An Effort toward Assimilation of F16 SSMIS UPP Data in NCEP Global Forecast System

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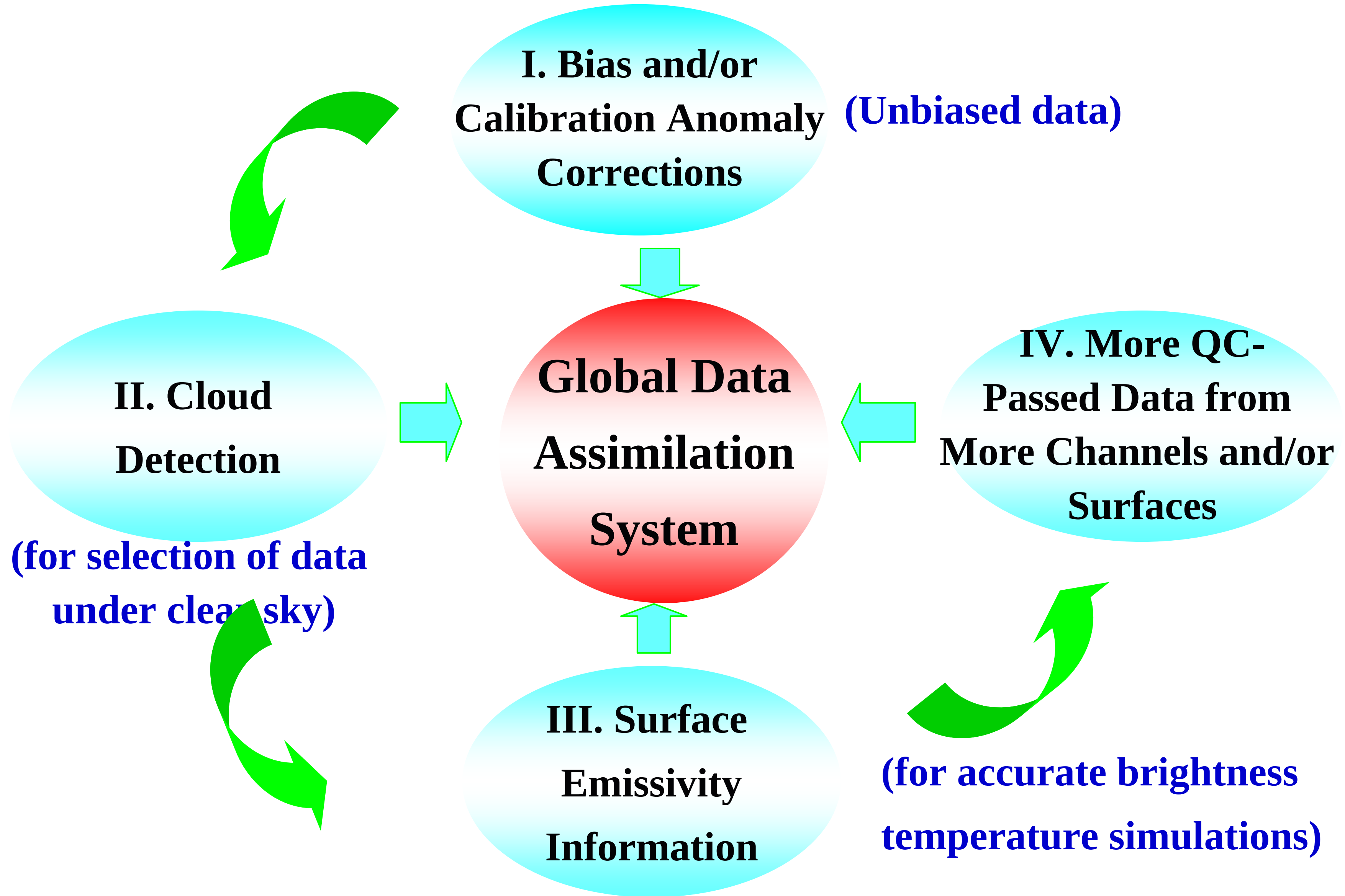
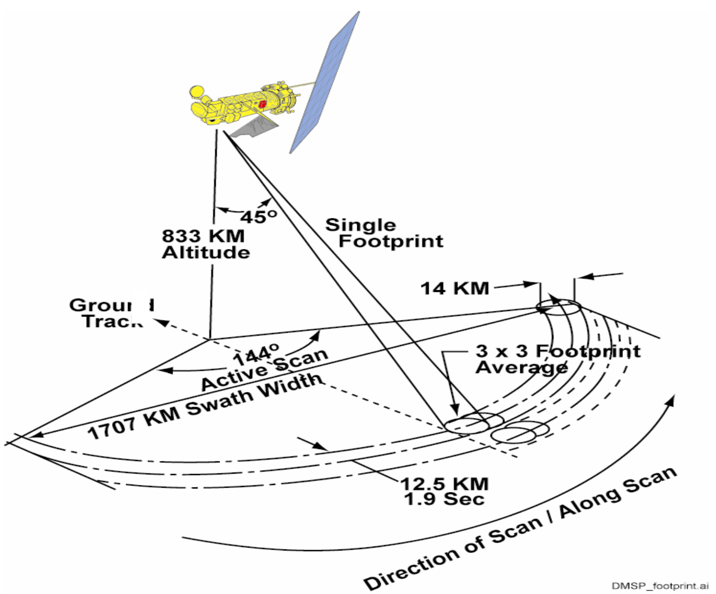
Four Major Considerations for Microwave Satellite Data Assimilation Impact Study



F16 SSMIS Key Characteristics

- 24 Channels (19-183 GHz)
- Conical Scan Geometry (45°)
  - Relatively stable peak altitude of weight function
  - Constant FOV along scan
  - Scan position dependent bias
- Calibration Anomaly: solar intrusion and antenna emission



(Kunkee et al. 2008)

TABLE 1. Channel characteristics of SSMIS sensor (Poe et al. 2001)

Channel	Center Freq.(GHz)	3-db Width (MHz)	Freq. Stab.(MHz)	Pol.	NEDT (K)	Sampling Interval(km)
1	50.3	380	10	V	0.34	37.5
2	52.8	389	10	V	0.32	37.5
3	53.596	380	10	V	0.33	37.5
4	54.4	383	10	V	0.33	37.5
5	55.5	391	10	V	0.34	37.5
6	57.29	330	10	RCP	0.41	37.5
7	59.4	239	10	RCP	0.40	37.5
8	150	1642(2)	200	H	0.89	12.5
9	183.31+/-6.6	1526(2)	200	H	0.97	12.5
10	183.31+/-3	1019(2)	200	H	0.67	12.5
11	183.31+/-1	513(2)	200	H	0.81	12.5
12	19.35	355	75	H	0.33	25
13	19.35	357	75	V	0.31	25
14	22.235	401	75	V	0.43	25
15	37	1616	75	H	0.25	25
16	37	1545	75	V	0.20	25
17	91.655	1418(2)	100	V	0.33	12.5
18	91.655	1411(2)	100	H	0.32	12.5
19	63.283248+/-0.285271	1.35(2)	0.08	RCP	2.7	75
20	60.792668+/-0.357892	1.35(2)	0.08	RCP	2.7	75
21	60.792668+/-0.357892+/-0.002	1.3(4)	0.08	RCP	1.9	75
22	60.792668+/-0.357892+/-0.0055	2.6(4)	0.12	RCP	1.3	75
23	60.792668+/-0.357892+/-0.016	7.35(4)	0.34	RCP	0.8	75
24	60.792668+/-0.357892+/-0.050	26.5(4)	0.84	RCP	0.9	37.5
Notes	(1) Sampling refers to along scan direction based on 833km spacecraft altitude. (2) NEDT for instrument temperature 0C and calibration target 260K with integration times of 8.4 msec for Channels 12-16; 12.6 msec for Channels 1-7, 24; and 25.2 msec for Channels 19-23 and 4.2 msec for Channels 8-11, 17-18. (3) Number of sub-bands is indicated by (n) next to individual 3-db width (4) RCP denotes right-hand circular polarization.					

