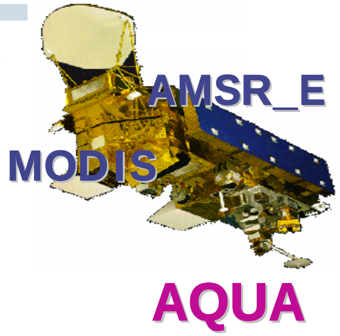

Instantaneous Emissivities Estimation Using AMSR-E Measurements over Land

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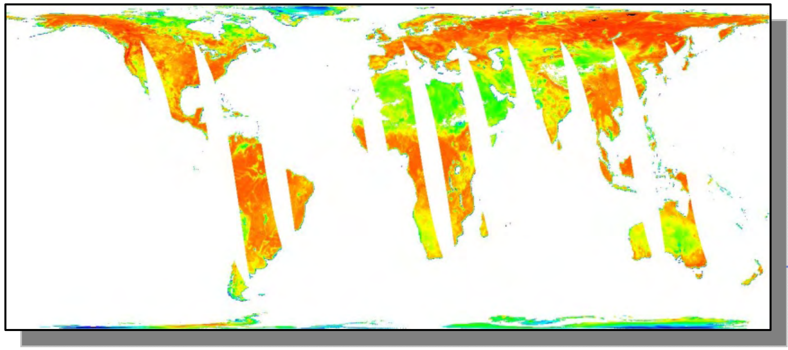
[b] Institute for Computational Earth System Sciences, University of California, Santa Barbara, CA 93106 USA.

ybqiu@ceode.ac.cn



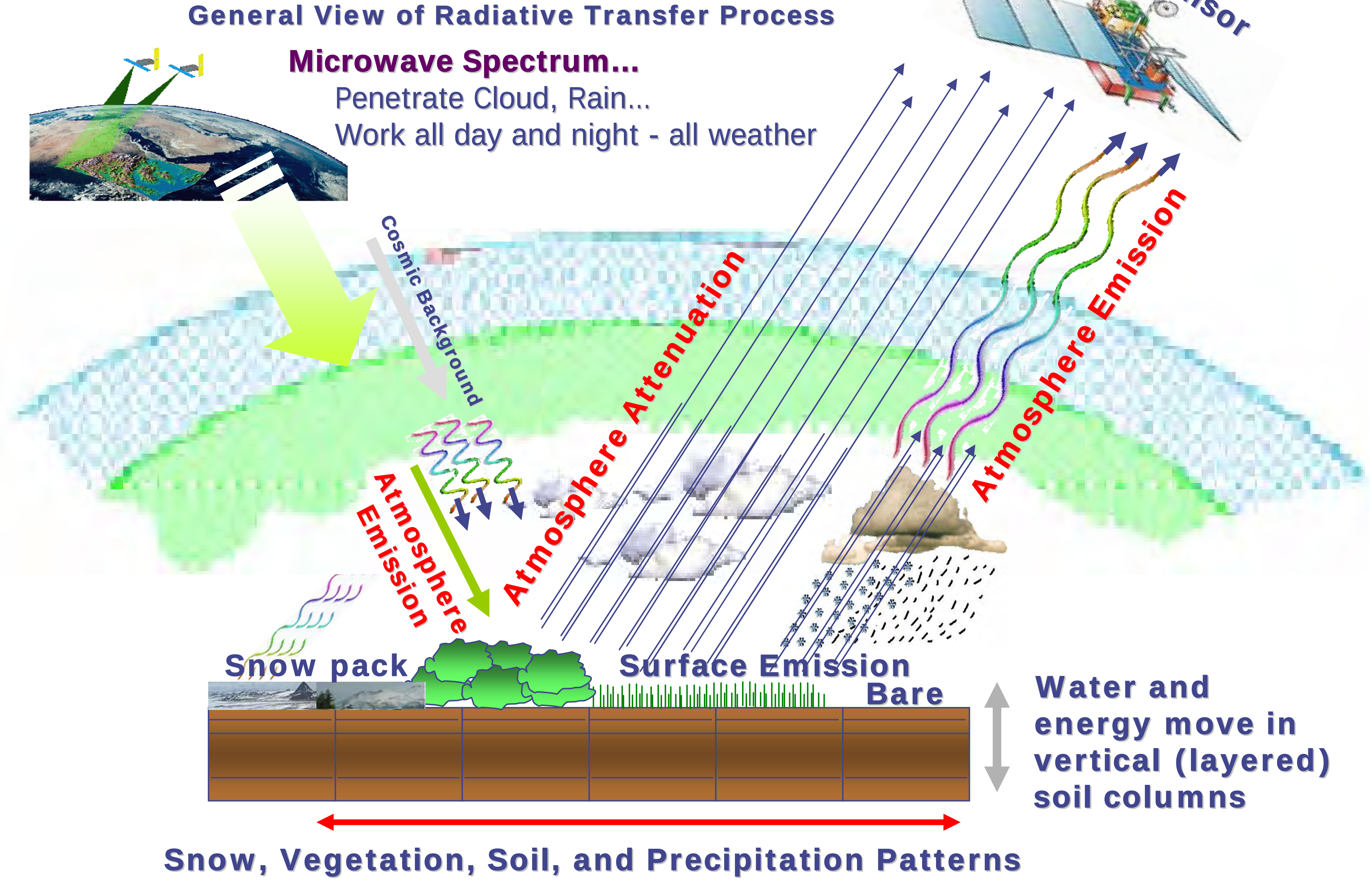
AMSR-E 10.7GHz Emissivity

9 June 2009

Outline

- **Introduction**
  - General View of Radiative Transfer Process
  - Microwave Atmosphere Influence
- **Emissivity Estimation Theoretical Background and Dataset**
  - Method
  - Input Data Description and Estimation Scheme
- **Result and Evaluation**
  - Estimation Result Analysis
  - Comparison with the Previous Result
- **Time Series and Frequency Dependency Analysis**
  - Time Series
  - Frequency Dependency Analysis
  - Discrepancy with Simulation?
  - Emissivity estimation under cloudy condition...
- **Conclusion**

Introduction - Physical fundamental (1/3)

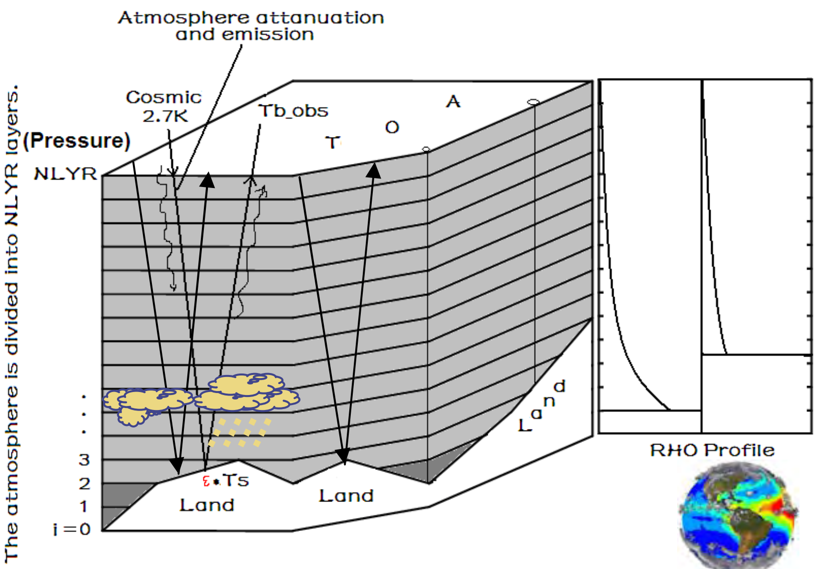


Introduction - Physical fundamental (2/3)

- For a non-scattering plane-parallel atmosphere, the integrated radiative transfer equation (*RTE*) in the *Rayleigh-Jeans* approximation over a flat lossy surface can be expressed in terms of the total brightness temperature observed by satellite radiometer at certain frequency, polarization and incidence angle at the top of atmosphere (*TOA*).

$$T_{bp}(\nu,\theta) = e_{s,p}(\nu,\theta)\cdot T_s \cdot \Gamma(\nu,\theta) + T_{a,atmos\uparrow}(\nu,\theta) +$$
$$T_{a,atmos\downarrow}(\nu,\theta)\cdot(1-e_{s,p}(\nu,\theta))\cdot\Gamma(\nu,\theta) +$$
$$T_{CB}\cdot(1-e_{s,p}(\nu,\theta))\cdot(\Gamma(\nu,\theta))^2$$

  - molecular oxygen, water vapor, cloud liquid water
  - *Liebe* (1985, 1989)
  - *Rosenkranz* (1998) – water continuums absorption



The atmosphere struct according to the plane–plane assumption

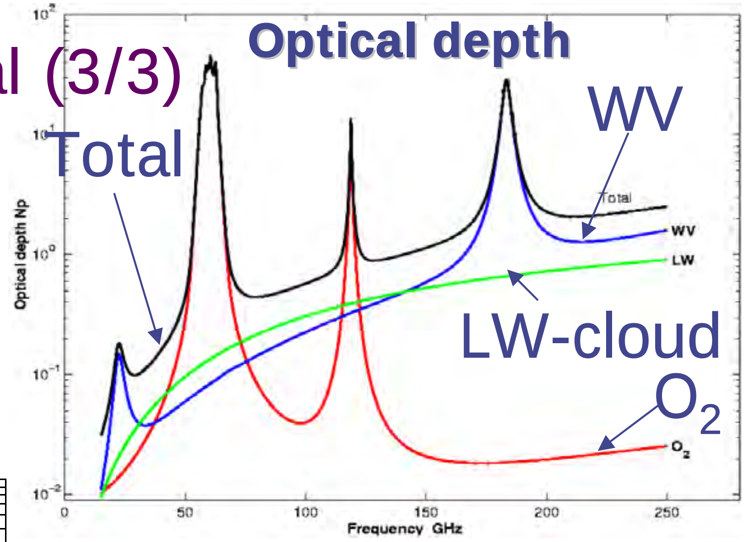
atmosphere model

- For a scattering plane-parallel
  - rain, snow, ice and graupel
  - $\gamma_{s\_hydro}(\nu,z) = \sum_{h=1}^{H}\gamma_{s\_h}(\nu,z) \quad \gamma_{a\_hydro}(\nu,z) = \sum_{h=1}^{H}\gamma_{a\_h}(\nu,z)$
  - *Mie* (1908)
  - *RTE – Eddington-based* (*Kummerow 1993, Olson, 2001*) *– 1-D Atm. Mod.*

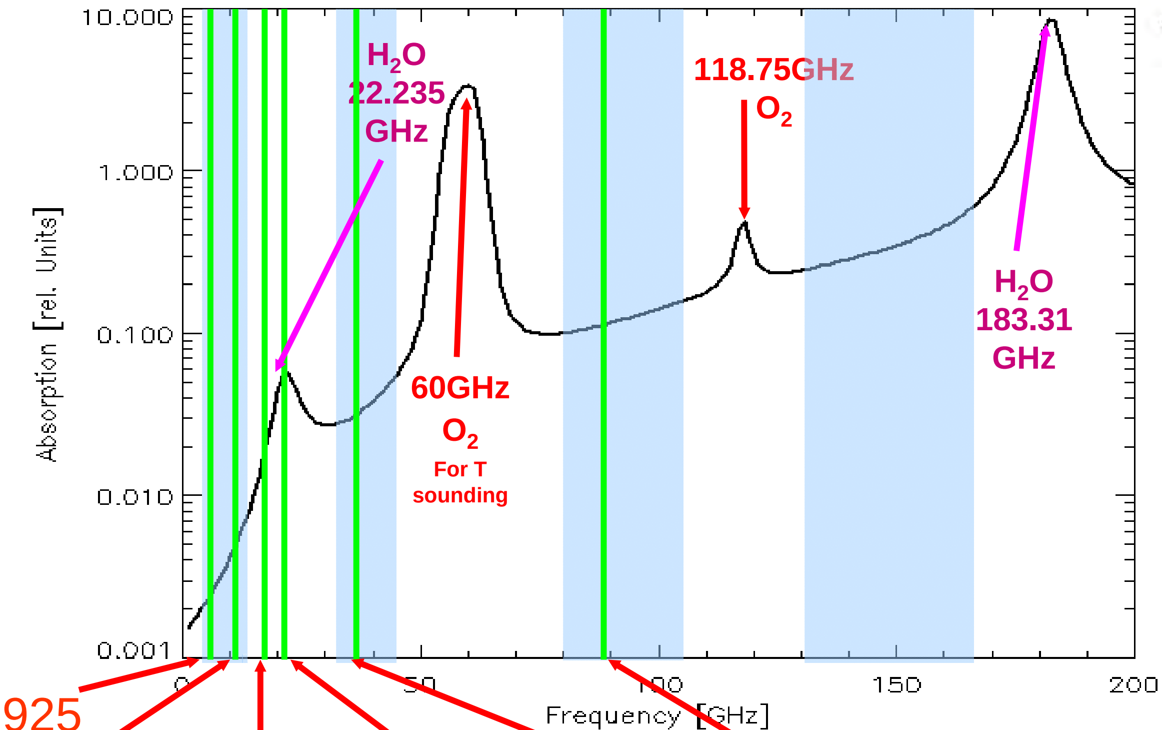
$$\gamma(\nu,z) = \gamma_{a\_h2o}(\nu,z) + \gamma_{a\_o2}(\nu,z) + \gamma_{a\_hydro}(\nu,z) + \gamma_{s\_hydro}(\nu,z)$$

Introduction - Physical fundamental (3/3)

✓AMSR-E frequency configuration and the atmospheric absorption curve

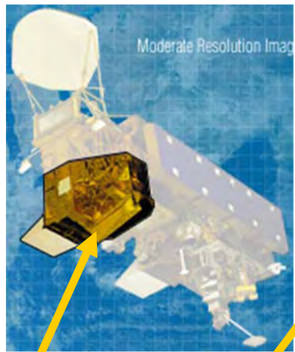


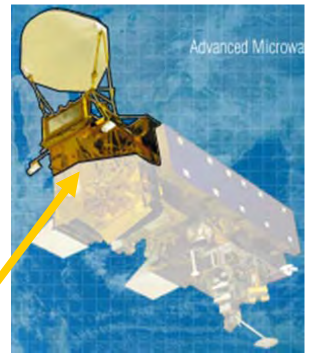
Microwave spectral range



AMSR_E 6 freq. (GHZ)

Parameter	AMSR-E(Aqua)
Time Period	Beginning 2002
Frequencies (GHz)	6.9, 10.7, 18.7, 23.8, 36.5, 89





MODIS / AMSR-E provide the synchronous earth observation

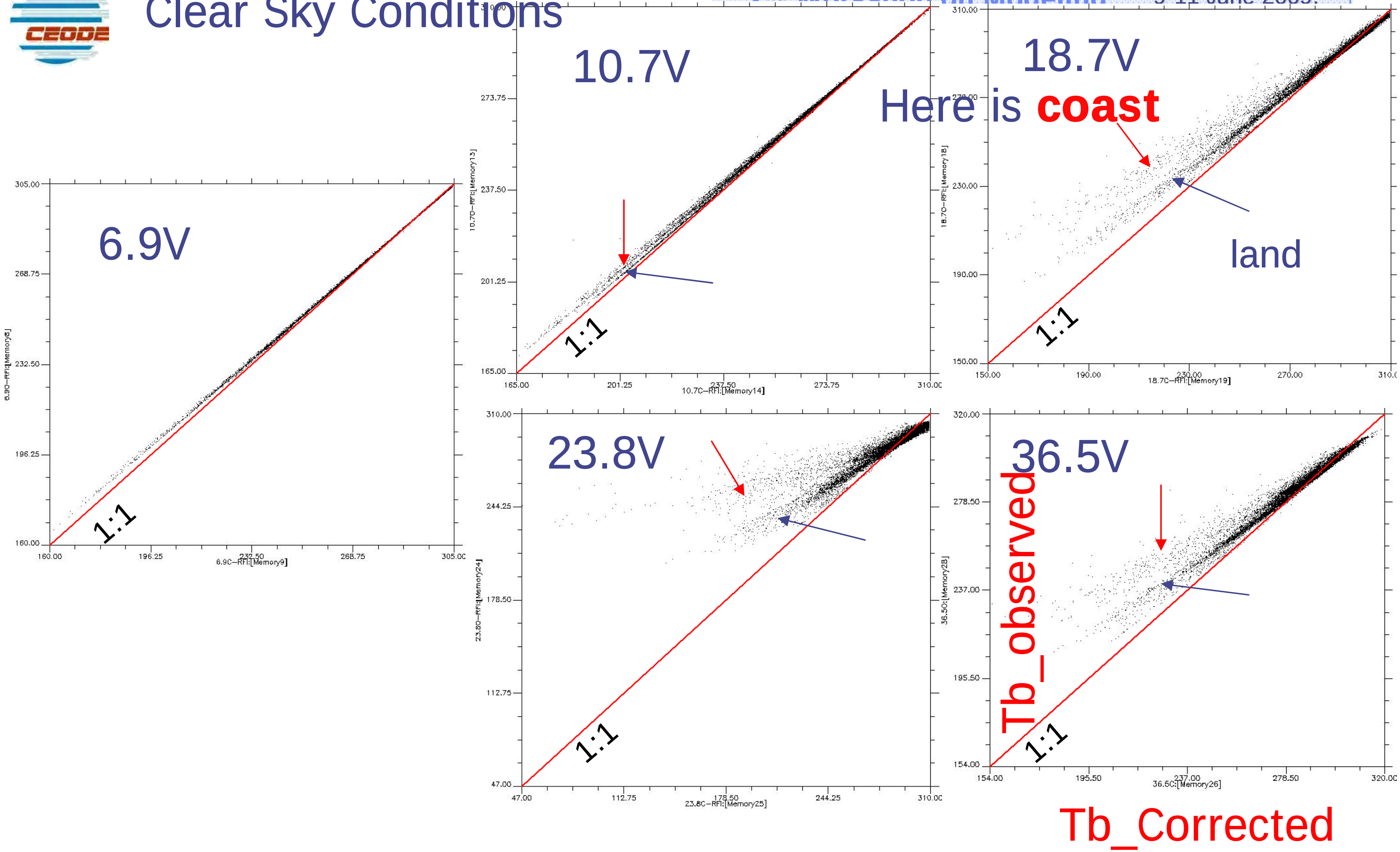
Introduction - Microwave Atmosphere Influence

✓The retrievals of many geophysical parameters from microwave radiometry pay emphasis on the effect of **soil moisture**, **snow cover** and **vegetation** by quantitative methods, while the effect of the atmosphere (PWV, cloudy-CLW) is generally assumed to **be ignored**, especially in the low frequency (< 40GHz).

✓The brightness temperature observed by Satellite at TOA is a function of **frequency**, the **water vapor content**, **liquid water (cloud), oxygen, hydrometers, atmospheric temperature** and **underlying surface parameters**.

- Atmosphere absorption and scattering to microwave spectrum
- With frequency increasing, the atmospheric contribution to the signal of sensor becomes more important.

