TPE-GHP/GEWEX Joint Workshop

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Surface Energy Distribution Characteristics in the Third Pole Region from Remote Sensing

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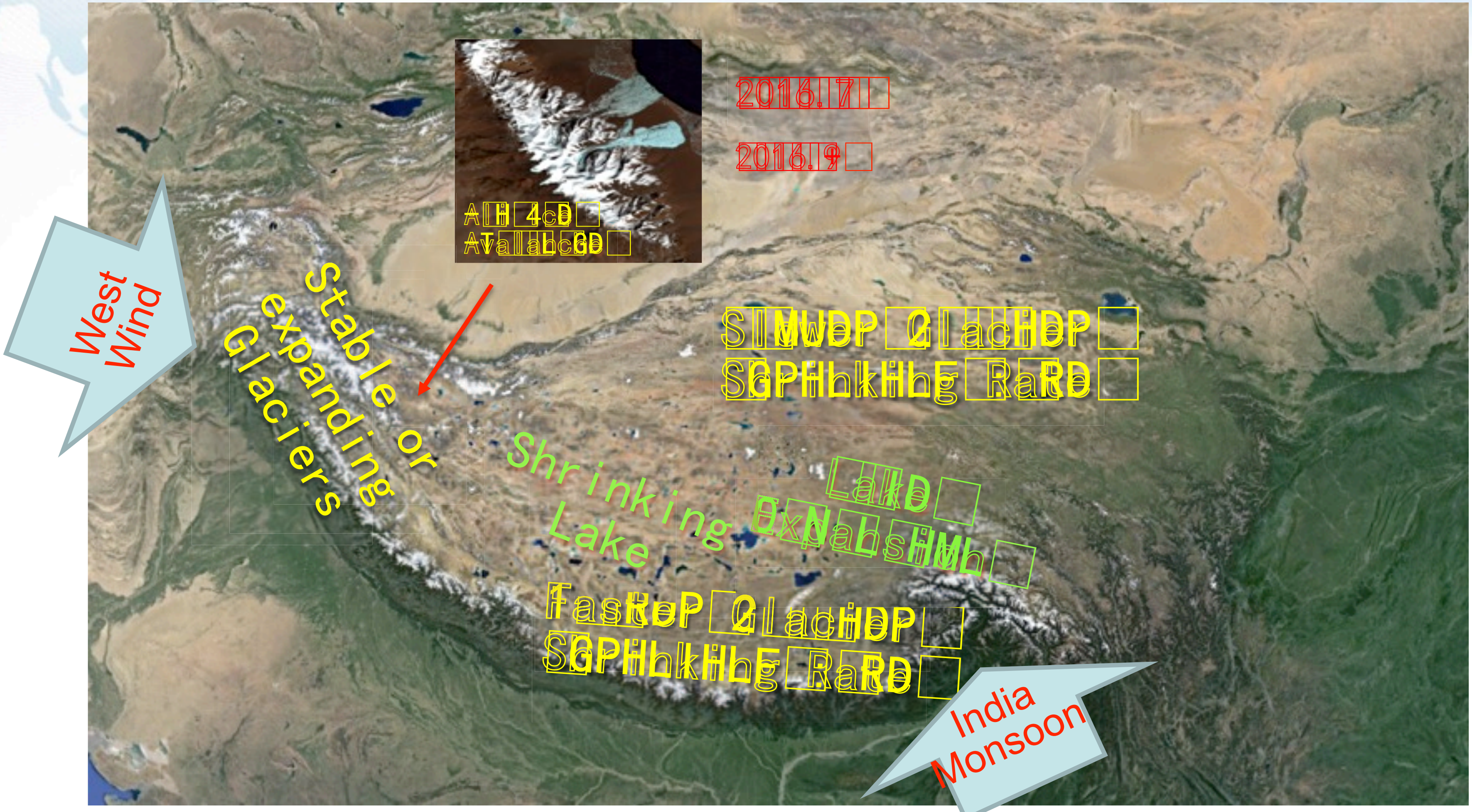
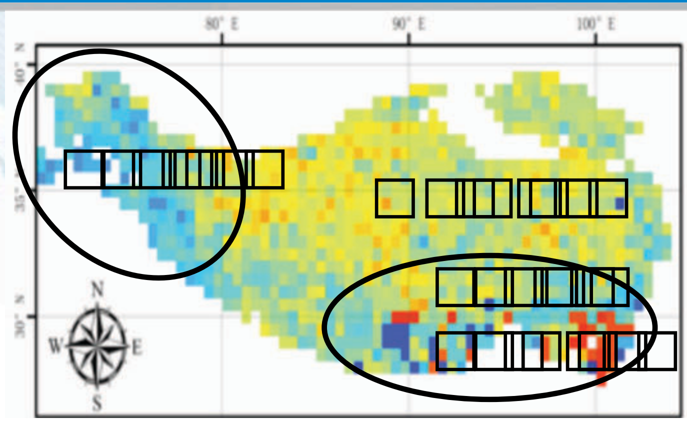
Background



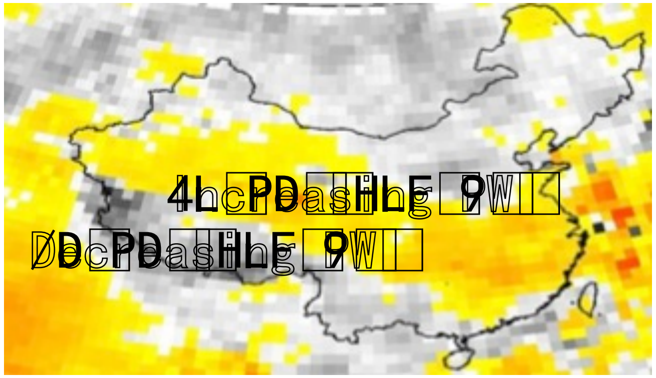
Science question: How and why are the glaciers and seasonal snow cover of the Third Pole region changing?

What is climatic driving factor impact on glacier change?



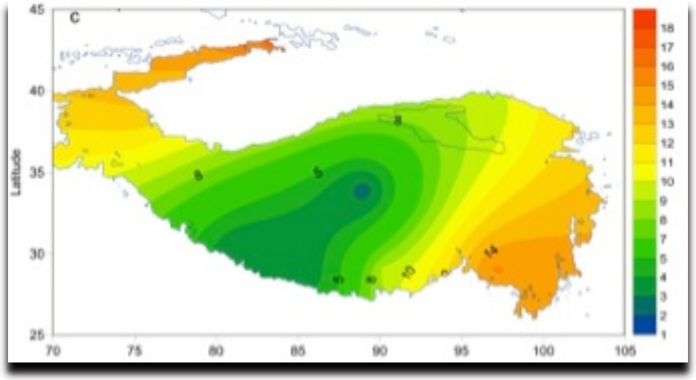
Temperature change?

(Yao et al. NC 2012; Yang et al. GPC 2014; Qin et al. Climatic change 2009)



PW impacting precipitation?

