Met Office highlights using GNSS-RO for NWP

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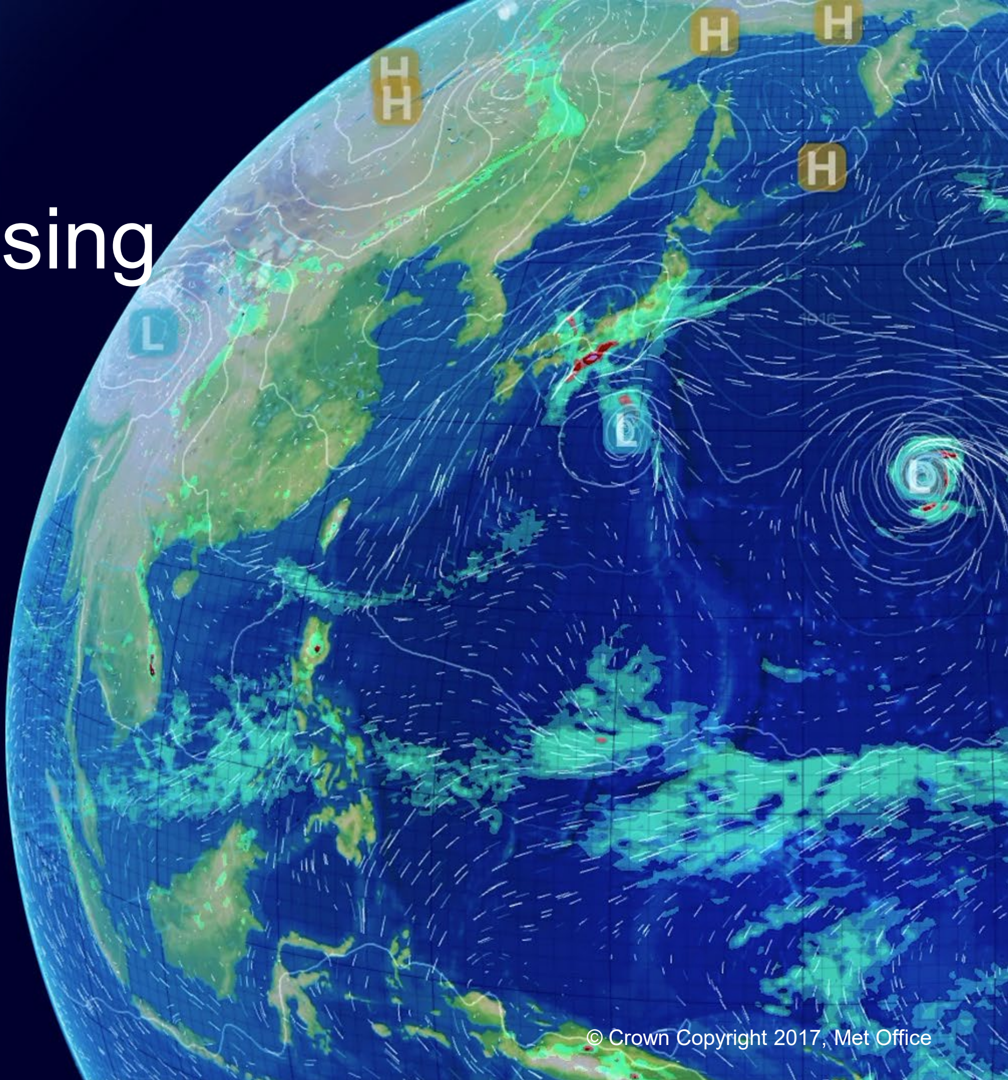

