Developments in the all-sky assimilation of microwave imagers at ECMWF

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ECMWF

All-Sky Assimilation of Microwave Imagers

- Microwave imager data helps to improve atmospheric humidity, cloud and precipitation analyses.
- Data assimilation under all sky conditions was introduced at ECMWF in 2009 (see Bauer et. al. 2010, Geer et al., 2010, Geer and Bauer, 2010 and 2011).
- Microwave imagers currently assimilated at ECMWF under all-sky conditions are listed below.
- Work on further exploiting these sensors, as well as improving the associated observation operator, is a continual process.

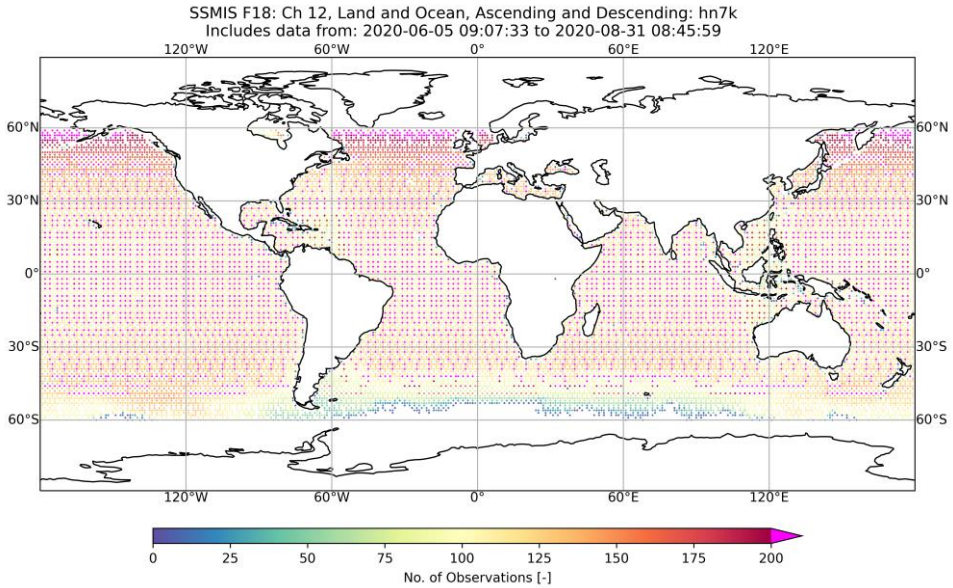
Microwave imagers currently assimilated in the ECMWF IFS

Sensor	Platform
SSMIS	DMSP-F17, -F18 (some channels)
GMI	GPM
AMSR2	GCOM-W
MWRI	FY-3D

- Structure of talk today:
  - Inclusion of SSMIS on-board DMSP-F18
  - Improving representation of convective clouds
  - Future Plans

Inclusion of SSMIS data from DMSP-18

- SSMIS on-board DMSP-17 (F17) (6:40 orbit) has been utilised in ECMWF-IFS since December 2009.
- However, SSMIS imaging channels on-board DMSP-18 (F18) (4:50 orbit) have not yet been fully exploited.
- Experiments undertaken to determine if incorporating channels 12 – 17 (excl. 15) improves the forecast.
- As the 5th microwave imager added, SSMIS (F18) complements SSMIS (F17), AMSR2 & MWRI (both 13:30 orbits) and GMI (65° inclination).



Summary of SSMIS channels utilised from DMSP-17 and -18 (previously unexploited channels bordered in red)

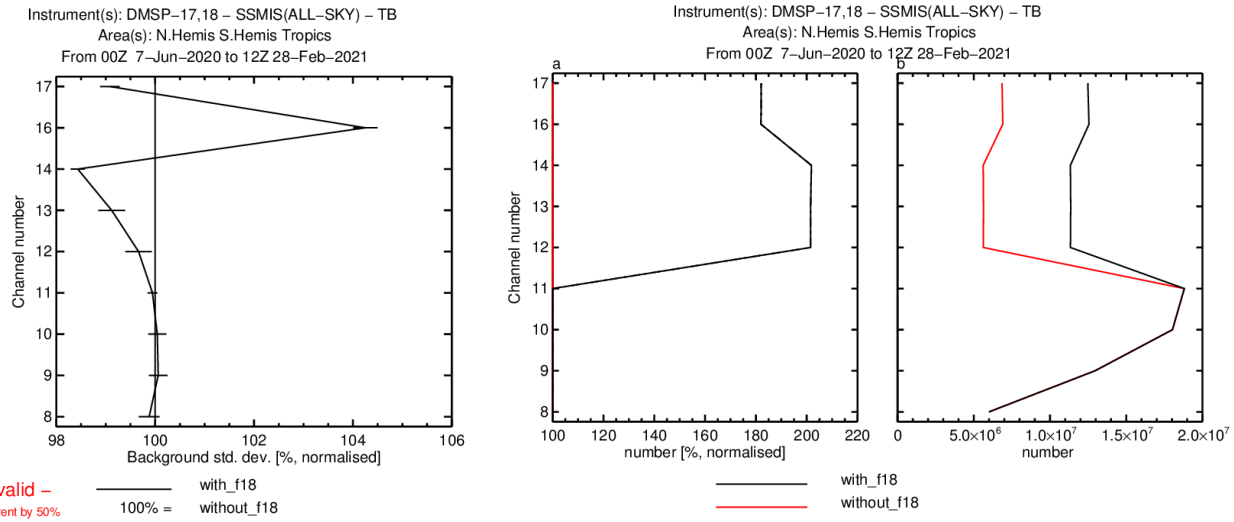
Band	Central Freq. [GHz]	DMSP-17 SSMIS	DMSP-18 SSMIS
8	150 H	Land and ocean (between 45 N and S)	As current - Failed Feb 2014, not used
9	183.31 ± 6.6 H	Land and ocean, exclude 2016-10-05 to 2016-11-09	As current - Over ocean excluding sea ice
10	183.31 ± 3.0 H		
11	183.31 ± 1.0 H		
12	19.35 H	Ocean only, exclude sea ice	Add over oceans only, excluding sea ice
13	19.35 V		
14	22.235 V		
16	37.0 V	Land and ocean, exclude sea ice	
17	91.655 V		

Number of observations available for SSMIS-F18 Ch. 12 for the JJA experiment.