(Garadelle et al. NG 2012; Yao et al. NC 2012; Lv et al. JC 2015)

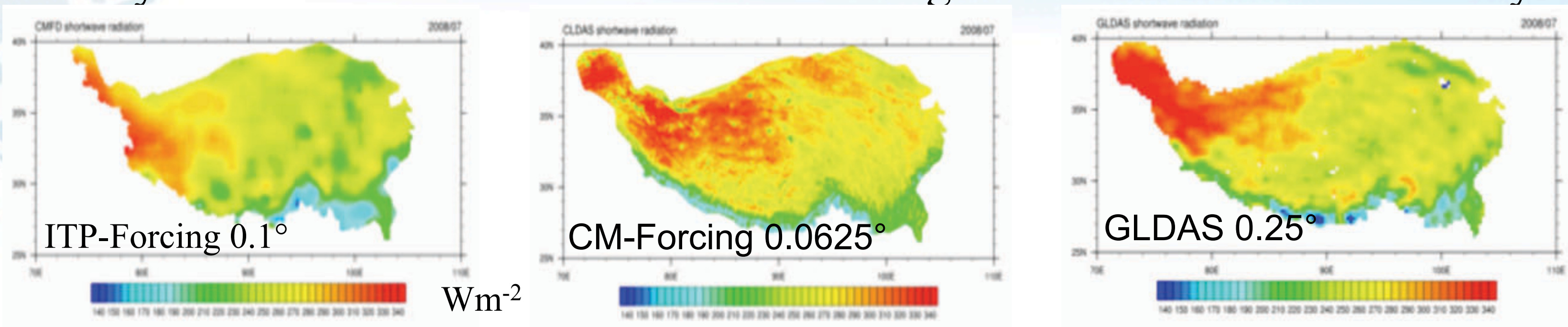


Black carbon impacting albedo?

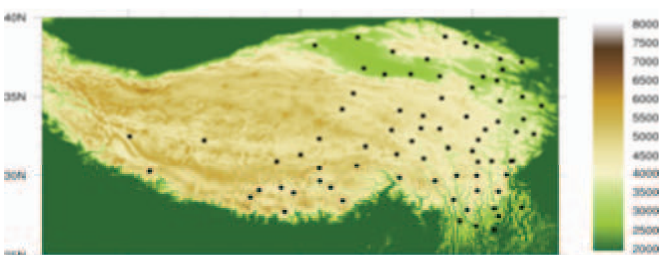
(Xu et al. PNAS 2009)

Challenges in Modeling & Observation

- Re-analysis data of shortwave radiation has huge difference even at monthly mean

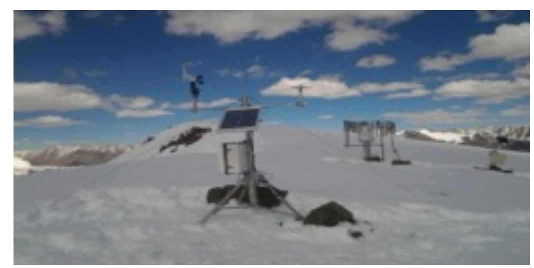


- Most of weather station are at relative flat and low elevation, not useful for improving forcing data and validation in high mountain regions



Most weather stations (72) below 4500m

Financial and human difficulties to establish long term regular measurements on glaciers



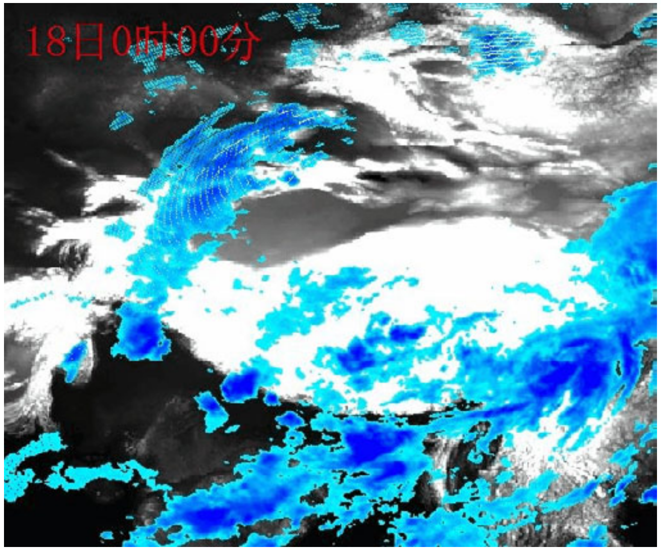
Most glaciers above 4500m

How Local Convection Cloud Impacts Regional Energy&Water Cycle Systems?

Missing knowledge

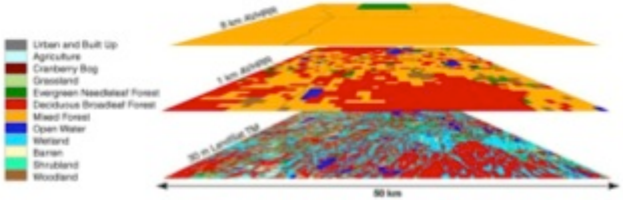
1 Coarse resolution climate model cannot correctly simulate local convection cloud process

2 Land surface and hydrological models driving by the re-analyses data can not reflect the surface inhomogeneity (spatiotemporal distribution of snow, frozen/thaw, lake, soil moisture, vegetation)



Great impacts of local convection process and surface inhomogeneity on local energy and water balance distribution

Transported water vapor from outside is only about 40% of the total precipitation over Plateau. (Curio, et al., 2015)



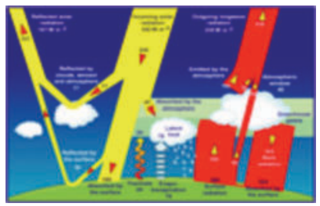
Impact of inhomogeneity

Project Summary

Key Science Question

How and why are the glaciers and seasonal snow cover of High Mountain Asia region changing?

Approach:



Goal

Improved models and observations suitable for complex terrain to understand the scientific questions.

Building capacities (Models + Observations) on Glaciers & Surrounding Regions in Tibet

- Improve our understanding and characterizing changes of Tibet's energy & water cycle; Not only individual component but also system characteristics;
- Build the basic dataset;

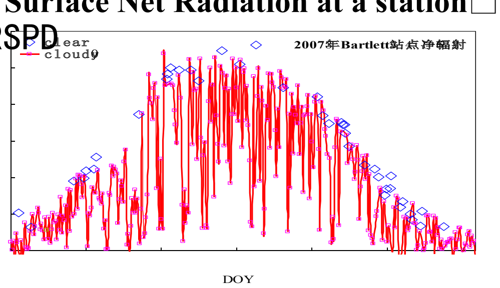
Objective-1	Objective-2	Objective-3	Objective-4
Surface Energy Balance	Water Cycle Components	Seasonal Snow Cover	Modeling Glacier Melting

Surface Radiation Balance

Science Question

- Characteristics and spatiotemporal [illegible] Surface Net Radiation [illegible]

Surface Net Radiation at a station



$$R_n = R_n^s + R_n^l = (1-\alpha)F_d^s + \varepsilon F_d^l - \sigma\varepsilon T^4$$

Challenges

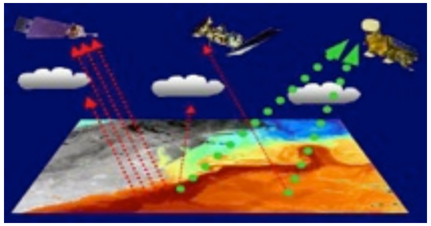
- Surface Net Radiation at [illegible] scale
- [illegible] physical [illegible] parameters
- [illegible]

Approach

High temporal resolution (15 – 30 min)

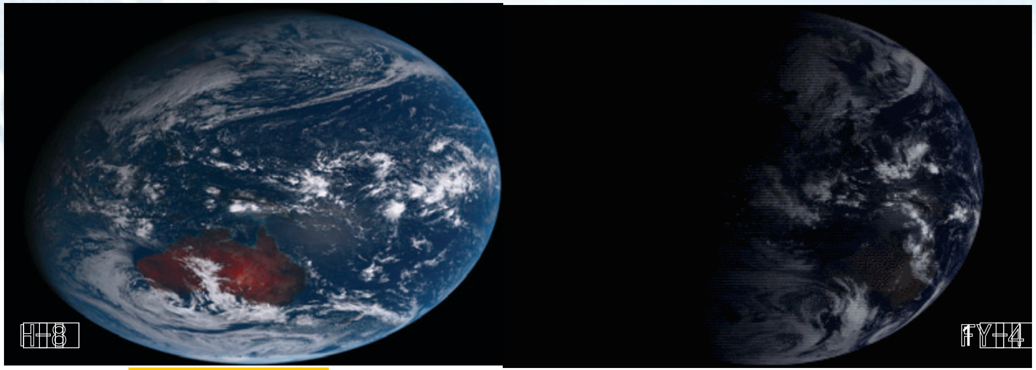
- Himawari-8
- FY-2,4

Using Microwave penetration capability, develop combined Optical + Microwave technique