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- ROMEX
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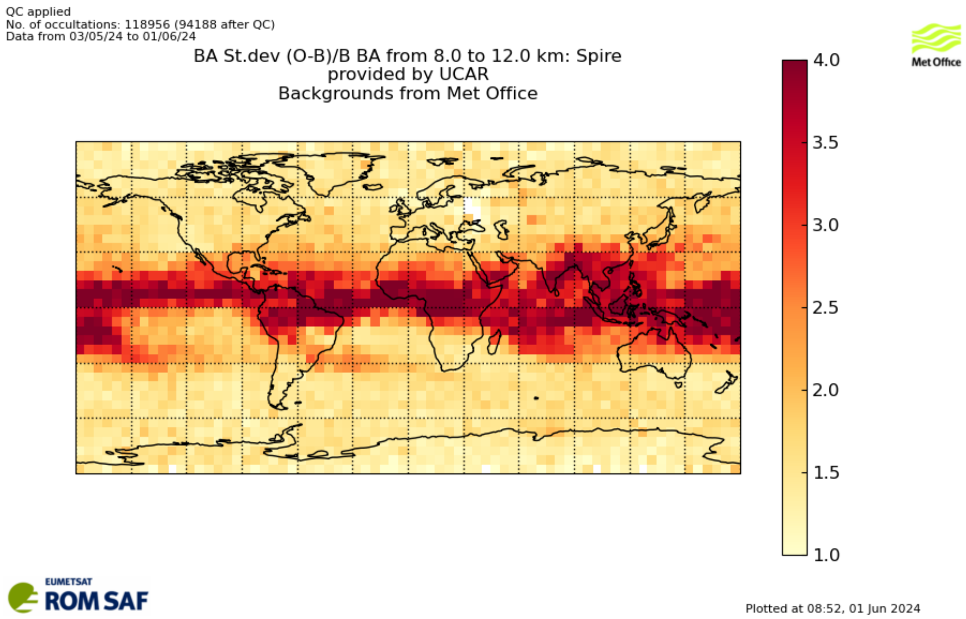
NRT monitoring



- Provides monitoring graphs of a variety of satellites
- Main work has been in reforming parallelism
  - Previously parallel in python
  - Now separate tasks in workflow
  - More reliable, better with large data

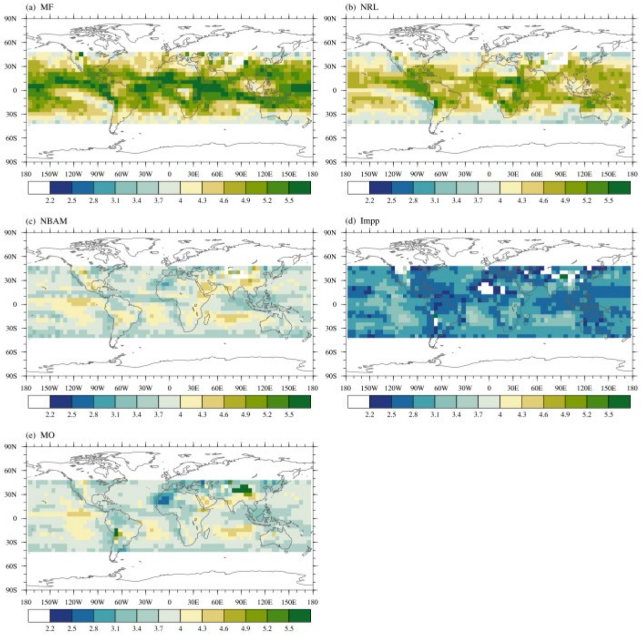
https://rom-saf.eumetsat.int/monitoring/index.php

Visiting scientist – Quality Control

- Hailing Zhang visited Met Office in Oct-Nov 2023
  - Continued working part-time over winter / spring
  - Report ready for review
- Variety of QC methods coded into JEDI
- Common framework for testing QC methods
  - Background forecast from Met Office operations
  - Using Met Office operator (modified)
  - Same observations for all QC methods
  - Common preliminary QC checks
- Focused on super-refraction

