Enhancing the use of all-sky microwave sensors at ECMWF using inter-channel error correlations

Developments for the advanced use of future sensors

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What is the goal of this work?

- We know that observations have correlated errors:
  - Spatial (in latitude/longitude).
  - Vertical (across the channels of one instrument).
- At ECMWF, observations assimilated in clear-sky conditions (with cloud- and precipitation-affected observations screened out) have inter-channel error correlations accounted for. However, no quality control (VarQC) is applied.
- Observations assimilated in all-sky conditions have VarQC applied, but inter-channel error correlations are not accounted for.
- Handling inter-channel error correlations in all-sky will be important for extracting the most information from future instruments with increased numbers of humidity/ice-sensitive channels.

Micro-Wave Sounder: 183 GHz	Arctic Weather Satellite: 183 & 325 GHz
Micro-Wave Imager: 183 GHz	Ice Cloud Imager: 183, 325 & 448 GHz

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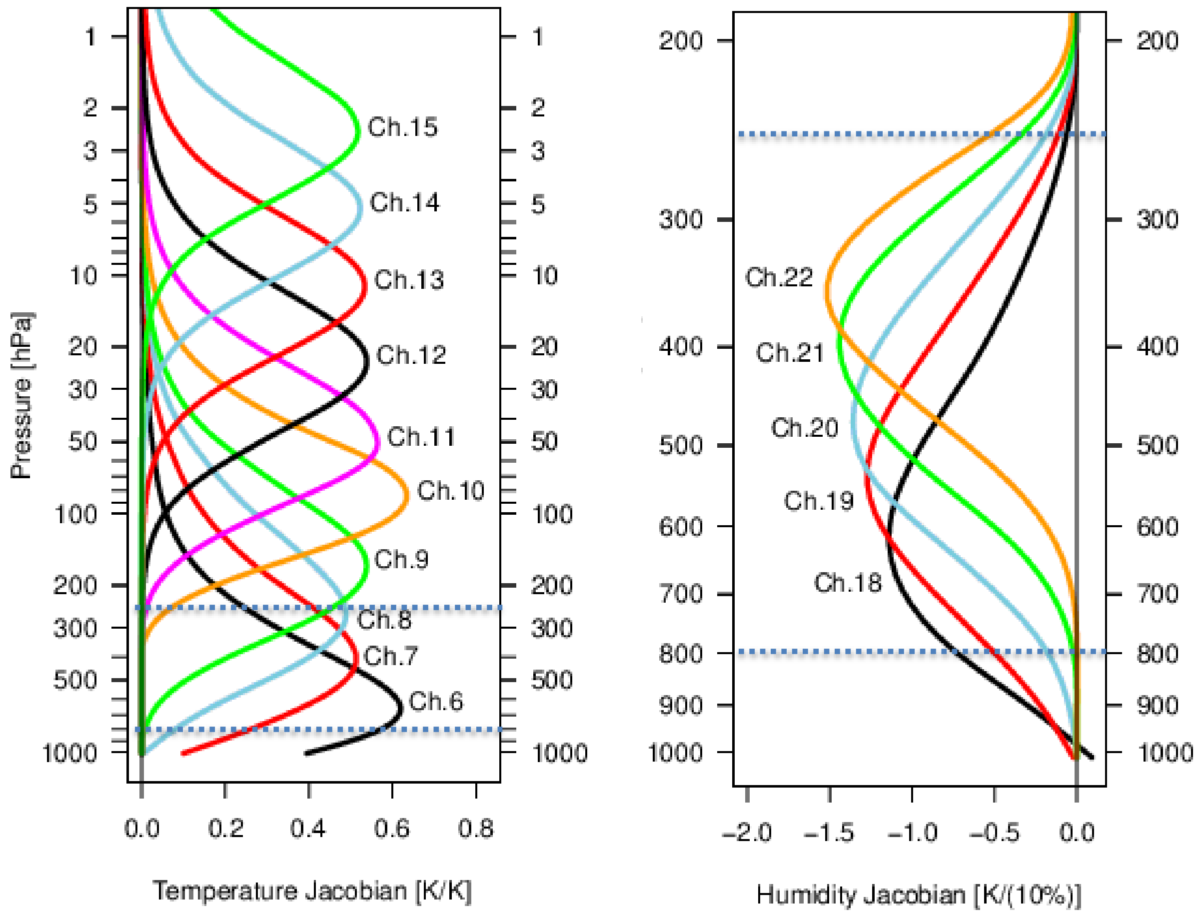
- Here we present the progress made at ECMWF to allow inter-channel error correlations and VarQC to be applied to all-sky microwave sounder assimilation – beginning with tests using the Advanced Technology Microwave Sounder (ATMS) instrument.