- AMSR-2
- AIRS/AMSU
- MODIS
- VIIRS

Geostationary Satellites



Himawari-8			FY-4		
Band	Wavelength (μm)	Spatial Resolution (Km)	Band	Wavelength (μm)	Spatial Resolution (Km)
1	0.46	1	1	0.46	1
2	0.51	1	2	0.64	0.5～1
3	0.64	0.5	3	0.86	1
4	0.86	1	4	1.38	2
5	1.60	2	5	1.61	2
6	2.30	2	6	2.25	2～4
7	3.90	2	7	3.80 (high)	2
8	6.20	2	8	3.80 (low)	4
9	7.0	2	9	6.5	4
10	7.3	2	10	7.2	4
11	8.6	2	11	8.5	4
12	9.6	2			
13	10.4	2			
14	11.2	2	12	11.0	4
15	12.3	2	13	12.0	4
16	13.3	2	14	13.3	4
OM	圆盘数据,四个区域/10 分钟		OM	圆盘数据 /15-30 分钟	

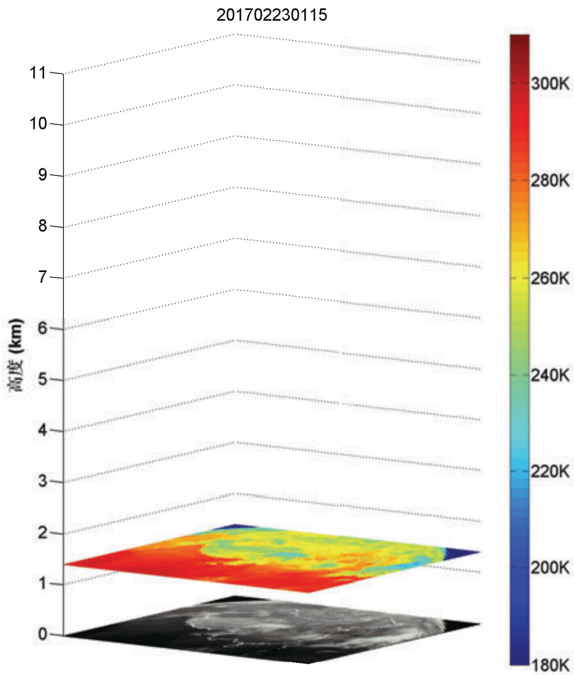
FY-4A Instruments:

AGRI: Advanced Geosynchronous Radiation Imager

GIIRS: Geo. Interferometric Infrared Sounder: Temperature & humility profiles

LMI: Lightning Mapping Imager

SEP: Space Environment Package



Cloud Properties from Geostationary Observations

Cloud properties and downward radiation from Himawari-8

Himawari-8 Satellite data

↓

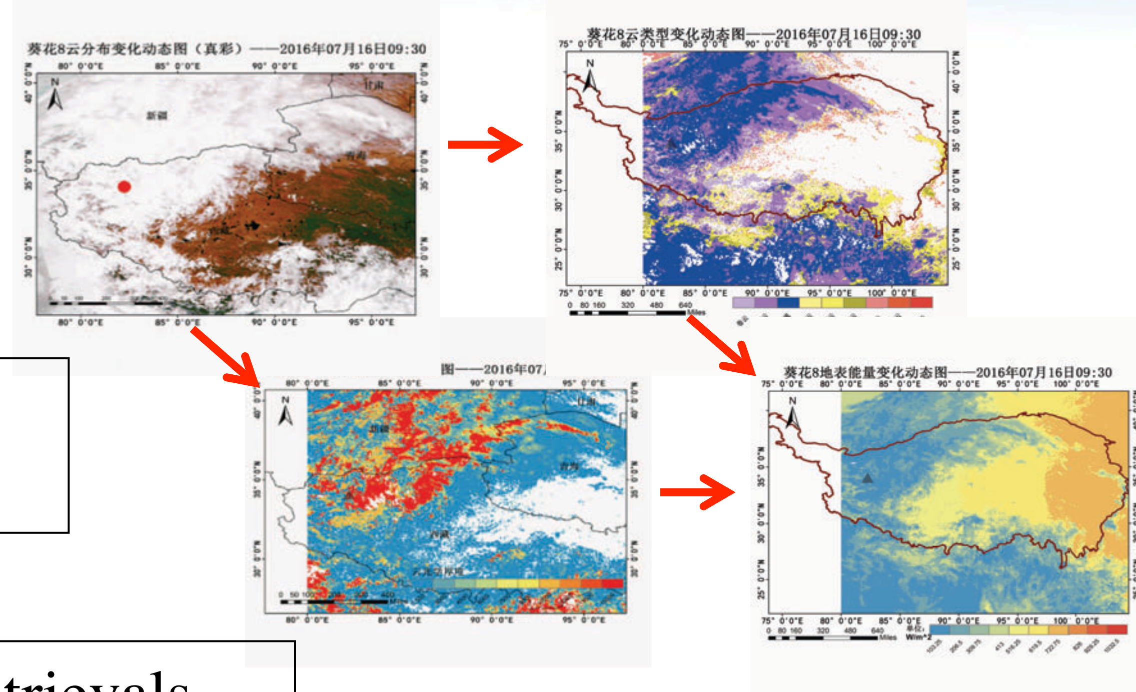
Cloud screening (cloud phase)

↓

Cloud property retrievals (Tc, Re, CTT, CTP) → ISCCP cloud type

↓

Downward radiative flux

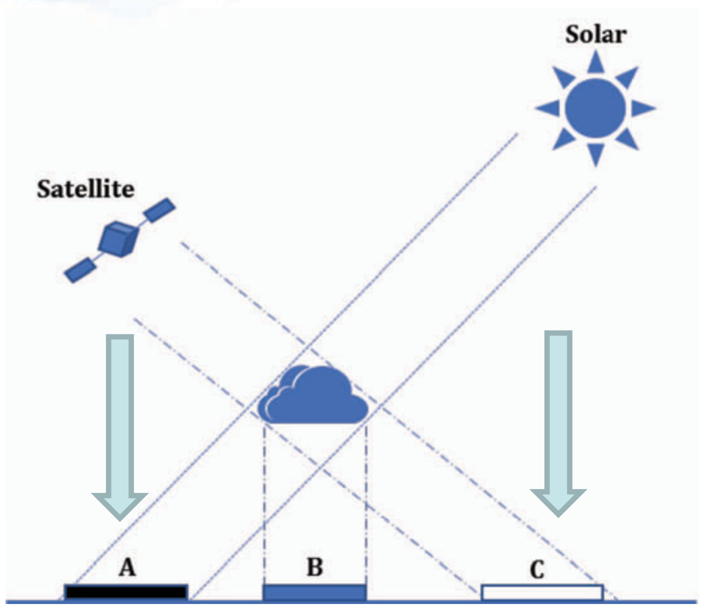


Tc: Cloud optical thickness
Re: Effective particle radius
CTT: Cloud top temperature
CTP: Cloud top pressure

