Assimilation of AMSU-A Near-Surface Channels in CMA_GFS 4DVar over Land

Hongyi Xiao, Wei Han, Juan Li, Hua Zhang, Jincheng Wang, Liwen Wang

CMA Earth System Modeling and Prediction Centre (CEMC), China Meteorological Administration

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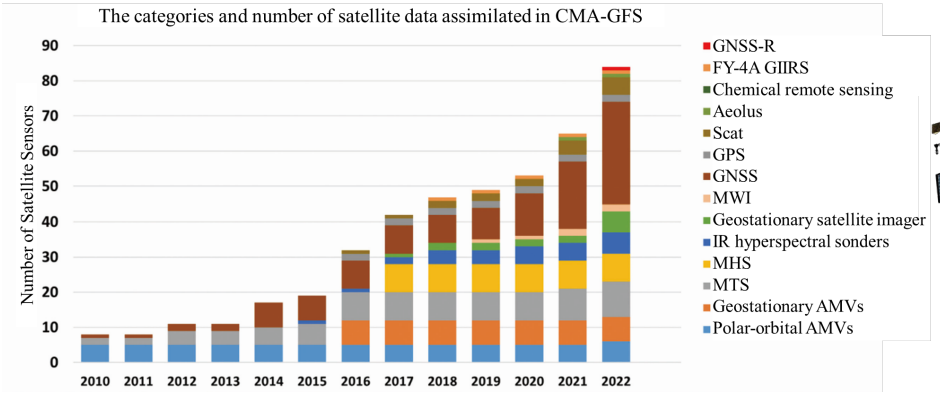
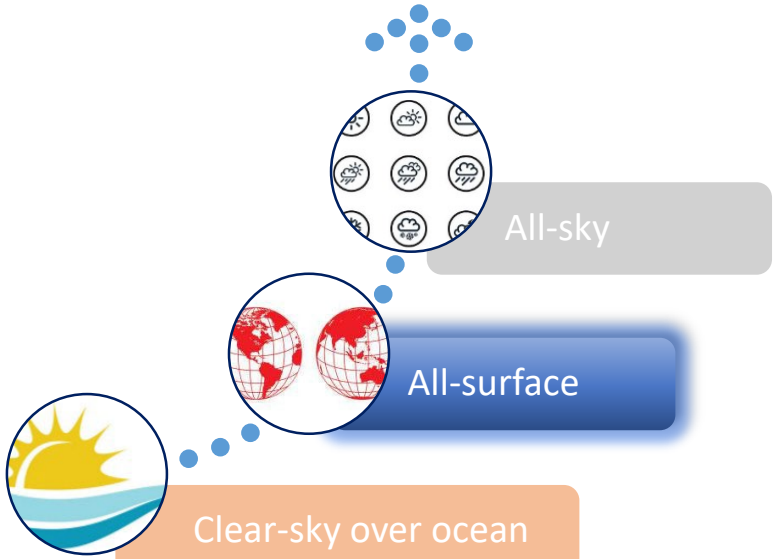
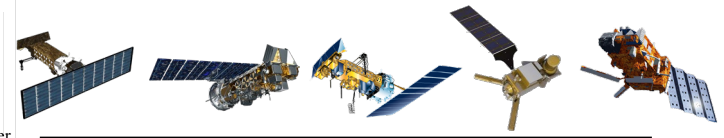
Introduction : Assimilation of Surface-Sensitive Channels in CMA_GFS over Land





NOAA15/16/17 MetOp-A/B

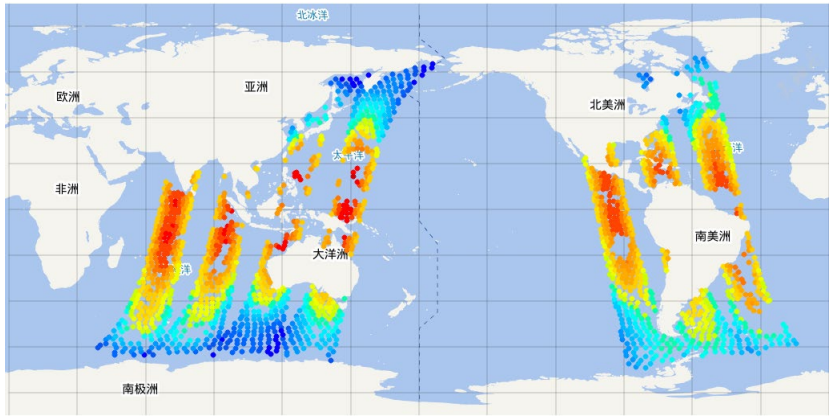


AMSU-A (NOAA-15/16/17/18/19, MetOp-A/B, AQUA)		
Ch#	Frequency(GHz)	Sensitivity
1	23.8	Surface
2	31.4	Surface
3	50.3	Surface
4	52.8	Temperature
5	53.596±0.115	Temperature
6	54.4	Temperature
7	54.9	Temperature
8	55.5	Temperature
9	57.290(=ν_9)	Temperature
10	ν_9±0.217	Temperature
11	ν_9±0.322±0.048	Temperature
12	ν_9±0.322±0.022	Temperature
13	ν_9±0.322±0.010	Temperature
14	ν_9±0.322±0.0045	Temperature
15	89	Surface

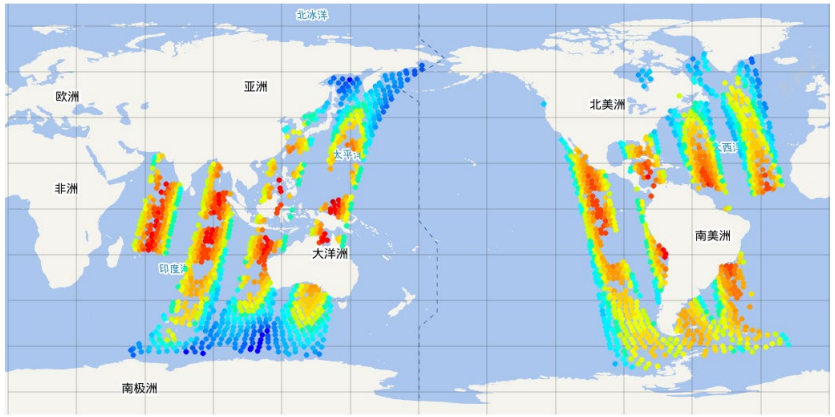
Window channel

Surface-sensitive channel

CH5 assimilation till 2021



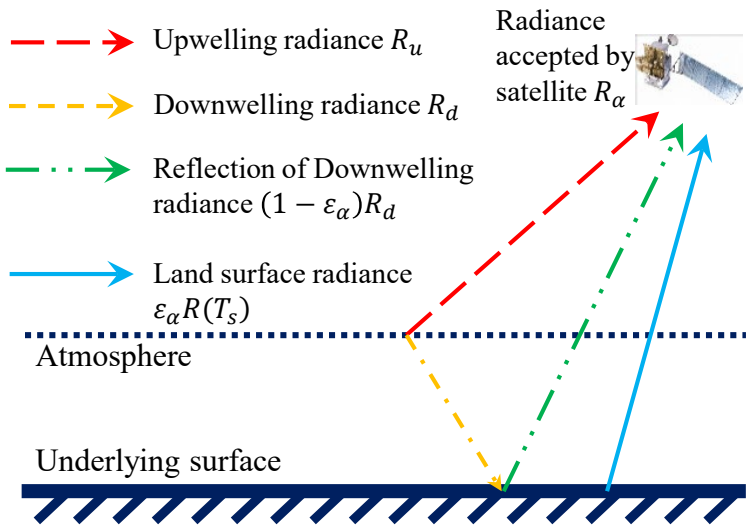
CH6 assimilation till 2021



（pictures coming from CMA data assimilation monitoring system）

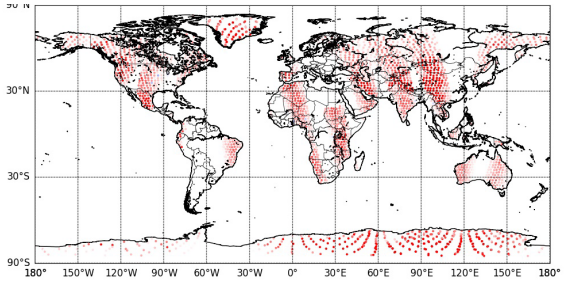
The observational data affected by land surface is **NOT ACTIVATED**!