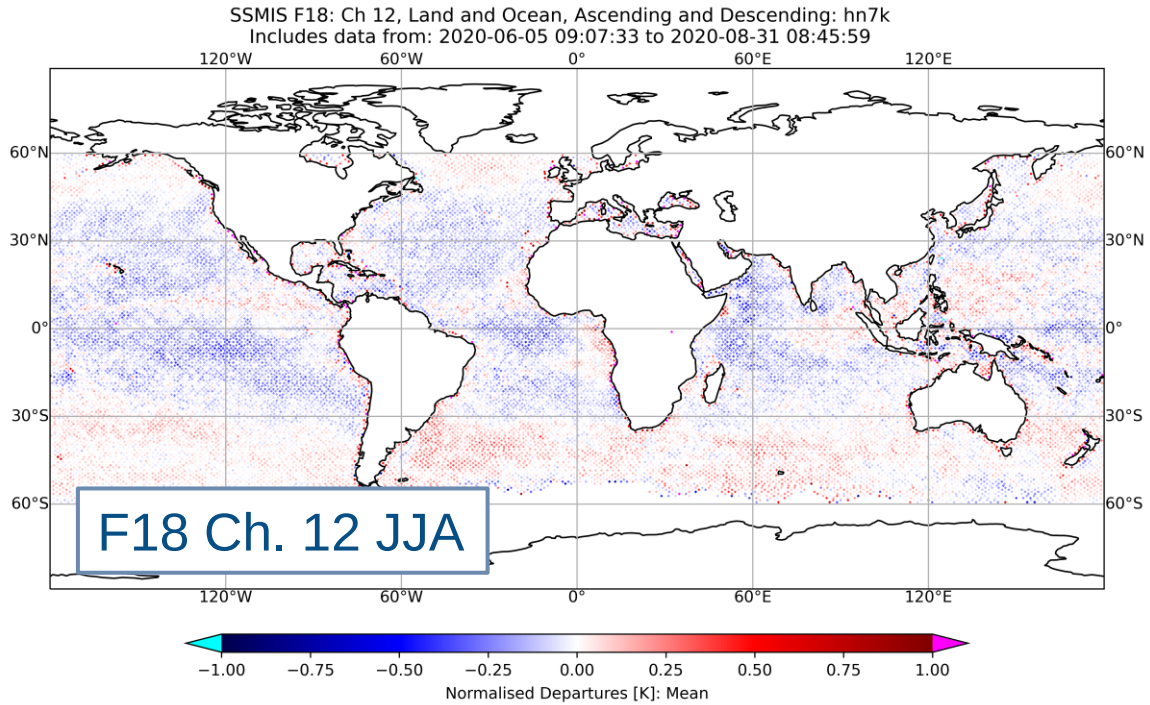
O-B Statistics – SSMIS

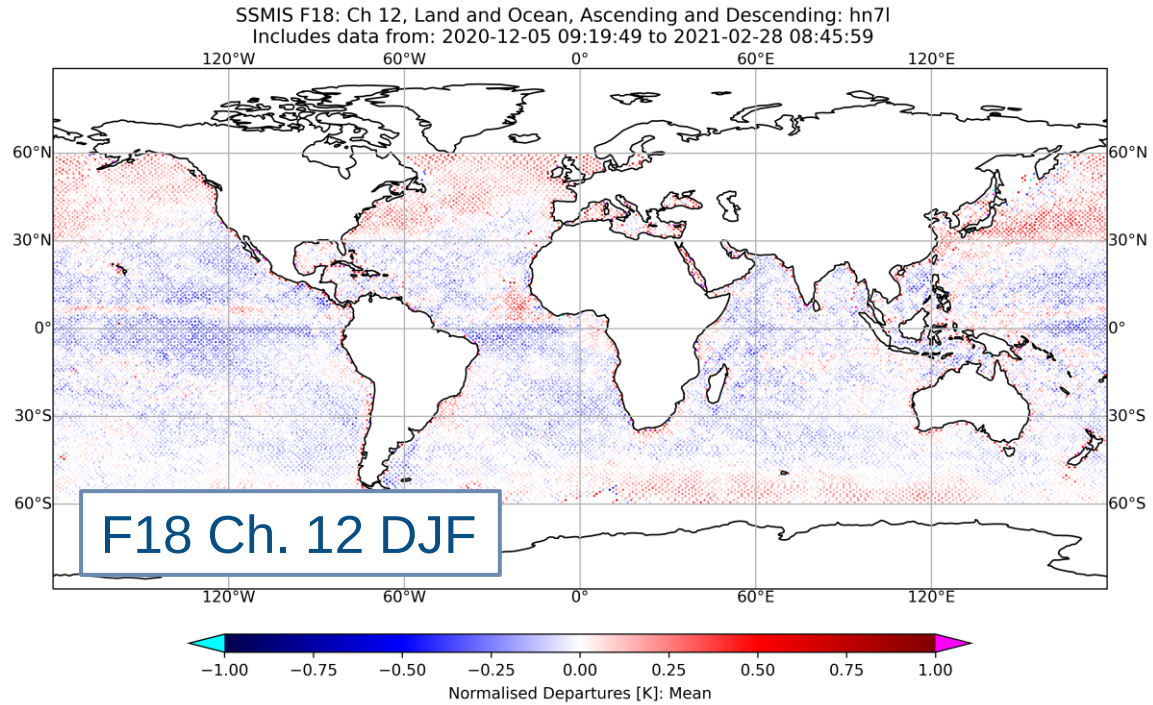
- SSMIS on F18 added for channels 12, 13, 14, 16 and 17 results in:
  - Expected increase in observation numbers.
  - Mainly decreases in the standard deviation of O-B with the notable exception of 37.0 GHz V (Channel 16).

Change in std(O-B) and number of observations for SSMIS relative to control experiments. Includes all seasons.



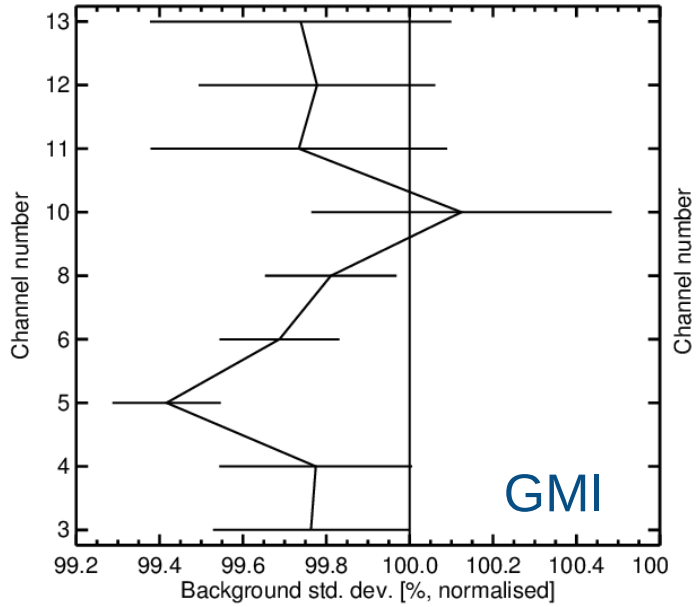
Mean of O-B over time for SSMIS F18 channel 12 for the summer and winter seasons.

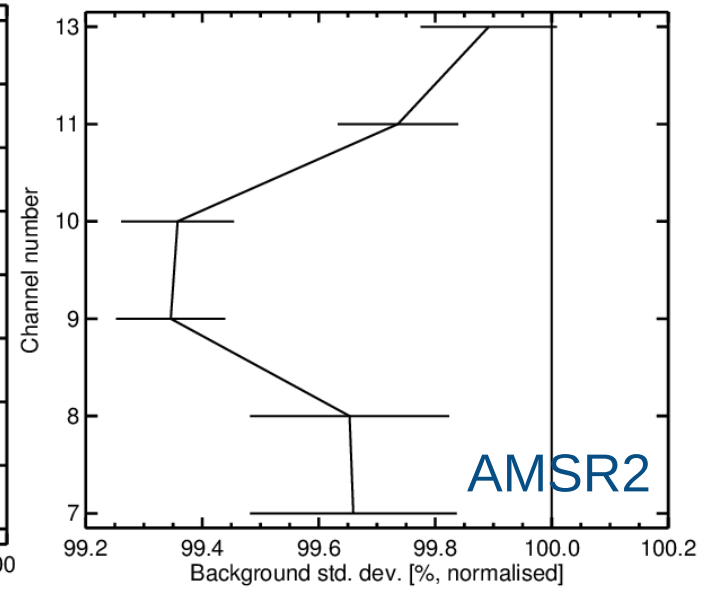


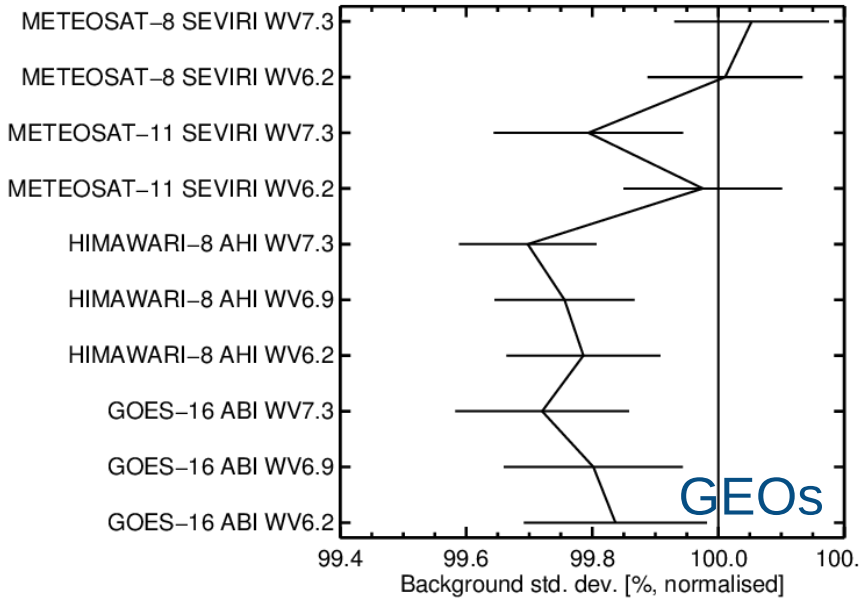


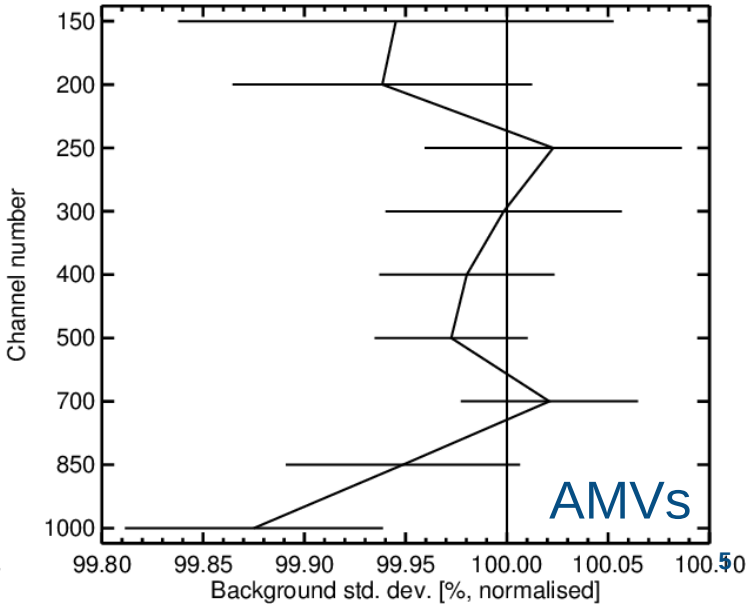
O-B Statistics – Microwave Imagers

- The standard deviation of O-B has reduced in the microwave imagers (top) as well as other sensing systems (bottom).
- Improvements in independent sensors provide encouragement that the inclusion of SSMIS F18 is improving the situation.







