Assimilate AMSR2 Brightness Temperature Data in All-sky Conditions with GEOS-5

Jianjun Jin, Min-Jeong Kim, Will McCarty (GMAO, GSFC, NASA)
Kevin Garrett, Erin Jones (JCSDA)

Acknowledgements to Yanqiu Zhu and Emily Liu (EMC, NOAA)

14th JCSDA Technical Review Meeting & Science Workshop on Satellite Data Assimilation
May 31-June 2, 2016

Introduction

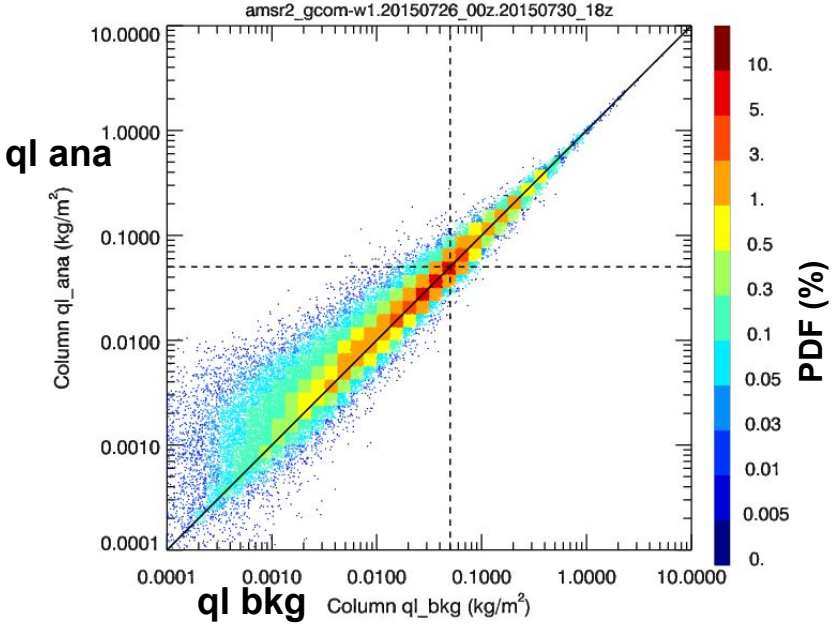
- GMAO plans to assimilate AMSR2 brightness temperature data for atmospheric analysis (this talk) and sea surface temperature analysis.
- GEOS-5 atmospheric data assimilation system
  - Ensemble - Variational hybrid atmospheric data system
    - Half of background error is estimated with 32 ensemble members and the other half of the background error is made from climatological statistics using the NMC method.
  - Add four hydrometeors, liquid cloud (ql), ice cloud (qi), rain-water (qr), and snow water (qs) as clouds control variables in **all-sky assimilation**.
  - CRTM version 2.2.3
- In this talk
  - The static background error for clouds in a hybrid system.
  - Clouds identification, used for quality control, observation bias correction, and assigning observation error in all-sky radiance data assimilation.
  - Some procedures for assimilating AMSR2 Tb data in all-sky conditions.

Static Background Error For Clouds

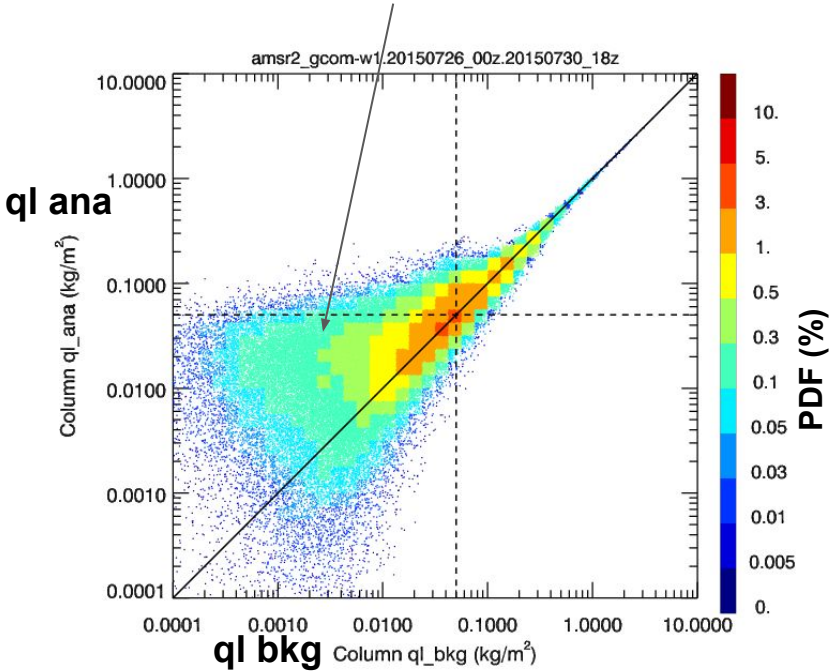
- New **CWOPTION(=3)**, "Cloud water error variance is designed to be large where cloud already exists, thus reducing spurious cloud increments" (**Yanqiu Zhu, EMC**)
- In GSI, the static background error is 5 % of clouds (cw = liquid + ice in EMC's GFS)

Old configuration: Without Y. ZHU's new CWOPTION.

Climatological static background error cause too much more clouds in analysis than in forecast.



GEOS-5 analyzed (ana) ql vs forecasted (bkg) ql bkg in a hybrid run.

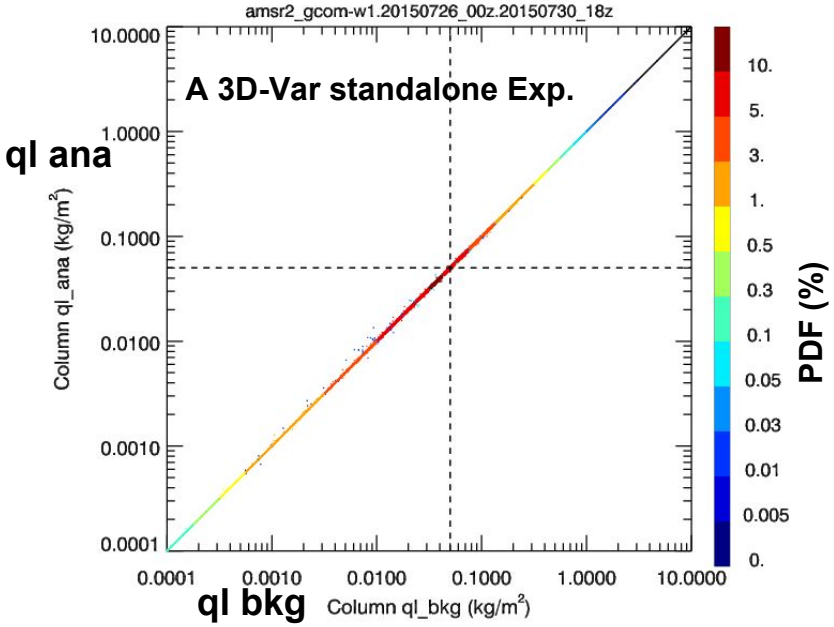


GEOS-5 analyzed (ana) ql vs forecasted (bkg) ql in a hybrid run.

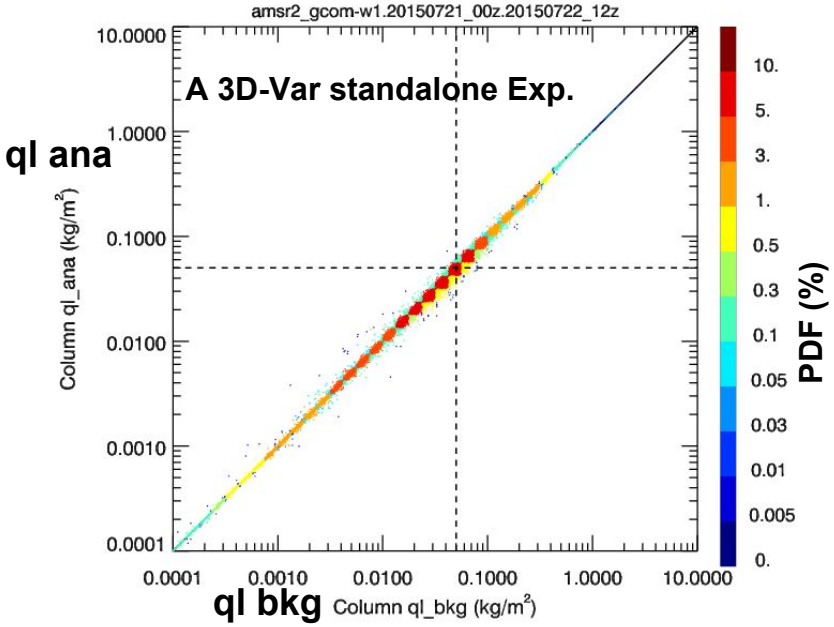
Static Background Error For Clouds

- No error is taken from ensemble forecasts.
- Clouds' background error variances are only 5 % of the amount of the hydrometeors.
- It contributes little in GEOS-5 ADAS.

