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

David Anselmo & Godelieve Deblonde
Data Assimilation and Satellite Meteorology Division
Meteorological Service of Canada

ITSC-14 Beijing, China

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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^{o}, 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)	σ = 2: CH 3	σ = 2: CH 2 σ = 4: CH 3,4,5	σ = 2: CH 1-7
Thinning	250 km	250 km	200 km

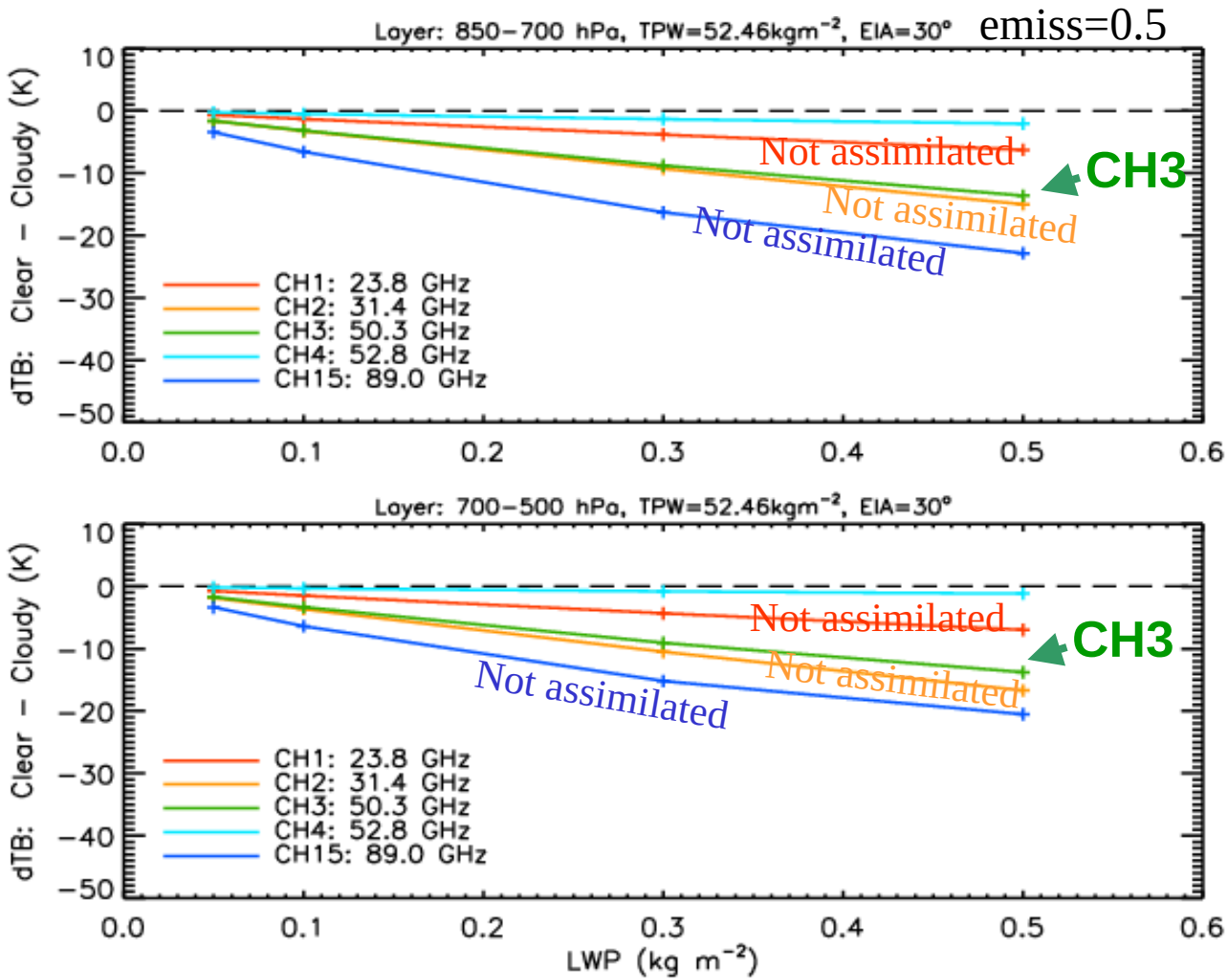
Enhanced Filtering of AMSU Data

- 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

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

700-500 hPa



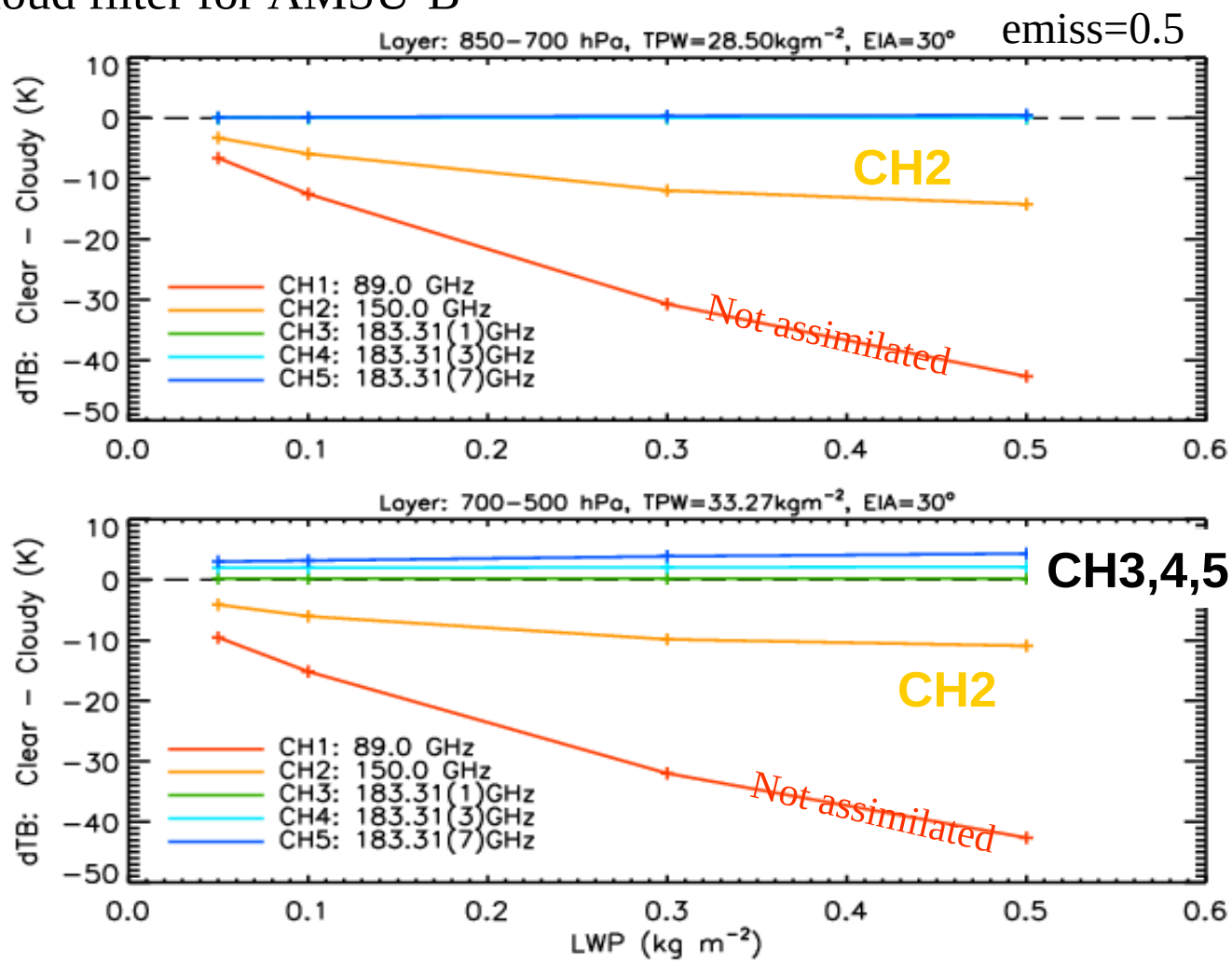
Enhanced Filtering of AMSU Data