Clear Sky Conditions



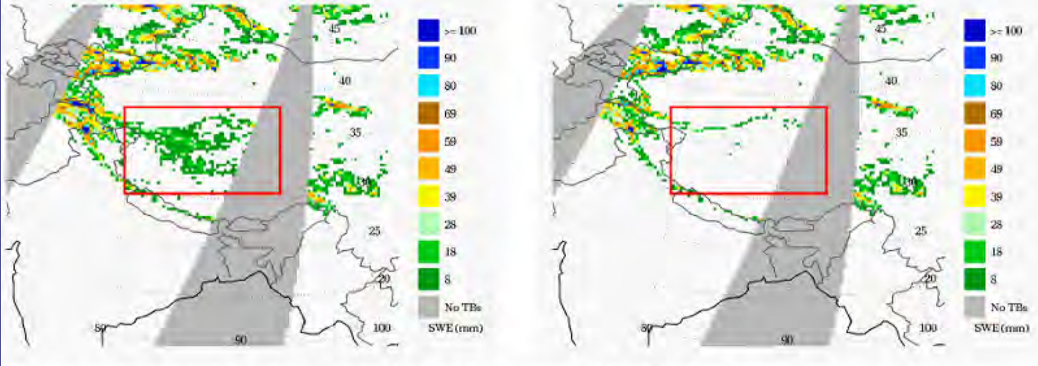
AMSR-E and MODIS/Aqua correction even clear sky-conditions

Atmosphere influences the low brightness temperature much

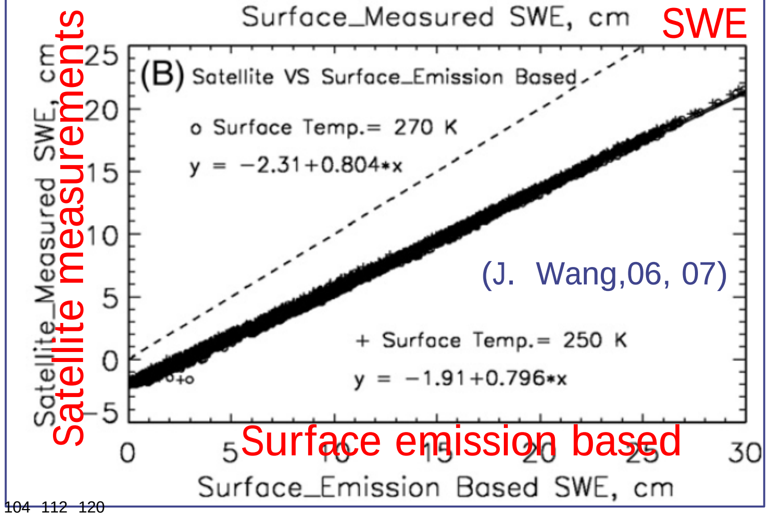
By Yubao Qiu, 2008

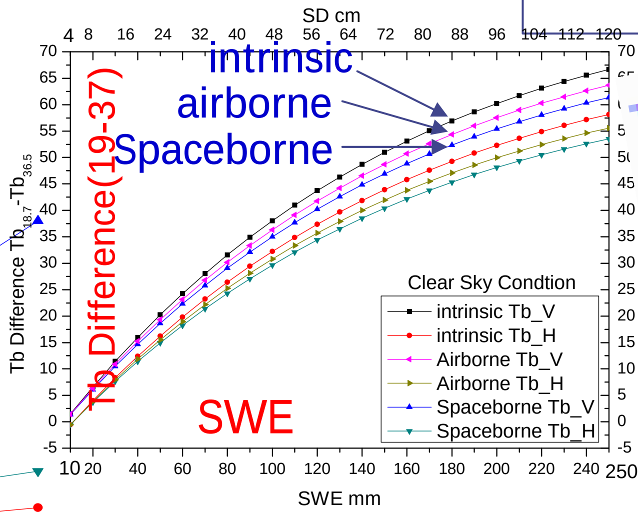
other findings

many researchers have mentioned that the atmospheric impact on microwave spectrum is an undeniable factor in microwave propagation.

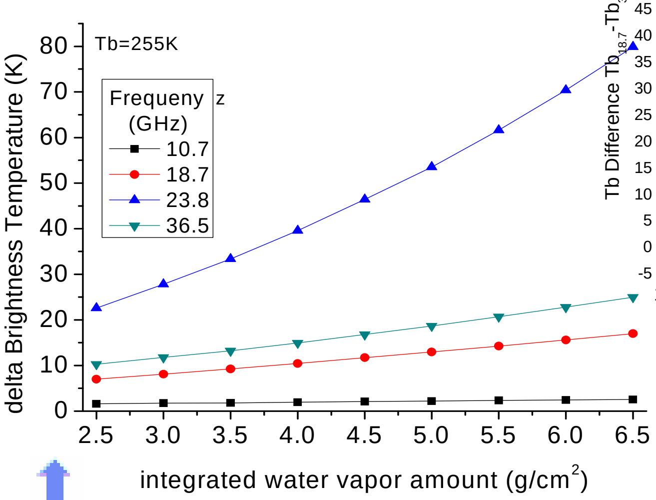


Result of atmospheric correction, November 29, 2003. SWE derived from uncorrected AMSR-E (left) and corrected AMSR-E (right). (Amstrong,2004)



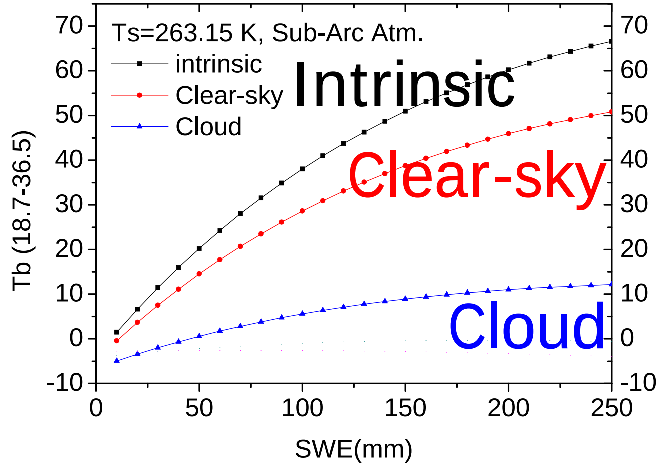


A Simulation work in Sodankylä, Finland - subarctic-winter with HUT-SNOW model with clear-sky condition (no cloud or precipitation)



Simulation work Yubao Qiu, 2007,Taiwan

Atmospheric conditions do significantly impact on estimating surface properties with AMRS-E, SSM/I...



Simulation work, 2008

Motivation

The motivation is

to improve the surface presentations.

Based on what mentioned above, try to understand that:

How the effective (intrinsic) instantaneous surface emissivity (polarization difference, frequency / time dependency under difference surface types) relationship.

To do...

... to do the atmospheric correction..., then try to improve the surface parameters retrieval...

... to upgrade the NWP models... improve understanding of the surface emissivity, especially over land - i.e. to assimilation...

Also need to study the intrinsic emissivity in a “effective” pixel (mixture) instead of the model description (theoretical).

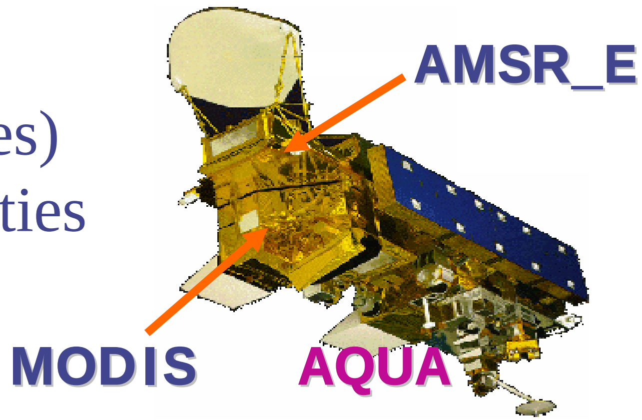
Emissivity Estimation

- Fundament – derive from the radiative transfer model directly

$$e_{s,p}(\nu,\theta)=\frac{T_{bp}(\nu,\theta)-T_{atm\uparrow}(\nu,\theta)-T_{CB}\cdot\Gamma^2(\nu,\theta)}{T_s\cdot\Gamma(\nu,\theta)-T_{atm\downarrow}(\nu,\theta)\cdot\Gamma(\nu,\theta)-T_{CB}\cdot\Gamma^2(\nu,\theta)}$$

$e_{s,p}(\nu,\theta)$ can be readily estimated from above equation, with inputs from AMSR-E measured $T_{bp}(\nu,\theta)$ and MODIS-derived T_s and atmosphere parameters.

✓The atmosphere correction under clear-sky condition – using the MODIS Atmosphere parameters (the atmosphere 20 layered profiles)
✓ and can provide the instantaneous emissivities result under clear-sky condition at 6.9Ghz ~ 89.0Ghz.



The former work can be traced via Prigent C. and Karbou, F.'s work.

Emissivity Estimation

◆ Estimation scheme - operational

Atmosphere radiative transfer (reverse) - *Eddington-based (Kummerow 1993, Olson, 2001) – 1-D Atm. Mod. – clear-sky*

1 AMSR-E L2A – brightness temperature

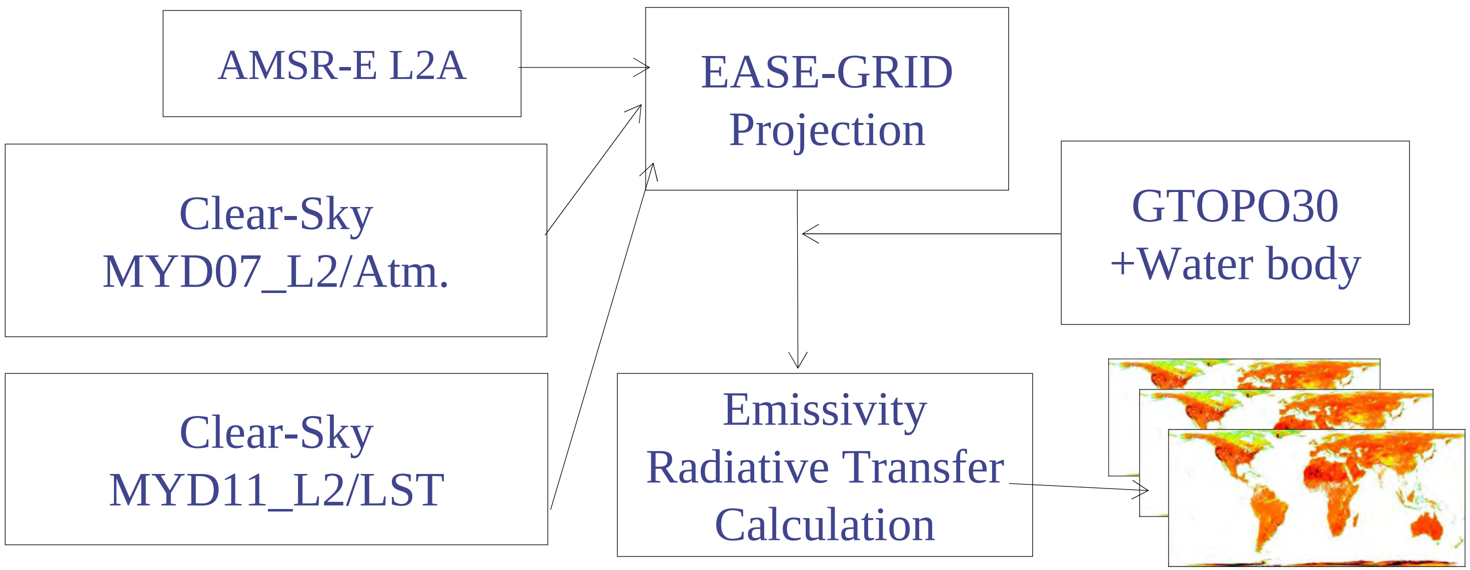
2 MODIS LST, mask out the cloudy and rainny pixels

3 atmosphere parameters from *MODIS*

Ancillary input:

4 Water body - mask out the inland water body and ocean >80%

5 Gtopo30 *DEM – consider the atmosphere thickness*

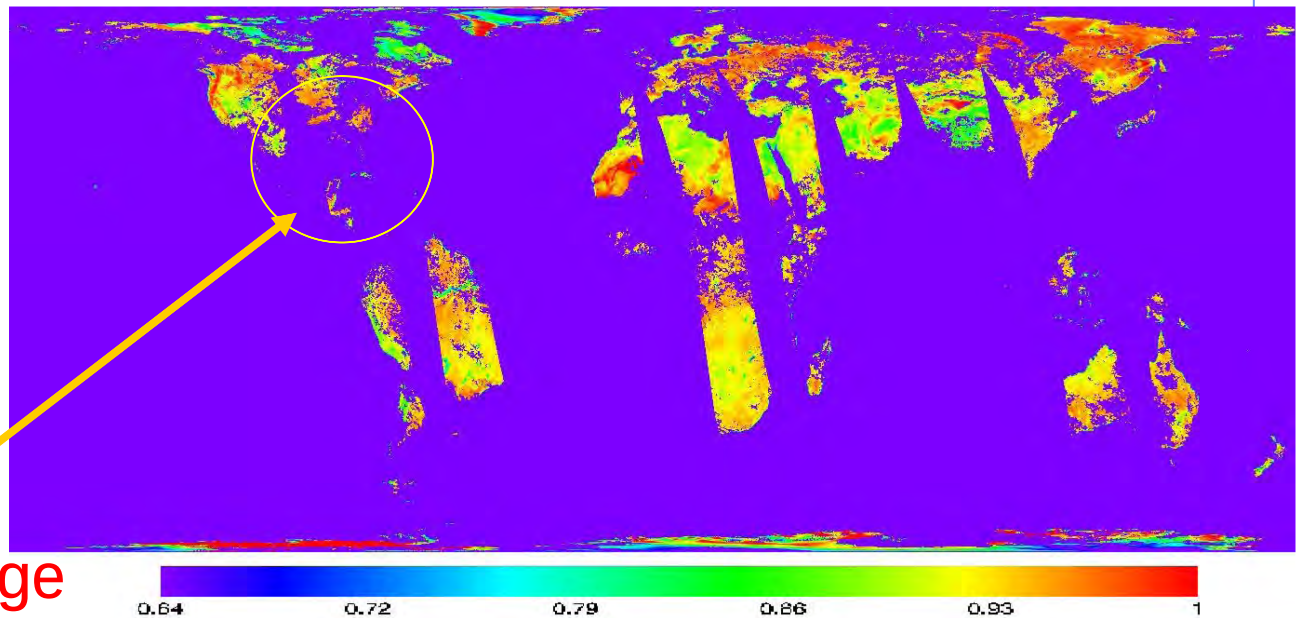


Operational scheme for the emissivity calculation

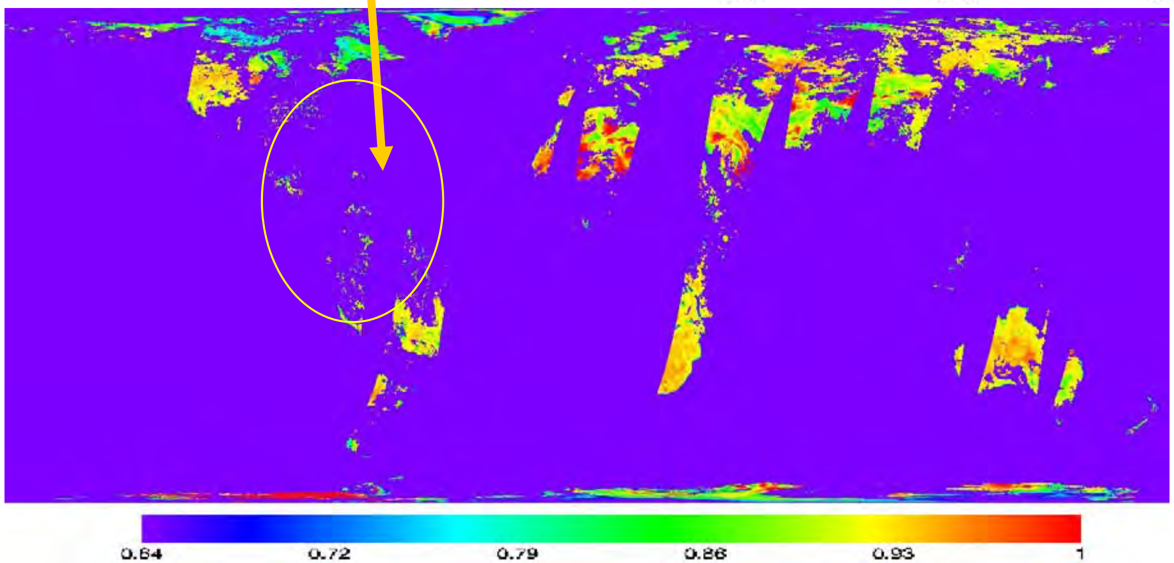
Result Quick View

Land surface Emissivity over clear sky condition for the Day of 2006-7-26

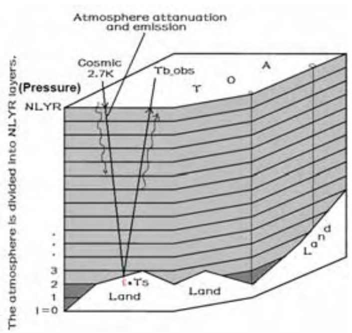
18.7V
Ascending orbit

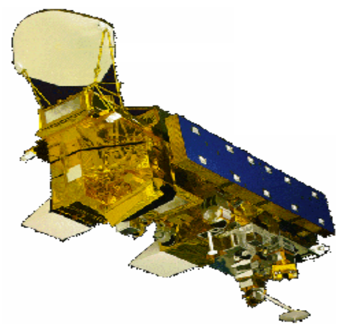


Cloud cover...
influence the coverage

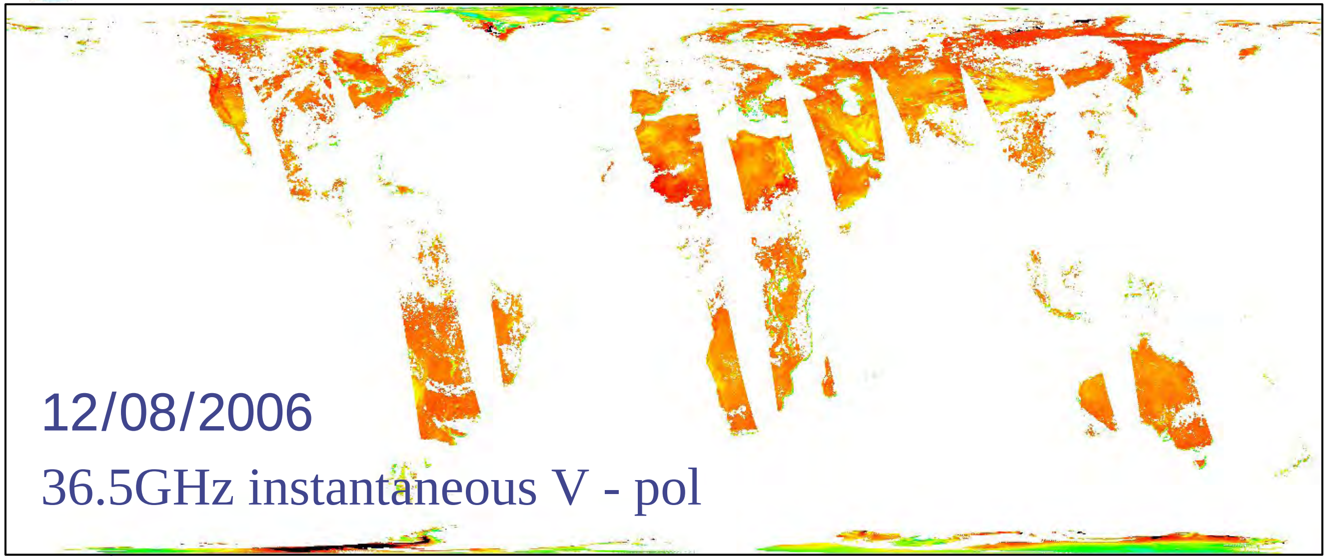


18.7V
Descending orbit



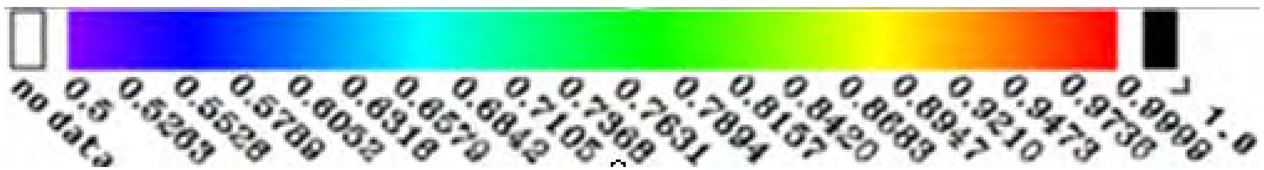


Result Evaluation

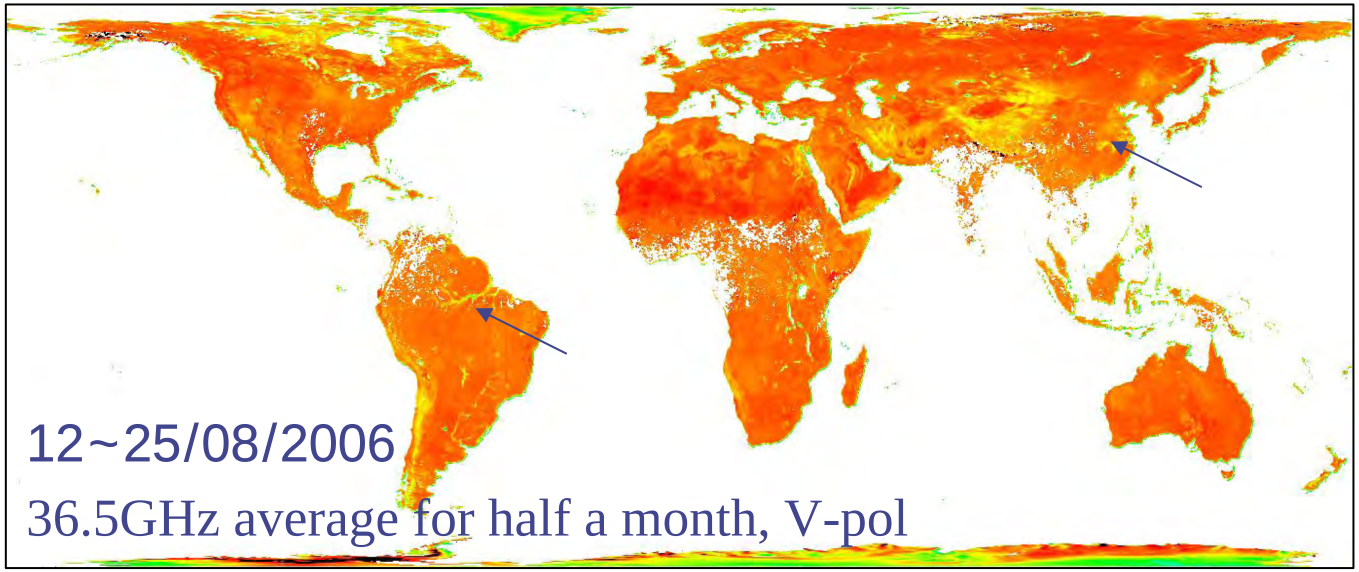


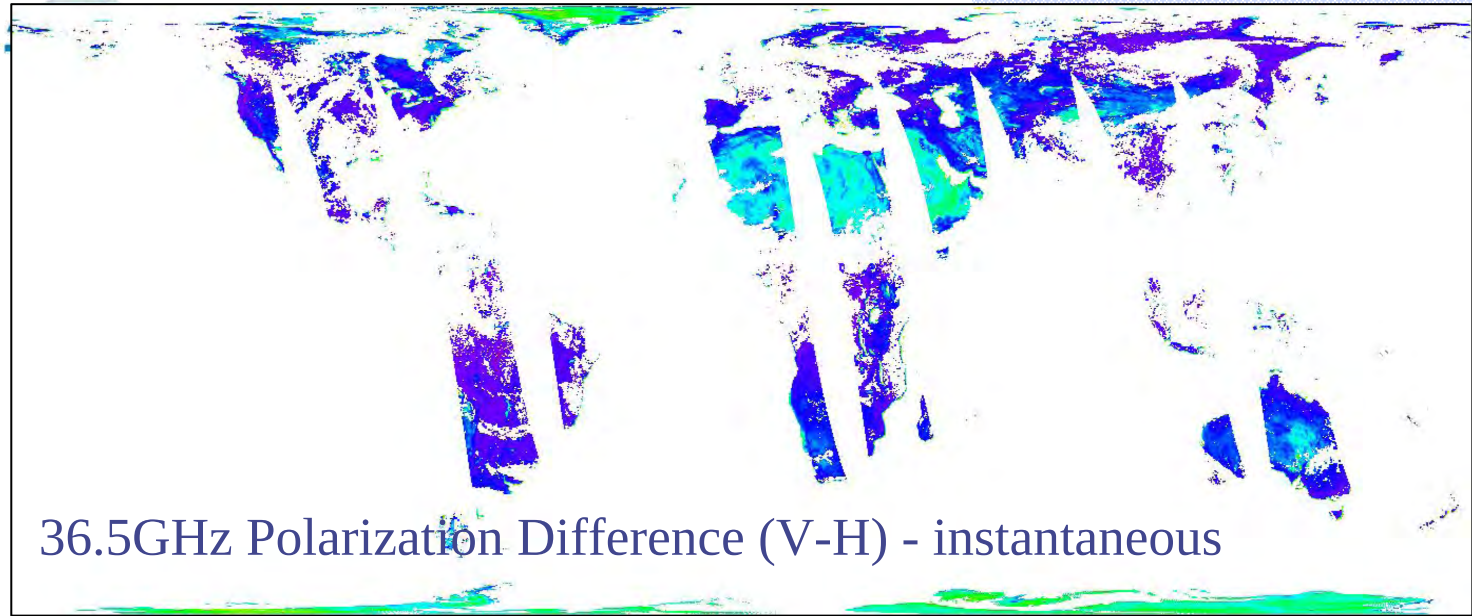
Sample:
12~25/08/2006

These emissivity maps show the expected spatial structure with different surface types.



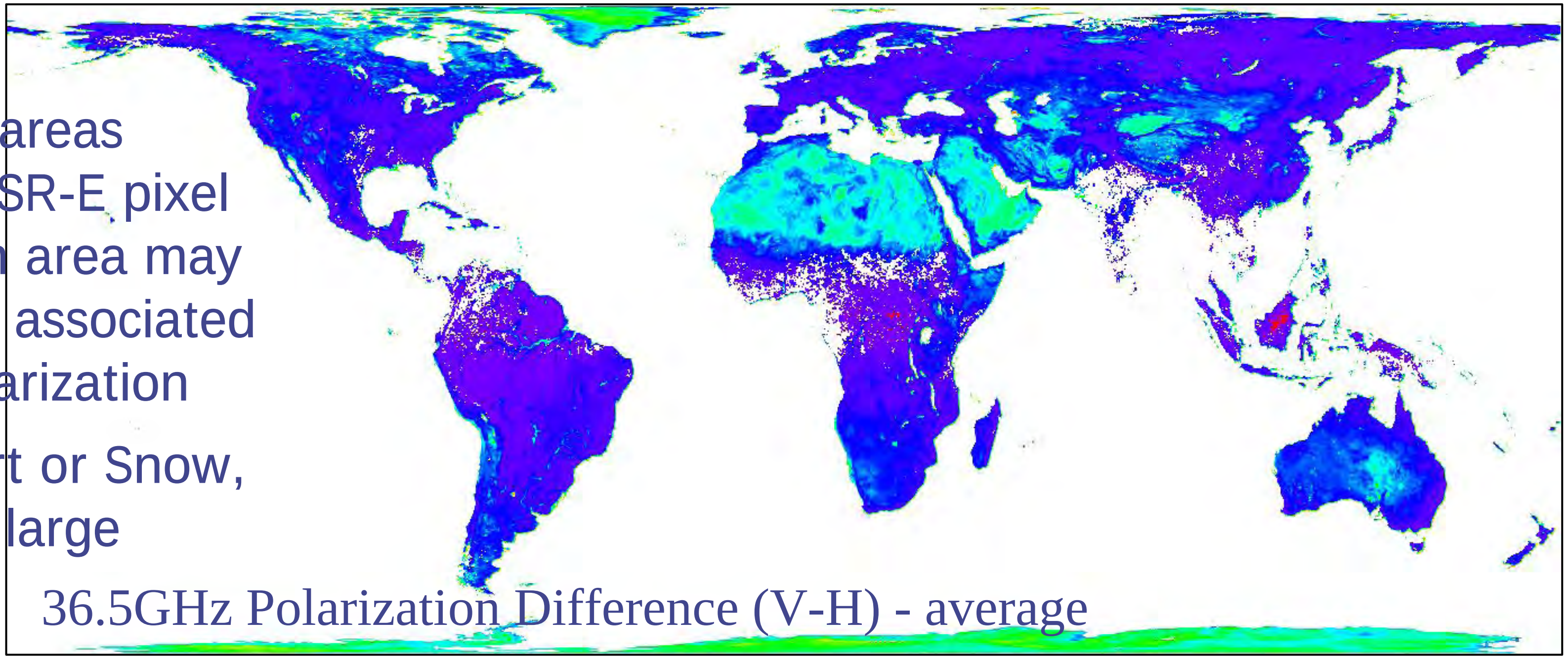
Small open water (lakes, rivers) exhibits low emissivities with high polarization differences. The major river systems (Amazon, Yangtze and Yellow River) and their associated wetlands and river branches appear clearly on the maps.





36.5GHz Polarization Difference (V-H) - instantaneous

The Emissivity in V-pol is bigger than that in H-pol., which agrees with the model description.

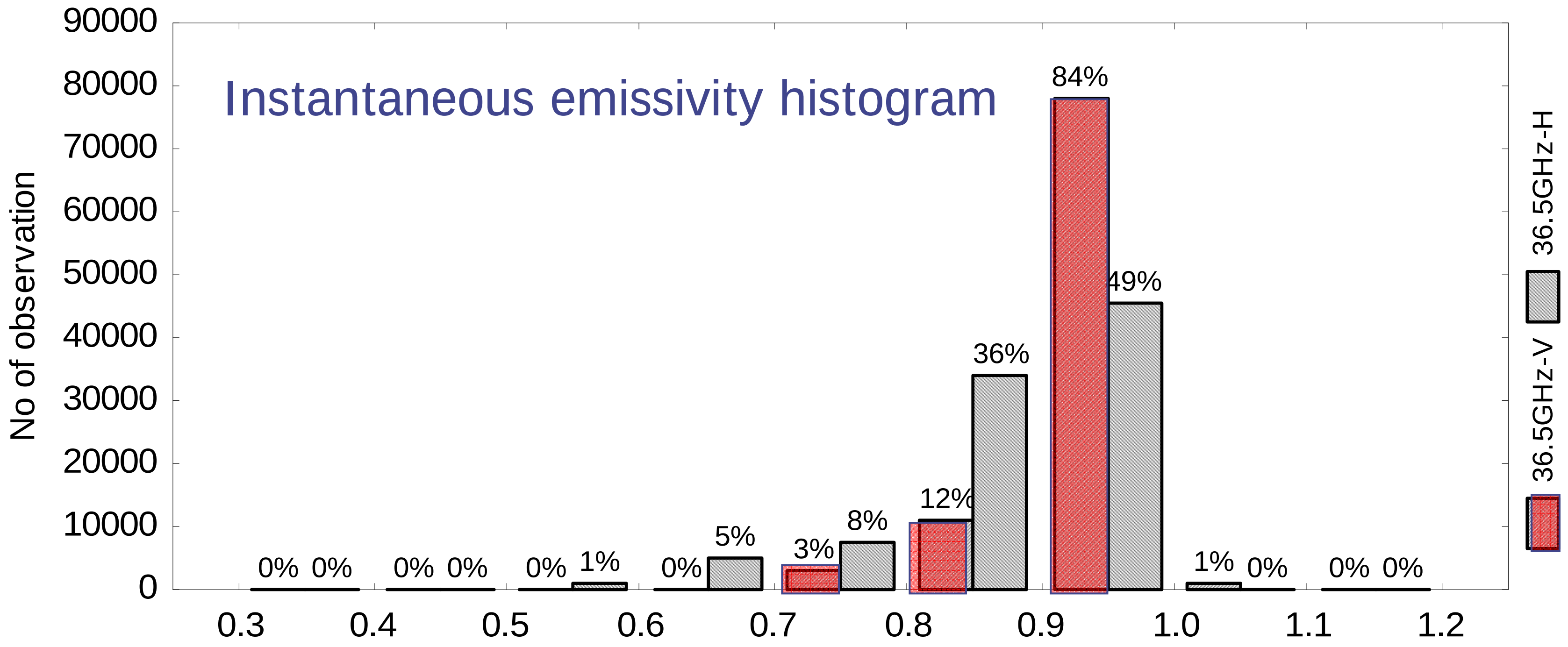


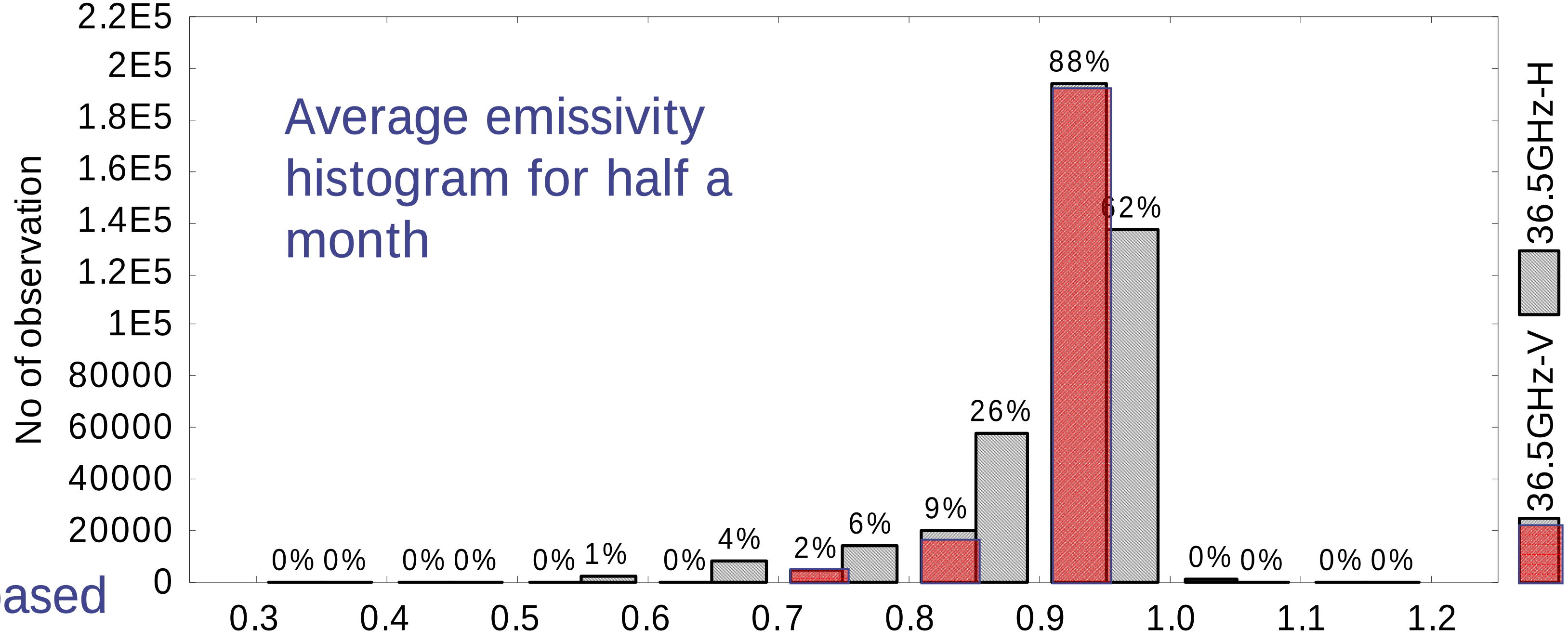
36.5GHz Polarization Difference (V-H) - average

In the costal areas where an AMSR-E pixel include ocean area may display low ’s associated with high polarization

Areas - Desert or Snow, Ice – show a large difference.

e 2009,
, France





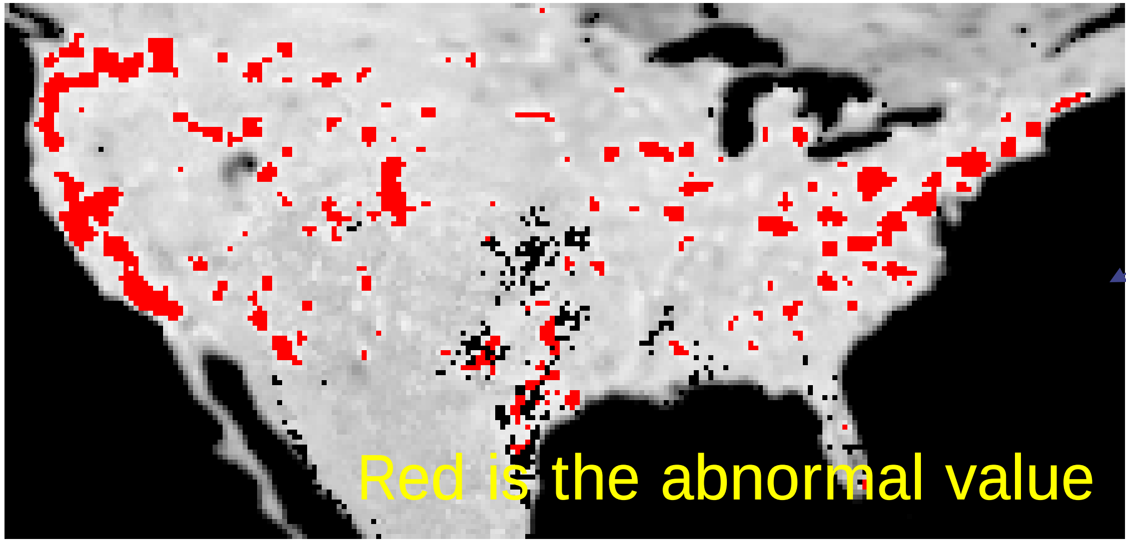
MODIS-based result

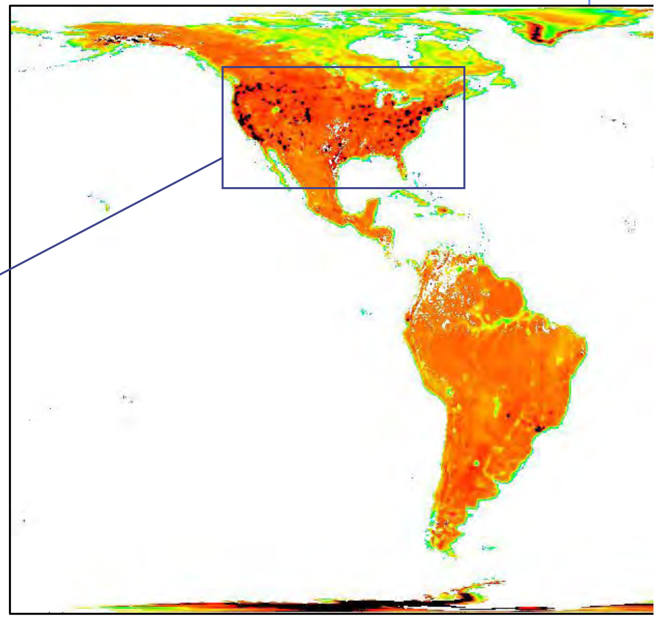
Statistical Analyses

A Statistic of Minimum, Maximum and Mean Microwave Surface Emissivity with The Abnormal Value Percentage from Instantaneous and Average Emissivity. A is Average Result for Half a Month, B is the Instantaneous Result for 12-08-2006 (Ascending)

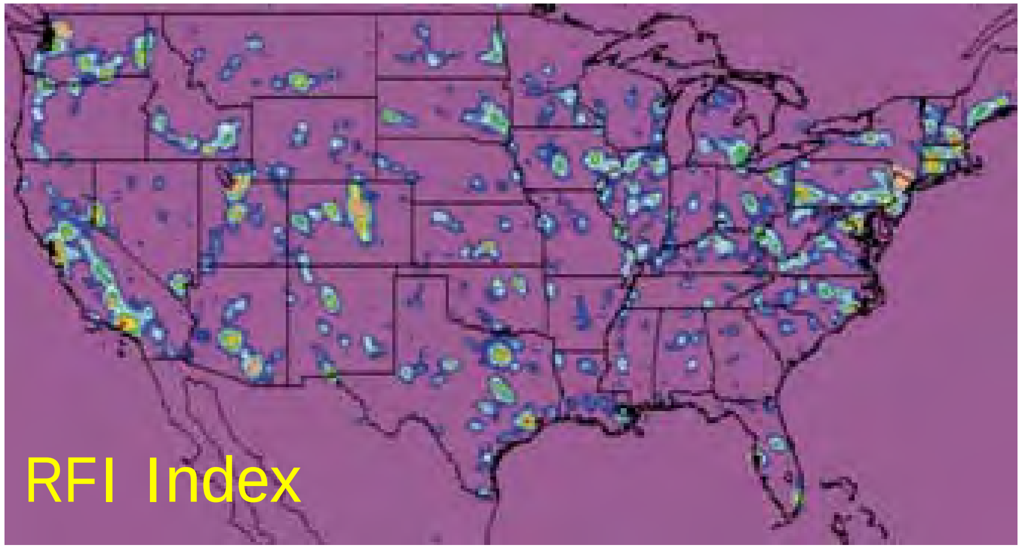
Freq. (GHz)	Minimum		Maximum		Mean		>1.0 (%)	
	A	B	A	B	A >	B	A	B
6.9V	0.5475	0.5632	1.2133	1.1501	0.9365	0.9282	2.60	3.82
6.9H	0.2681	0.2801	1.3692	1.1532	0.8524	0.8319	0.14	0.13
10.7V	0.5746	0.5770	1.2074	1.1257	0.9346	0.9263	1.37	2.39
10.7H	0.0008	-0.2356	1.2492	1.1097	0.8513	0.8264	0.09	0.02
18.7V	0.6371	0.6351	1.1352	1.1084	0.9418	0.9323	0.91	1.61
18.7H	0.3574	0.3784	1.1330	1.0822	0.8813	0.8613	0.06	0.07
23.8V	0.6514	0.6559	1.1336	1.1102	0.9446	0.9325	0.59	1.12
23.8H	0.4410	0.4503	1.1287	1.0885	0.8961	0.8754	0.06	0.07
36.5V	0.6651	0.6638	1.1143	1.1078	0.9379	0.9279	0.36	0.83
36.5H	0.4350	0.4180	1.1061	1.0827	0.8904	0.8732	0.06	0.05
89.0V	0.6597	0.6312	1.1214	1.1194	0.9540	0.9393	0.39	0.73
89.0H	0.5928	0.5865	1.1168	1.1052	0.9255	0.9060	0.09	0.09