- The same as left (but, it is 1-day Exp). Clouds' background error variances are 25 % of the amount of the hydrometeors, which gives more freedom for analysis. Use this 25%, for static background error contribution in this talk.



GEOS-5 analyzed (ana) ql vs forecasted (bkg) ql in a 5-day standalone run.



GEOS-5 analyzed (ana) ql vs forecasted (bkg) ql in a 1-day standalone run.

How to Identify Clouds?

- In GMAO's early developments on assimilating GMI in all-sky conditions, we follow ECMWF, using an index C37 to identify clouds with observed and forecasted brightness temperature data (Tb).
- The index uses Tb polarization differences between 37V GHz and 37H GHz. The thicker the clouds, the smaller the Tb difference Tb(37V) - Tb (37H).

$$P37 = \frac{T^v - T^h}{T^v_{clr} - T^h_{clr}} \simeq \tau^2_{37}.$$

Square of transmittance at 37 GHz

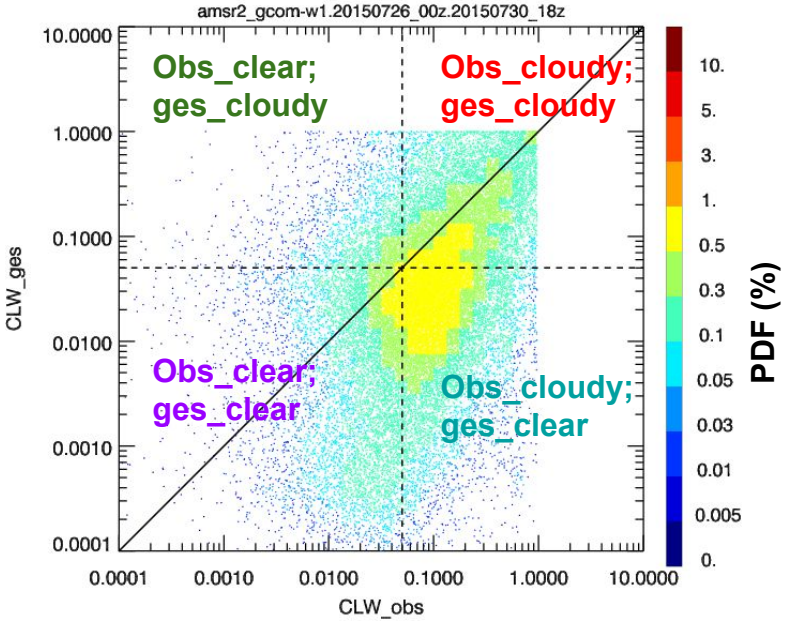
$$C37 = 1 - P37$$

C37, proportional to cloud amount.
0, no clouds
1, extremely thick clouds.

(Geer, et al., 2010)

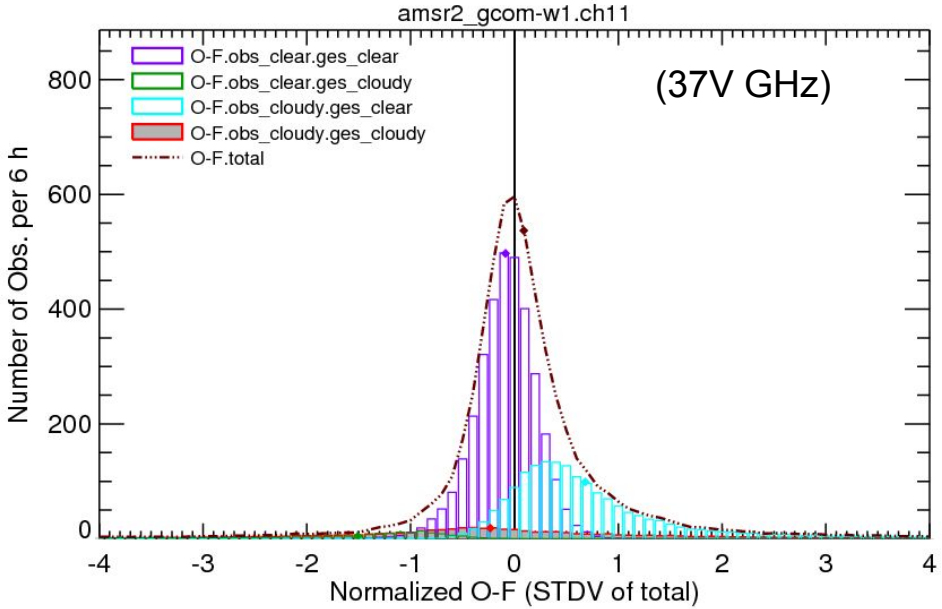
How to Identify Clouds? --- Use Cloud Index C37

- **Assign observations and forecasts to different categories in order to make BIAS CORRECTION and assign OBSERVATION ERROR.**



CLW obs (X-axis(vs CLW_ges (Y-axis). Dashed lines are 0.05 (C37)

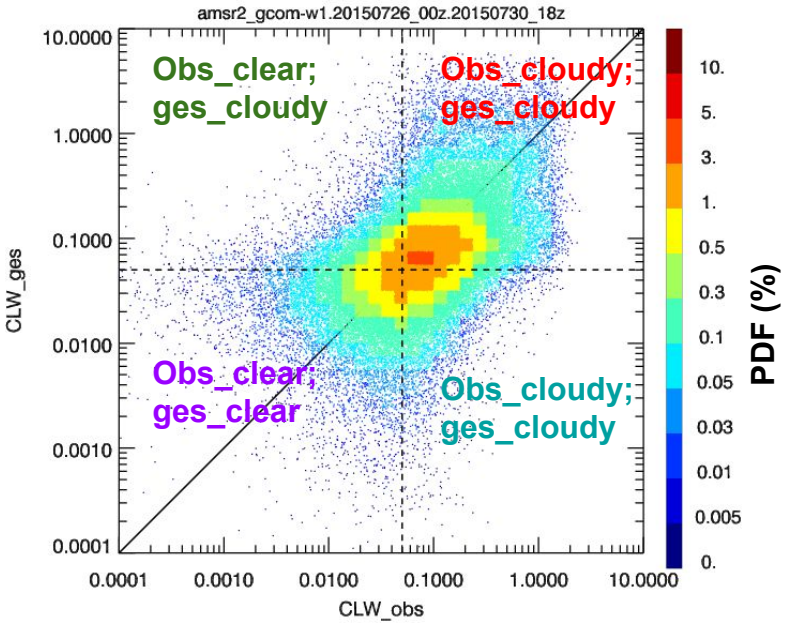
O-F after BC and QC



- **Not able to identify clouds in guess (background) results in smaller observations error is assigned to cloudy observations.**