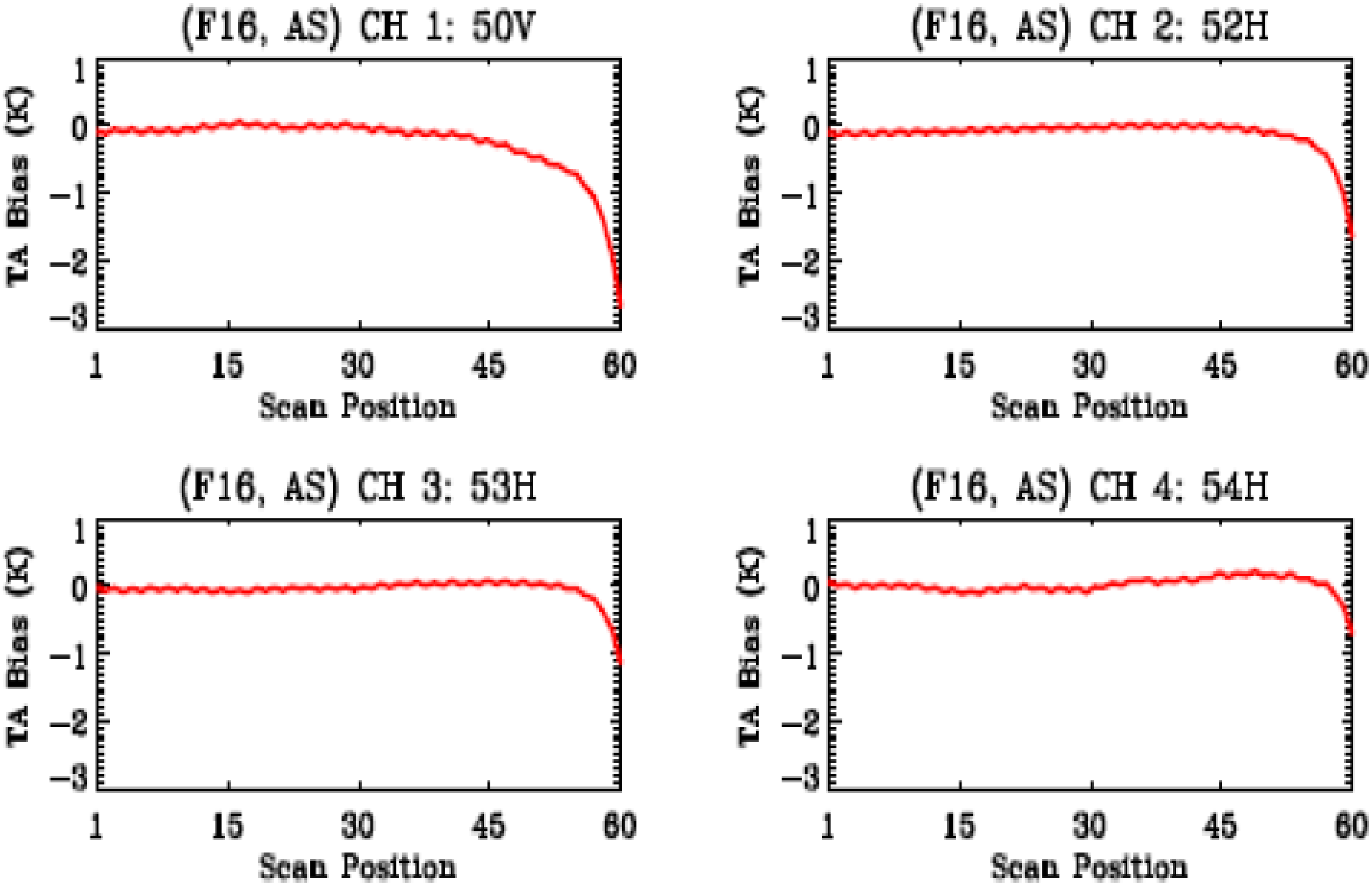
LAS

H_2O

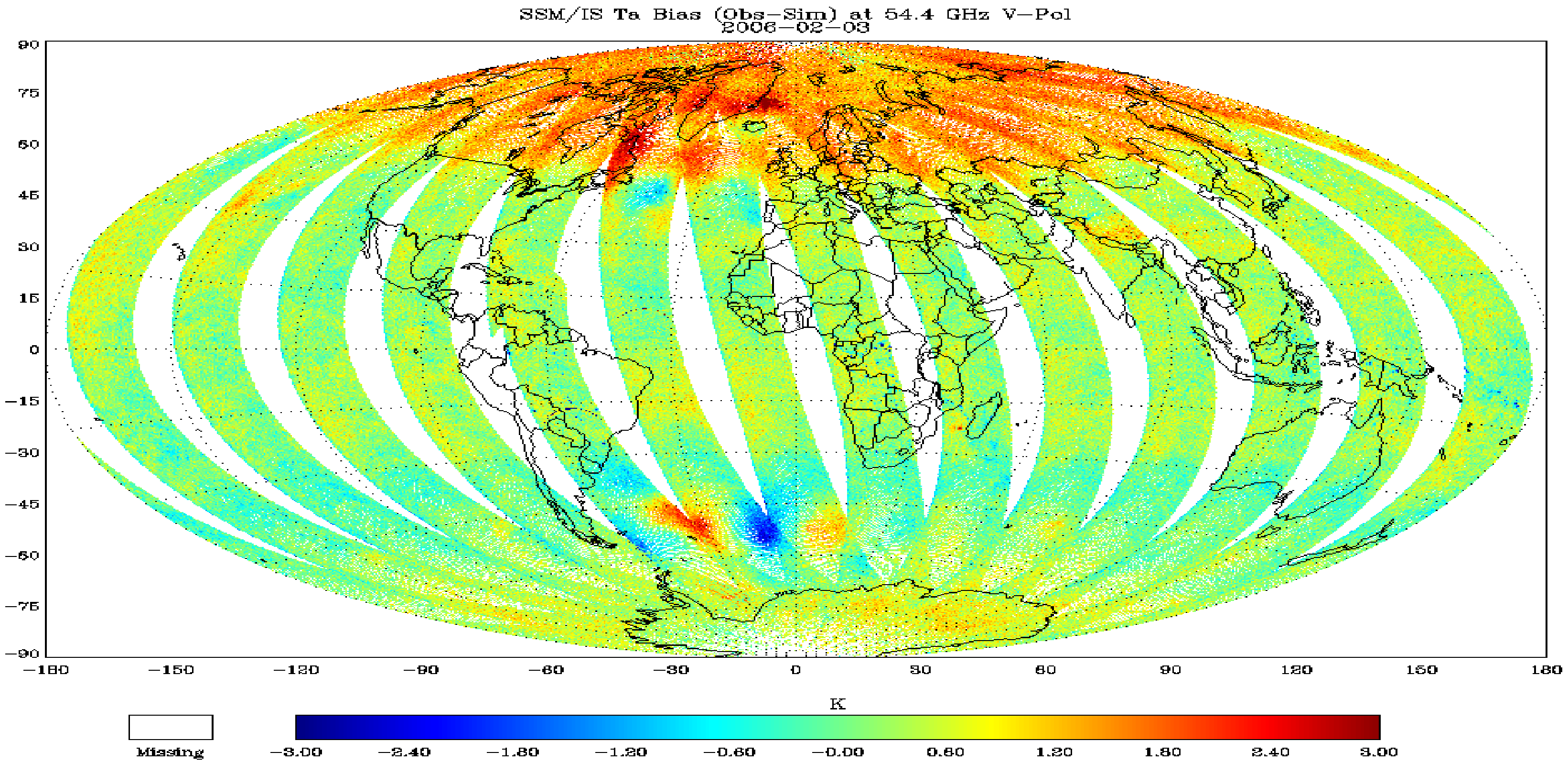
SSM/I like-CHs

UAS

Scan Dependency of F16 SSMIS



F16 SSMIS Anomaly Distribution



Shown is the difference between observed and simulated SSMIS at 54.4 GHz. The SSMIS is the first conical microwave sounding instrument, precursor of NPOESS MIS. The outstanding anomalies have been identified from three processes: 1) antenna emission after satellite out of the earth eclipse which contaminates the measurements in ascending node and small part in descending node, 2) solar heating to the warm calibration target and 3) solar reflection from canister tip, both of which affect most of parts of descending node.

No.1: **Accurate calibration anomaly and scan-dependent bias corrections for F16 SSMIS data since forecast model uses unbiased data**

F16 SSMIS Calibration Anomaly Correction

- **NRL/UK MetOffice SSMIS Unified Pre-Processor (UPP)**
  - Correct antenna emission for LAS
  - Removal of warm load anomaly
  - Doppler shift correction for UAS
  - Spatial averaging to reduce to the sub-Kelvin levels

- **NESDIS SSMIS Pre-processor**
  - Correct antenna emission for LAS
  - Removal of warm load anomaly
  - UAS bias removal using SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) measurements simulated as truth
  - Spatial filter for noise reduction
  - Linear mapping of SSMIS imager to its predecessor (SSM/I) using the F15 and F16 Simultaneous Conical Overpass observations
  - Inter-sensor calibration for SSMIS imager non-linearity (for climate reprocessing)

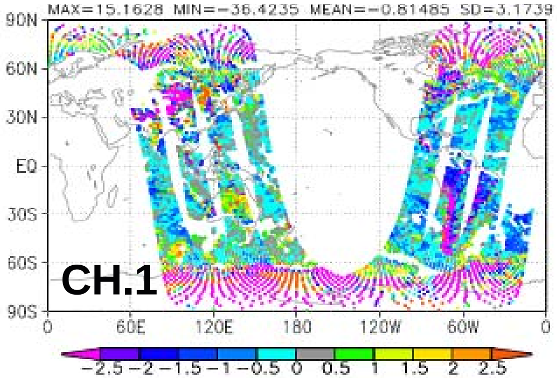
Microwave Sensors Bias Correction in NCEP GDAS

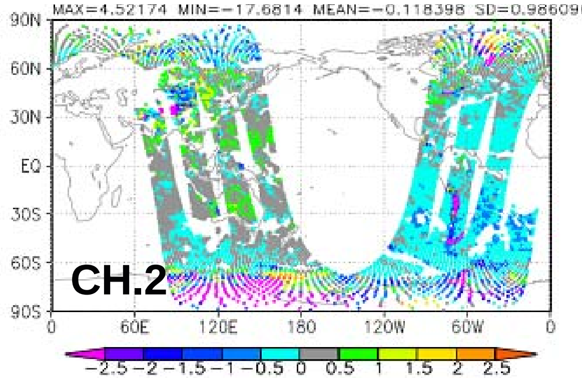
- Angle dependent (Cross-track sensors)
- Scan beam position dependent (Conic scanning sensors)
- Simple non-linear equation to predict bias
  - Control vector augmented by Coefficients (additional analysis variables)
  - Predictors scaled so that same background error variance used for each coefficient
  - Major predictors
    - Scan angle or scan position
    - Lapse rate (Γ)
    - Lapse rate squared (Γ^2)

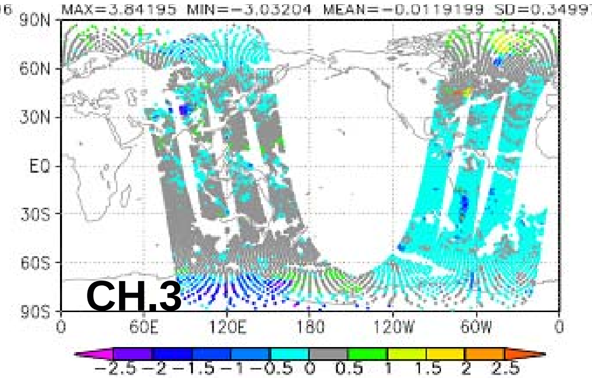
$$\Delta T_B = \Delta T_B^{SCAN}(n) + a_1\Gamma + a_2\Gamma^2 + ..$$

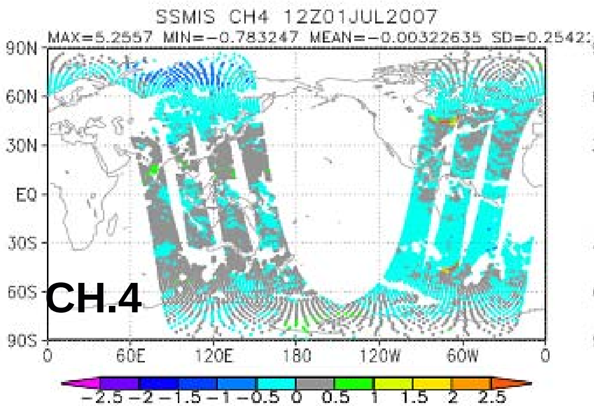
(Derber and Wu)

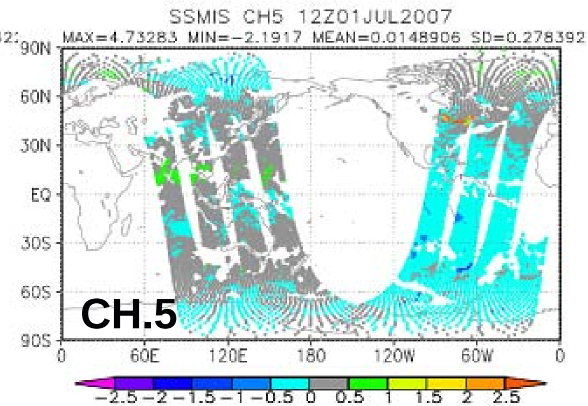
TB (Observation) – TB (Simulation) Differences (DTB) for F16 UPP at LAS Channels (WBC)