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

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

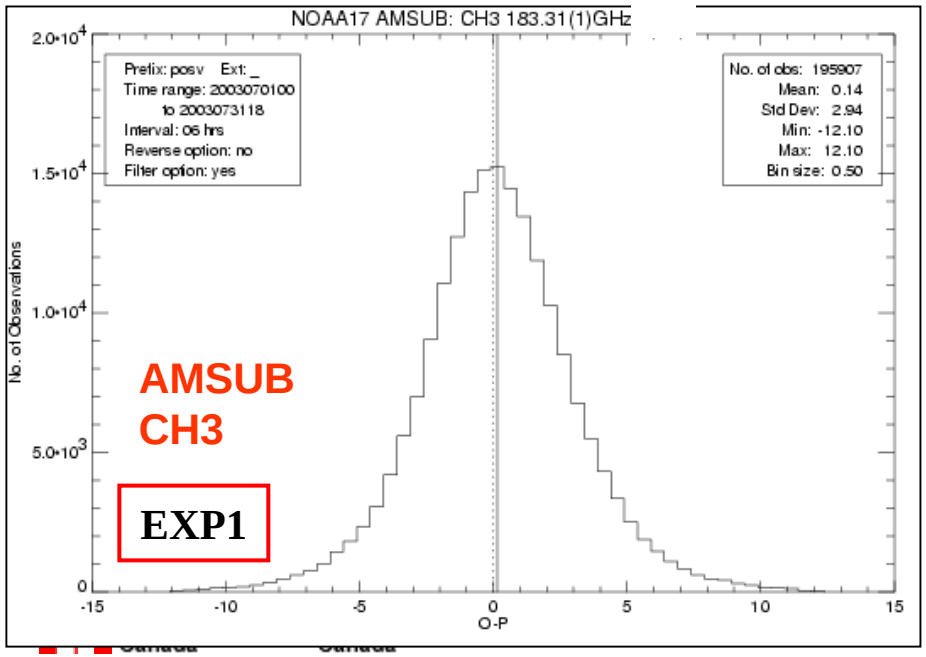
850-700 hPa

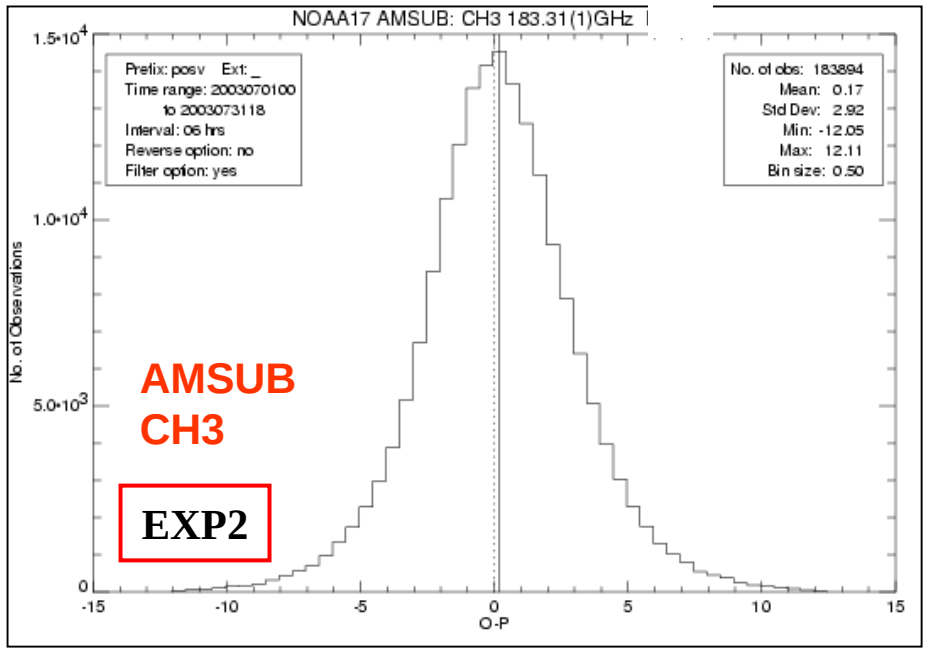
700-500 hPa



Enhanced Filtering of AMSU Data

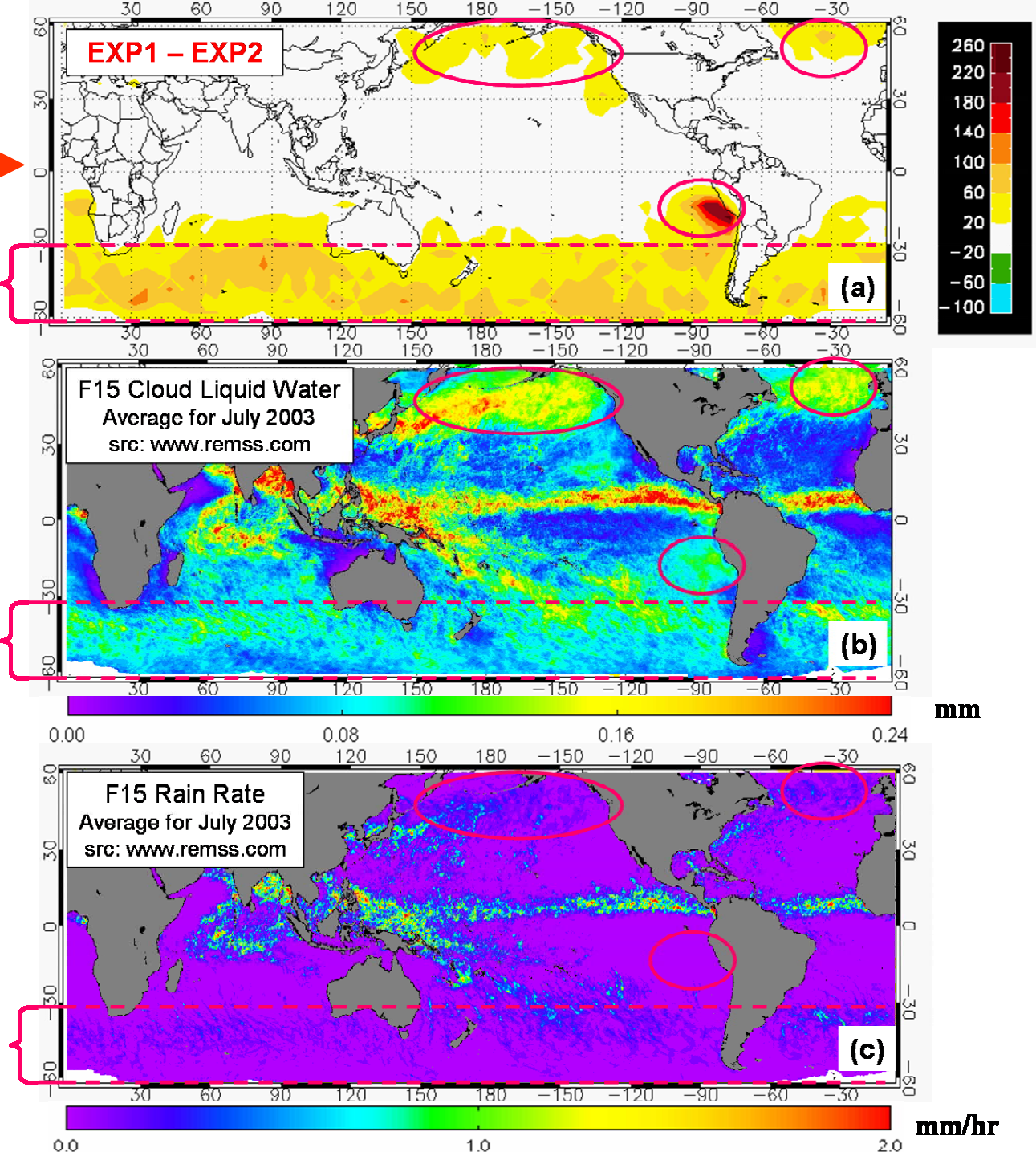
- Extra filtering of AMSU-B CH2,3,4,5 over oceans (remove observations where CH2 |O-FG|≥5K):
  - Weak sensitivity of CH3,4,5 to mid-level clouds
  - Currently no cloud filter for AMSU-B
  - Acts as proxy cloud filter: many obs in persistently cloudy, non-precipitating regions are no longer assimilated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



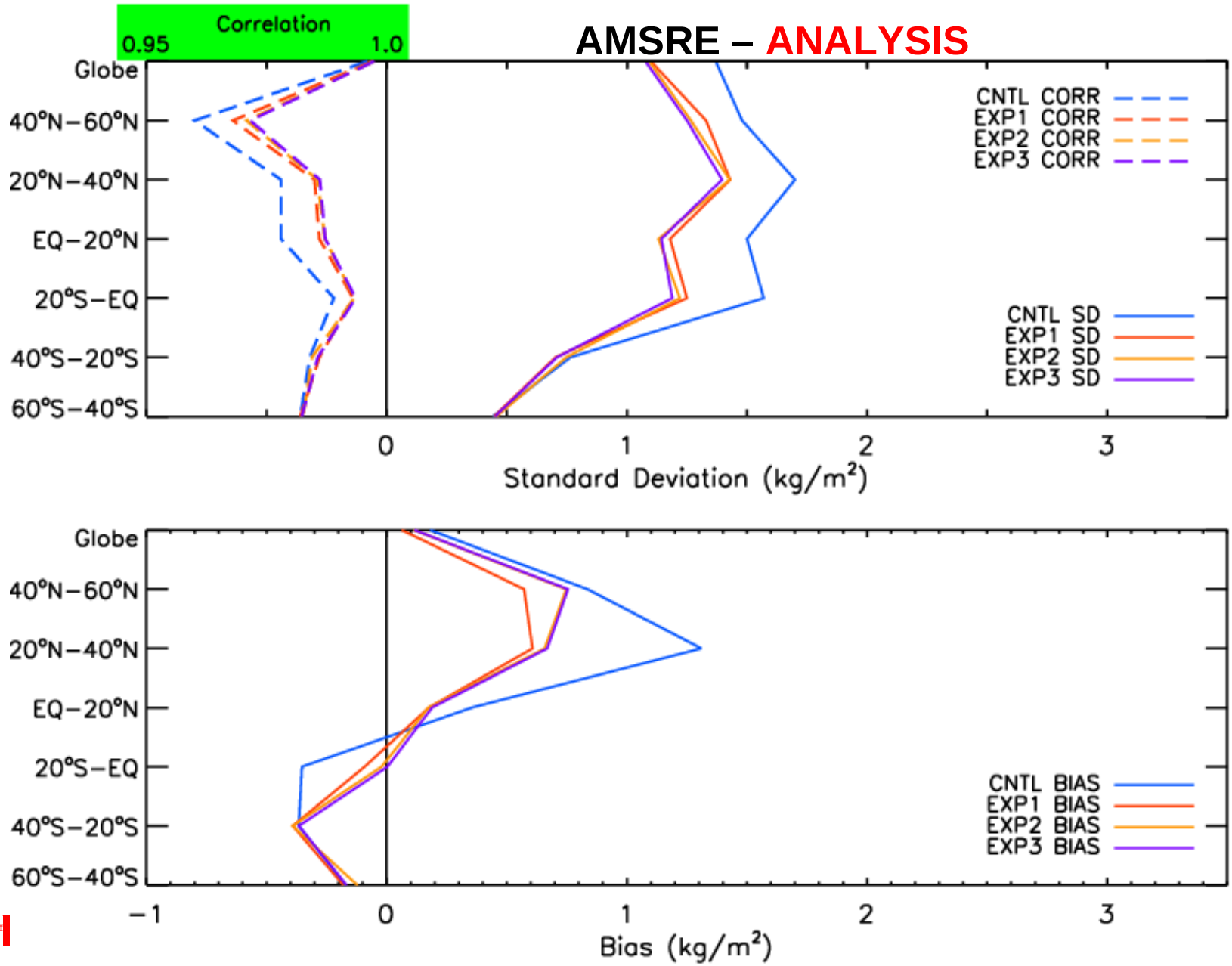


Difference in # of obs assimilated for **AMSU-B CH3**:

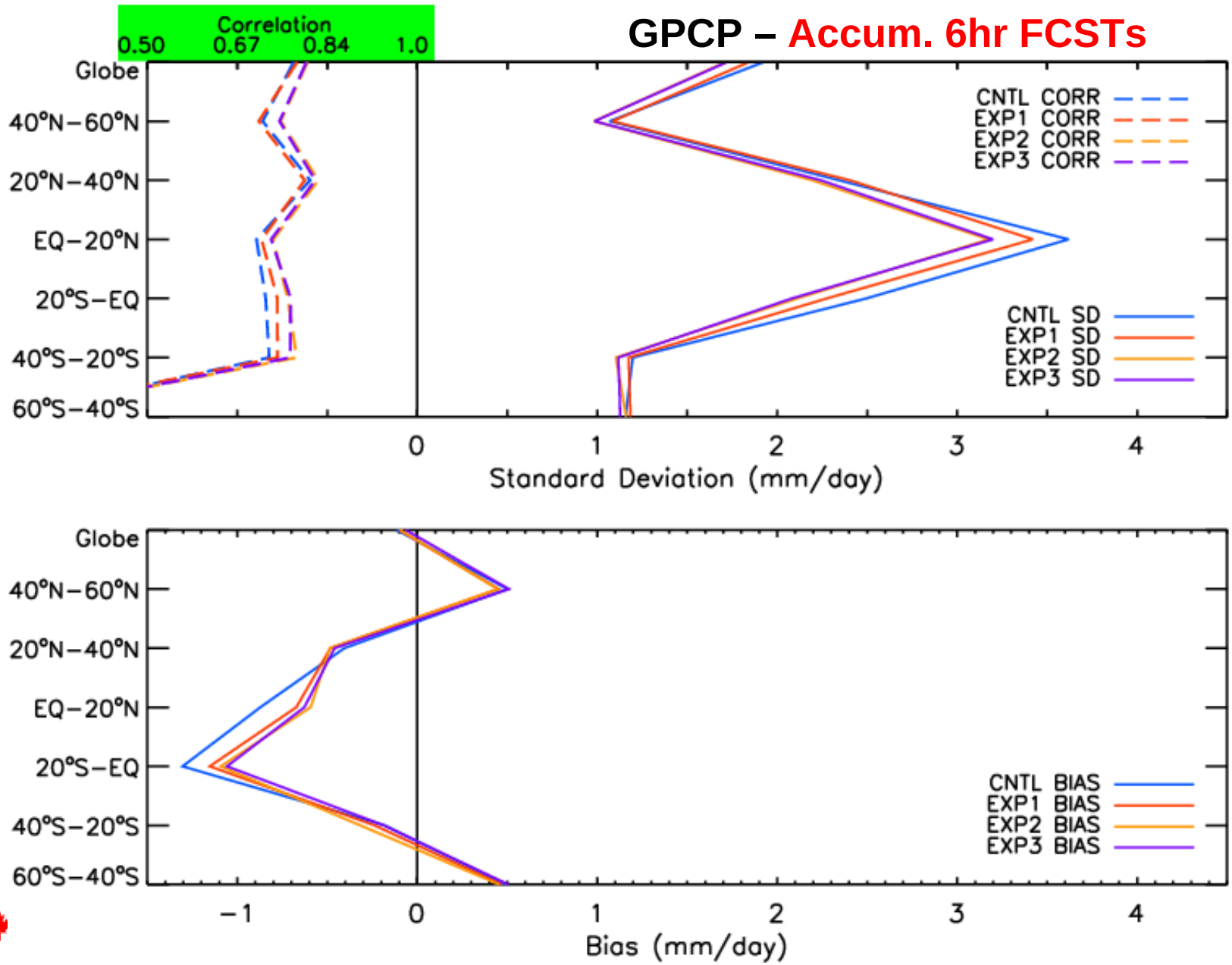
Effect of Proxy Cloud Filter



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

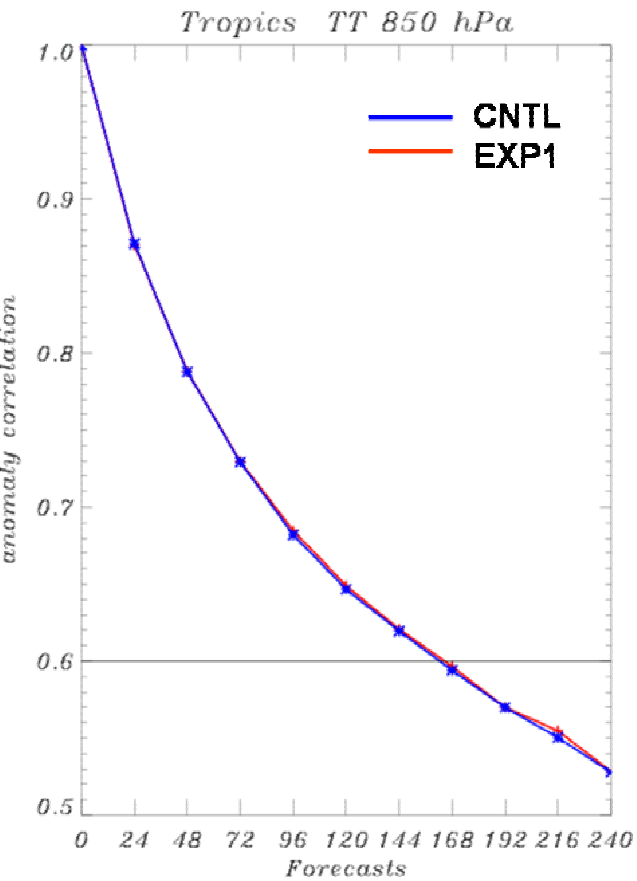


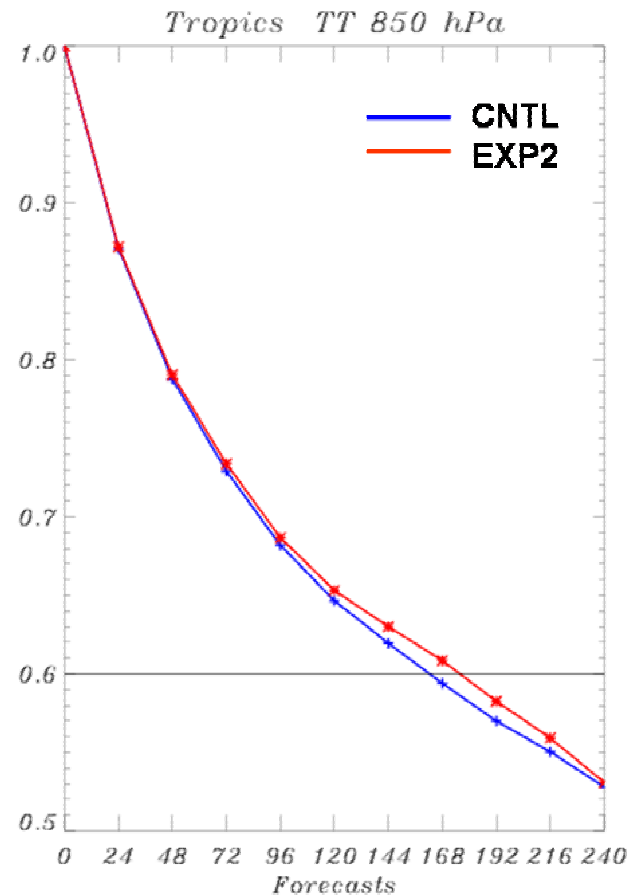
Mean Daily Precipitation Rate (mm/day): July 2003