Overview of the ATMS instrument

- Cross-track scanner with 22 channels.
- Temperature sounding channels at 50-60 GHz.
- Humidity sounding channels at 183 GHz.
- At ECMWF we assimilate channels 6-15 (temperature) and 18-22 (humidity).
- Channel-dependent screening is performed to remove observations over sea ice, snow and high orography.



Creating correlation matrices

- For clear-sky assimilation, only one correlation matrix per instrument is needed for all observations. Great!

- For all-sky assimilation, the correlation matrix will be different depending on the cloudiness of the observation.

- As every observation will have a different cloudiness, this means a different correlation matrix would be needed for every observation.

- To complicate things further, the parameter to determine cloudiness for ATMS observations (the cloud proxy) differs depending on the surface type and channel.

Surface type	Temp chan	Humi chan
Ocean	LWP	SI
Land	SI	SI

SI = scattering index

LWP = liquid water path

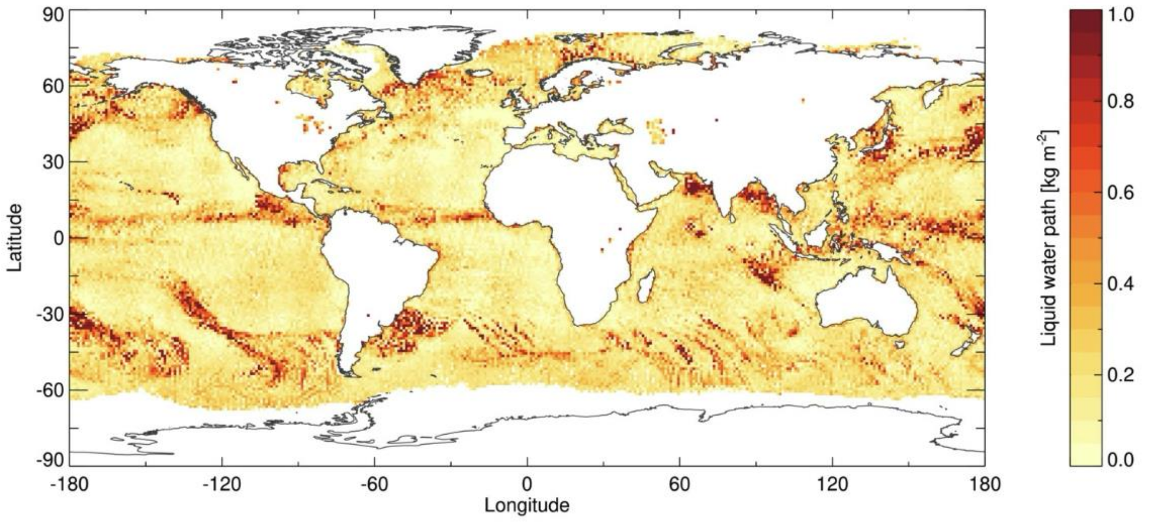
Examples of cloud proxies

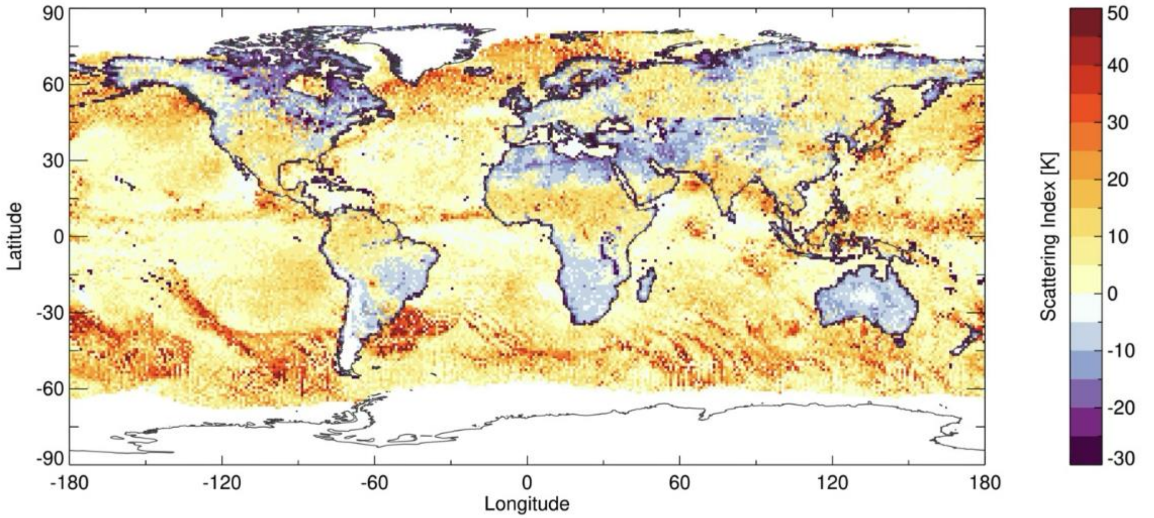
- Liquid water path for temperature-sounding channels peaks at around 1.2 kg m^{-2}.

- Scattering index for humidity-sounding channels peaks at around 60 K.

- After looking at the statistics of observations and SI/LWP values, we decided to use the following bins to create the correlation matrices:

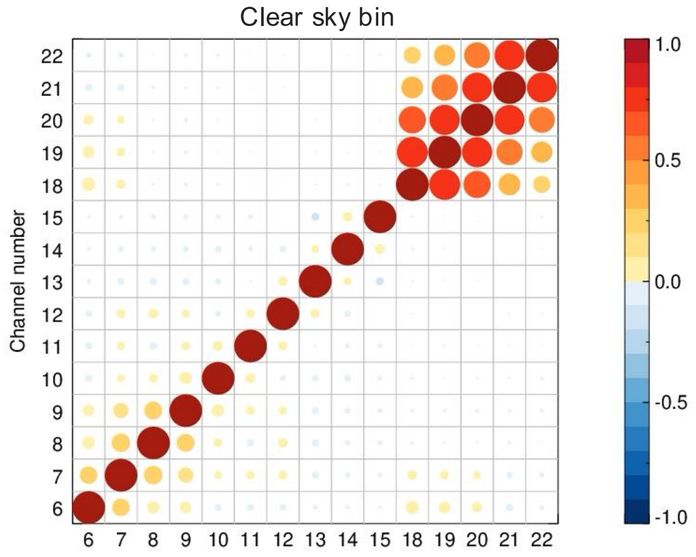
	Lower bin	Middle bin	Upper bin
Temp, ocean	< 0.2 kg m^{-2}	0.2 − 0.4 kg m^{-2}	> 0.4 kg m^{-2}
Humi, ocean	< 5 K	5 − 20 K	> 20 K
Temp, land	< −10 K	−10 − 0 K	> 0 K
Humi, land	< −10 K	−10 − 5 K	> 5 K