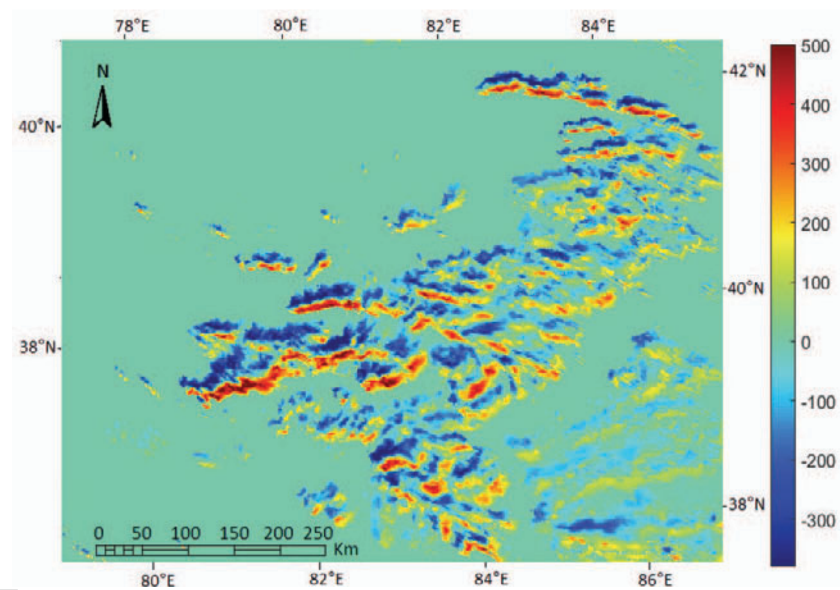
Solar-Cloud-Satellite Geometry Effect

Solar-cloud-satellite geometry (SCSG) affects on the derived land surface radiation.

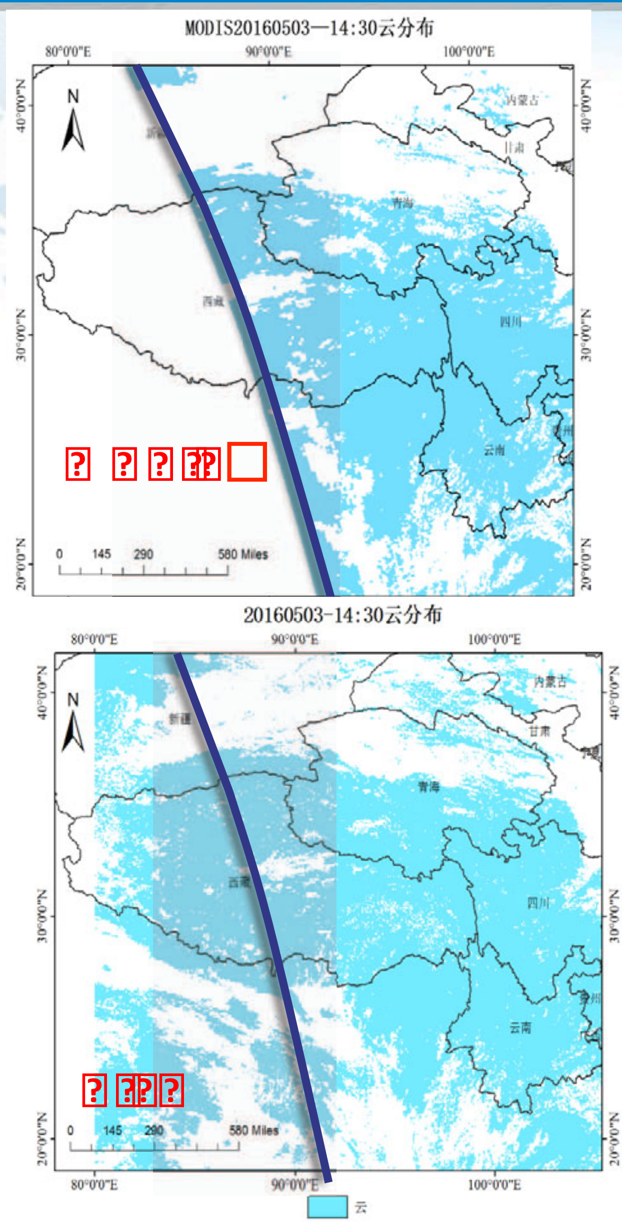
the effect of clouds and shadows



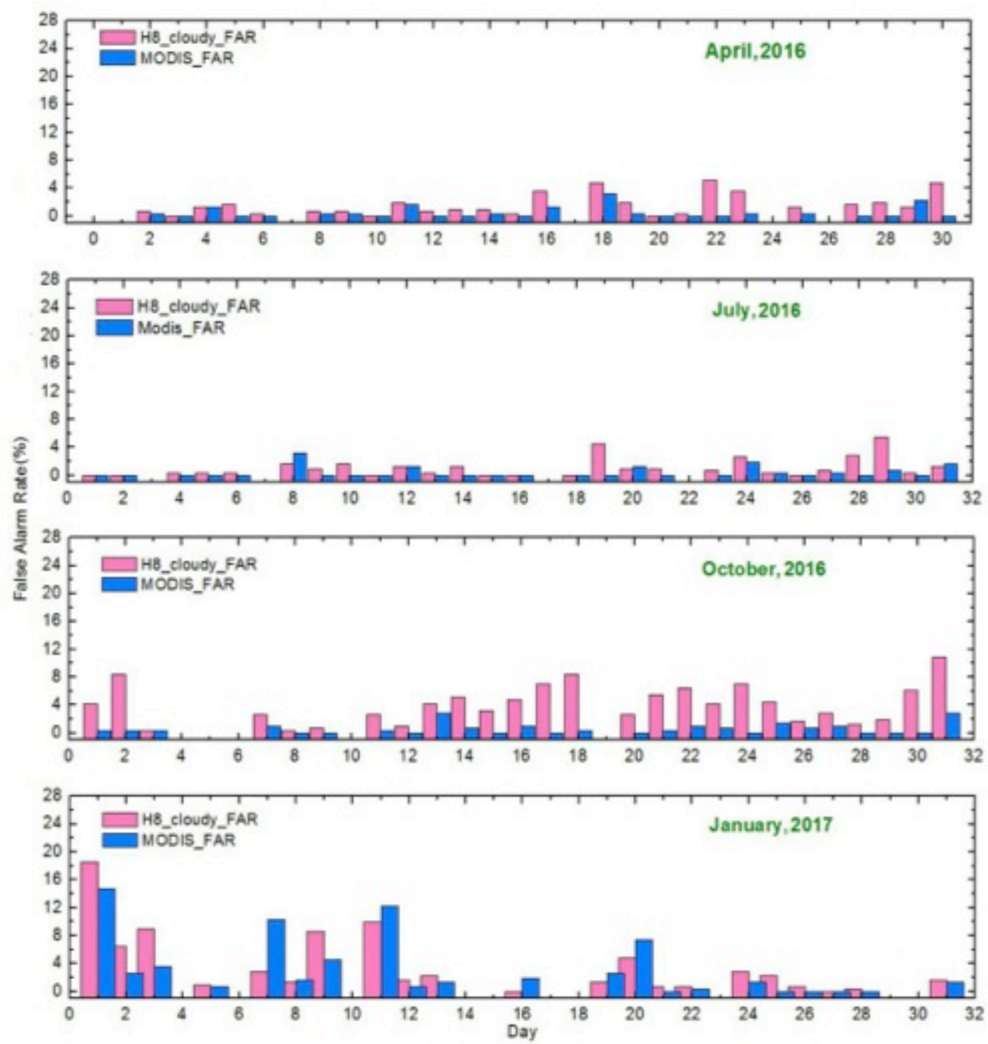
Difference map of SWDR (W/m^2). (Corrected SWDR minus original one wherein solar-cloud-sensor geometry is not considered).