Evaluation

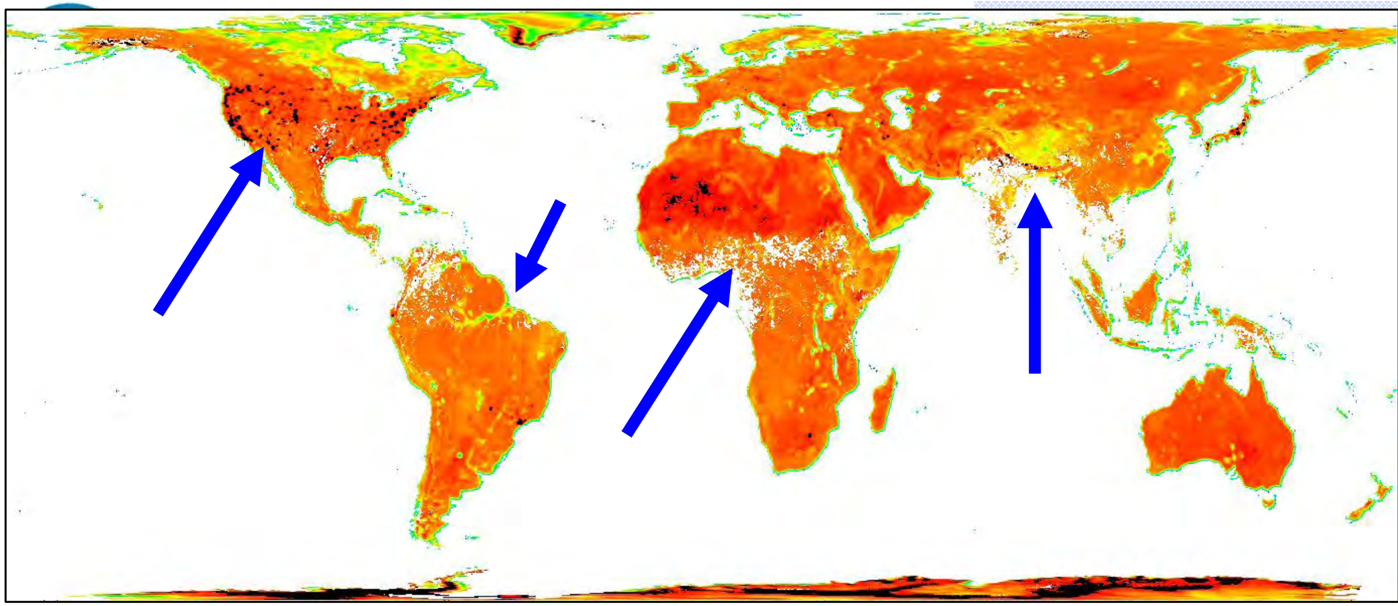




A close examination of the emissivity maps, particularly over the continental USA, reveals that areas with emissivity > 1.0 are closely associated with the AMSR-E RFI index map. This helps explain higher percentages of emissivity > 1.0 at lower frequencies.



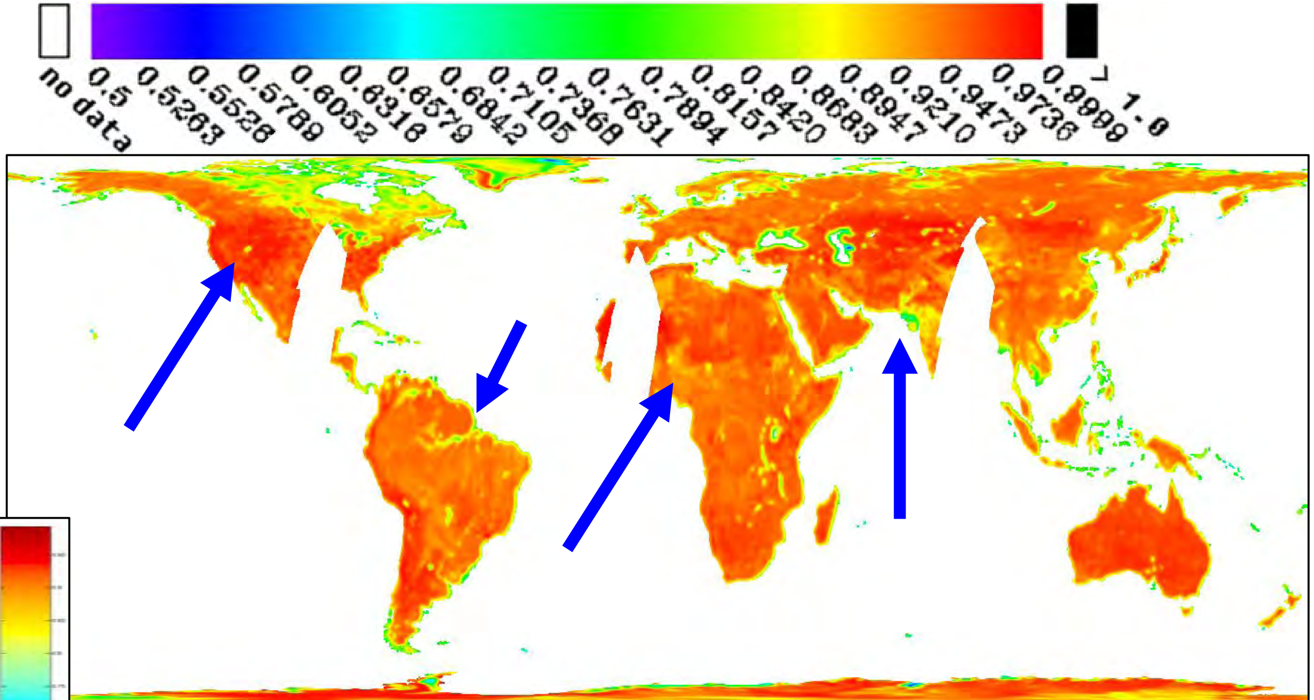
Comparison between the abnormal Emissivity(6.9 GHz V-pol) and RFI index map.



Comparison with other result in different method, but the same time-span

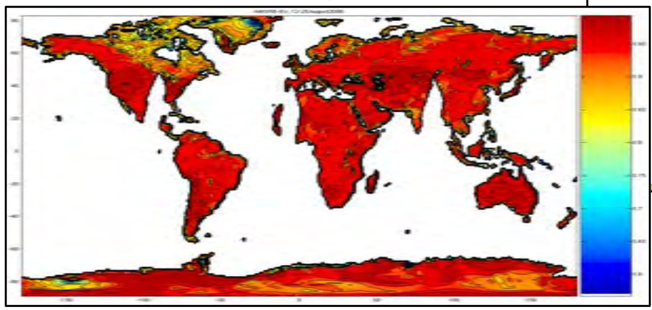
It shows the same pattern.

Fatima(2005)



ISCCP LST
ECWMF
AMSR-E

RTTOV Radiative Transfer Equation



http://www.cnrm.meteo.fr/gmap/mwemis/mwemis.html

Comparison

Statistical Characters of Global Emissivities on V-pol, M Denotes the MODIS-based Results and F.K. is Fatima Karbou's Result.

Freq. (GHz)		Mean	Median	SD	25th%	75th%
6.9 V	M	0.9365	0.9511	0.0581	0.9322	0.9639
	F.K.	0.9336	0.9480	0.0449	0.9221	0.9601
10.7V	M	0.9346	0.9495	0.0554	0.9311	0.9612
	F.K.	0.9294	0.9425	0.0405	0.9175	0.9542
18.7V	M	0.9418	0.9564	0.0488	0.9380	0.9672
	F.K.	0.9387	0.9518	0.0415	0.9284	0.9638
23.8V	M	0.9450	0.9567	0.2167	0.9407	0.9656
	F.K.	0.9320	0.9437	0.0410	0.9212	0.9574
36.5V	M	0.9379	0.9502	0.0417	0.9345	0.9600
	F.K.	0.9222	0.9340	0.0423	0.9141	0.9474
89.0V	M	0.9540	0.9638	0.0341	0.9504	0.9716

Quite Consistency. F.K.'s is a little bit smaller than that of M's, the difference is no more than 0.02, mostly.

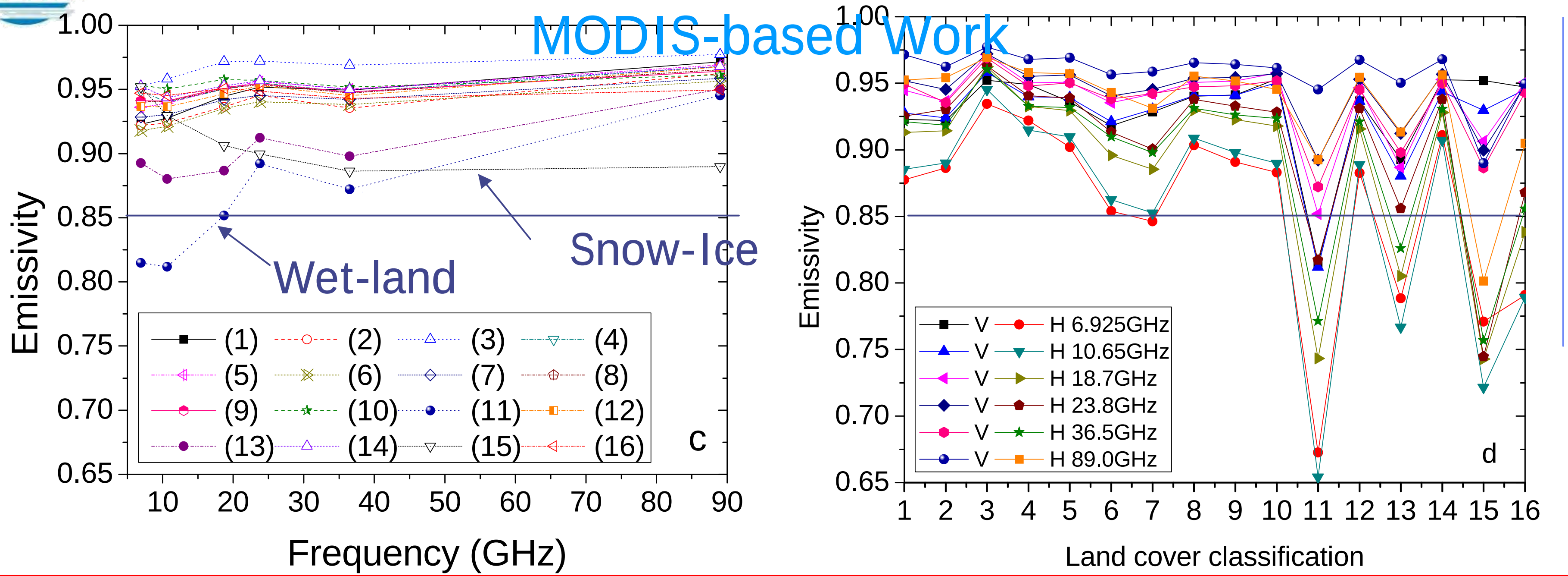
Analysis over difference land covers

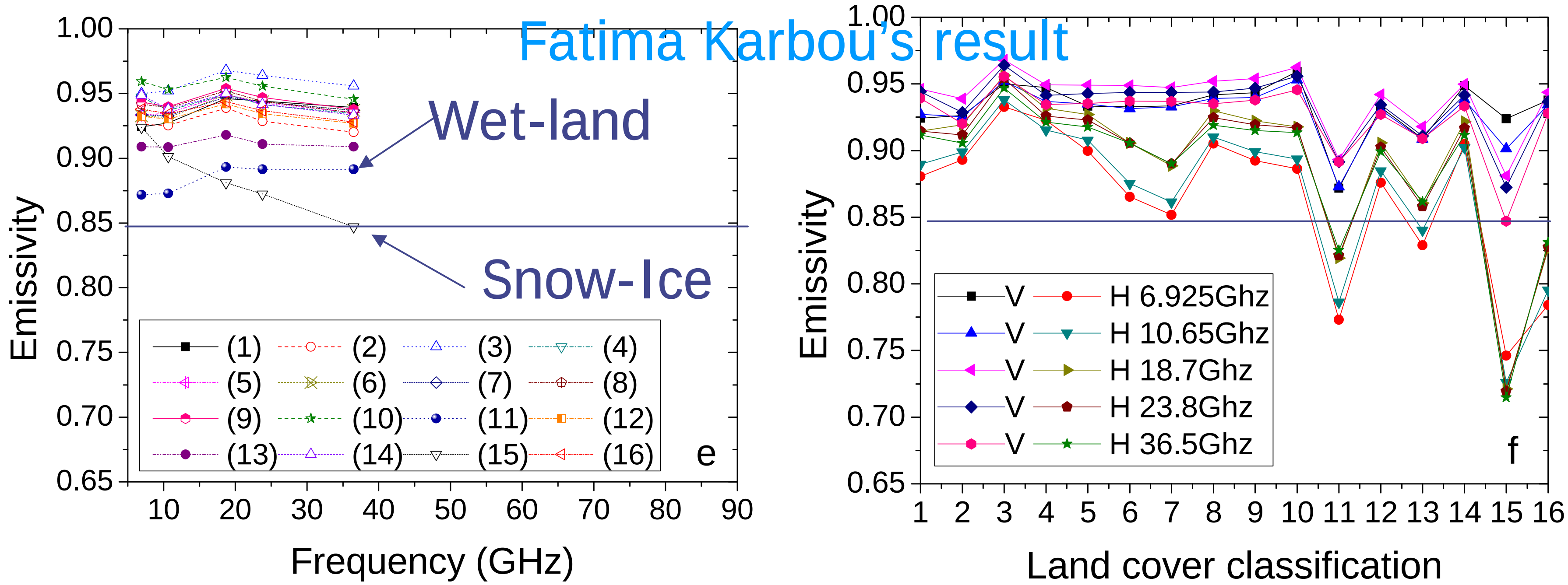
CLASSIFICATION	INDEX	COLOR
Majority Land Cover Type 1		
water	0	
evergreen needleaf forests	1	
evergreen broadleaf forests	2	
deciduous needleaf forests	3	
deciduous broadleaf forests	4	
mixed forests	5	
closed shrublands	6	
open shrublands	7	
woody savannas	8	
savannas	9	
grasslands	10	
permanent wetlands	11	
croplands	12	
urban and built-up	13	
cropland/natural vegetation mosaic	14	
snow and ice	15	
barren or sparsely vegetated	16	

MODIS-IGBP-Based

IGBP classification index

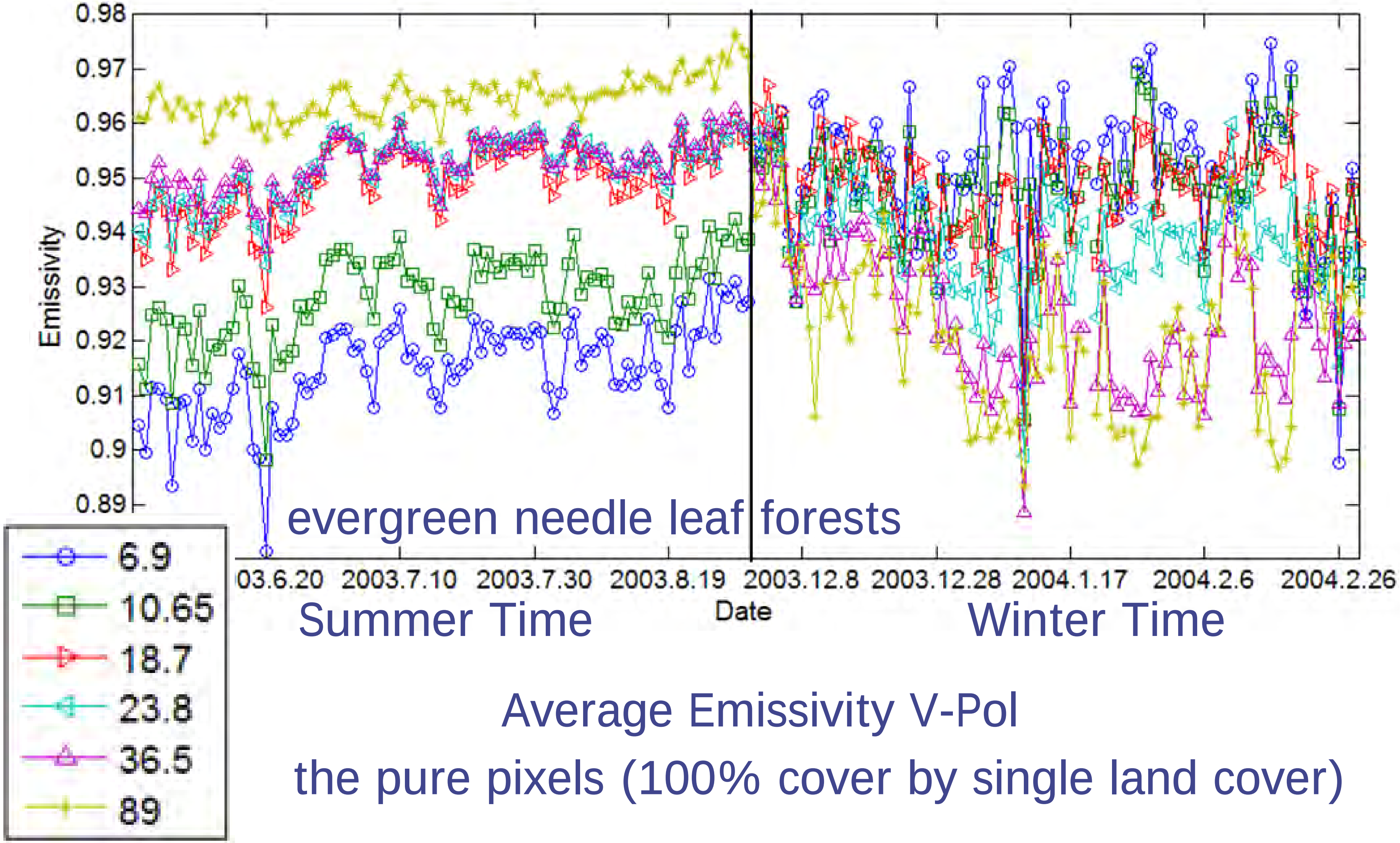
Comparison – over different Freq. and Land covers





Time Series Analysis - half a year for summer and winter time

- 3 months for summer time and 3 month for the winter time (in the year of 2003~2004)

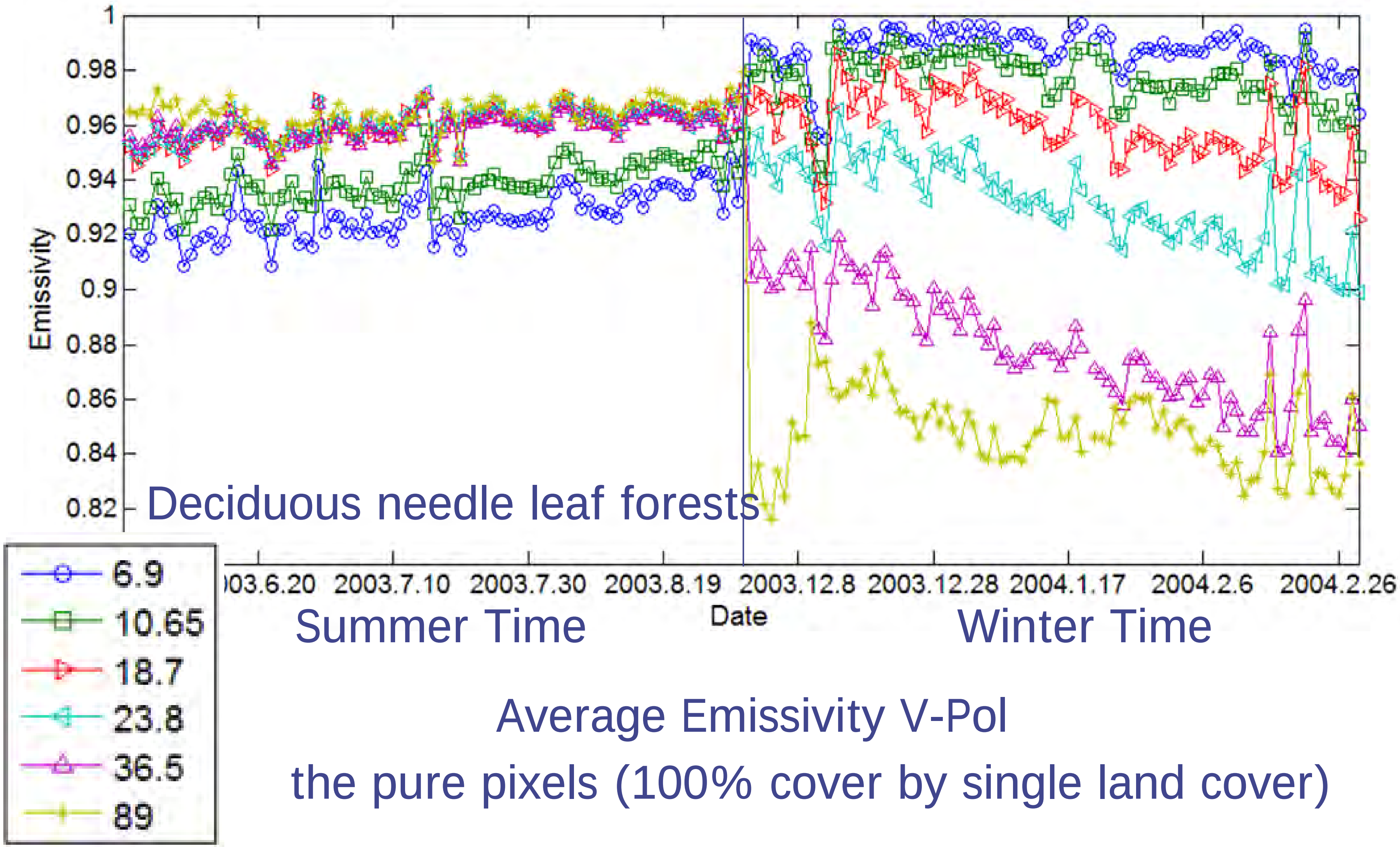


Average Emissivity V-Pol

the pure pixels (100% cover by single land cover)