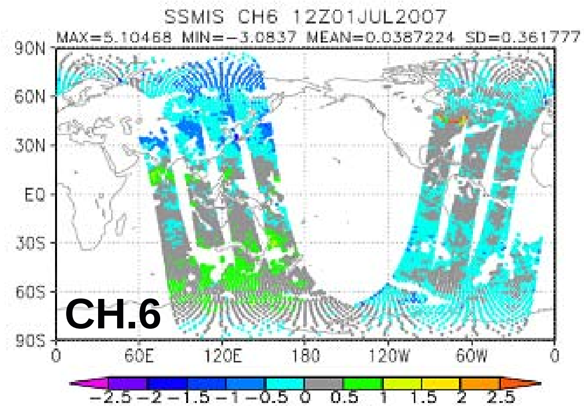


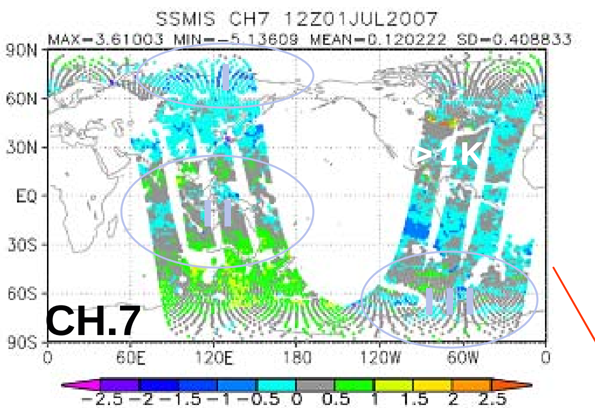








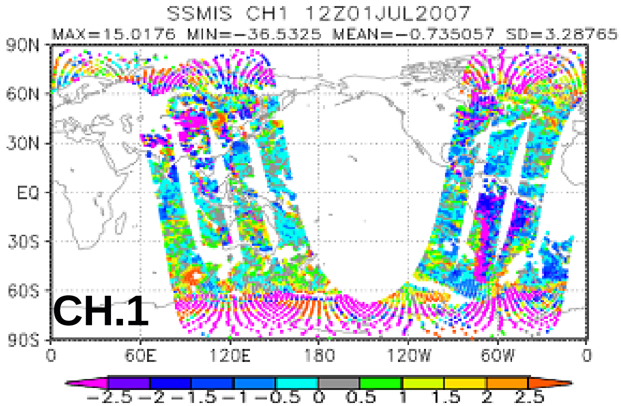


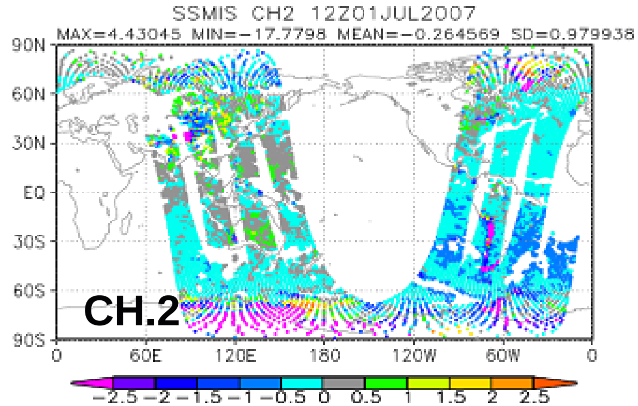


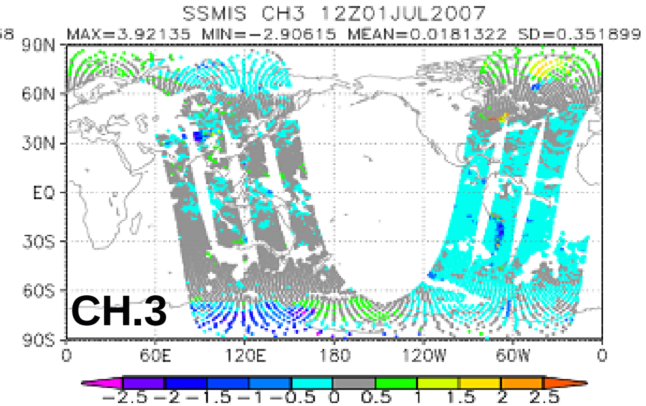
CH.	ΔT_B(wobc)	ΔT_B(wbc)	σ (wobc)	σ (wbc)
1	0.74	0.82	3.29	3.17
2	0.26	0.12	0.98	0.99
3	0.02	0.01	0.35	0.35
4	0.38	0.00	0.25	0.25
5	0.21	0.01	0.30	0.28
6	0.57	0.04	0.45	0.36
7	1.71	0.12	0.48	0.41

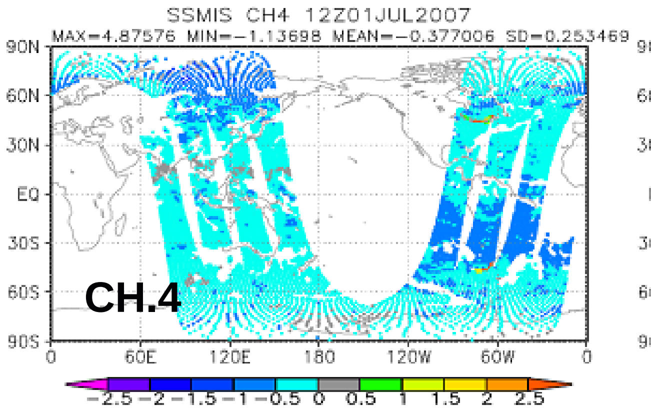
Regionally dependent bias after bias correction

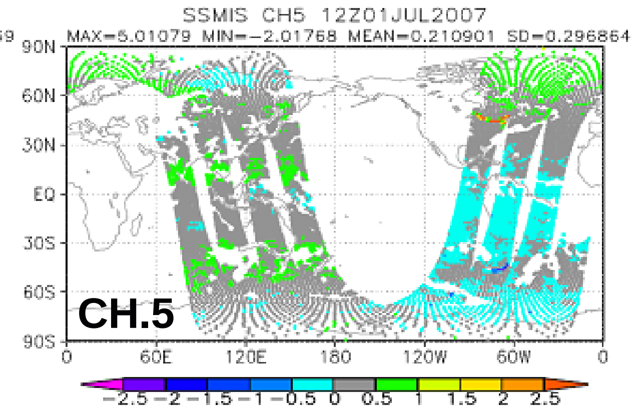
UPP DTB Distributions at LAS Channels (WOBC)