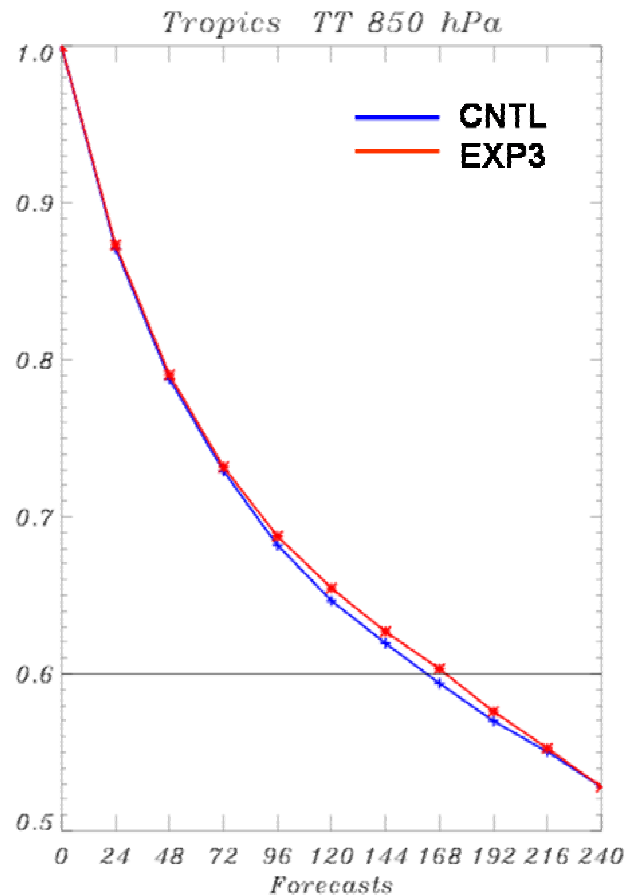


Forecast Validation Using Analyses

Anomaly Correlation
Temperature, 850 hPa, Tropics

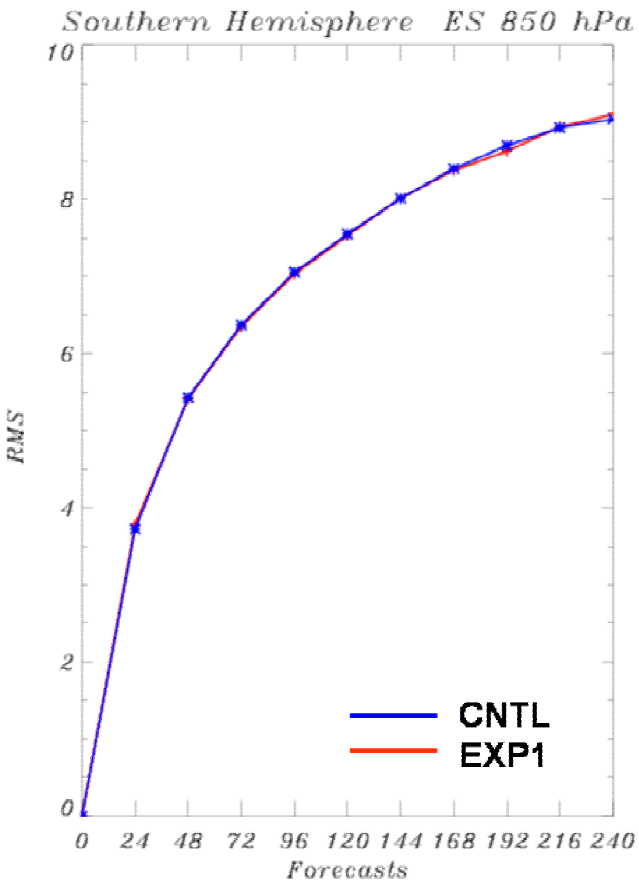


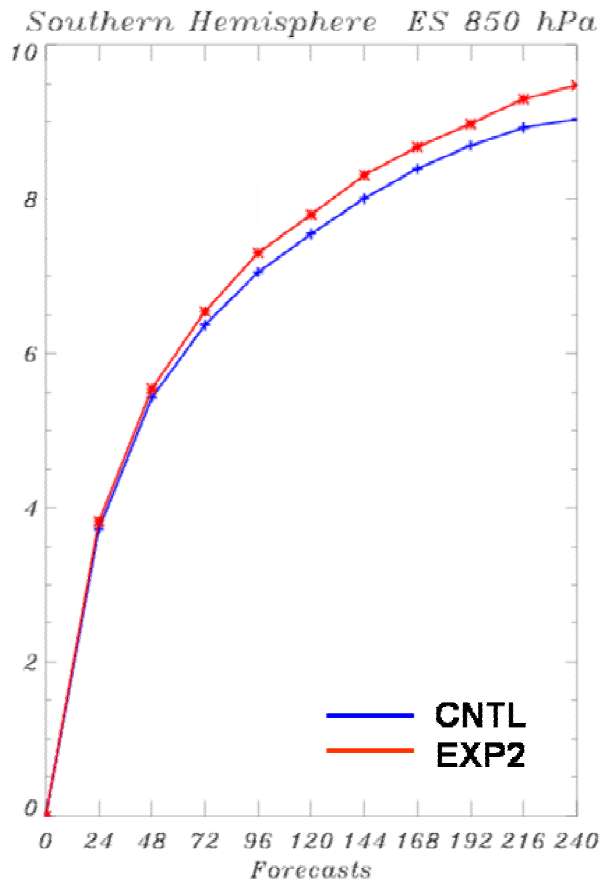


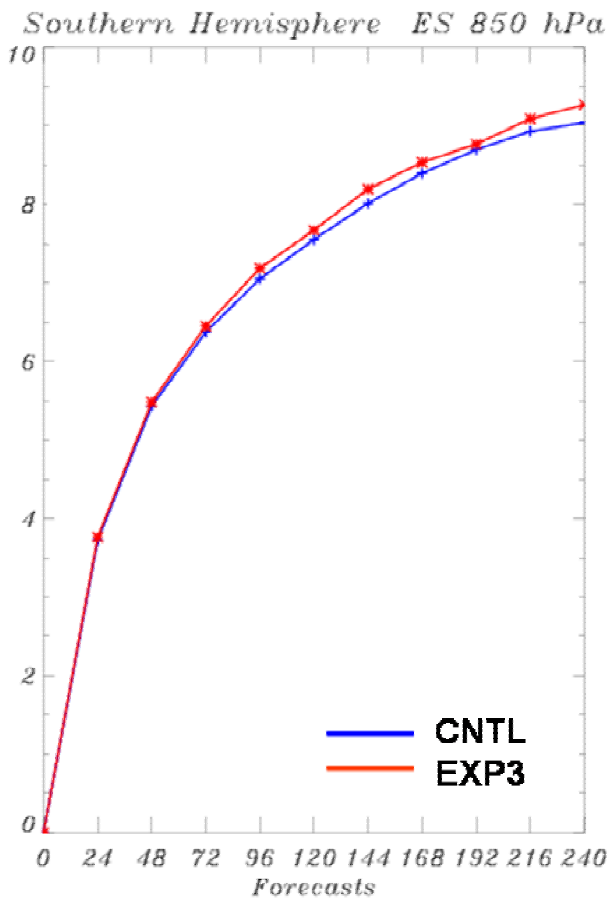


Forecast Validation Using Analyses

RMS
Dewpoint Depression, 850 hPa, Southern Hemisphere



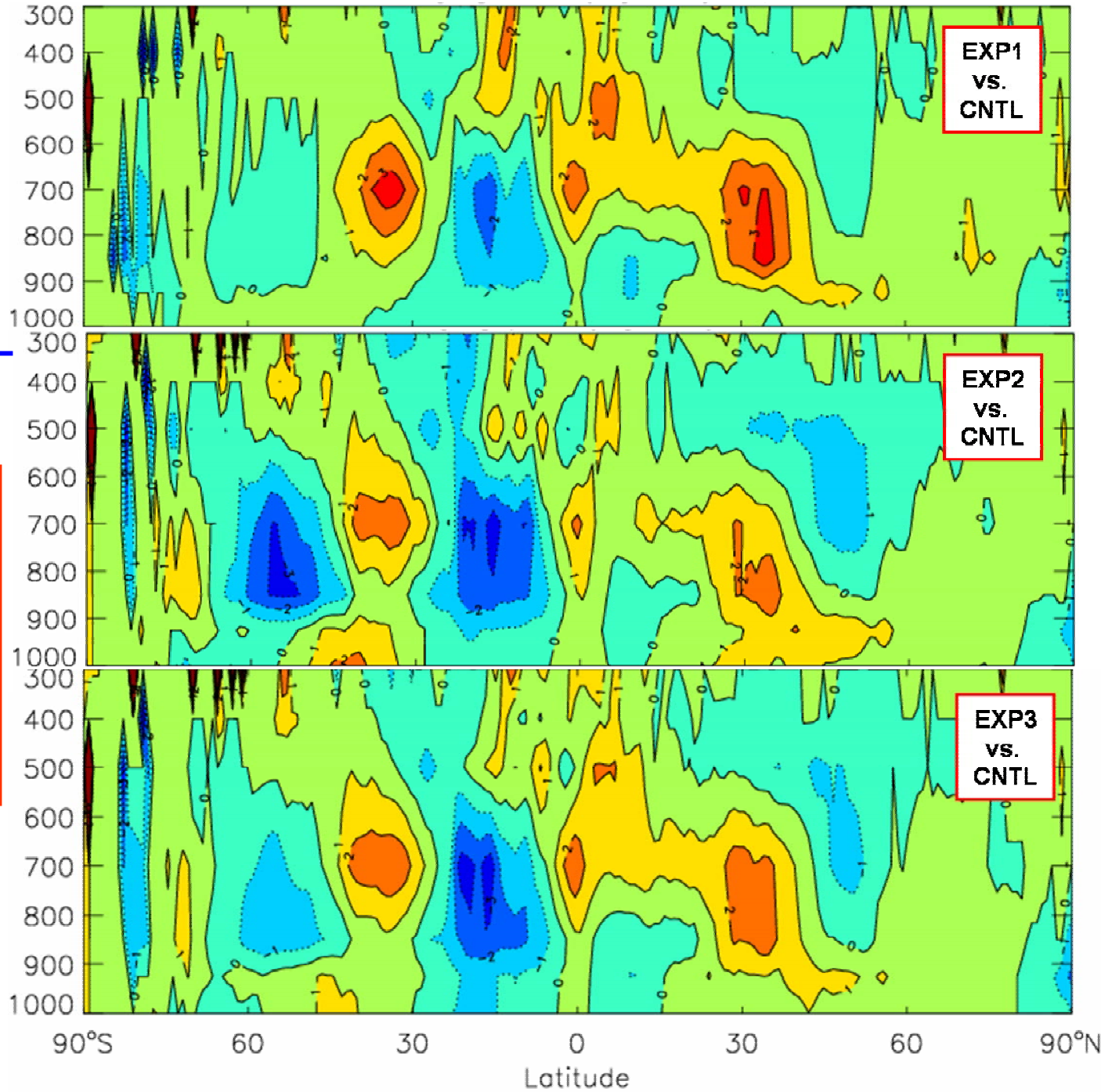




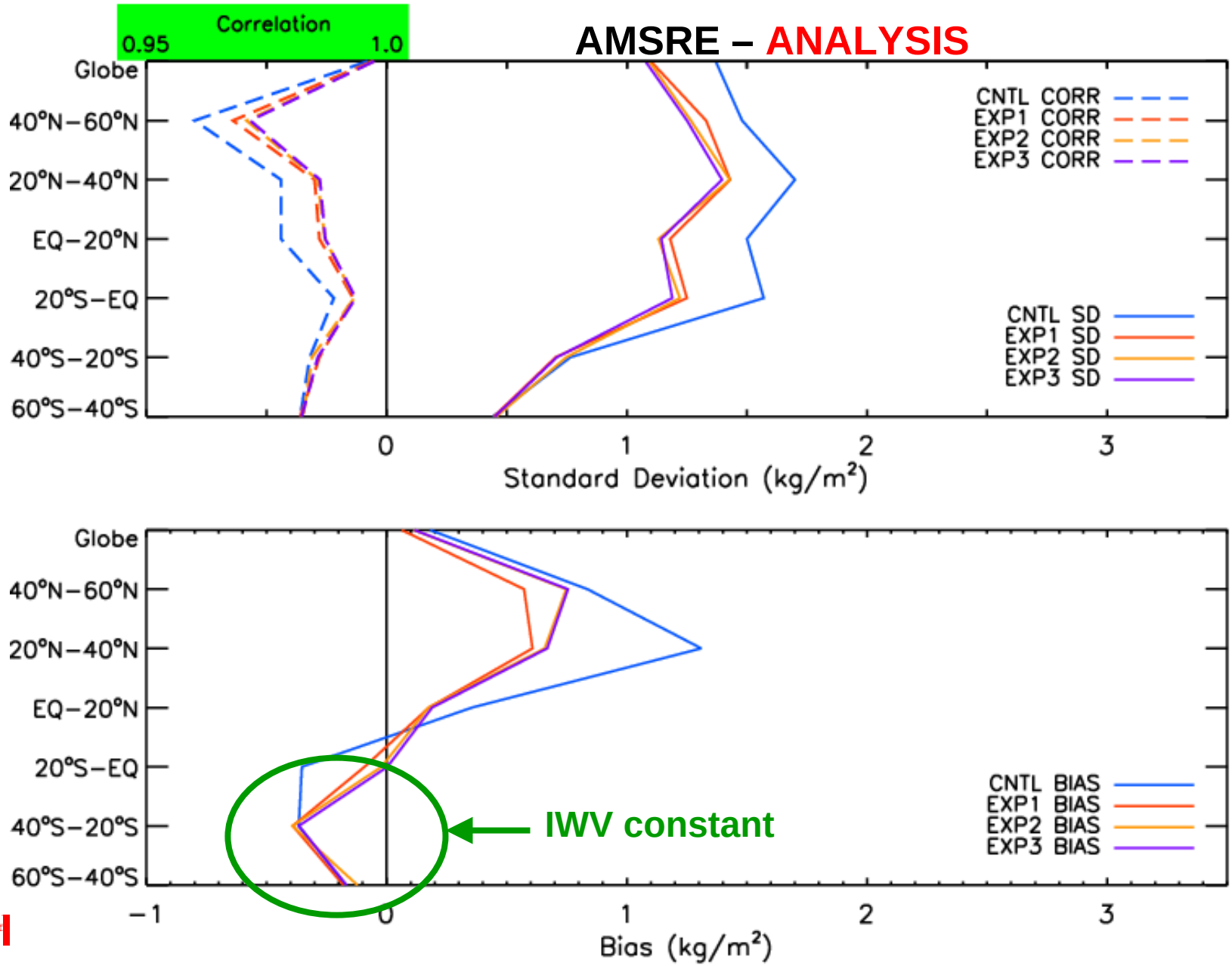
Vertical Distribution of Moisture

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

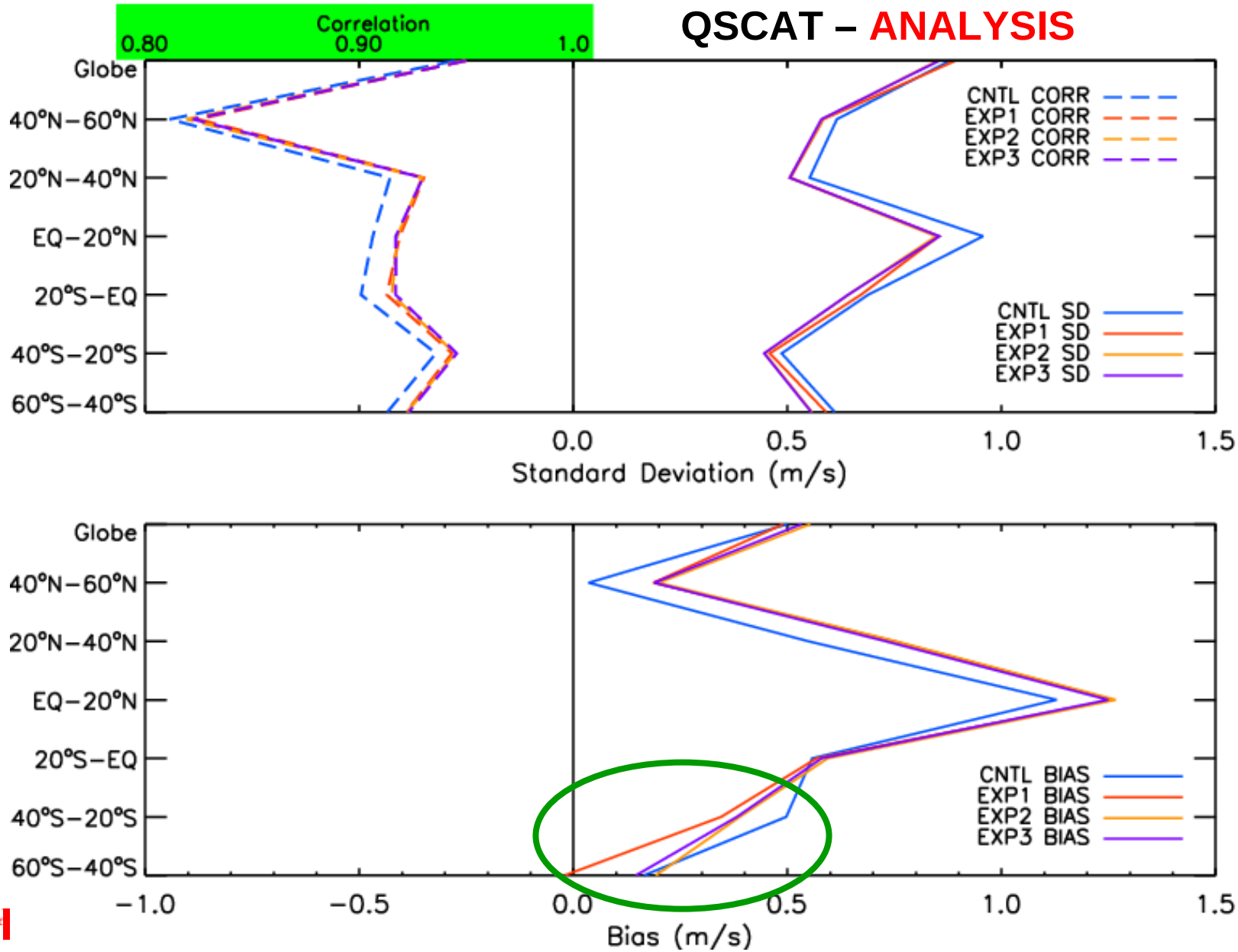
