The Assimilation of *AMSU* and *SSM/I* Brightness Temperatures in Clear Skies at the Meteorological Service of Canada

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Outline

- Objectives / experiment descriptions
- AMSU vs. SSMI: comparison of quality control
- Motivation for enhanced filtering of AMSU data
- Experiment results
- Conclusions and Future Work

Data Assimilation at MSC – May 2005

- Current operational global analysis system:
  - GEM Global model: 0.9°, 28 levels, 10 hPa model top
  - 4D-Var (March 15, 2005)
  - Direct assimilation of satellite radiances:
    - GOES-W, GOES-E (water vapour channel)
    - NOAA15, NOAA16, AQUA AMSU-A Tb
      - CHs 3-10 ocean, 6-10 land
    - NOAA15, NOAA16, NOAA17 AMSU-B Tb
      - CHs 2-5 ocean, 3-4 land

Objectives

1. **Demonstrate the impact of assimilating SSM/I data**
2. **Implement stricter filtering of AMSU data and test**

- Experiment Setup
  - Period: July 1 - July 31, 2003
  - **Control**: 3D-Var, Global 0.9^{o} model, direct assim. of GOES-W, and NOAA15,16,17 AMSU-A & AMSU-B Tbs, plus conventional obs
  - **Experiment 1**: addition of SSM/I data over oceans in clear skies
  - **Experiment 2**: removal of AMSU-A CH3 and AMSU-B CH2, **&** reject AMSU-B CH3, 4, 5 over oceans where CH2 |O-FG| ≥ 5K **&** addition of SSM/I data
  - **Experiment 3**: removal of AMSU-A CH3, **&** reject AMSU-B CH2, 3, 4, 5 over oceans where CH2 |O-FG| ≥ 5K **&** addition of SSM/I data

Objectives

- Experiment Analysis
  - Evaluate monthly averaged analyzed fields using observations from AQUA AMSR-E (**Integrated Water Vapour - IWV**), QuikScat (**Surface Wind Speed - SWS**), GPCP (**Daily Precip. Rate - DPR**)
  - Validate 10-day forecasts using RAOBS and analyses
  - Verify QPFs over North America

Instrument Properties

AMSU

NOAA15, 16, & 17

Cross-track scanner

2200 km swath

830 km altitude

Channel	Frequency (GHz)	Nominal Res. at nadir (km)	Assimilation
AMSU-A 3	50.3 V	48	Ocean
AMSU-B 2	150.0 H	16.7	Ocean

↑ Data removed (EXP2,EXP3) ↑

↓ Data added (EXP1,EXP2,EXP3) ↓

SSMI

DMSP13, 14, & 15

Conical scanner

1400 km swath

830 km altitude

Channel	Frequency (GHz)	Nominal Res. at nadir (km)	Assimilation
1	19.35 V	25	Ocean
2	19.35 H	25	Ocean
3	22.235 V	25	Ocean
4	37.0 V	25	Ocean
5	37.0 H	25	Ocean
6	85.5 V	12.5	Ocean
7	85.5 H	12.5	Ocean

Operational Quality Control: AMSU vs. SSM/I

Filter	AMSU-A	AMSU-B	SSM/I
Bias Corrections	Harris & Kelly, 2001	Harris & Kelly, 2001	Harris & Kelly, 2001
	Predictors: 1000-300mb, 200-50mb GZ		
Land/Ice/Sea-ice	√	√	√
Gross TB check	√	√	√
Clear-sky filtering	Grody scattering index (>9) **Grody:** **CLW > 0.3 mm**	Bennartz scattering index (>15 over sea) **NO cloud filter**	Alishouse & Petty: IWV, Precip. Screen **F. Weng:** **CLW > 0.01 mm**
Background Check (O-FG)	$\sigma = 2$: CH 3	$\sigma = 2$: CH 2 $\sigma = 4$: CH 3,4,5	$\sigma = 2$: CH 1-7
Thinning	250 km	250 km	200 km

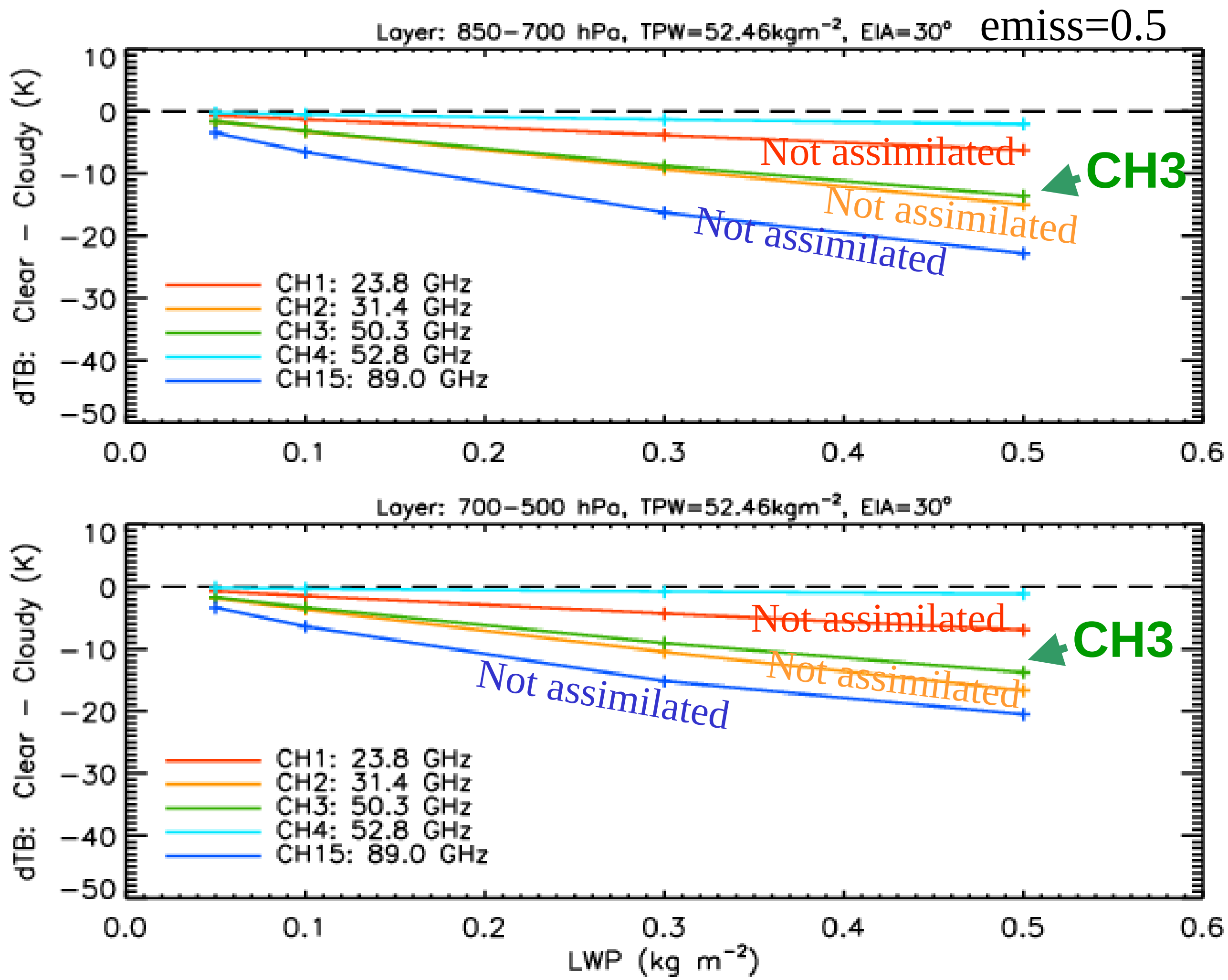
Enhanced Filtering of AMSU Data

- Removal of AMSU-A CH3:
  - Moderate sensitivity to water vapour and clouds
  - Current CLW threshold of 0.3 mm is very high (CLW not part of forward model)

850-700 hPa

700-500 hPa

AMSU-A Sensitivity vs. Liquid Water Path (kg m^{-2})

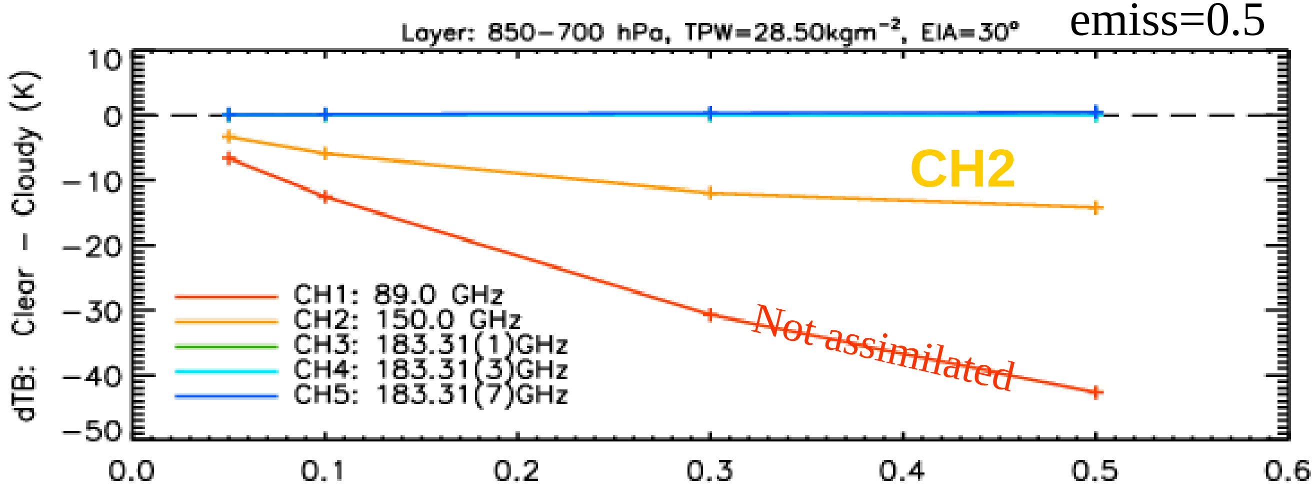


Enhanced Filtering of AMSU Data

- Removal or additional filtering of AMSU-B CH2:
  - Moderate sensitivity to clouds
  - Currently no cloud filter for AMSU-B