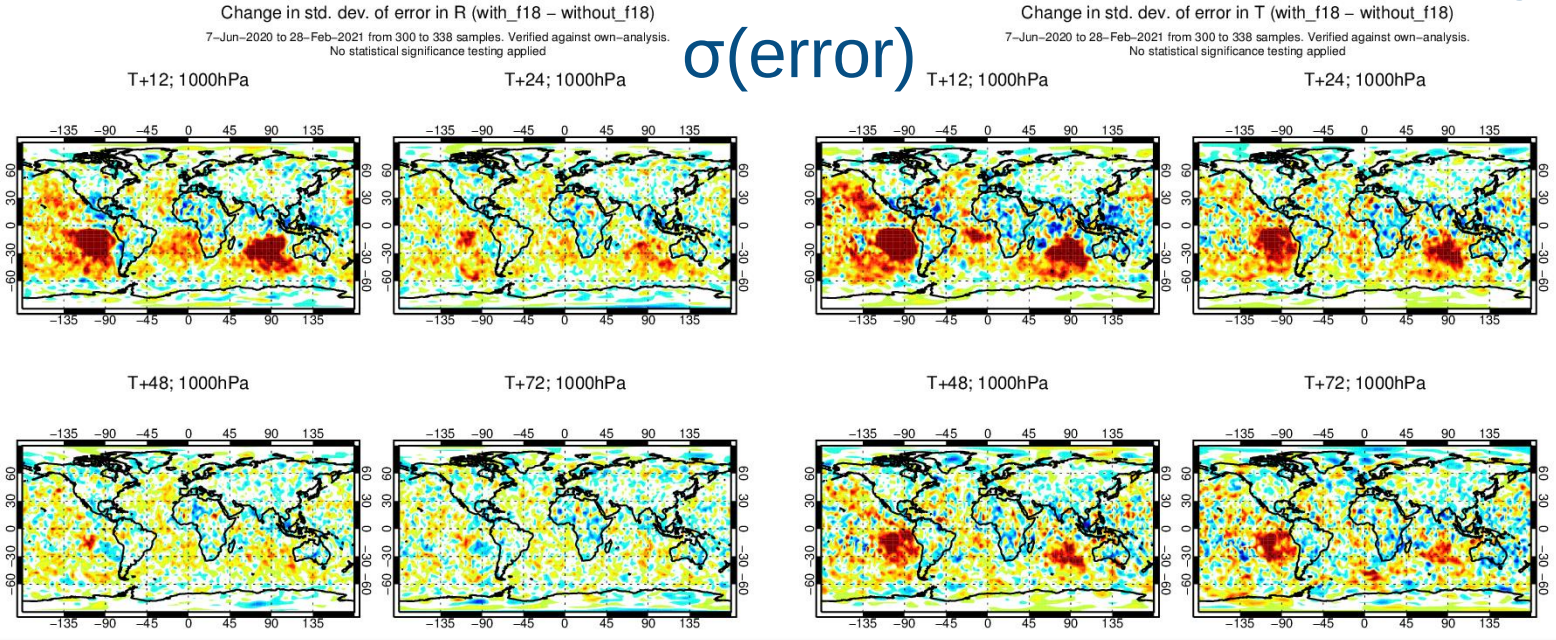


Change in std(O-B) for microwave sensors (top) and other systems (bottom) relative to control experiments. Includes all seasons.

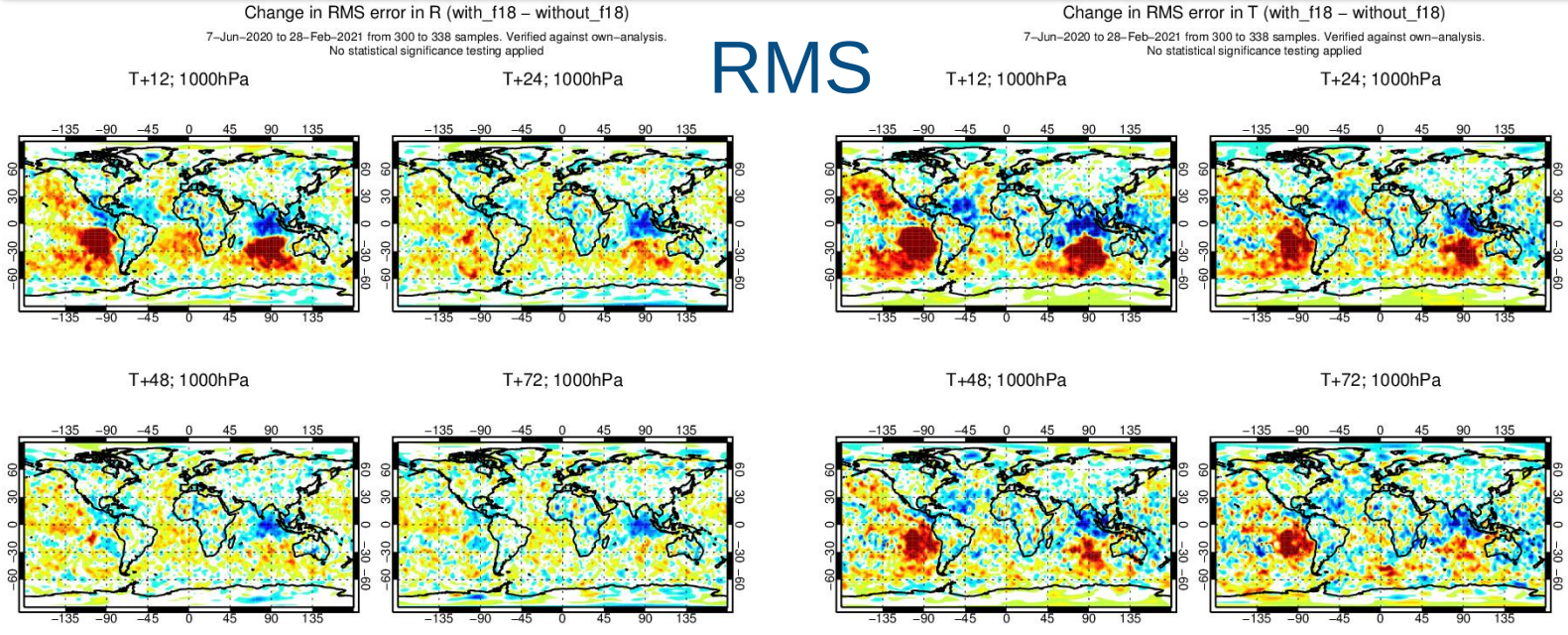
ECMWF

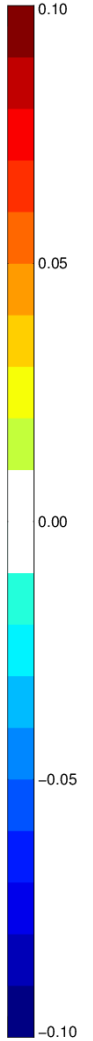
Differences in the forecast due to adding SSMIS-F18

σ(error)