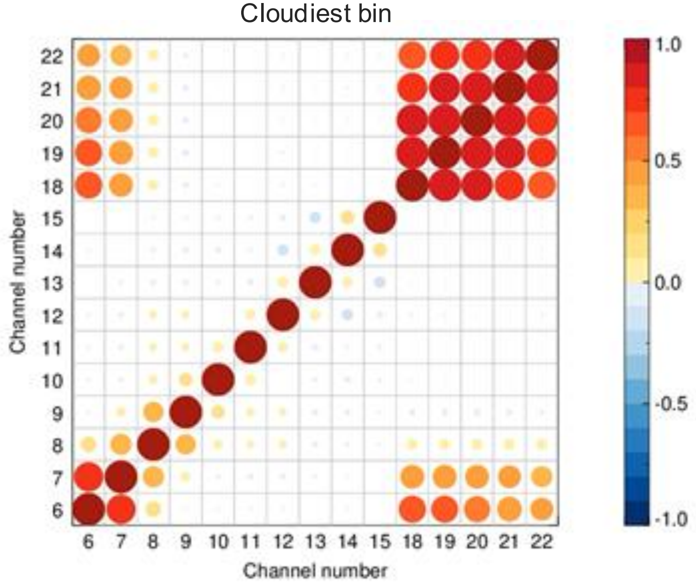




Correlation matrix examples

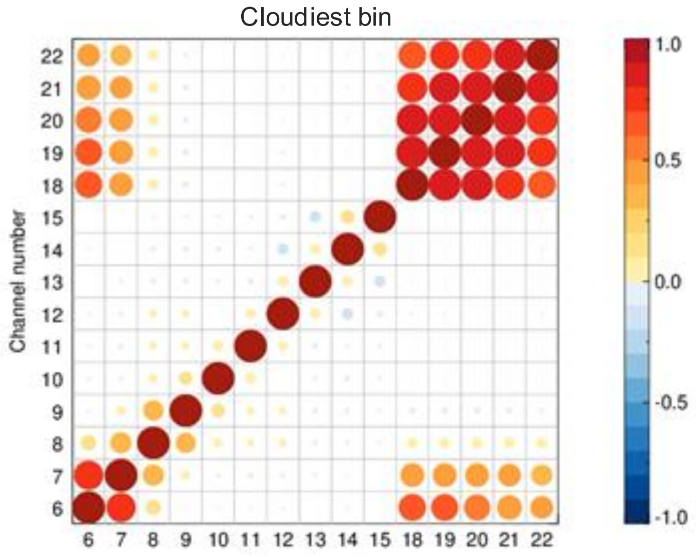
- Two examples from clear sky and cloudiest bins over the ocean, calculated using Desroziers statistics.
- Most noticeable difference is that in cloudy regions the correlations between the humidity channels increase.
    - This is because if cloud/precipitation is mis-represented in the model, errors will appear in all humidity-sensitive channels.
- There are also prominent correlations between the humidity channels and temperature channels 6-7.
    - This is due to the regions of the atmosphere these channels are sensitive to.
- The lowest peaking temperature channels (6-8) also show stronger correlations.
    - Due to both correlated instrument noise and the effects of incorrectly modelled clouds/precipitation.