Verification of forecasts against **RAOBS** shows a neutral impact for EXP1 and small positive impacts for EXP2, EXP3

- 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

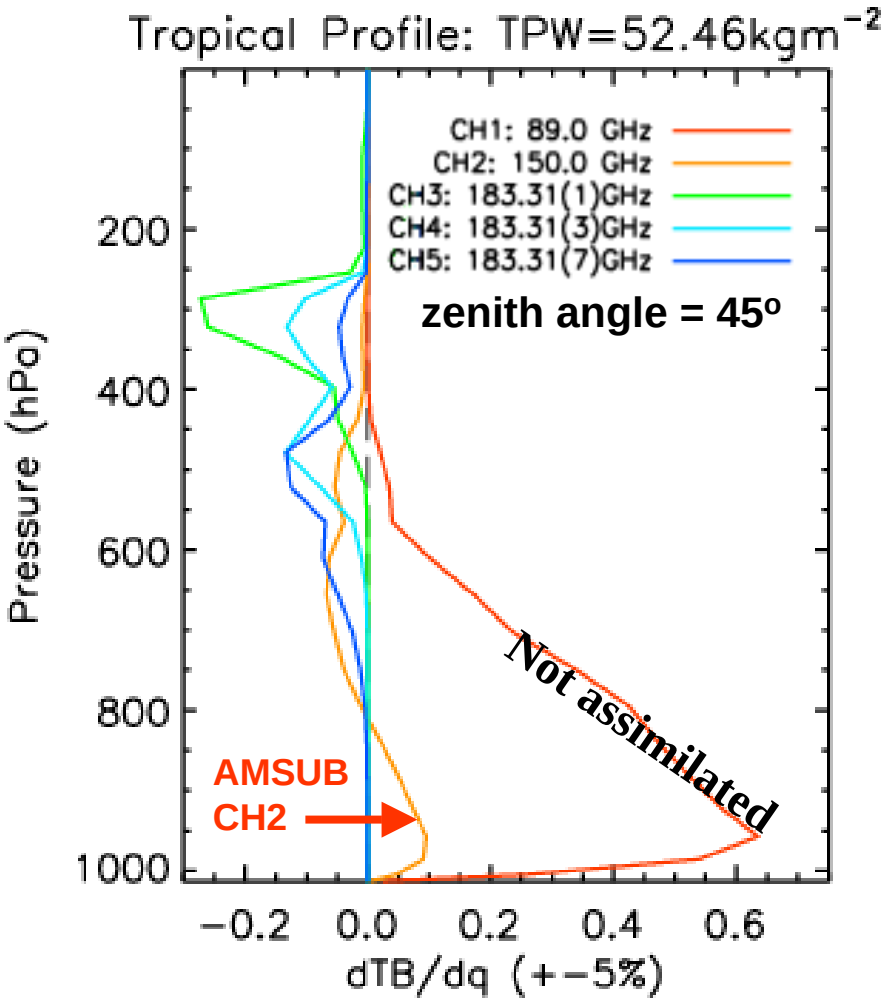
- DMSP: Defense Meteorological Satellite Program
- TRMM: Tropical Rainfall Measuring Mission
- TMI: TRMM Microwave Imager
- SSM/I: Special Sensor Microwave Imager
- AMSR-E: Advanced Microwave Scanning Radiometer for EOS
- AMSU: Advanced Microwave Sounding Unit
- GPCP: Global Precipitation Climatology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