RMS

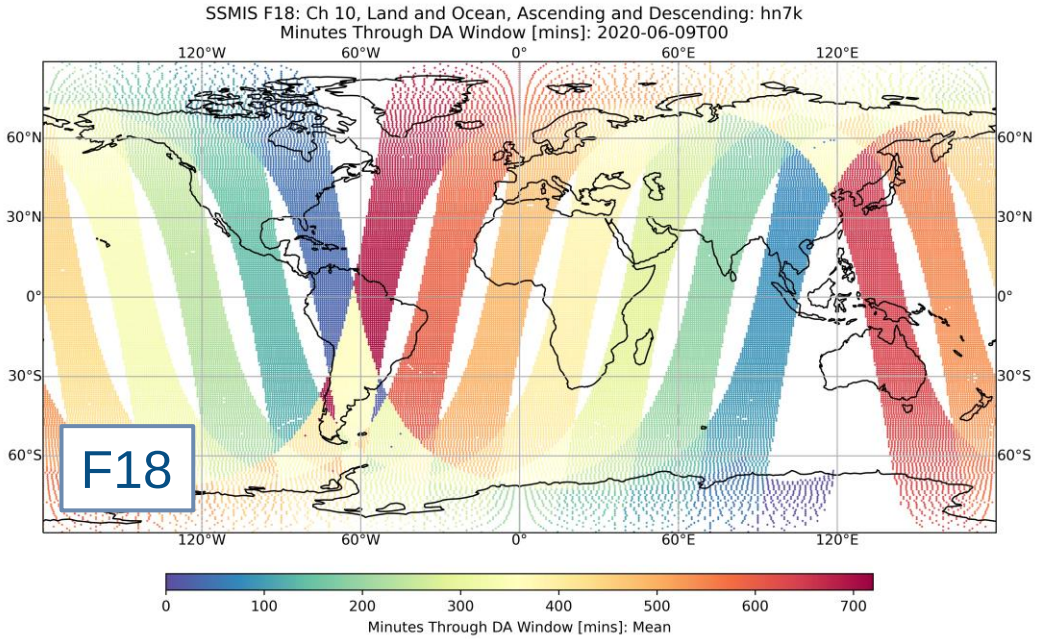


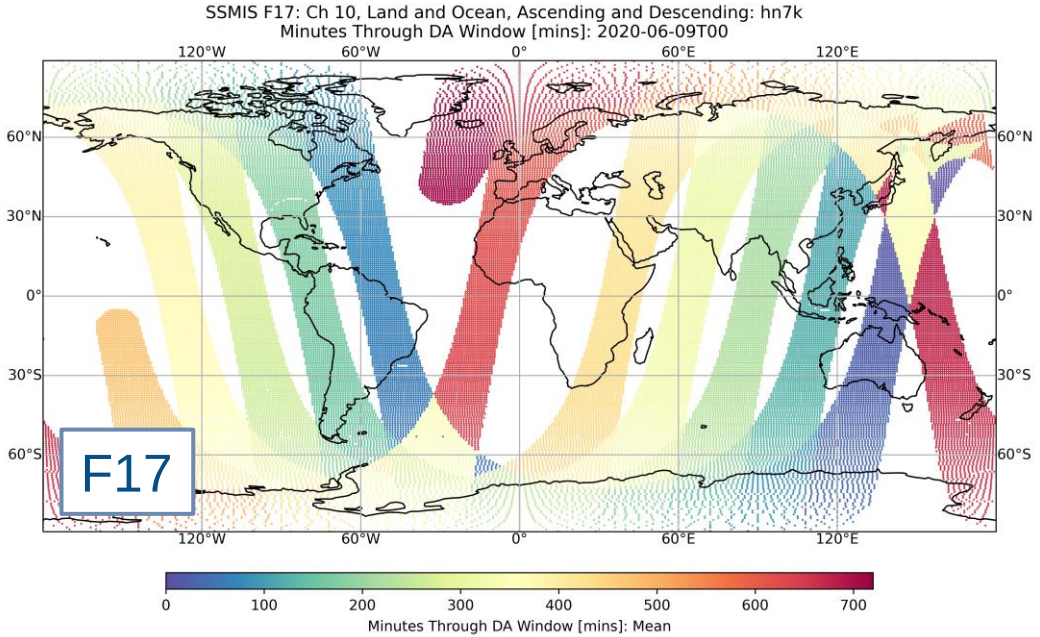


Std. Dev. of error (top) and RMS error (bottom) between the forecast with and without SSMIS F18 for relative humidity (R) and temperature (T).

- Adding SSMIS from F18 has resulted in some unexpected, large differences in the forecast for humidity (R) and temperature (T).
- Differences are prominent for the first day in R and out to day 3 in T.

Minutes Through DA Window vs. Differences in Forecast

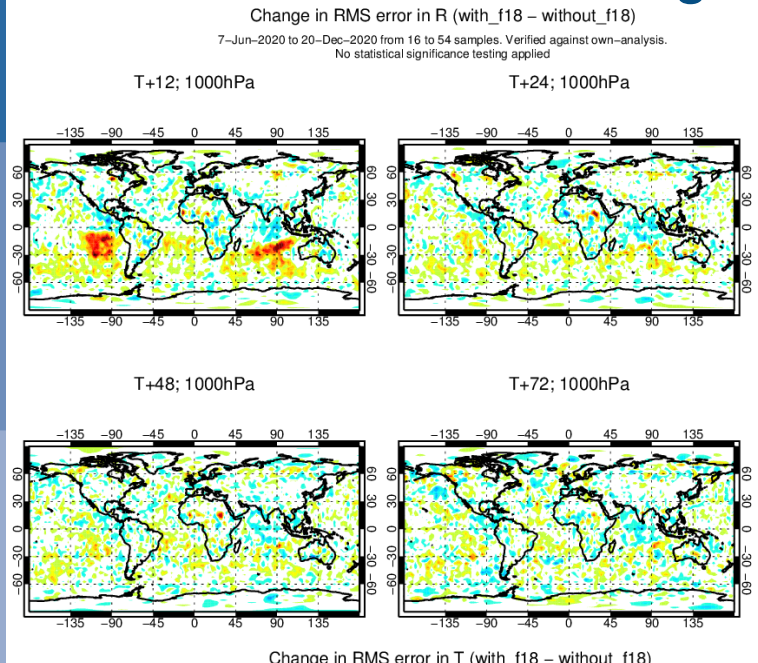


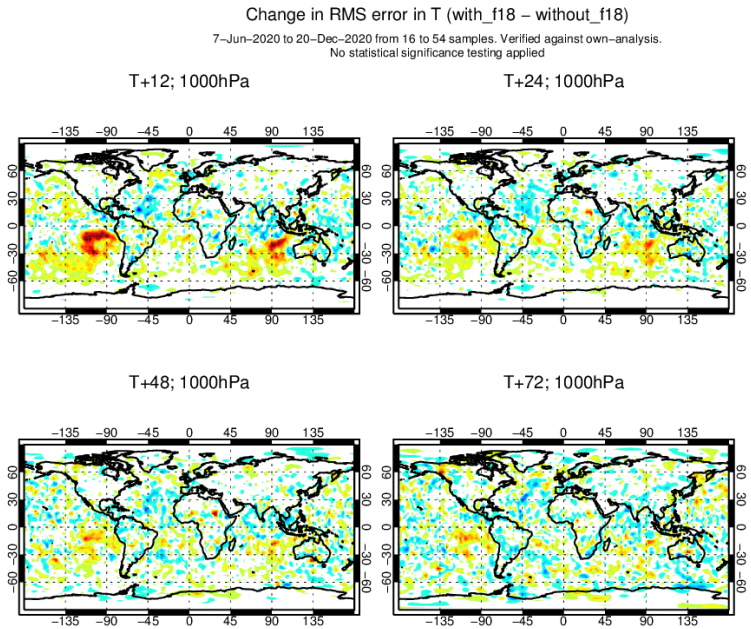


- The areas of concern (from the previous slide) coincide with data within the first 4 hours of the assimilation window (shown here for the 0Z window).
- The overpass time varies slightly between F17 (06:40) and F18 (04:50) meaning there is a shift in where the first four hours lie.
- These first hours could be adversely affecting the initialisation of cloud within the model, resulting in forecast differences.

Minutes through the data assimilation window for SSMIS on F17 and F18 for 9th June 2020 for 0Z window.