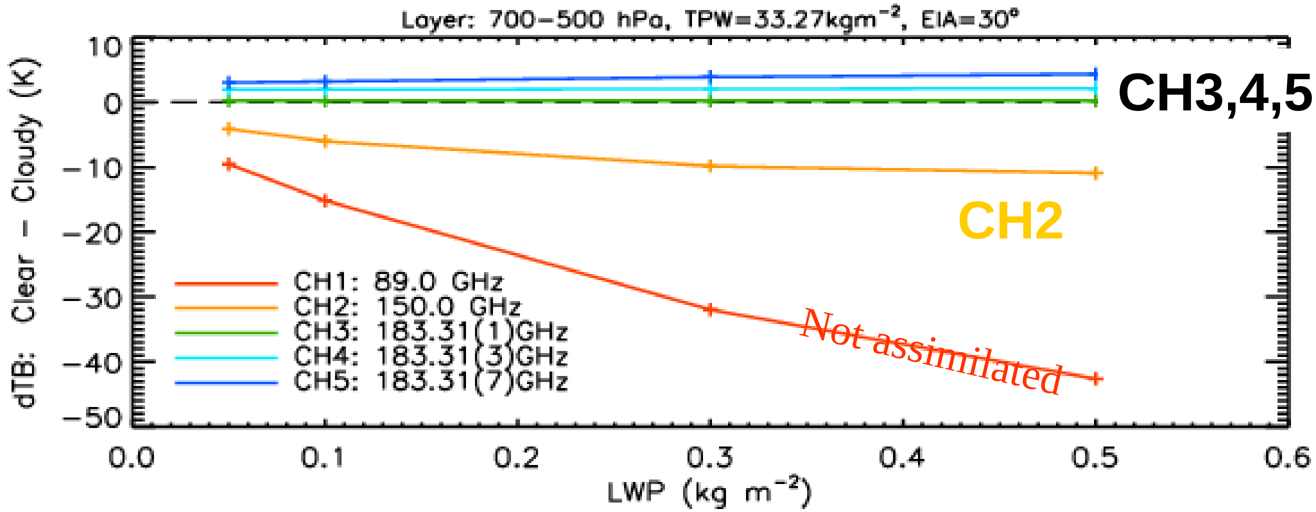
emiss=0.5

850-700 hPa



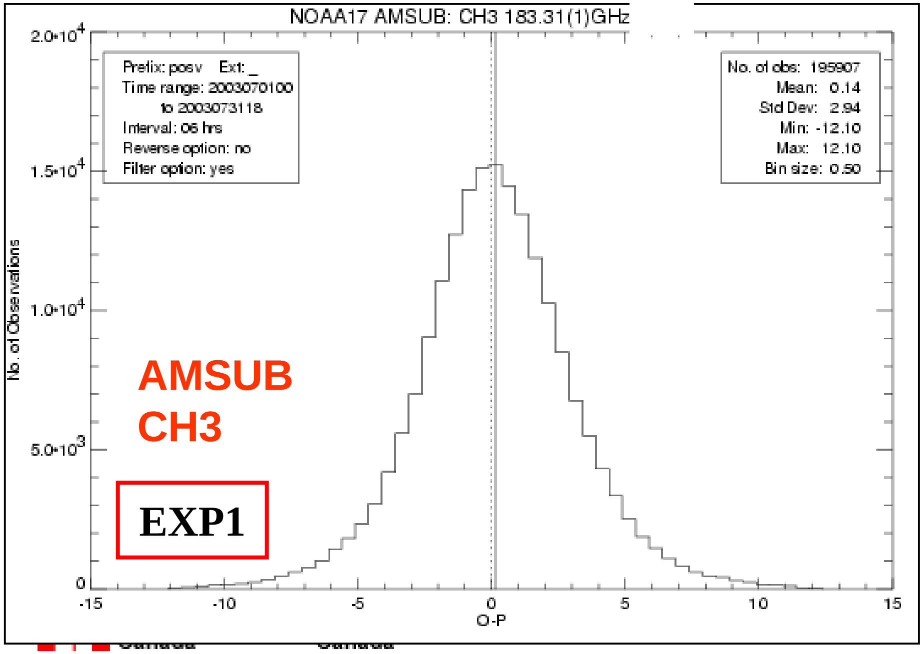
AMSU-B Sensitivity vs. Liquid Water Path (kg m^{-2})

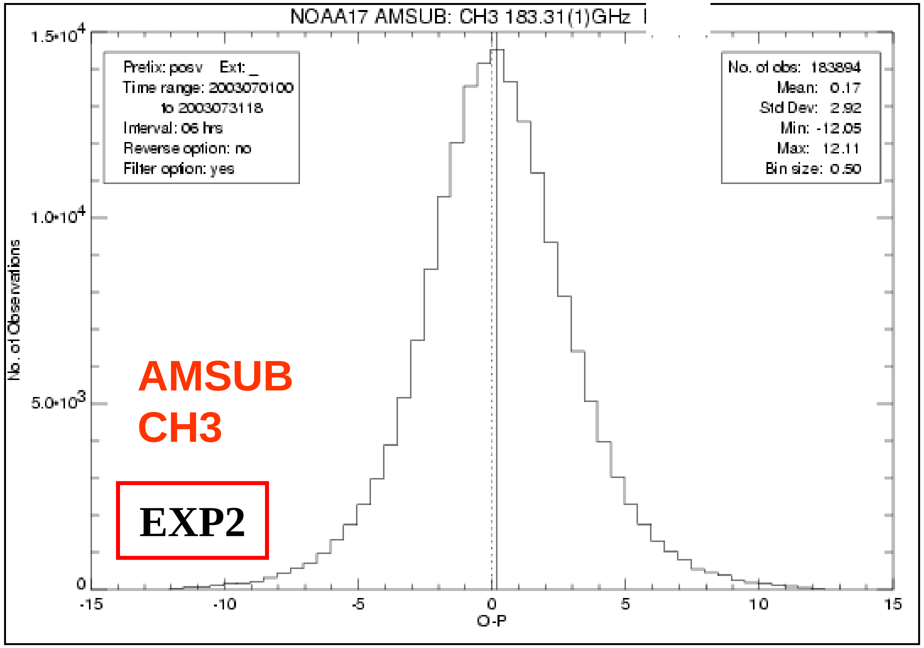
700-500 hPa



Enhanced Filtering of AMSU Data

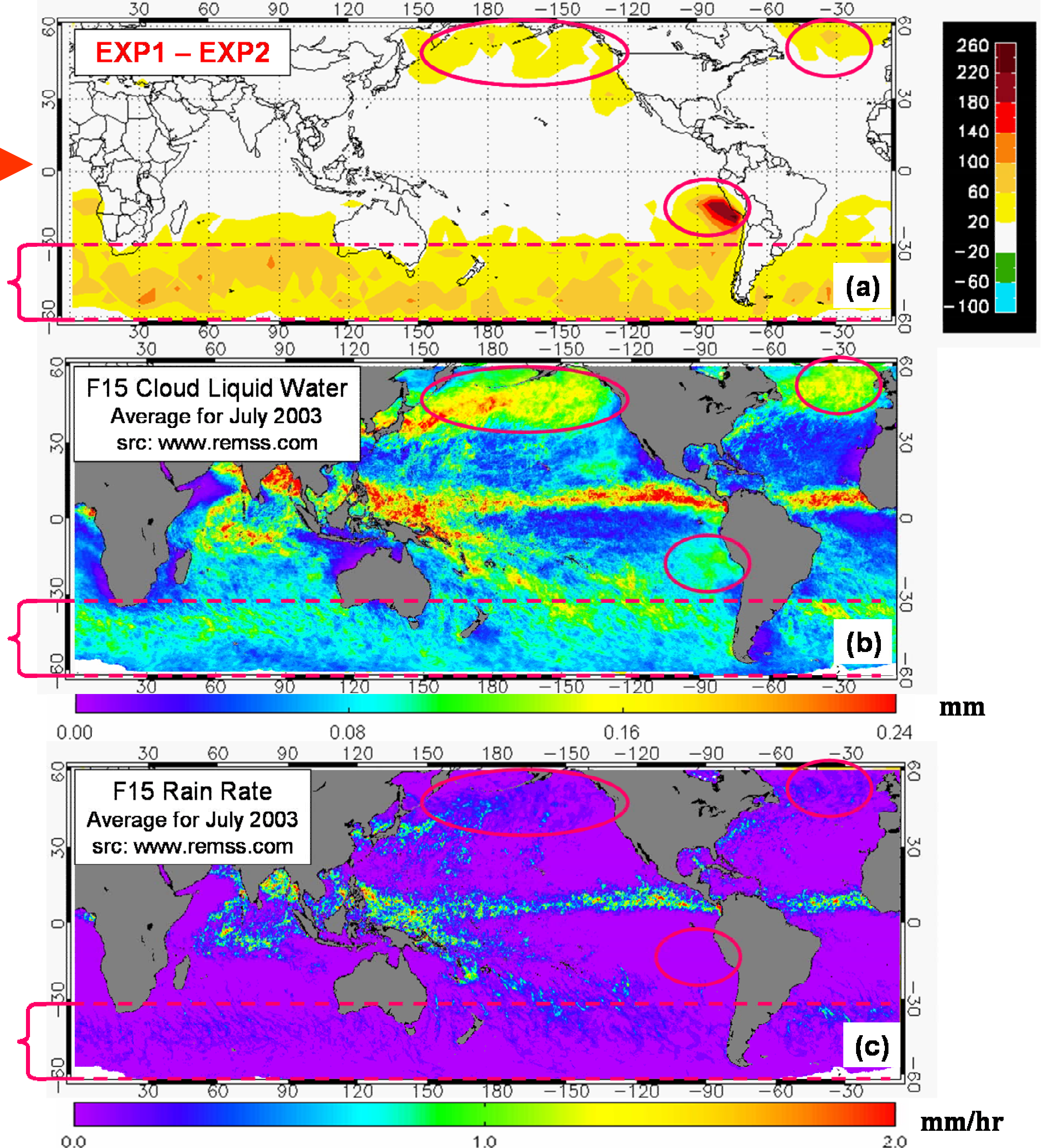
- Extra filtering of AMSU-B CH2,3,4,5 over oceans (remove observations where CH2 |O-FG|≥5K):
  - Weak sensitivity of CH3,4,5 to mid-level clouds
  - Currently no cloud filter for AMSU-B
  - Acts as proxy cloud filter: many obs in persistently cloudy, non-precipitating regions are no longer assimilated (see next slide)
  - Same filtering applied at ECMWF and Meteo-France
- Results in ~100 less obs assimilated for each channel every period (~7% loss)