Introduction : Challanges in Assimilation of Surface-Sensitive Channels over Land



$$R_\alpha = R_u + \tau(1-\varepsilon_\alpha)R_d + \tau\varepsilon_\alpha R(T_s)$$

Calculation precision of instantaneous land surface emissivity (LSE) is **badly not enough!**



leading to ~10K Error!

Calculation of LSE

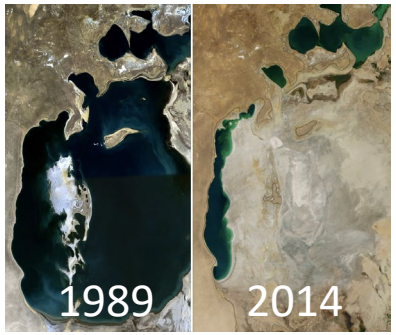
- **Theoretical model** → **FASTEM**
- **Historical statistic** → **TELSEM2**
- **Window Channel Retrieval Method (WCRM)**

Surface type	FASTEM parameters 1:5
Typical RTTOV default for land	3. 0, 5.0, 15.0, 0.1, 0.3
Summer land surface	
Forest	1.7, 1.0, 163.0, 0.0, 0.5
Open grass	2.2, 1.3, 138.0, 0.0, 0.42
Bare soil	2.3, 1.9, 21.8, 0.0, 0.5
Winter surface type	
Forest and snow	2.9, 3.4, 27.0, 0.0, 0.0
Deep dry snow	3.0, 24.0, 60.0, 0.1, 0.15
Frozen soil	117.8, 2.0, 0.19, 0.2 ,0.35
Sea ice	
Grease ice	23.7, 7.7, 17.3, 0.0, 0.15
Baltic nilas	1.6, 3.3, 2.2, 0.0, 0.0
New ice (no snow)	2.9, 3.4, 27.0, 0.0, 0.0
New ice (snow)	2.2, 3.7, 122.0, 0.0, 0.15
Brash ice	3.0, 5.5, 183.0, 0.0, 0.0
Compact pack ice	2.0, 1700000.0, 49000000.0, 0.0, 0.0
Fast ice	1.5, 77.8, 703.0, 0.1, 0.35
Lake ice + snow	1.8, 67.1, 534.0, 0.1, 0.15
Multi-year ice	1.5, 85000.0, 4700000.0, 0.0, 0.0

Tool to **E**stimate **L**and-**S**urface **E**missivities at **M**icrowave frequencies

SSM/I (1993~2004)

Aral Sea

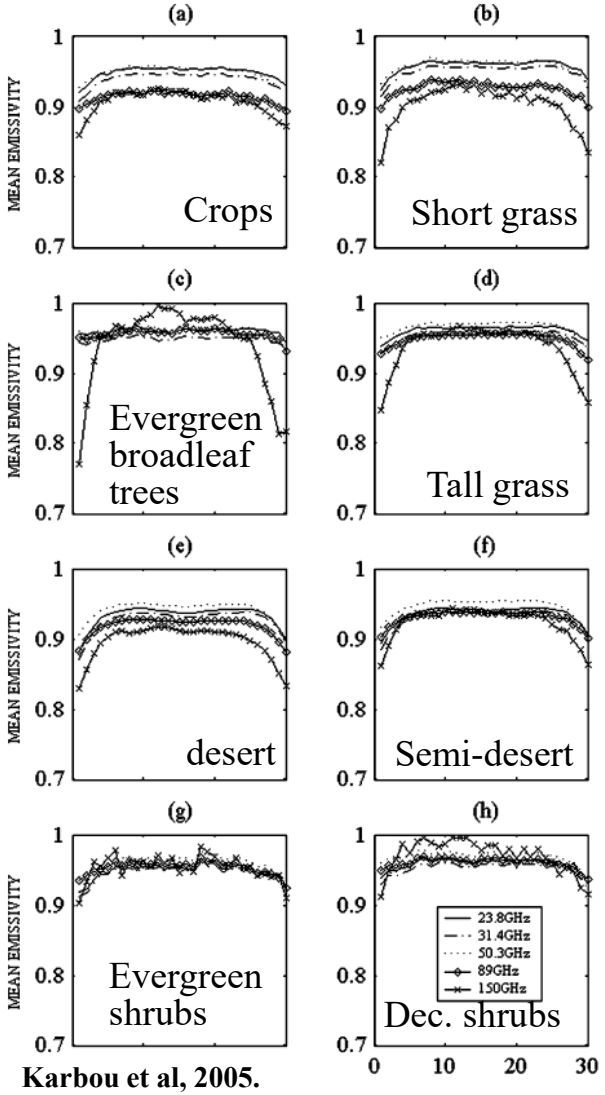


https://en.wikipedia.org/wiki/Aral_Sea

SSMIS	ECMWF	Baordo and Geer, 2016
AMSU-A	Météo-France	Karbou et al., 2006

AMSU-A CH5/6 Assimilation over Land: Window Channel Retrieval Method (WCRM)

Mechanism of WCRM

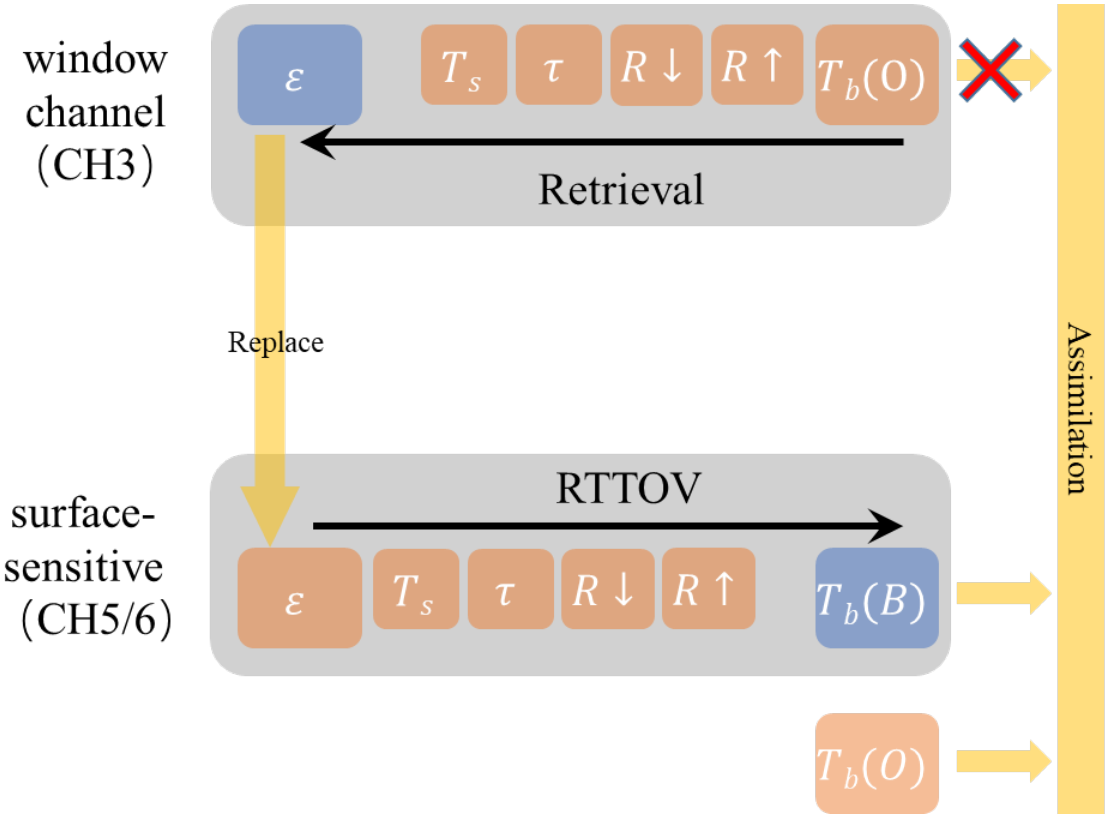


Karbou et al, 2005.