Removing the First 4 Hours of Data in Each Window

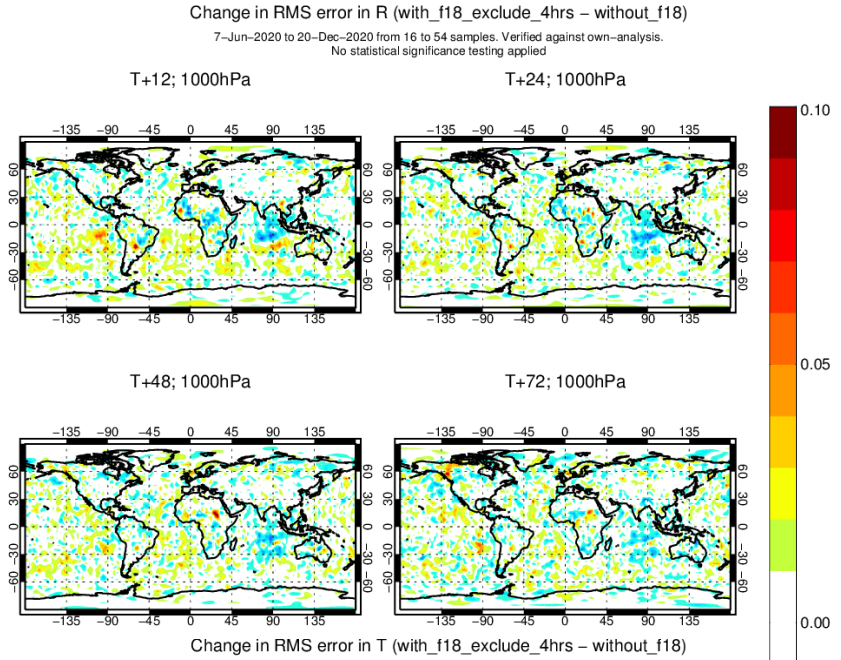


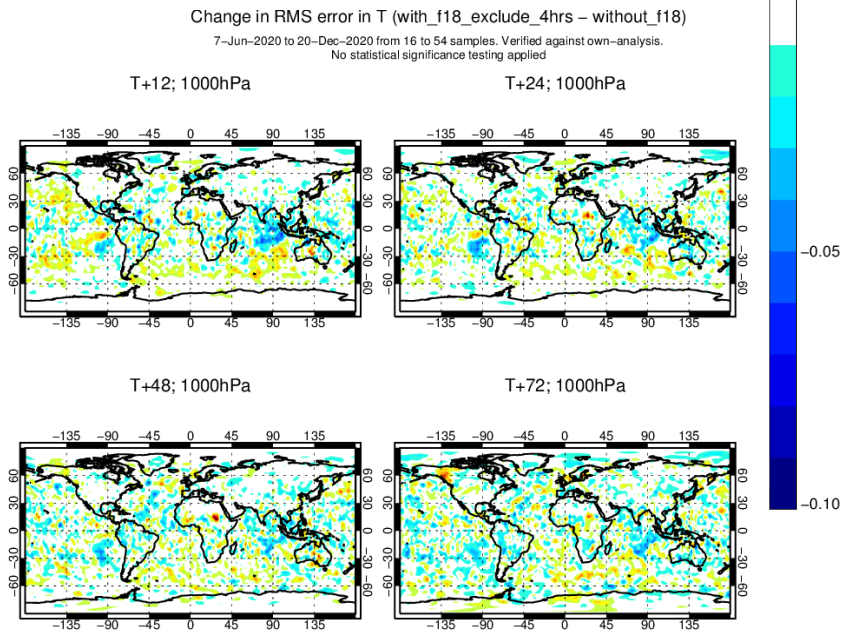


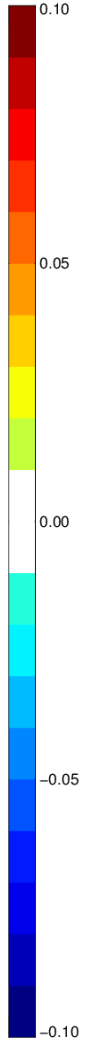
- Experiment run without the first four hours of SSMIS F18 data (in each DA window).
- Only 20 days through, but so far indicate it could be related to these observations (for all metrics).

Minus the first four hours of observations from SSMIS F18 in each DA window

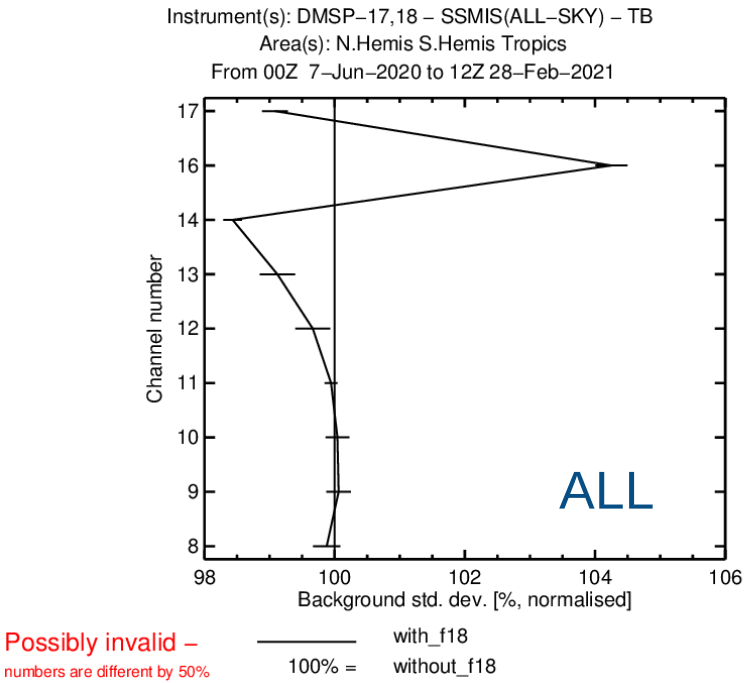
RMS error between the forecast with and without SSMIS F18 for R and T (left) and the same setup but excluding data in the first four hours of the DA window (right). For all seasons.