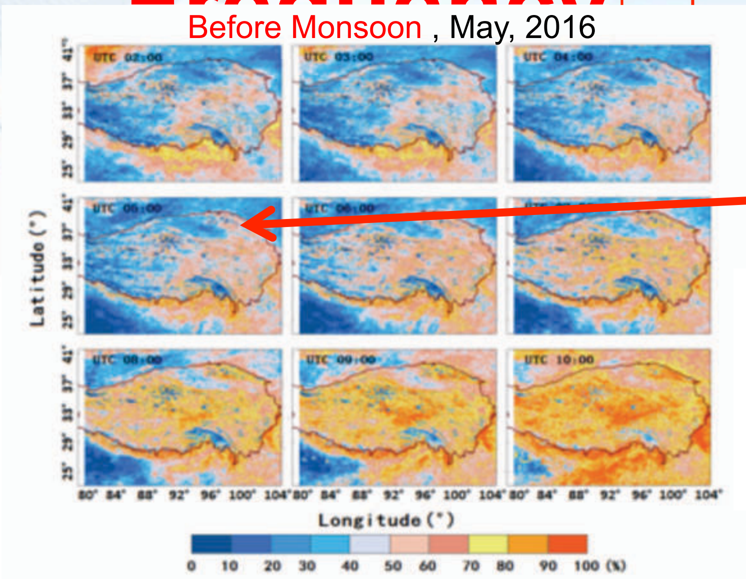
Initial Comparison of MODIS and H8 on Cloud Detection over Tibet

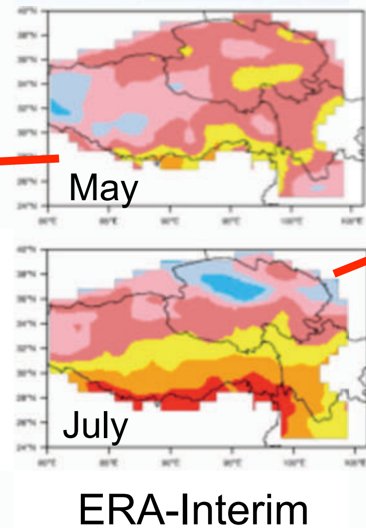


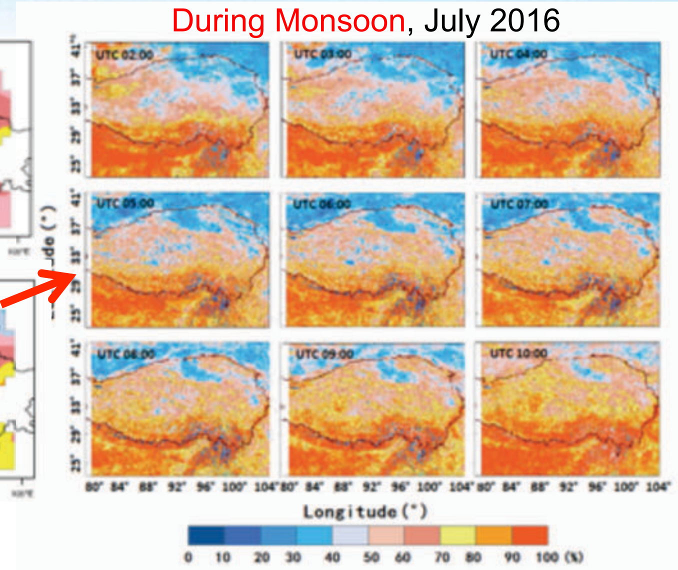
False Alarm Rate of MODIS and Himawari-8 Based on CALIPSO measurements

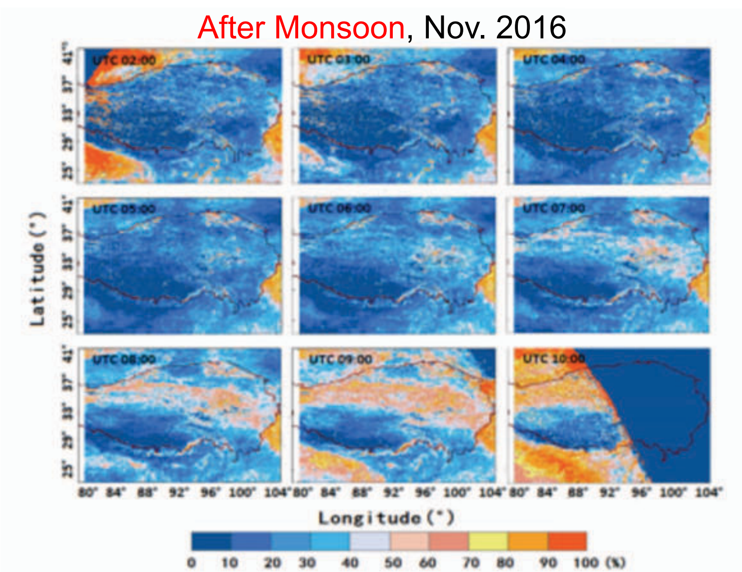


Himawari-8 Monthly Cloud Frequency









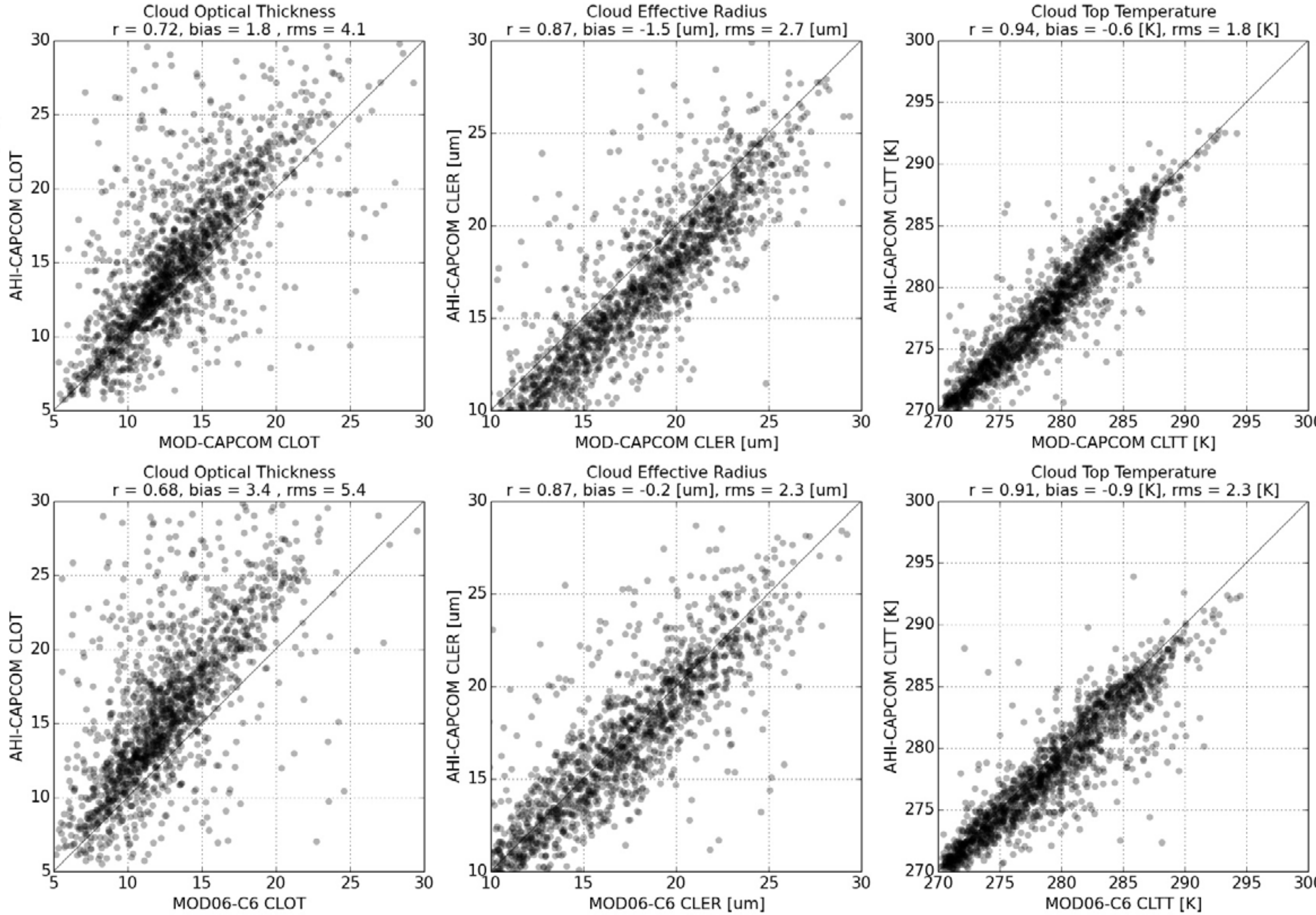
- Daily cloud increases from morning to early evening;
- Significant seasonal difference;
- Great difference in comparison Himawari-8 with ERA-Interim.