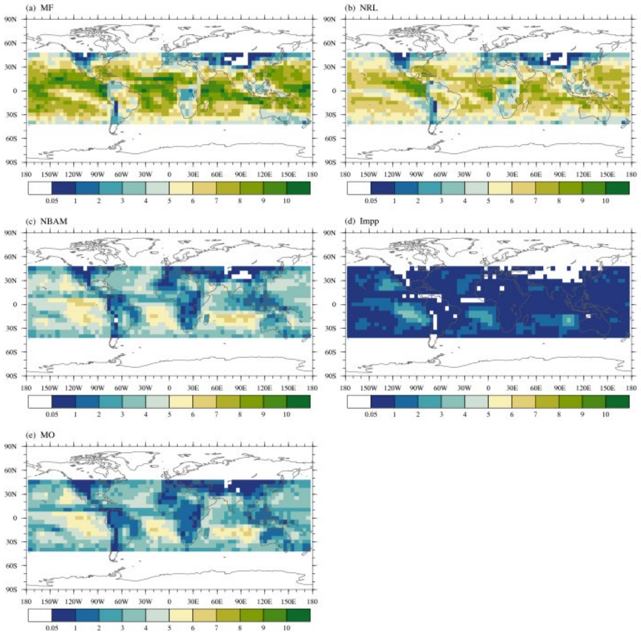
S1	Check for sharp refractivity gradients and its second derivative in the observations	$\frac{dN}{dz} > -0.05\ \mathrm{N\ m^{-1}}$ $\frac{dN}{dz} < -10^{-6}\ \mathrm{N\ m^{-1}}$ $\left\lvert\frac{\mathrm{d}^2 N}{\mathrm{d}\,z^2}\right\rvert < 10^{-4}\ \mathrm{N^{-2}\ m^{-2}}$ $\frac{dN}{dz} \neq 0$	MF	Any threshold is violated
S2	Check difference between the maximum and minimum of simulated bending angles in a 1 km layer.	$\max(\alpha_{model}) - \min(\alpha_{model})$	NRL	> 0.005 rad
S3	2-step methods based on the modelled refractivity gradient	at level k, and $IH_{obs} \leq 5$km *a.* $\left\lvert\frac{dN}{dx}\right\rvert > 0.75\ \mathrm{CRV}$ *b.* $\left\lvert\frac{dN}{dx}\right\rvert > 0.5\ \mathrm{CRV}$ and $\max(\alpha_{obs}) \geq 0.03$ rad	NCEP	a. reject observations whose impact parameter $\leq \mathrm{IH_{model}(k+5)}$ b. reject observations below the profile maximum
S4	Check the vertical difference of the modelled impact parameter between a given layer and the one below	dx	ECMWF /UKMO	> 10 m
S5	Check the vertical gradient of the modelled refractivity is above some thresholds.	$\frac{dN}{dz}$	UKMO	< –0.08 N m^{-1} +500m
			DWD	0.5 CRV

Super-refraction – average SR height



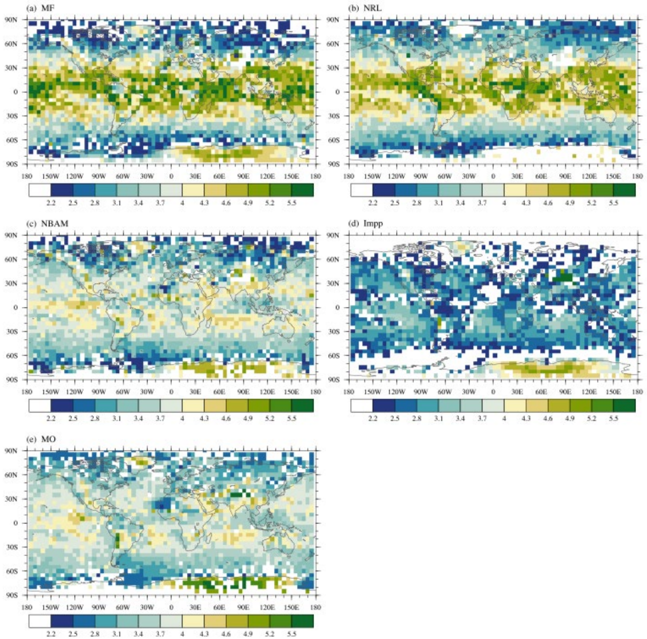
- MF and NRL give highest average SR height
- NBAM and MO similar
- Impact parameter check gives lowest SR heights
- Observations from COSMIC-2

