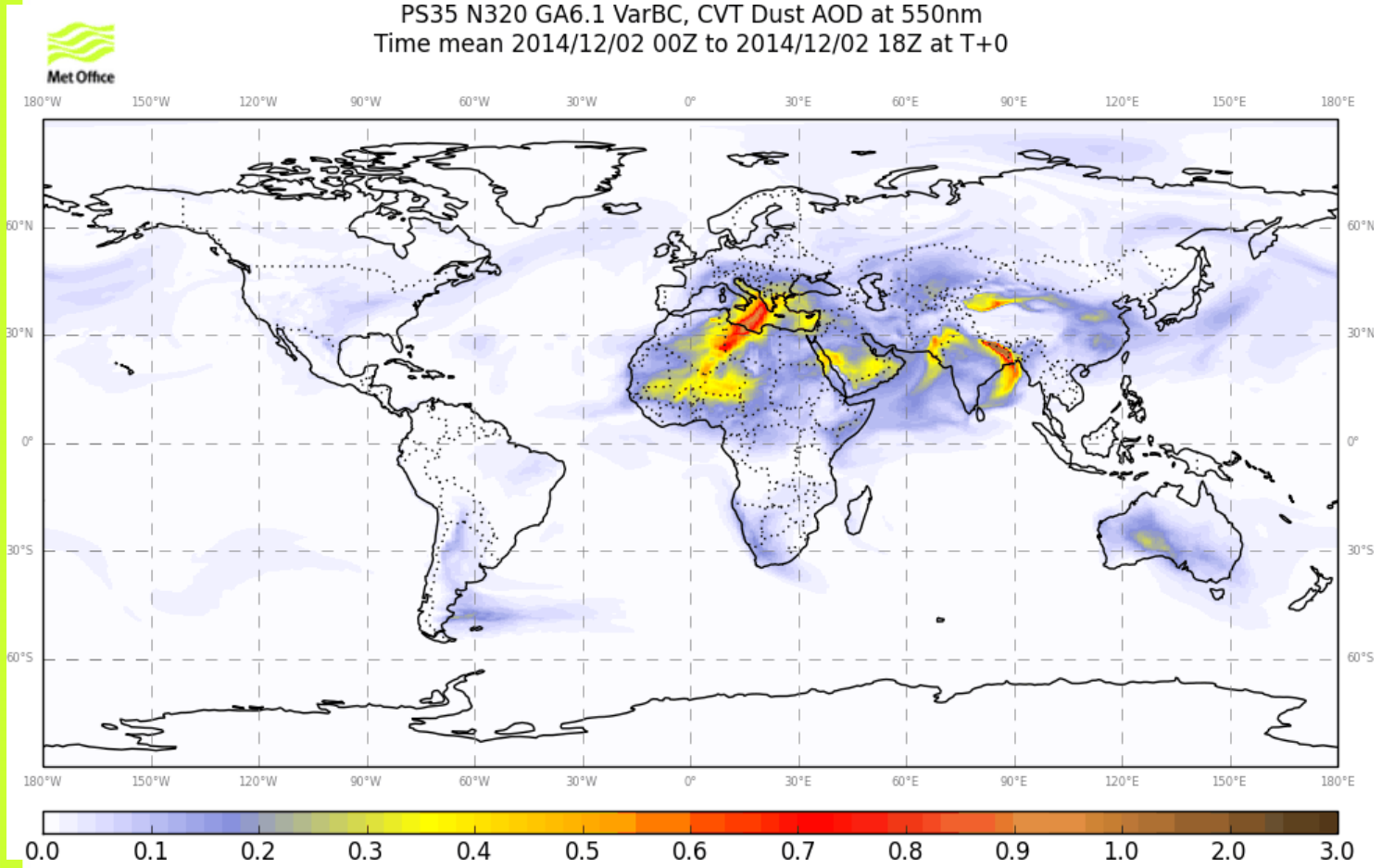


Also reduced skill in high AODs in analysis

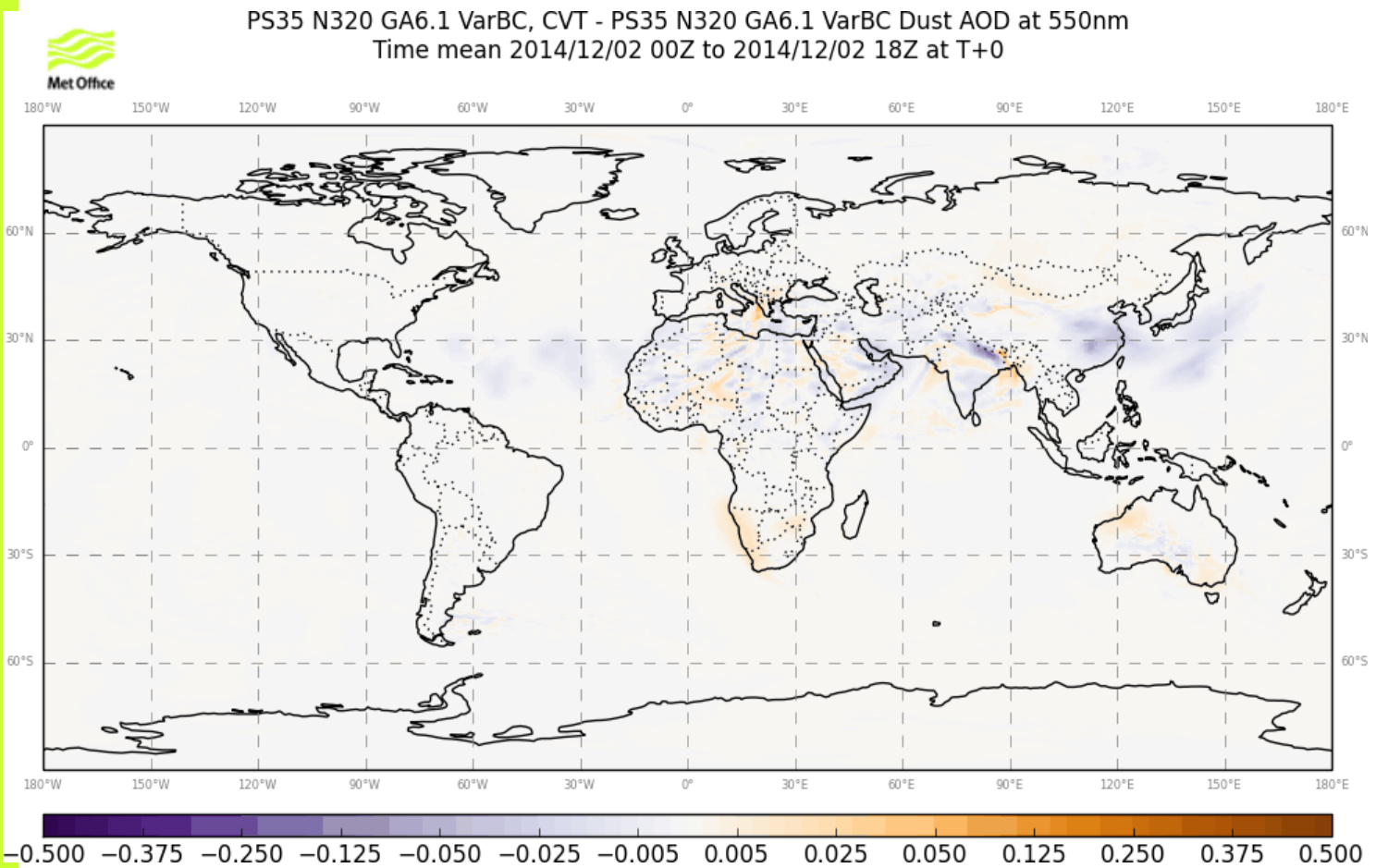
Summer trial – dust impact
Second trial



Summer trial – dust impact



Summer trial – dust impact



Appears fixed: how?

Dust covariances

Old dust COV stats generated using NMC method, with longer/larger spatial length scales.