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

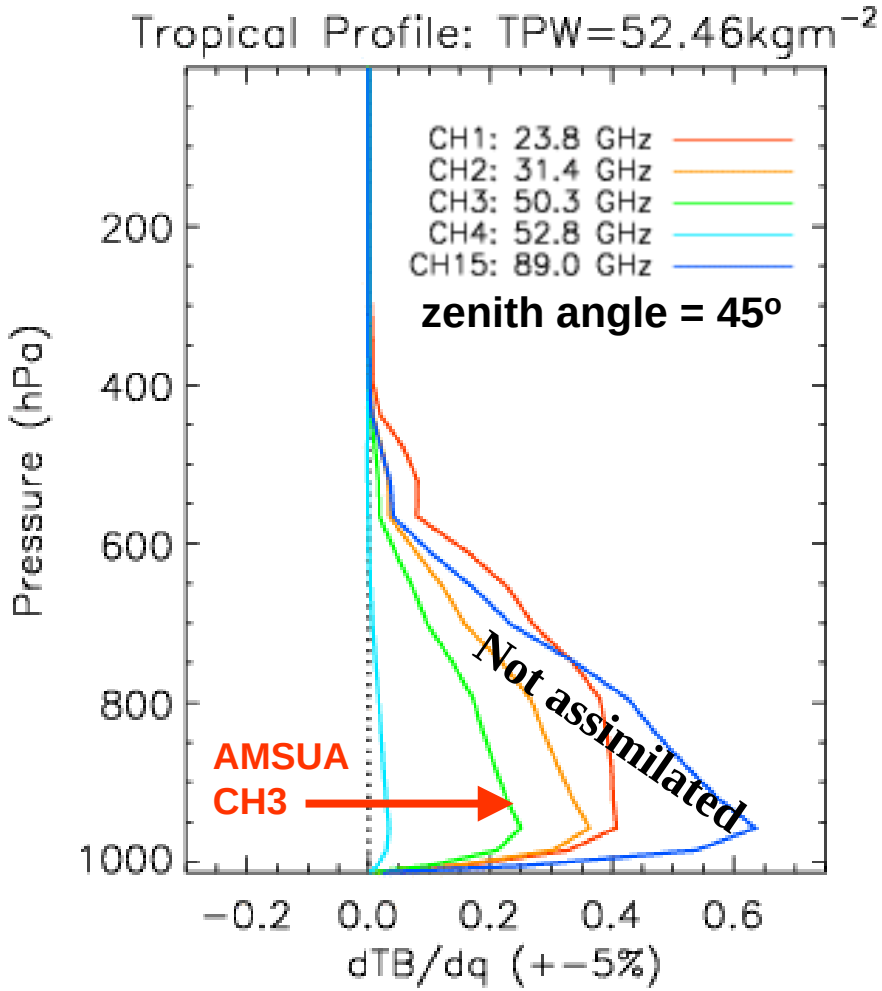


Weighting Functions wrt Humidity

AMSU-B

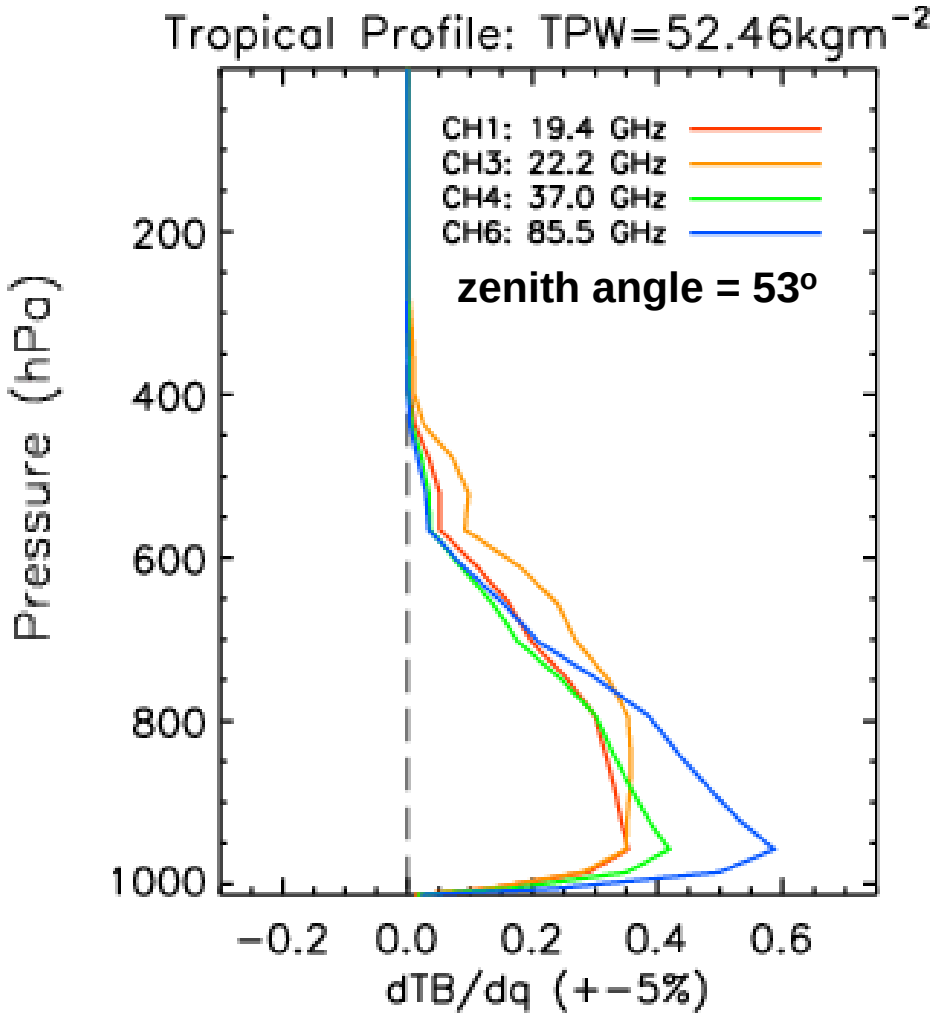


AMSU-A



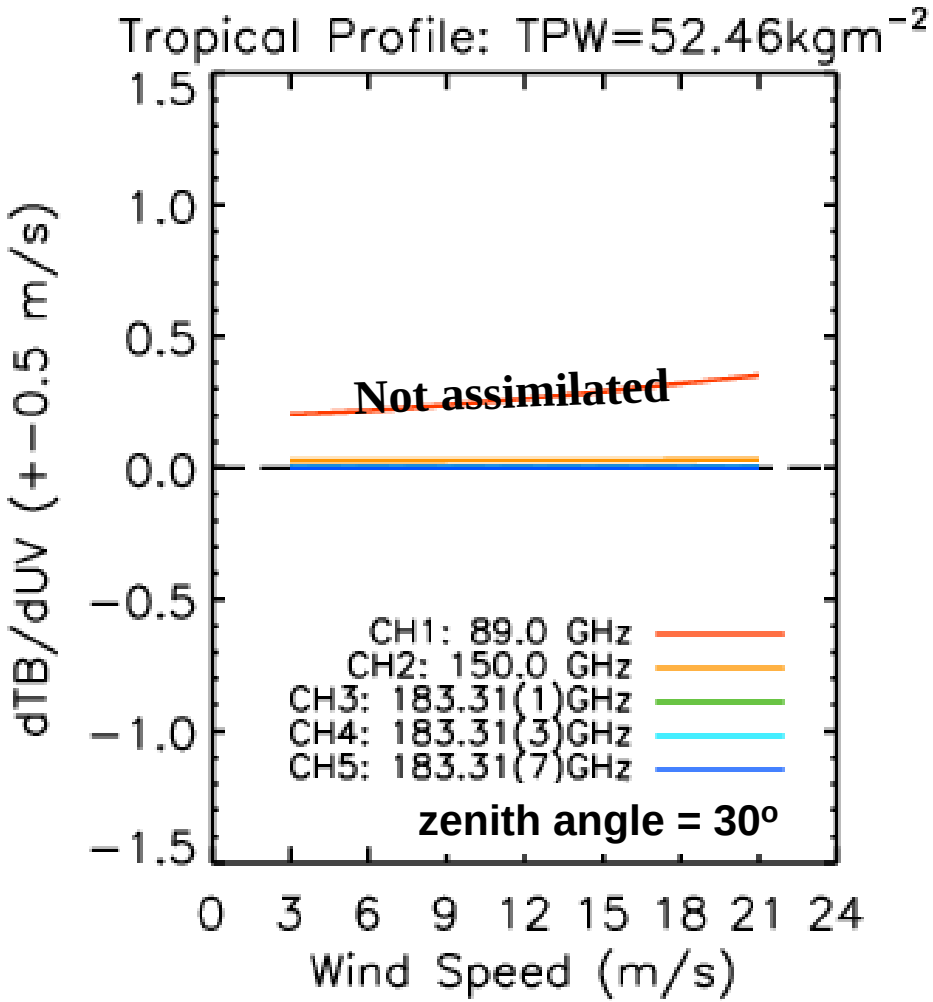
Weighting Functions wrt Humidity

SSM/I

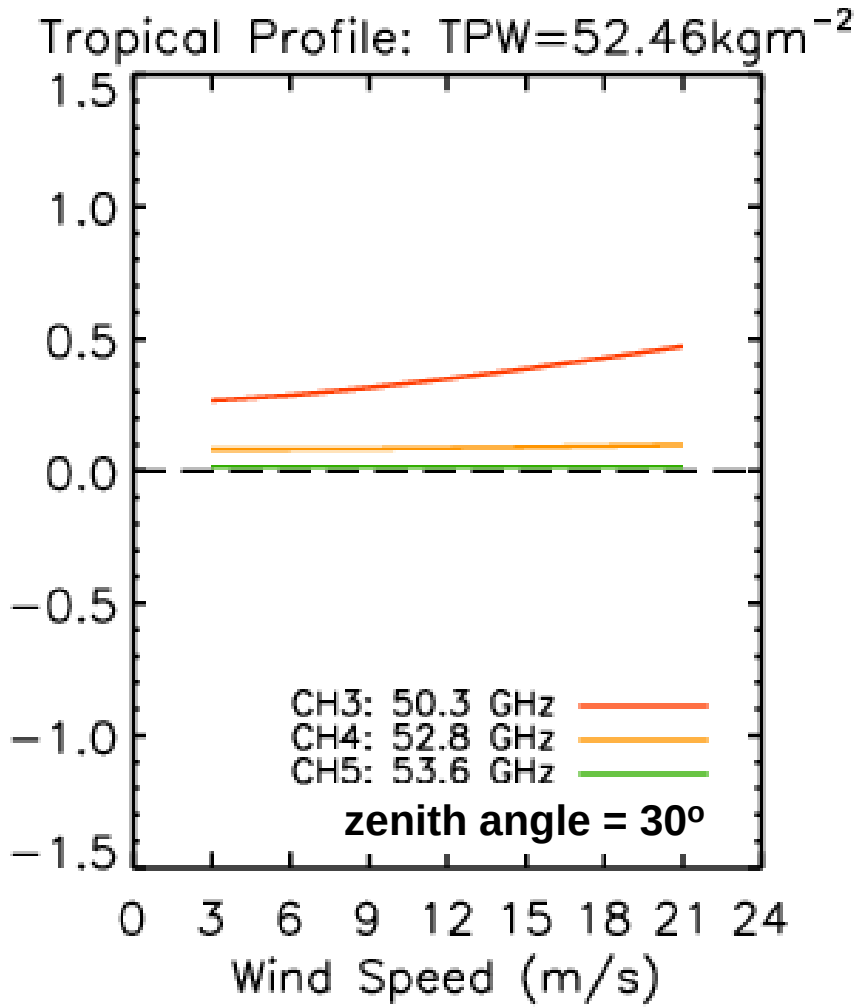


Sensitivity wrt Surface Wind Speed

AMSU-B

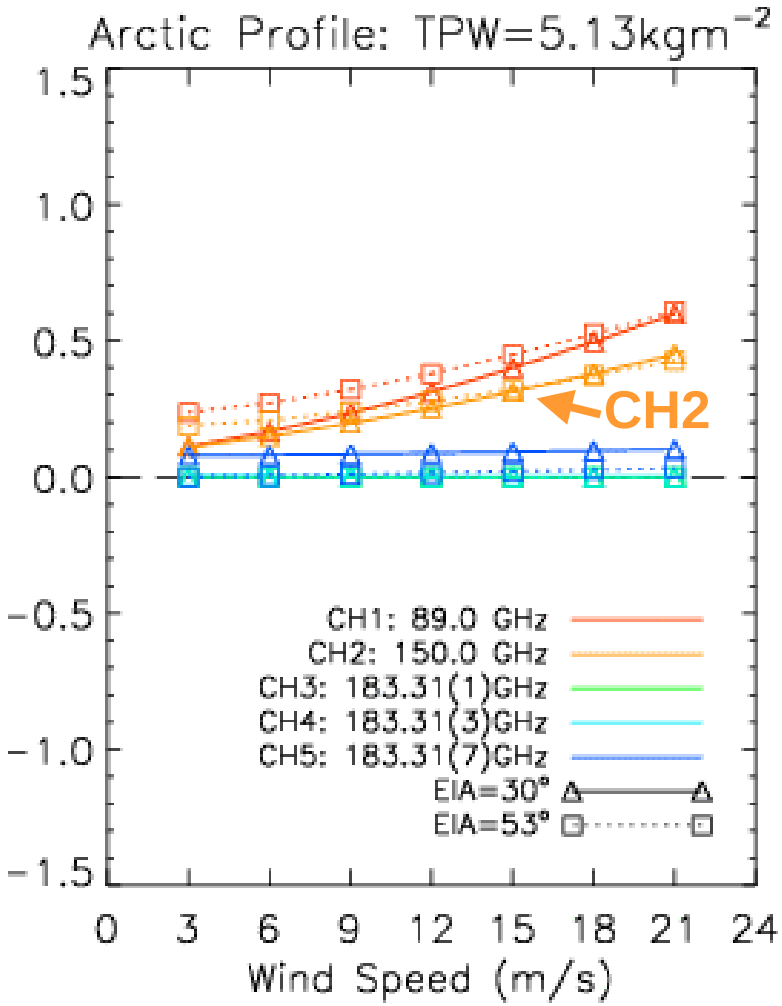


AMSU-A

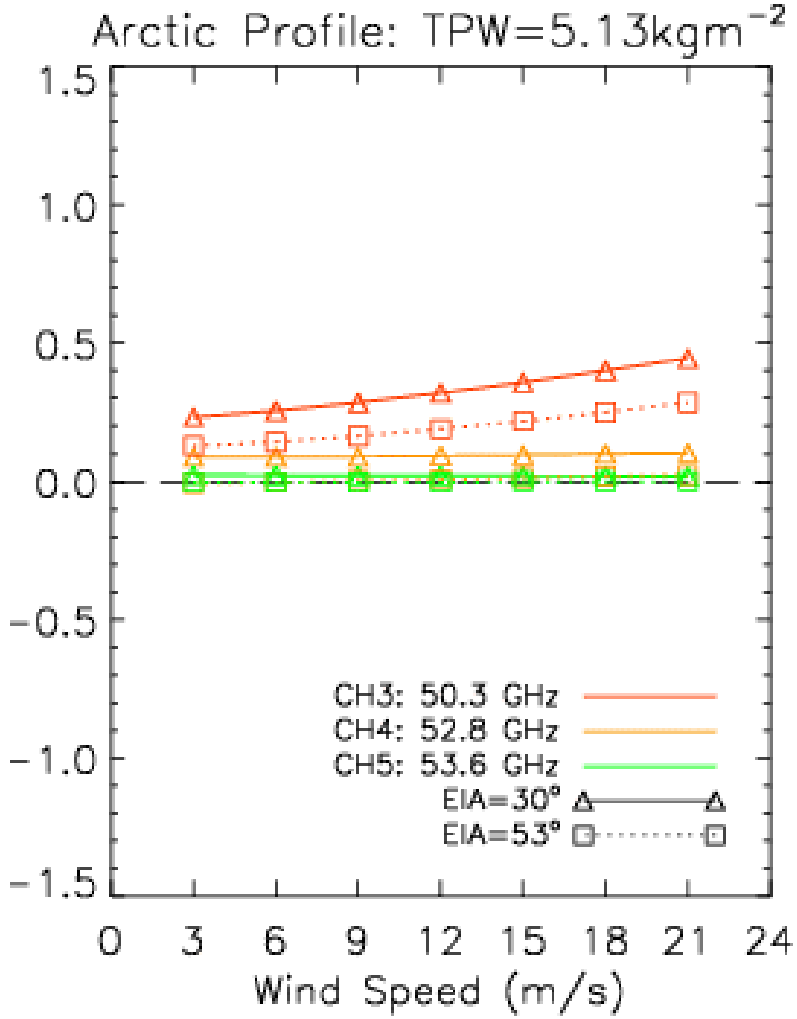