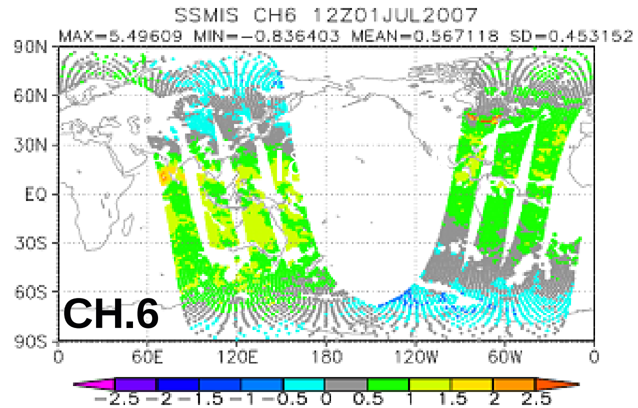


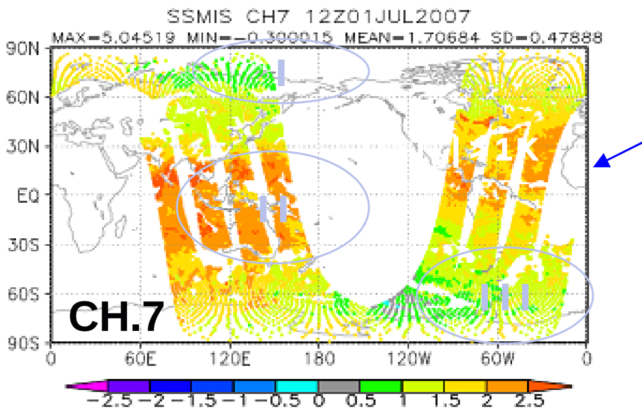






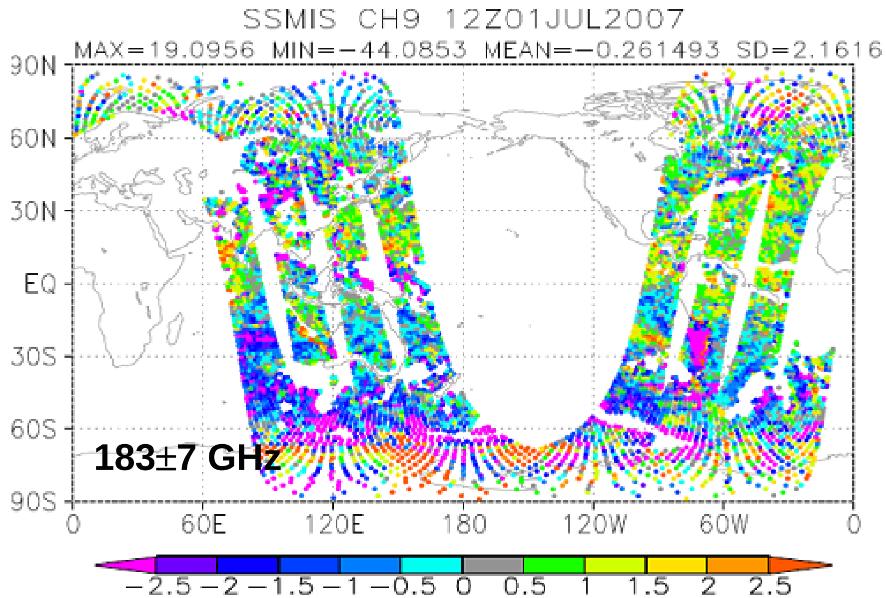


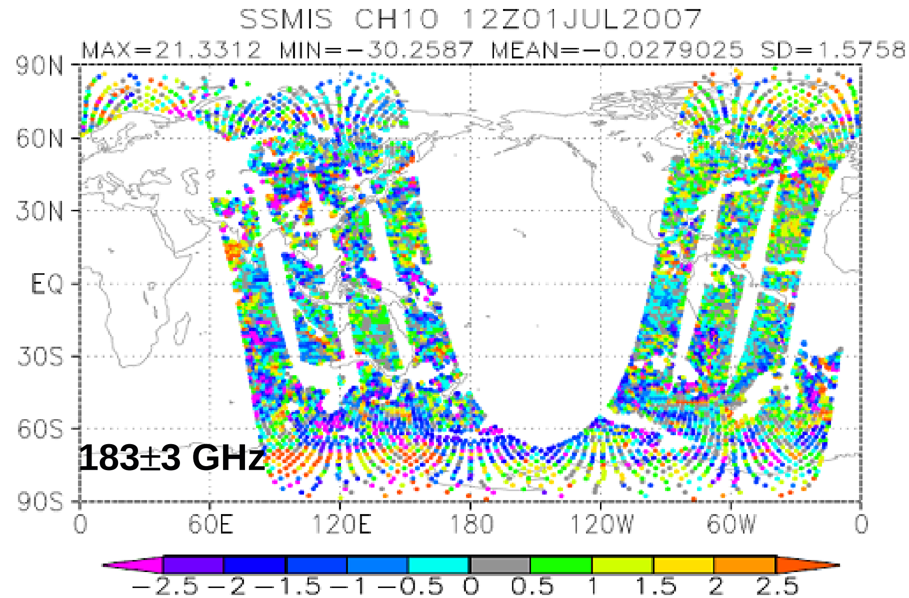


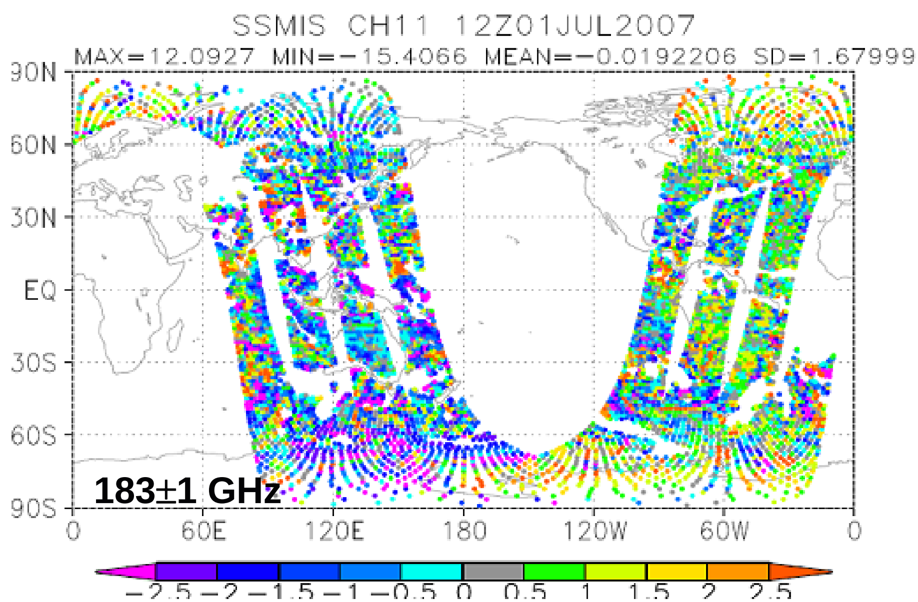


There remain some regional biases after calibration anomaly correction in SSMIS UPP data.

UPP DTB Distributions at Water Vapor Channels (WBC)

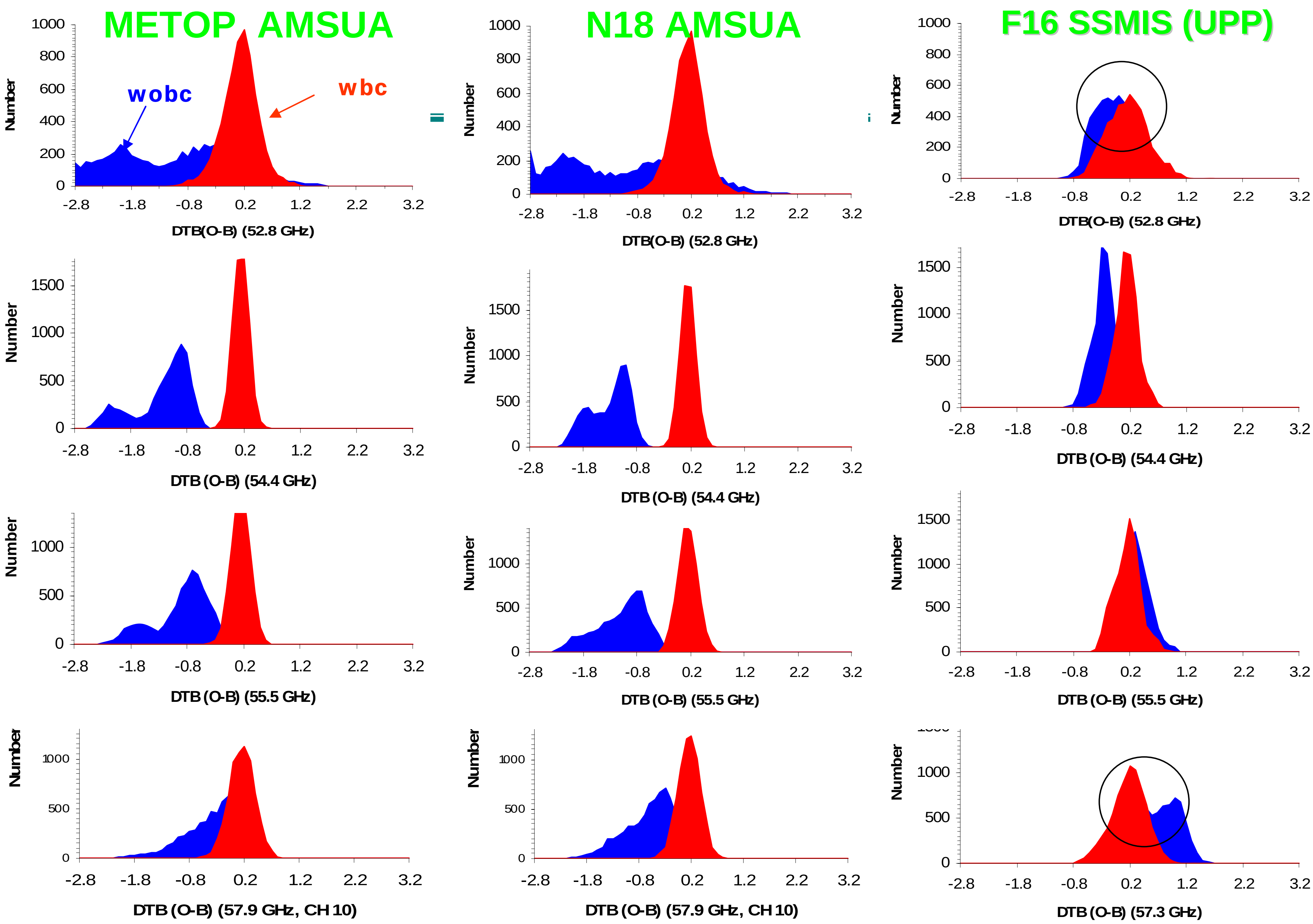






f_0	ΔT_B	σ
183±7	0.26	2.17
183±3	0.03	1.58
183±1	-0.01	1.73

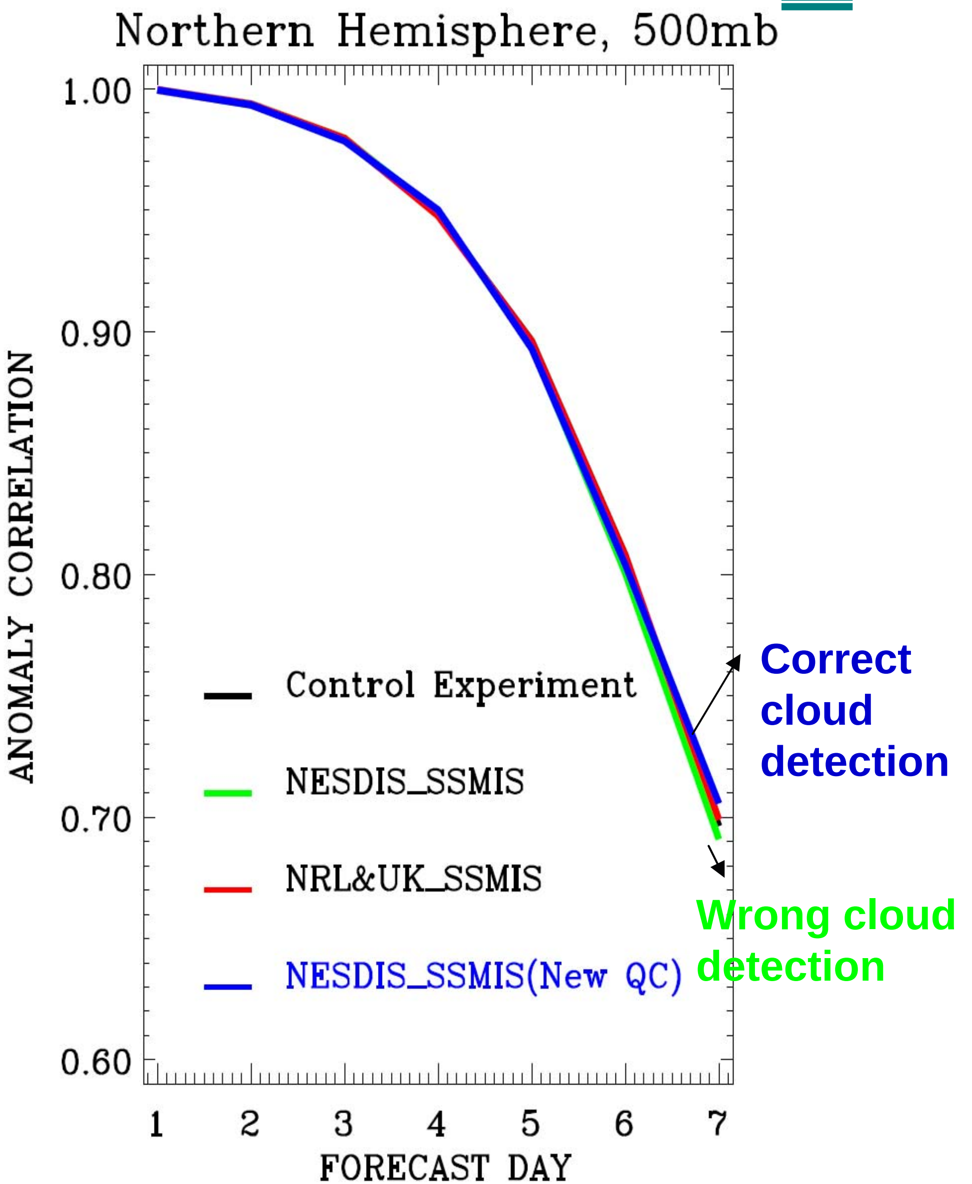
O – B Histograms for QC Passed Data over (Cloud-free) Oceans



No.2: A reliable cloud detection for selection of UPP data under clear sky

Cloud Detection Algorithm & Assimilation Impact

- Over oceans: SSM/I CLW heritage algorithm (Weng &Grody, 1994), where SSMIS TBs are remapped to SSM/I TB (Yan &Weng, TGRS, 2008)
- Over land: a newly developed cloud detection algorithm is used.
- SSMIS IWP algorithm is developed by Sun & Weng (2008, TGRS) based on the AMSU IWP heritage algorithm by Zhao & Weng (2002, JAM).



