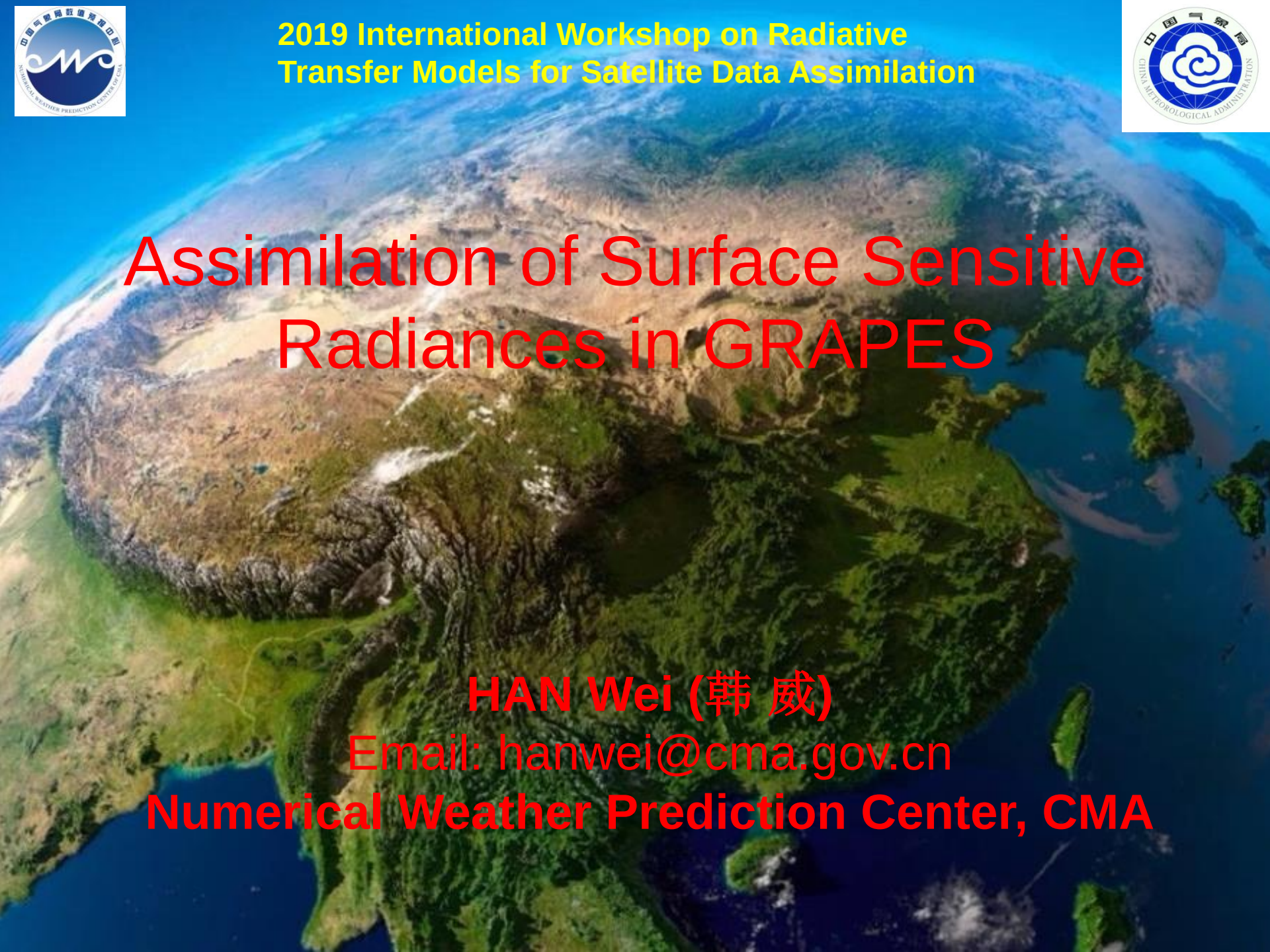

2019 International Workshop on Radiative Transfer Models for Satellite Data Assimilation

Assimilation of Surface Sensitive Radiances in GRAPES

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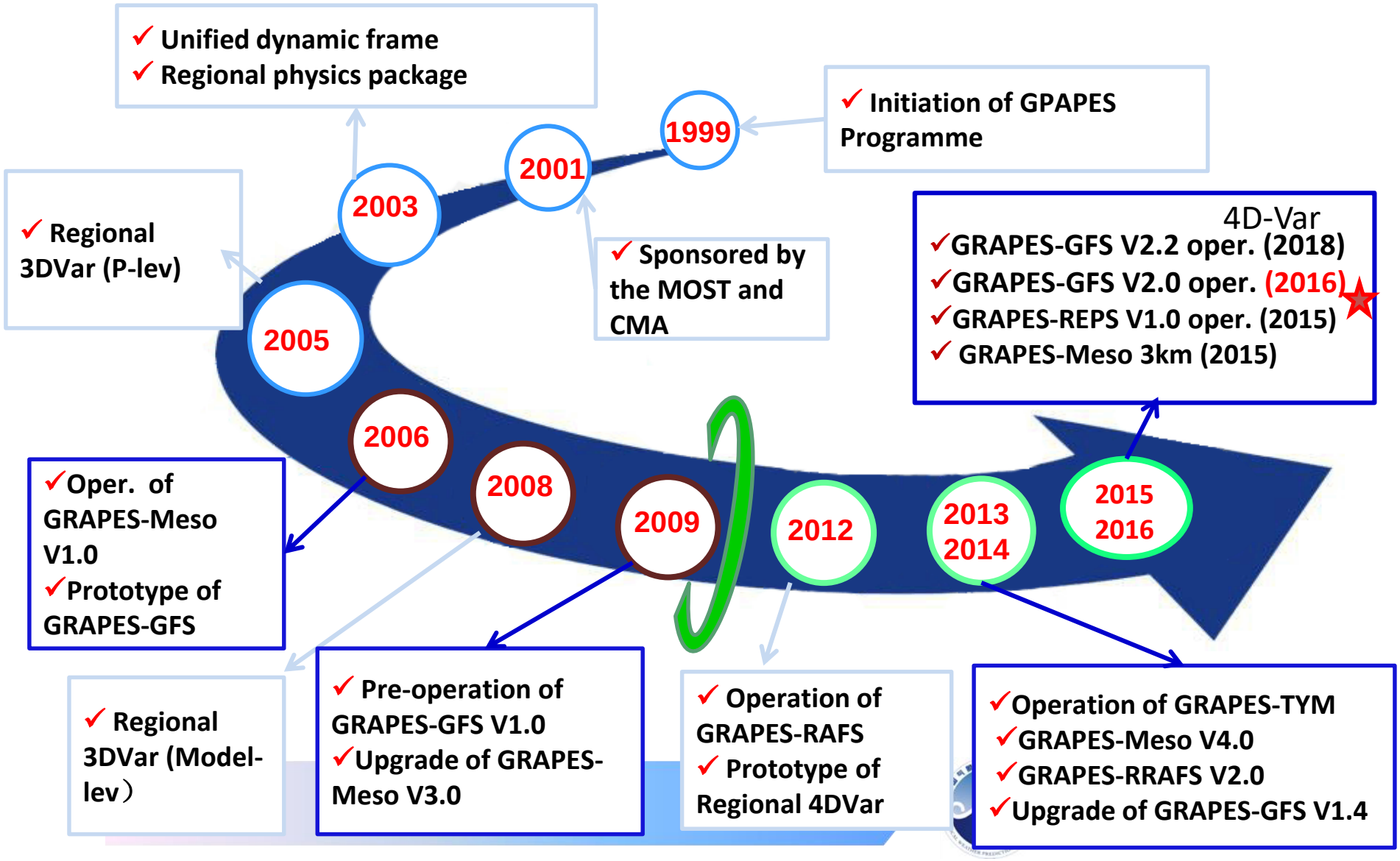
Numerical Weather Prediction Center, CMA

Outline

- **Background**
  - Progress of GRAPES
  - Analysis Uncertainty Over Asia
  - Key Issues in Satellite Radiance Assimilation：**Emissivity**
- **Progress**
  - Emissivity physical model, datasets , retrieval
  - Impact on O-B
  - Impact on analyses and forecasts using satellite radiances over land
- **Future Plan**
  - Use of more FY3、FY4 and other Satellite observations effectively
  - Focus on Tibetan Plateau and Sahara Desert

Milestones of GRAPES

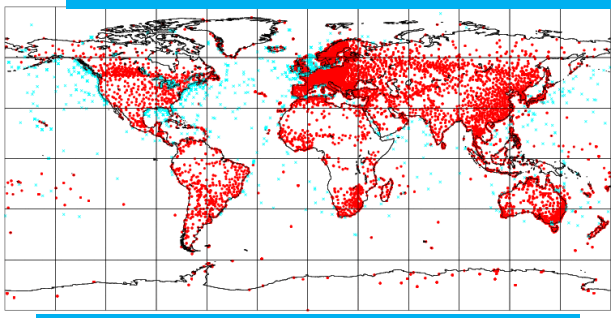
GRAPES =Global/Regional Assimilation PrEdiction System



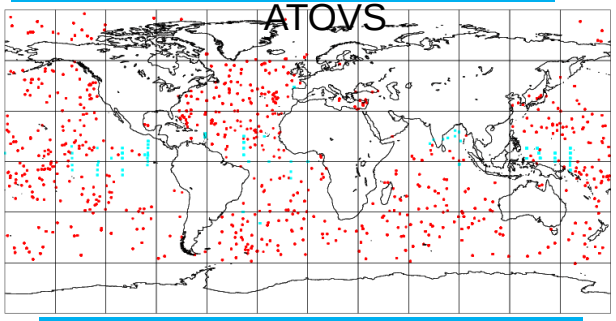
Observations in GRAPES-GFS Data Assimilation

(-3h~+3h) Time Window

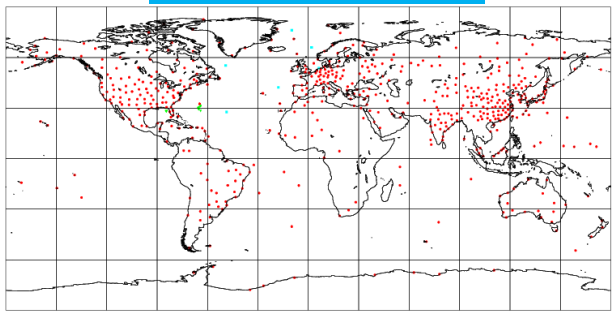
Synops and ships



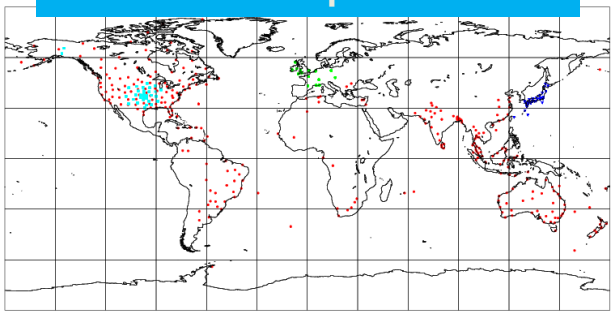
Buoys



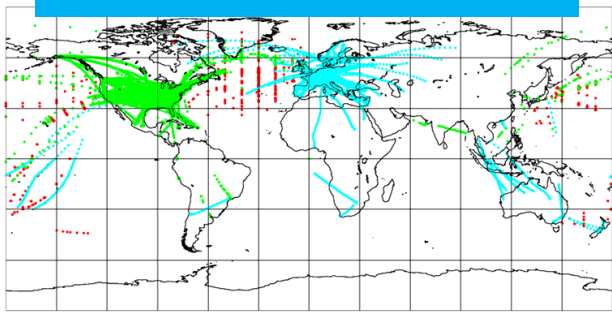
Radiosondes



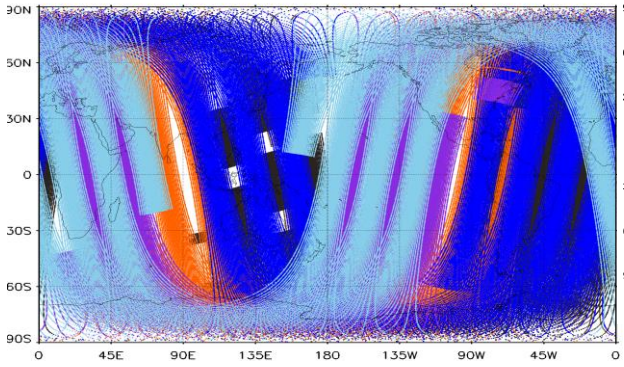
Pilots and profilers

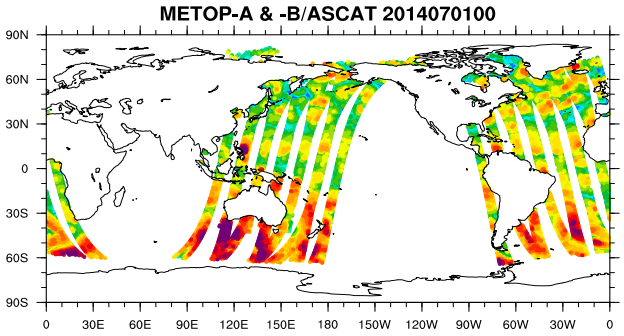


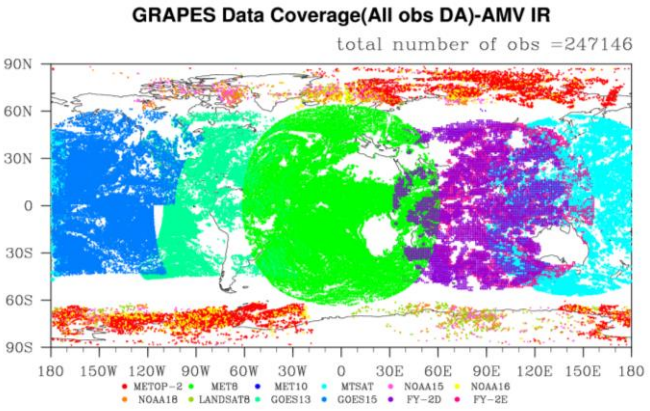
Aircraft



Polar(AMSU,ATMS)