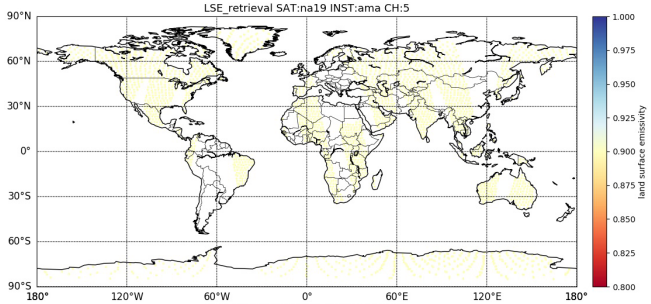
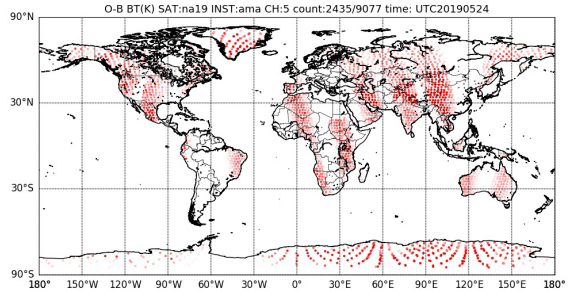
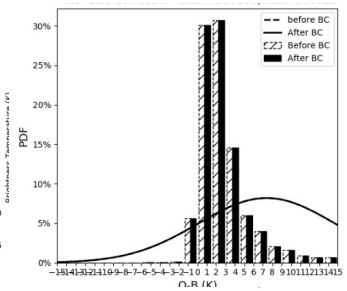
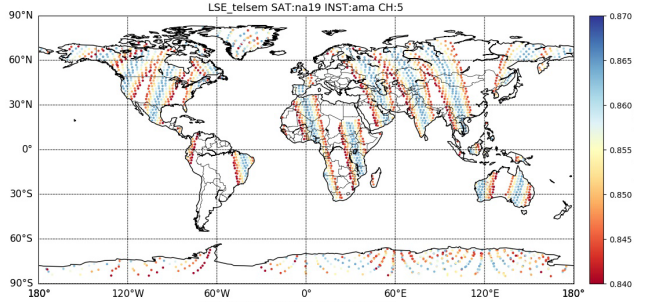
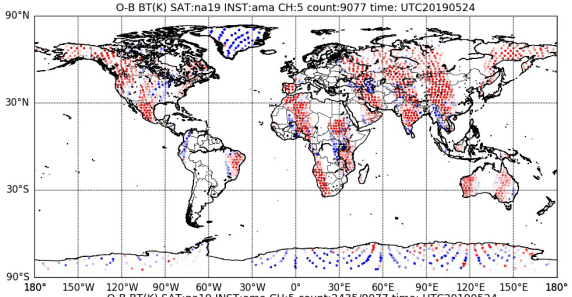
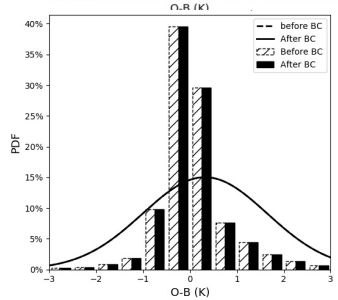
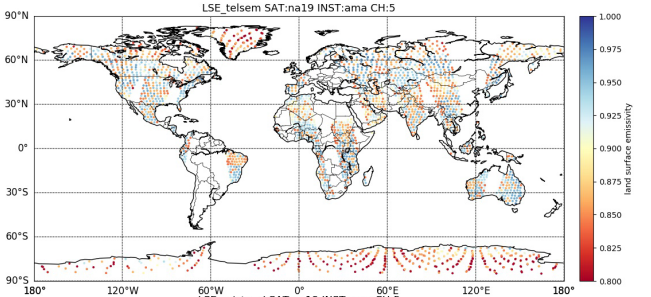
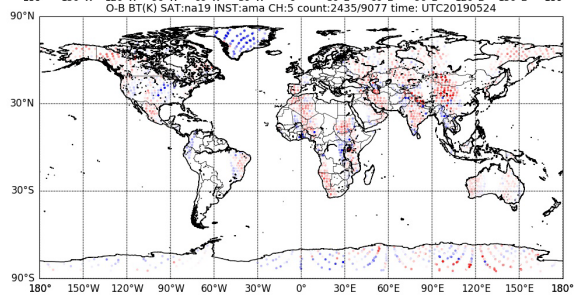
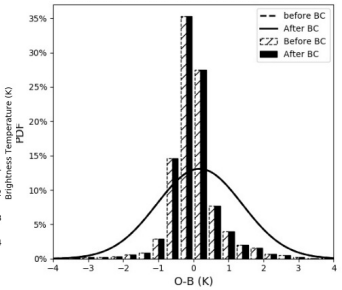
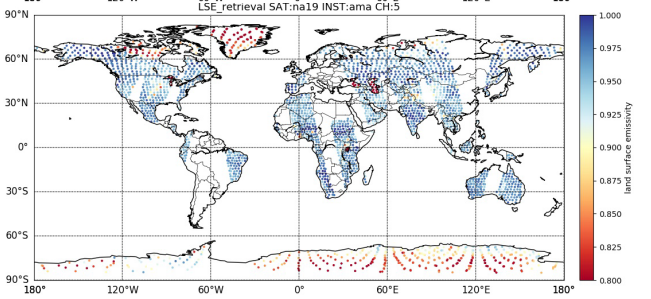
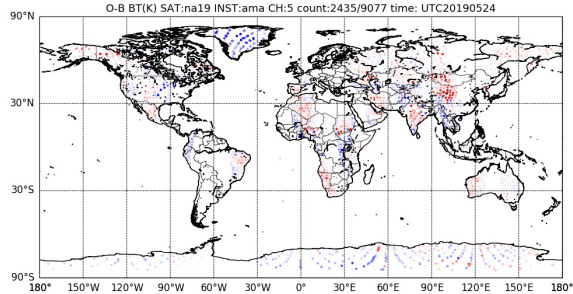
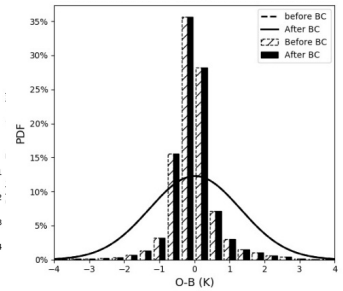
Normal Assimilation