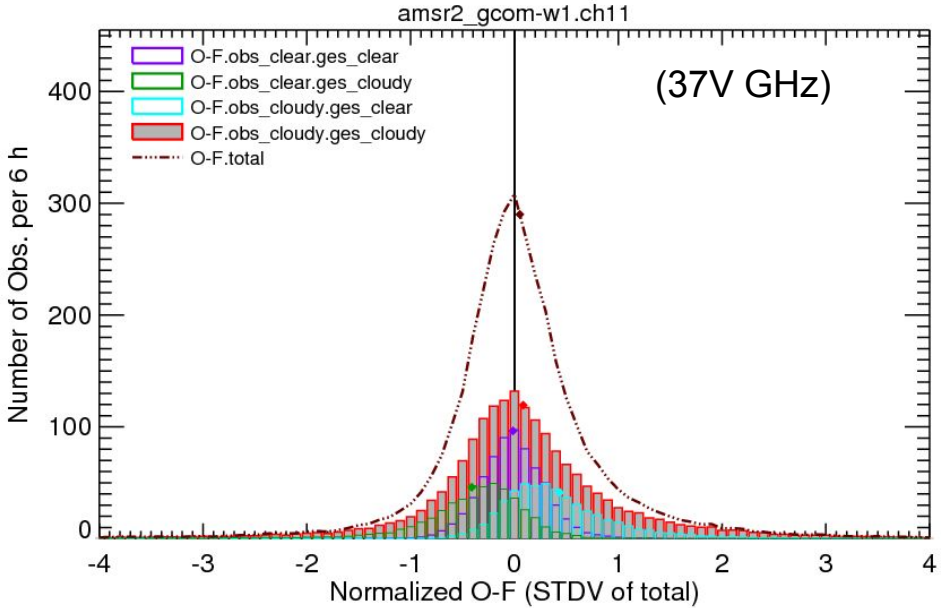
How to Identify Clouds? --- Use a retrieval algorithm

- Use the retrieval algorithm developed by K. Garrett for AMSR2.
- Observed clouds are retrieved from observed Tb.
- Guess clouds are retrieved from forecasted Tb by CRTM with inputs from GEOS-5 profiles including clouds.



CLW obs (X-axis) vs CLW_ges (Y-axis). Dashed lines are 0.05 kg/m^2

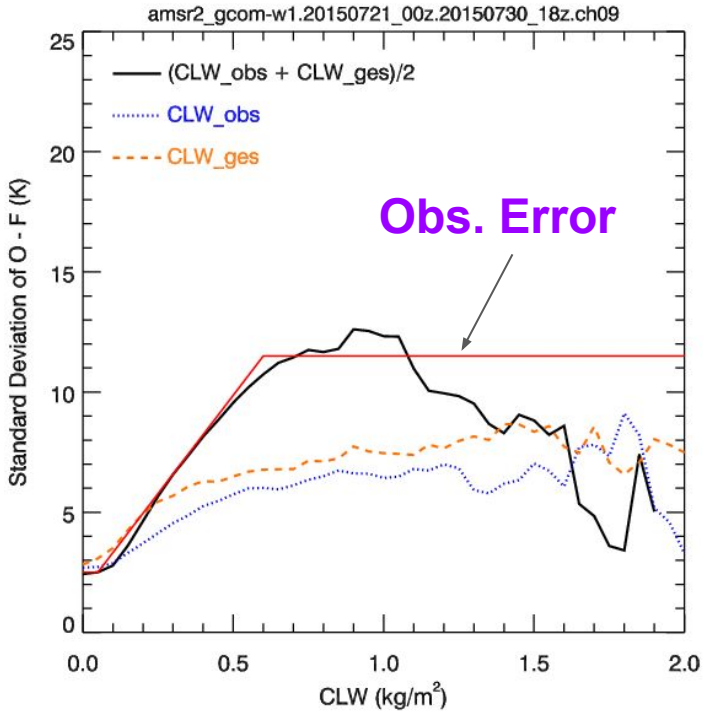
O-F after BC and QC



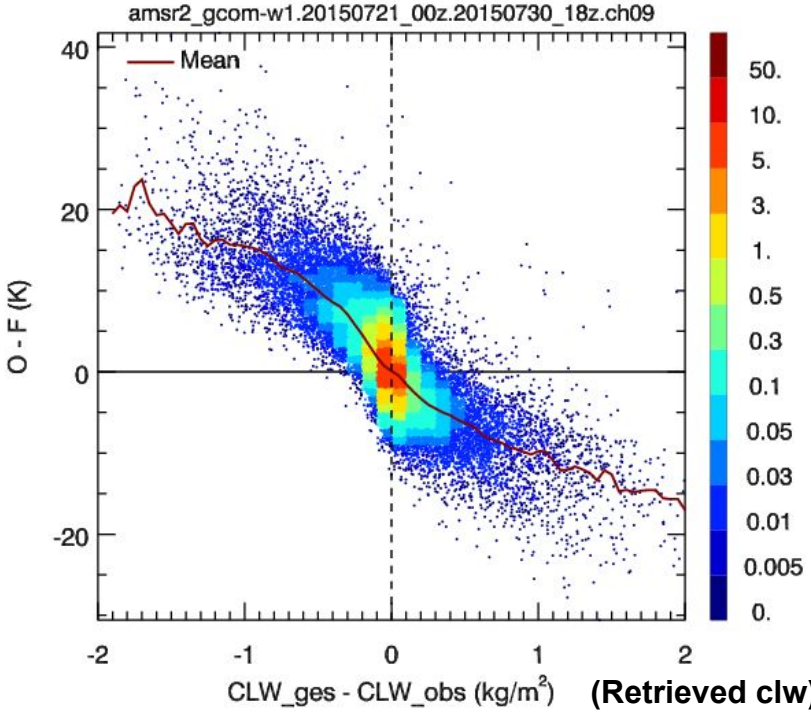
This gives nearly symmetric mis-matched cloudy cases and identify more data with clouds in both observations and forecast.

Observation Error as a Function of Symmetric Clouds

STDV of O-F vs cloud amount



O-F vs (CLW_ges - CLW_obs)



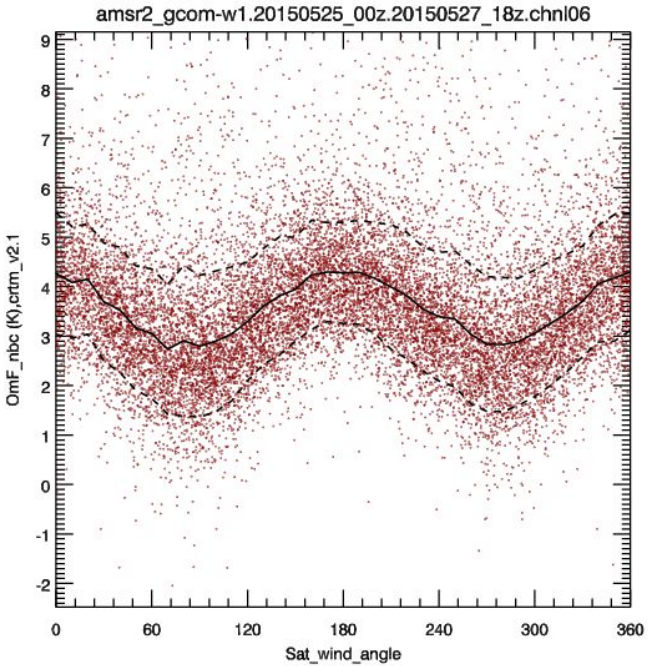
(Retrieved clw)

JUST concerns: (1), Observations can be assigned smaller observation errors for mis-matched cases than matched cloudy-cloudy cases. (2) Observation error is always large for cloudy-cloudy cases even the STDV of O-F is not. As a result, cloudy observations are given a small weight when model has matched clouds.

A Praise to CRTM's Update on Water's Emissivity.