Super-refraction – observation rejection rate



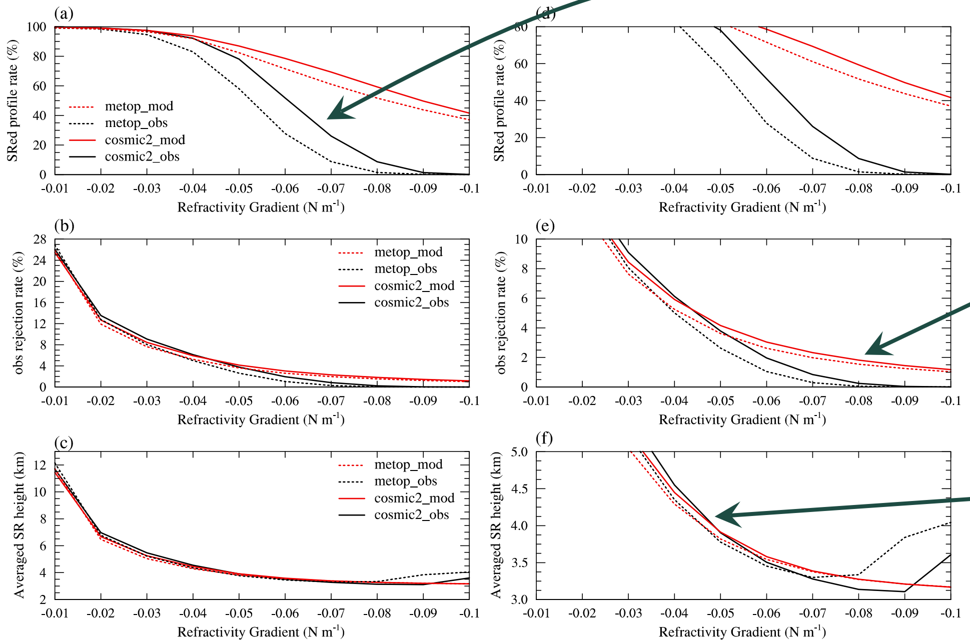
- NBAM, Impp and MO all show maximum rejection in marine stratocumulus regions
- MF and NRL reject most observations over broader area

Super-refraction – average SR height



- Similar patterns seen for Metop
  - Noisier, since fewer observations
- Increased SR height over Greenland & Antarctica

Effect of refractivity gradient threshold



- Fraction of observed profiles with sharp gradients is small
- Rejection rate with model gradients stays consistent at high thresholds
- Average SR height largely consistent

Region of most impact

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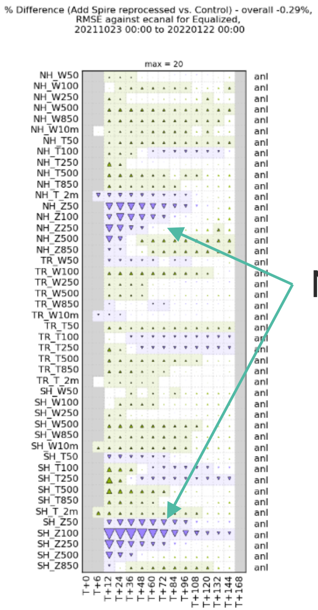
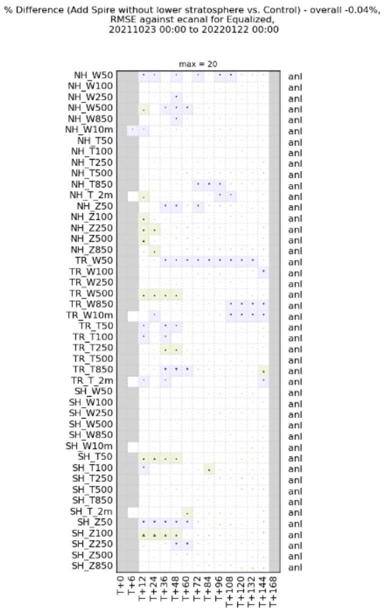
Region of most impact



Note increased RMSE for geopotential height

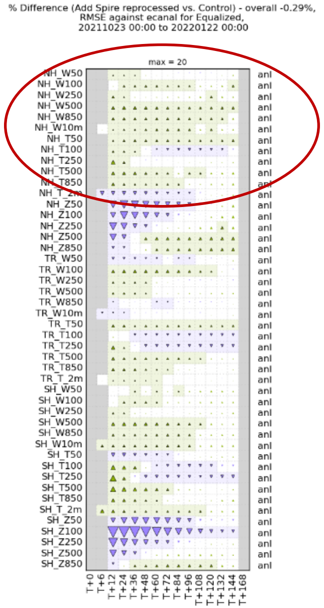


- Control: assimilate operational GNSS-RO observations
- Experiment 1: add high-volume Spire observations
- Experiment 2: add high-volume Spire observations, excluding 15-25 km