Comparison of MODIS and H8 on Estimated Cloud Properties over Tibet

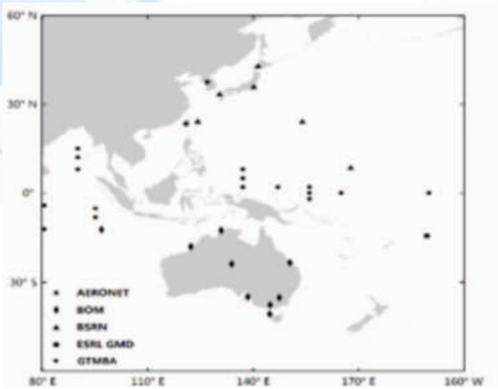
COT | CER | CTT

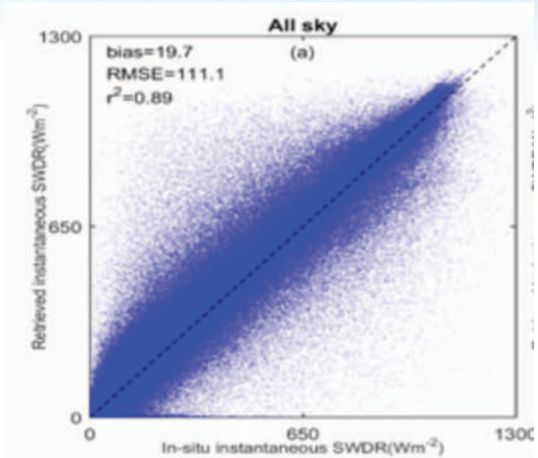
H8-CAPCOM vs. MODIS-CAPCOM

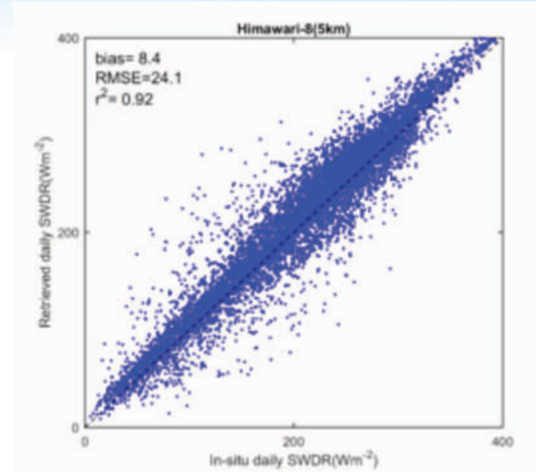
H8-CAPCOM vs. MOD06 C6



Validations of solar radiation product of Himawari-8□



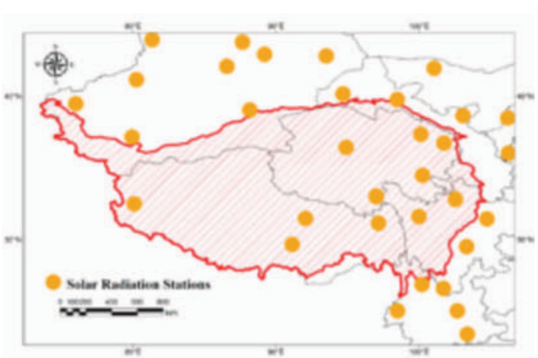


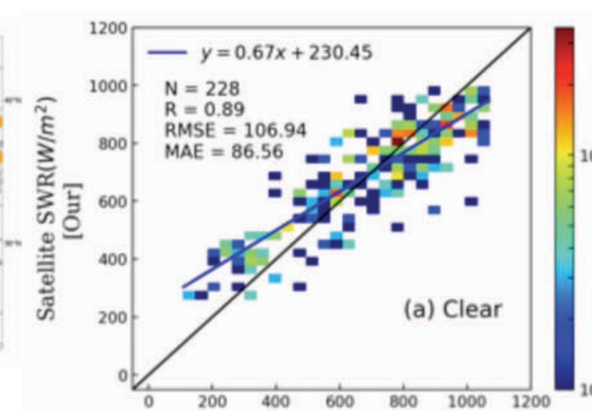


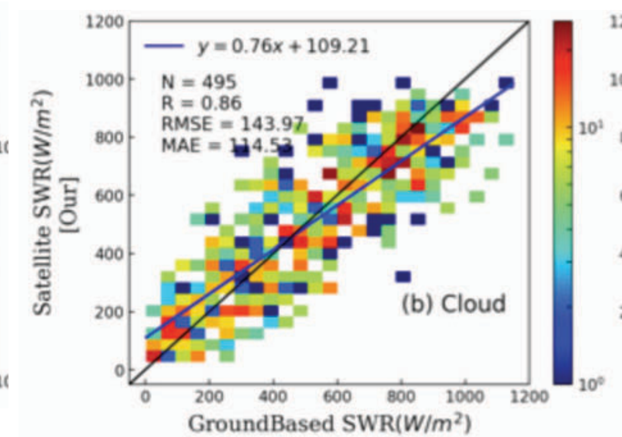
Spatial distribution of **observation sites** (34 in total) used for validation over the Western Pacific Ocean region□