The approximate **constancy of LSE** versus the frequency in the microwave range

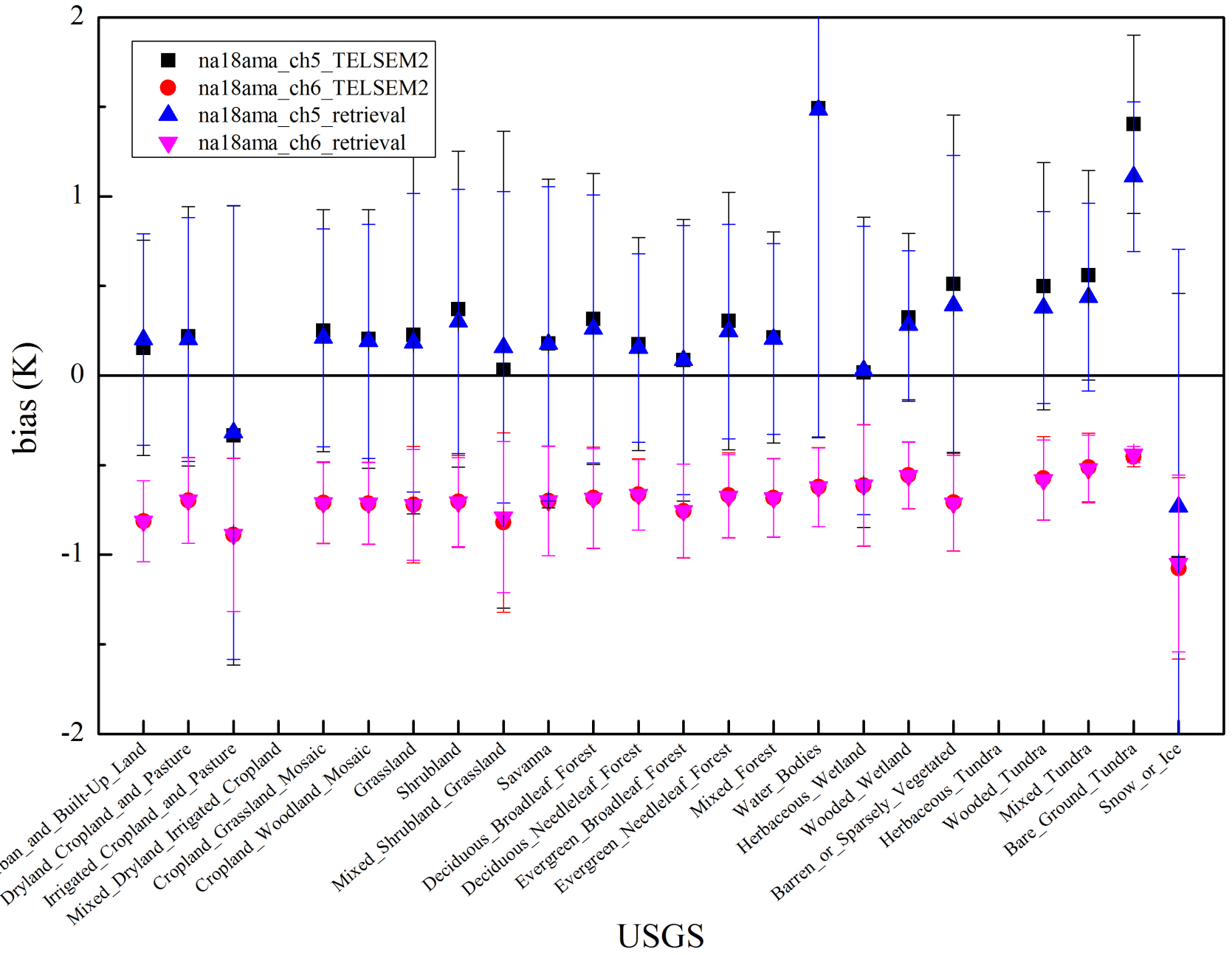
Assimilation based on WCRM



AMSU-A CH5/6 Assimilation over Land: Observation-Minus-Background (OMB)

	LSE	OMB	OMB PDF	
Constant (=0.9)				Bias=7.39K Std=7.30K
FASTEM				Bias=0.32K Std=1.33K
TELSEM2				Bias=0.17K Std=1.22K
WCRM				Bias=0.01K Std=1.30K

Reduction of OMB by Window Channel Retrieval Method relative to TELSEM2



1Urban and Built-up Land
2Dryland Cropland and Pasture
3Irrigated Cropland and Pasture
4Mixed Dryland / Irrigated Cropland
5Cropland / Grassland Mosaic
6Cropland / Woodland Mosaic
7Grassland
8Shrubland
9Mixed Shrubland / Grassland
10Savanna
11Deciduous Broadleaf Forest
12Deciduous Needleleaf Forest
13Evergreen Broadleaf Forest
14Evergreen Needleleaf Forest
15Mixed Forest
16Water Bodies
17Herbaceous Wetland
18Wooded Wetland
19Barren or Sparsely Vegetated
20Herbaceous Tundra
21Wooded Tundra
22Mixed Tundra
23Bare Ground Tundra
24Snow or Ice

3 CH5 Improved

15 CH5 not improved

The window channel retrieval method can successfully improve the OMB of CH5 on each AMSU-A, while it has only limited impacts on the OMB of CH6.

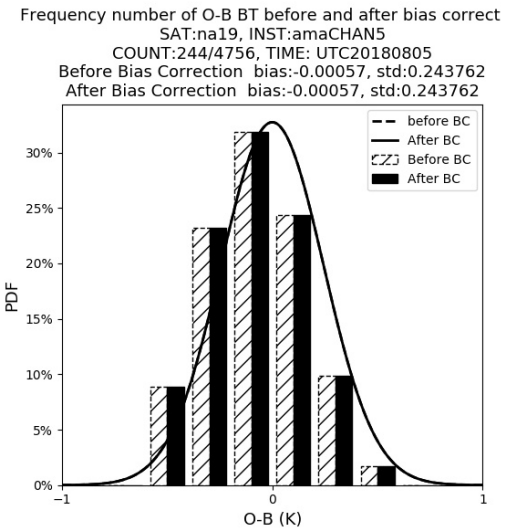
The mean(OMB) of CH6 of all AMSU-As except MetOp-B AMSU-A is larger than that of CH5 when the window channel retrieval method is employed.

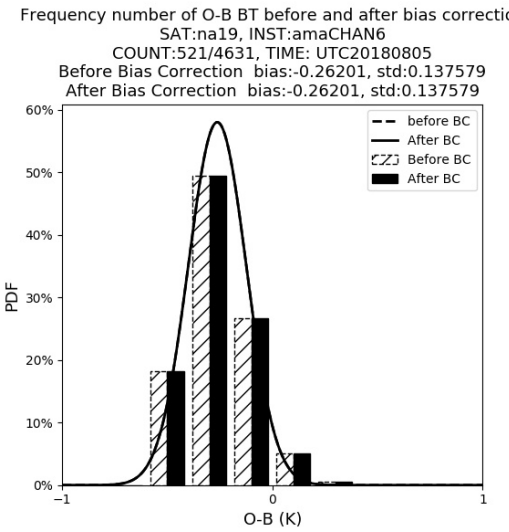
On the other hand, there is obviously lower standard deviation of OMB in CH6 than CH5 for any land cover category.

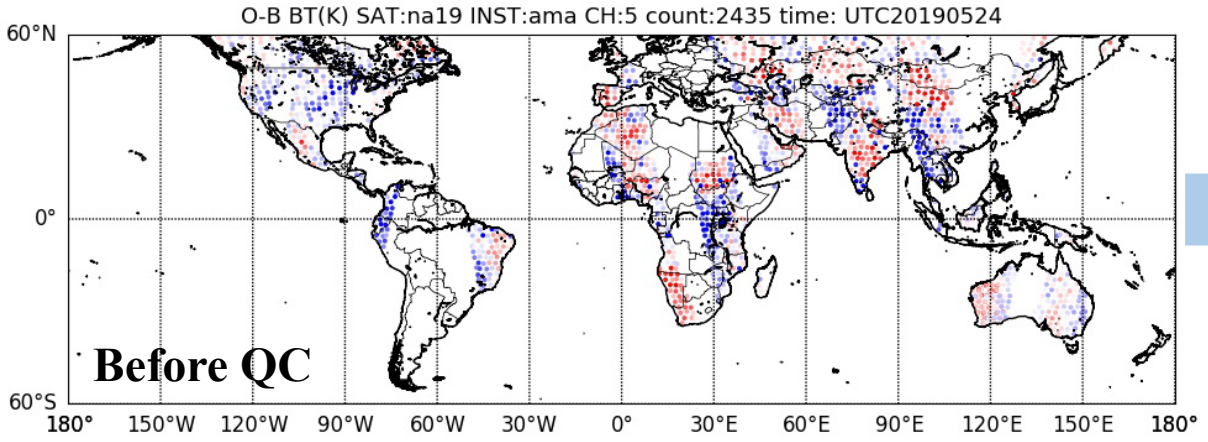
USGS

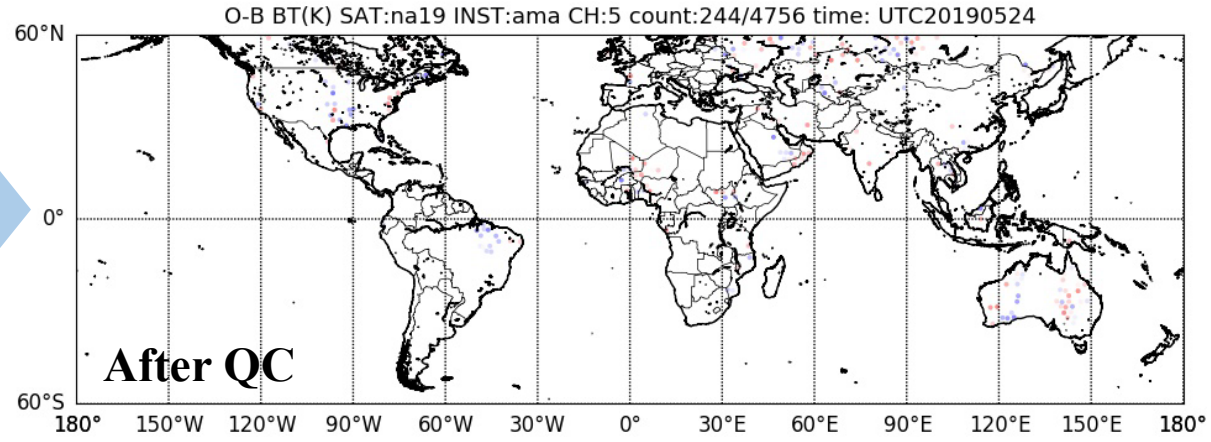
AMSU-A CH5/6 Assimilation over Land: Quality Control