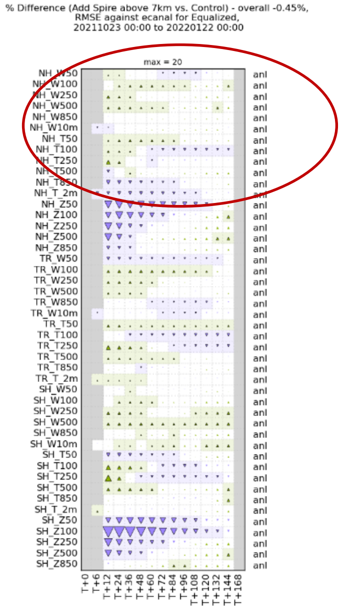
Experiment 1

Experiment 2

Region of most impact



Experiment 1



Experiment 3

- Third experiment
  - Add all Spire observations above 7km
- Impact similar to all-obs experiment, but degraded RMSE in certain regions

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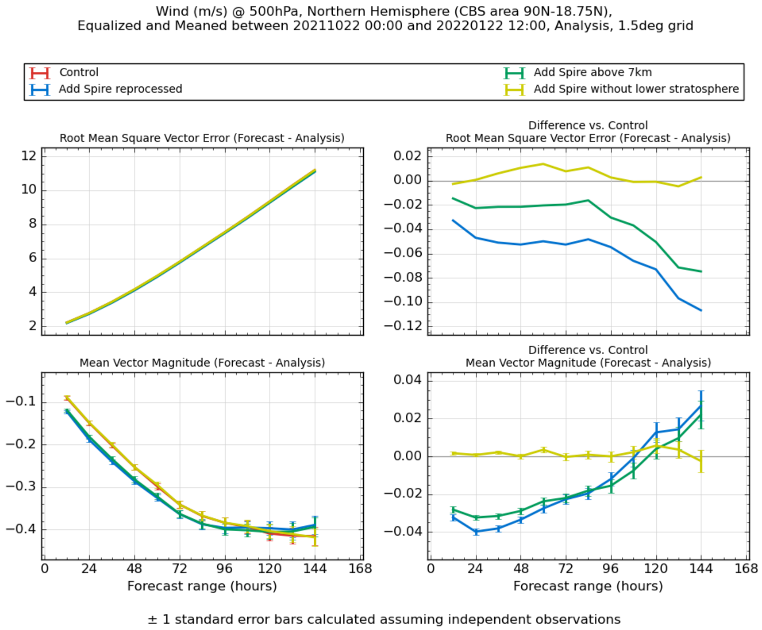
Region of most impact



- Almost no impact from adding lots of Spire observations below 15km and above 25km
- Removing tropospheric obs also causes degradation
- Tropospheric obs: useless on their own, but helpful in combination?