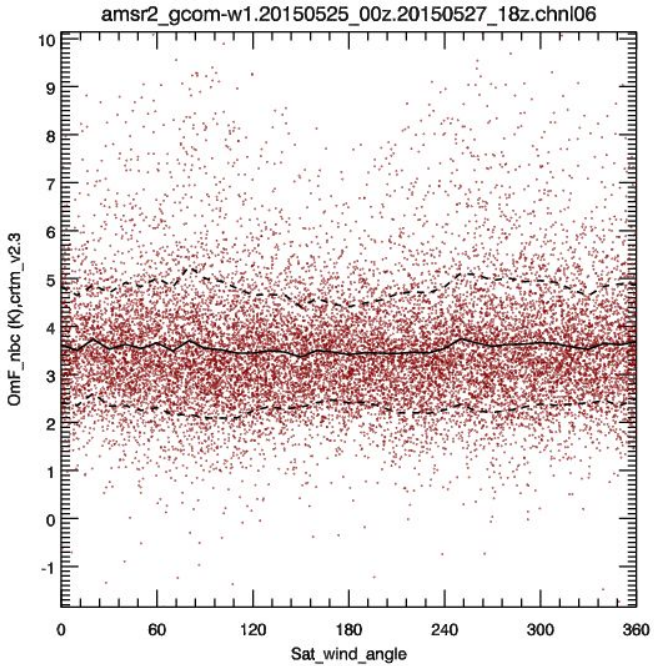
CRTM(v2.1)

O-F, Ch6
10HGHz



CRTM (v2.2, FSTEM 5/6)

O-F, Ch6
10HGHz



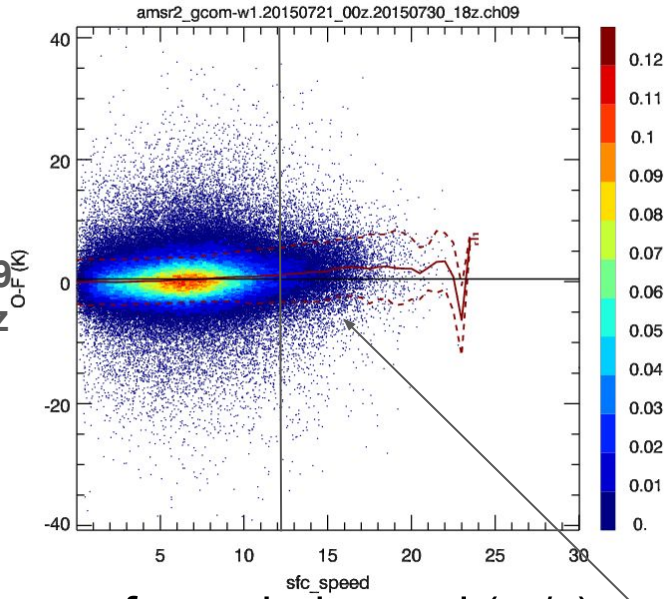
X-axis: Angle between wind direction and satellite azimuth angle

Note: In order to reduce bias, satellite azimuth angles should be correctly read in or calculated by GSI in the implementation of satellite data.

AMSR2 Data Quality Control: Examples

O-F vs surface wind speed

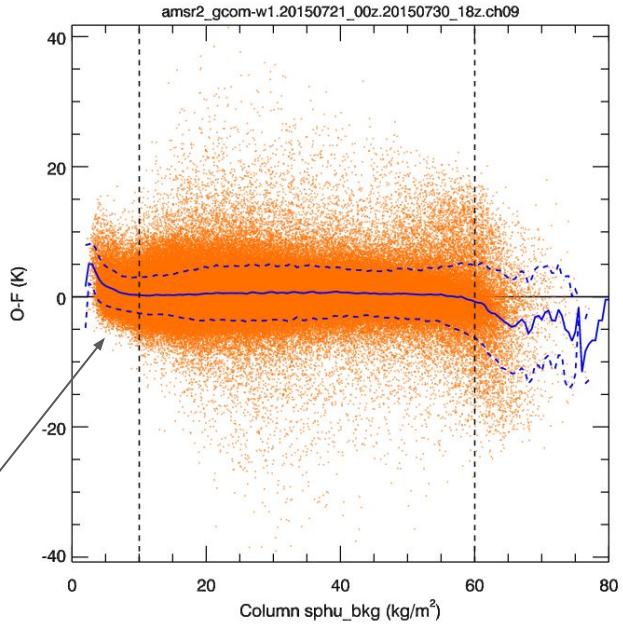
O-F, Ch9
23V GHz



surface wind speed (m/s)

O-F vs model column water vapor

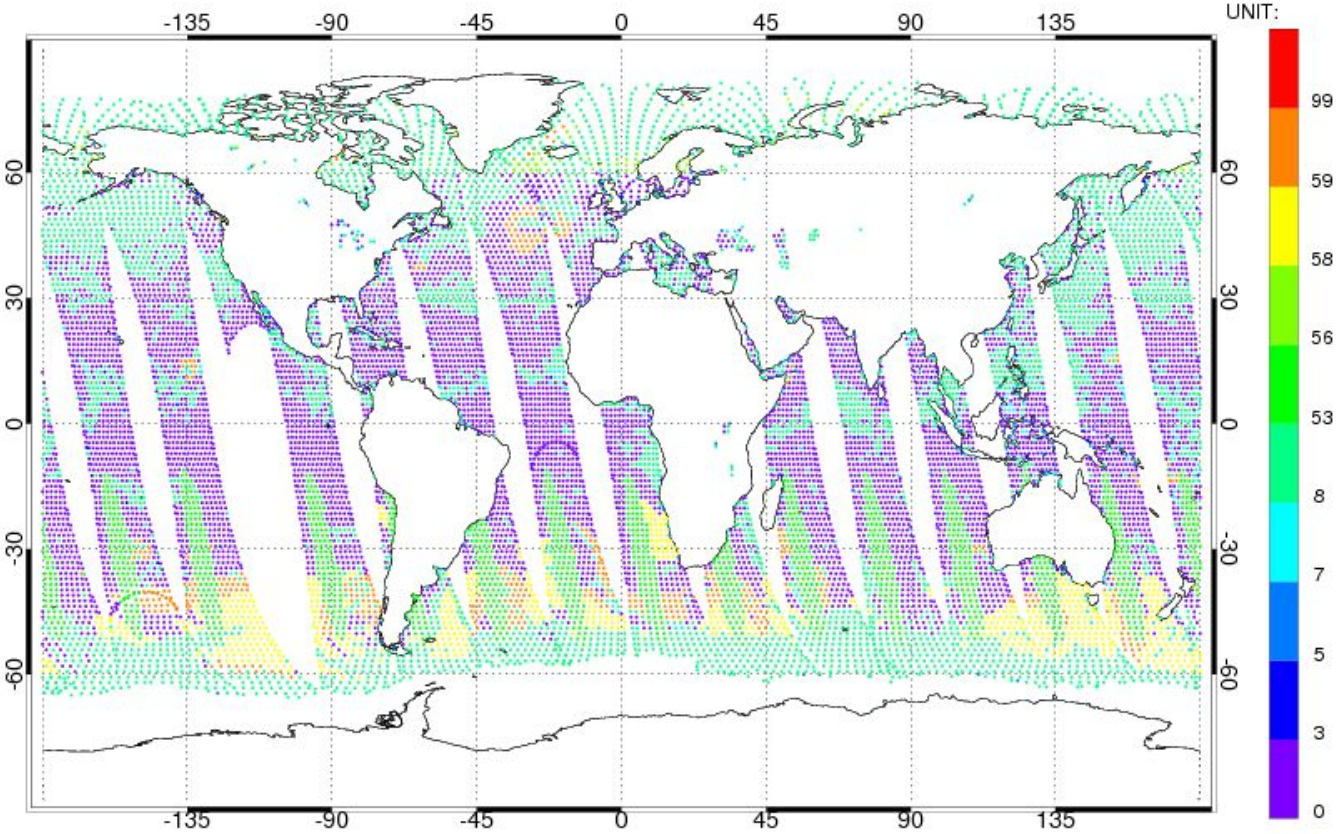
O-F, Ch9
23H GHz



Column water vapor (kg/m^2)

Observations not pass QC

QC Flag Over Water Surface



99, is NOT a QC flag.

59, surface wind speed > 12 m/s

58, model tqv < 15 kg/m^2

56, polar-ward of 60º N/S.