No. 3: Reliable surface emissivity information for accurate SSMIS brightness temperature simulations

Data Assimilation Scheme

Significance? In satellite data assimilation scheme, the cost function is defined as

$$J = \frac{1}{2}\left(\mathbf{x}-\mathbf{x}^{b}\right)^{T}\mathbf{B}^{-1}\left(\mathbf{x}-\mathbf{x}^{b}\right)+\frac{1}{2}\left[\mathbf{I}(\mathbf{x})-\mathbf{I}^{o}\right]^{T}(\mathbf{E}+\mathbf{F})^{-1}\left[\mathbf{I}(\mathbf{x})-\mathbf{I}^{o}\right]$$

Satellite Observations

RTM Simulations

where

$\mathbf{x}$ is a vector related to atmospheric and surface parameters.

$\mathbf{I}_0$ is the observed radiance vector

$\mathbf{I}$ is the radiance vector

$\mathbf{B}$ is the error covariance matrix of background

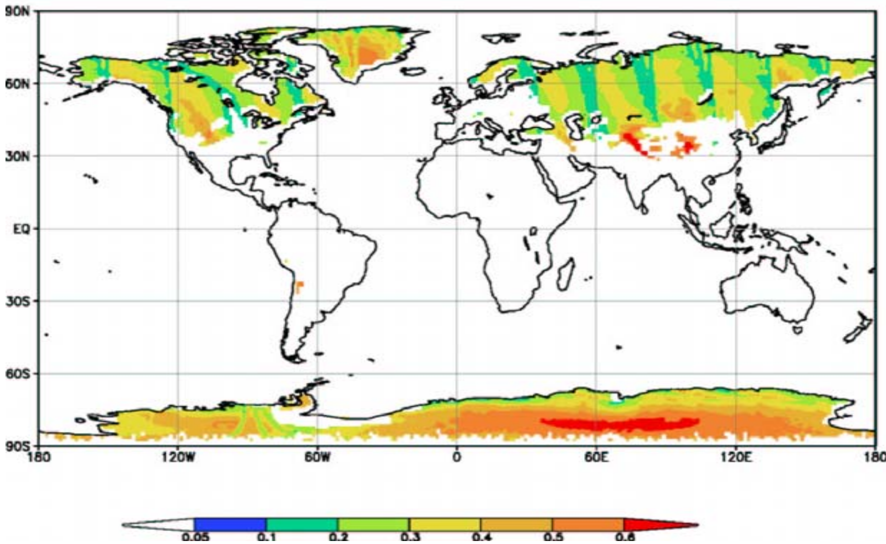
$\mathbf{E}$ is the observation error covariance matrix

$\mathbf{F}$ is the radiative transfer model error matrix

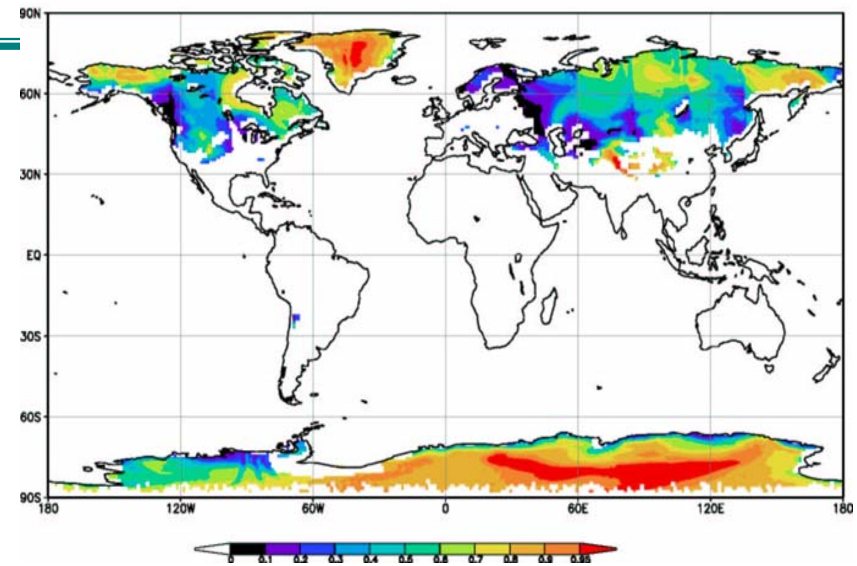
With a surface emissivity model, the difference dT_B (=I(X)-I^O) is calculated and further is used to adjust the surface and atmospheric parameters

Atmospheric Transmittance at Four Sounding Channels

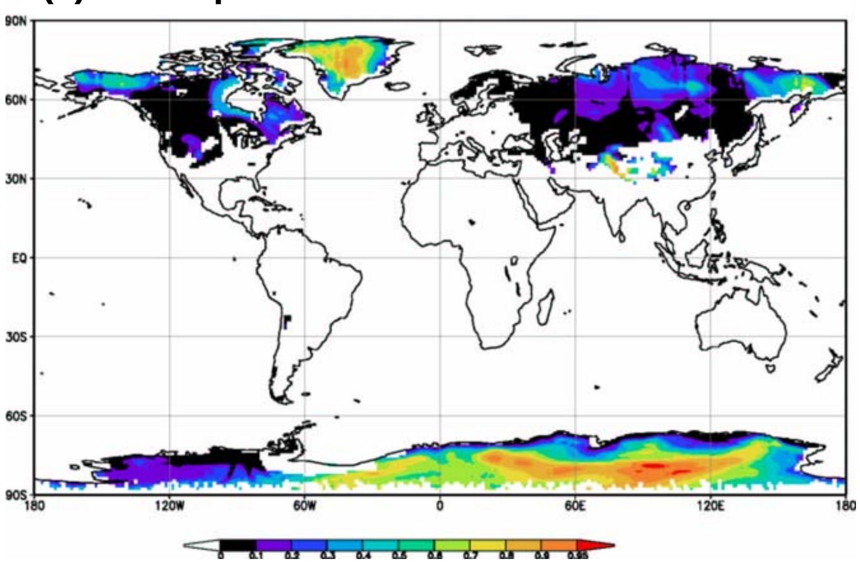
(a) Atmospheric Transmittance at 52.8 GHz



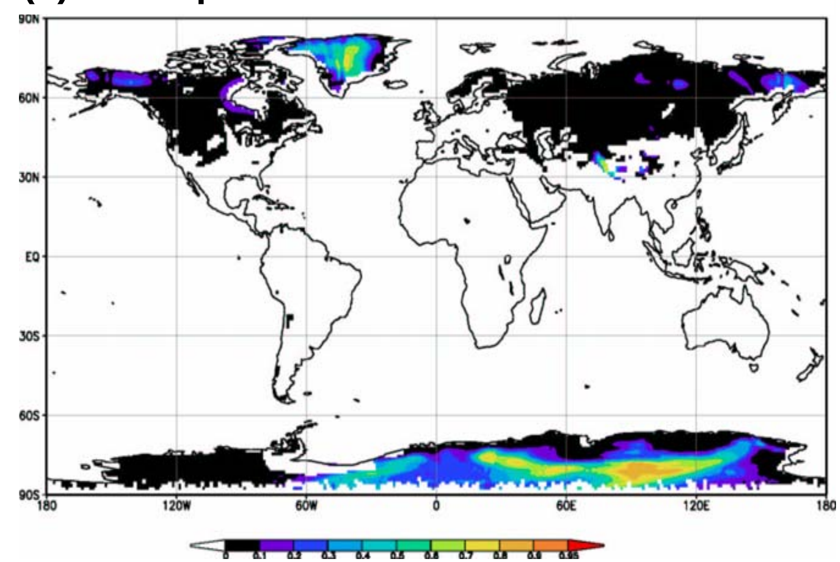
(b) Atmospheric Transmittance at 183±7 GHz



(c) Atmospheric Transmittance at 183±3 GHz



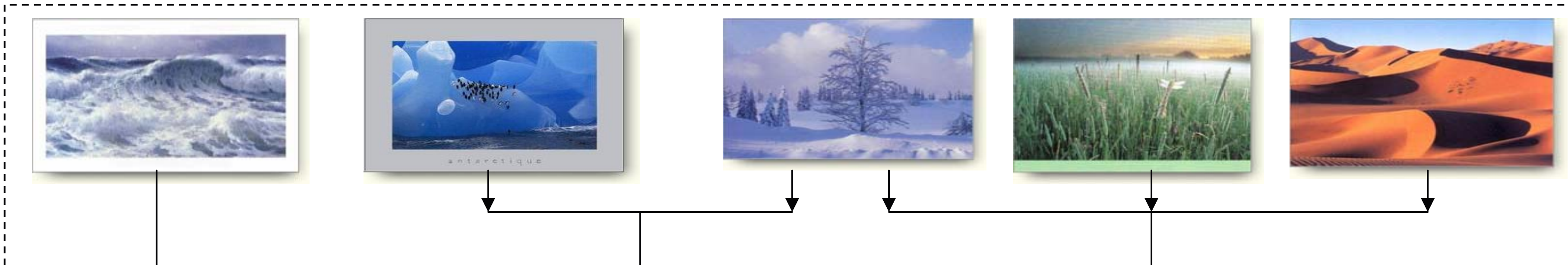
(d) Atmospheric Transmittance at 183±1 GHz