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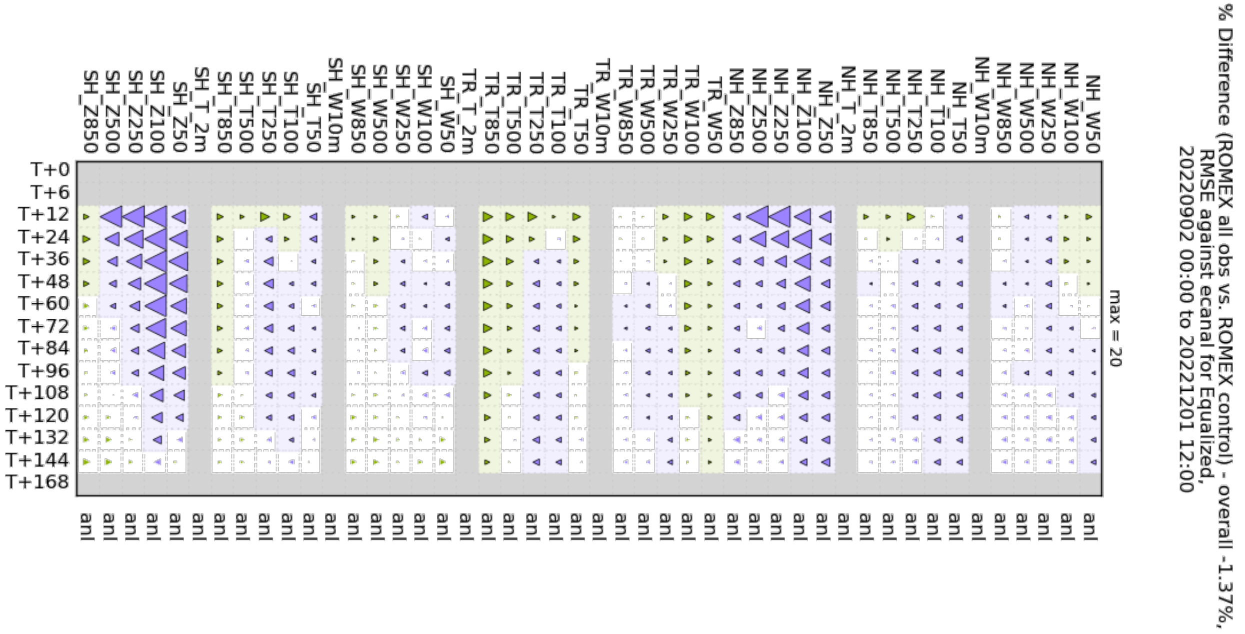
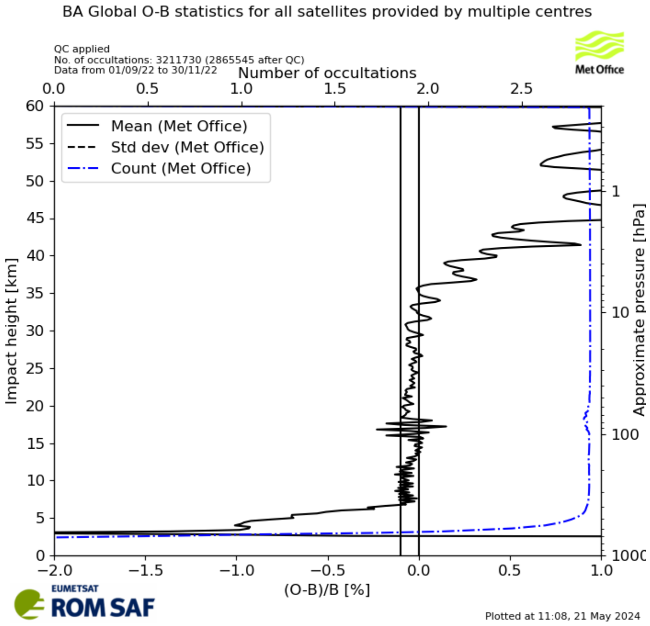
ROMEX – all obs



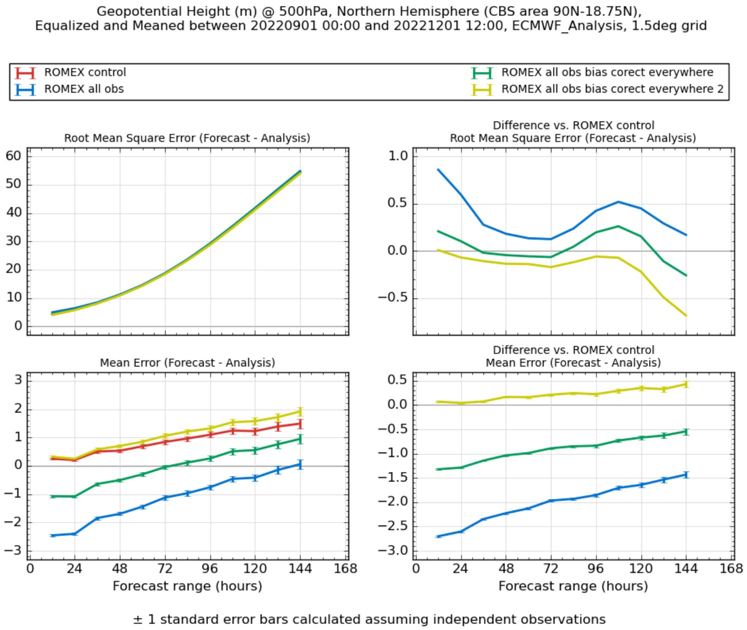
- Change in RMSE measured against ECMWF operational analyses
- Assimilating all observations, compared with control