AMSU-A CH5/6 Quality Control over Land			
#	Schemes	Targets	References
1	Latitudes higher than 60°	Snow or ice	Baordo and Geer, 2016: Q. J. R. Meteorol. Soc., 142: 2854-2866.
2	Mixed land types	Land surface contamination	
3	Land surface temperature is lower than 278 K	Snow or ice	
4	Land surface emissivity difference between WCRM and TELSEM2 is larger than a specific threshold value	Abnormal	
5	Land surface emissivity calculated from the window channel is larger than 1 or lower than 0.55	cloud/rain mismatch	
6	TELSEM2 atlas is unavailable	Abnormal	
7	$C = 0.8 + \left[w_4 \Delta T_b(6)\right]^2 \geq 1$	Rain cloud	Zhu, Liu, Kleist, et al., 2016: Mon. Wea. Rev., 144:4709-4735.
8	$C = (w_1 \times 0.6)^2 + \left[w_2 \Delta T_b(4)\right]^2 > 0.5$	Thick cloud	
9	Ch5 (>500m); Ch6 (>1500m)	Lans surface contamination	Yang, et al., 2011: Meteorological Monfthly, 37(11): 1395-1401.
10	OMB larger than 3σ	Abnormal	









AMSU-A CH5/6 Assimilation over Land: Bias Correction

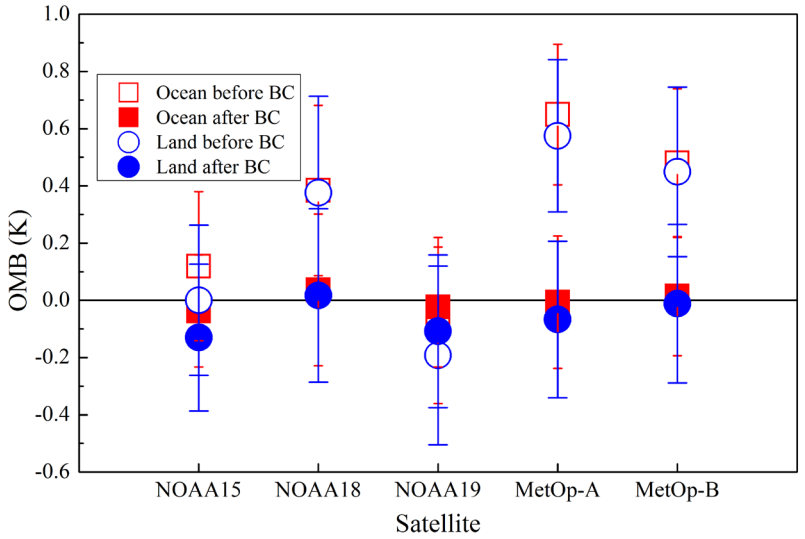
Scan position bias correction

+

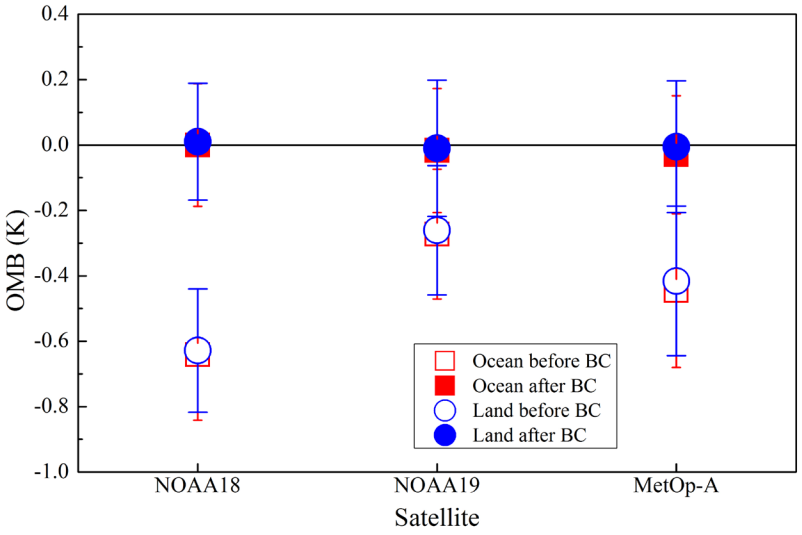
Predictors

1.1000-300hPa layer thickness
2.200-50hPa layer thickness
3.50-10hPa layer thickness

CH5



CH6



The predictors and regression coefficients for ocean areas also successfully reduce the systematic biases of satellite observations over land:

1) For CH5, the impact of bias correction over land on NOAA-18/MetOp-B AMSU-A is even **better than** that over the ocean;

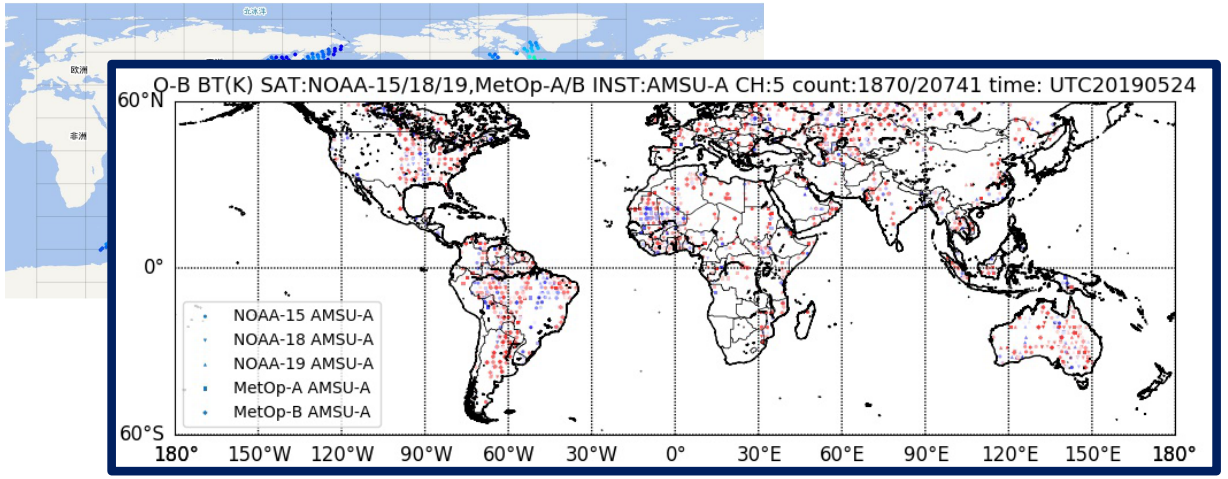
2) The impact in CH5 of NOAA-15/19/MetOp-A over land is slightly worse than that over the ocean, but it is still **sufficient and practical**.

3) All CH6 which are available achieve **optimal impacts** of bias correction over land compared to the ocean.