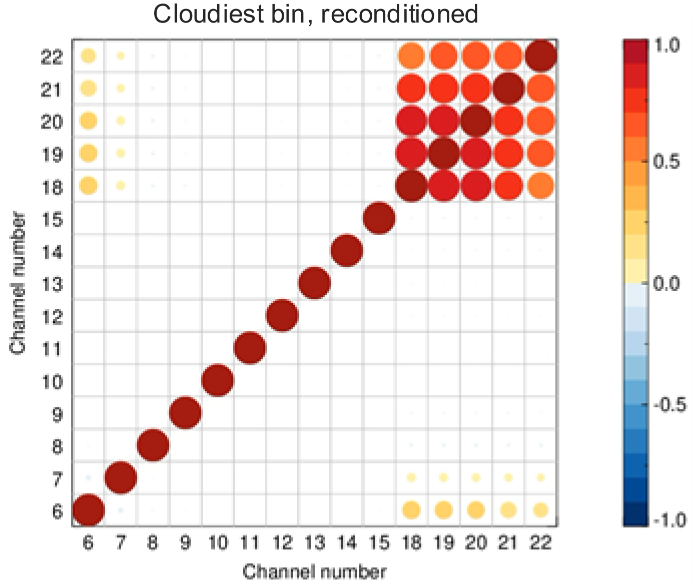




Overview of experiments performed

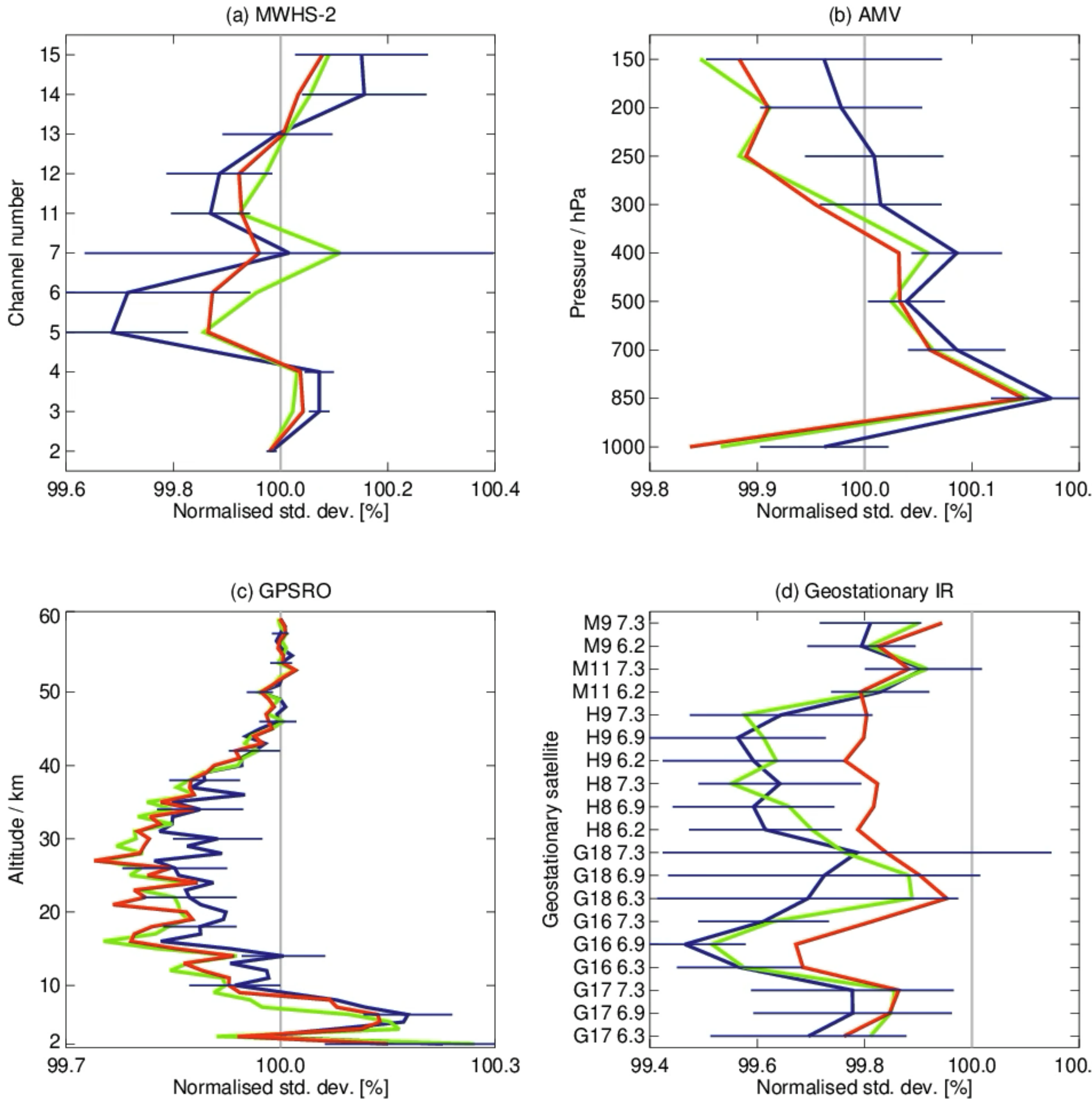
- We decided to use 9 correlation matrices, covering the range of SI and LWP encountered.
- Experiments are being performed for JJA and DJF.
- We are testing correlation matrices derived from O-B and Desroziers statistics, as well as testing conditioned and unconditioned matrices.
- Conditioning might improve the minimization, but it might also be removing important correlations between humidity and temperature sounding channels.
- In order to use VarQC with the correlated errors, we perform eigendecomposition of the correlation matrices, and calculate eigendepartures.
- The weights applied to the observations are based on their eigendepartures, rather than their departures.