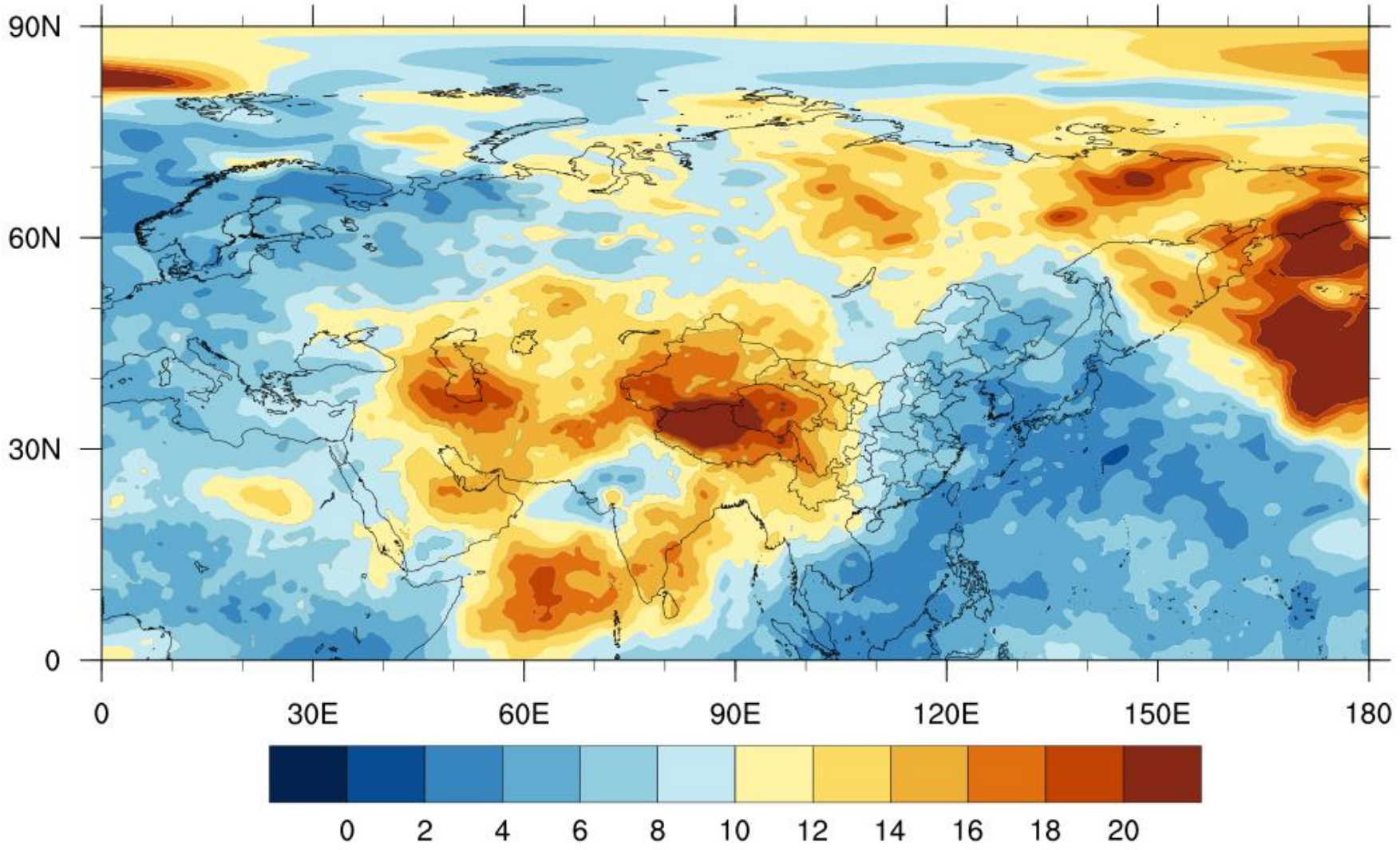




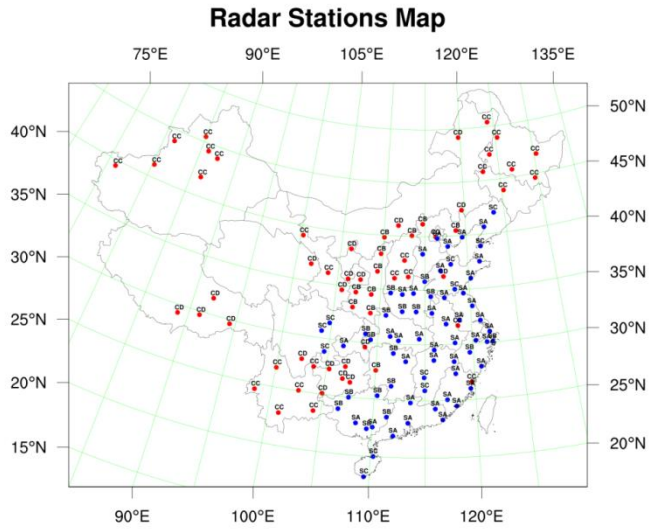


CNWP

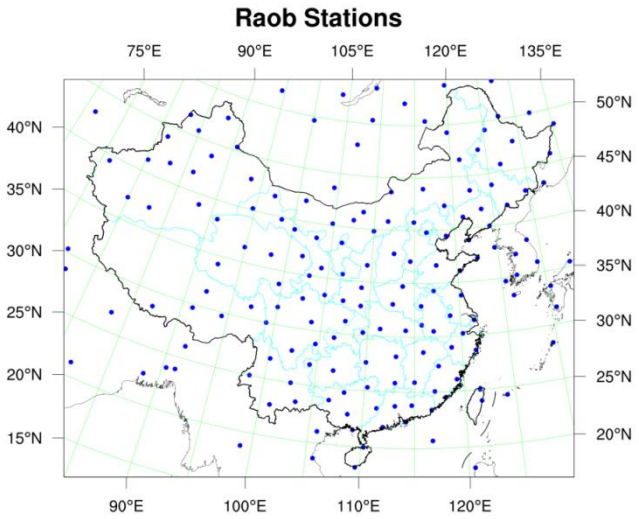
Analysis Uncertainty Over East Asia(500hPa)



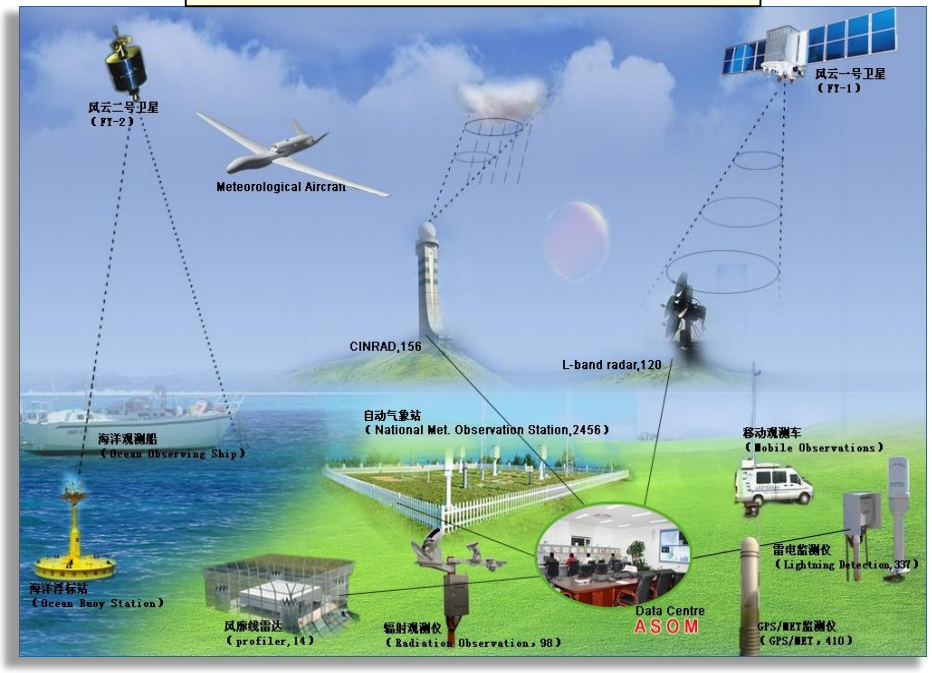
Mean RMS(H_GRAPES-H_ECMWF) at 500hPa for July 2016.

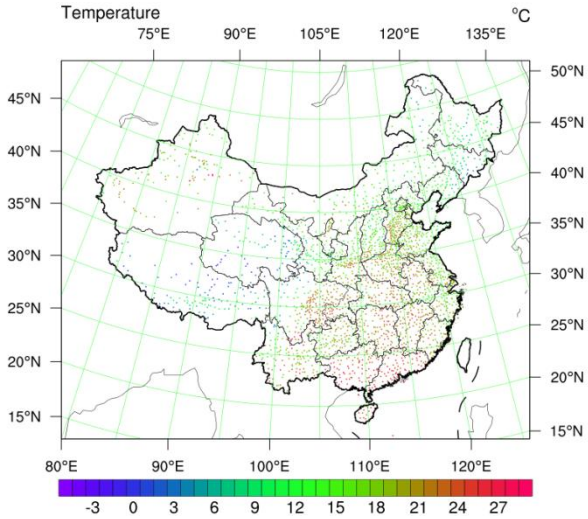


Weather Radar



Sonde station



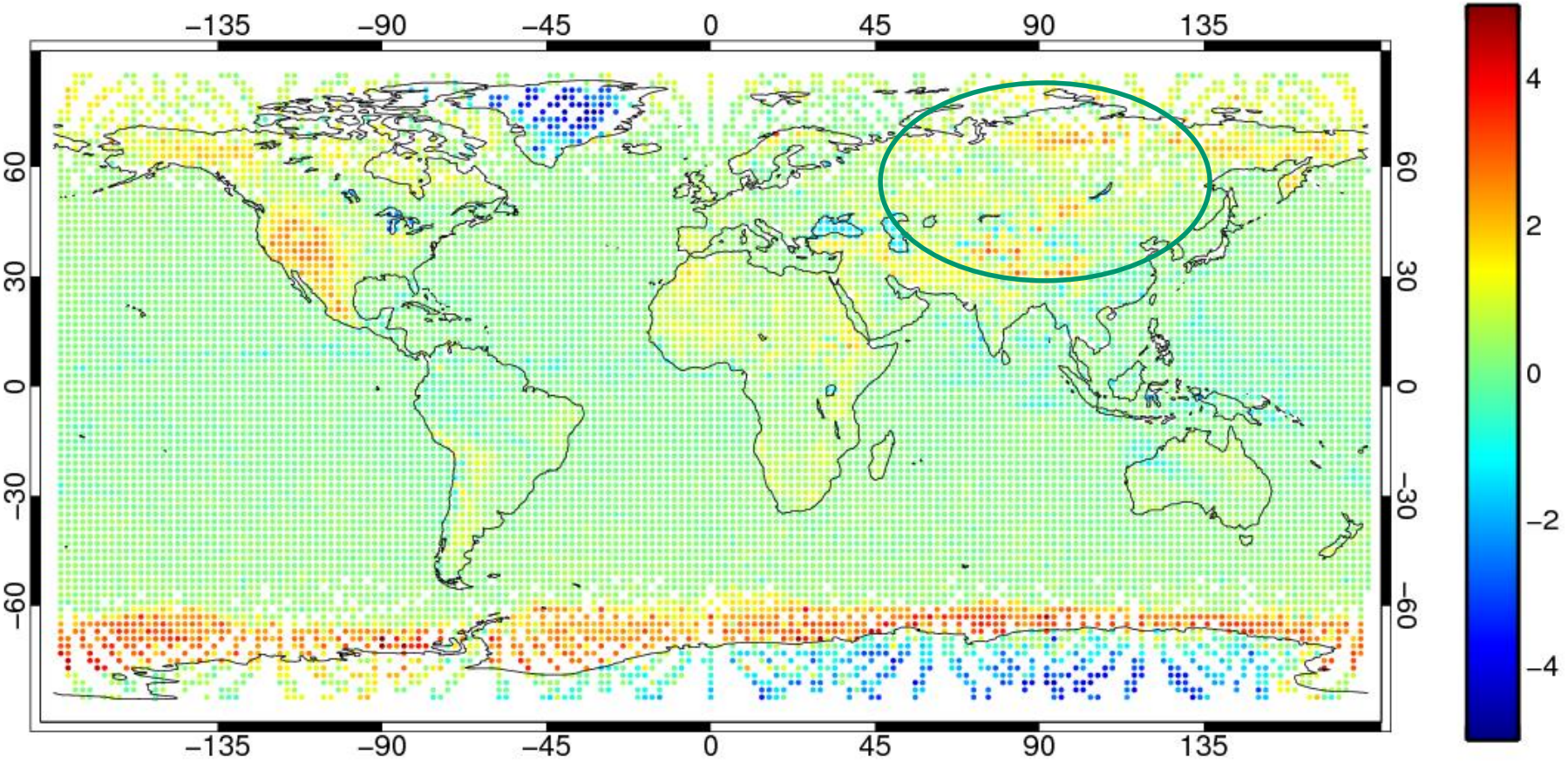


Surface Station

Large O-B over Land (2013/6/1~ 2013/6/10)

GRAPES

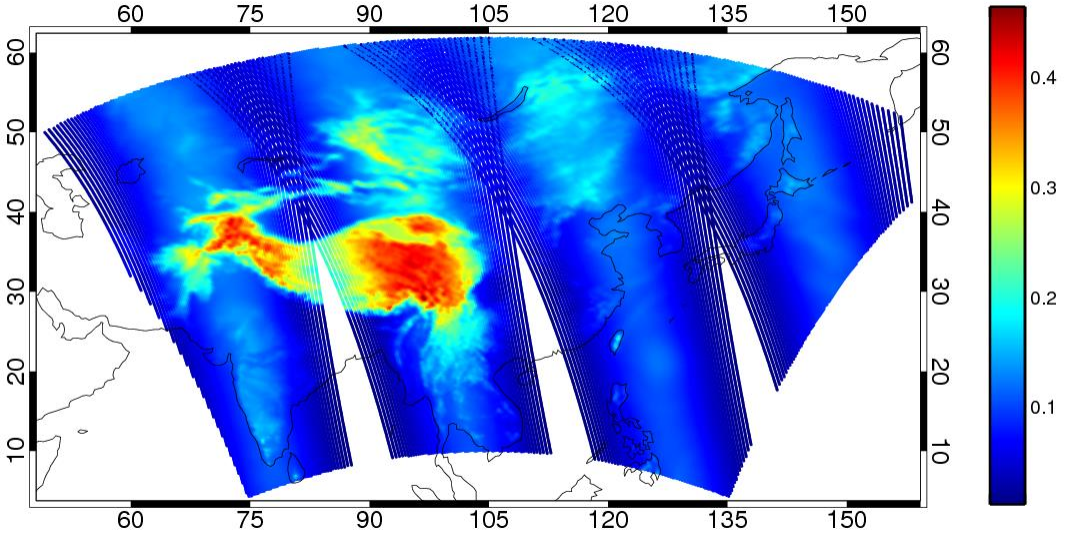
Ch5: 700hPa(WF peak)



2*2 degree box mean

Atmospheric Transmittance

- **Sounding channels (Temperature and moisture)**

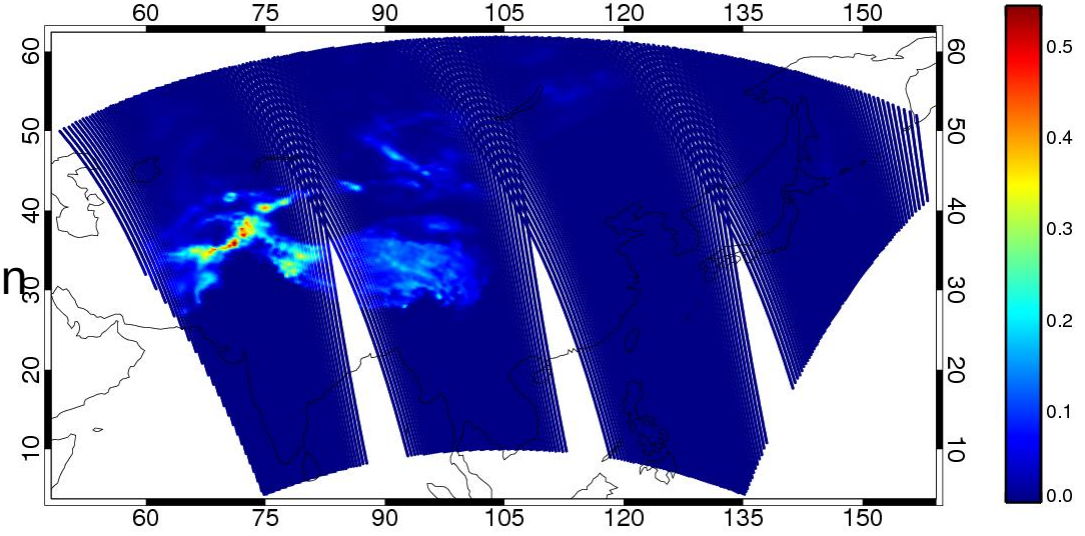


Temperature Sounding

Ch7,54.4GHz,400hPa

- **Tibetan Plateau**

Contribution from land surface need to be modeled accurate enough For extracting atmospheric information



Moisture Sounding

Ch19,183.31±4.5GHz,700hPa

Brightness Temperature Sensitivity to Surface Emissivity

Courtesy of Dr. Banghua Yan

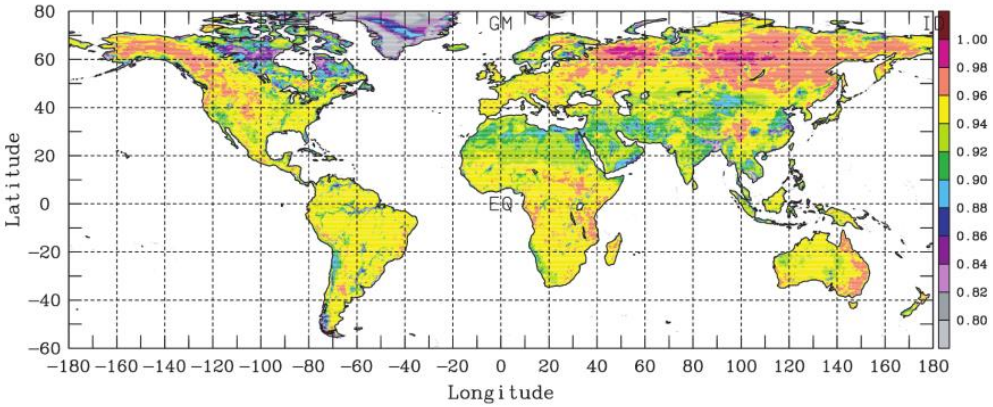
Freq (GHz)	Ts = 230 K and TPW = 0.5 mm					
	Ps = 600 (mb)			Ps = 1000 (mb)		
	T_d(K)	τ	ΔT_B(K)	T_d(K)	τ	ΔT_B(K)
50.3	49.30	0.774	5.593	112.5	0.487	2.289
52.8	111.2	0.492	2.337	188.6	0.153	0.253
150	4.4	0.980	8.844	12.5	0.944	8.209
183.3±7	16.6	0.925	7.893	43.5	0.807	6.018
183.3±3	55.3	0.750	5.242	104.1	0.538	2.709
183.3±1	134.6	0.392	1.496	160.1	0.288	0.806