Initial CVT COV stats generated from ensemble data, gives much smaller spatial scales.

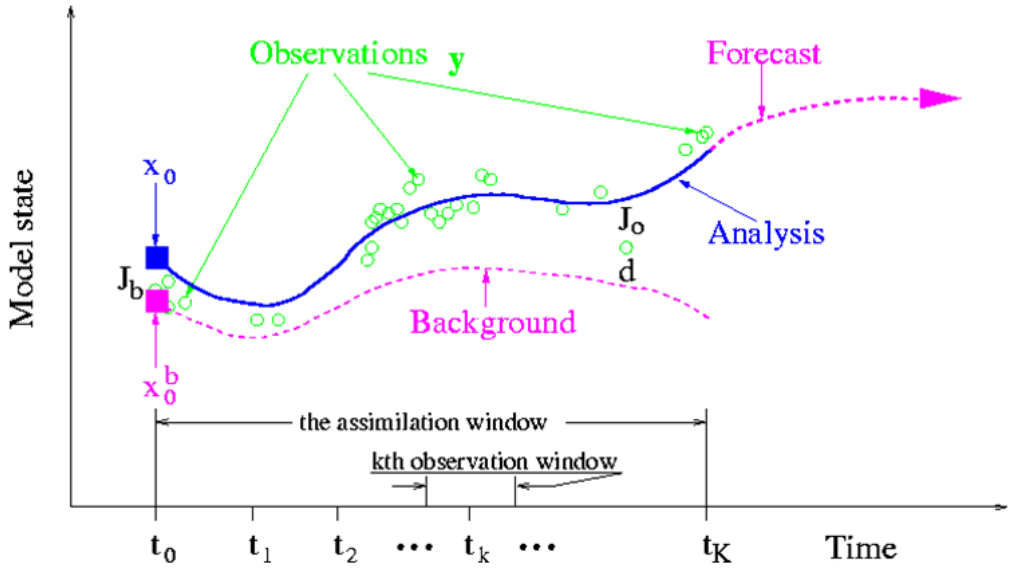
For dust, our AOD obs are still sparse, so smaller spatial scale reduces their impact.

New COV stats took old covariance file, but through swapped transform framework.

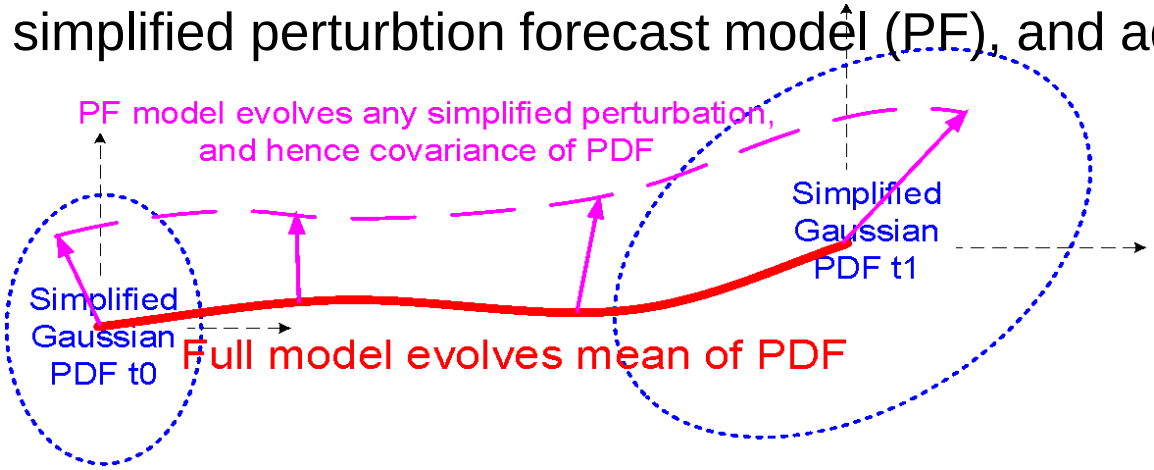
We have lost latitudinal variability in background error variance – but impact was small.