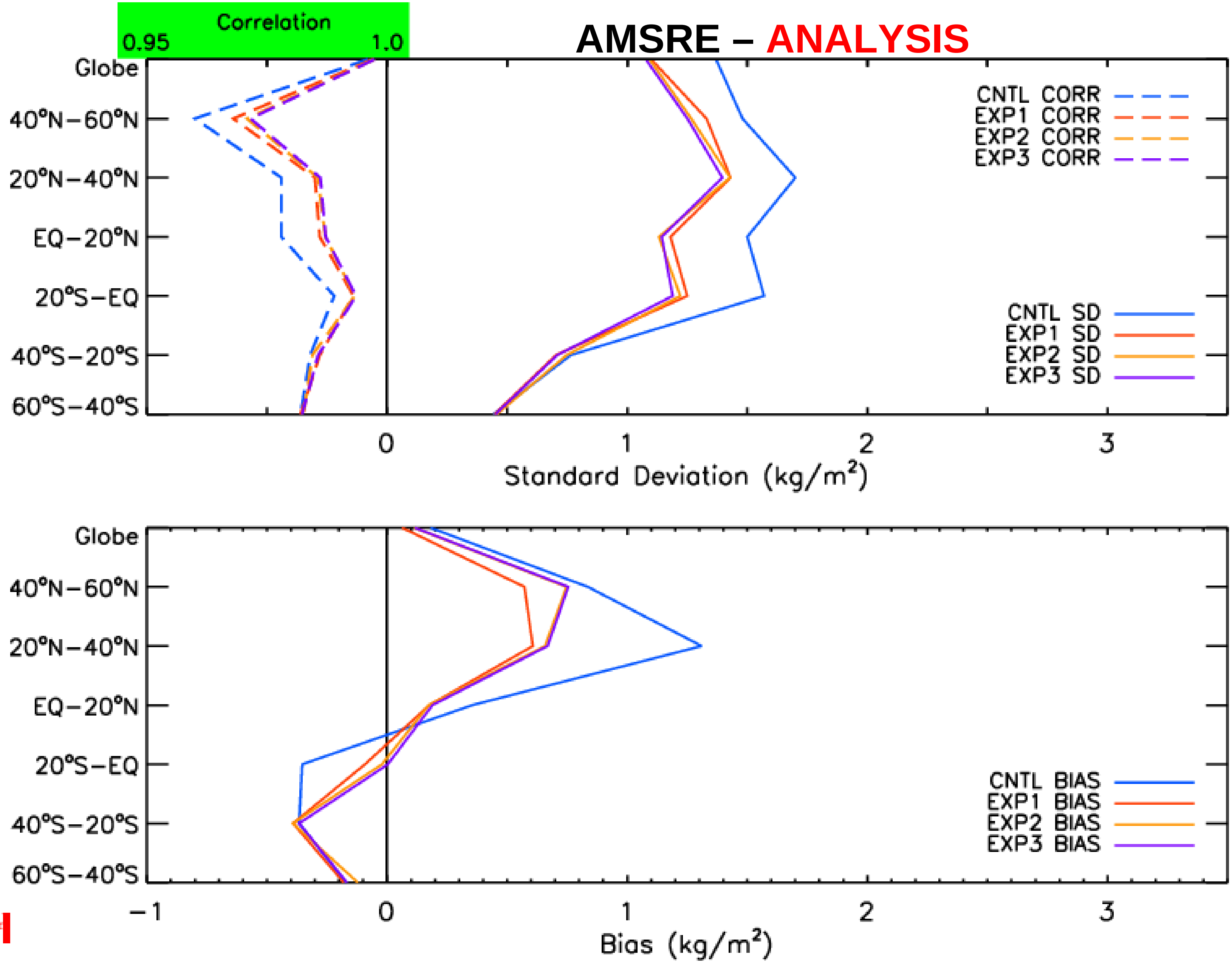


Difference in # of obs assimilated for **AMSU-B CH3**:

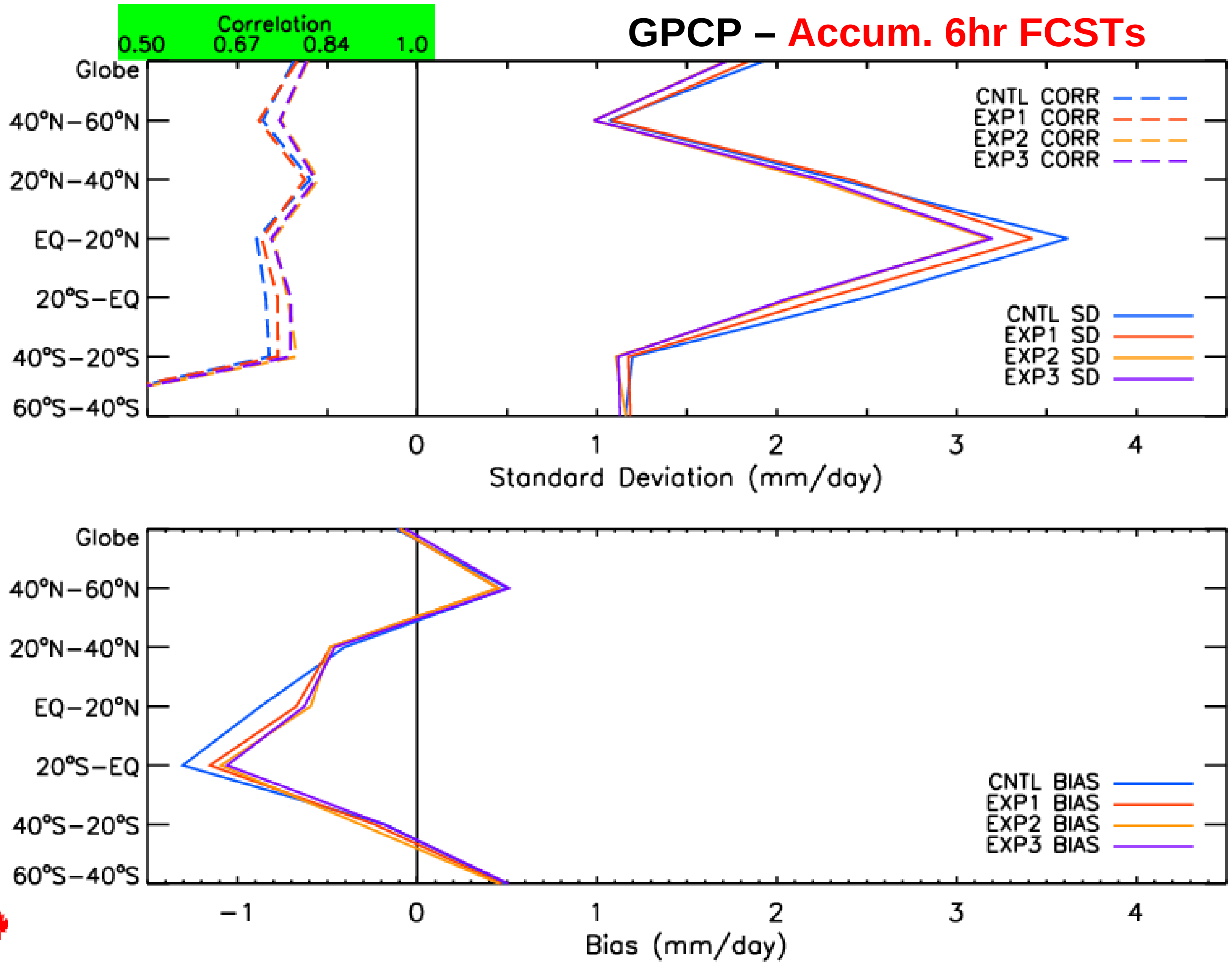
Effect of Proxy Cloud Filter



Mean Analyzed Integrated Water Vapour (kg m^{-2}): July 2003

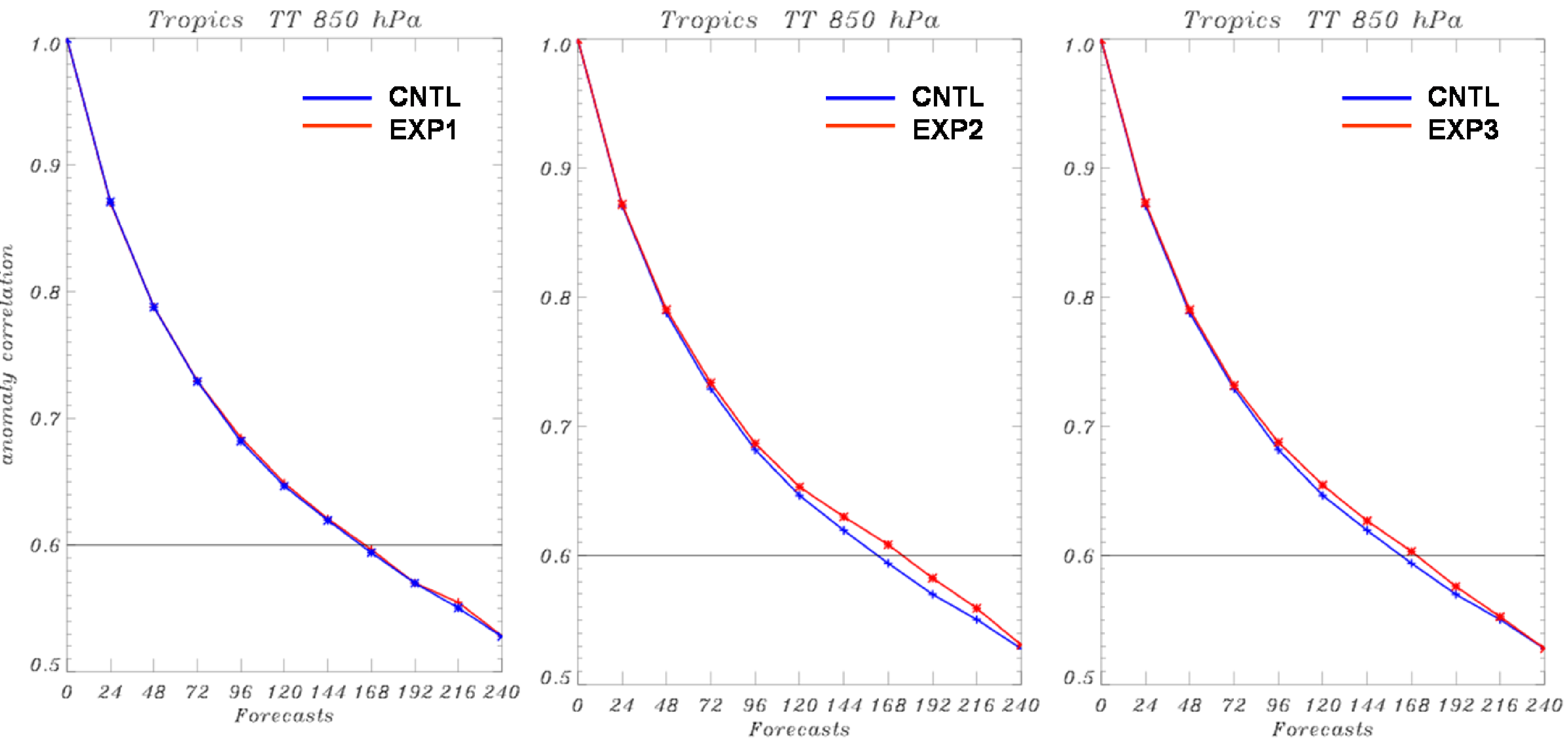


Mean Daily Precipitation Rate (mm/day): July 2003



Forecast Validation Using Analyses

Anomaly Correlation
Temperature, 850 hPa, Tropics



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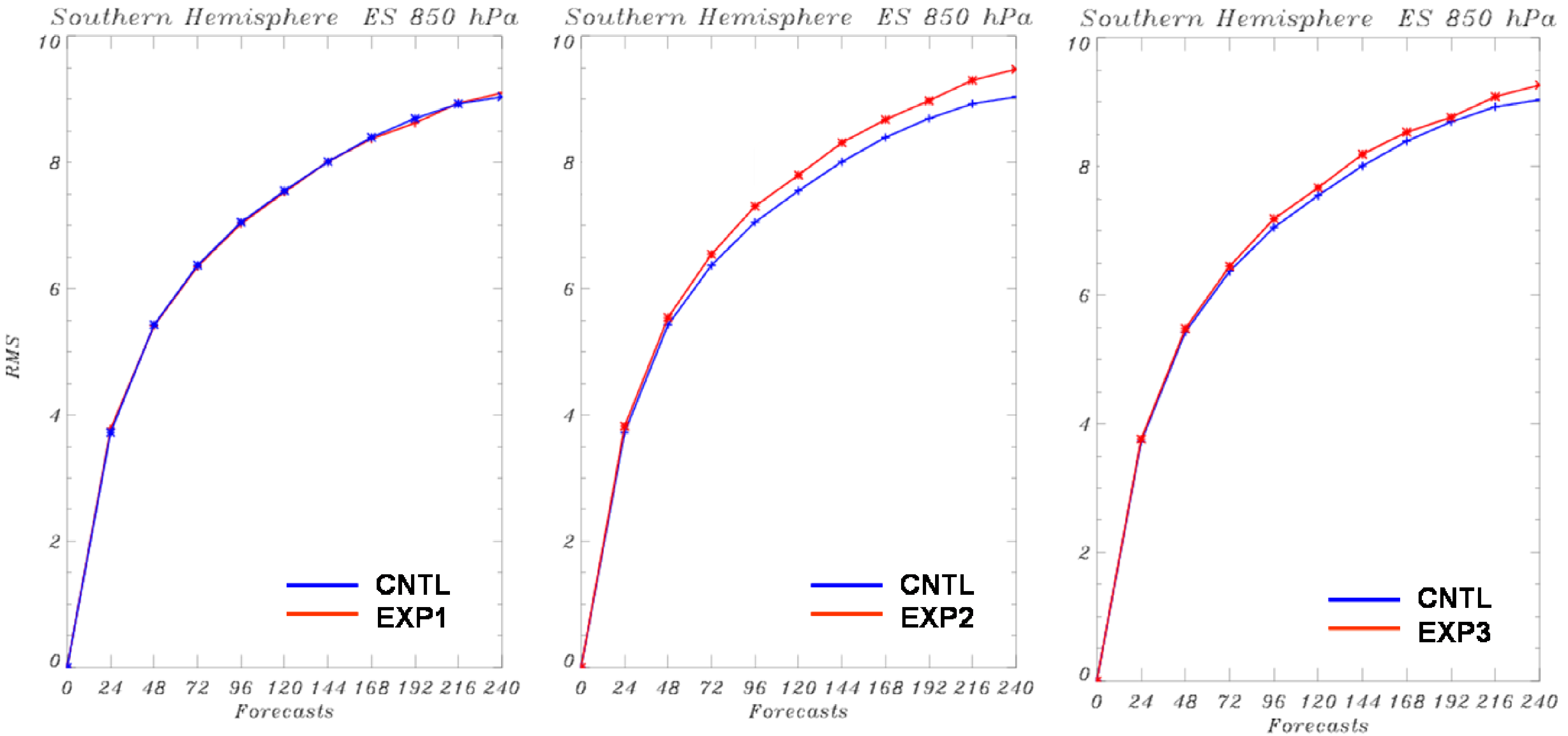
Forecast Validation Using Analyses

RMS
Dewpoint Depression, 850 hPa, Southern Hemisphere



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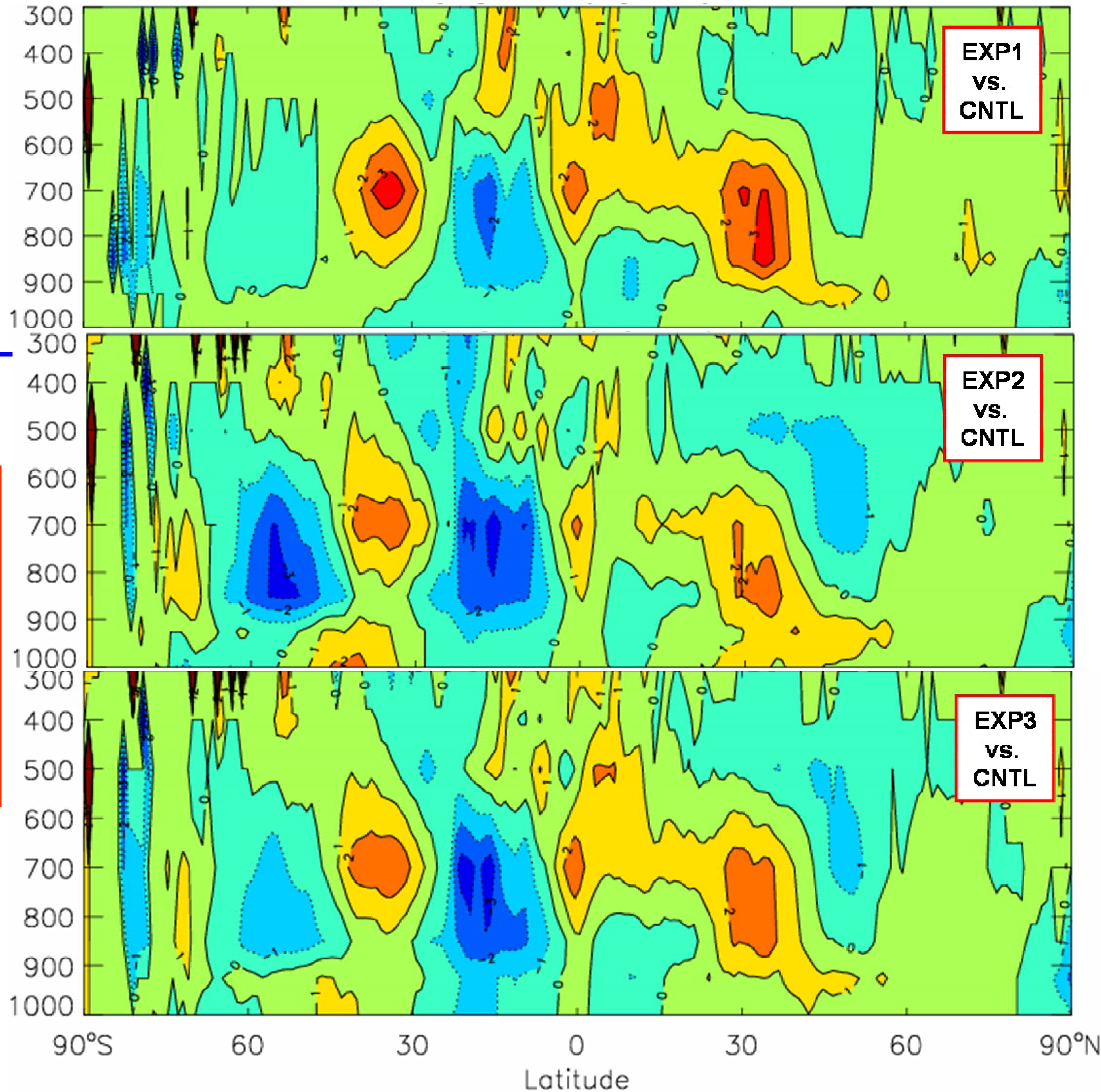
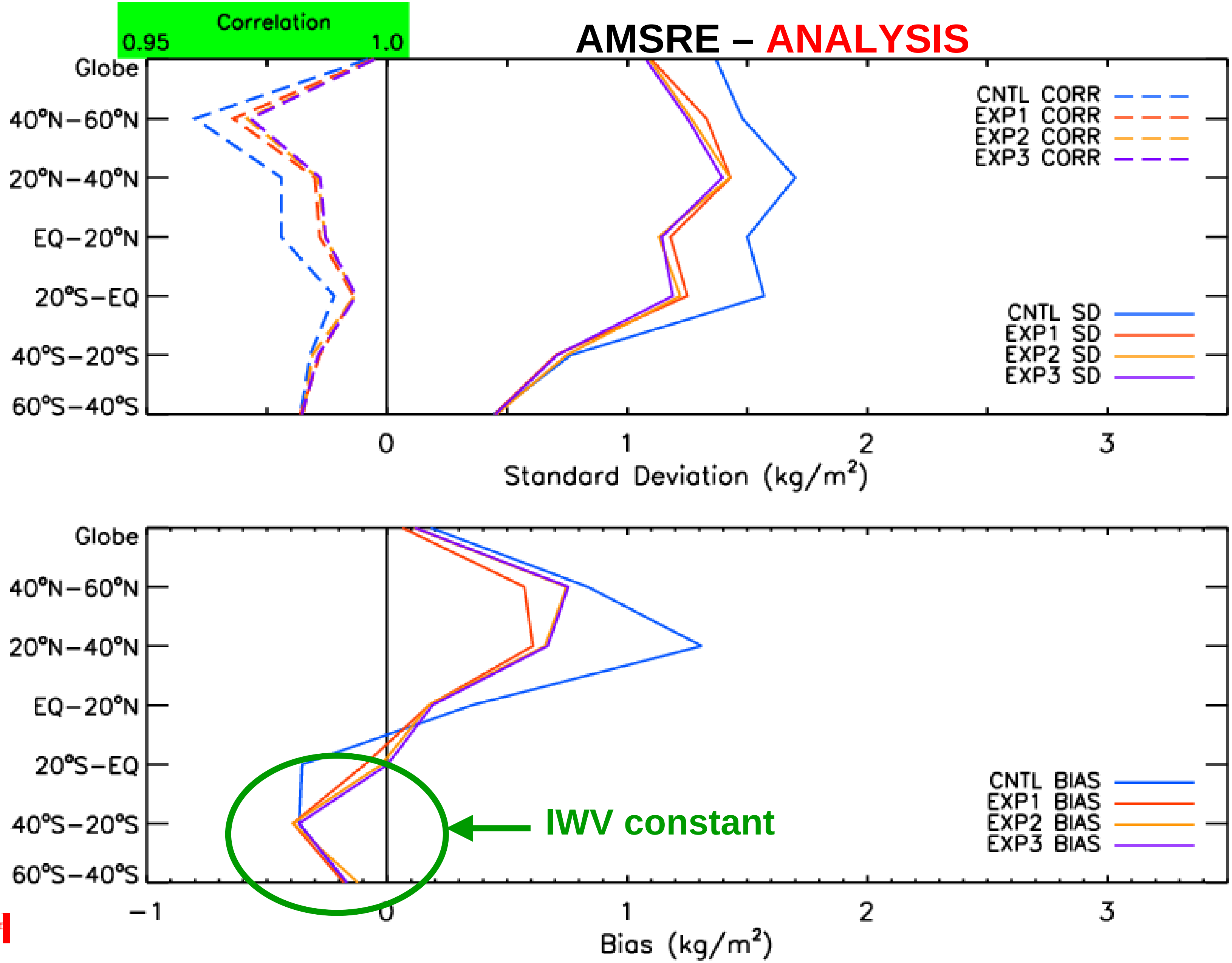
Vertical Distribution of Moisture