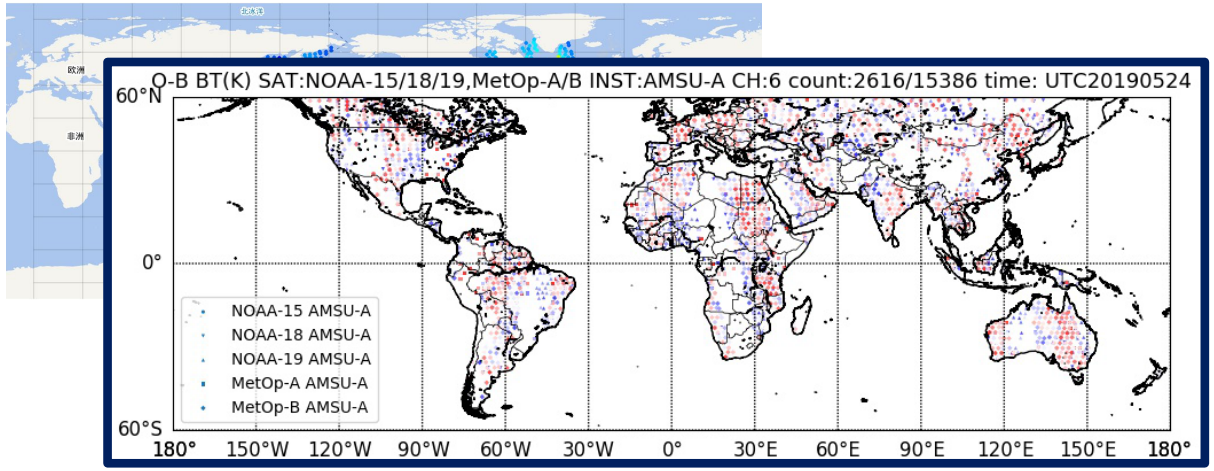
AMSU-A CH5/6 Assimilation over Land: Increasing of Data Utilization

The application restrictions of surface-sensitive channels over land are broken through.

AMSU-A CH5

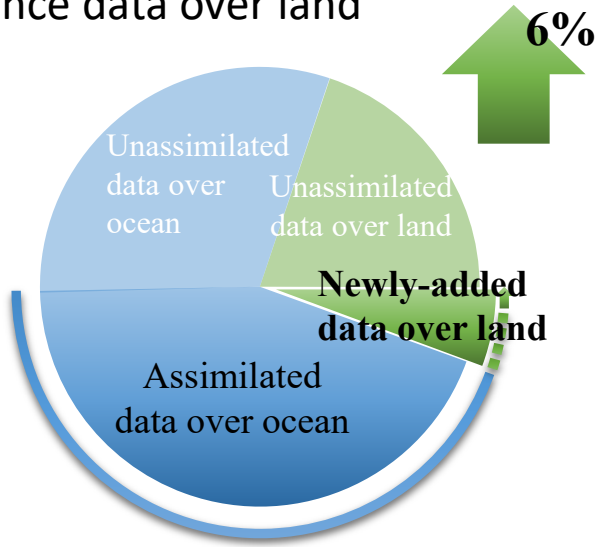


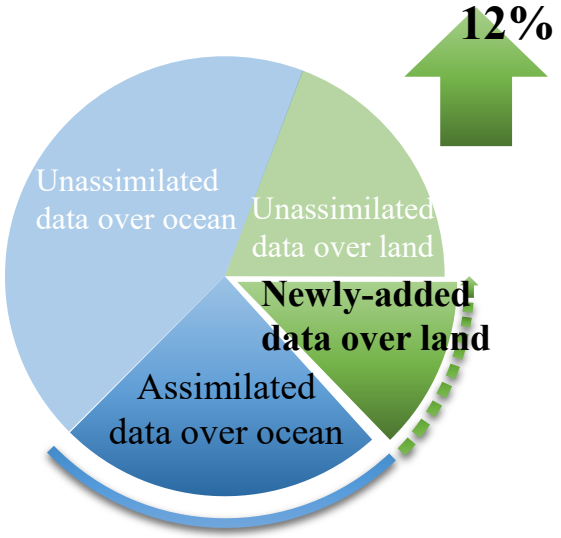
AMSU-A CH6



Five Instruments, eight channels in total, bring **4200 newly-added observations** in each 6-h assimilation time window.

The **improvements of coverage and quantity** brought by the radiance data over land

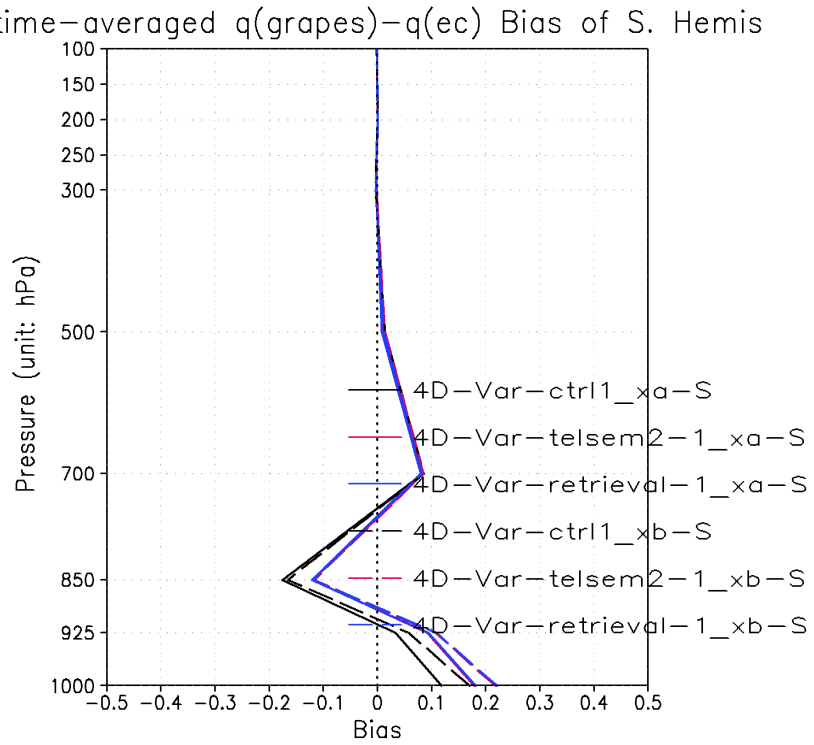




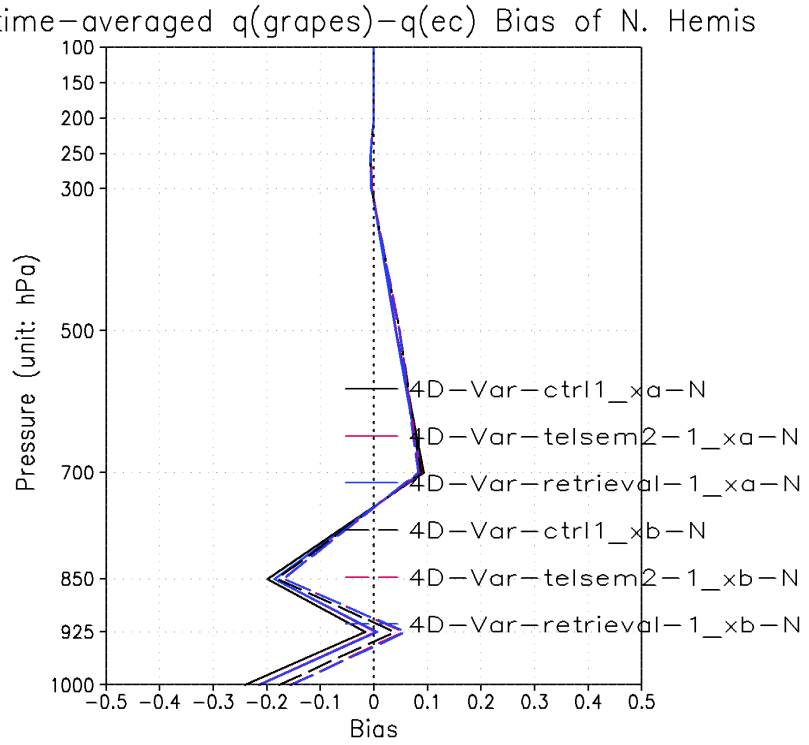
AMSU-A CH5/6 Assimilation over Land: Analysis