Stratosphere bias correction



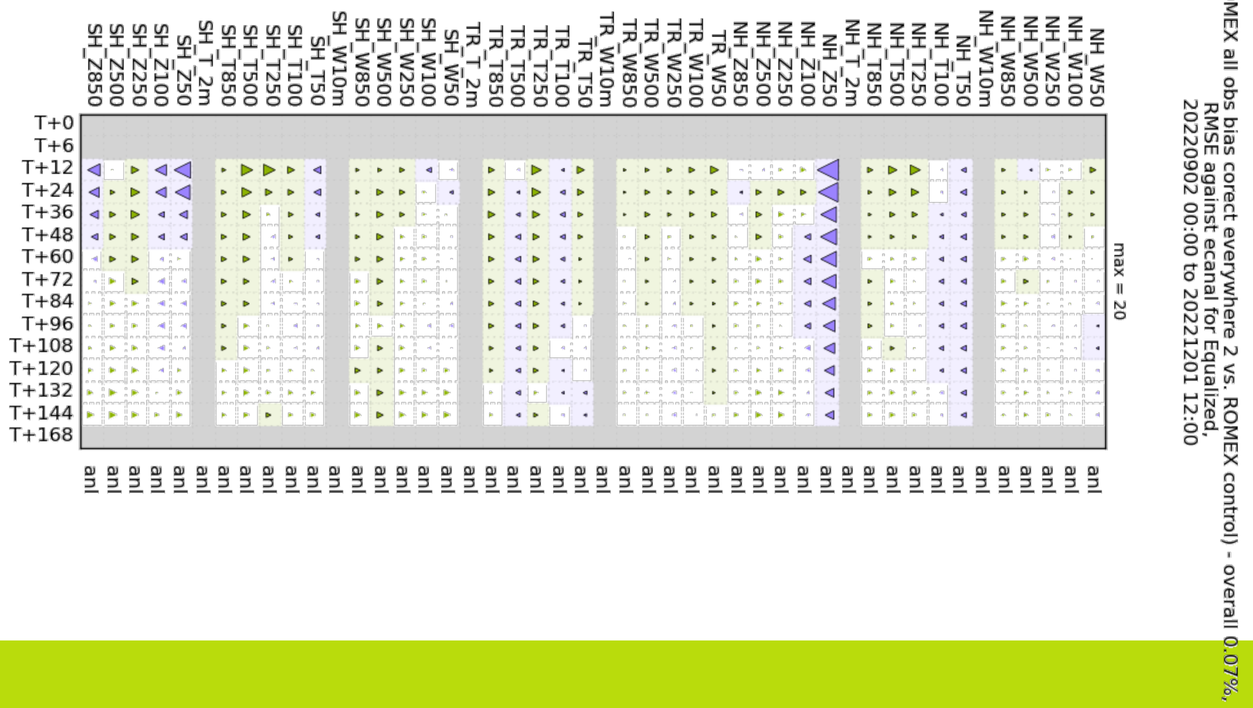
- Global statistics indicate -0.05% bias in lower stratosphere
- Add 0.05% to **all** observed bending angles
- Additional x2 experiment