Time Series Analysis - half a year for summer and winter time

- 3 months for summer time and 3 month for the winter time (in the year of 2003~2004)



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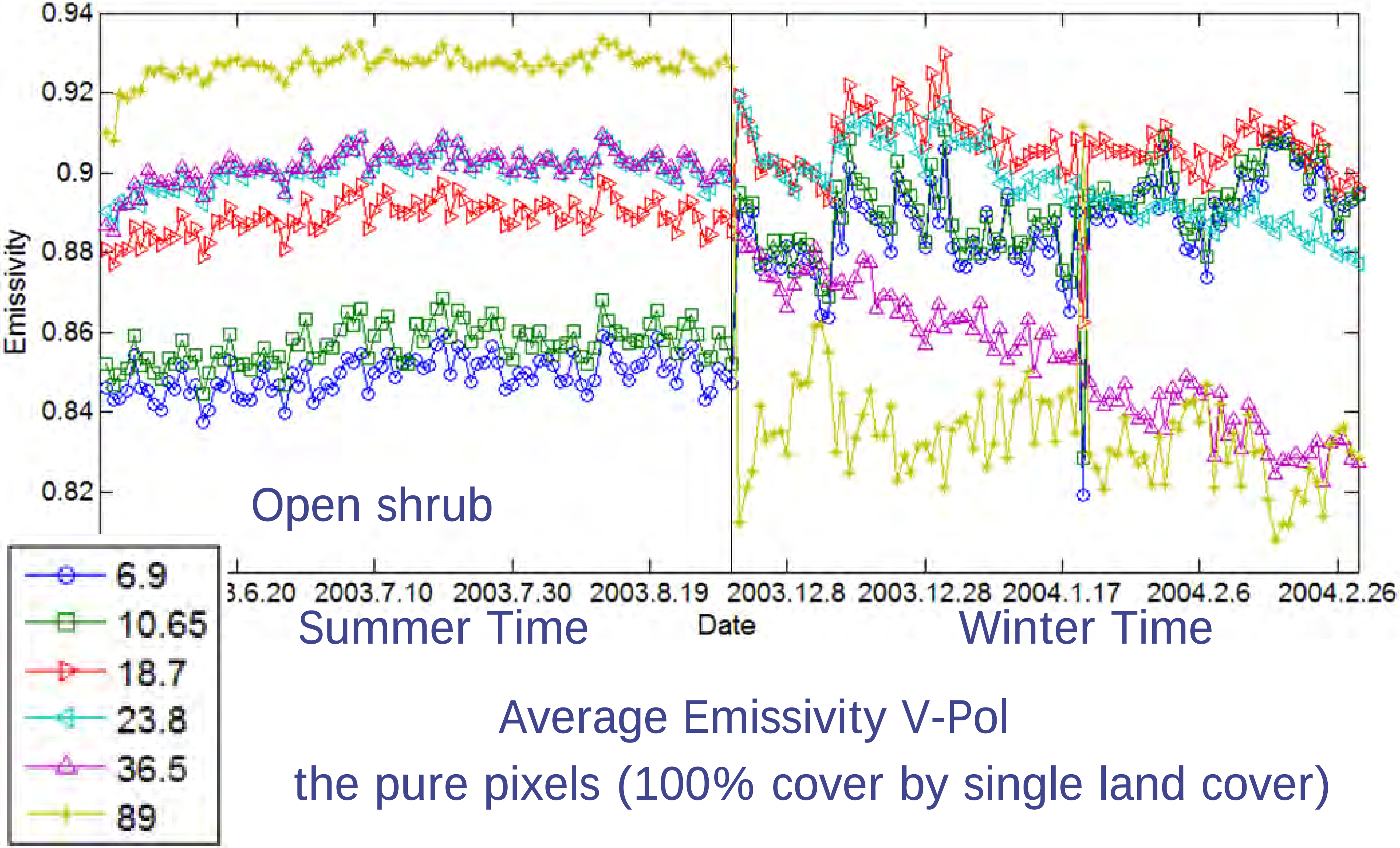

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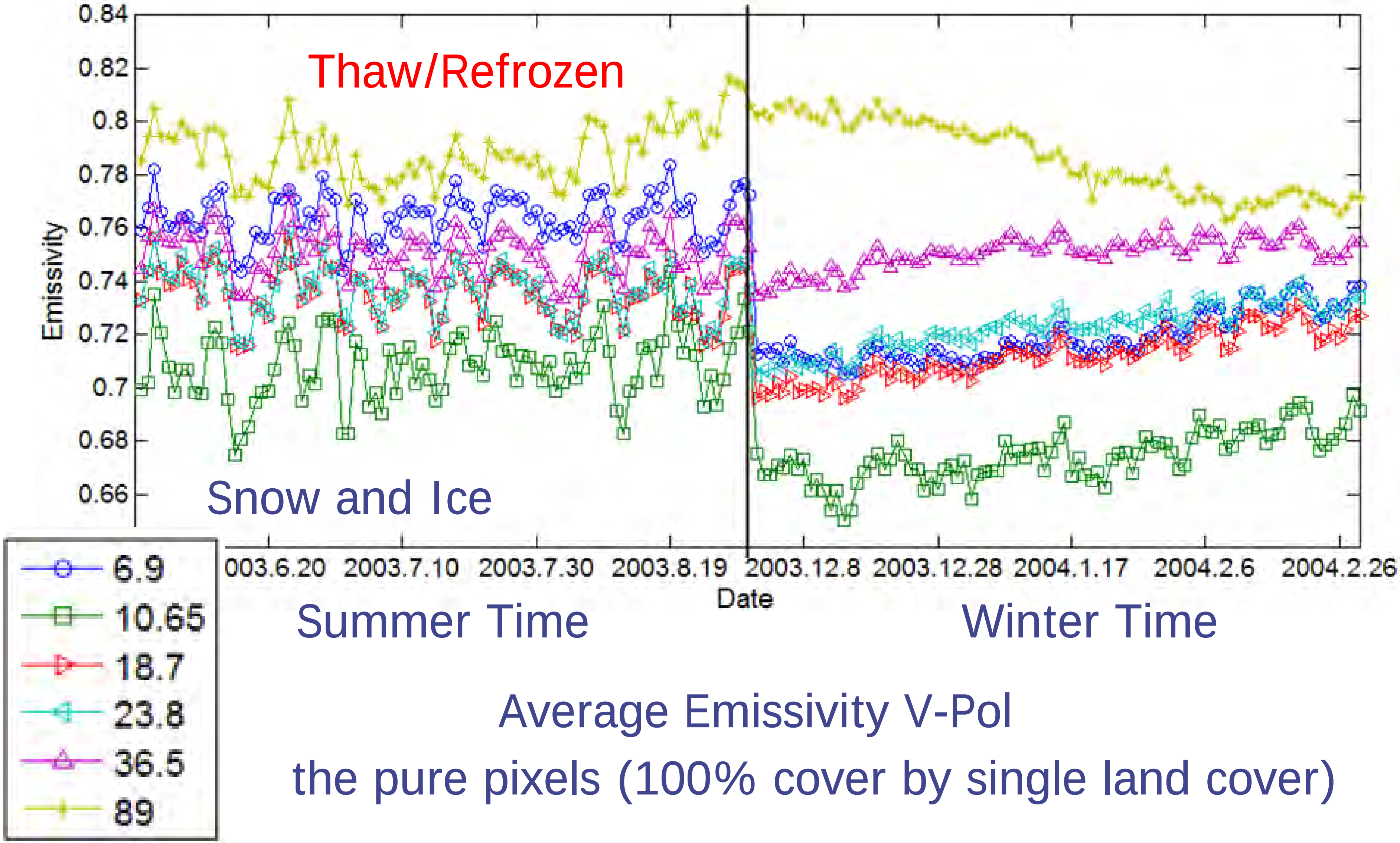


Average Emissivity V-Pol

the pure pixels (100% cover by single land cover)

A preliminary summary

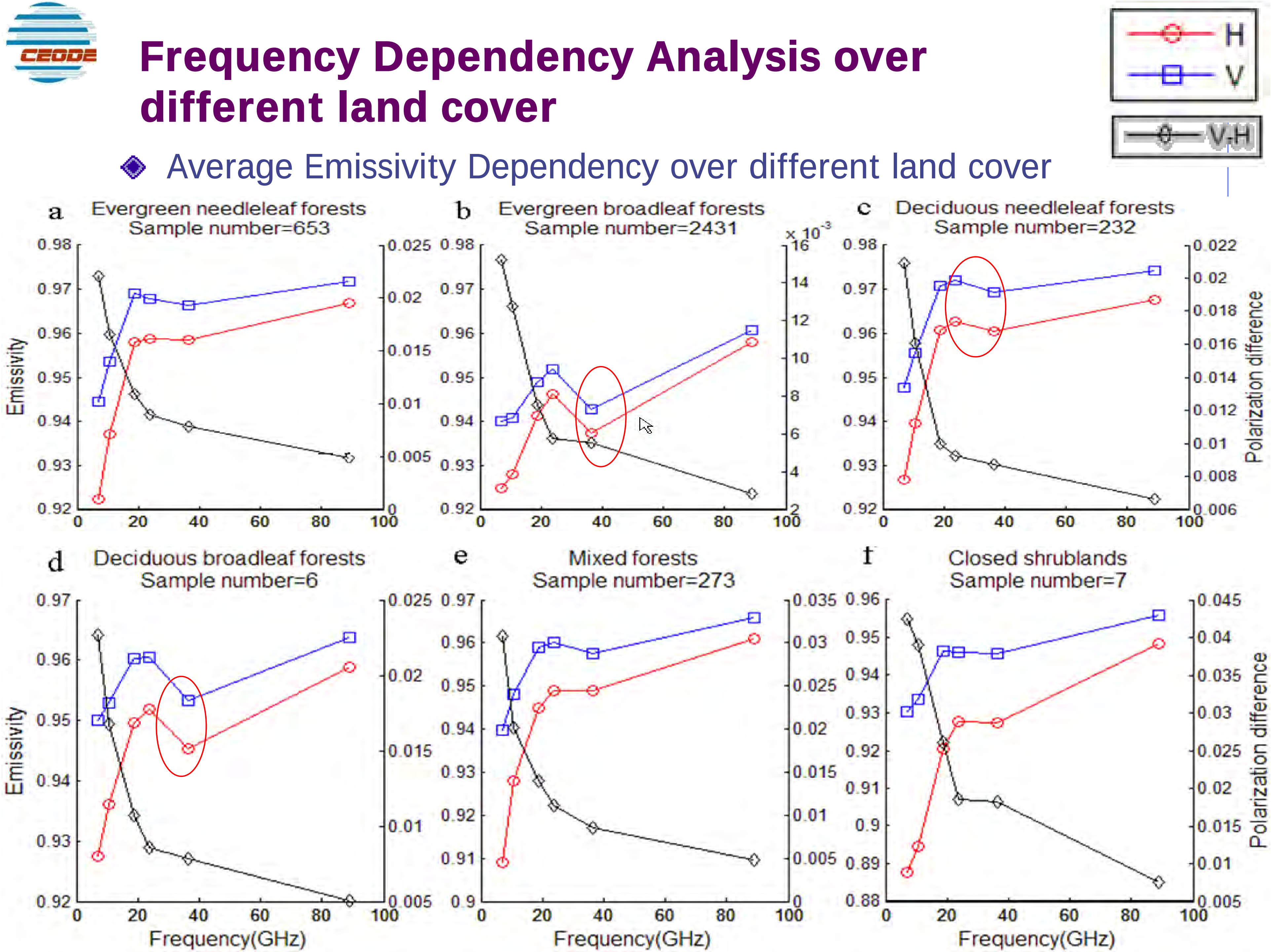
- Summer is stable, while in winter time, the snow or frozen phenomena drivers the emissivity viability (most pixels over the northern hemisphere)

- While over snow/ice, reversely..., because of the Thaw/Refrozen process...in summer time, and winter time has a increasing snow or ice trend...

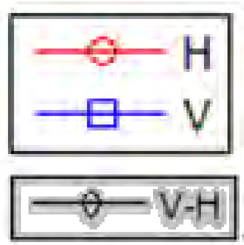
- The emissivity is increasing as the frequency increasing. Some of them fit well with the model result, but there are also some discrepancy, this should be more work...

Frequency Dependency Analysis over different land cover

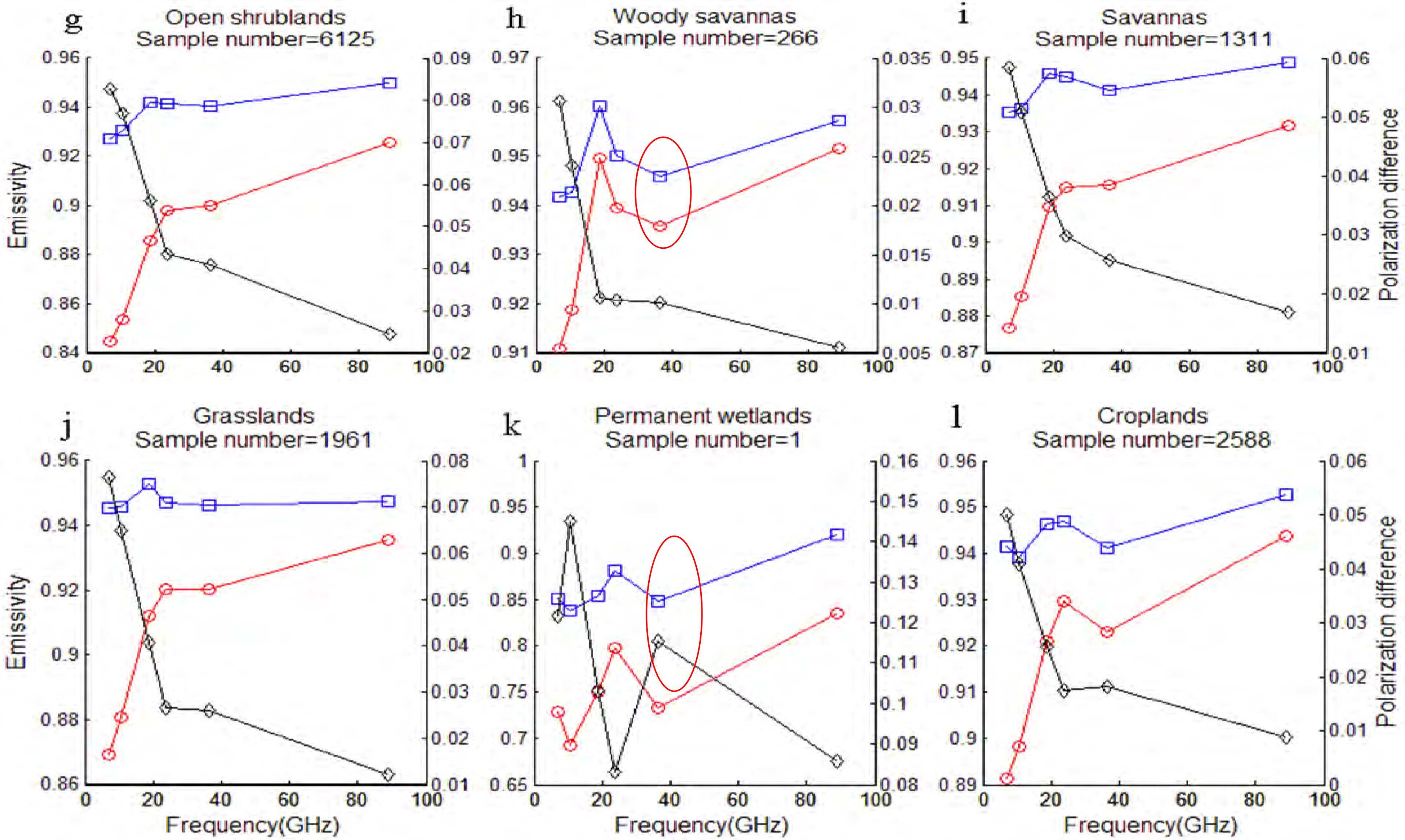
◆ Average Emissivity Dependency over different land cover



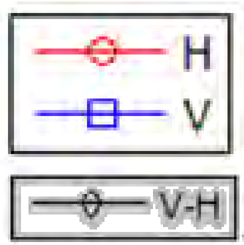
Frequency Dependency Analysis over different land cover



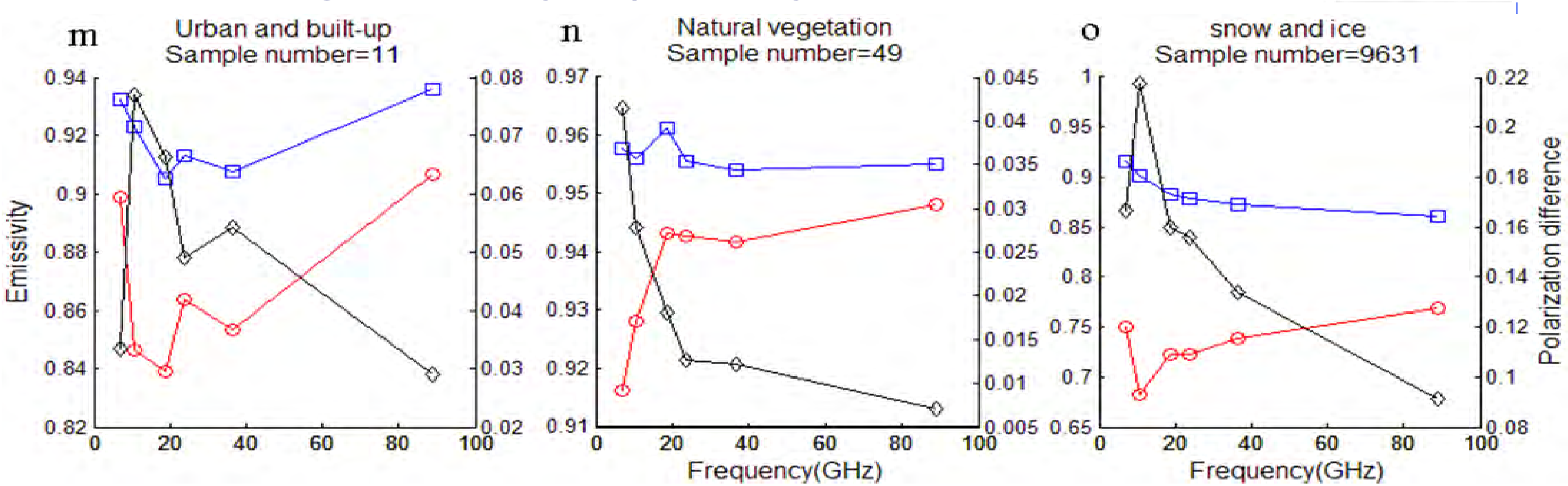
- Average Emissivity Dependency over different land cover

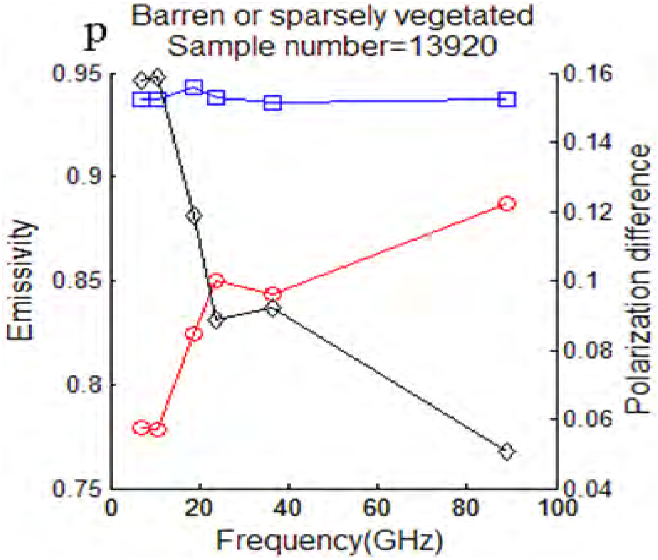


Frequency Dependency Analysis over different land cover



- Average Emissivity Dependency over different land cover





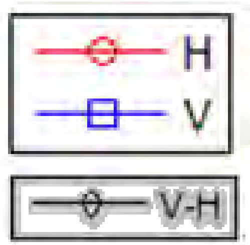
1, Higher Freq. - Small Polarization Difference.