Instantaneous solar radiation (5km) validation results

Daily solar radiation (5km) validation results



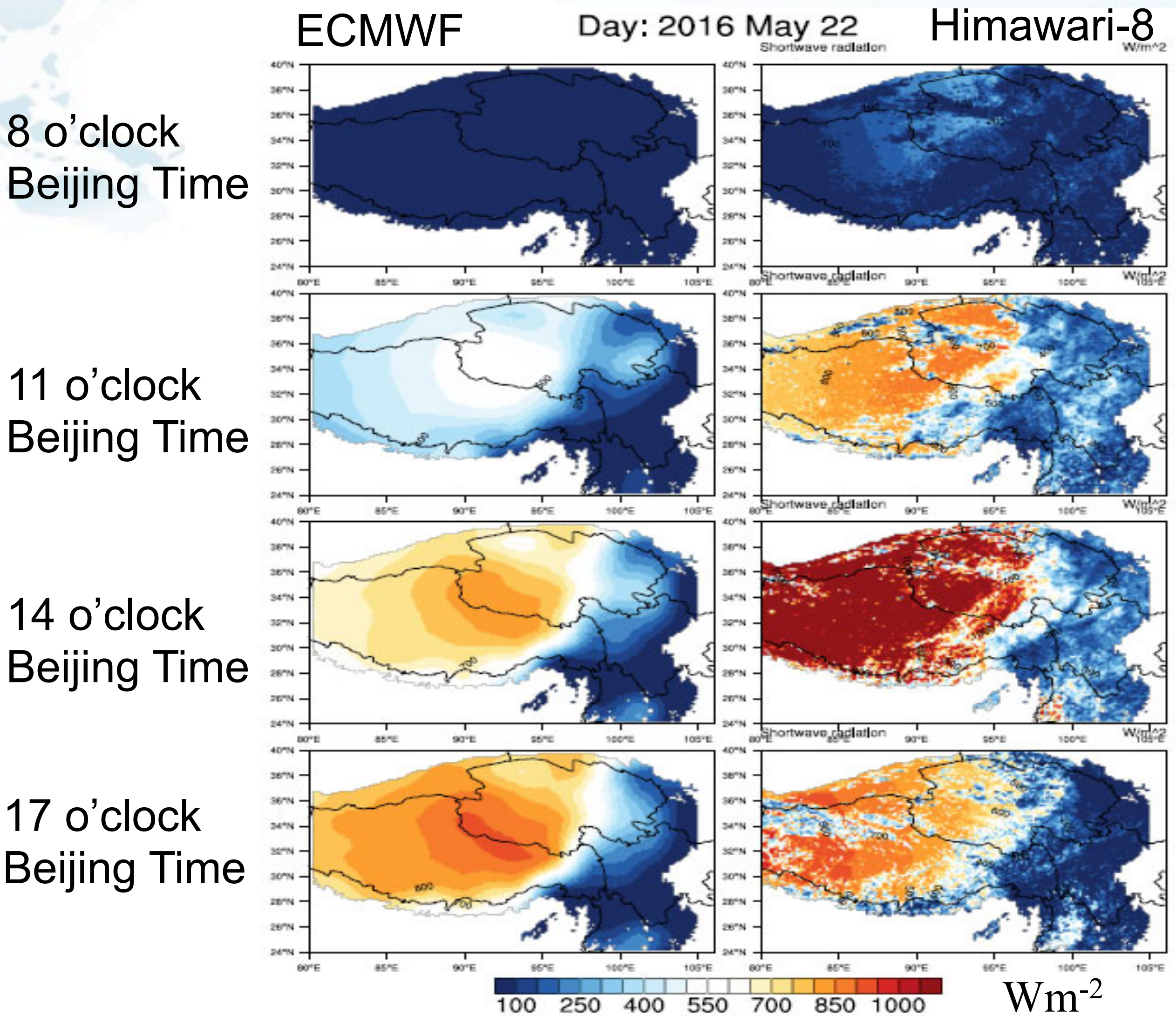




Location of the ground stations □12□in **Tibetan plateau**

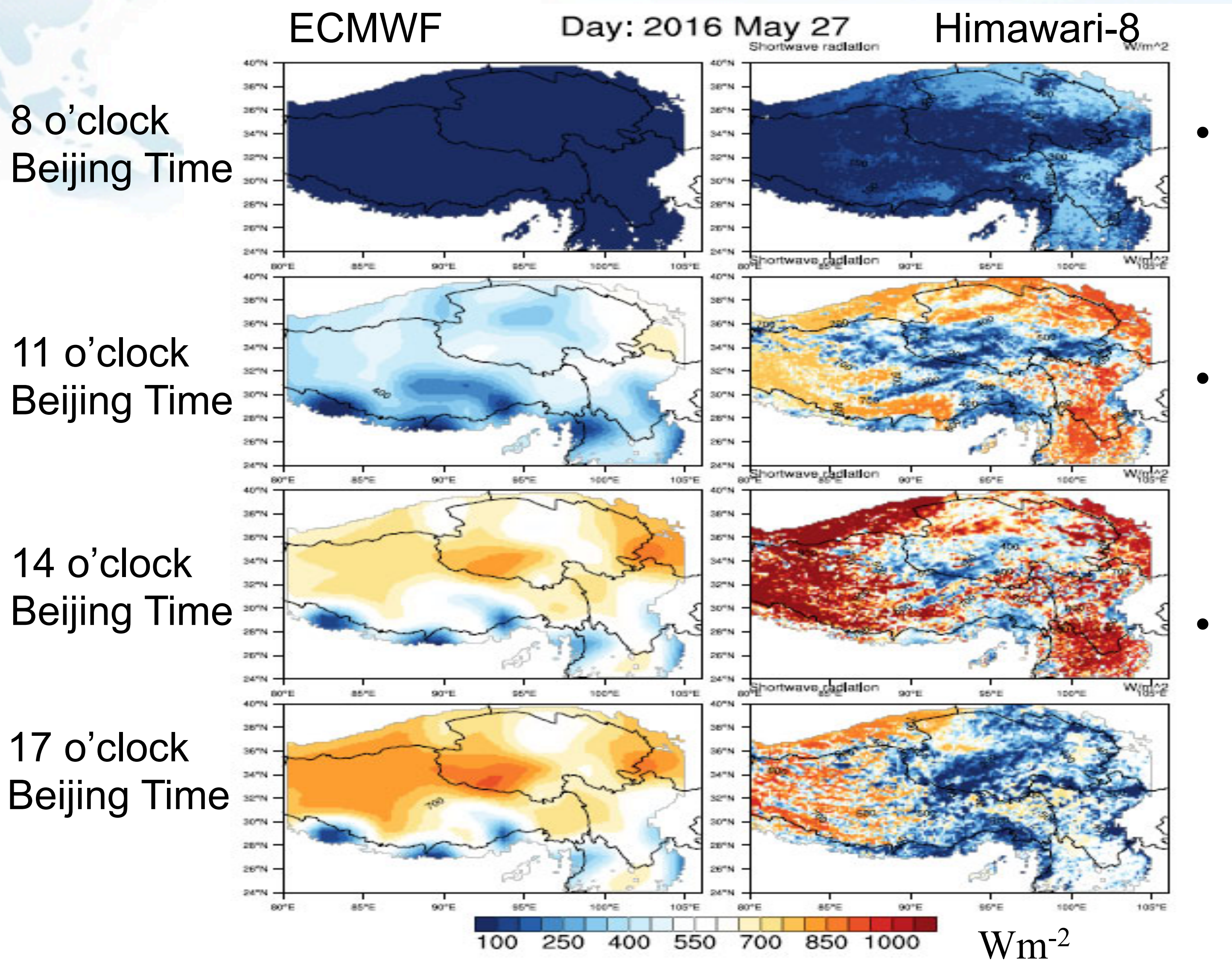
Similar accuracies at hourly scale!

Comparison of Downward Shortwave Radiation at Surface (1)



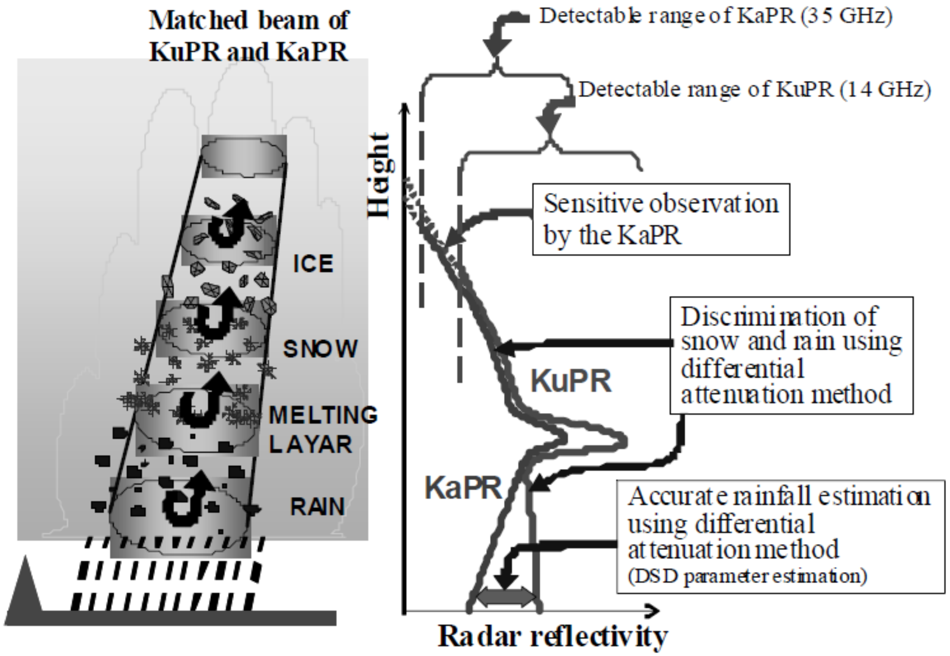
- SWR show high spatial correlation in this day;
- Mainly due to similar cloud patterns;
- Only differences in magnitudes and scale effects