Percent Change in Specific Humidity:

$$100 * \frac{[Q_{EXP1} - Q_{CNT1}]}{Q_{CNT1}}$$



Mean Analyzed Integrated Water Vapour (kg m^{-2}): July 2003



Conclusions

- Proxy cloud filter is effective at removing AMSU-B observations in cloudy, non-precip. regions
- Evaluation of monthly averaged IWV, SWS, DPR fields shows improvements for EXP1, EXP2, EXP3
  - **Mostly due to addition of SSM/I data**
- Verification of forecasts against **RAOBS** shows little to no impact for EXP1, and small positive impact for EXP2, EXP3
  - Weak signal not surprising since most RAOBS are land based
- Verification of forecasts against **analyses** shows positive effects in AC and RMS for all experiments
  - Stronger signal for EXP2, EXP3 than EXP1 (**SSM/I has little impact**)
  - **Exception: SH moisture field for EXP2**

Conclusions (2)

- Results indicate that assimilating AMSU-B CH3,4,5 without CH2 leads to a less accurate vertical distribution of moisture
  - SSM/I unable to compensate, though the weighting function for SSM/I CH7 is similar to AMSU-B CH2
  - Very likely SSM/I and AMSU-B obs are not coincident, in which case, absent CH2, AMSU-B bias corrections need to be re-evaluated (?)

Future Work

- Re-compute bias corrections with a data set lacking 'cloudy' AMSU-B obs, and run experiment to see if humidity field returns to CNTL
  - Keep benefits of EXP2,EXP3; avoid negative effects
- Launch and evaluate Northern Hemisphere winter experiments with same configurations
- Launch and evaluate experiments using 4D-Var for a 2-month summer and a 2-month winter cycle

END

Extras

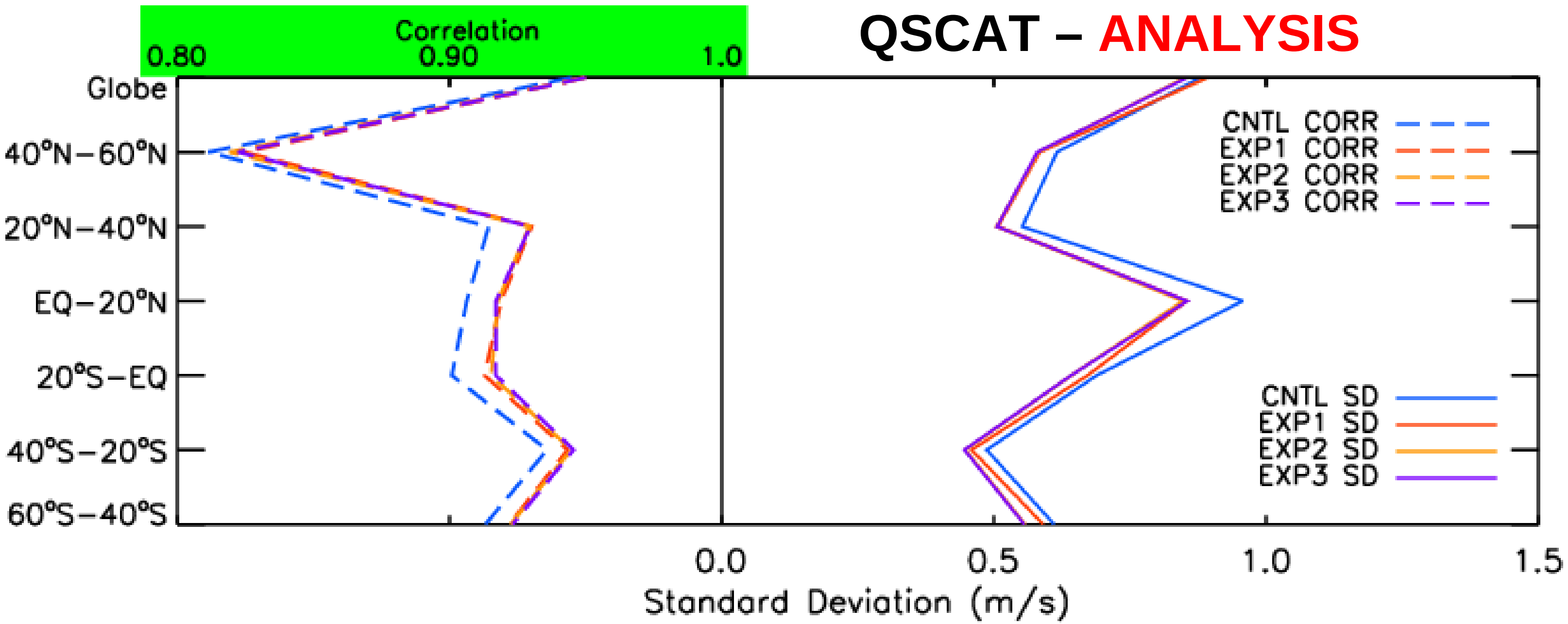
Verification of forecasts against **RAOBS** shows a neutral impact for EXP1 and small positive impacts for EXP2, EXP3