Sensitivity wrt Surface Wind Speed

AMSU-B

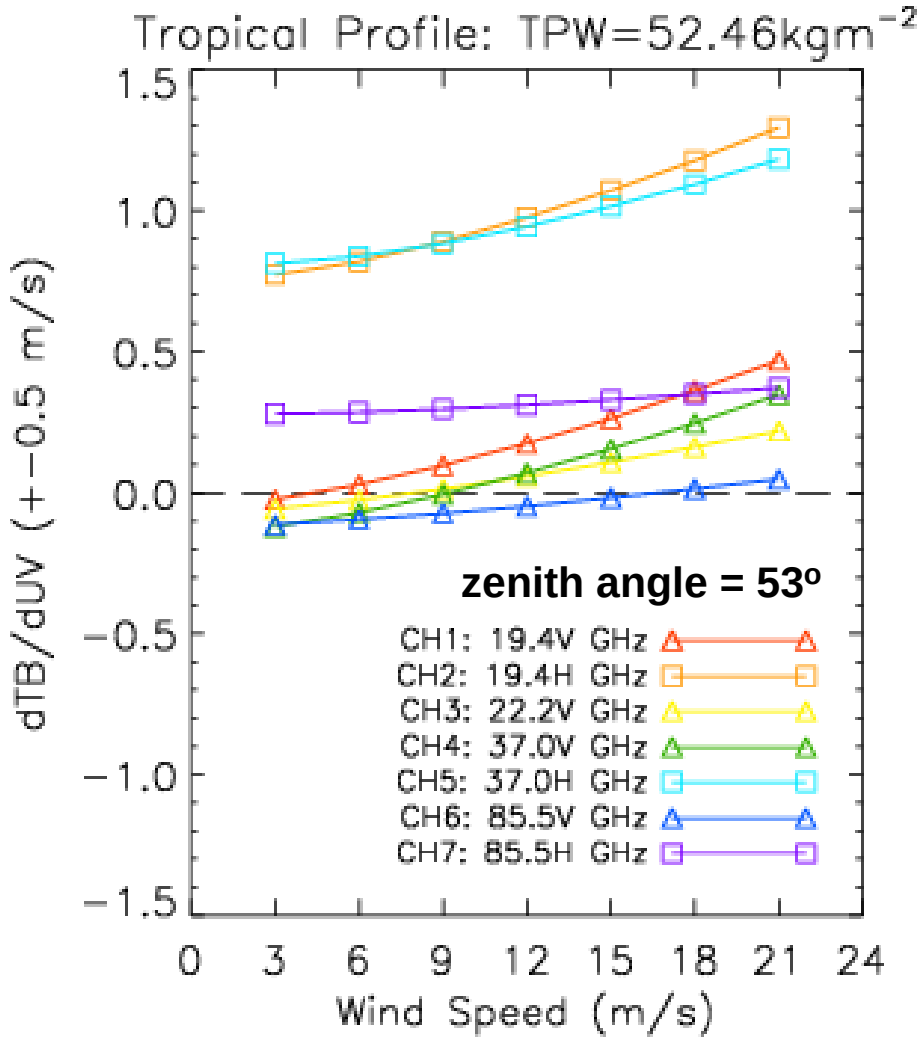


AMSU-A



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

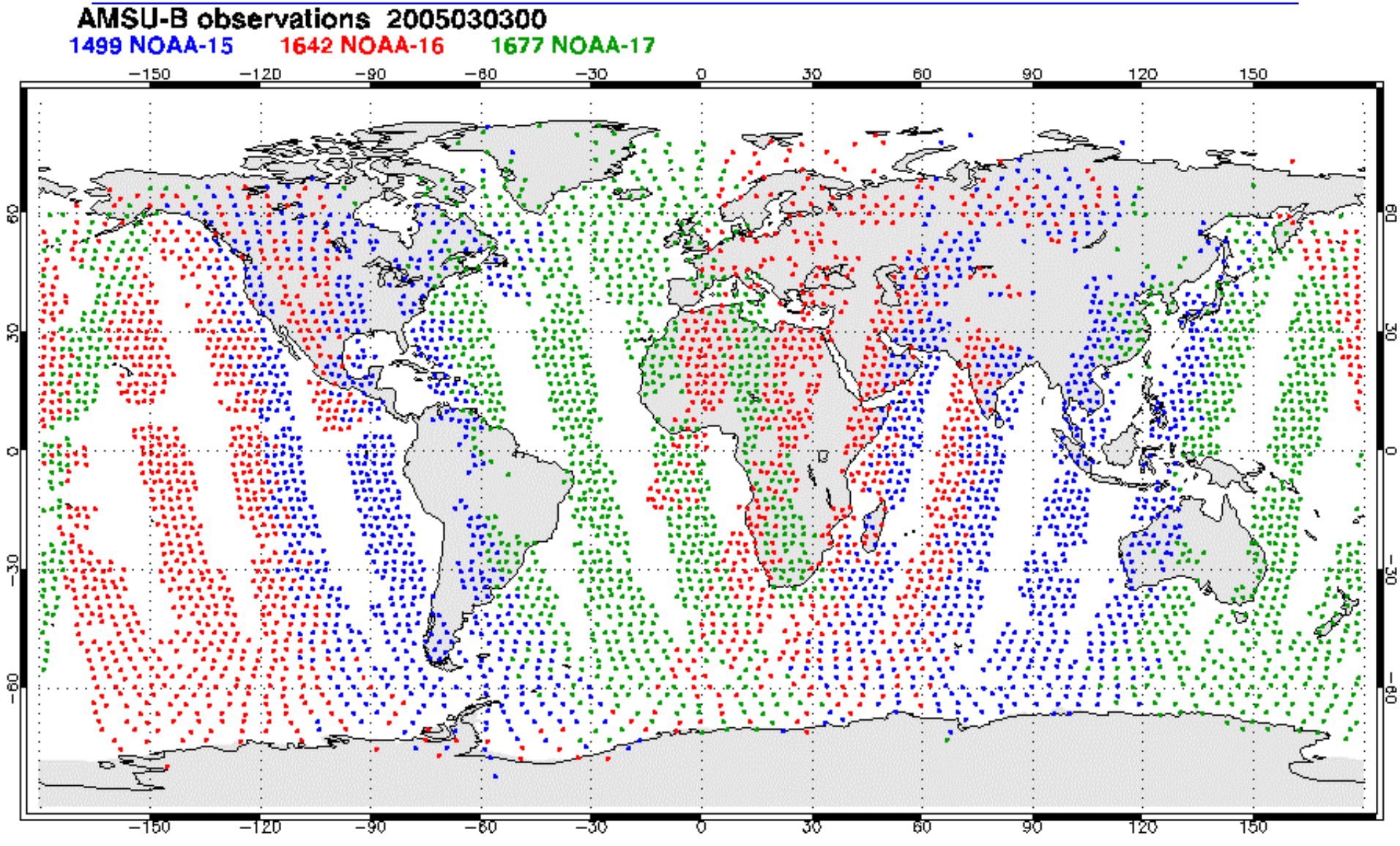
SSM/I

QuikSCAT (SWS)

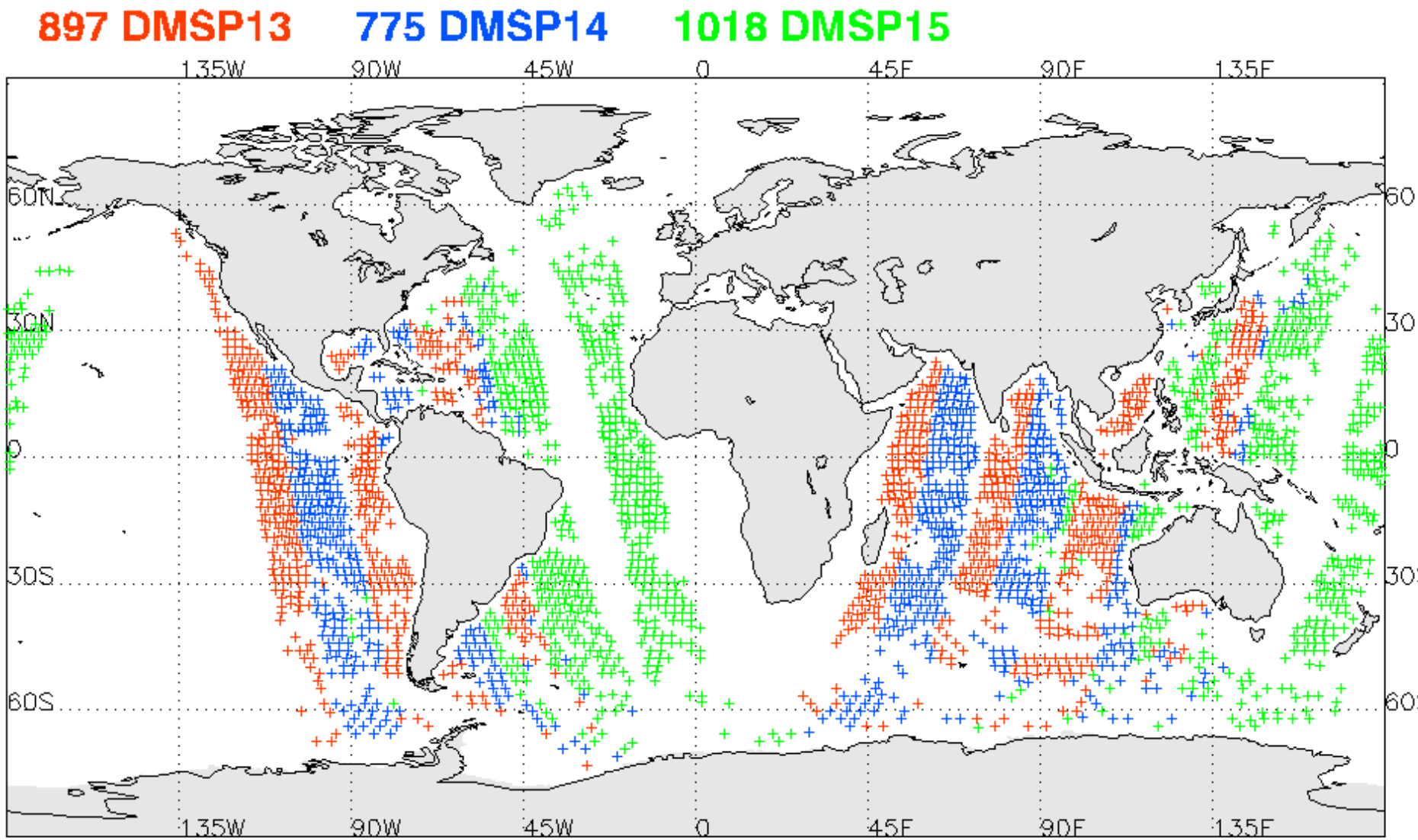
active scatterometer (MW radar)
13.4 GHz channel @ 25 km res.
Range: 3 – 20 m/s
Accuracy: 2 m/s, 20°
1800 km swath
803 km altitude

Data source: Remote Sensing Systems
www.remss.com

AMSU-B coverage after thinning



SSM/I coverage after thinning



International TOVS Study Conference, 14th, ITSC-14, Beijing, China, 25-31 May 2005. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2005.

International TOVS Study Conference, 14th, ITSC-14, Beijing, China, 25-31 May 2005. Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center, Cooperative Institute for Meteorological Satellite Studies, 2005.