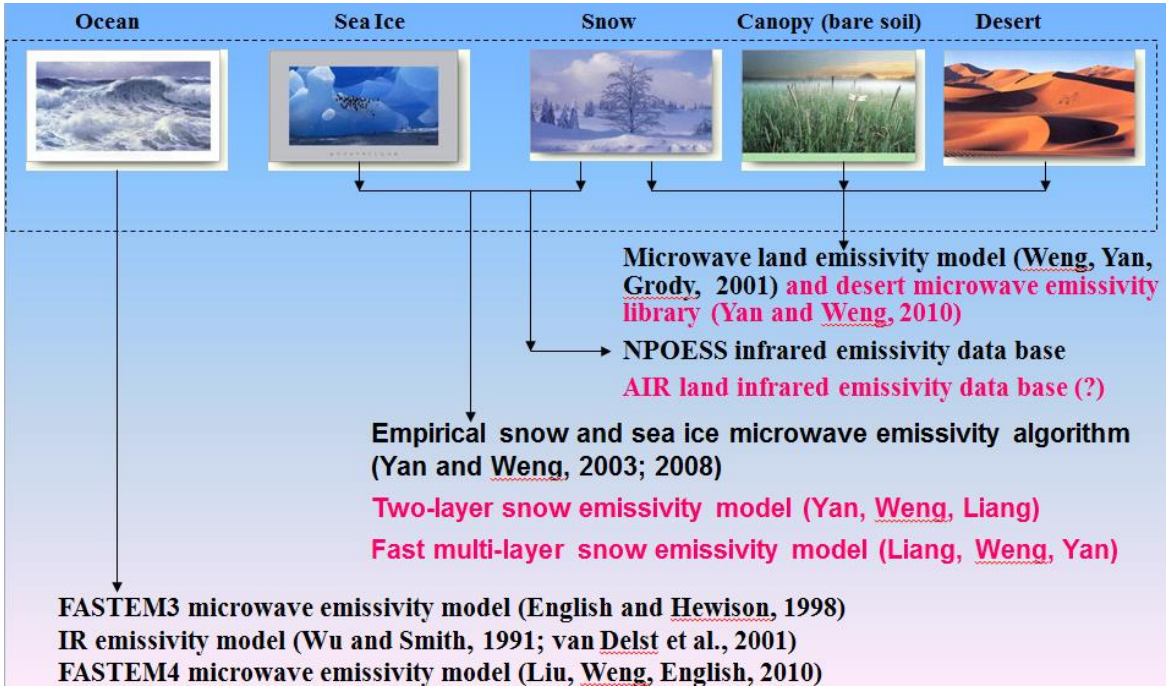
$$\Delta T_B = \tau(T_s - T_d)\Delta\varepsilon \qquad \Delta\varepsilon = 0.04$$

Three main techniques for land emissivity in NWP

- Physical model (Weng)
- Datasets (Catherine)
- Window channel retrieval

$$\varepsilon_\alpha = \frac{R_\alpha - R_u - \tau R_d}{\tau(R(T_s) - R_d)}$$

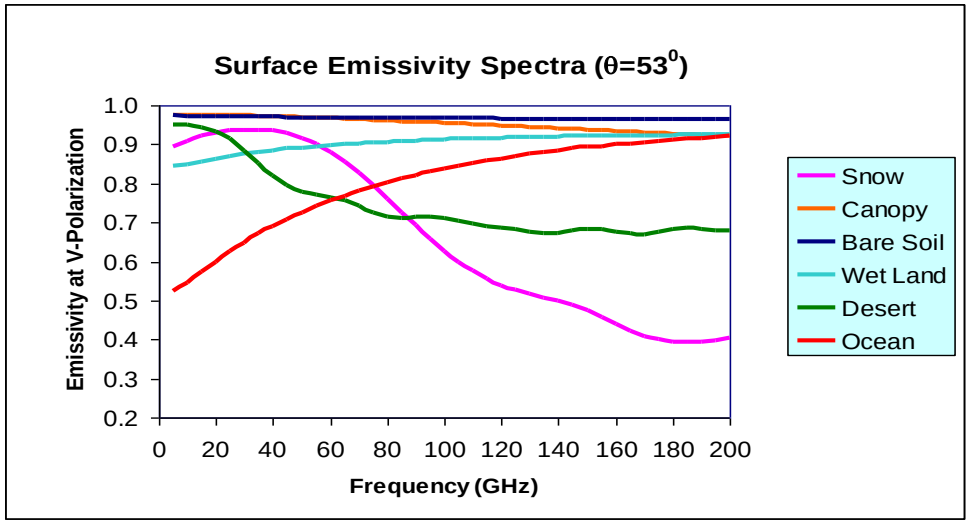


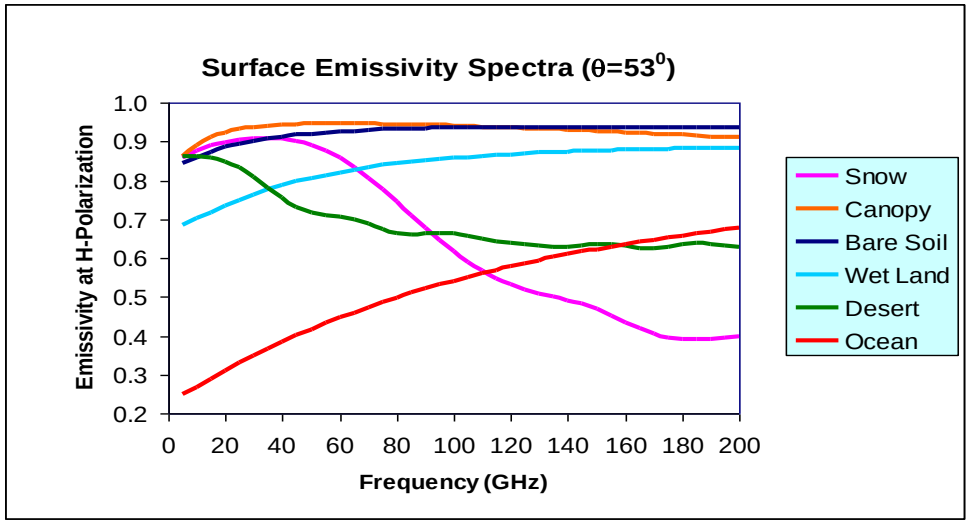


Surface Emissivity Spectrum vs. Surface Type

- **Open water** – two-scale roughness theory
- **Sea ice** – Coherent reflection
- **Canopy** – Layer clustering scattering
- **Bare soil** – Coherent reflection and surface roughness
- **Snow/desert** – Random media

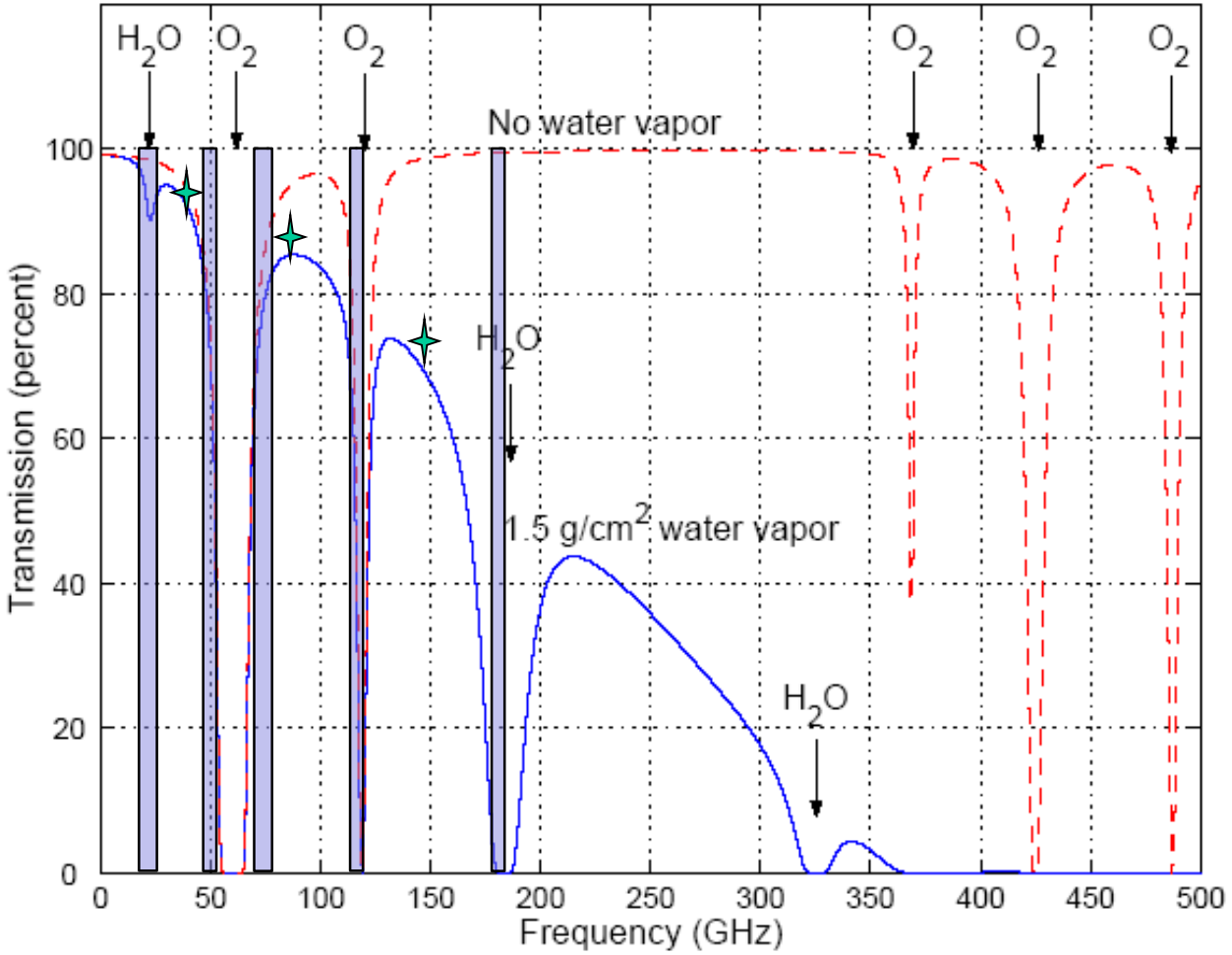
Weng et al (2001, JGR)





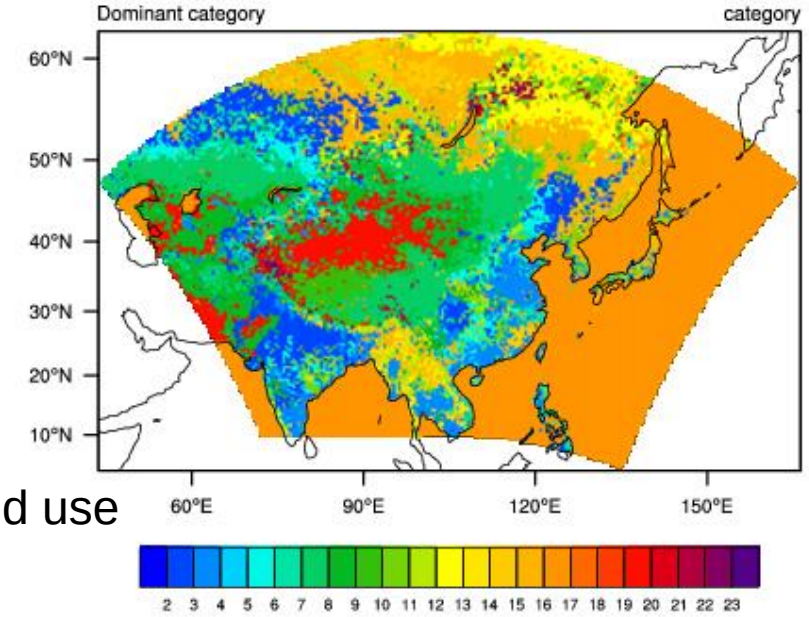
Atmospheric Transmission at Microwave Wavelengths

$$\varepsilon_\alpha = \frac{R_\alpha - R_u - \tau R_d}{\tau(R(T_s) - R_d)}$$

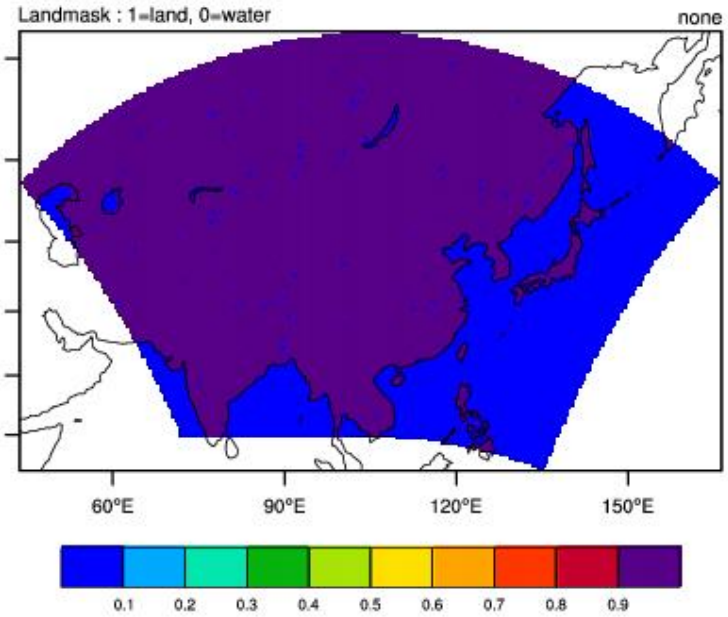


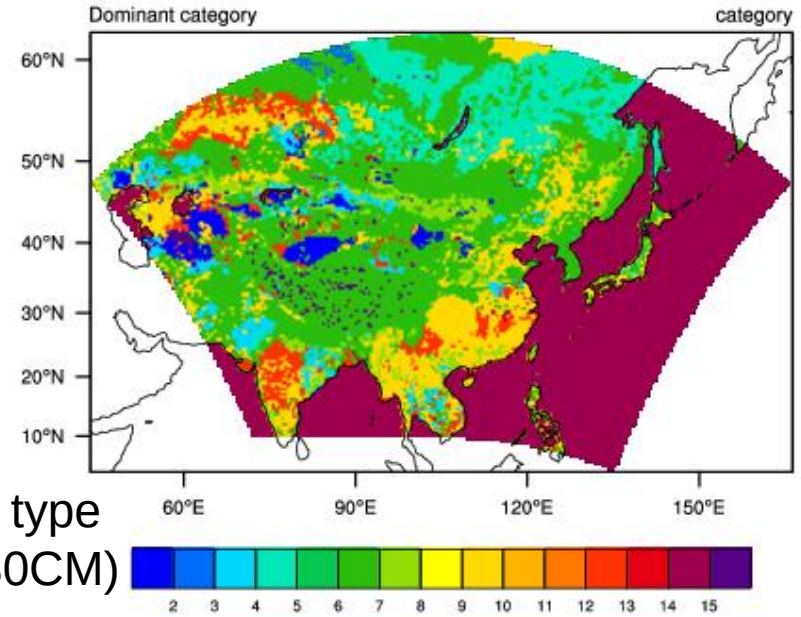
Using the window channel to retrive the emissivity, interpolated to nearby frequency channels