53, sun glint angle < 25º

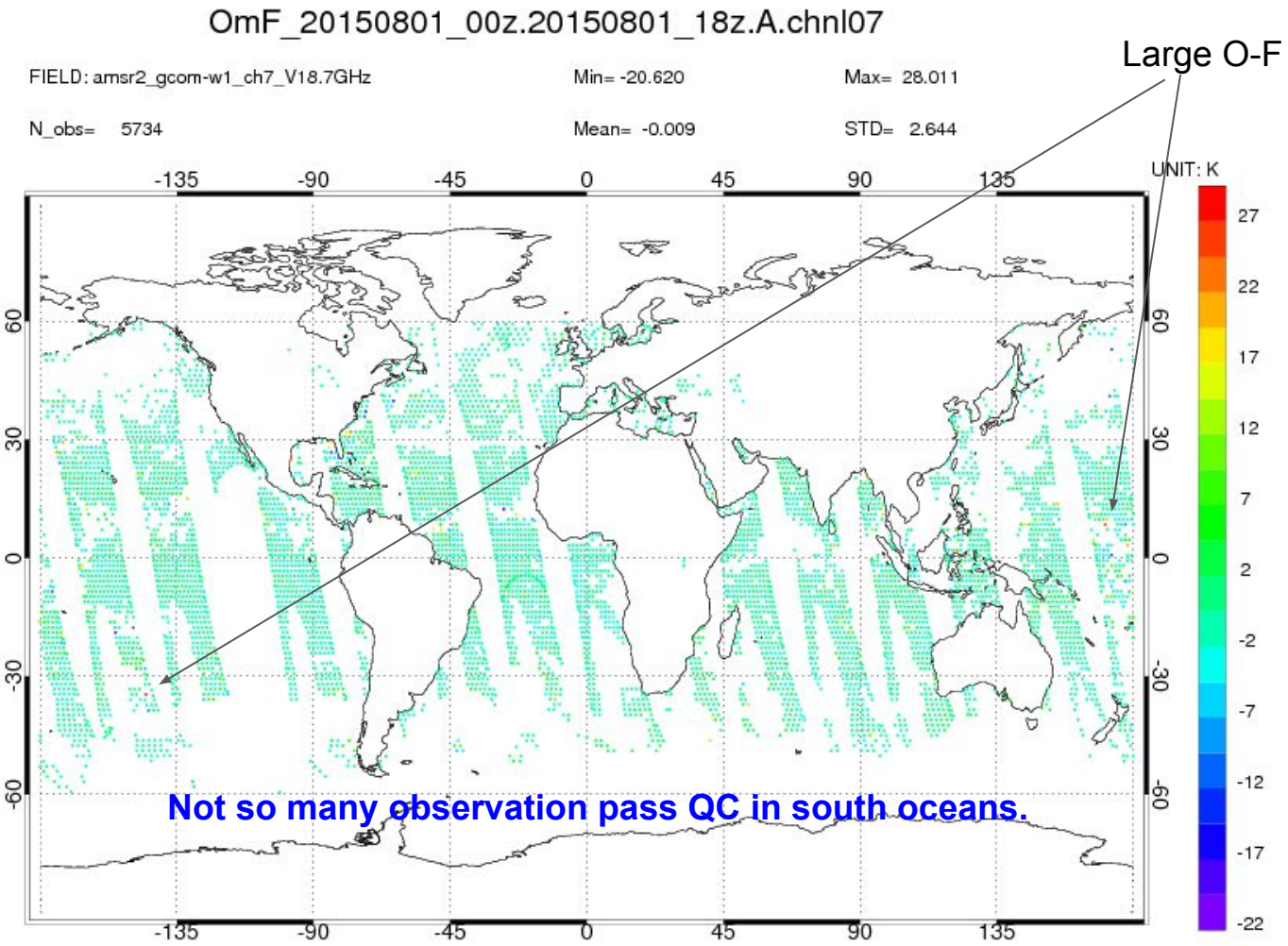
8, emissivity check or **cold SST (< 275 K).**

7, clouds > 2 kg/m^2

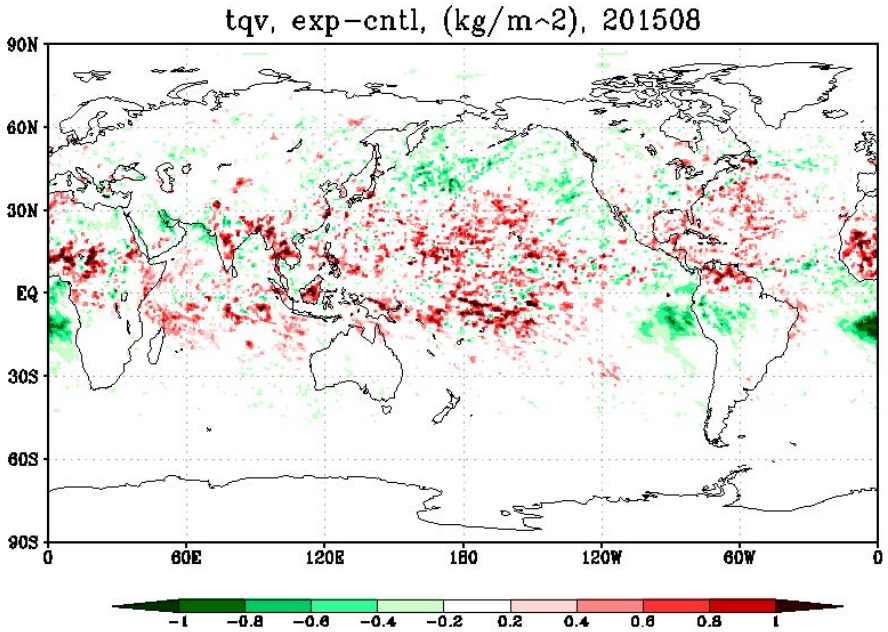
5, surfac type check

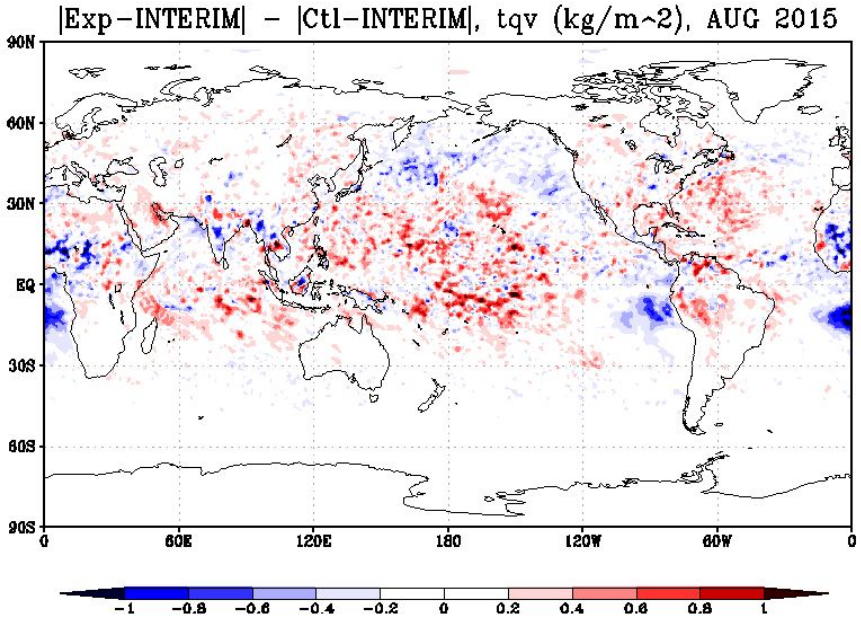
3, gross erros

0, pass QC


OmF_20150801_00z.20150801_18z.A.chnl07
FIELD: amsr2_gcom-w1_ch7_V18.7GHz
Min= -20.620
Max= 28.011
N_obs= 5734
Mean= -0.009
STD= 2.644
Large O-F
UNIT: K
27
22
17
12
7
2
-2
-7
-12
-17
-22
-135
-90
-45
0
45
90
135
60
30
0
-30
-60
Not so many observation pass QC in south oceans.