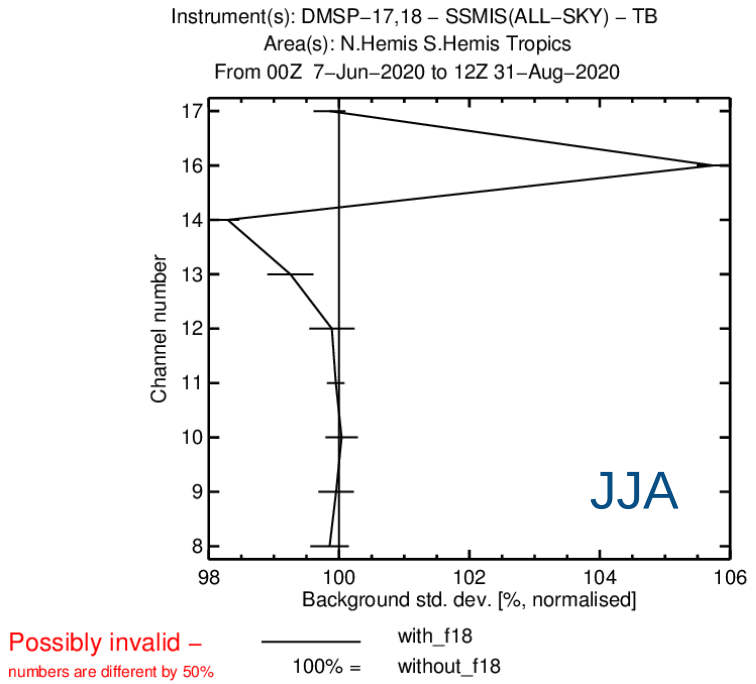


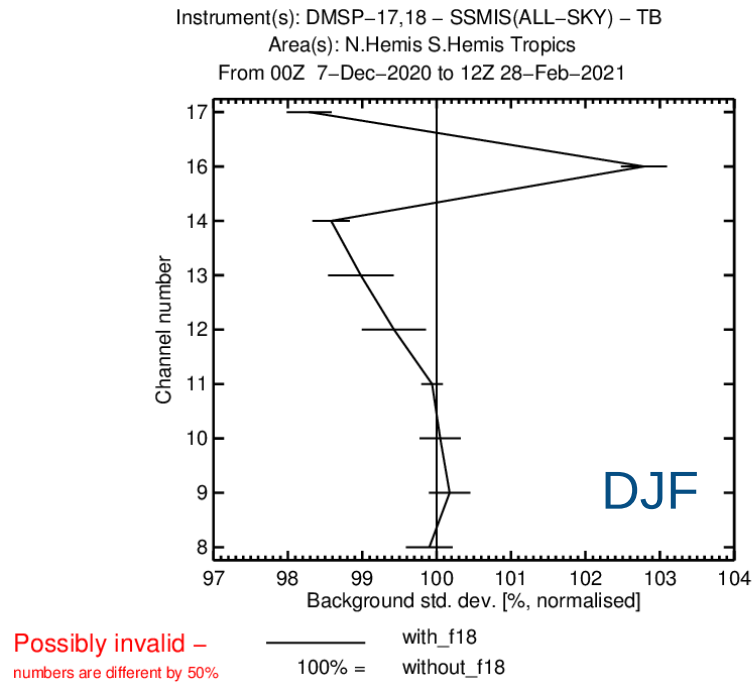




Comparison of Std. Dev. of O-B Between Experiments



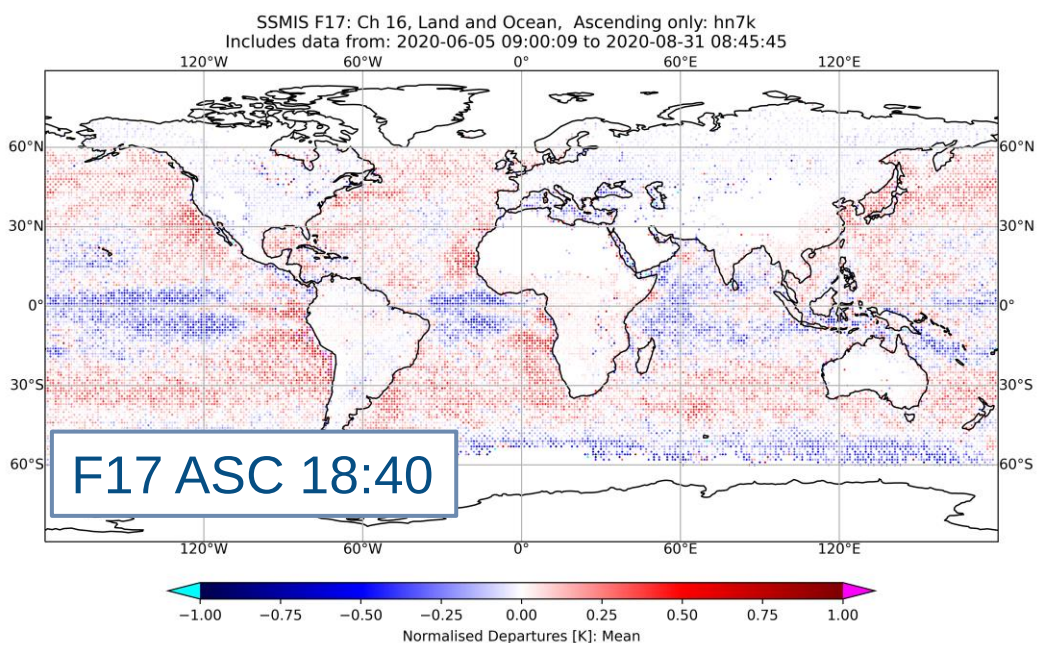


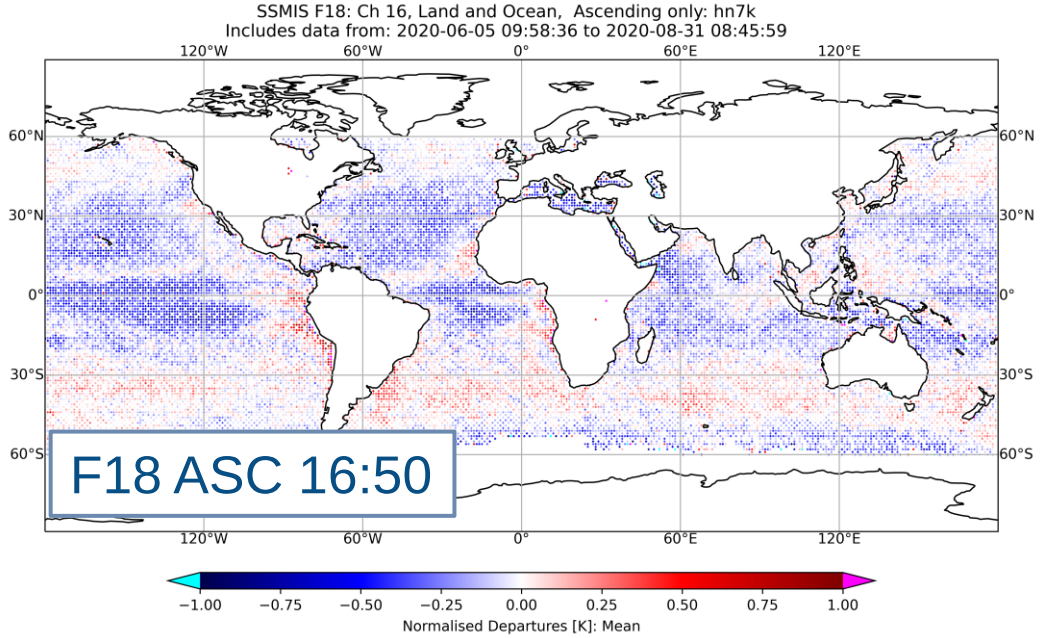


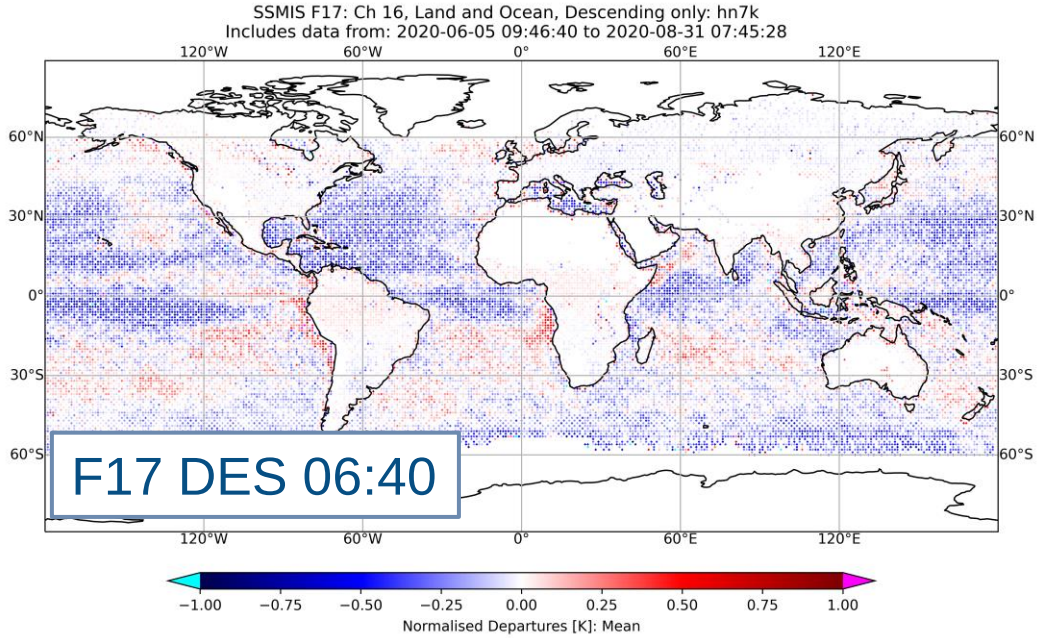
- In channel 16 (37.0 GHz V), we see large differences in the standard deviation of the departures.
- Partly due to the difference in the sample (F17 is used over land and ocean, whereas F18 is only used over ocean).

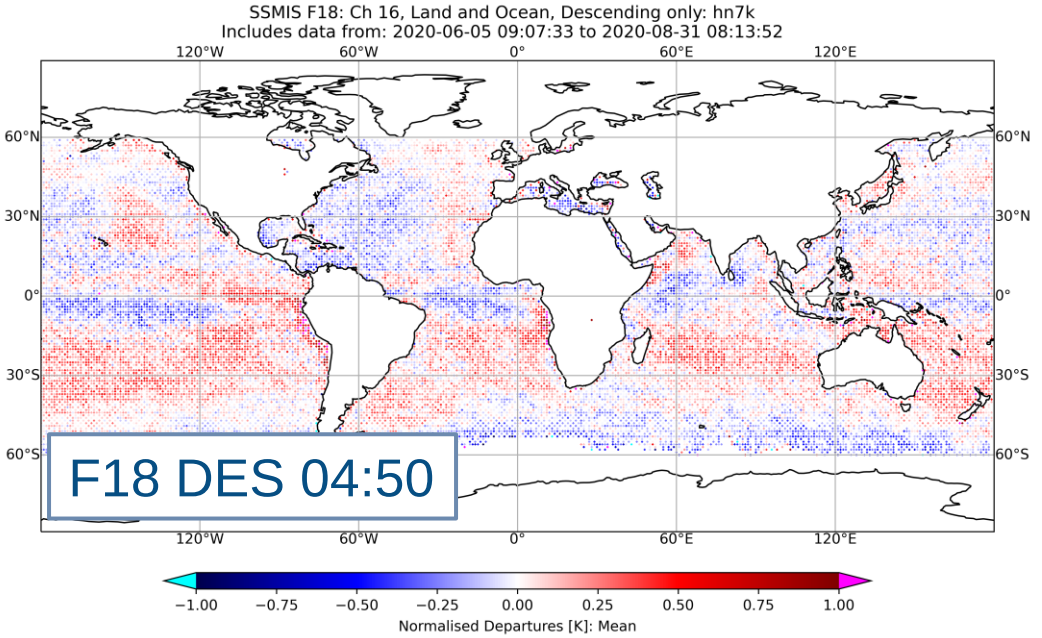
Differences in the standard deviation of O-B between experiments (with and without SSMIS on-board F18). From left to right: both seasons, NH summer (JJA), NH winter (DJF).

Ascending / Descending Differences – NH Summer (JJA)