Land use and soil category

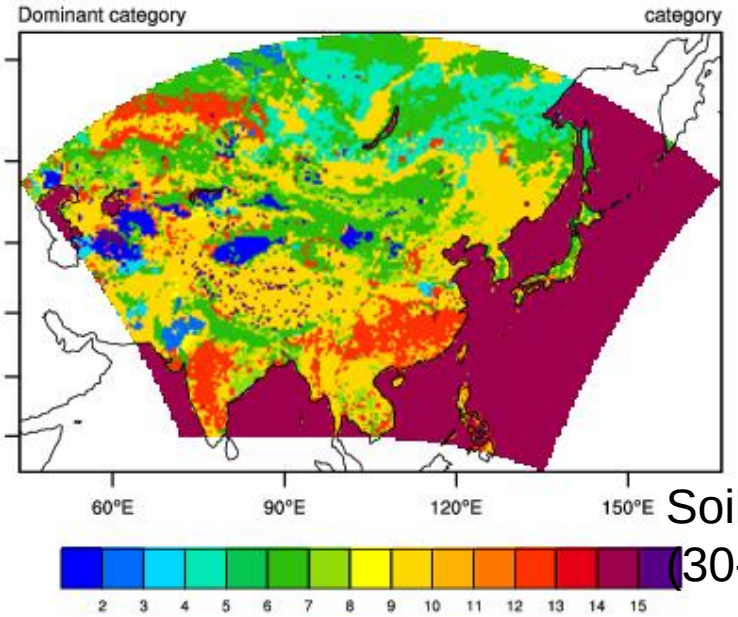


Land use



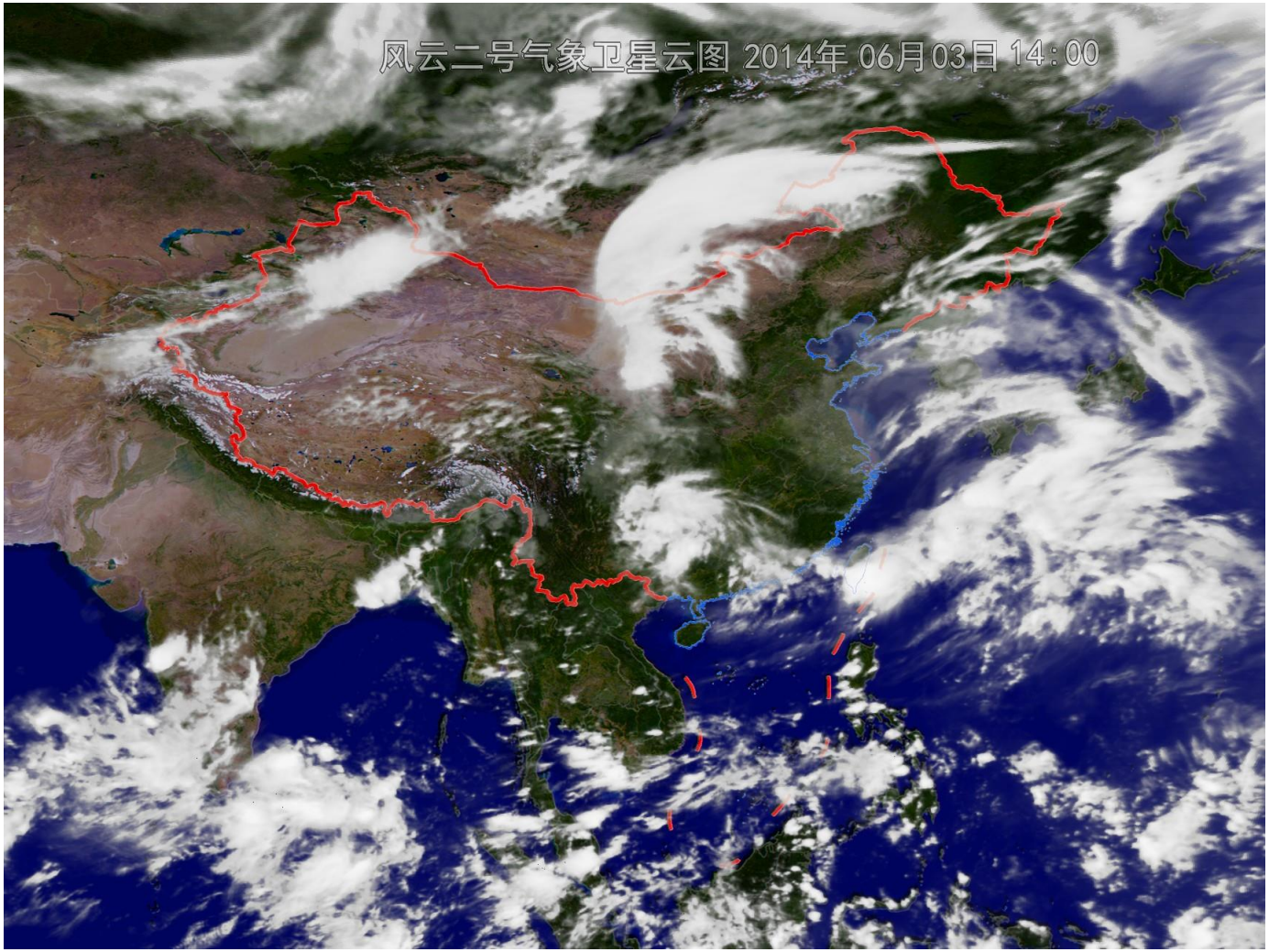


Soil type (0-30CM)



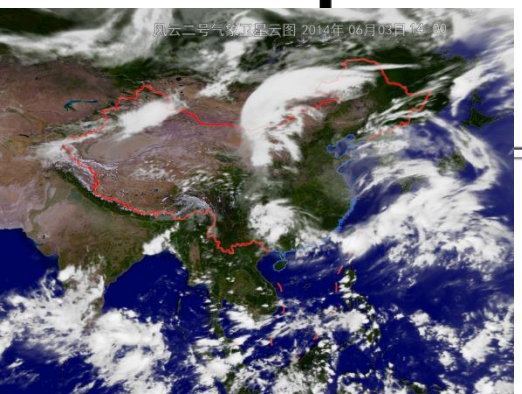
Soil type (30-60CM)

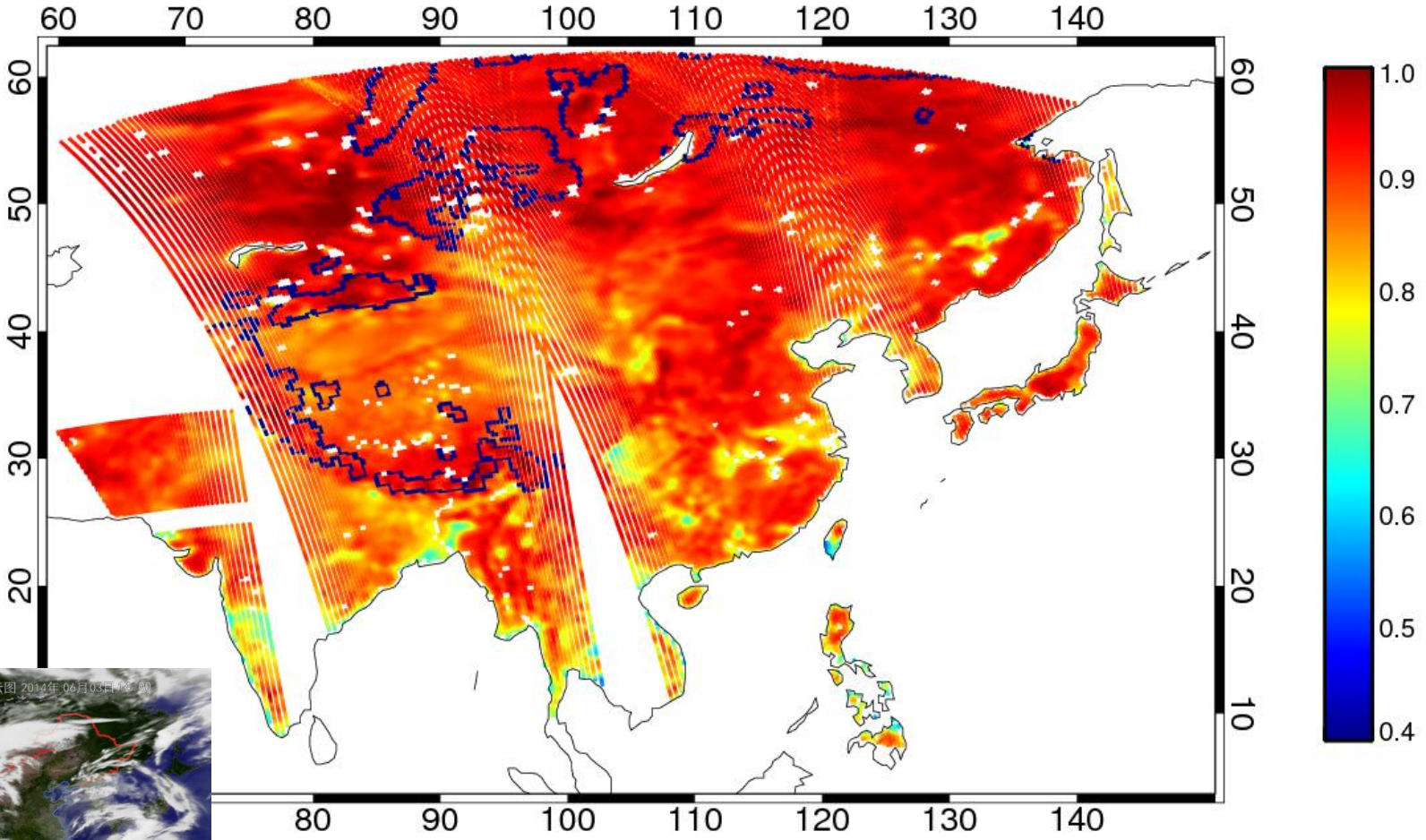
Case study: 06Z 3 June,2014



Emissivty Retrieval (ATMS Ch4)

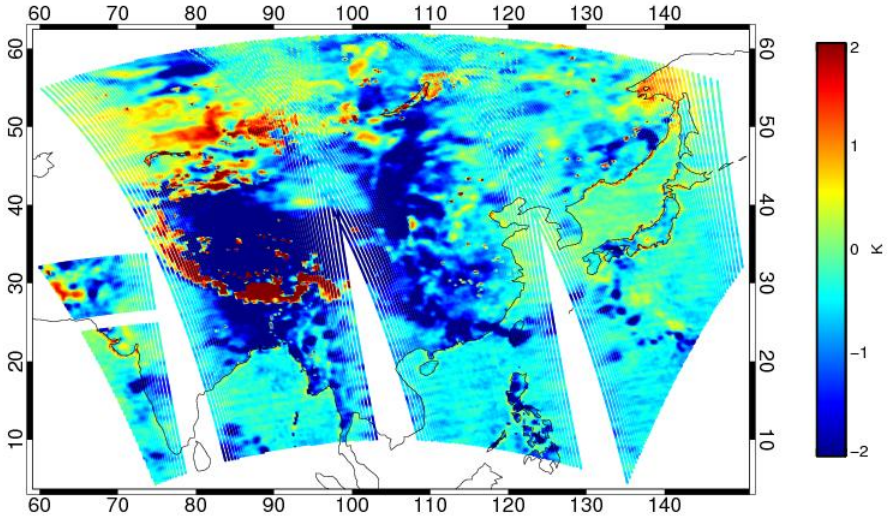
$$\varepsilon_\alpha = \frac{R_\alpha - R_u - \tau R_d}{\tau(R(T_s) - R_d)}$$

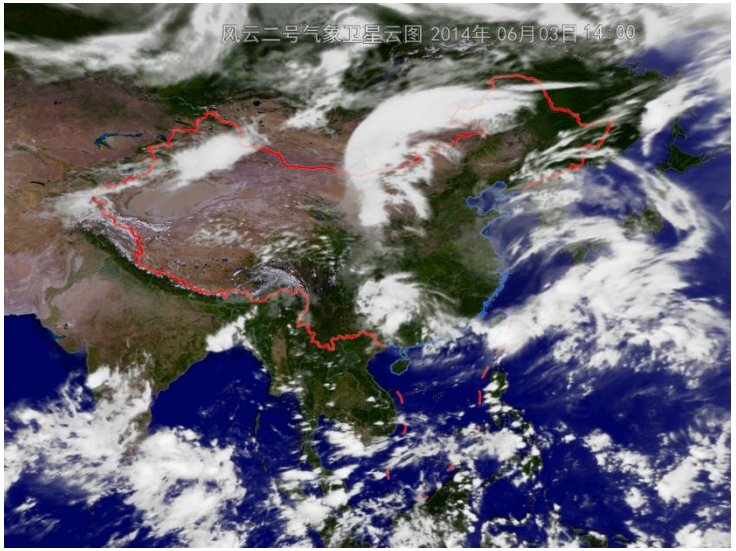




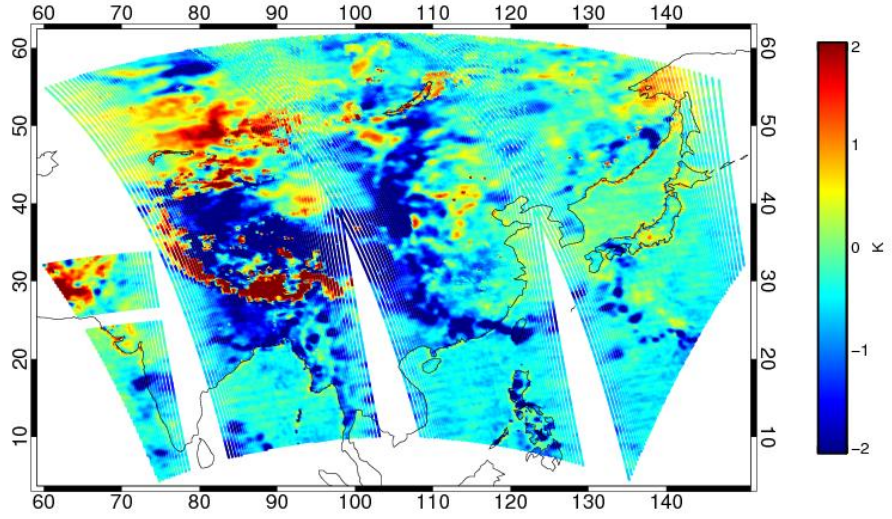
Es impact on O-B (ch7,54.4GHz)