Results: Column Water Vapor



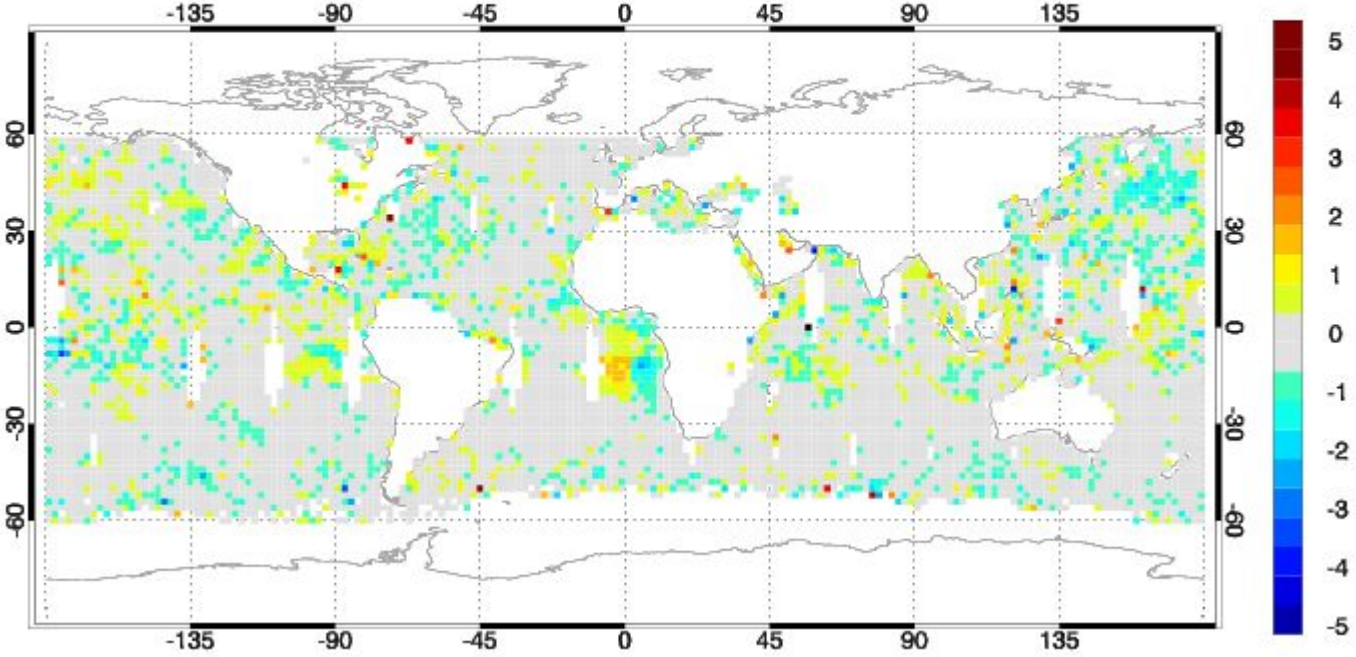


Blue, EXP is closer to INTERIM; **Red, control is closer to INTERIM**

Control: Ensemble - Variational hybrid run in CLEAR conditions.
Exp: Ensemble - Variational hybrid run in ALL-SKY conditions.
Note, both control and experiment are made for a 26-day period.

Compare EXP and Control tqv with Remote Sensing System (RSS) 's AMSR2 tqv retrievals in Aug 2015.

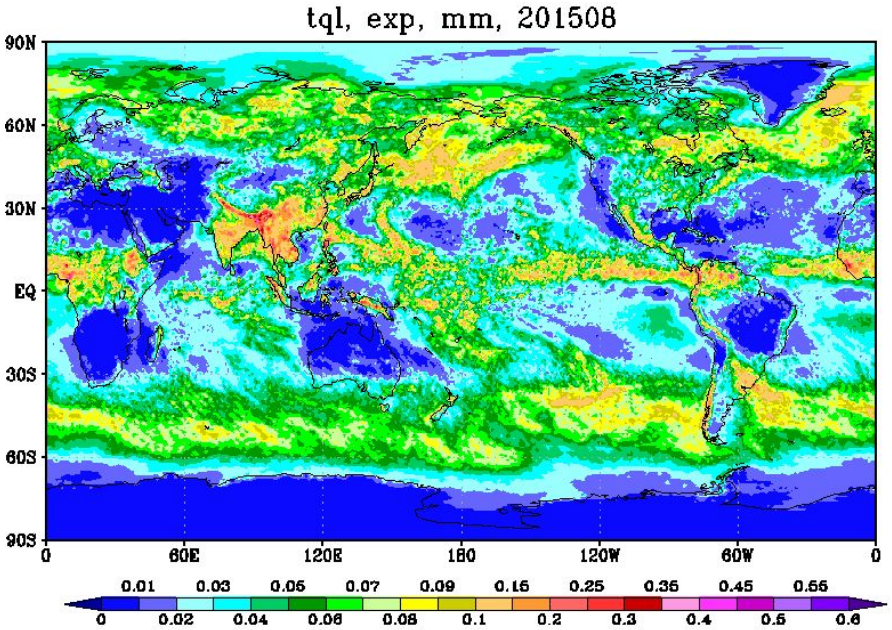
Absolute difference in tqv: |Exp - RSS| - |Control - RSS|

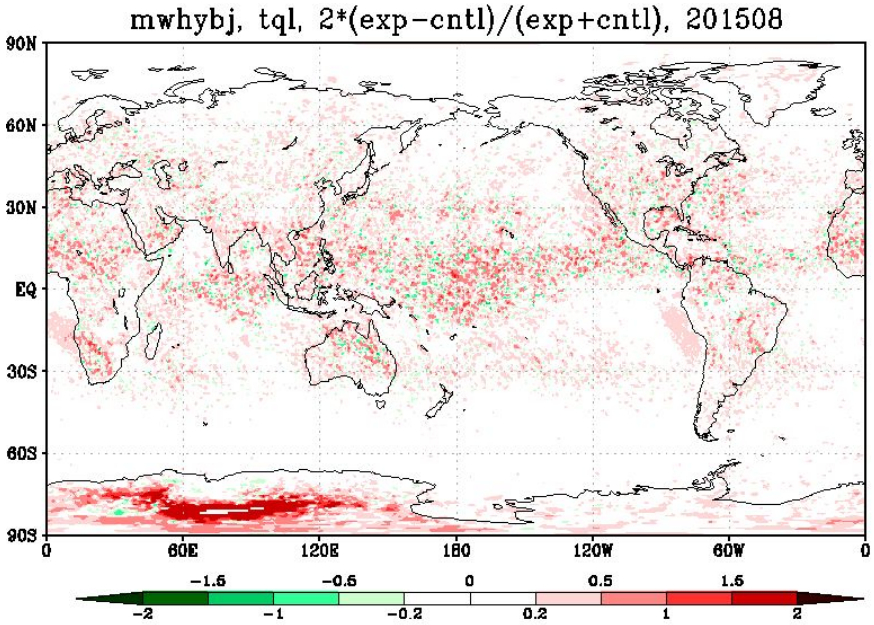


Red, Control is closer to EC_OPS

Blue, EXP is closer to EC_OPS

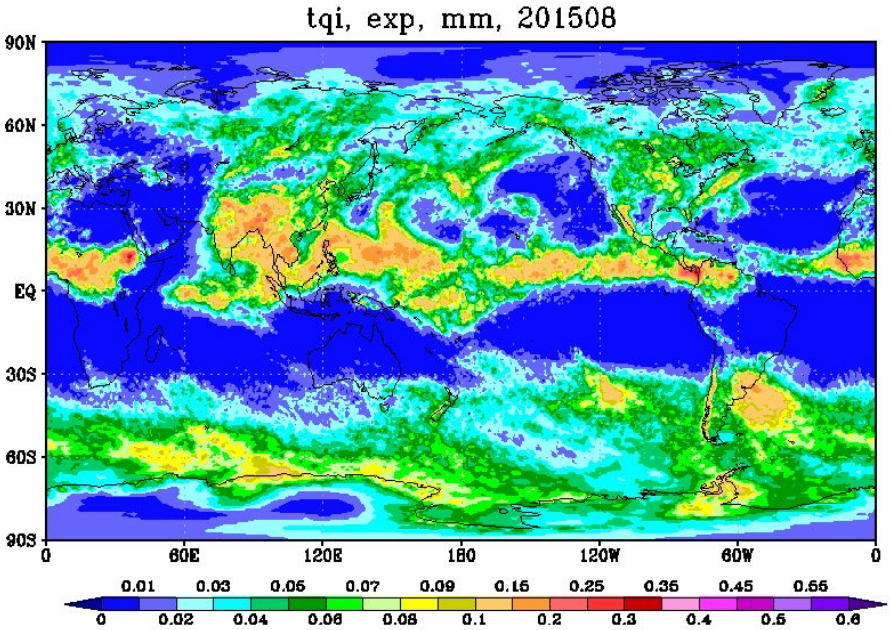
Column ql: Analysis and Relative Difference Compared to Control