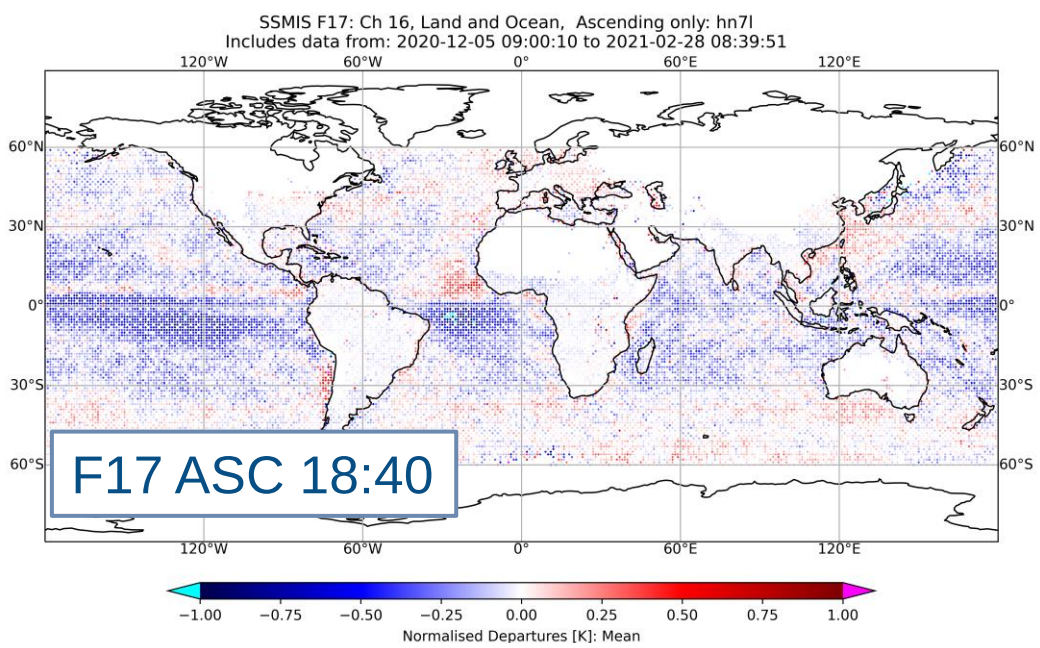


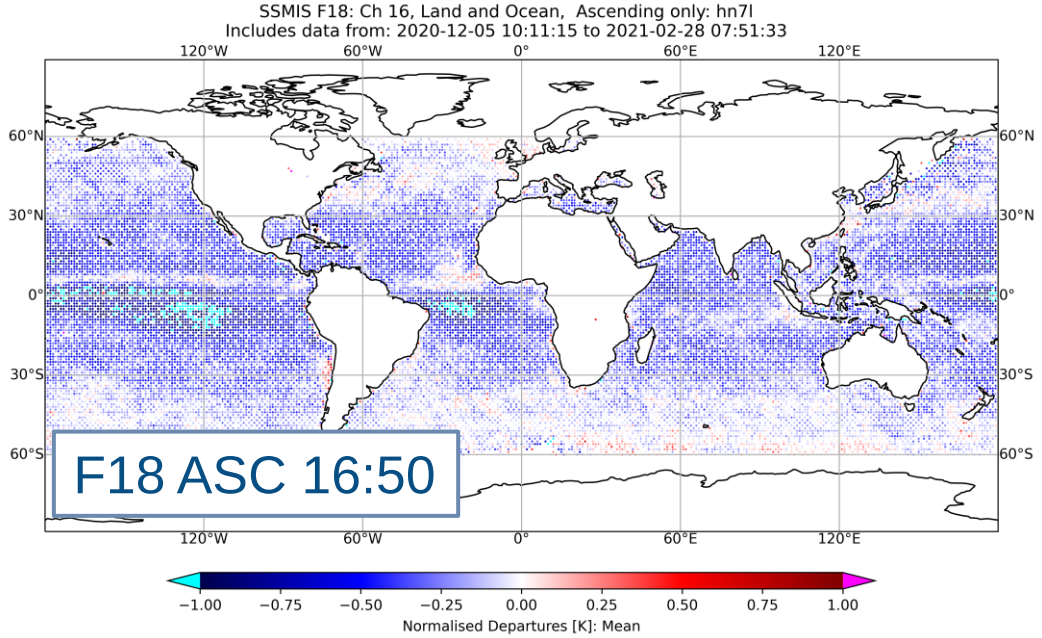


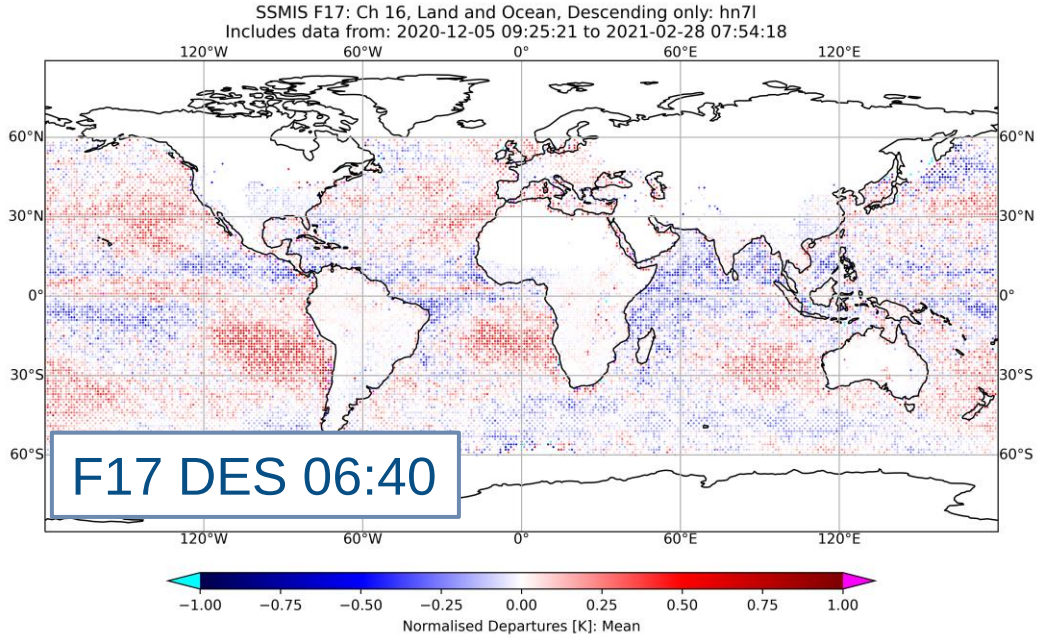


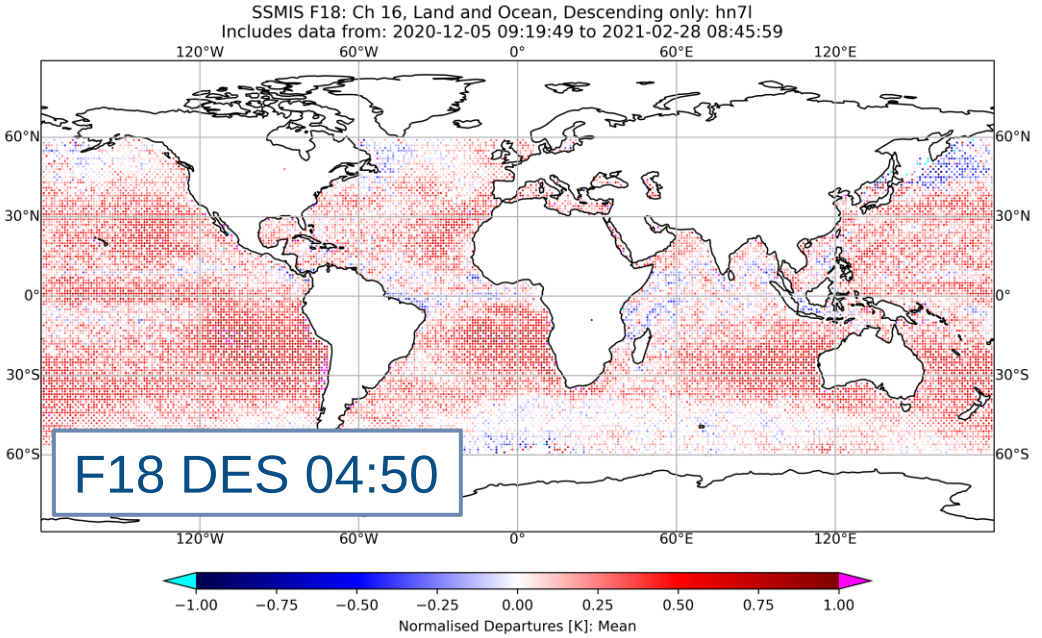
Normalised departures for SSMIS F17 and F18 for different orbital nodes - JJA

Ascending / Descending Differences – NH Winter (DJF)