CRTM_BASE

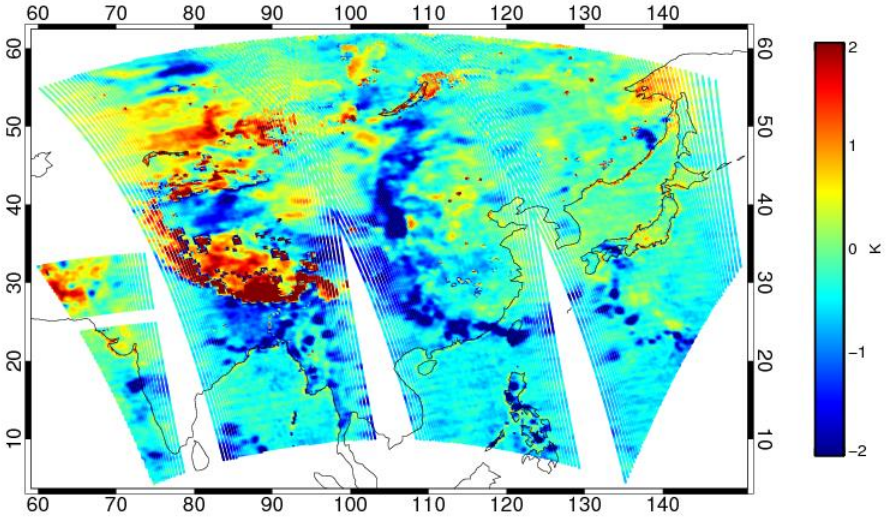




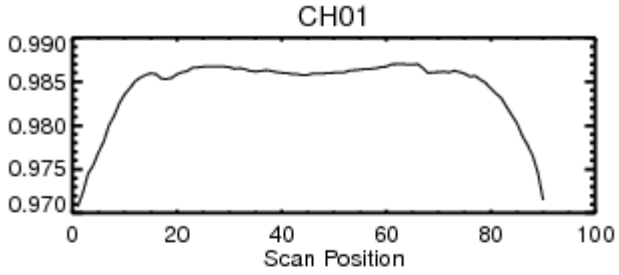
TESEM

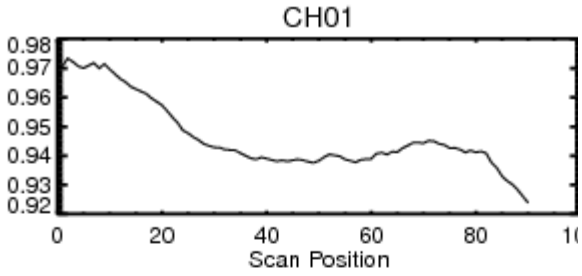


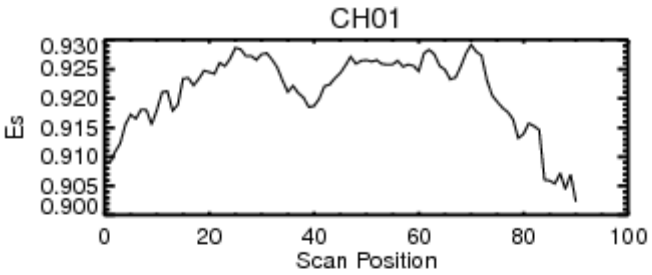
Window channel retrievalCH4

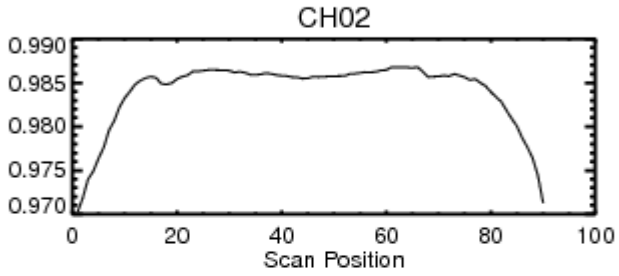


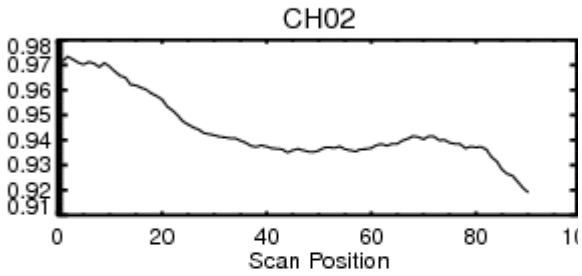
Emissivity scan angle dependence

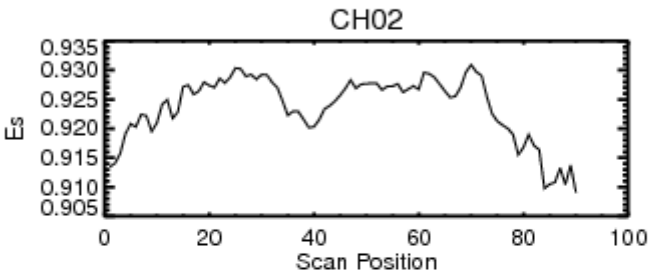


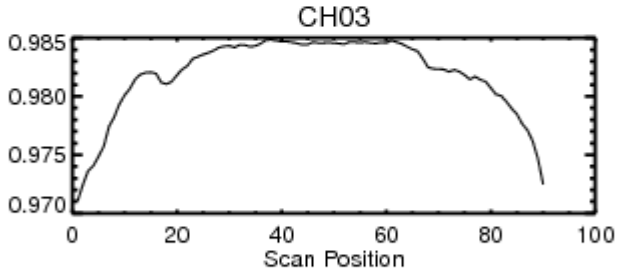


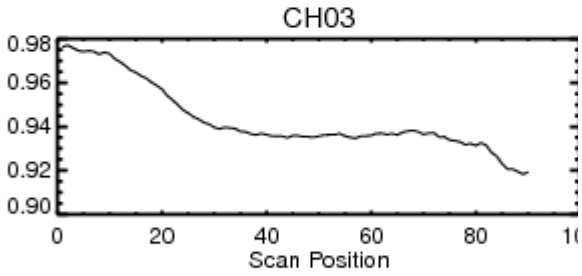


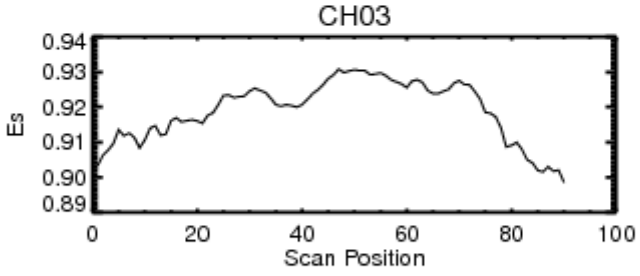


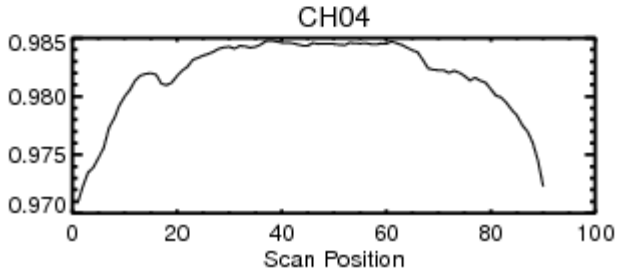


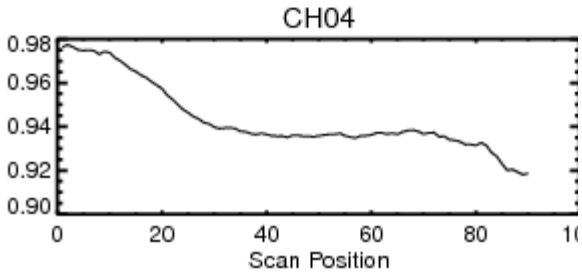


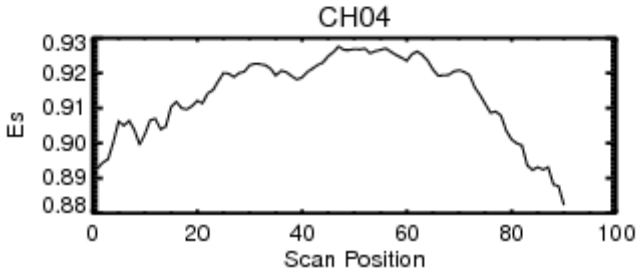




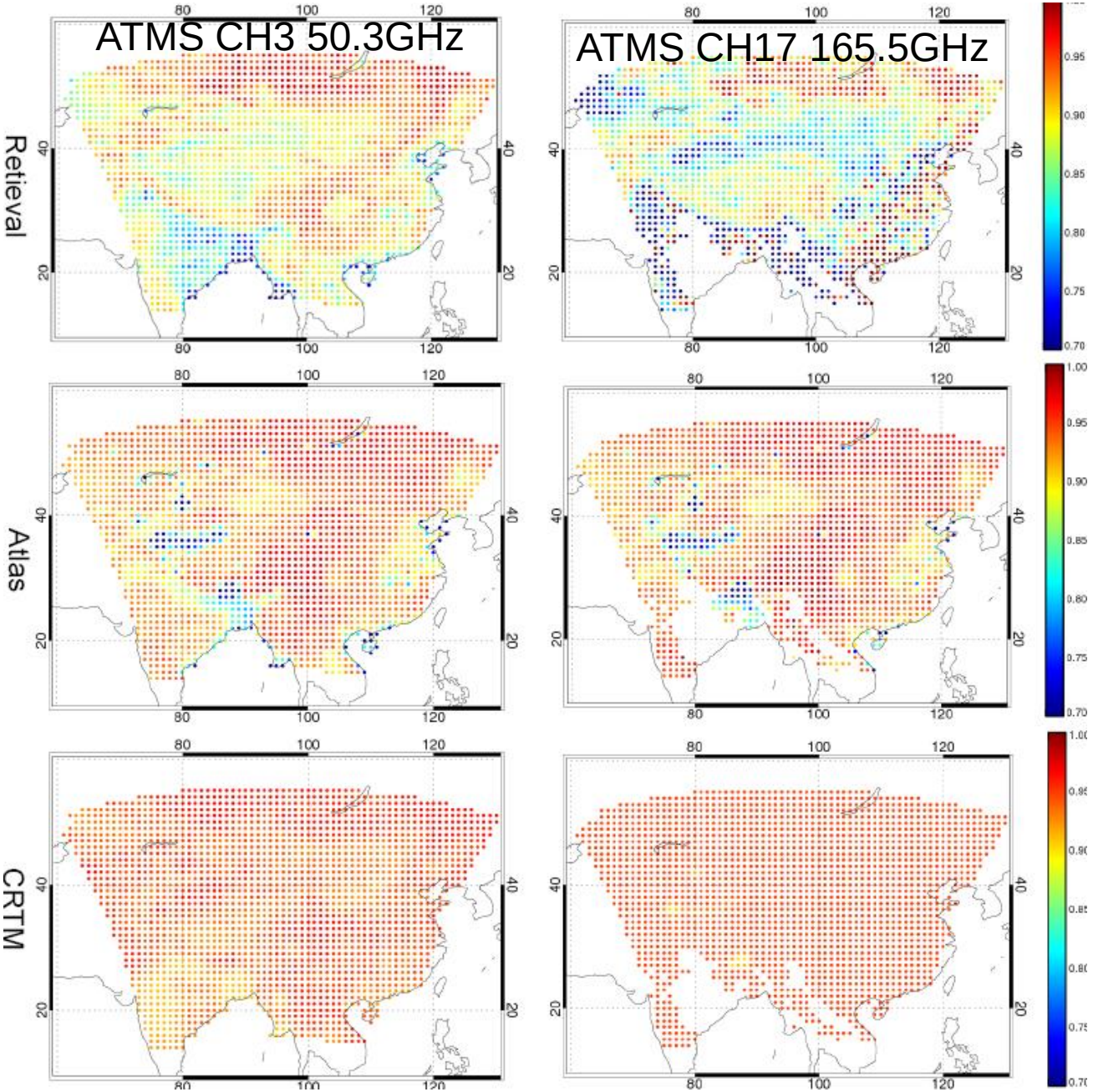








Mean Emissivity (20120801~20120807)



Impact of emissivity scheme on O-B (ATMS)

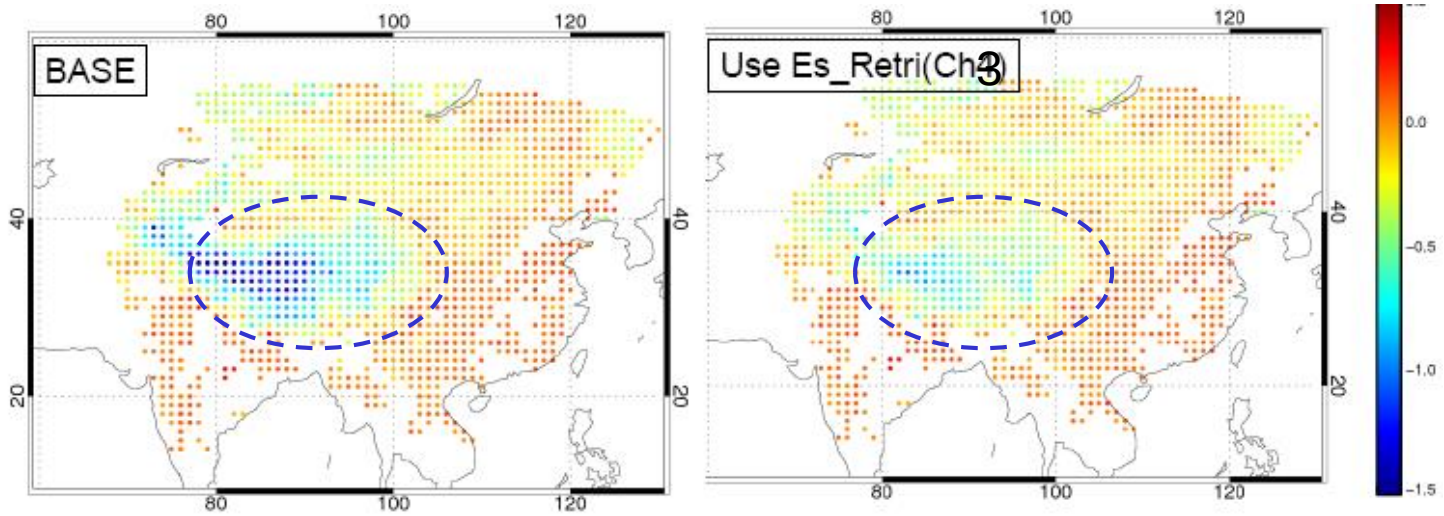


Fig.3: <O-B>, August 1-7.2012. ATMS CH7 54.4GHz

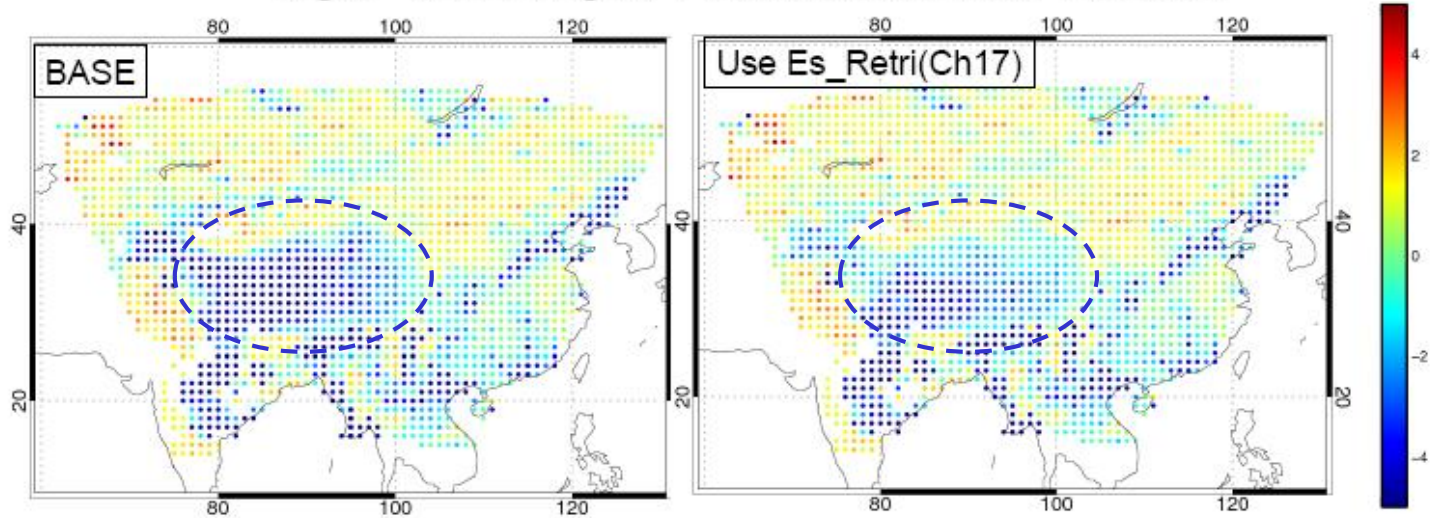
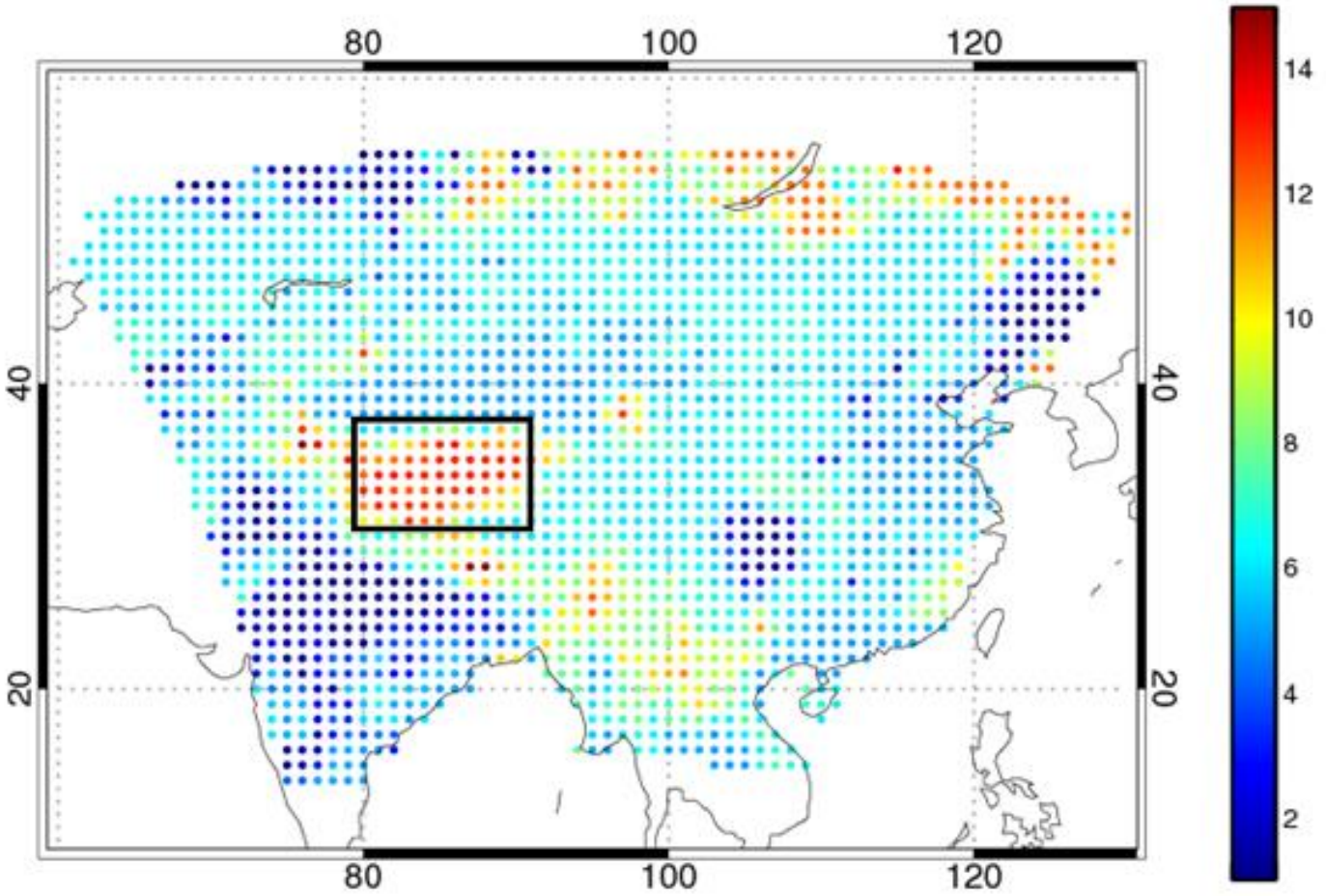
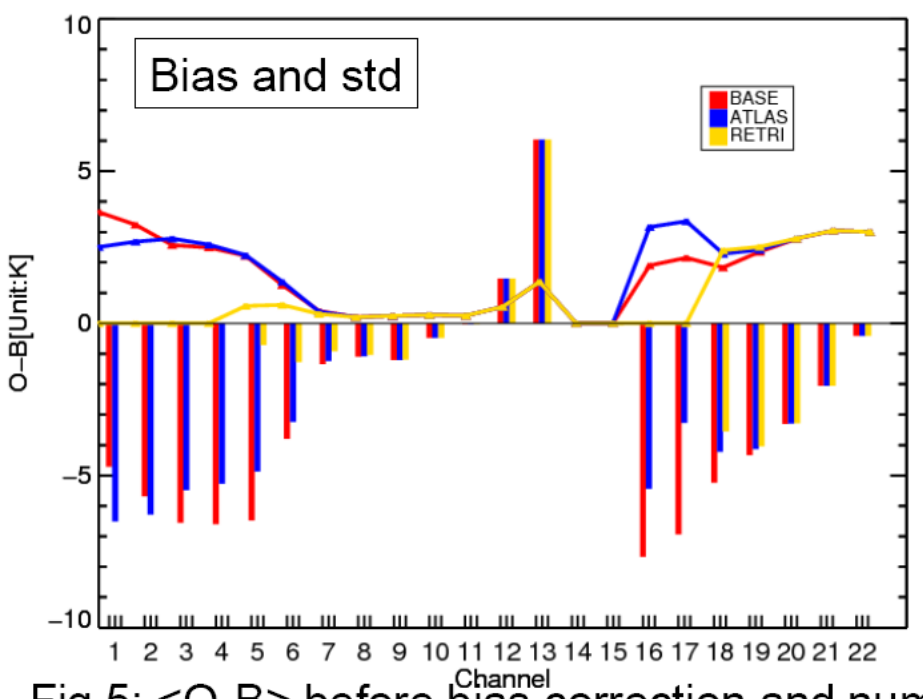