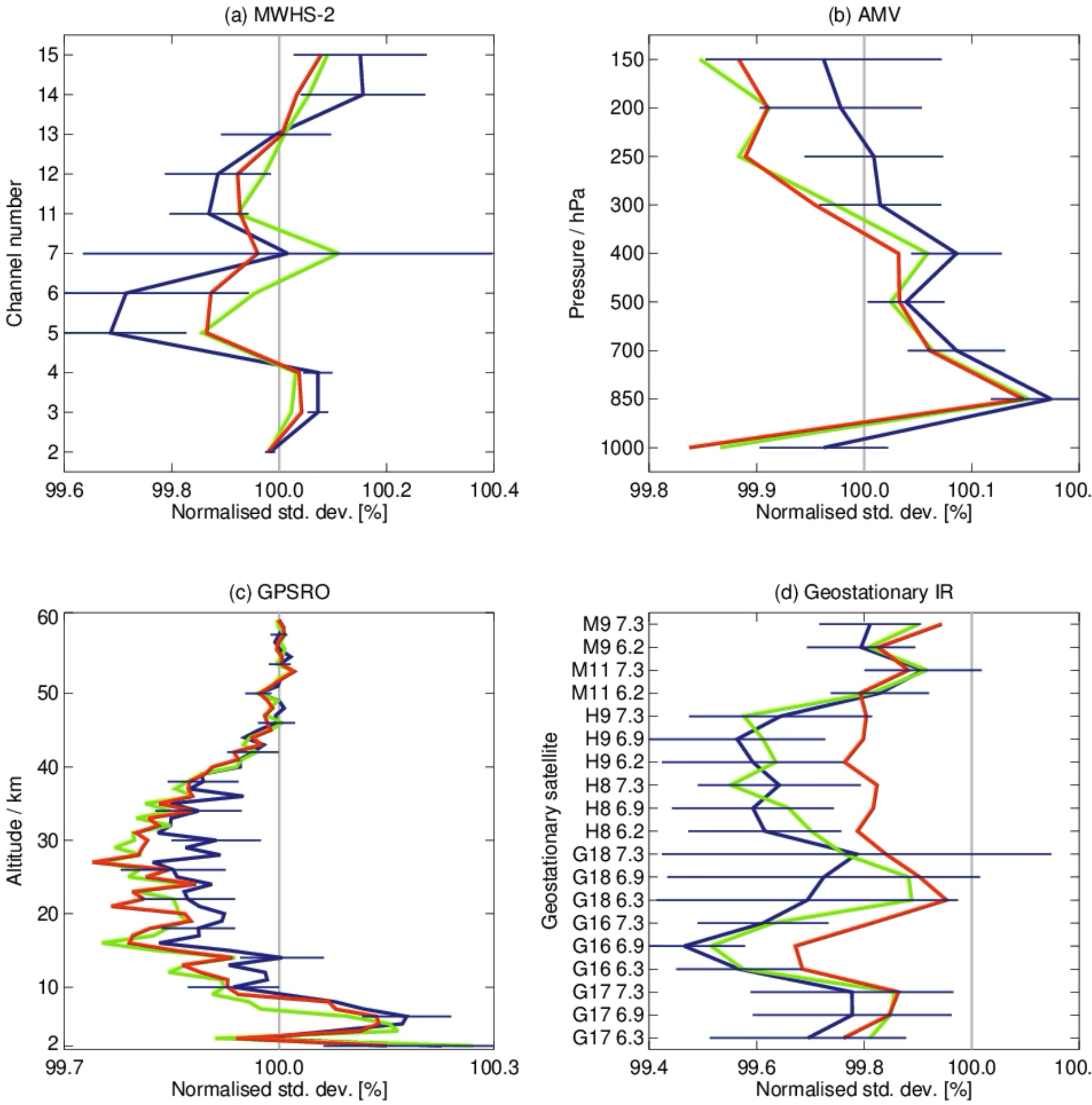
Initial results – short range (12-hr) forecasts