Humidity Field

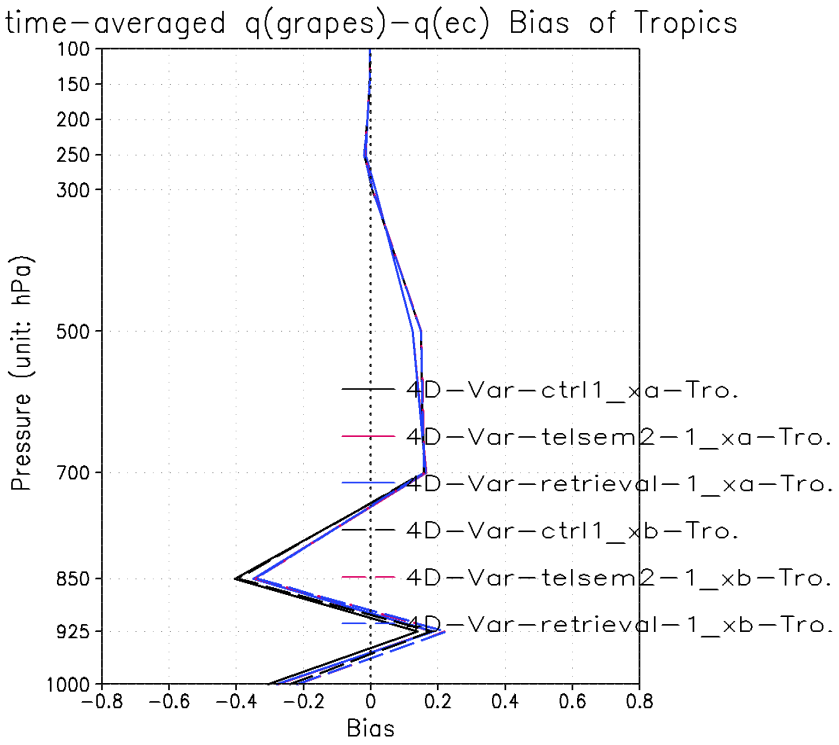
Southern Hemisphere



Northern Hemisphere



Tropic



The humidity analysis at lower layer (1000–700 hPa) is effectively improved, and the improvement by the window channel retrieval method is equivalent to that by TELSEM2.

AMSU-A CH5/6 Assimilation over Land: Forecasting

TELSEM2

Score Card for TELSEM2_1 against CTRL1

Domain	Parameter	Level	Anomaly Correlation	RMS Error
NH	HGT	850	▲	▲
		500	▲	▲
		250	▲ ▲	▲ ▲
	TEMP	850	▲ ▲	▲ ▲
		500	▲ ▲	▲
		250		▲
	UWND	850	▲	▲
		500	▲ ▲	▲
		250	▲	▲
	VWND	850	▲	▲
		500	▲	▲
		250	▲	
SH	HGT	850	▲	
		500		
		250		
	TEMP	850	▲ ▲ ▲	▲ ▲ ▲
		500	▲	▲
		250		▲
	UWND	850	▲	▲
		500		
		250		
	VWND	850		
		500		
		250		
EASI	HGT	850		▲
		500	▲ ▲	▲ ▲ ▲
		250	▲ ▲	▲ ▲ ▲
	TEMP	850	▲ ▲ ▲ ▲	▲ ▲
		500	▲	▲ ▲ ▲
		250		▲
	UWND	850		▲ ▲
		500	▲	▲
		250		▲
	VWND	850	▼	▼ ▼
		500		▲
		250		
TRO	HGT	850	▲	▲ ▲
		500	▲ ▲	▲ ▲ ▲
		250	▼	▲ ▲ ▲
	TEMP	850	▼	
		500		
		250		▼
	UWND	850	▲	▲ ▲
		500		▲
		250		
	VWND	850		▼ ▲
		500		
		250		

▲: Far better ▲: Better ▲: Better but not significant ▲: Worse but not significant ■: Equality
▼: Far worse ▼: Worse ▼: Worse but not significant

WCRM

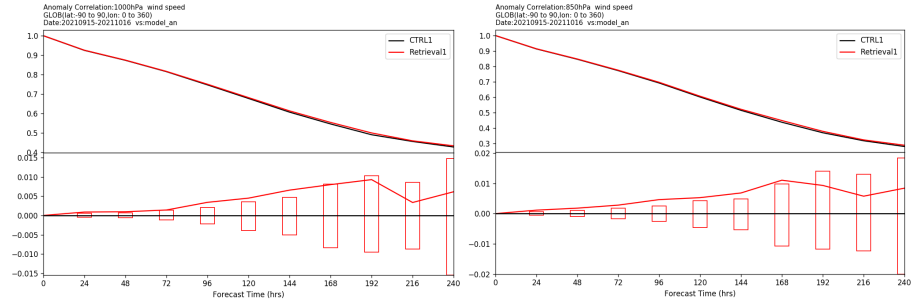
Score Card for Retrieval1 against CTRL1

Domain	Parameter	Level	Anomaly Correlation	RMS Error
NH	HGT	850	▲ ▲	▲ ▲ ▲ ▲
		500	▲ ▲	▲ ▲ ▲ ▲
		250	▲ ▲	▲ ▲ ▲
	TEMP	850	▲ ▲ ▲ ▲	▲ ▲ ▲
		500	▲ ▲ ▲ ▲	▲ ▲
		250	▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
	UWND	850	▲ ▲	▲ ▲ ▲
		500	▲ ▲	▲ ▲ ▲
		250	▲ ▲	▲ ▲ ▲
	VWND	850	▲ ▲	▲ ▲ ▲ ▲
		500	▲ ▲	▲ ▲ ▲
		250	▲ ▲	▲ ▲
SH	HGT	850	▲ ▲ ▲ ▲	
		500	▲ ▲	▲ ▲
		250	▲ ▲ ▲	▲ ▲ ▲
	TEMP	850	▲ ▲ ▲	▲ ▲
		500	▲	▲ ▲
		250	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
	UWND	850	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
		500	▲ ▲ ▲	▲ ▲ ▲ ▲
		250	▲ ▲ ▲	▲ ▲ ▲ ▲
	VWND	850	▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
		500	▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
		250	▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
EASI	HGT	850	▲	▲ ▲ ▲
		500	▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
		250	▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
	TEMP	850	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲
		500	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
		250	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
	UWND	850	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
		500	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
		250	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
	VWND	850	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
		500	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
		250	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲
TRO	HGT	850	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
		500	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
		250	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
	TEMP	850	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
		500	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
		250	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
	UWND	850	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
		500	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
		250	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
	VWND	850	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
		500	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲
		250	▲ ▲ ▲ ▲ ▲ ▲	▲ ▲ ▲ ▲ ▲ ▲

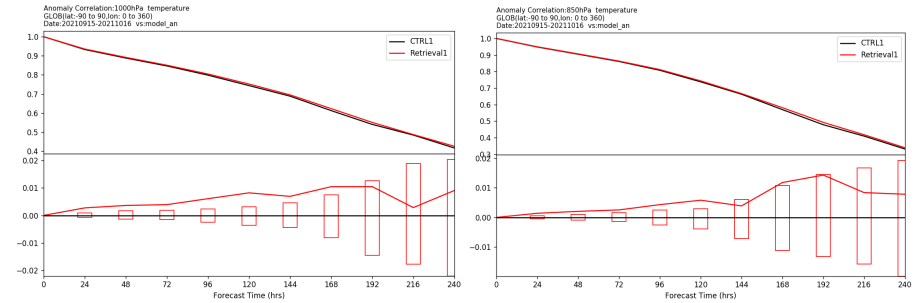
▲: Far better ▲: Better ▲: Better but not significant ■: Equality
▼: Far worse ▼: Worse ▼: Worse but not significant

1000hPa **850hPa**

Wind Speed



Tempe-rature



- ✓ AMSU-A CH5/6 assimilation over land **is beneficial to the anomaly correlation of various variables at low layer.**

- ✓ The assimilation of AMSU-A CH5/6 over land has **obvious positive impacts on forecasting skills, especially in Northern Hemisphere** which has larger land area.
- ✓ The impacts of WCRM are similar to but **better than** TELSEM2.