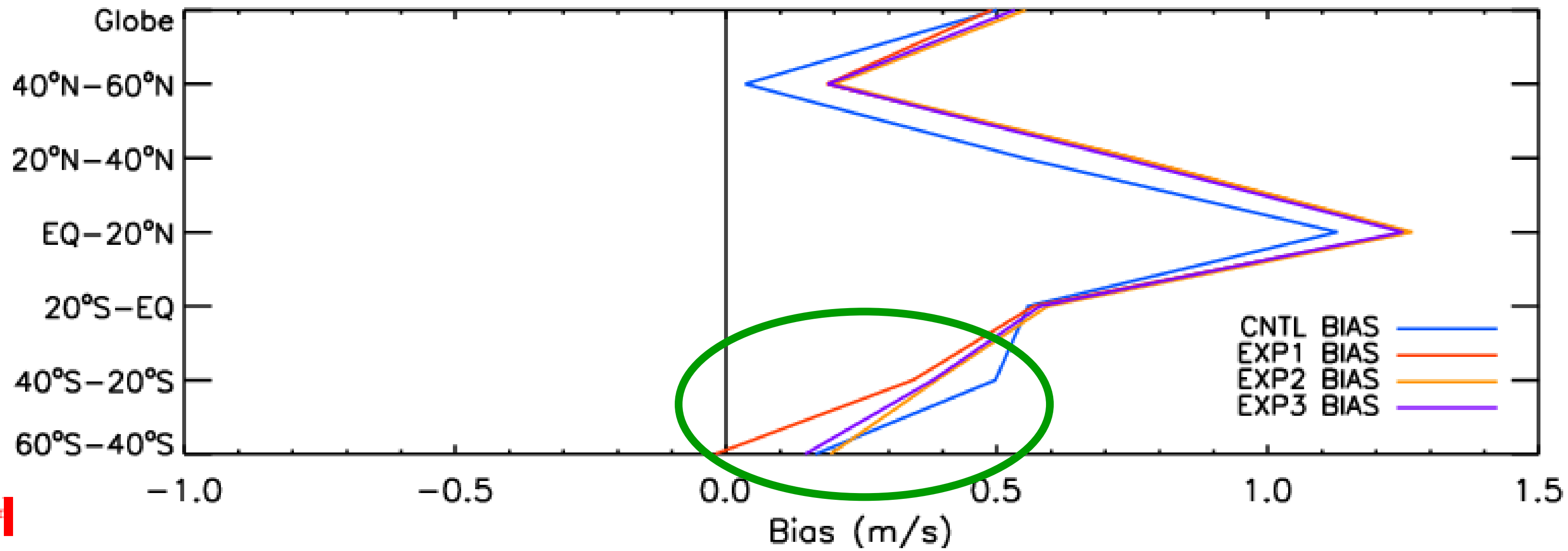
- Little impact within first 5 days
- No notable change to vertical profile of temperature (despite removal of AMSU-A CH3)
- Weak signal is not surprising since RAOBS are mostly land based

Acronymns

- DMSP: Defense Meteorological Satellite Program
- TRMM: Tropical Rainfall Measuring Mission
- TMI: TRMM Microwave Imager
- SSM/I: Special Sensor Microwave Imager
- AMSR-E: Advanced Microwave Scanning Radiometer for EOS
- AMSU: Advanced Microwave Sounding Unit
- GPCP: Global Precipitation Climatology Project
- TOVS: TIROS Operational Vertical Sounder
- TIROS: Television InfraRed Observation Satellite

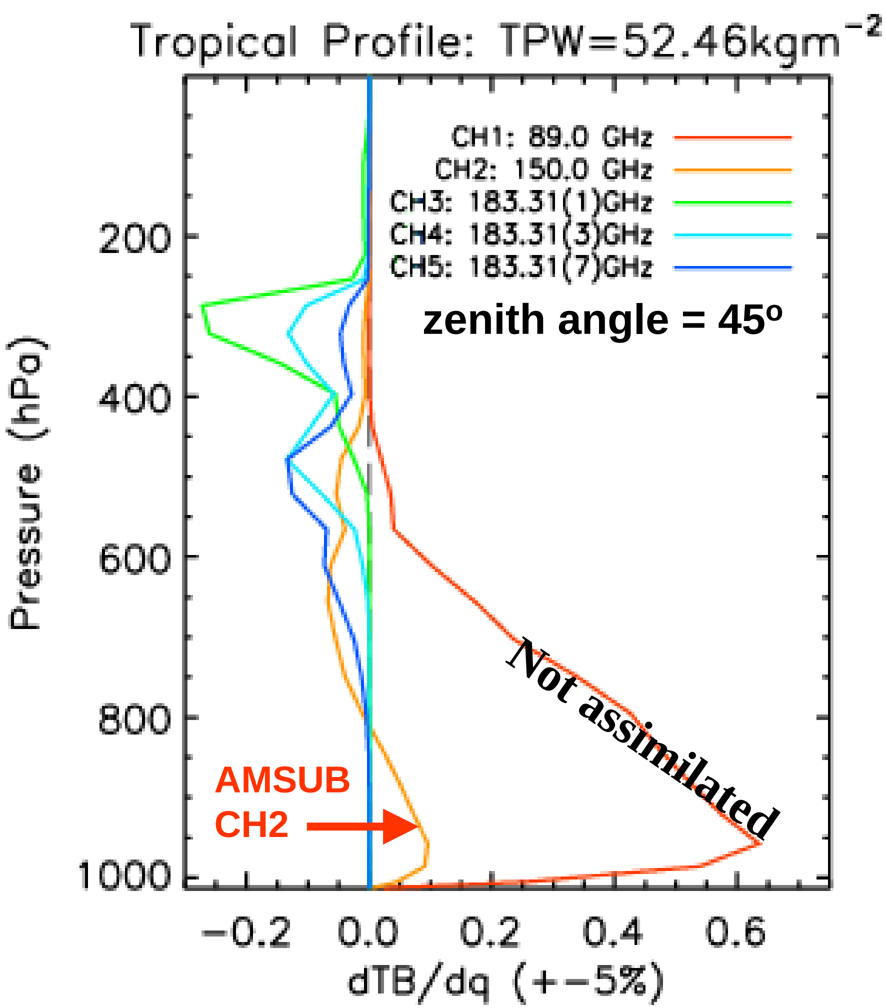
Mean Analyzed Surface Wind Speed (m s^{-1}): July 2003