Fig.4: <O-B>, August 1-7,2012, ATMS CH18 183±7GHz

Type 13 over Tibetan Plateau



O-B and active obs. number



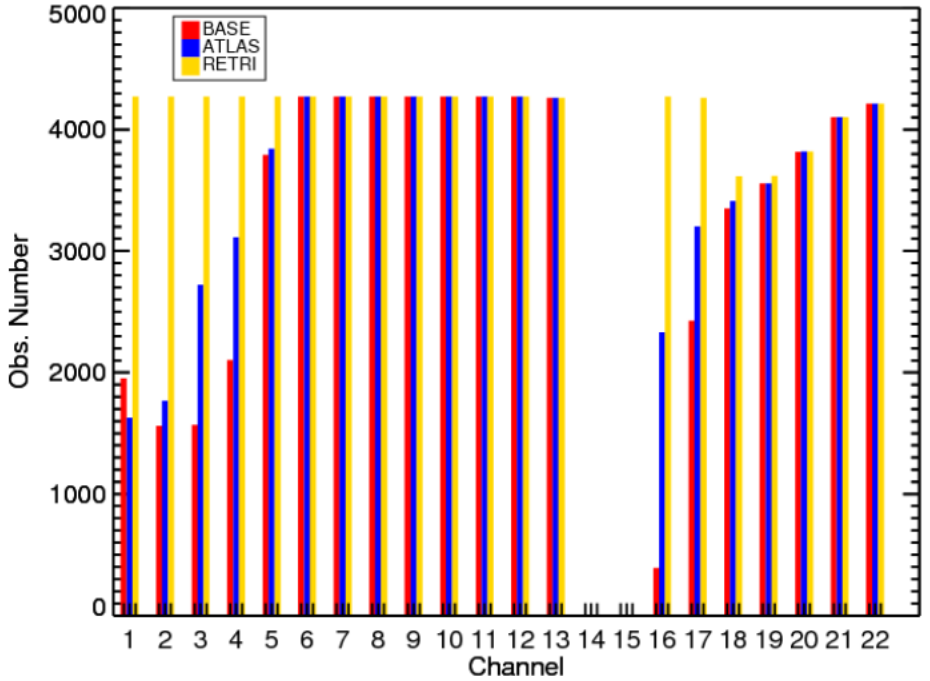
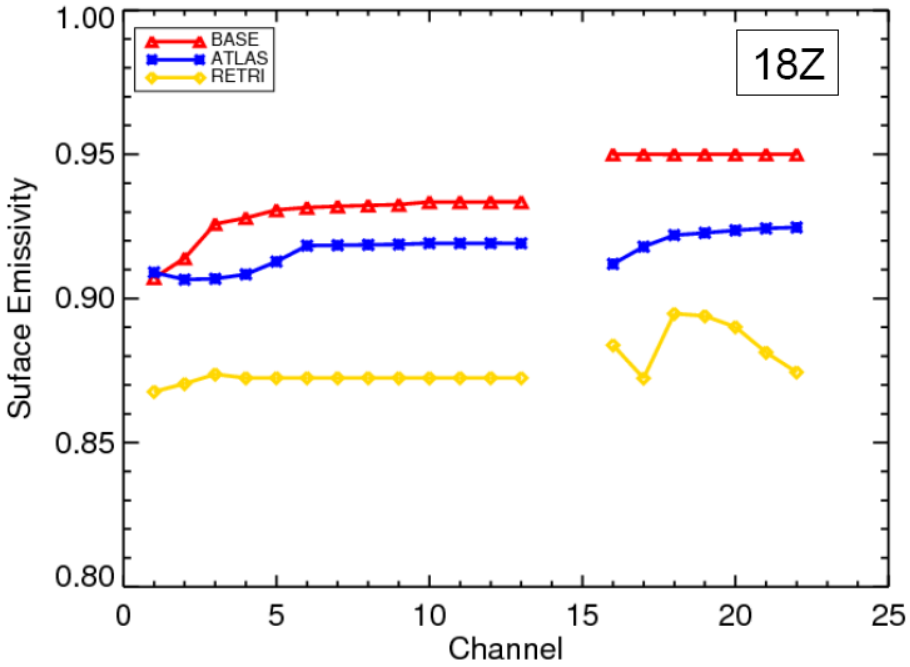


Fig.5: <O-B> before bias correction and number of used observations for land type 13 over Tibetan Plateau.



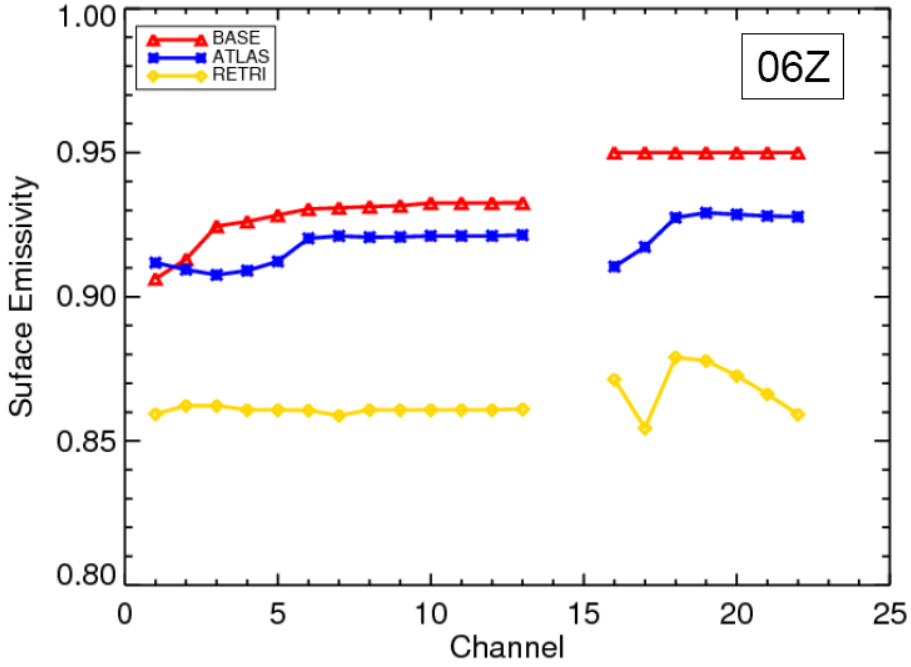


Fig.7: Mean surface emissivity for land type 13 over Tibetan Plateau in the thee schemes at 18Z (2AM, local time) and 06Z(2PM,local time)

How to improve the physical model?

Table 1. Mean Emissivity and Its Standard Deviation for Bare Soil[a]

Frequency, GHz	Mean h-pol		Bias h-pol	Mean v-pol		Bias v-pol	Standard Deviation			
							h-pol		v-pol	
	M	S	$M - S$	M	S	$M - S$	M	S	M	S
4.9	0.7509	0.7484	−0.0025	0.8868	0.9127	−0.0259	0.0740	0.0866	0.0333	0.0331
10.4	0.8430	0.8207	0.0223	0.9007	0.9233	−0.0226	0.0482	0.0608	0.0293	0.0203
21.0	0.9035	0.8717	0.0318	0.9178	0.9253	−0.0075	0.0349	0.0387	0.0230	0.0160
35.0	0.9068	0.8952	0.0116	0.9151	0.9254	−0.0103	0.0339	0.0264	0.0242	0.0150
94.0	0.9354	0.9259	0.0095	0.9438	0.9376	0.0062	0.0209	0.0200	0.0135	0.0141

Reported parameters: viewing angle, 50°; temperature range, 0°C to 25°C; soil moisture range, 12–45%. Specified parameters: roughness rms, 0.25; clay and sandy fraction, 0.9 and 0.1, respectively; soil and solids density, 1.18 and 2.65 g cm^3, respectively.

[a]Symbols "v-pol" and "h-pol" represent vertical and horizontal polarization, respectively. "M" and "S" are denoted for the measurements and

Table 2. Mean Emissivity and Its Standard Deviation for Short Grass

S

Frequency, GHz	Mean h-pol		Bias h-pol	Mean v-pol		Bias v-pol	Standard Deviation			
							h-pol		v-pol	
	M	S	$M - S$	M	S	$M - S$	M	S	M	S
4.9	0.9284	0.8887	0.0397	0.9395	0.9330	0.0029	0.0076	0.0060	0.0115	0.0123
10.4	0.9508	0.9345	0.0163	0.9565	0.9451	0.0114	0.0075	0.0056	0.0079	0.0080
21.0	0.9440	0.9471	−0.0031	0.9409	0.9501	−0.0092	0.0114	0.0045	0.0101	0.0062
35.0	0.9474	0.9500	−0.0026	0.9428	0.9519	−0.0091	0.0095	0.0034	0.0083	0.0059
94.0	0.9424	0.9507	−0.0083	0.9477	0.9518	−0.0041	0.0082	0.0023	0.0097	0.0046

Reported parameters: viewing angle, 50°; grass height, 5–10 cm; temperature range, >0°C; soil moisture range, 13–60%. Specified parameters: roughness rms, 0.25; clay and sandy fraction, 0.9 and 0.1, respectively; soil and solids density, 1.18 and 2.65 g cm^3, respectively; leaf area index, 1.5 and leaf thickness, 0.15 mm; leaf orientation, random ($g = 0.5$ for v- and h-pol); canopy gravimetric water content, 0.55–0.8.

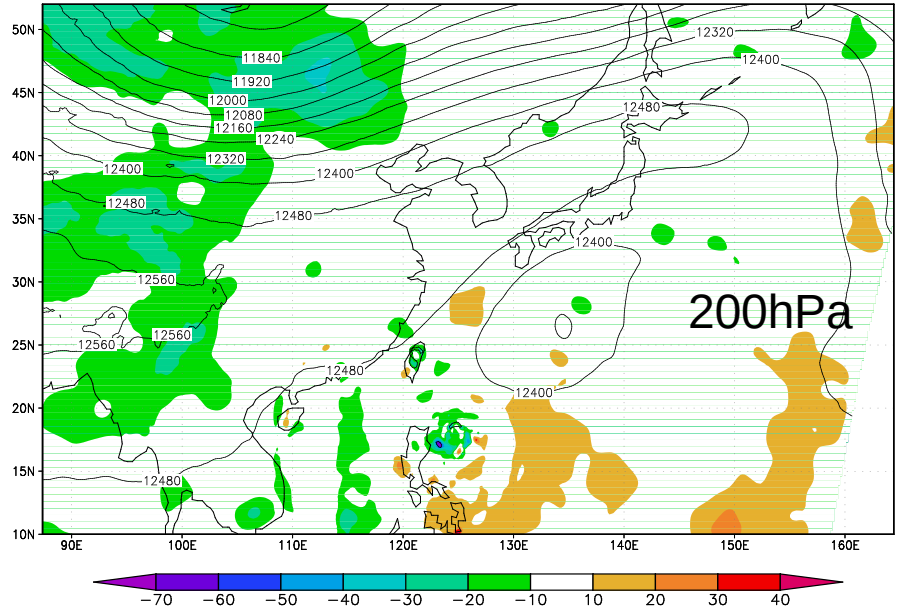
Impact of assimilation microwave radiances over land

- **Typhoon Tembin in 2012**
  - Importance of Mid-latitude weather system for Typhoon Track Forecasts
  - Better use of data in Central Asia, Better Typhoon Track Frorecasts

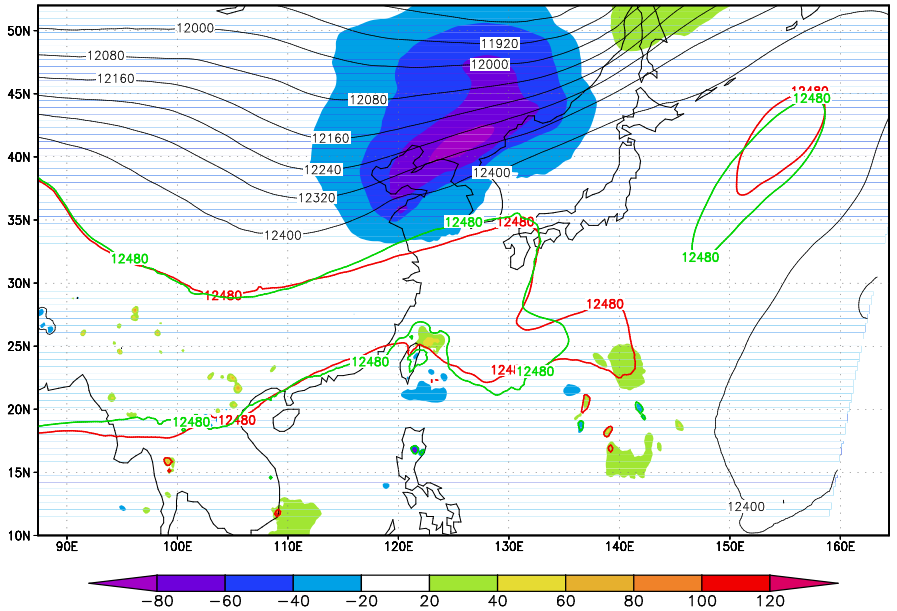
- **Heavy rainfall in 2007 (Jina “718”)**
  - Importance of Moisture information from satellite over land
  - Clear Sky Radiances Assimilation