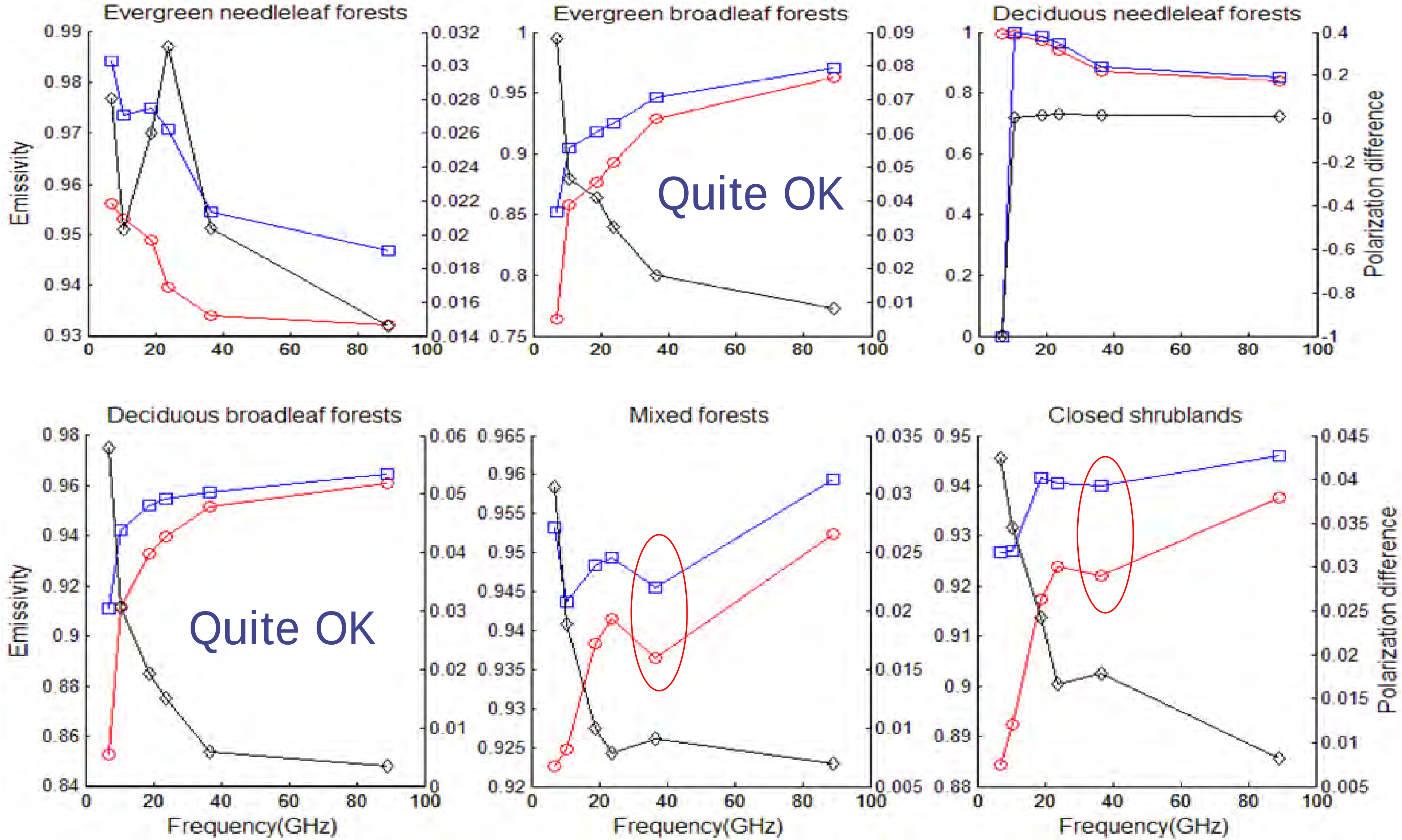
2, The emissivity at 19.0GHz are higher than the that of its sideward Frequencies.

...Unstable behalves...

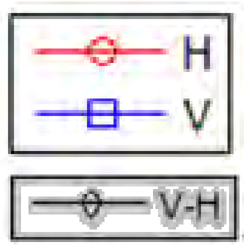
Frequency Dependency Analysis over different land cover

- Instantaneous Emissivity Dependency over different land cover

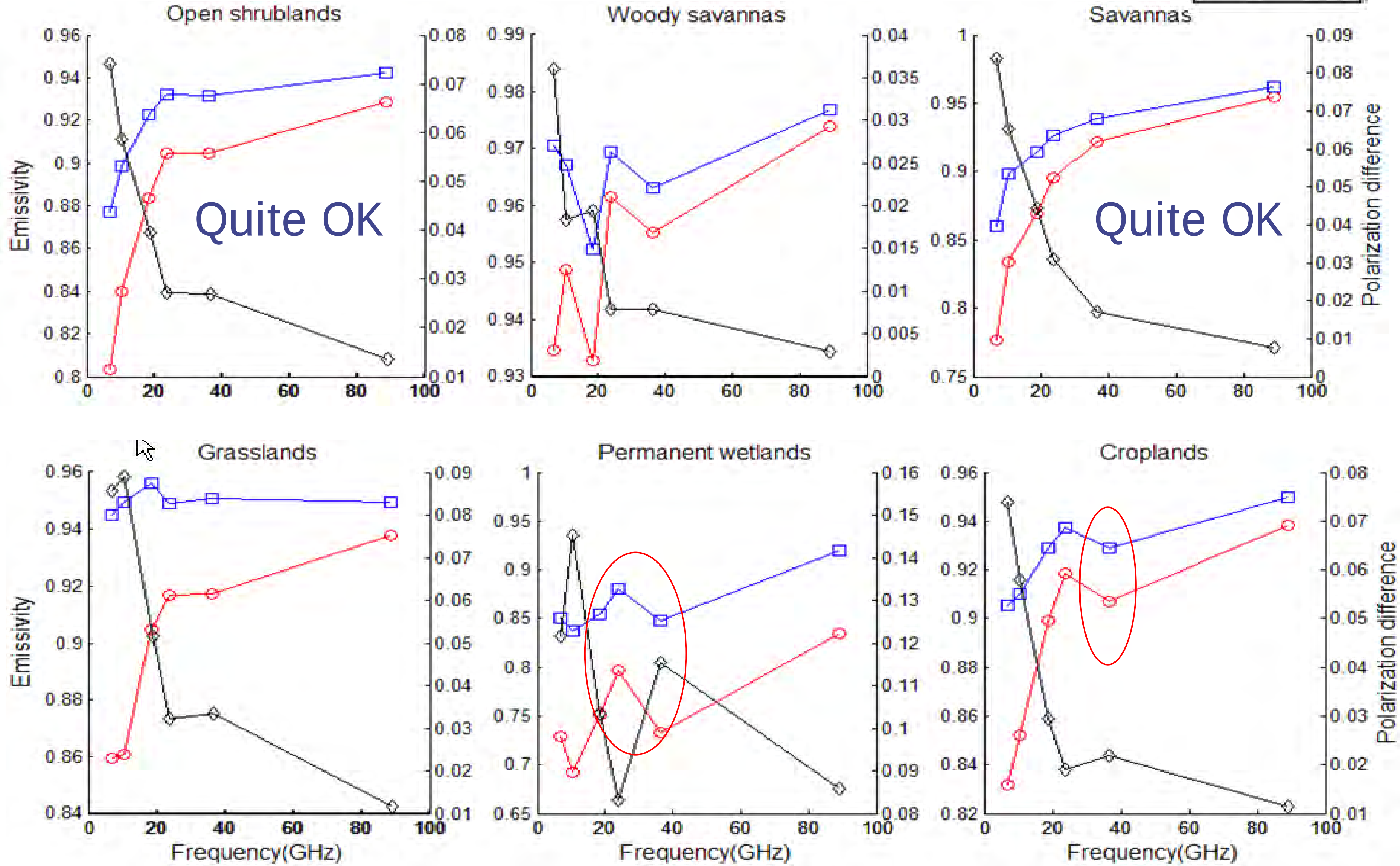




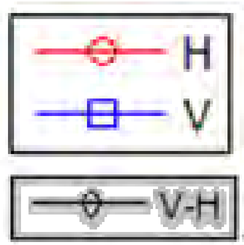
Frequency Dependency Analysis over different land cover



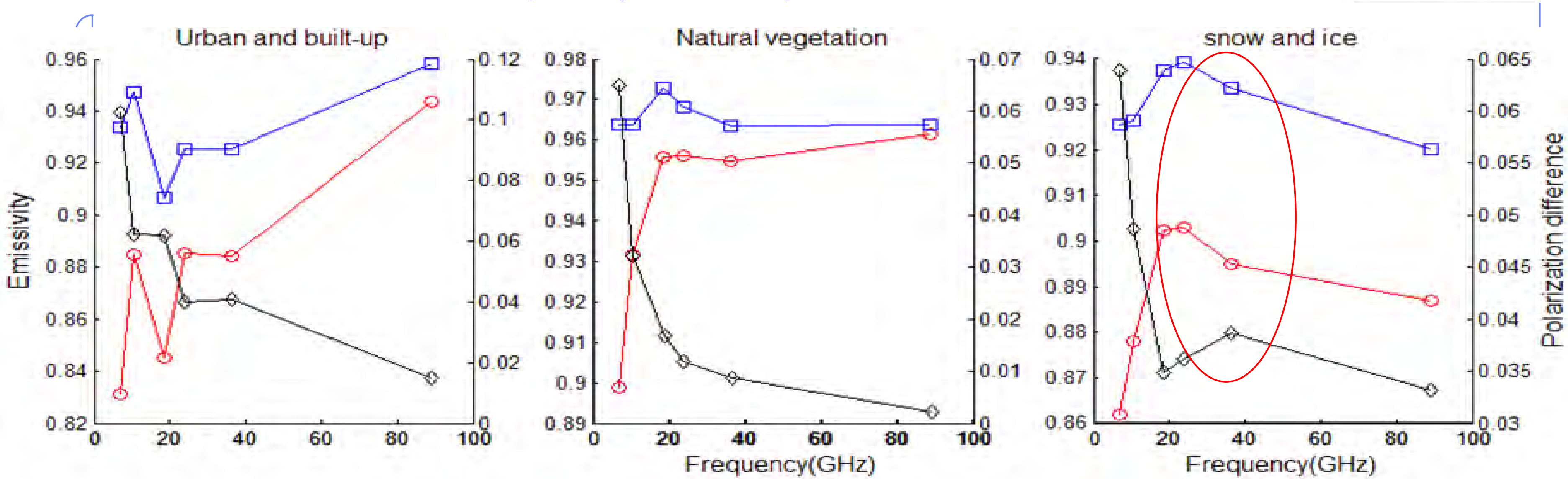
- Instantaneous Emissivity Dependency over different land cover

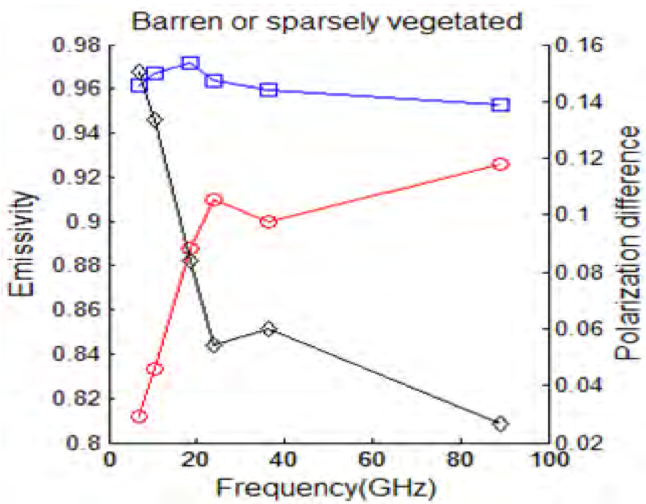


Frequency Dependency Analysis over different land cover



- Instantaneous Emissivity Dependency over different land cover



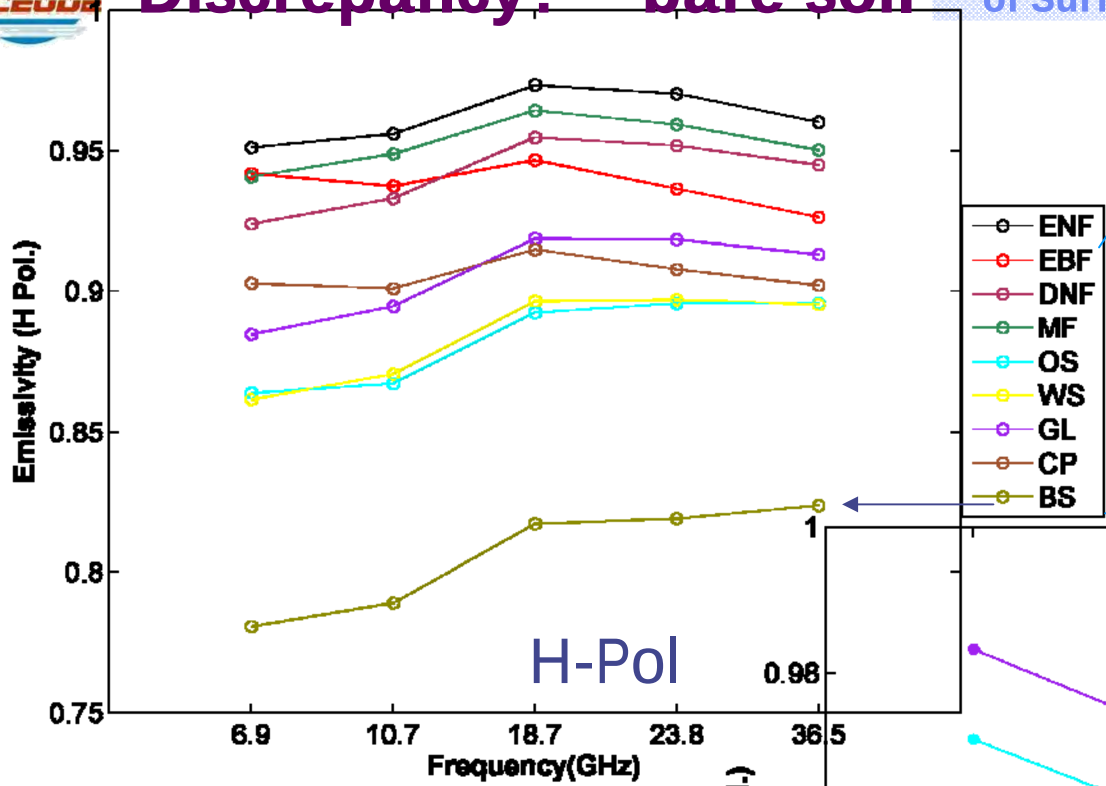


Show the same result with the average

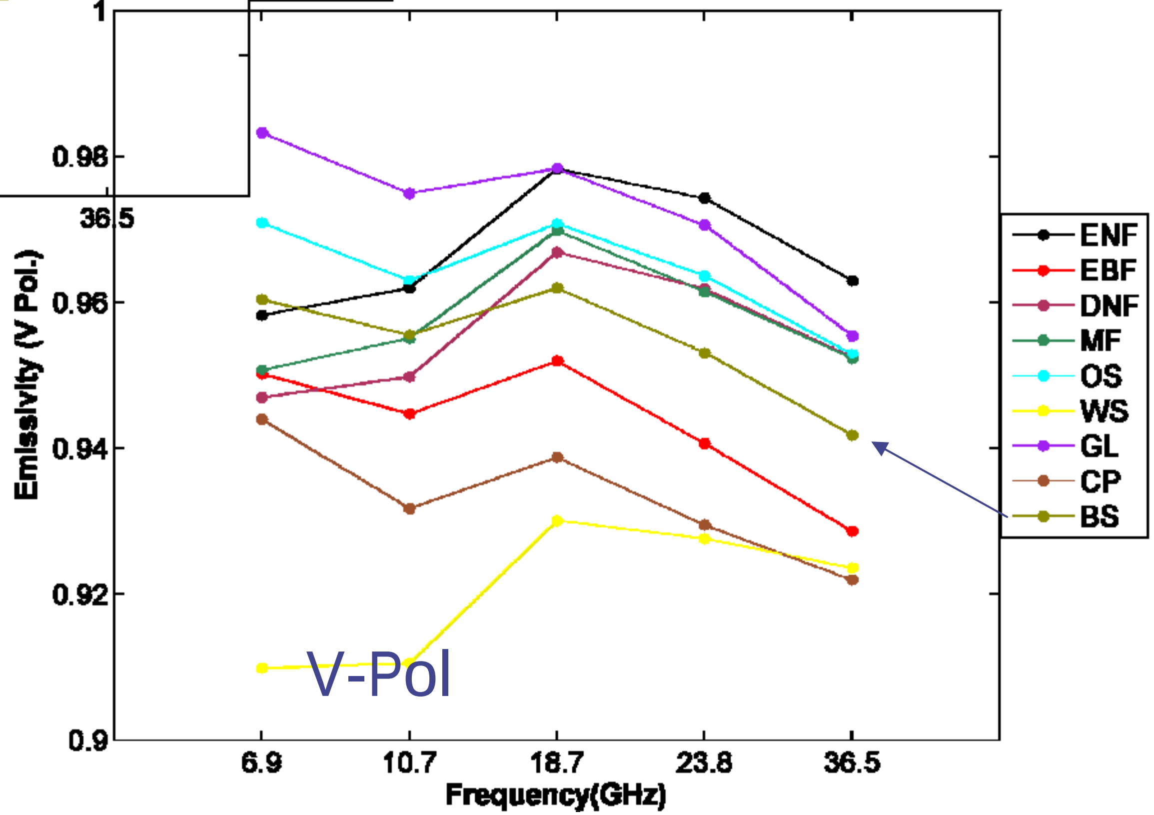
Some of then are quite well with the common knowledge

The PDs are in same trend.

Discrepancy? – bare soil



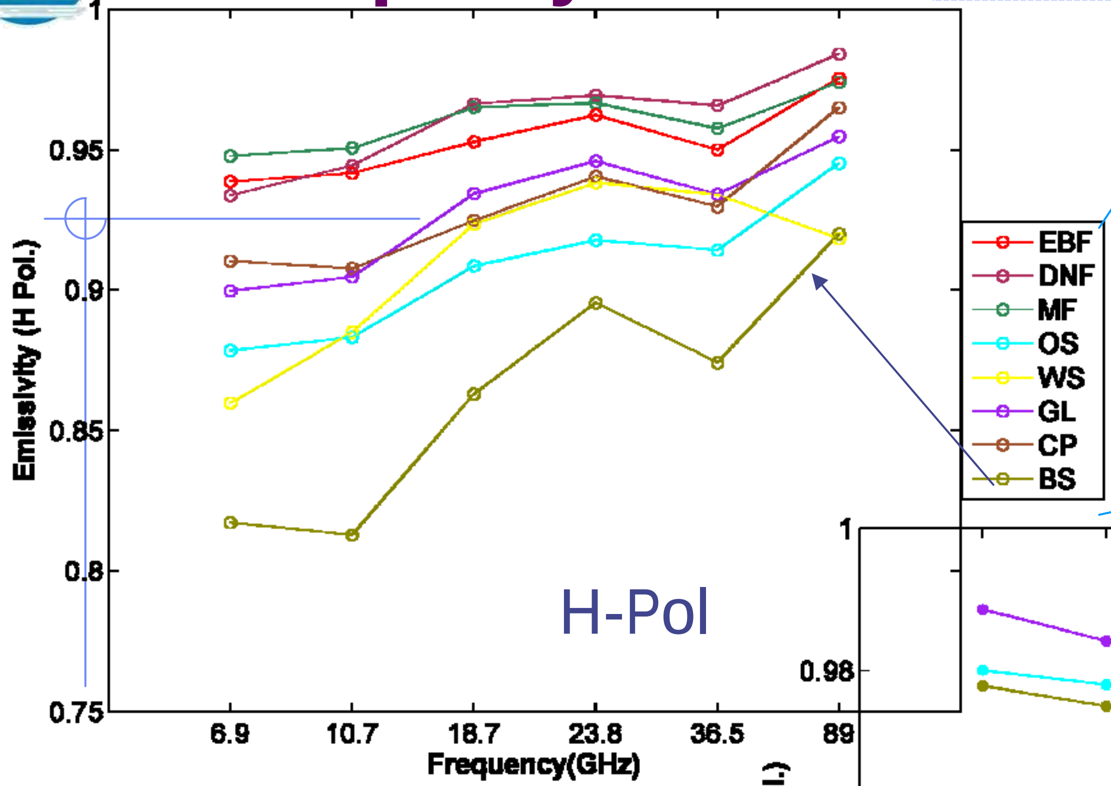
Evergreen Needleleaf Forest
Evergreen Broadleaf Forest
Deciduous Needleleaf Forest
Mixed Forest
Open Shrubland
Woody Savannas
Grasslands
Croplands
Barren or Sparsely Vegetated



Mean emissivity for the F.K.'s result

Estimation result

Discrepancy?