- Experiments were performed to obtain a first assessment of using ATMS in all-sky with correlated errors and VarQC.
- No attempt at ‘tuning’ was made.
- Plots show comparisons against four different observation types.
- Three experiments are compared against a clear-sky ATMS experiment (= 100%):
  - All-sky ATMS, no correlations
  - All-sky ATMS, correlations from O-B
  - All-sky ATMS, correlations from Desroziers
- Values < 100% represent improvements compared to the clear-sky ATMS assimilation.



Initial results – short range (12-hr) forecasts

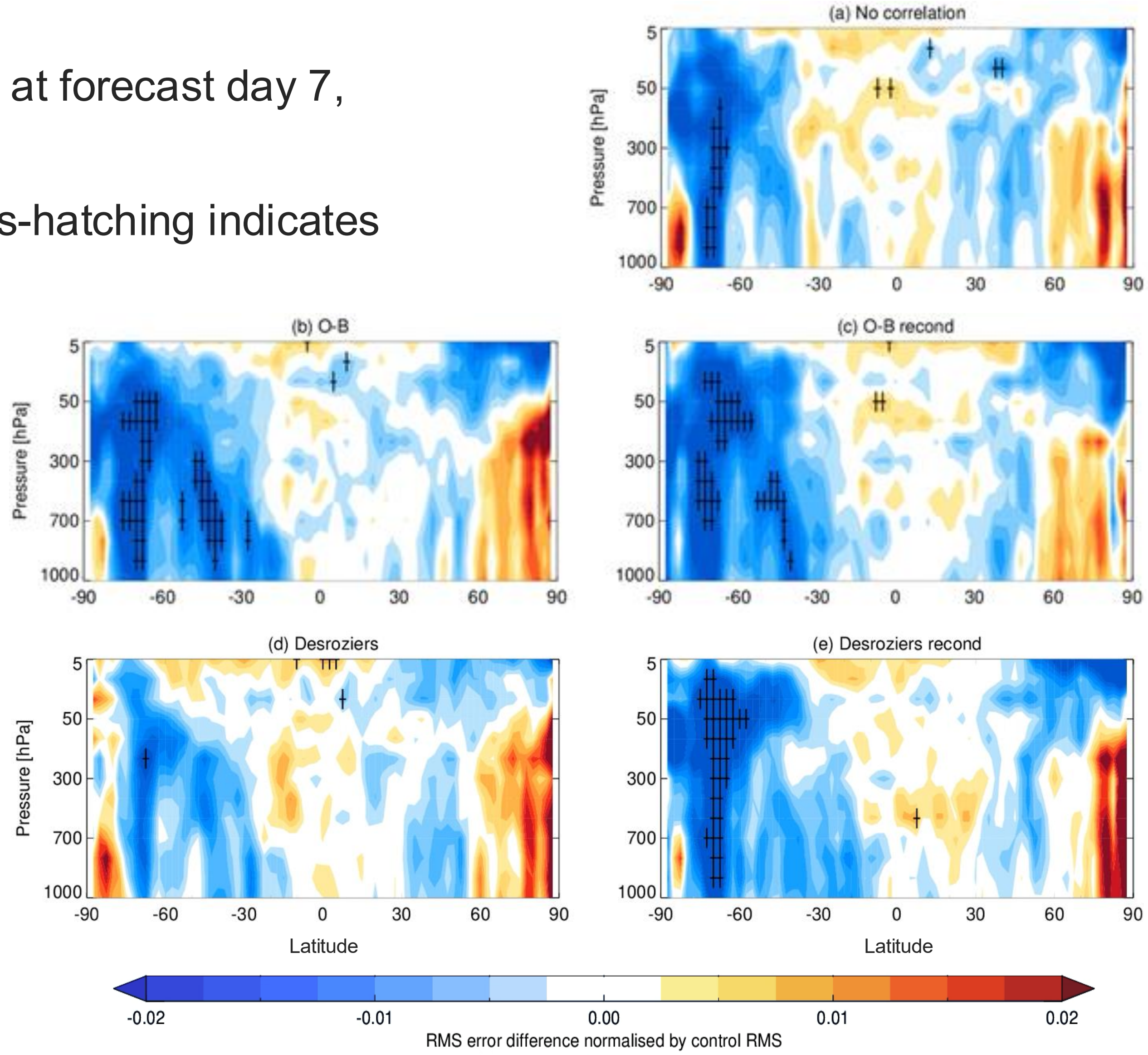
- Initial results are mixed, but promising considering no attempt at tuning was made.
- For the MWHS-2 channels where degradations are seen (2-4 and 14-15), adding correlated errors reduces the degradations.
- The same is true for Atmospheric Motion Vectors.
- For Radio Occultation data, assimilating ATMS in all-sky generally improves the agreement, with correlated errors resulting in larger improvements.
- For Geostationary IR water vapour channels, improvement is seen when using all-sky data, but the benefits of correlated errors are less clear.



All-sky ATMS, no correlations
All-sky ATMS, correlations from O-B
All-sky ATMS, correlations from Desroziers

Initial results – medium range forecasts

- Plots show the zonally-averaged wind differences at forecast day 7, compared against a clear-sky ATMS assimilation.
- Blue represents forecast improvements, and cross-hatching indicates statistically-significant changes.
- The main improvements from assimilating ATMS in all-sky with no correlated errors are in the southern hemisphere, up to ~50 hPa.
- When accounting for correlated errors derived from O-B statistics, a larger improvement is seen in the wind, extending further in latitude and altitude.
- When using correlated errors derived from Desroziers statistics, the reconditioned matrix appears to perform better – need to investigate why.



Conclusions

- At ECMWF progress has been made to allow inter-channel error correlations and variational quality control to be applied to all-sky microwave sounder assimilation.
  - We have been testing the developments with assimilation of the ATMS instrument.
  - This work will be important for extracting the most information from future instruments with increased numbers of humidity/ice-sensitive channels.
- Different correlation matrices are required to encompass the range of cloudiness seen in the observations, and to account for the different cloud proxy types (SI or LWP).
- Current results look promising, with some benefits seen in both short-range and medium-range forecasts.
- There is still more work to do to understand the reasons for the differences when using correlation matrices derived with different statistics.
- I'm sorry I can't be there, but I am happy to answer any questions by email (liam.steele@ecmwf.int), or if you see another ECMWF colleague they may be able to help!