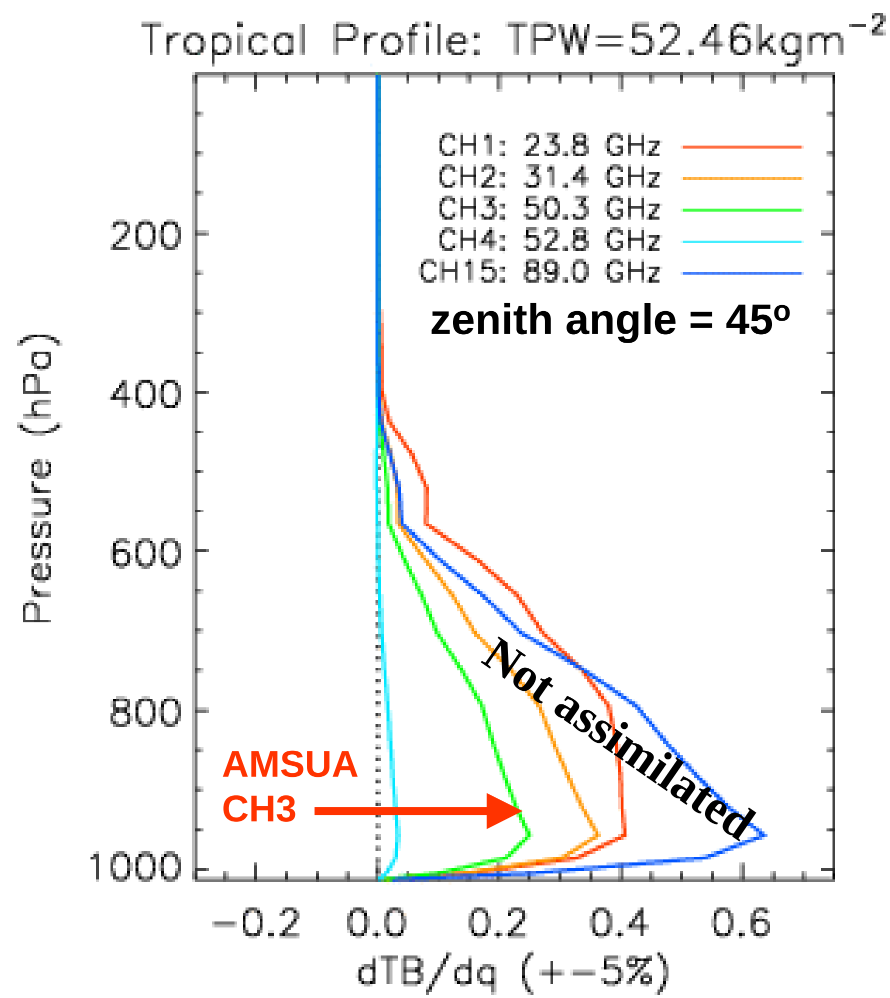


Weighting Functions wrt Humidity

AMSU-B



AMSU-A



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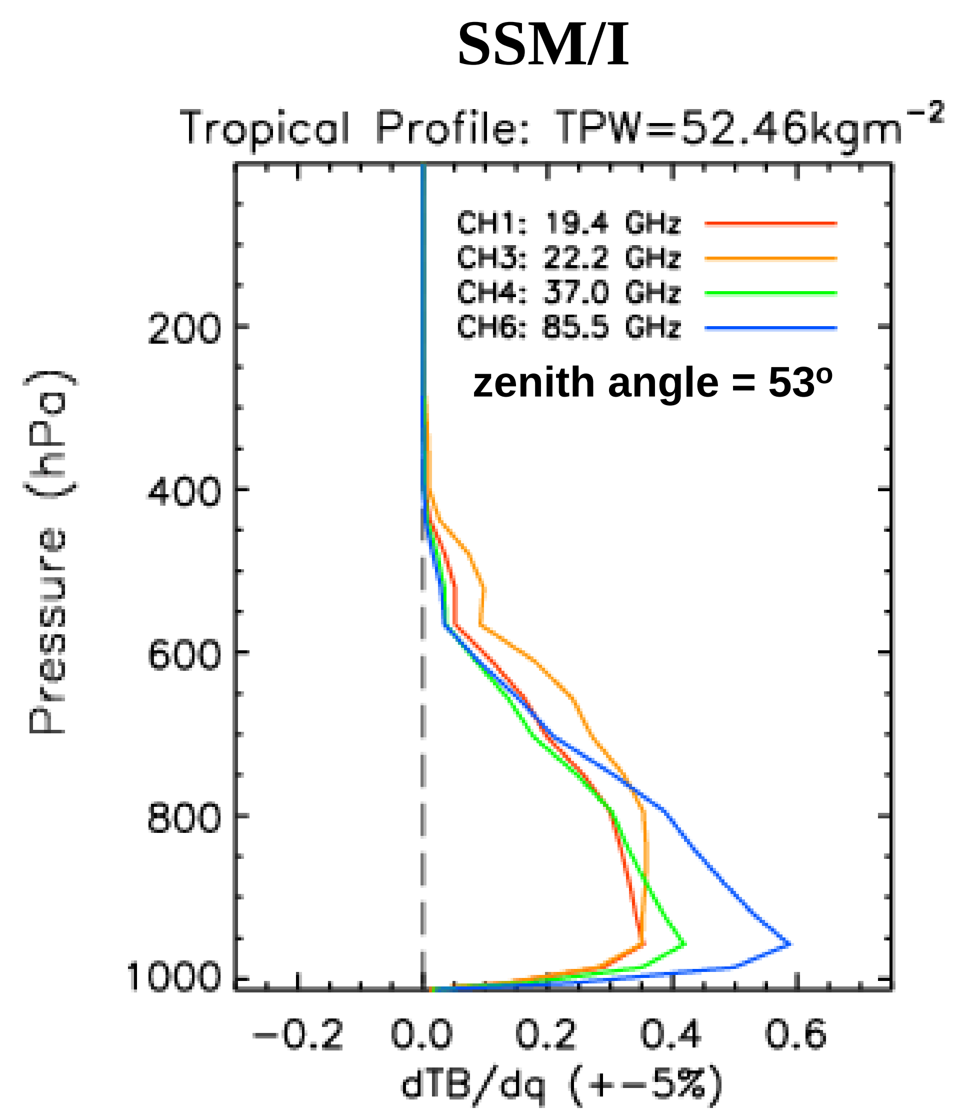
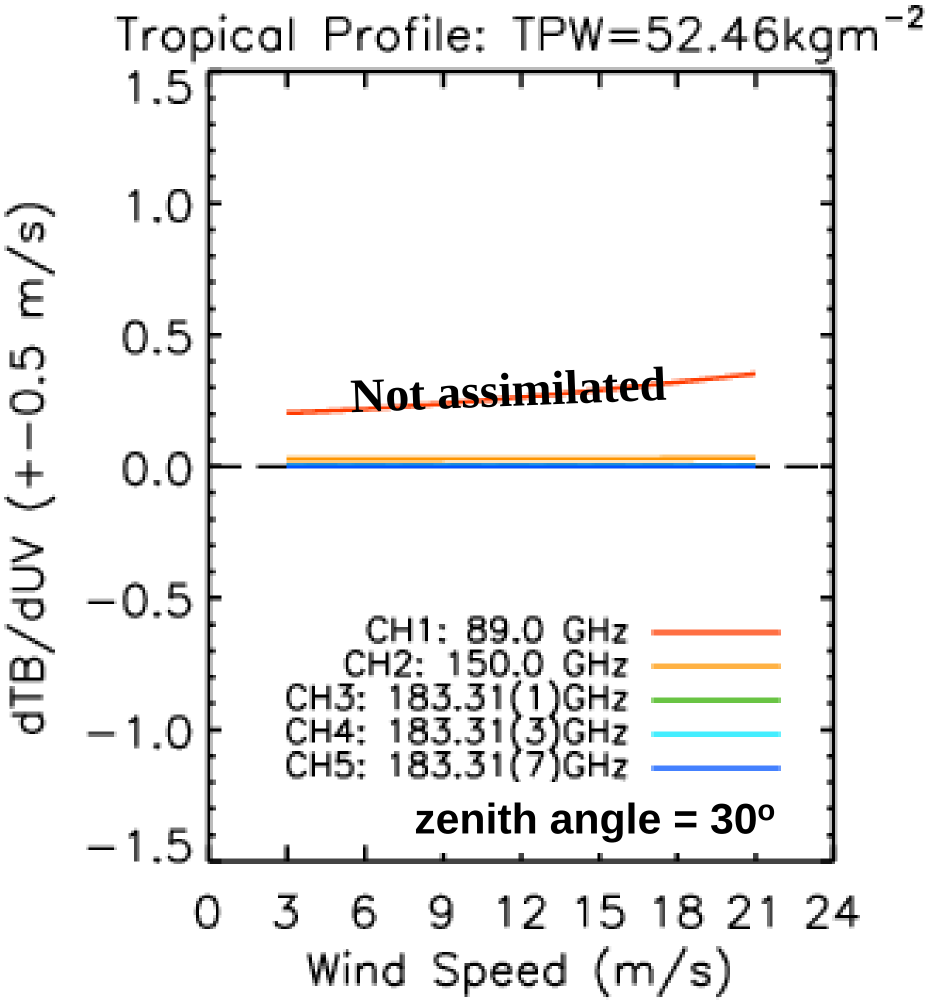
Weighting Functions wrt Humidity

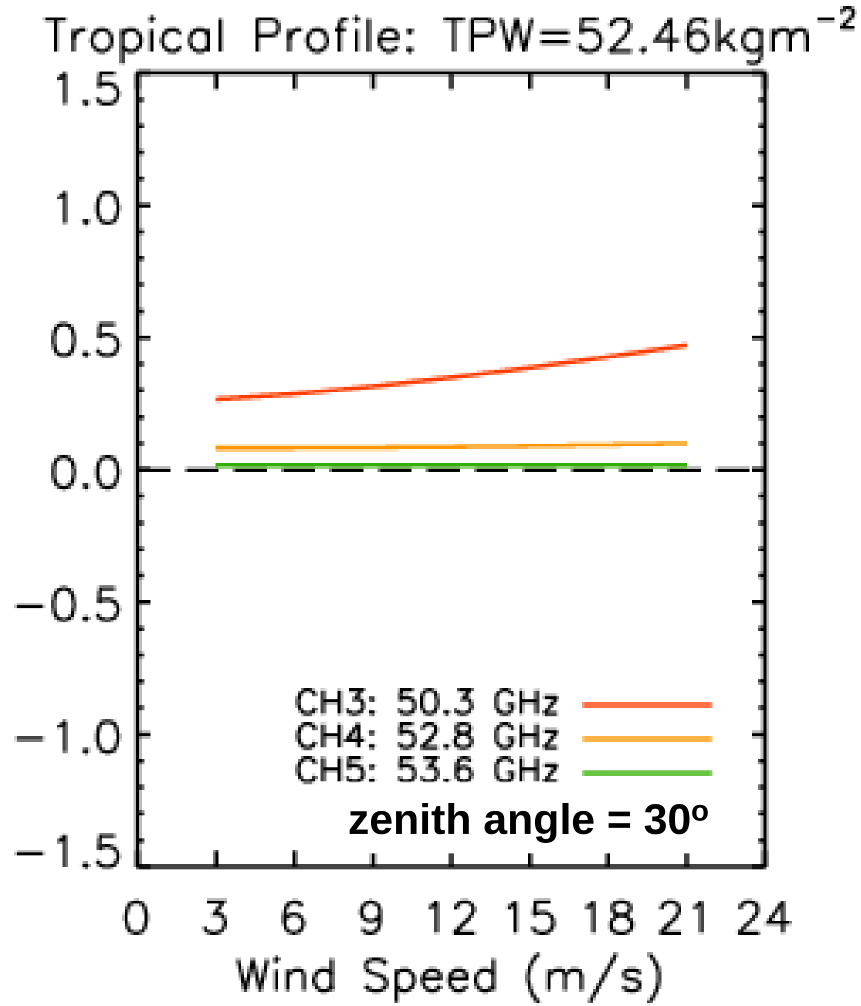


Sensitivity wrt Surface Wind Speed

AMSU-B



AMSU-A



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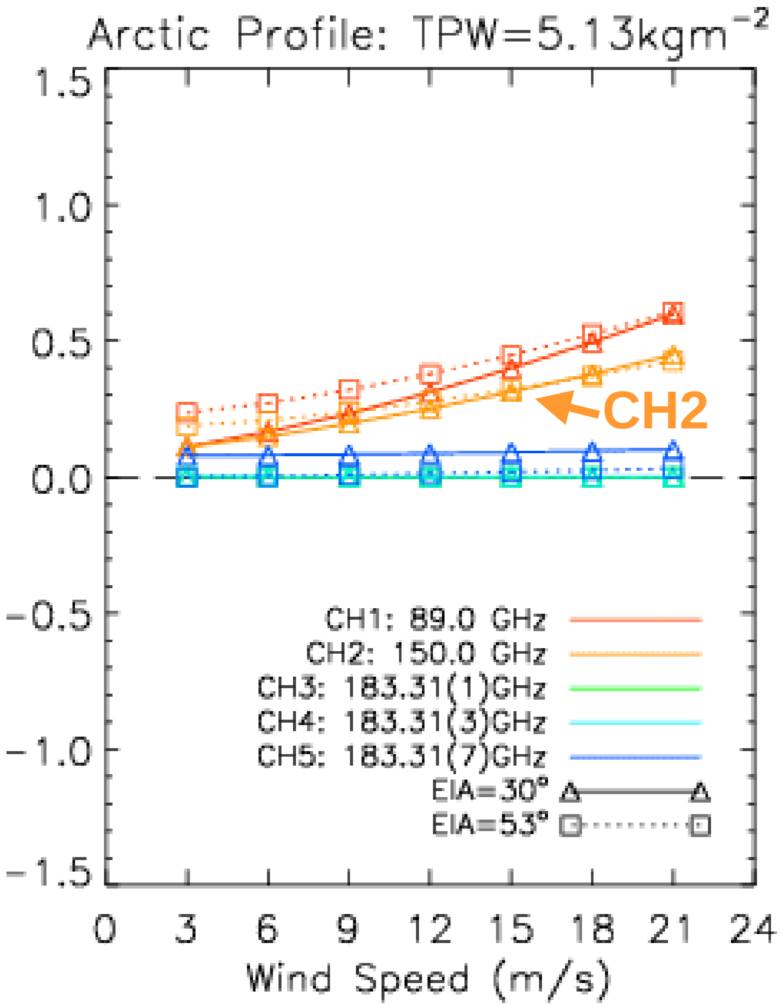
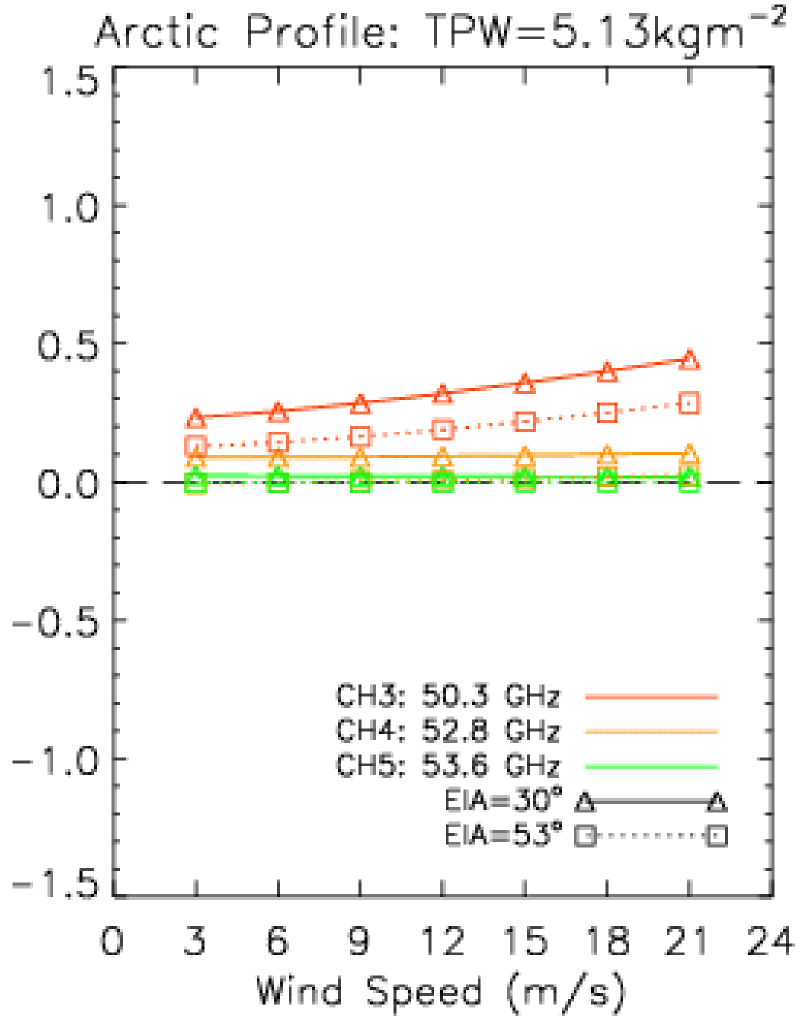
Sensitivity wrt Surface Wind Speed