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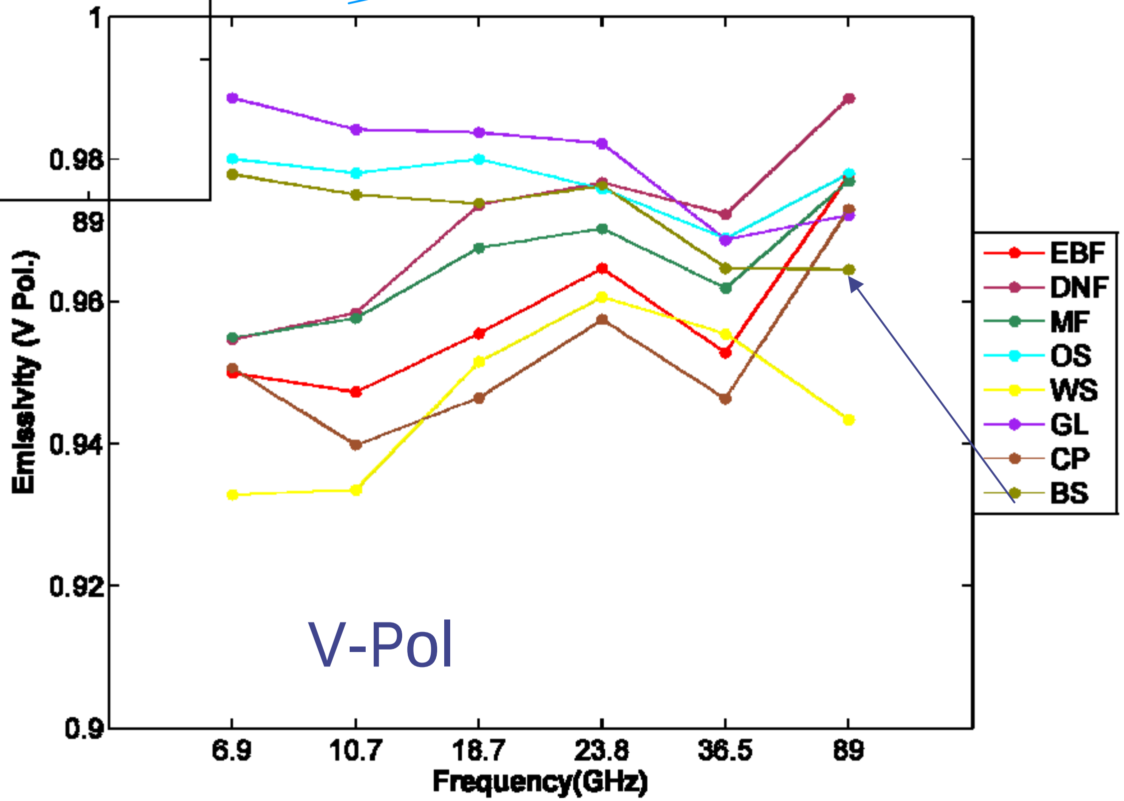


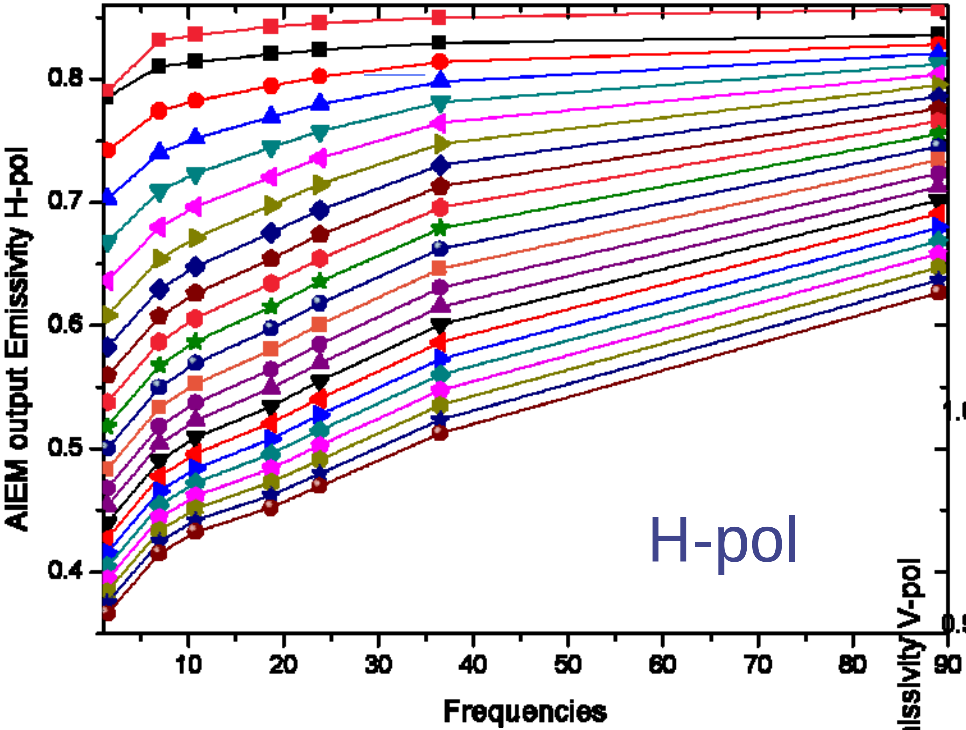
Mean emissivity of MODIS-based work

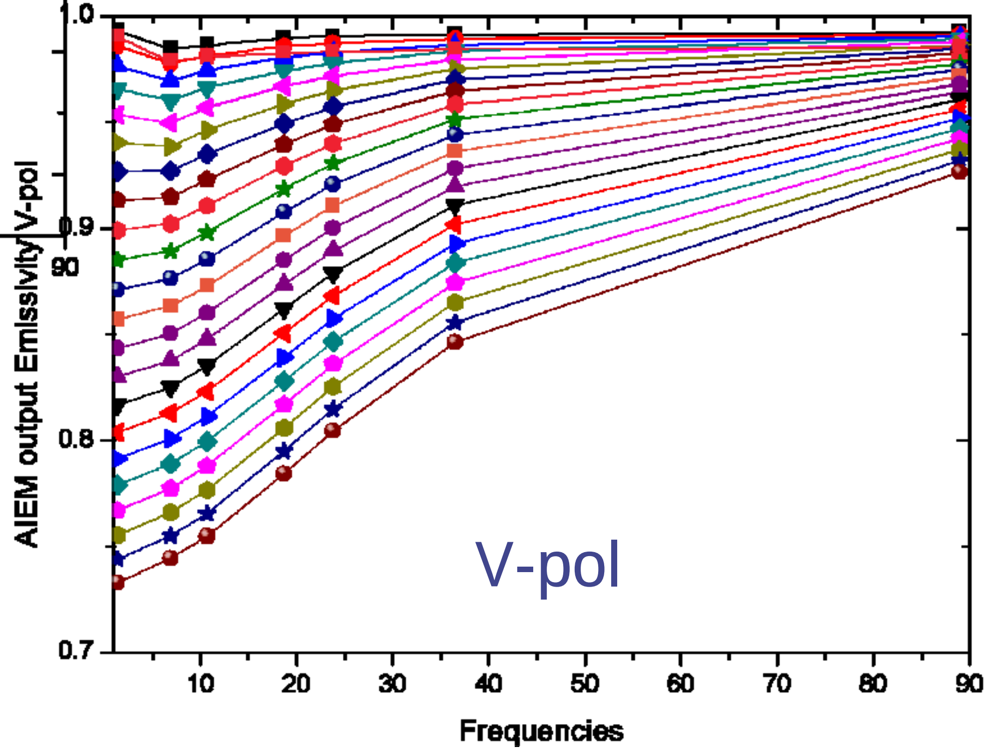
Estimation result

Discrepancy?

- Theory result

AIEM simulation – Bare Soil Emission





H-Pol is ok, but the V-Pol has a Discrepancy, but the MODIS-based and F.K. are the same trend.

Simulation result

Another concern is the global instantaneous emissivity: How the emissivities could be estimated from the cloudy sky

$$MPDI = (T_{bv} - T_{bh})/(T_{bv} + T_{bh})$$

MPDI ...(Microwave polarization difference index)

$$MPDI = (e_v - e_h)/(e_v + e_h + g)$$

$$g = 2(T_{\uparrow} + T_{\downarrow} \cdot \Gamma)/(T_s - T_{\downarrow} \cdot \Gamma)$$

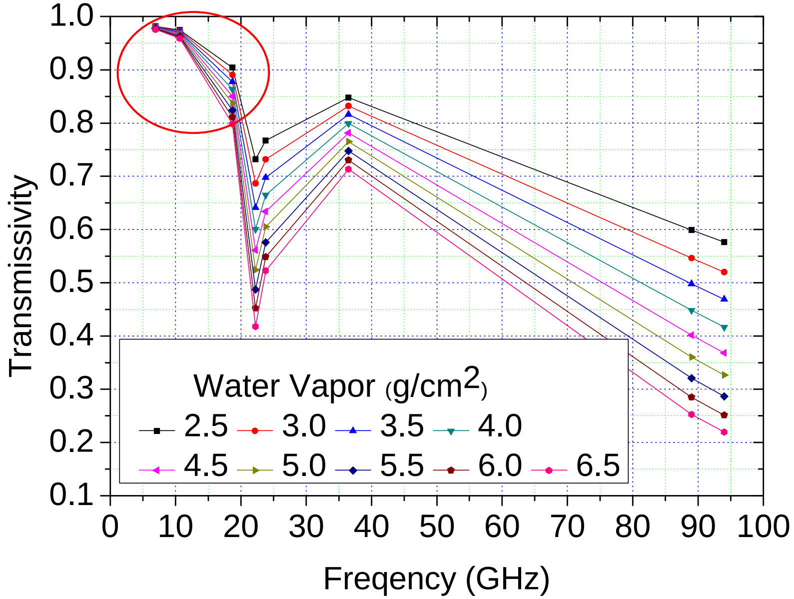
Γ Transmissivity

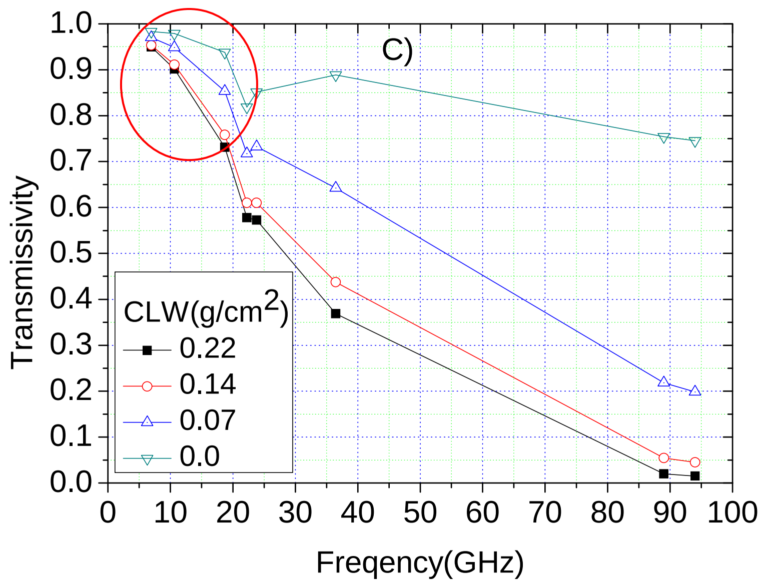
$T_{\uparrow}$ upwelling

$T_{\downarrow}$ Down welling

Assume: $T_s = T_a$ and $T_{\uparrow} = T_{\downarrow} = T_a \cdot (1 - \Gamma)$

Atmosphere influence to MPDI





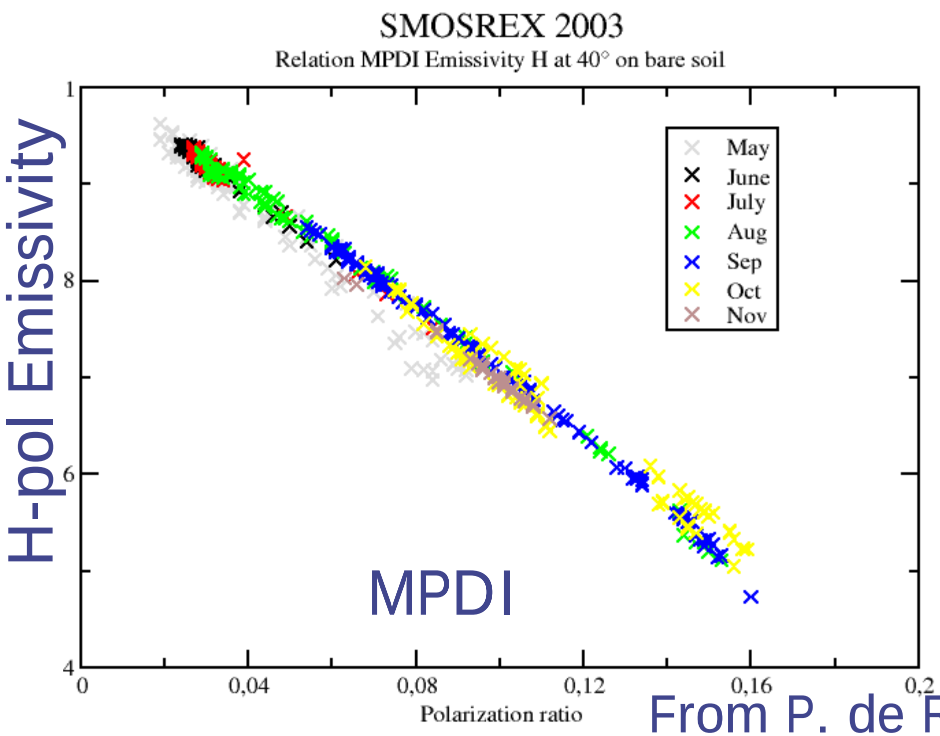
Atmosphere has less influence to the MPDI at low frequencies

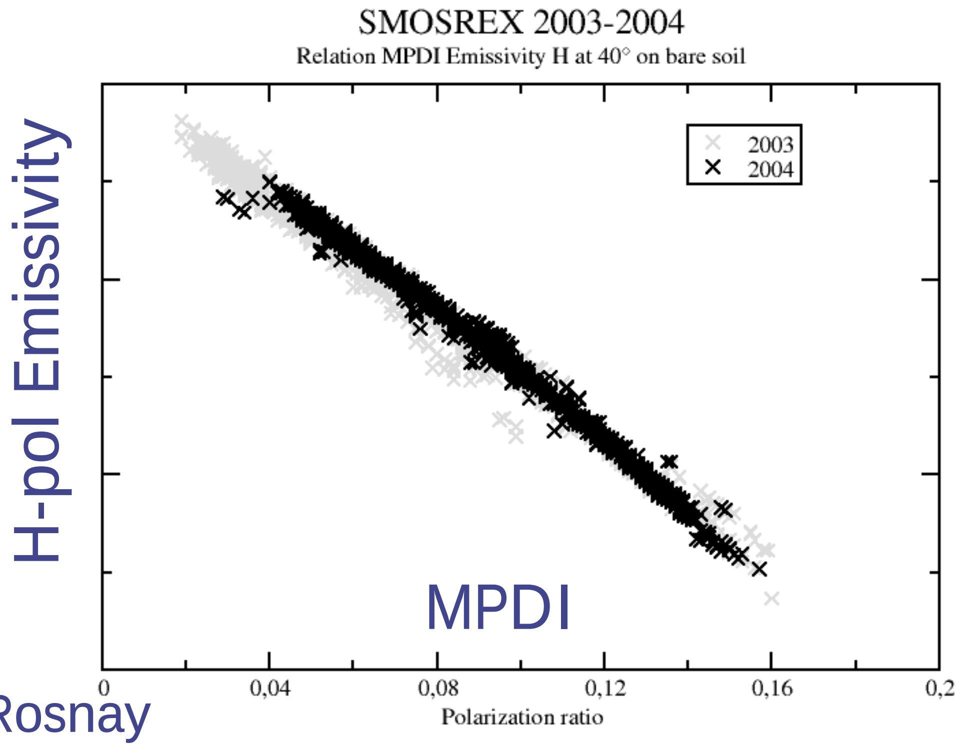
At low frequencies, MPDI is decide almost by the emissivity, with little atmosphere fluence.