Ensemble VAR (Mohamed Jardak)

Current 4D incremental 4DVAR*:



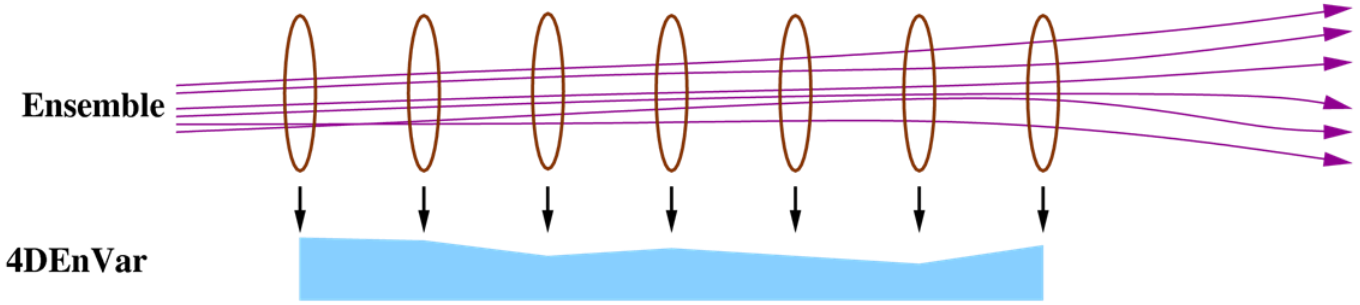
Uses simplified perturbtion forecast model (PF), and adjoint:



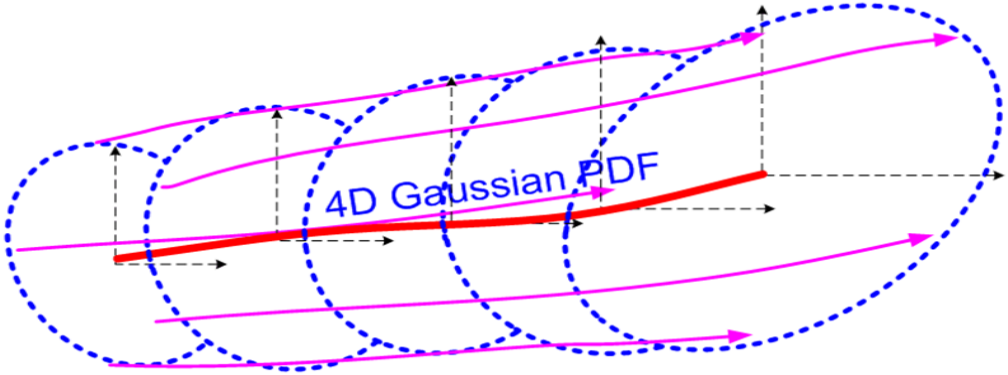
* Hybrid Ensemble 4D-VAR, the ensemble is used in background error Covariances

Ensemble VAR

Ensemble 4DVAR:



No need for simplified PF model as:



Trajectories of perturbations from ensemble mean

Full model evolves mean of PDF

Localised trajectories define 4D PDF of possible increments

Completely unifies the deterministic and ensemble systems.

But needs much larger ensemble!

Conclusions

Conclusions

1. Working on assimilating additional satellite obs of dust AOD: more MODIS ocean, SEVIRI, PMAP, MISR2.

2. Major structural changes in the DA system coming up:

3. VarBC – better Sat obs bias correction, by changing BC in VAR.

    a) Major impact on model generally, improves predictabilty but exposes some model biases.

    b) Very minor impact on dust.

Conclusions

4. CVT – Covariances and VAR Transfrom changes.
    a) Cleaner, easier to develop VAR system.
    b) Smaller scale, larger increments.
    c) Moderately beneficial to model generally.
    d) First version ‘broke’ dust assimilation
    e) Modified COV stats needed.

5. In the longer term, testing underway for move from (Hybrid) 4D VAR to Ensemble 4D-VAR.
    a) Unifies deterministic and ensemble system
    b) Much larger ensemble size.

Met Office

Questions, and answers