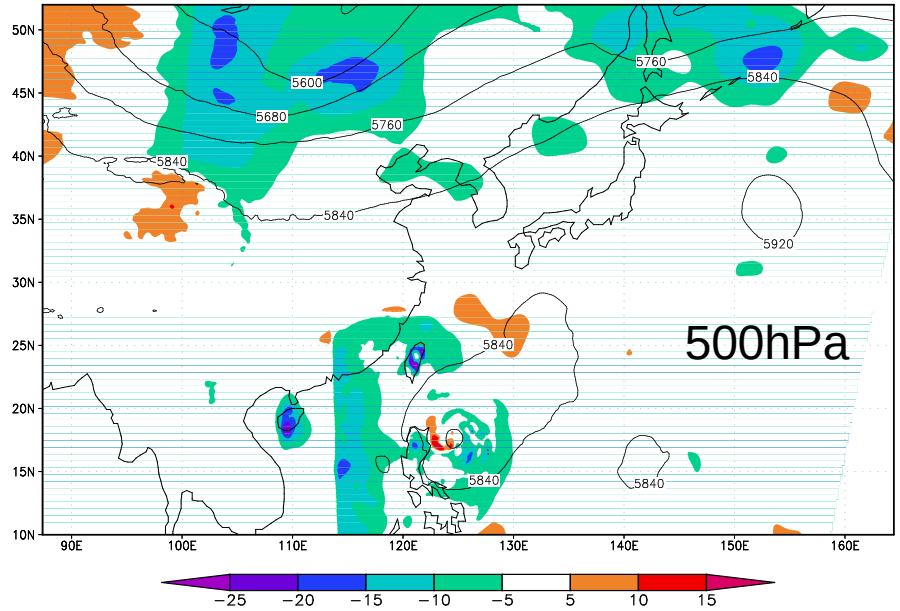
Use of microwave radiances over land

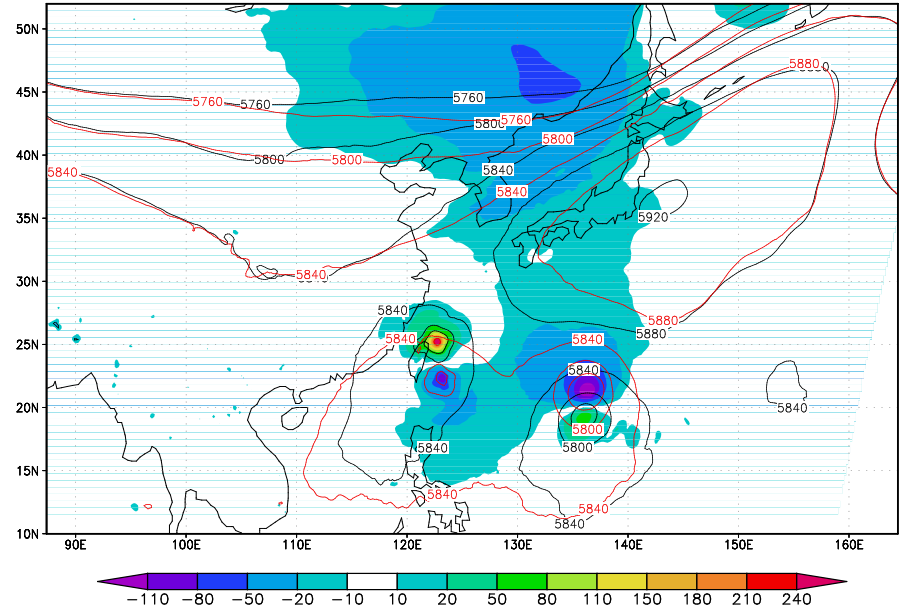
T=0



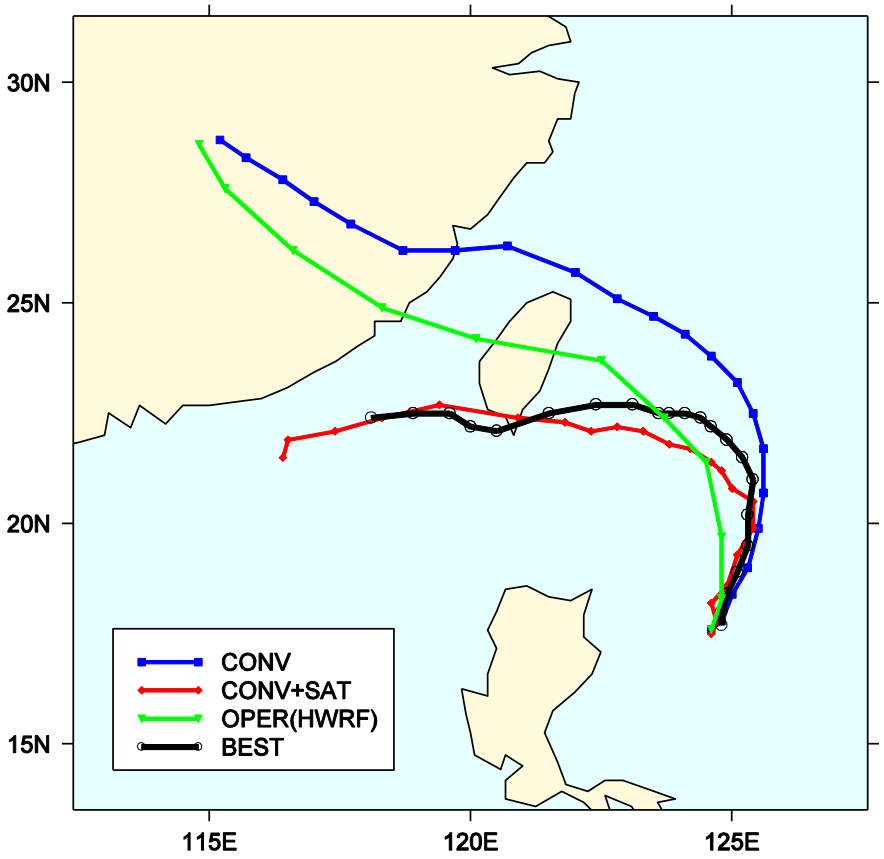
T=72H

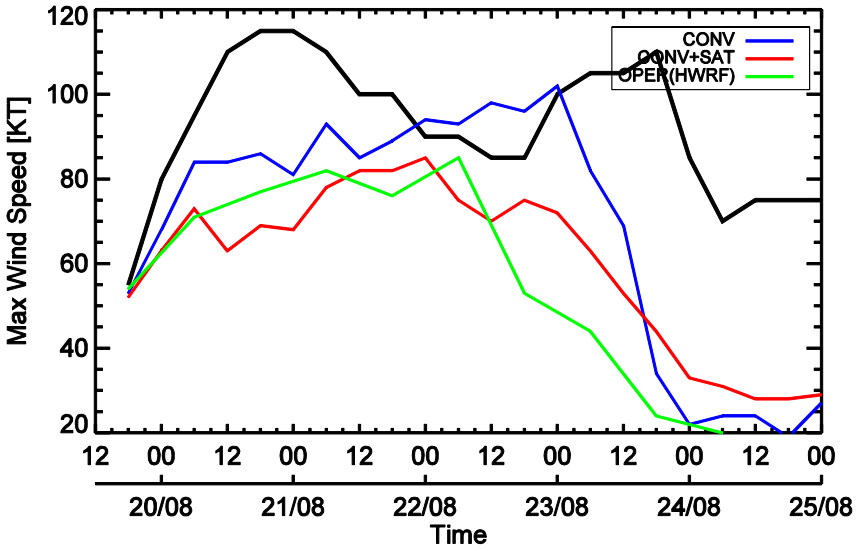


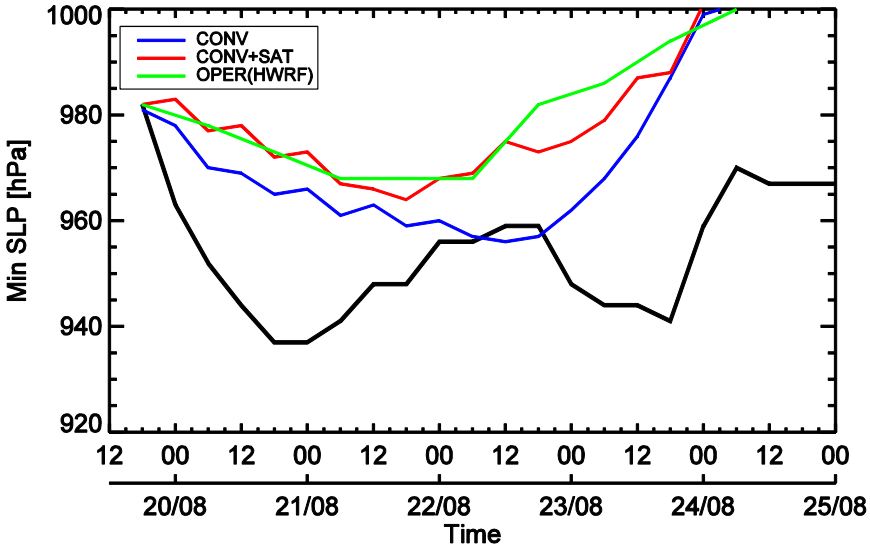




2012081918

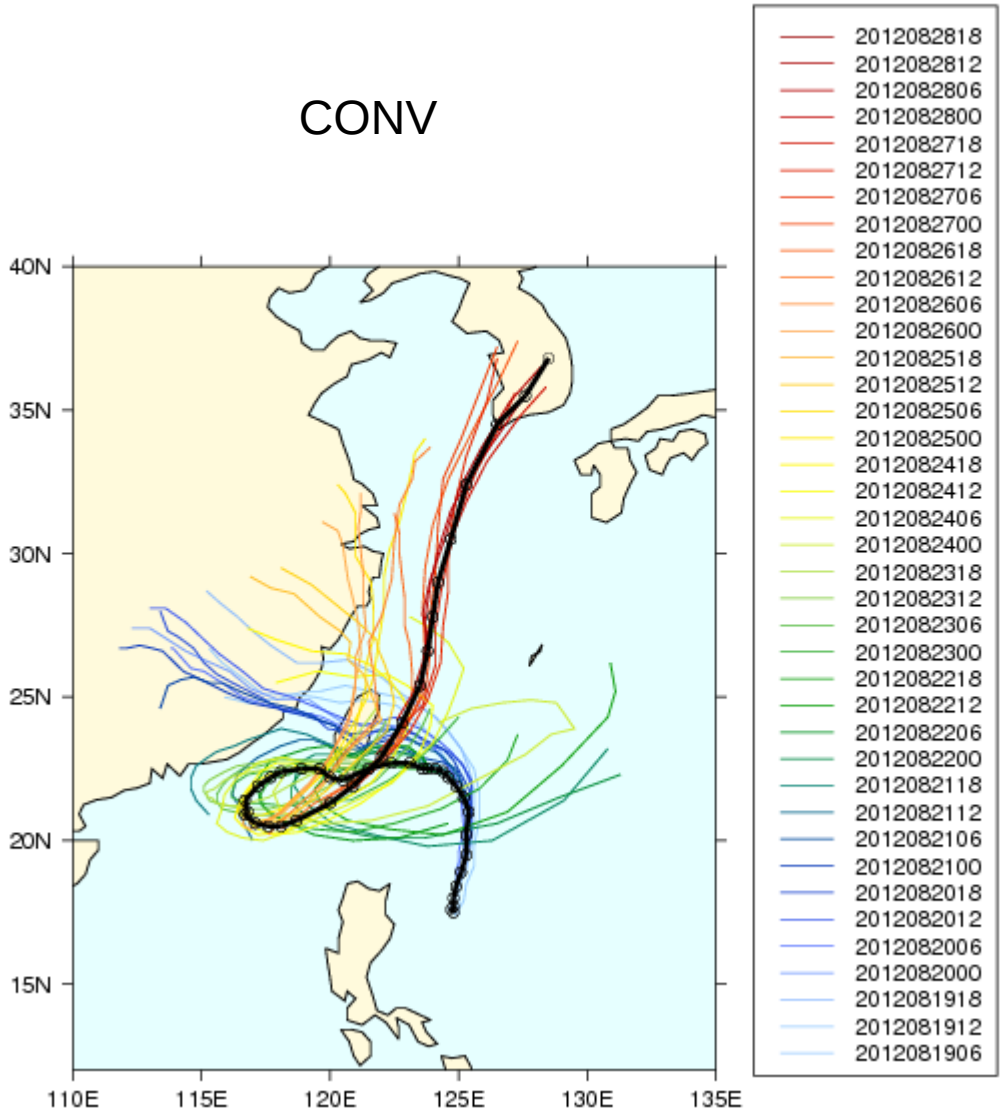

30N
25N
20N
15N
115E
120E
125E
CONV
CONV+SAT
OPER(HWRF)
BEST


Max Wind Speed [KT]
120
100
80
60
40
20
CONV
CONV+SAT
OPER(HWRF)
12 00 12 00 12 00 12 00 12 00 12 00 12 00
20/08 21/08 22/08 23/08 24/08 25/08
Time

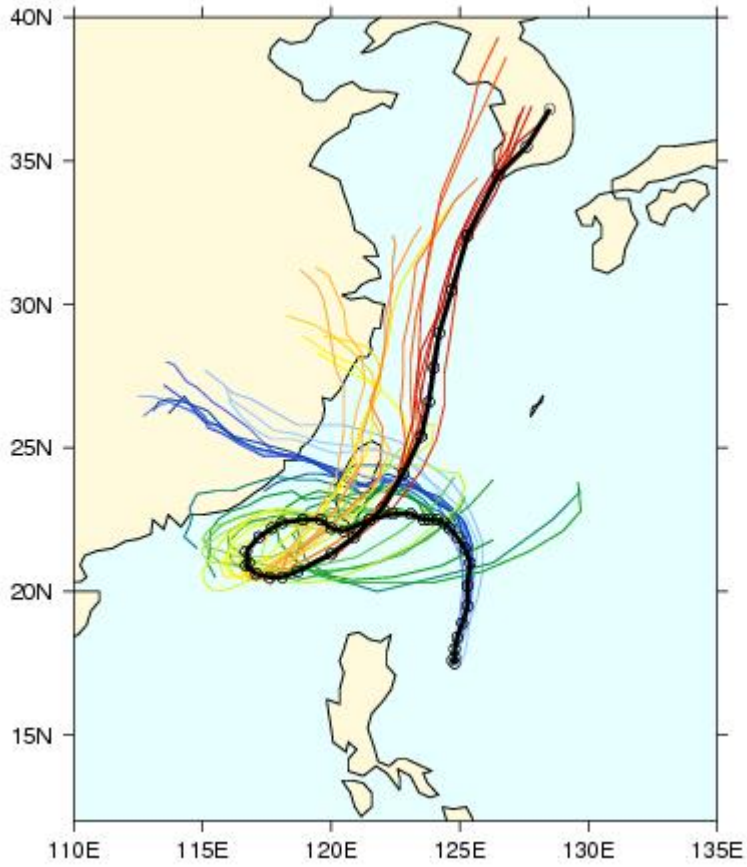

Min SLP [hPa]
1000
980
960
940
920
CONV
CONV+SAT
OPER(HWRF)
12 00 12 00 12 00 12 00 12 00 12 00 12 00
20/08 21/08 22/08 23/08 24/08 25/08
Time

Impact of ATMS over land on TEMBIN Track forecasts

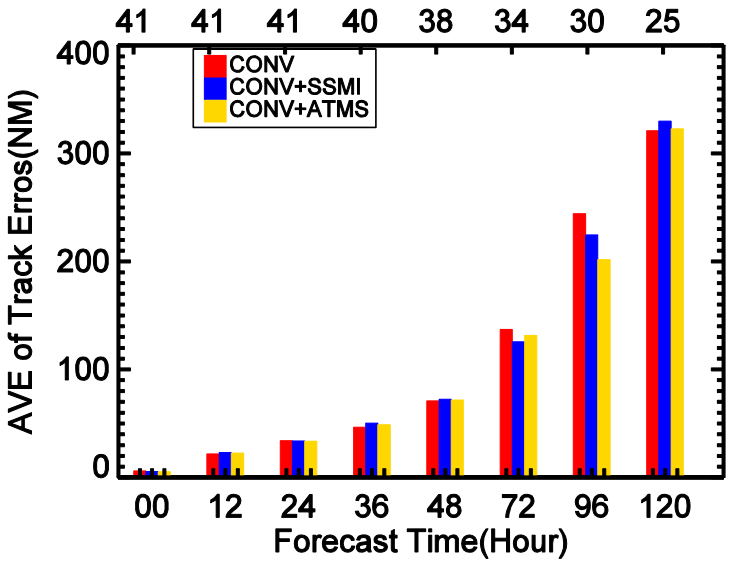
CONV

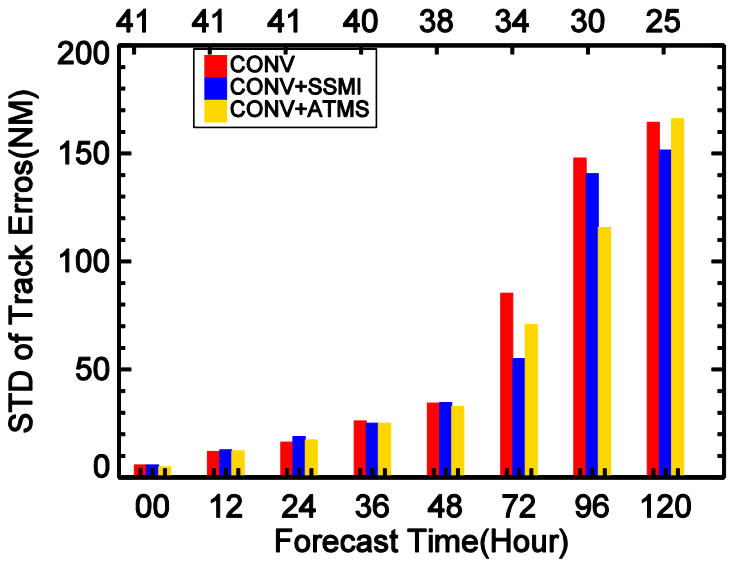


CONV+AMSUA(land)