We get...from experiment result

Avoid the influence from surface temperature and atmosphere effective temperature, we get:

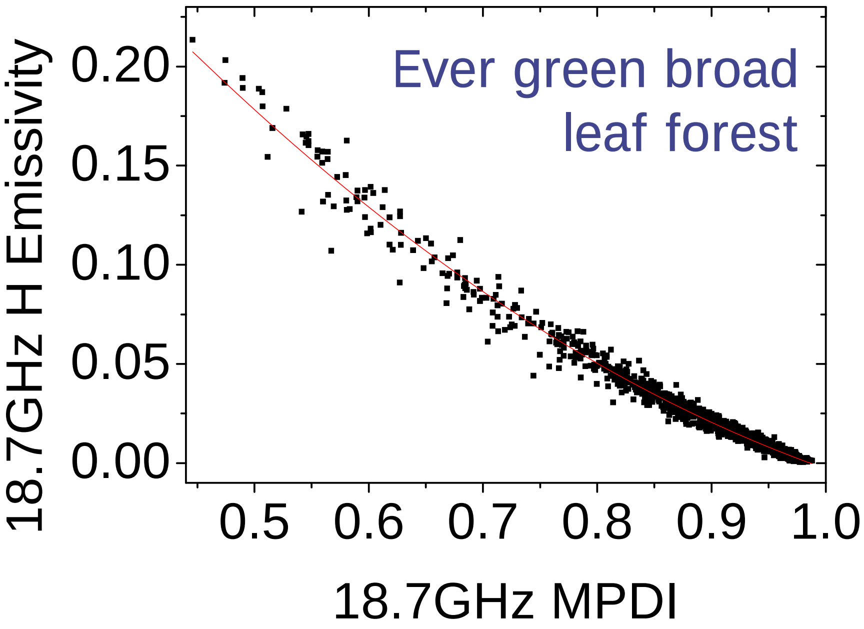
$$MPDI = (e_v - e_h)/(e_v + e_h + 1/\Gamma - 1)$$

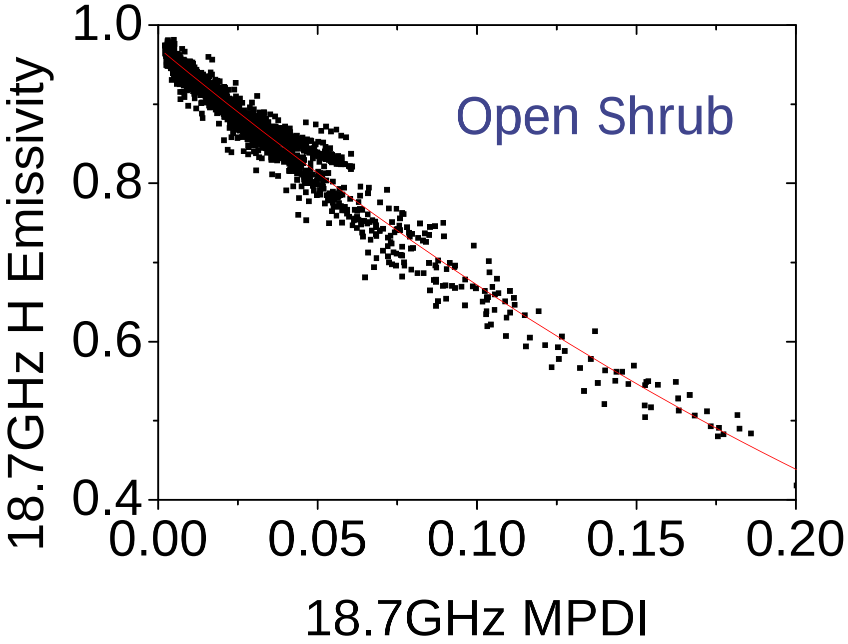




From P. de Rosnay

We get...from experiment result

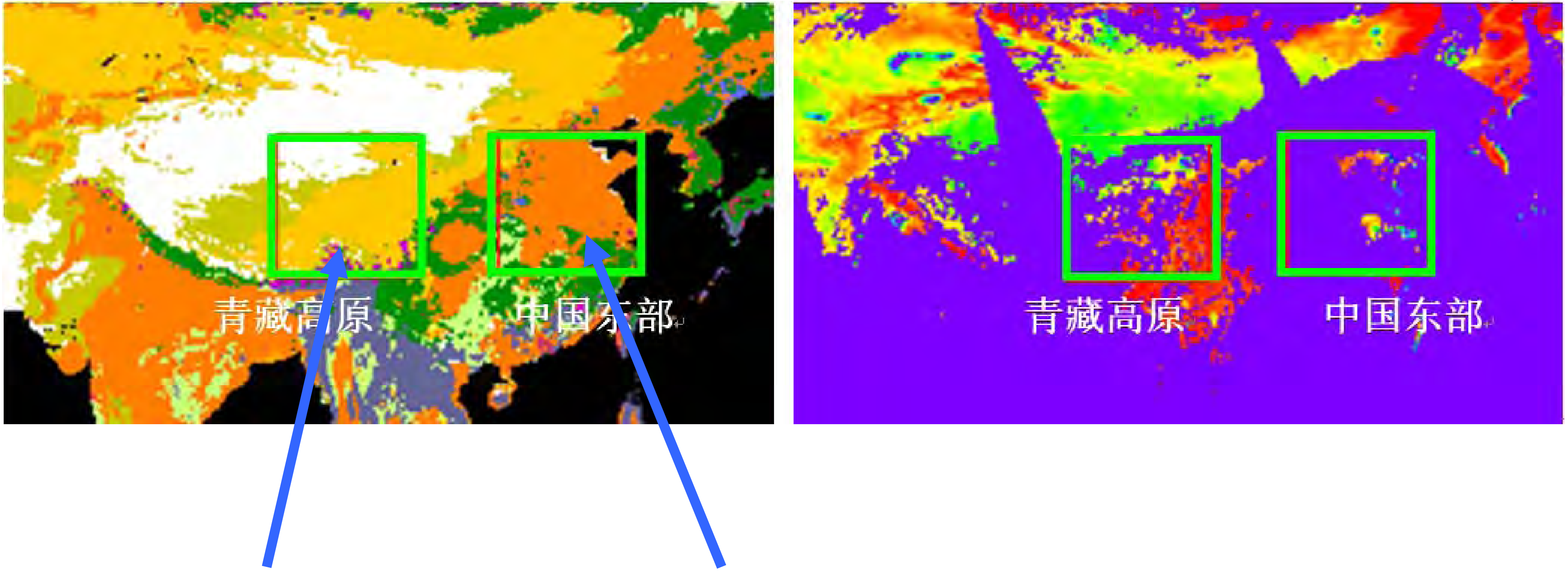




MPDI based H-pol emissivity prediction over different lad cover

Test Area

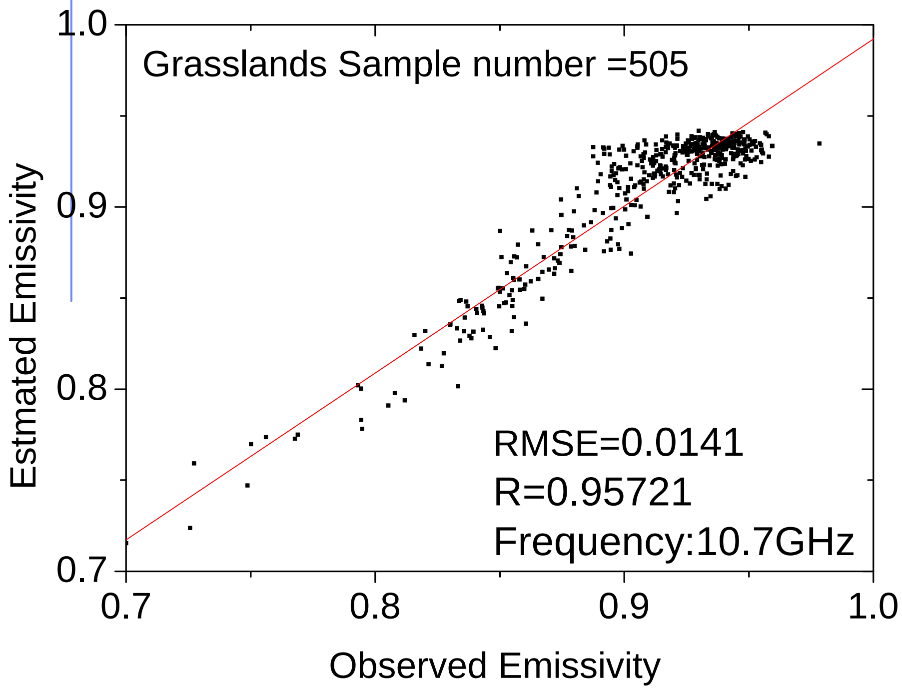
Eastern China and Tibet Area

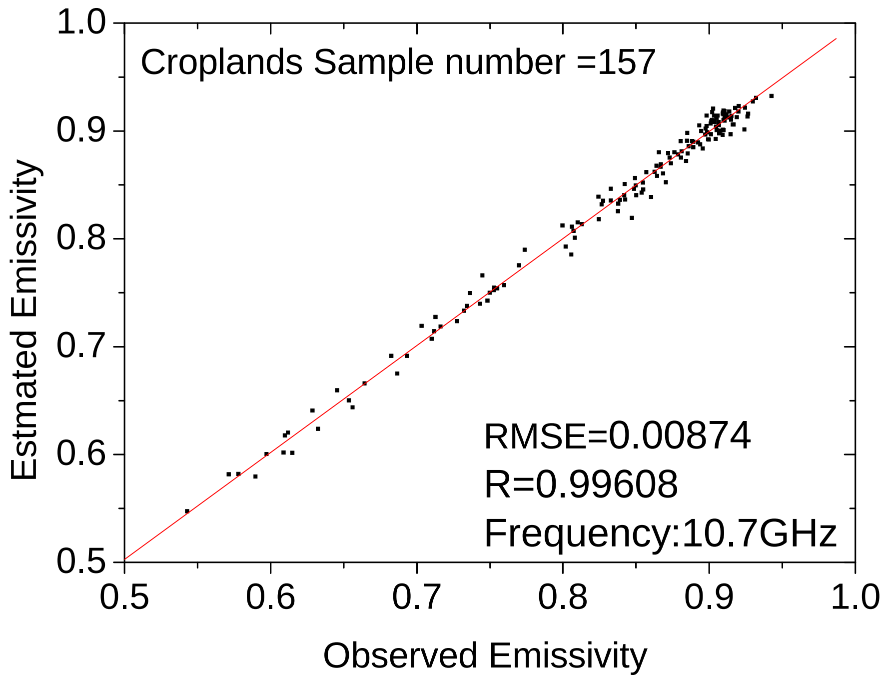


Grassland，sample 505   Cropland，sample 107

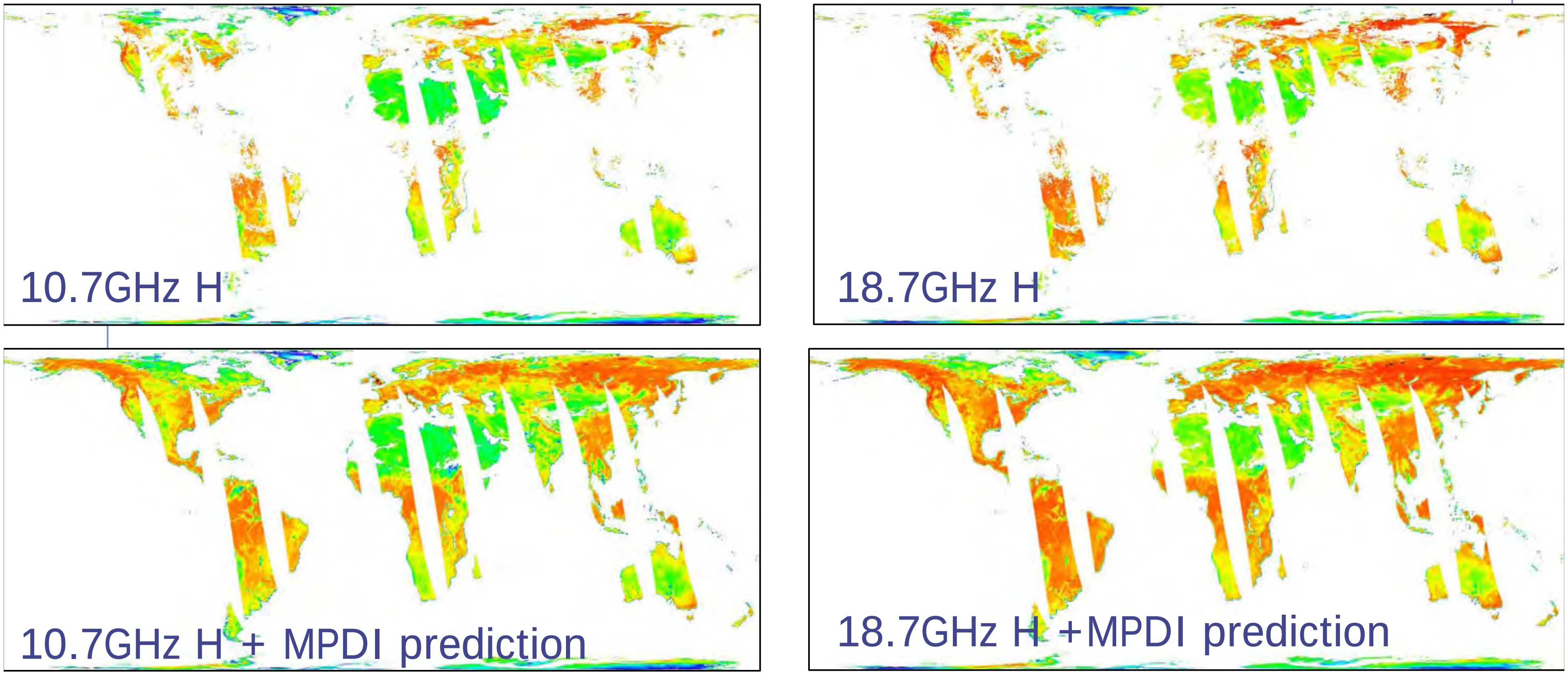
$$e_h = B_0 + B_1 \cdot PR/MPDI_{6.9} + B_2 \cdot PR/MPDI_{10.7} + B_3 \cdot PR/MPDI_{18.7}$$

Estimation of 18.7GHz and 10.7GHz

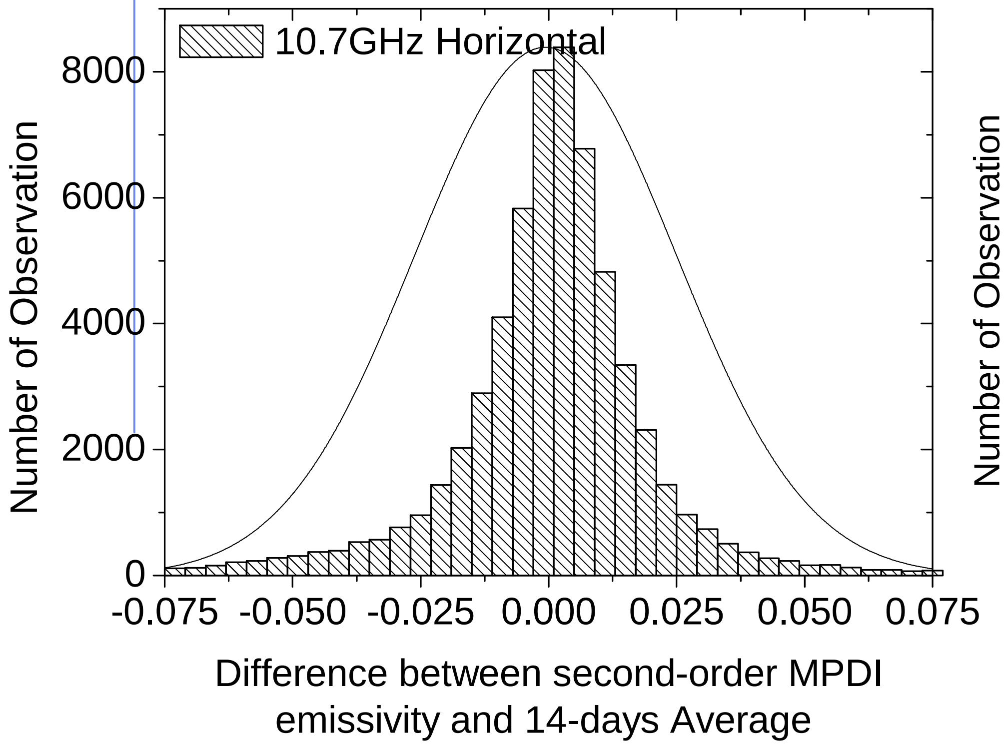


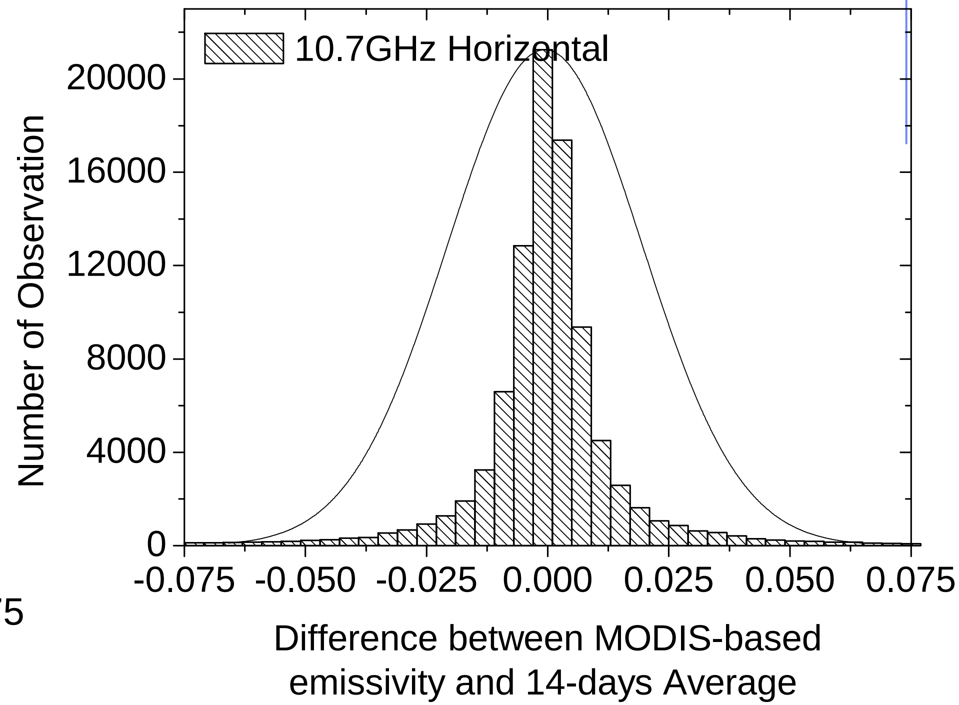


A try to global estimation for 10.7GHz and 18.7GHz



Statistical analysis – evaluation for 10.7Gz



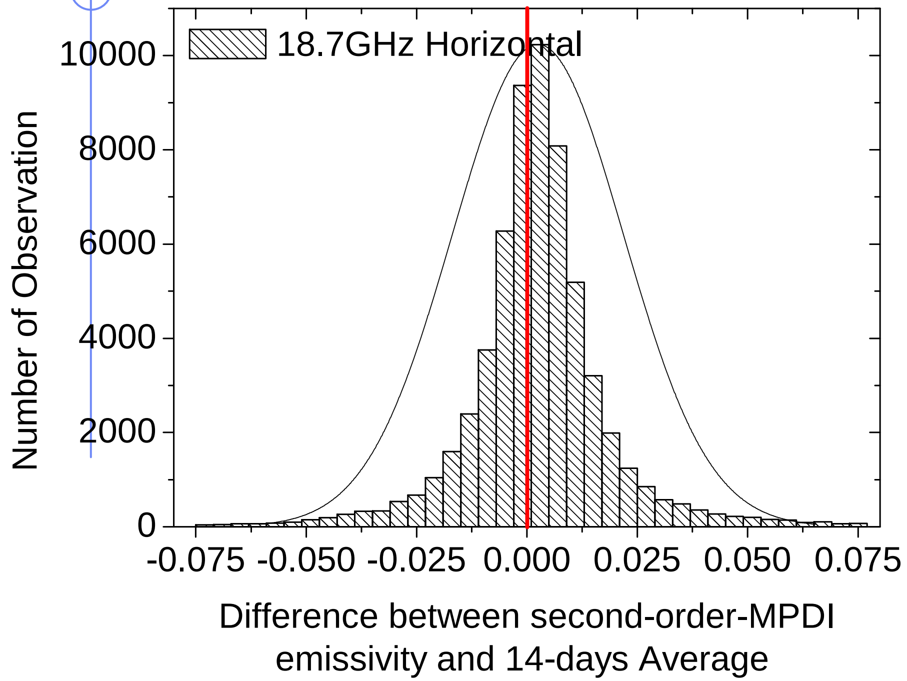


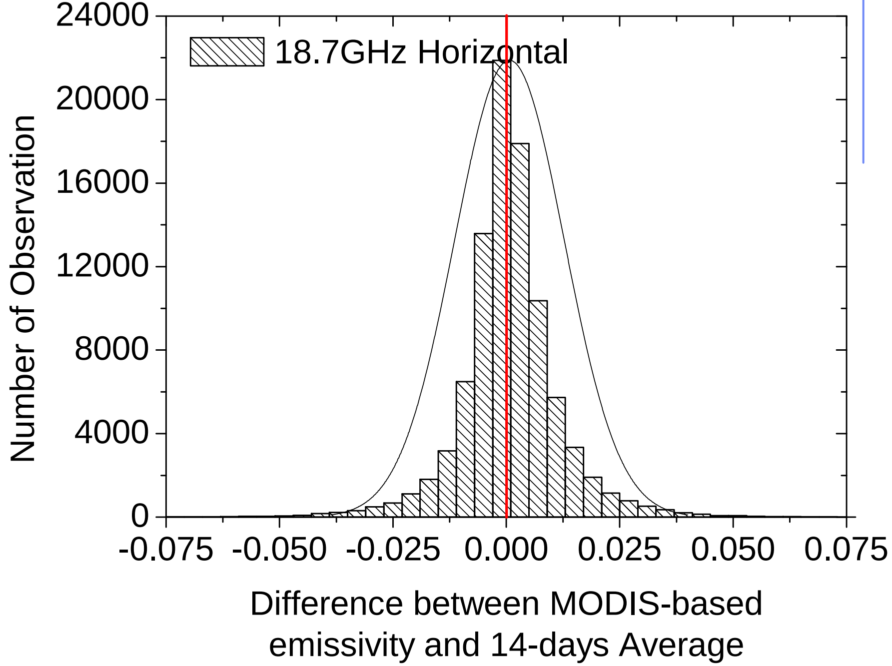
Prediction result globally

All clear sky – calculated directly

Histogram difference between instantaneous emissivity and average

Statistical analysis – evaluation for 18.7Gz





Prediction result globally

All clear sky – calculated directly

Histogram difference between instantaneous emissivity and average

Conclusion

- We have got the instantaneous emissivity daily and through comparison evaluation, it shows,
  - The average result agree well with the previous result
  - The long time series result express meaningful indicator of surface evolution
  - And appear some disagreement with the theory result, show discrepancy.
- A emissivity prediction method has been provide via the relationship between the MPDI and H-pol emissivity
  - The statistical evaluation seems that the result is relatively good.
  - These result could be used to do the atmosphere correction for parameters over land, to support the atmosphere retrieval.
- More detailed sensitivity analysis work of different input parameters should be conducted in the near future
  - Validation ? Comparison?


End
Thank you very much!
Any questions ?