Microwave Surface Emissivity Models

Five Surface Types

Ocean Sea Ice Snow Canopy (bare soil) Desert



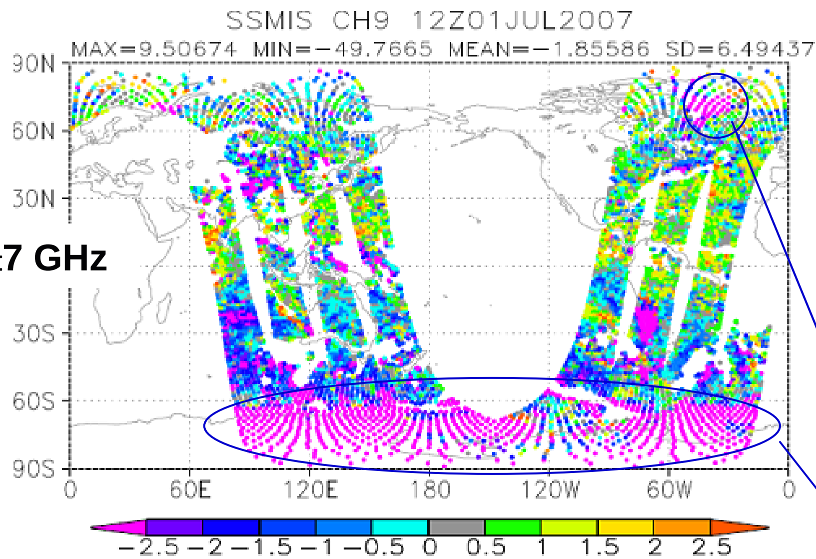
A microwave land emissivity model (LandEM) was developed by F. Weng, B. Yan, N. Grody (JGR, 2001)

Empirical snow and sea ice emissivity algorithm using microwave satellite window channels of measurements (B. Yan and F. Weng, 2003; 2008)

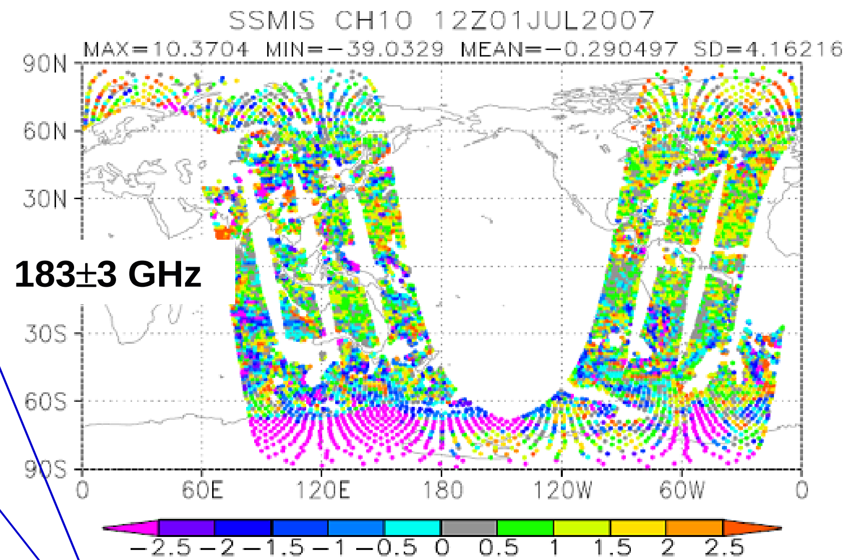
(1) A fast microwave ocean emissivity model (English and Hewison, 1998)
(2) Microwave ocean emissivity model (Weng and Yan)

UPP DTB Distributions at Water Vapor Channels Using Old Snow and Sea Ice Emissivity Simulations

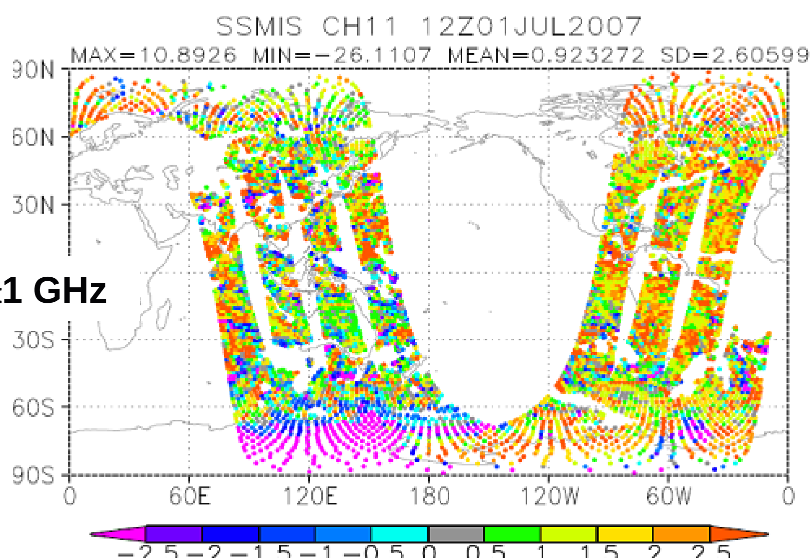
183±7 GHz



183±3 GHz



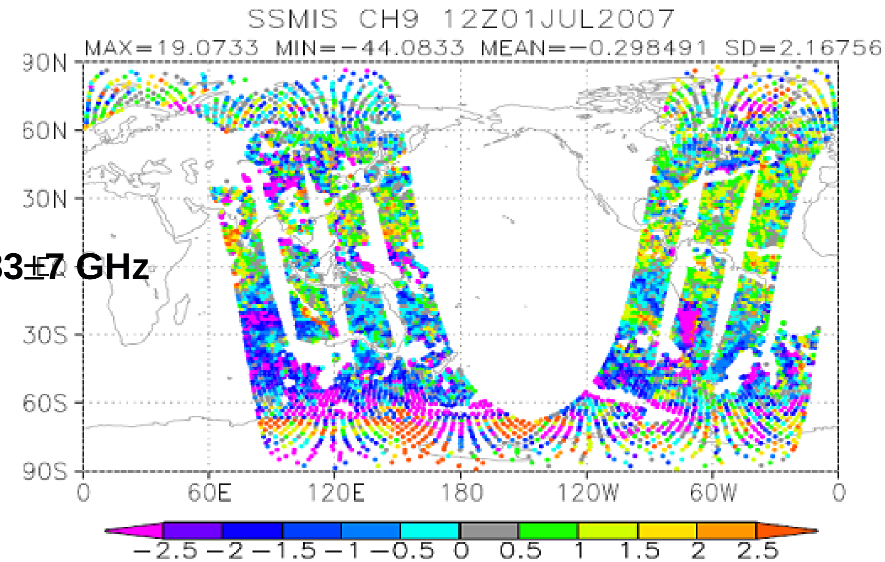
183±1 GHz

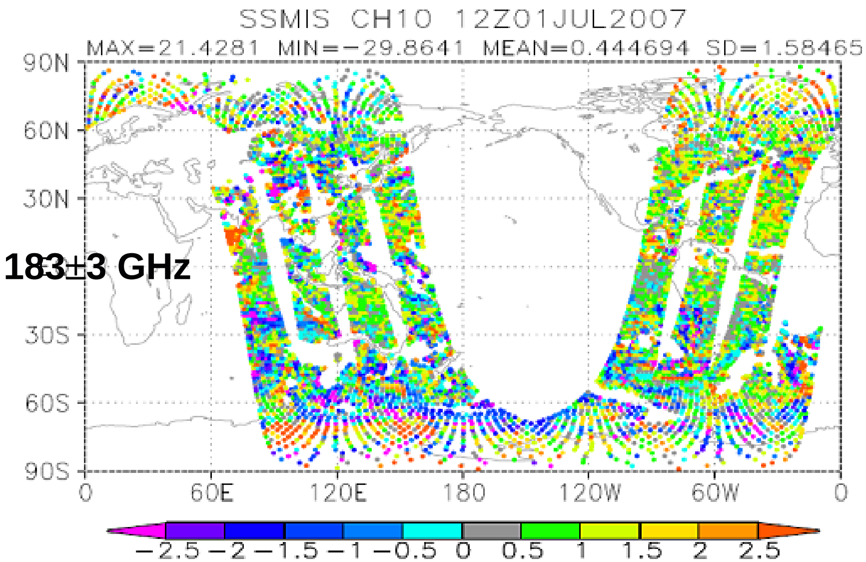


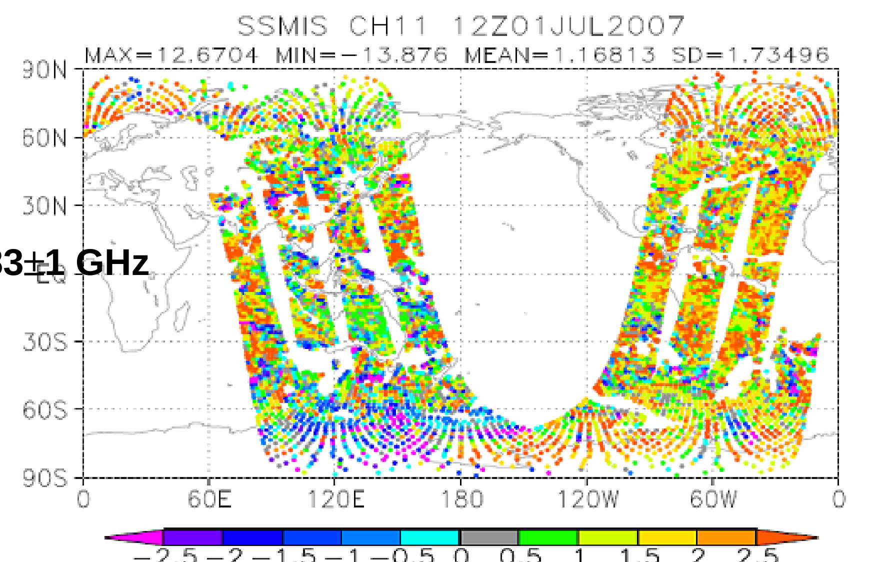
Lager DTB due to inaccurate emissivity simulations

f_0	ΔT_B (K)	σ (K)
183±7	1.86	6.49
183±3	-0.29	4.16
183±1	0.92	2.61

UPP DTB Distributions at Water Vapor Channels (WOBC) Using Improved Snow and Sea Ice Emissivity Simulations