Bias – geopotential 500 hPa



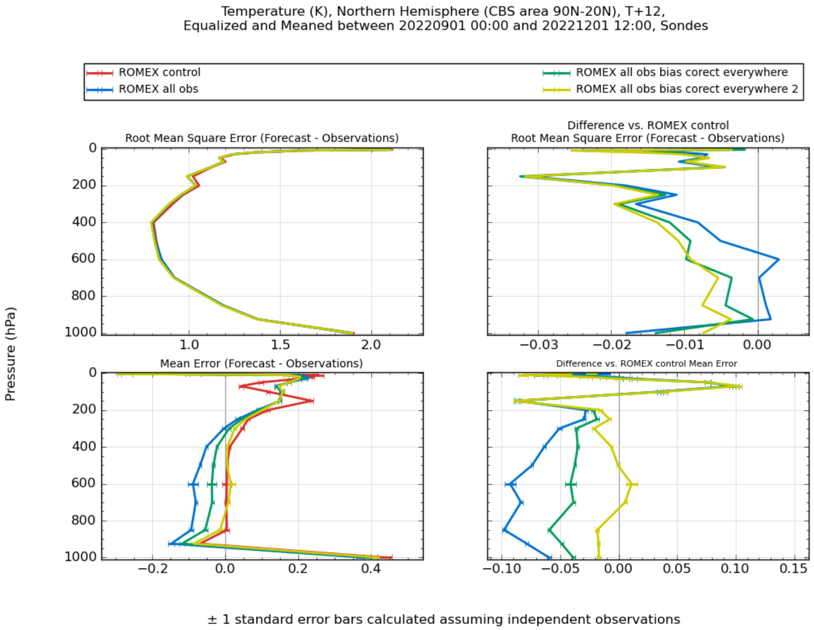
- No change in bias from:
  - Applying bias correction in lower troposphere
  - Applying vertical smoothing
- Effective bias correction from:
  - Applying bias correction to **all** bending angles (increase by 0.05% or 0.1%)
- Expect similar effect from reducing k_1 coefficient

ROMEX – all obs (bias correction x2)



- Change in RMSE measured against ECMWF operational analyses
- Assimilating all observations, compared with control
- Applying bias correction to **all** bending angles (increase by 0.1%)

Temperature (radiosondes, T+12)



- RMSE increased with normal observations
- RMSE reduced everywhere with bias-adjusted obs
- Temperature bias in troposphere affected
  - No change in stratosphere

Vertical smoothing

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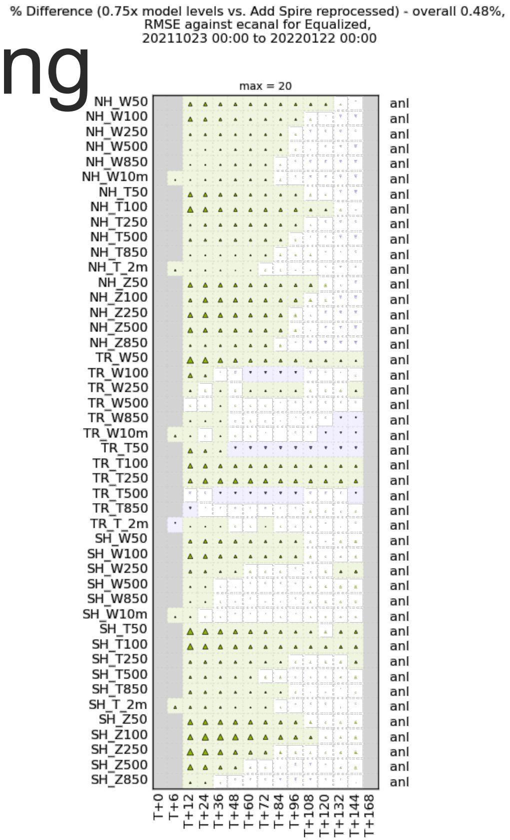
Vertical smoothing – pre-processing

- Developed smoothing within Met Office pre-processing
- Applied to BUFR data, all satellites
  - Local polynomial regression with cubic polynomial
  - Cannot have too little smoothing, as LPR will not work on too few points
- Smoothing length-scale in proportion to Met Office model level spacing
- Experimented with smoothing BA and log(BA)
  - Smoothing in BA seems better



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Vertical smoothing – next steps

- Write up report
- Follow-on project
  - Apply smoothing to high-resolution bending angle observations
    - Would avoid “minimum” smoothing scale
    - May help to reduce biases
    - ROMEX data?
  - Experiment with super-obbing
  - Confirm results with ECMWF model
- Ultimately – may want operational delivery of high-resolution data

Further work in CDOP-4

- Analysis of GS2 data from EUMETSAT Secretariat
- Provision of observation uncertainty estimates
- Testing and review Spline and PRO code
- FY-3E assessment
- Ongoing activities
  - NRT monitoring
  - Support for GBGP software

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Some suggestions

- Observations in lower stratosphere have largest impact
  - Why do we not get more from tropospheric observations?
- ROMEX work packages
  - Covering current work?
  - Future experiments?
  - How valuable are observations with different equator crossing times?