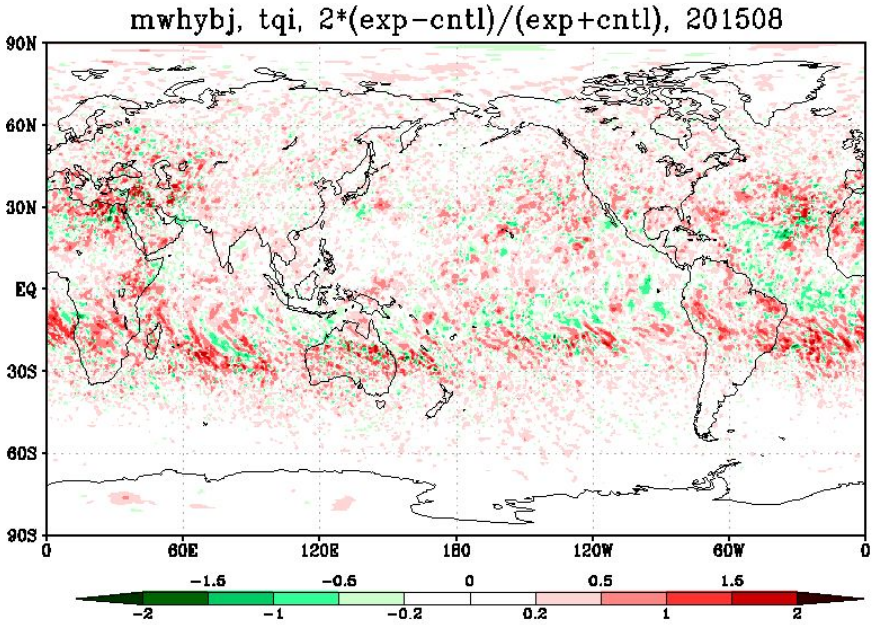




- More ql in analysis after AMSR2 data is assimilated in all-sky conditions.

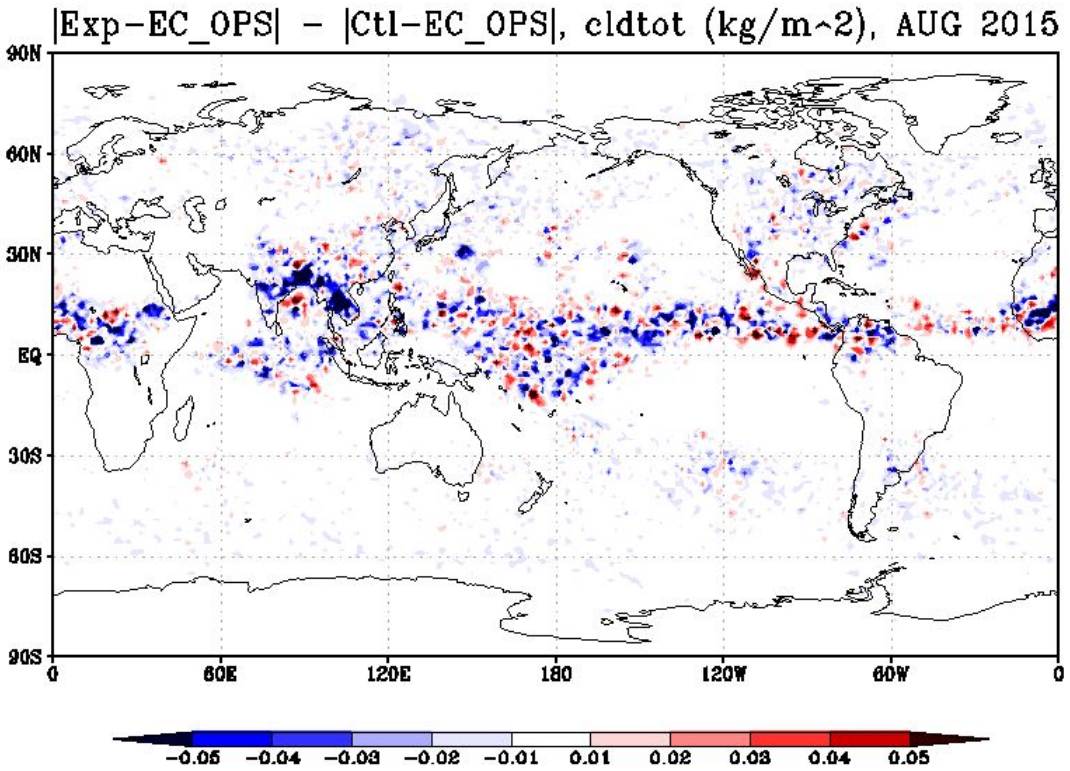
Column qi: Analysis and Relative Difference Compared to Control





- More qi in analysis after AMSR2 data is assimilated in all-sky conditions.

Compared With EC_OPS's Total Column Clouds

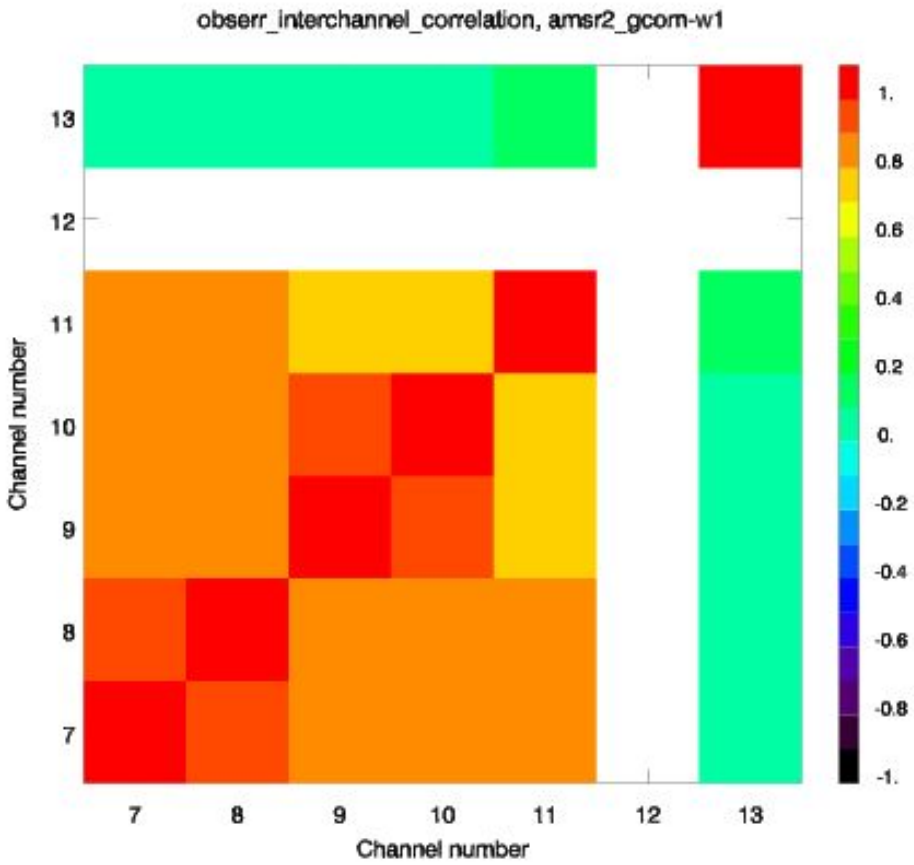


Blue, EXP is closer to EC_OPS

Red, control is closer to EC_OPS

- Total clouds' amounts are closer to EC_OPS in analysis after AMSR2 data is assimilated in all-sky conditions.

Inter-channel Correlation of Observation Error.



- There are large correlations among channels 7 - 11.
- Made with the Desroziers et al. (2005) method.