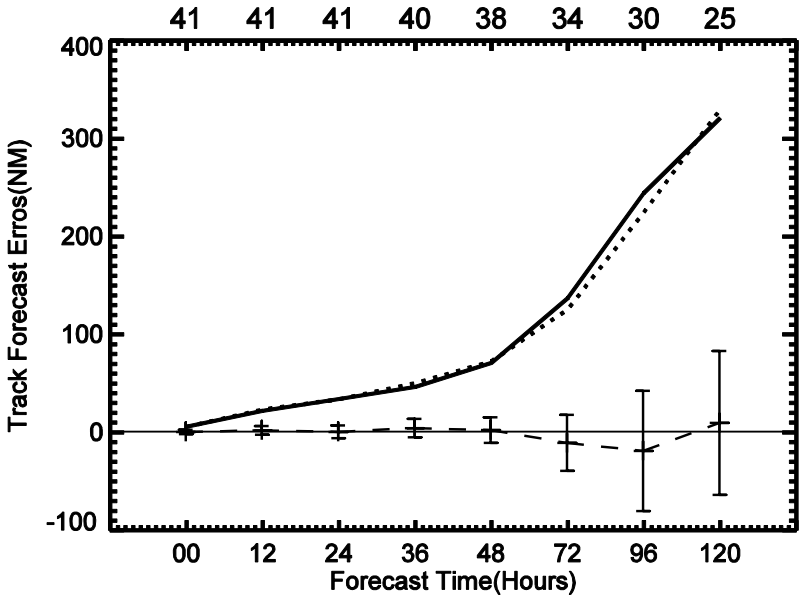


Track Error





SOLID: CONV
DOTTED:CONV+SSMIS_img



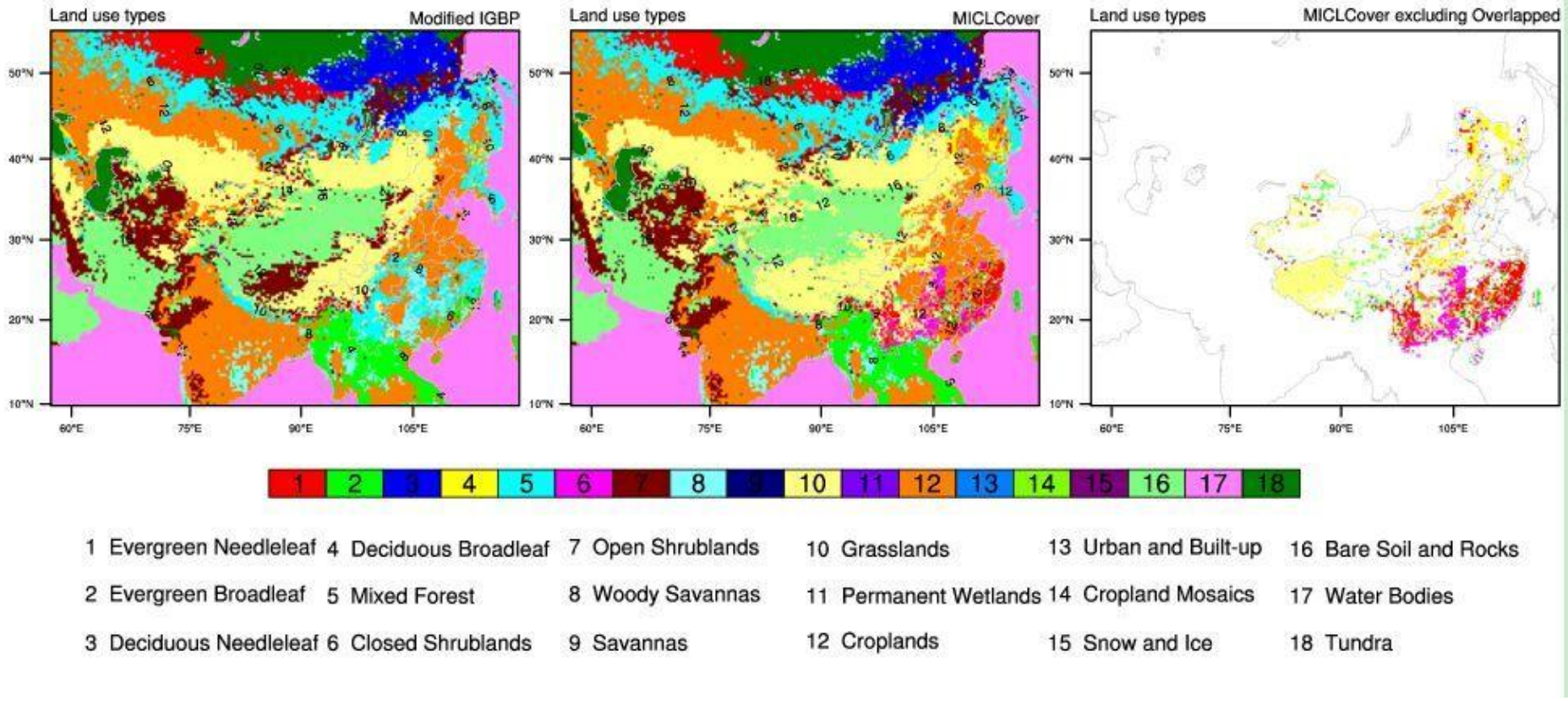
Future Plan

- **Improved Emissivity Physical model with local correction**
  - Update of land use and soil type datasets, sub-pixel
- **Cloud detection over land**
  - Scattering or Emission Based method ? Using Imager ?
- **Hyper-spectral IR sounder**
  - **Surface sensitive channels**
- **Focus on severe weather over Asia**
  - Vortex and Local heavy rainfall
- **Use of Satellite data in GRAPES-MESO**
  - More frequent observations (GIIRS)
- Coupled Data Assimilation
  - Emissivity (control variable?)

Land Use

Modified IGBP MODIS 20-category vegetation (land-use) data
MICLCover (Multi-source Integrated Chinese Land Cover) data (1km by 1km)
http://westdc.westgis.ac.cn/data/a4262c8a-1543-49c3-9d12-47722f3395f4

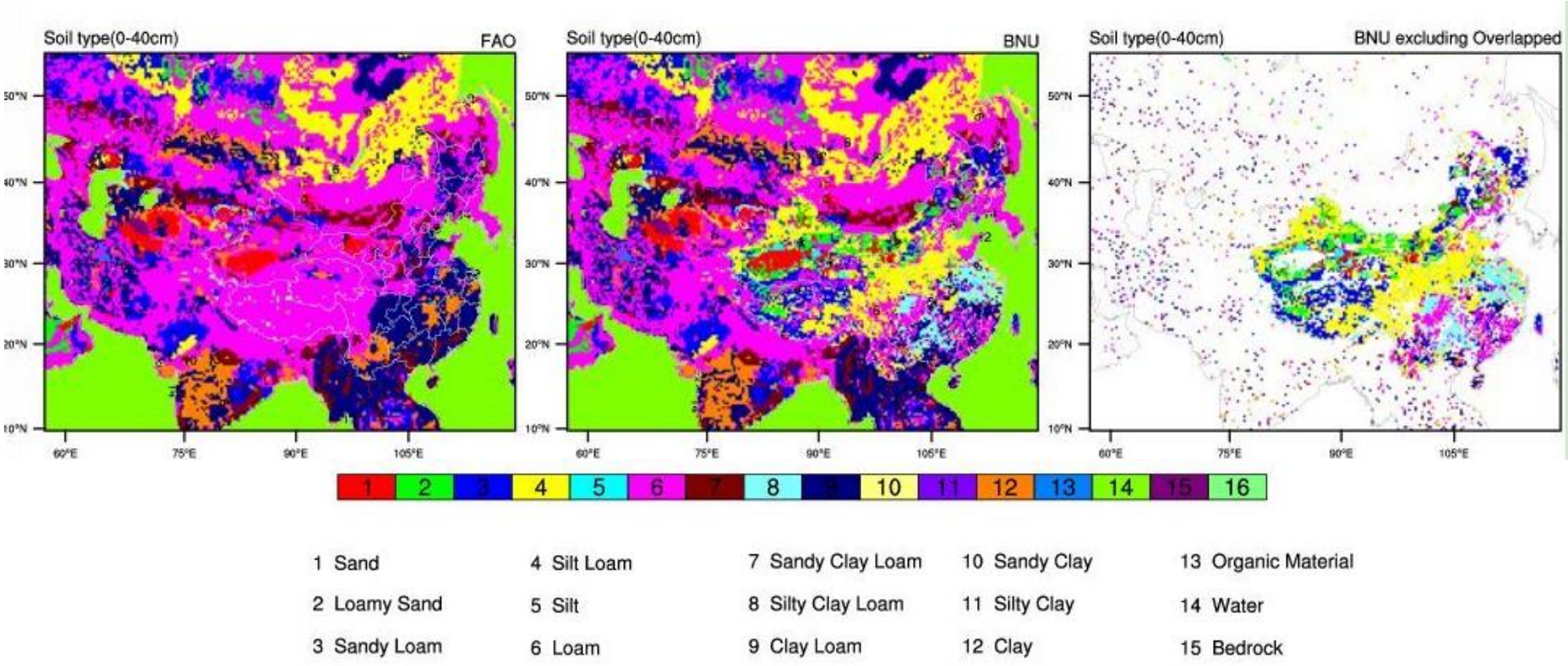
寒区旱区科学数据中心
基金委 国家地球系统科学数据平台



Soil type

*Hybrid STATSGO/FAO (30-second for CONUS /5-minute elsewhere) Soil Texture
*Soil texture classified from the datasets of particle-size distribution over China developed by Beijing Normal University (BNU) (1km by 1km)：
http://globalchange.bnu.edu.cn/research/soil

Land-Atmosphere Interaction Research Group at Beijing Normal University



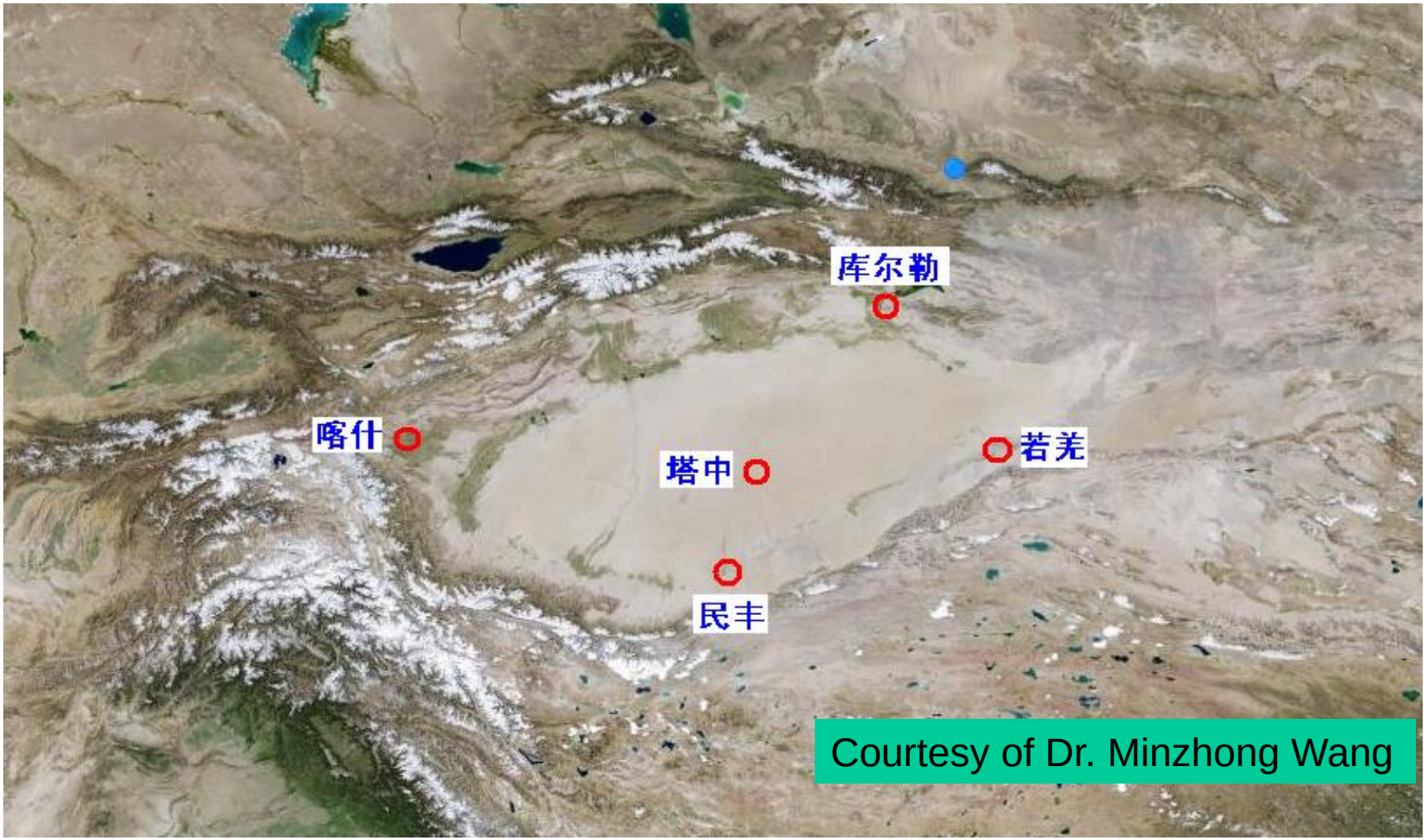
FOV of FY3C MWTS as an example

- **Inputs for physical emissivity model**
  - **sub pixel information**
  - **Antenna pattern**

roughness,
clay and sandy fraction,
soil and solids density,
leaf area index,
leaf thickness、leaf orientation,

Validation of satellite data using in-situ observations

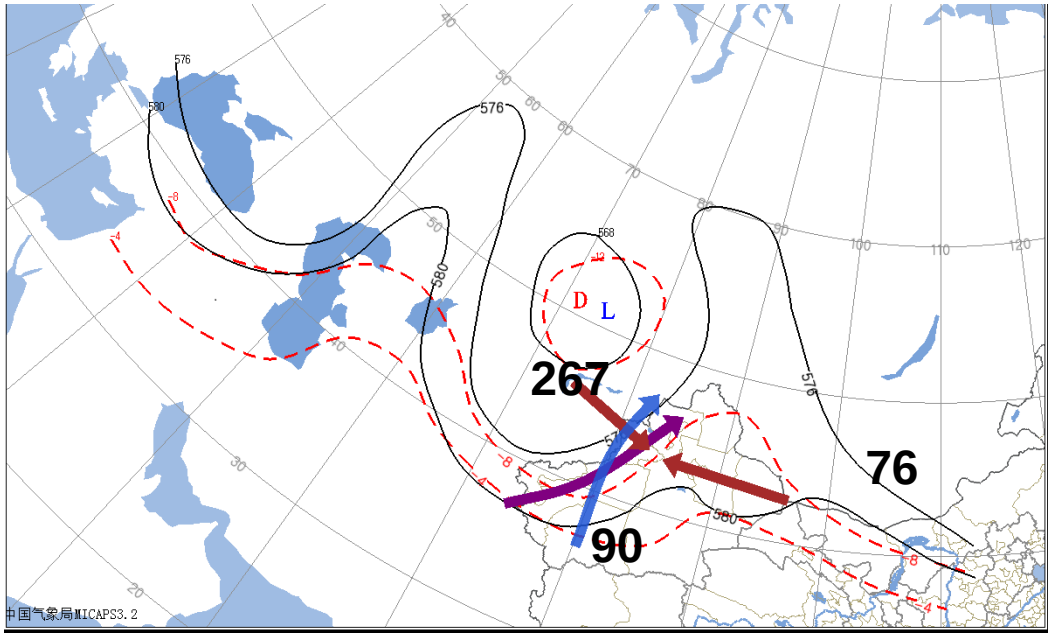
- Bias correction, Ts Error, Emissivity, …

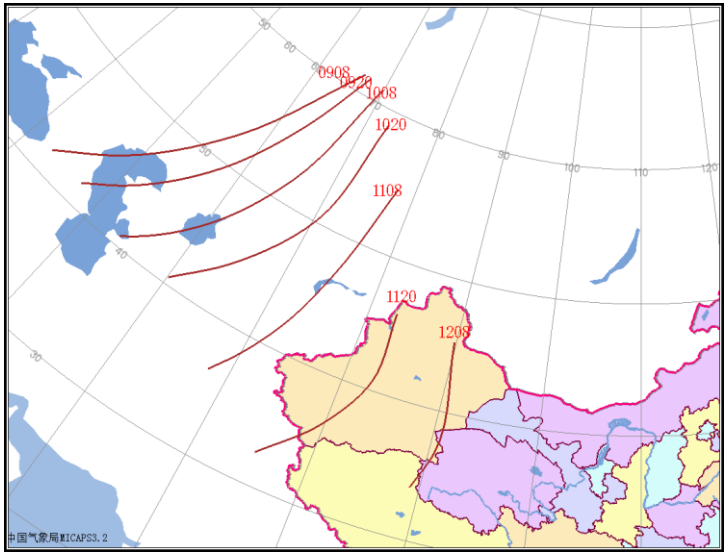


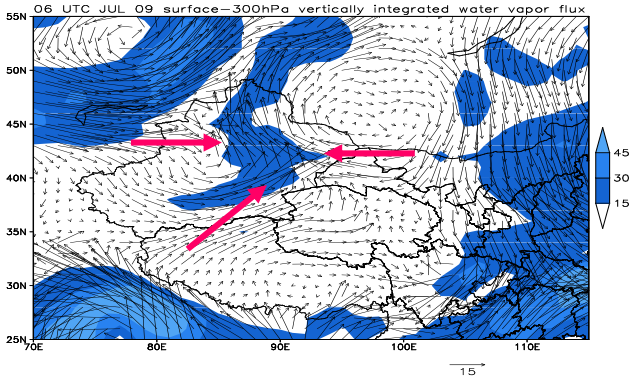
Improve the analysis of water vapor transportation by assimilation of satellite data

Courtesy of Dr. Lianmei Yang

Winds : AMVs(FY2G, Meteosat)
Moisture: **MHS,ATMS,MWHS II(FY3),MWRI(FY3),**IASI,AIRS,CrIS, GPS PW
Temperature: AMSU-A,ATMS







Surface-300hPa water vapor flux

2007070712-2007071012(UTC)
(267,90,76)*10^9 Ton

Conclusions and Discussions

- There is large uncertainty over East Asia analysis
- **The effective use of surface sensitive radiancs is important**
- Better description of the surface characteristics is fundamental
- **Looking forward to further cooperation on surface emissivity**

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