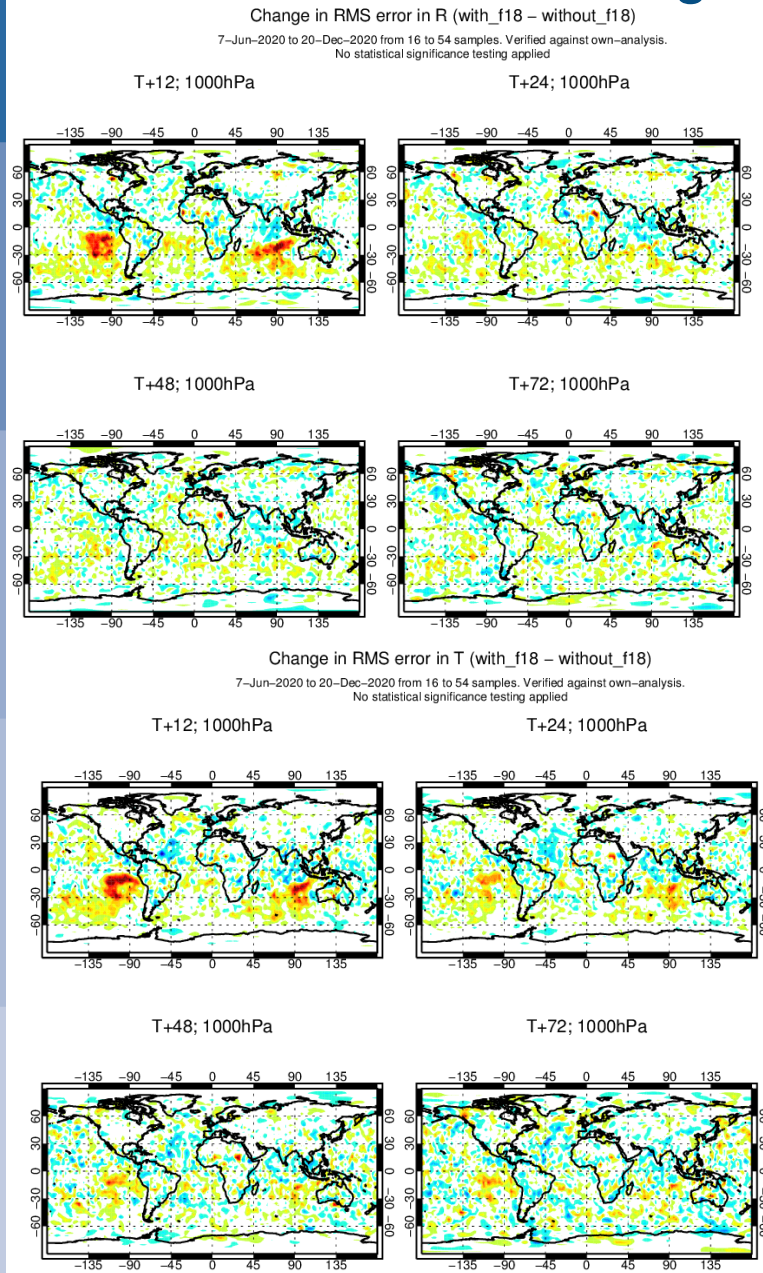






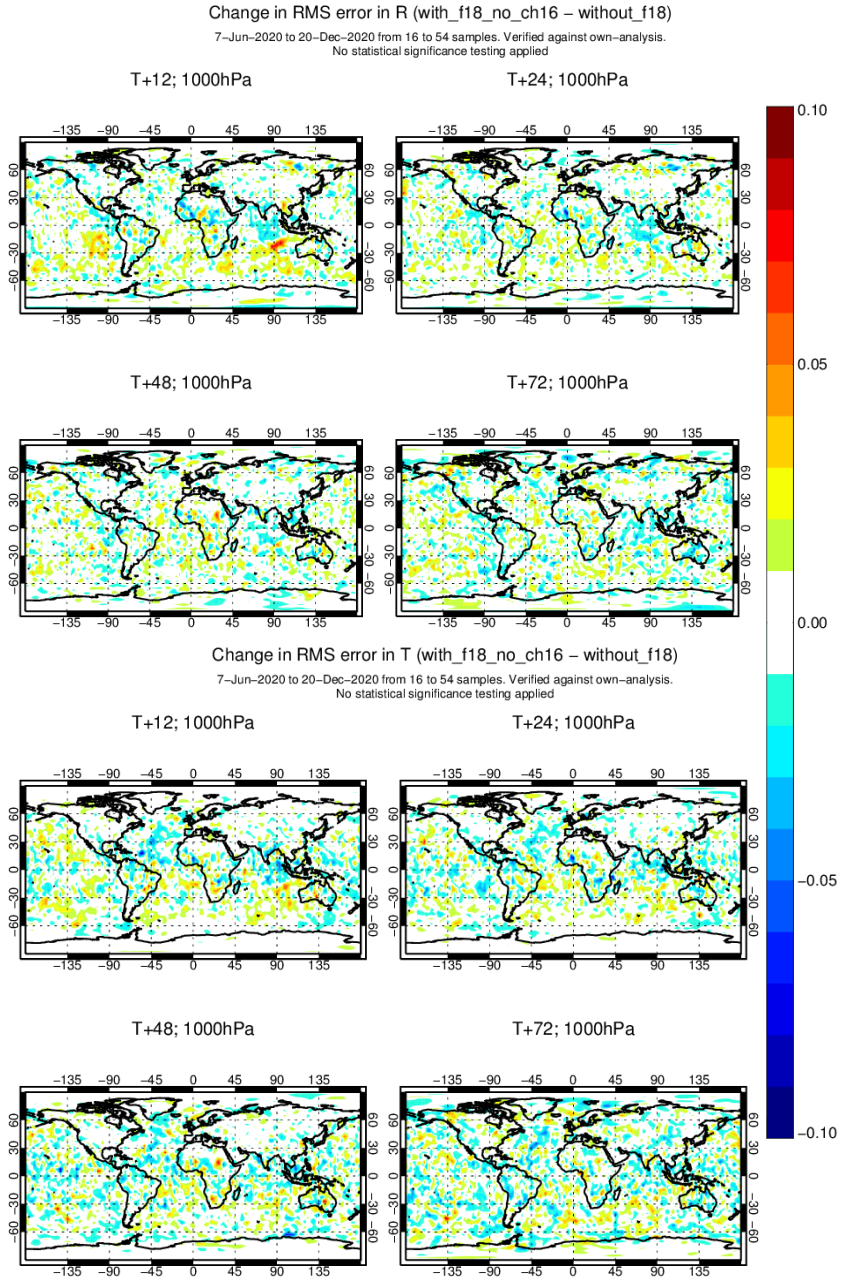
Normalised departures for SSMIS F17 and F18 for different orbital nodes - DJF

Removing the SSMIS F18 37.0 GHz Channel (Ch. 16)



- Experiment run without 37.0 GHz V (channel 16) included.
- Only 20 days through, but so far indicate it could be related to these observations (for all metrics).

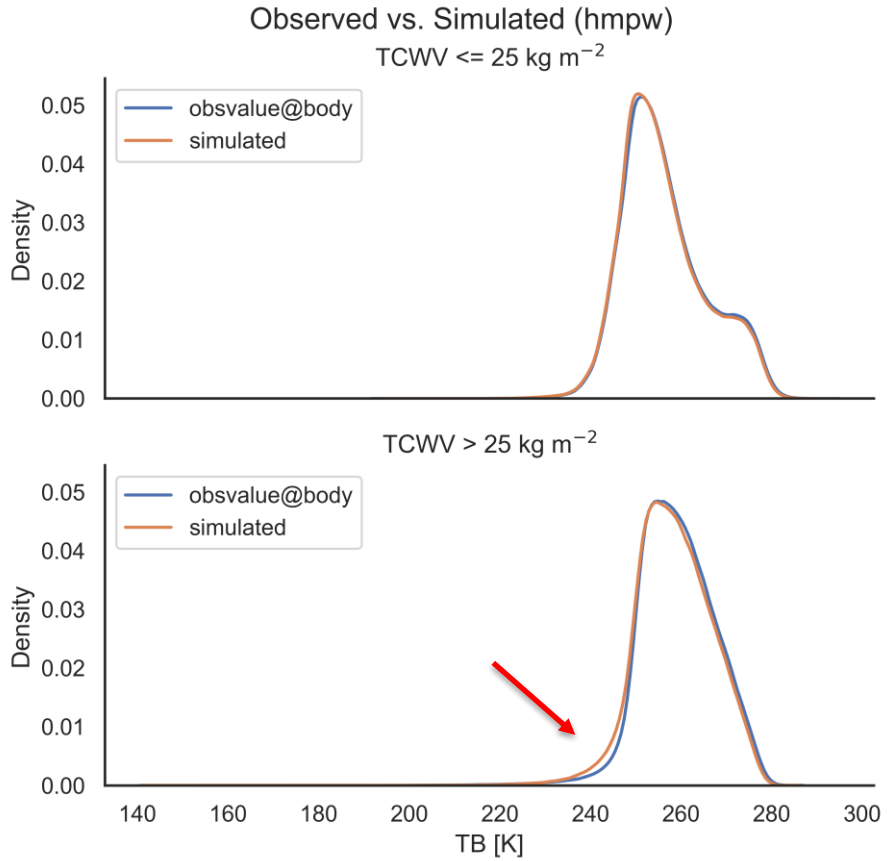
Without SSMIS F18 37.0 GHz V (Channel 16)



RMS error between the forecast with and without SSMIS F18 for R and T (left) and the same experiment excluding data from SSMIS F18 37.0 GHz V (Channel 16) (right).

Increasing Cloud Fraction in Convective Situations

- Currently, deep convective scattering signal in the tropics is underestimated in the observation operator (RTTOV-SCATT).
- This results in positive departures in areas where convective cloud is present.
- Work is underway to increase the cloud fraction in these areas (currently set to a constant of 5%).
- The new model linearly increases the cloud fraction from the bottom to the top of anvil clouds.



Density plots of the observed versus simulated (from the observation operator) brightness temperatures for the control experiment for SSMIS Channel 10 (183.31 ± 3.0 GHz H), split between total column water vapour below (top) and above (bottom) 25 kg m^{-2}. Red arrow shows the area targeted by the cloud fraction experiment.

Summary and Future Plans

- Inclusion of SSMIS-F18 into the IFS:
  - The use of SSMIS-F18 data has had a mostly positive effect.
  - Some questions remain around the apparent ascending / descending biases.
  - Experiments ongoing on excluding data to determine if this is related to the differences in the forecasts.
  - Would prefer to use channel 16 (37.0 GHz V) and the first four hours of data, therefore need to determine what is causing differences in the forecast.
- Improving representation of convective situations:
  - Experiments are ongoing to test a cloud fraction model within RTTOV-SCATT.
  - Experiments are also underway increasing the range of liquid water content and temperature in the hydrotables used in RTTOV-SCATT.

Questions?