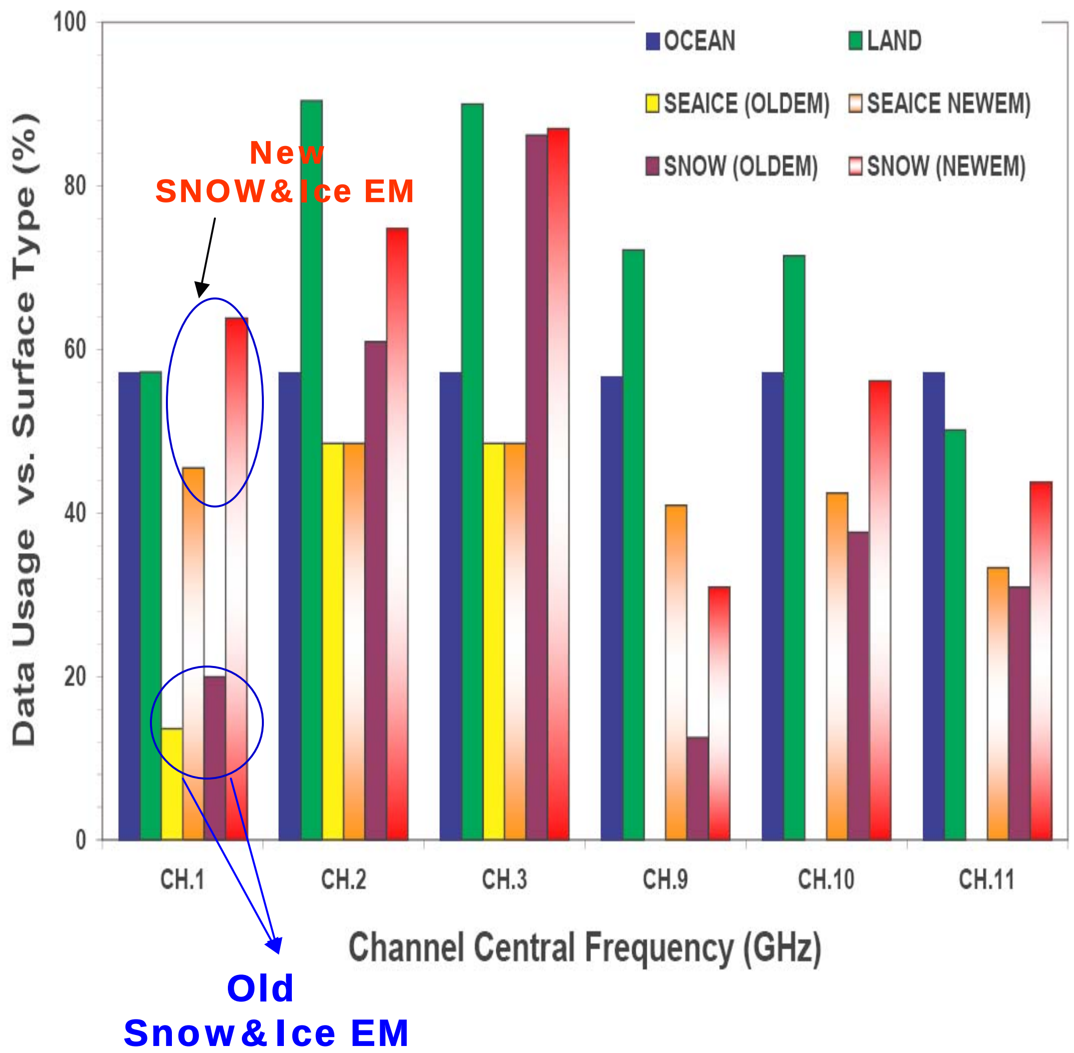
f_0	ΔT_B(Old)	ΔT_B(New)	σ (Old)	σ (New)
183±7	1.86	0.30	6.49	2.17
183±3	-0.29	0.44	4.16	1.58
183±1	0.92	1.16	2.61	1.73

Impact of Improved Snow and Sea Ice Emissivity at SSMIS Channels on F16 UPP SSMIS Data Usage

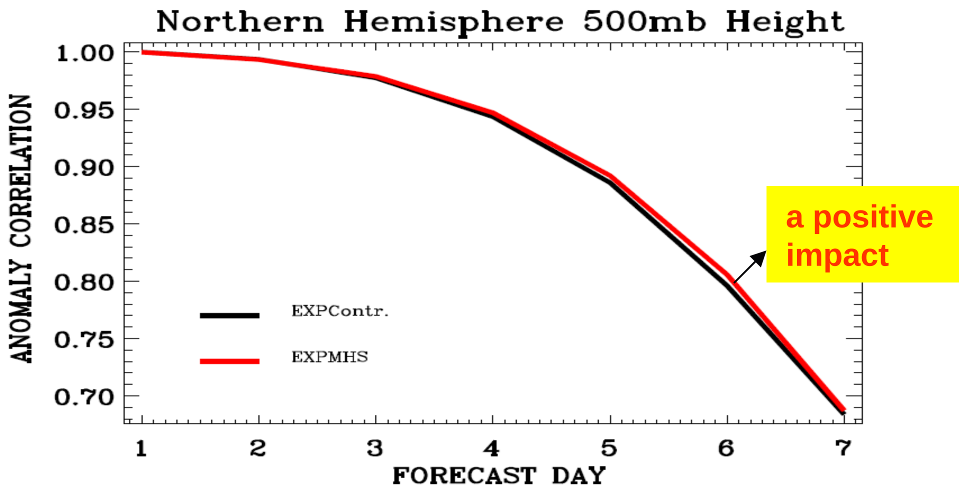
- Several SSMIS sounding channels are sensitive to highly variable emissivity especially over snow and sea ice conditions

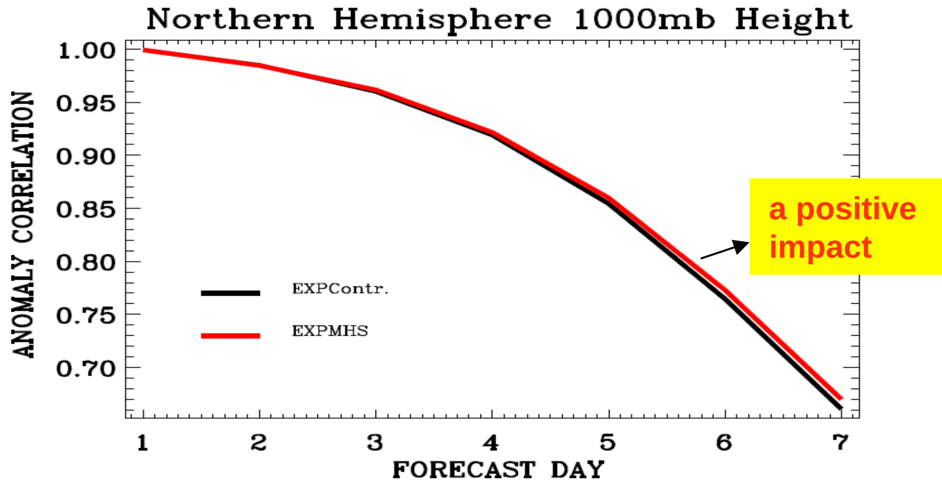
- Only about 20% SSMIS data passed quality control in NCEP/GSI using the old models

- Around 50% SSMIS data passed quality control due to improved SSMIS snow and sea ice emissivity simulations



Assimilation Impact of Improved Snow & Sea Ice Emissivity Simulations on NCEP GFS

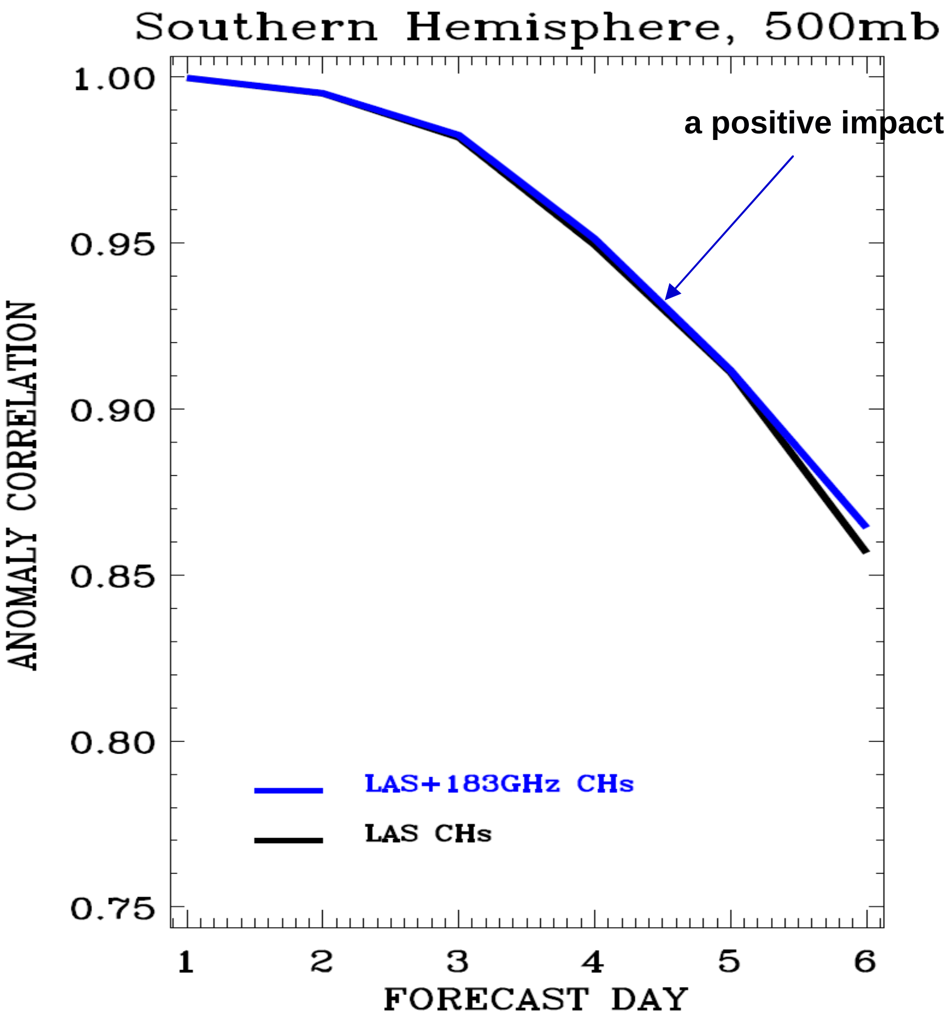




- **SSMIS and MHS include several sounding channels sensitive to variable emissivity especially over snow and sea ice conditions**
- **Improved snow and sea ice emissivity models results in around 60% SSMIS and MHS sounding data passing QC**
- **The impact of the MHS data using the new emissivity model is positive**