On-going and Future Work

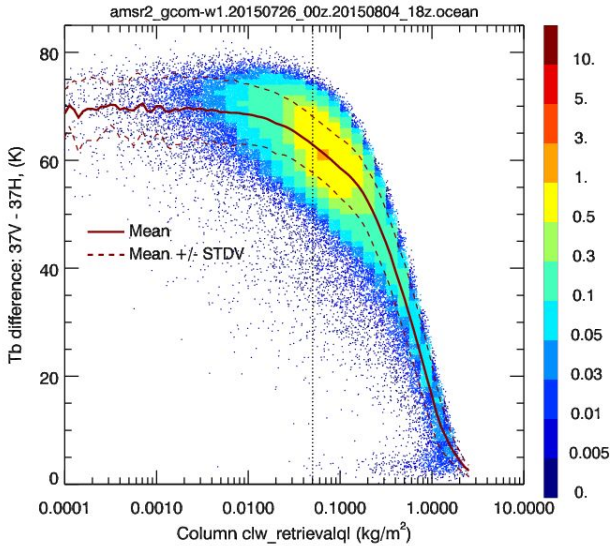
- AMSR2 data can improve GEOS-5 clouds analysis, and seems to have an neutral impact on tqv. (NO forecast skills check yet.)
- We are testing an option that replace the static background variance with variance from ensemble members for clouds.
- Need another look at assigning observation error in all-sky DA.
- How to assess the impact? How can it help forecast model's microphysics developments?
- Consider inter-channel correlations in observations errors.

Thank you!

Polarization Difference at 37 GHz in CRTM

Cyan: forecast w/o clouds

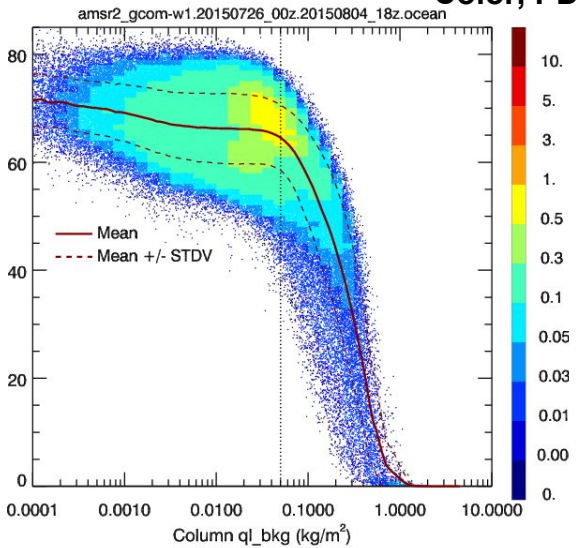
Y, Obs Tb_diff



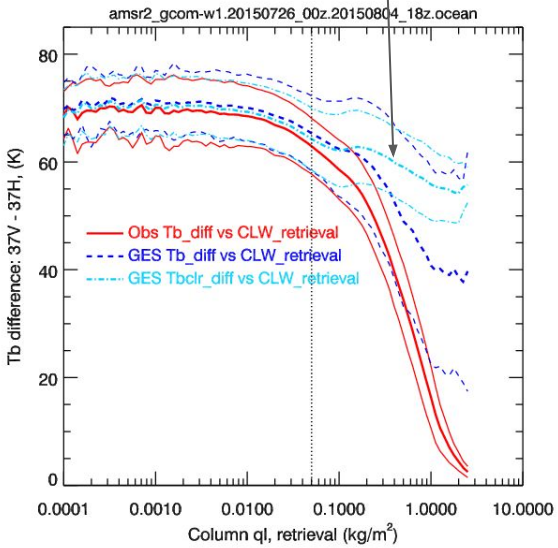
Retrieved clw

Y, Forecasted Tb_diff

Color, PDF



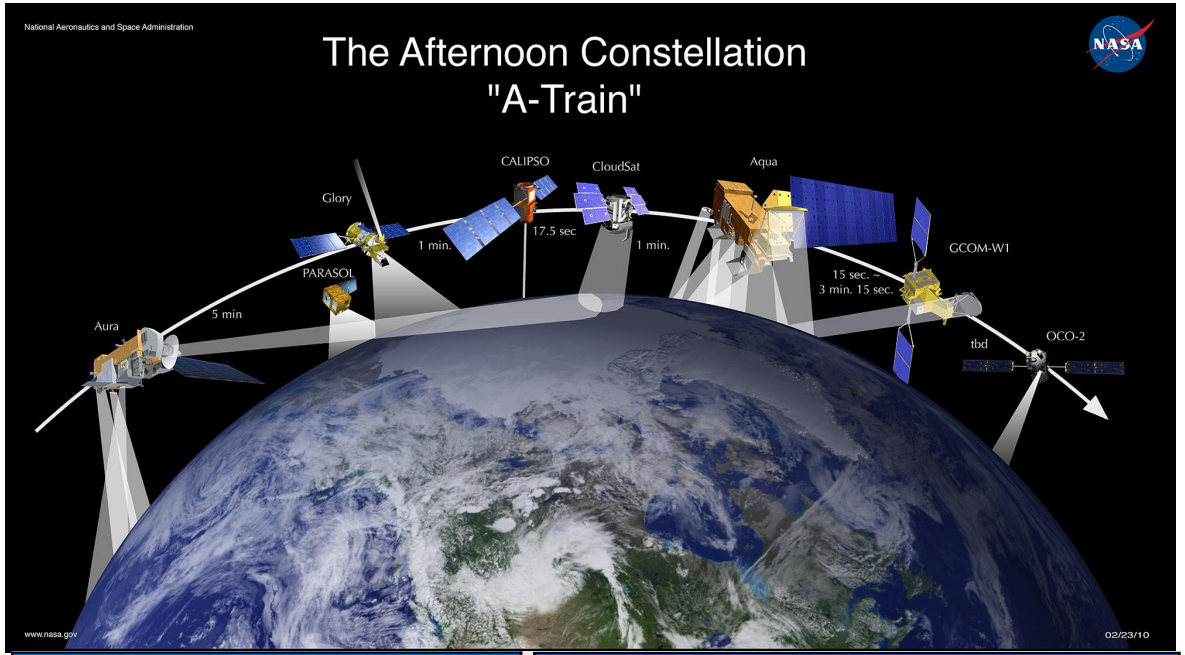
Forecasted ql



Retrieved or forecasted ql

- Retrievals are made using K. Garrett's retrieval algorithm implemented in GSI.
- Forecast is good in clear-sky: The polarization difference Tb37V - Tb37H follows the differences in observations when cloud amount is smaller.
- Issue in all-sky:
  - Model has less (thick) ql clouds than retrievals. Therefore, there are larger forecasted difference Tb37V - Tb37H, especially at locations where observations see thick clouds.
  - This (skrewed PDF in previous slide) can lead to: (1) more observation used for BC in "clear-clear" conditions; (2), smaller observation error are assigned to observation.

AMSR2 / GCOM-W1



- Launched in 2012
- Part of A-Train satellite constellation
- Lower frequency channels (ch1 - 6) good for sea surface temperature (SST) and heavy rain monitoring/retrievals.
- Ch 7 - 14 good for cloud and rain detection.
- We are going to assimilate its brightness temperature for SST and atmospheric analysis.

GCOM-W1/AMSR2 characteristics	
Scan and rate	Conical scan at 40 rpm
Antenna	Offset parabola with 2.0m dia.
Swath width	1450km
Incidence angle	Nominal 55 degrees
Digitization	12bits
Dynamic range	2.7-340K
Polarization	Vertical and horizontal

AMSR2 Channel Set				
Center Freq. [GHz]	Band width [MHz]	Pol.	Beam width [deg] (Ground res. [km])	Sampling interval [km]
6.925/ 7.3	350	V and H	1.8 (35 x 62)	10
10.65	100		1.2 (24 x 42)	
18.7	200		0.65 (14 x 22)	
23.8	400		0.75 (15 x 26)	
36.5	1000		0.35 (7 x 12)	
89.0	3000		0.15 (3 x 5)	5

(Table's source, JAXA)