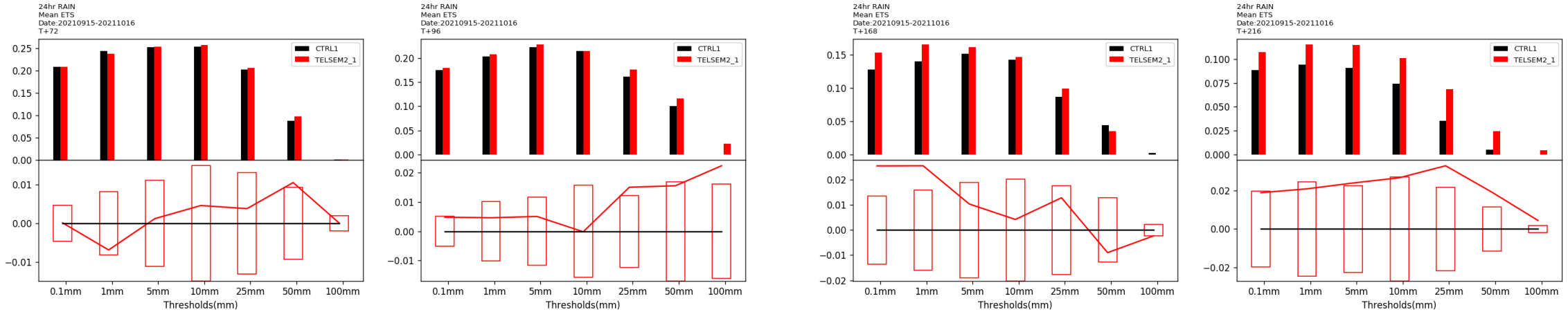
AMSU-A CH5/6 Assimilation over Land: Precipitation Forecasting

Equitable Threat Score (ETS) of 24hr Rain

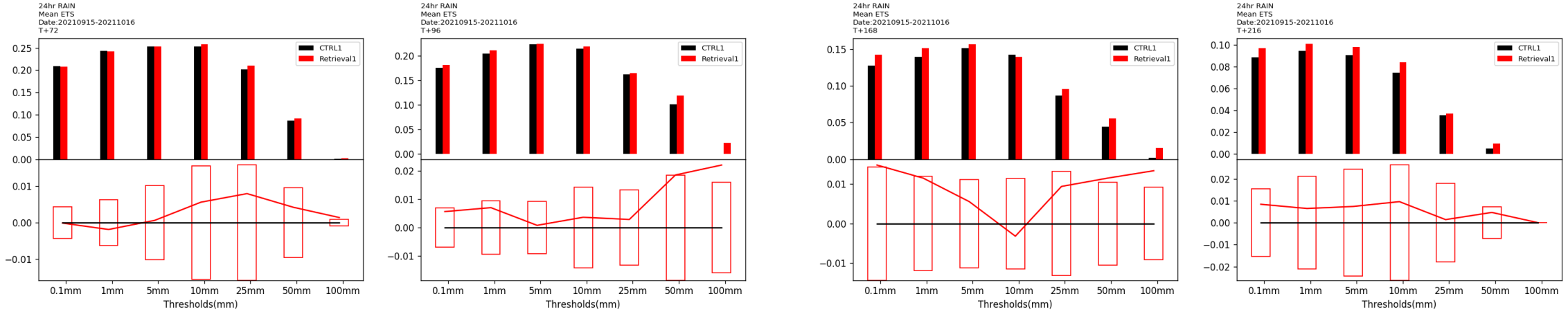
Medium-term **Long-term**

72h **96h** **168h** **216h**

TELSEM2



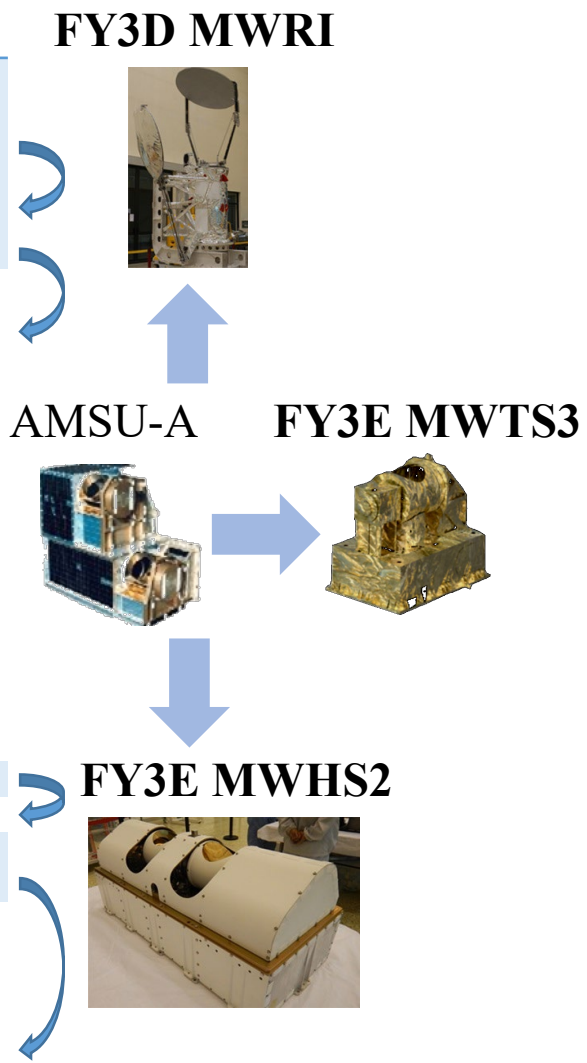
WCRM

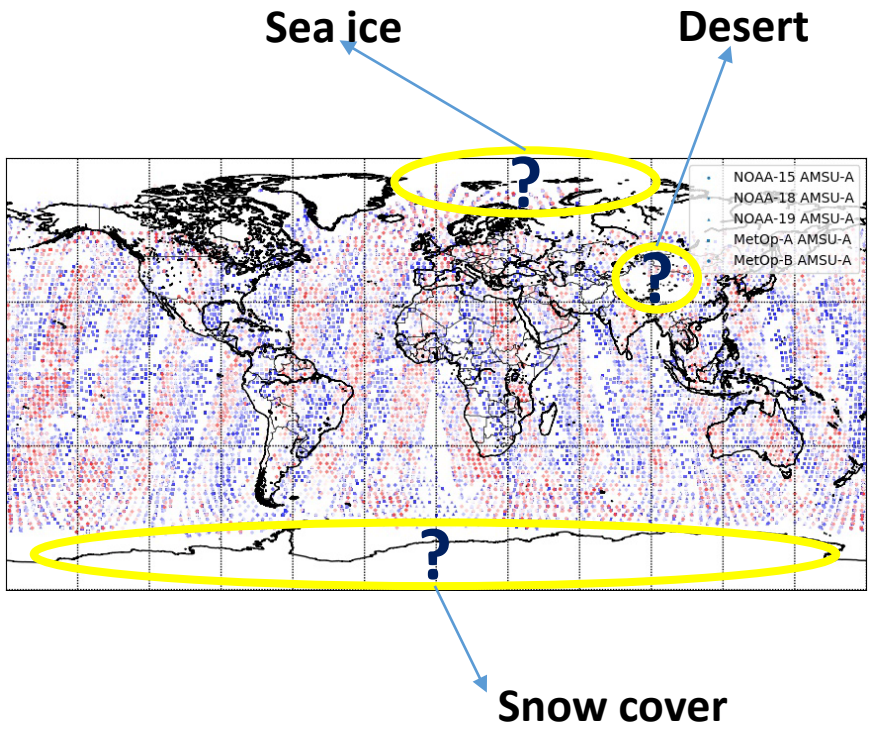


AMSU-A CH5/6 assimilation over land **is beneficial to the medium-term (~3-d) and long-term (~7-d) forecasting of precipitation** within various degrees.

AMSU-A CH5/6 Assimilation over Land: Future Work

Frequency(GHz)	AMSU-A/B	MWTS3	MWHS2	MWRI	Sensitivity
10.65				1, 2	S
18.7				3, 4	S
23.8	1	1		5, 6	S
31.4	2	2			S
37				7, 8	S
50.3	3	3			S
51.76		4			T
52.8	4	5			T
53.246±0.08		6			T
53.596±0.115	5	7			T
53.948±0.081		8			T
54.40	6	9			T
54.94	7	10			T
55.50	8	11			T
57.290344(=ν_0)	9	12			T
ν_0±0.217	10	13			T
ν_0±0.3222±0.048	11	14			T
ν_0±0.3222±0.022	12	15			T
ν_0±0.3222±0.010	13	16			T
ν_0±0.3222±0.0045	14	17			T
89	15, 16		1	9, 10	S
118			2~9		T
150	17				S
166			10		S
183.31±1	18		11		H
183.31±1.8			12		H
183.31±3	19		13		H
183.31±4.5			14		H
183.31±7	20		15		H





THANKS!