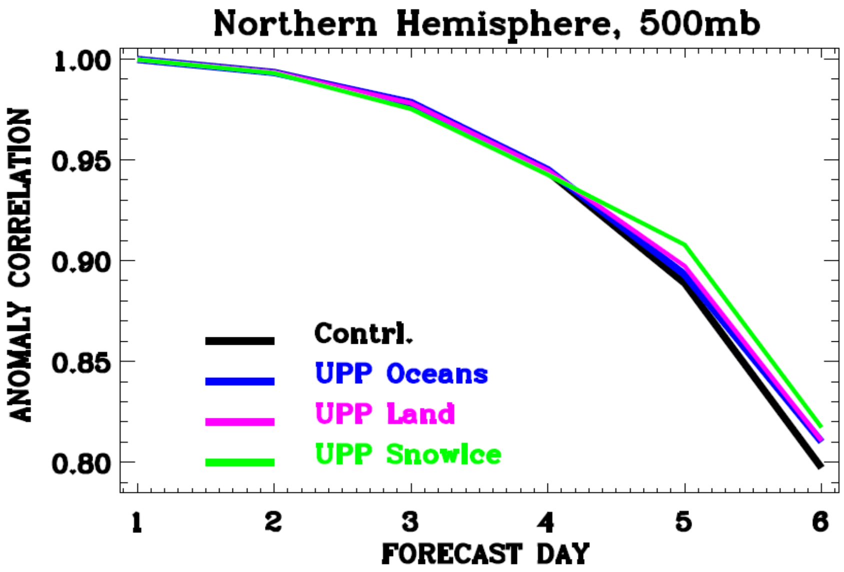
No.4: Assimilation impact of More QC-passed UPP data from LAS and water vapor sounding channels on forecast model

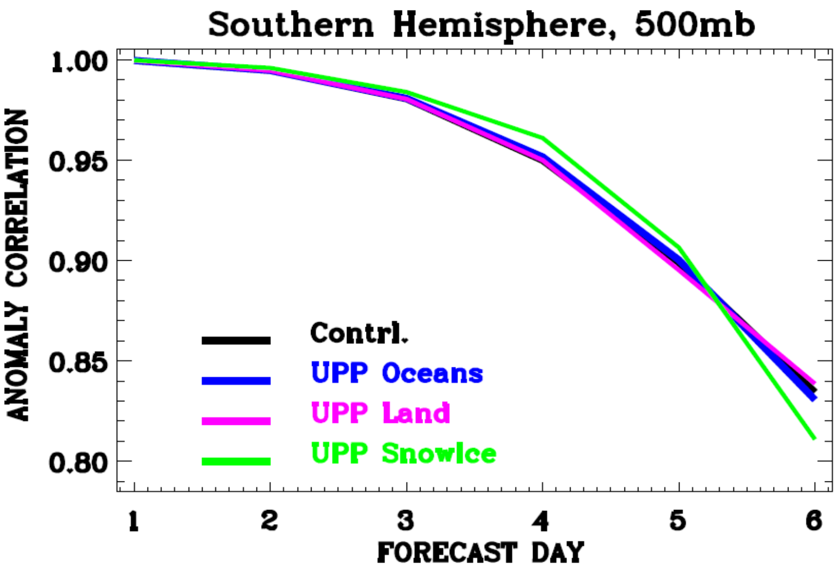
Assimilation impact of SSMIS UPP Water Vapor Sounding Data over Oceans on GFS



- **Experiment: 07/01/08 ~ 07/10/08**
- **UPP water vapor sounding data is assimilated over oceans**
- **Around 60% of UPP water vapor sounding data over oceans passes quality control**
- **A positive impact of UPP water vapor sounding data is observed over Southern hemisphere**

Assimilation Impacts of F16 SSMIS UPP Data on GFS Forecast Score





- Experiment: 07/01/08 ~ 07/14/08
- Contrl.: GFS operational data
- UPP ocean: Contrl.+UPP LAS and water vapor sounding data over oceans are assimilated into GDAS
- Around 50% of UPP data passed quality control depending surfaces
- Positive (neutral) impacts of UPP data for difference experiments are observed at 500 mb except for UPP Snow&Ice experiment over Southern Hemisphere

Summary

- Positive impacts of SSMIS UPP data can be obtained through improved cloud detection, surface snow and sea ice emissivity simulations
- A positive impact of SSMIS UPP data is anticipated by adding water vapor channels
- A positive or neutral assimilation impact on forecast model is seen by adding UPP data over land, snow and sea ice conditions
- The SSMIS UPP data displays some regional dependent biases at several sounding channels which would reduce their assimilation impact

Future Work

- Continue to investigate assimilation impacts of the SSMIS UPP data at LAS and water vapor sounding channels over oceans on GFS analysis fields.

- Investigate assimilation impact of the SSMIS UPP data at LAS and water vapor sounding channels over land, snow and sea ice conditions on GFS.

- Investigate the assimilation impact of SSMIS UPP data for the improved bias correction and quality control schemes on GFS

Acknowledgement

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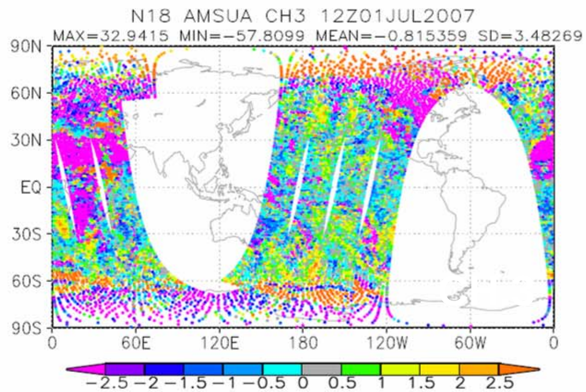
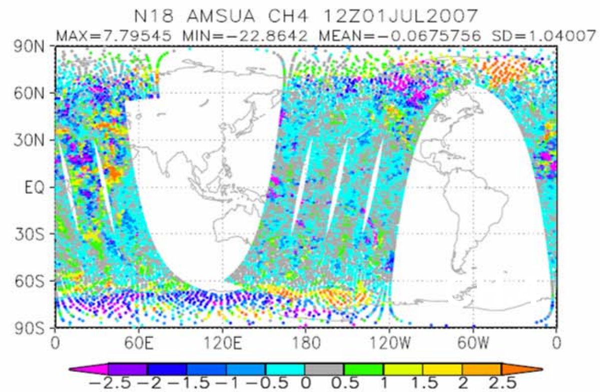
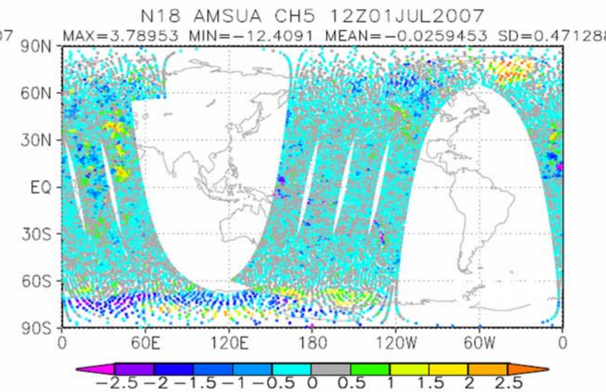
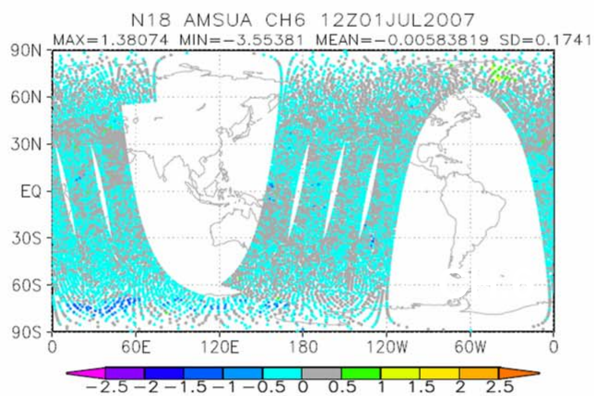
- Naval Research Laboratory: Dr. Nancy L. Baker, Steve Swadley
- United Kingdom Met Office: William Bell

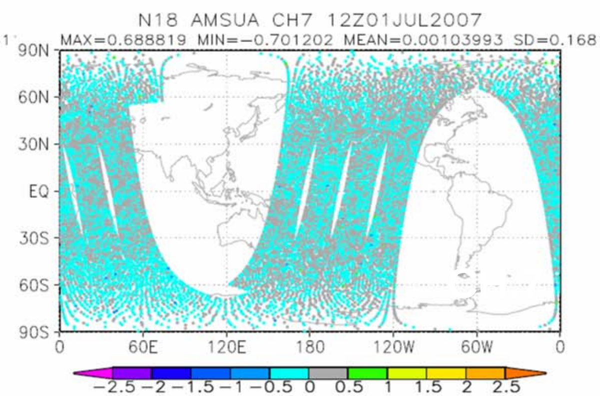
TB Differences (OBS – BK) for N18 AMSU-A at LAS Channels by Applying the Current Bias Correction Scheme

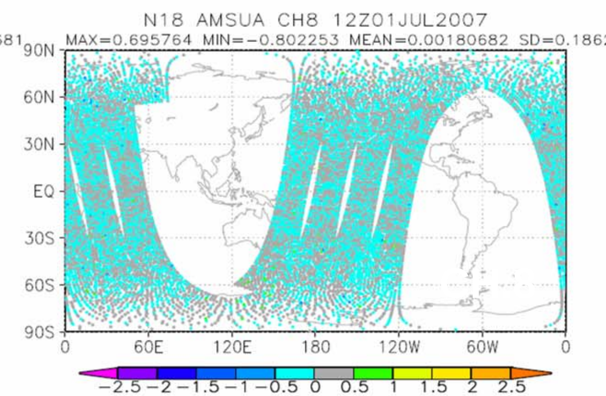


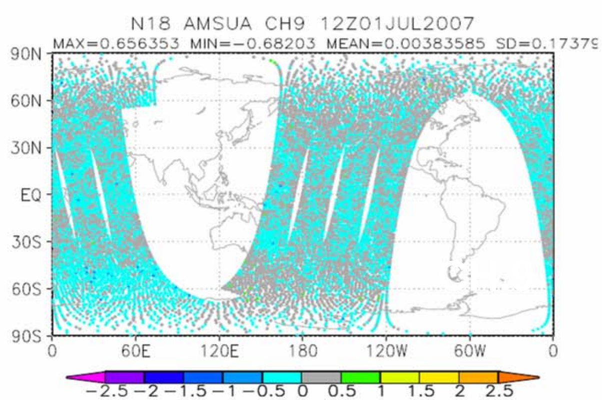












f_0	ΔT_B(N18)	ΔT_B(UPP)	σ (N18)	σ (UPP)
50.3	0.81	0.82	3.48	3.17
52.8	0.07	0.12	1.04	0.99
53.6	0.03	0.01	0.47	0.35
54.4	0.01	0.00	0.17	0.25
54.9	0.01	-	0.17	-
55.5	0.00	0.01	0.19	0.28
57.3	0.00	0.04	0.17	0.36
59.4	-	0.12	-	0.41

N18 AMSU-A data quality is better than UPP LAS data.

TB Differences (OBS – BK) for N18 MHS
by Applying the Current Bias Correction Scheme