AMSU-B



AMSU-A



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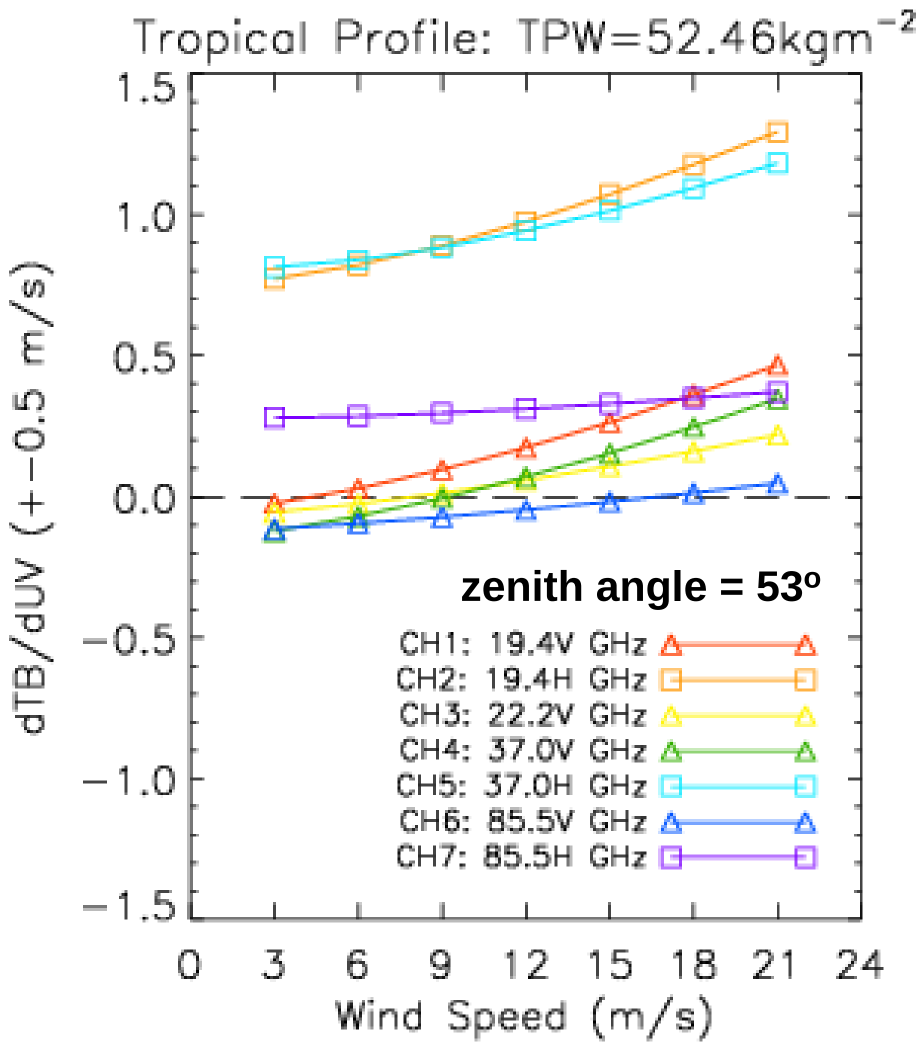
Sensitivity wrt Surface Wind Speed

SSM/I



Independent Observations

AMSR-E (IWV)

AQUA Research Satellite

Conical scanner

1445 km swath

705 km altitude

Sun-synchronous

Channel	Freq. (GHz)	Res. (km)
1 & 2	6.925 V,H	56
3 & 4	10.65 V,H	38
5 & 6	18.7 V,H	21
7 & 8	23.8 V,H	24
9 & 10	36.8 V,H	12
11 & 12	89.0 V,H	5.4

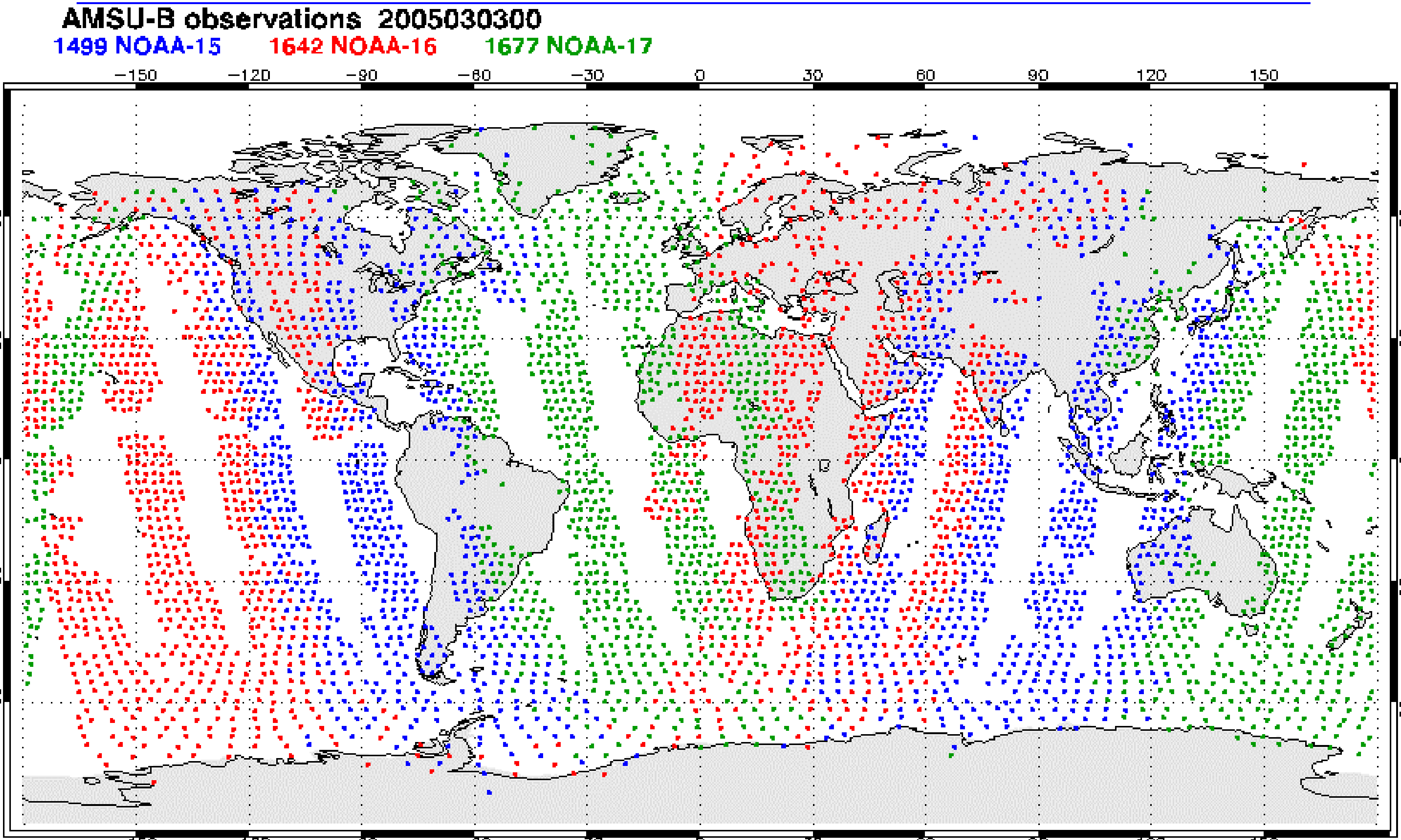
SSM/I

QuikSCAT (SWS)

active scatterometer (MW radar)
13.4 GHz channel @ 25 km res.
Range: 3 – 20 m/s
Accuracy: 2 m/s, 20^o
1800 km swath
803 km altitude

Data source: Remote Sensing Systems
www.remss.com

AMSU-B coverage after thinning



SSM/I coverage after thinning