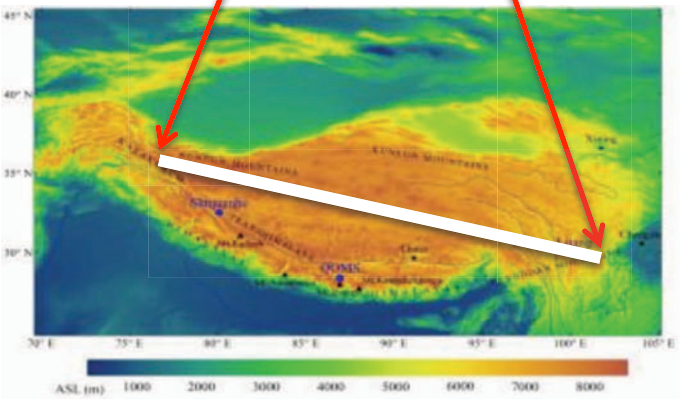
Comparison of Downward Shortwave Radiation at Surface (2)

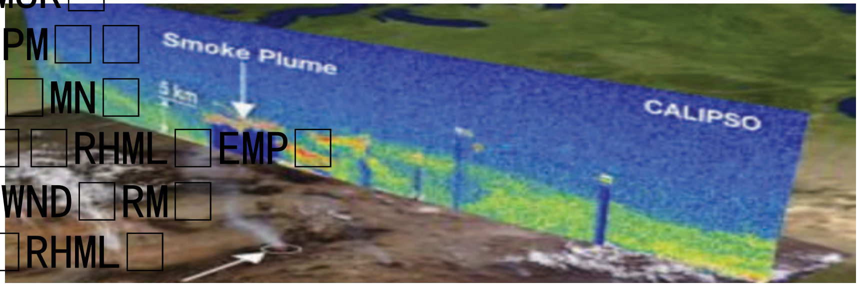


- SWR show low spatial correlation in this day;
- Mainly due to very different cloud patterns;
- Significant differences in magnitudes and patterns

Current Study: Improving Local Cloud Vertical Structure Information







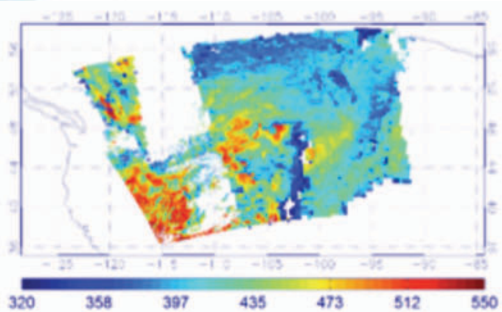
ANNPM□□G □ □□HLF□HLEMP□□RHML□□AMSR□
□□MSCY□□TDPRH□□□□□RPS□RSPD□EPM□□
.−□49□8. □MSC□□R□LC□296□9: □CDTD□MN□
□M□□□H□DC□□□MSC□N□P□□DRDPH□□RHML□EMP□
RH□D□CDNDLCDLR□CHEEDPDLR□□□MSC□RWND□RM□
H□NPMTD□P□CH□RHML□□LC□NPD□HNHR□RHML□
D□RH□□RHML□

Current Study: Develop Optical+Microwave and Terrain Correction Techniques

1) 8NRH a +Mi cr 6H avPMU+ TDMPHRG

MODIS+AMSR-E provide surface temperature under cloud cover

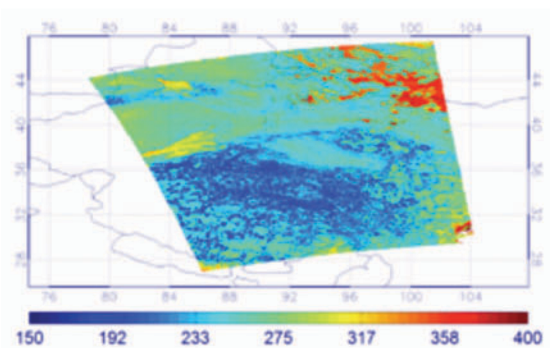
Upward L-Wave radiation



Merged multi-sensor technique

AIRS/AMSU+MODIS provide vertical profile for cloud temperature and downward long-wave radiation

Downward L-wave radiation



. D L IW . MSC

2) T DPP HL . MPPD RHML D GL HOS

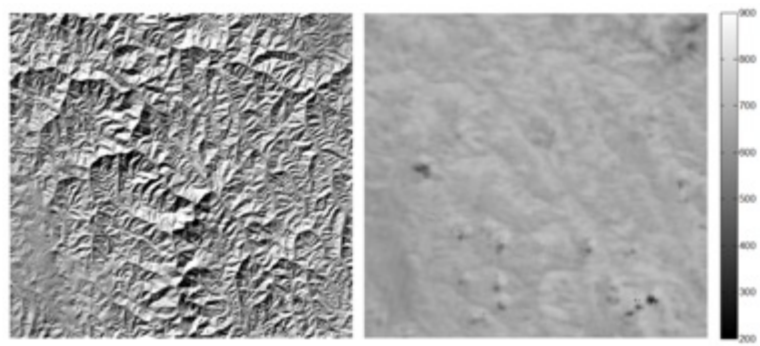
Short-wave terrain correction model

$$R_{net} = \frac{F^s_{net}}{F_{net}} = \frac{(V_d F^{\downarrow}_{sky} + \sum_{P=1}^{N} \frac{L_p \cos T_M \cos T_p dS_p}{r^2_{MP}} + \Phi \mu_s F_{dir})(1-\rho)}{(F^{\downarrow}_{sky} + \mu_0 F_{dir})(1-\rho)}$$

Long-wave terrain correction model

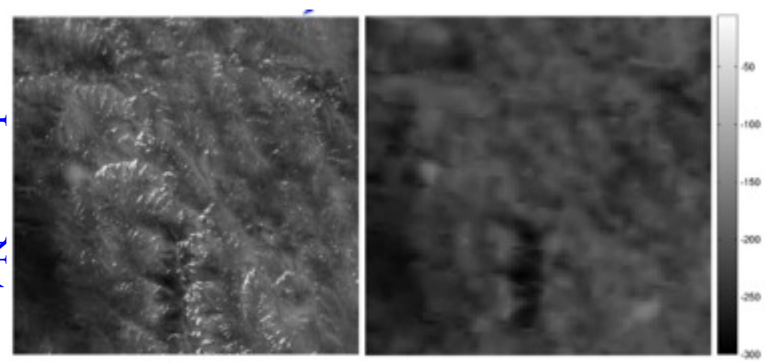
$$R^{lw}_{net} = \frac{F^s_{net}}{F_{net}} = \frac{\left\{V_d F^l_{lw} + \sum_{P=1}^{N} \frac{L_p \cos T_M \cos T_p dS_p}{r^2_{MP}}\right\}\varepsilon - f(LST, \Phi) F_{emi}}{F^l_{lw}\varepsilon - F_{emi}}$$

S-wave Net Radiation



The Max. error can reach 600W/m^2 (>65 %) In Tibet

L-wave Net Radiation



The Max. error can reach 100W/m^2 (>30 %) In Tibet

After correction Before correction

Summary□

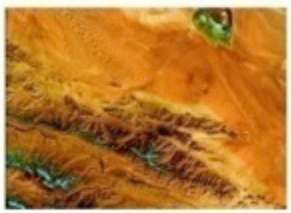
1) Convection process is very active and complex. It plays an important role in the characteristics of spatiotemporal radiation distribution over the Third Pole regions;

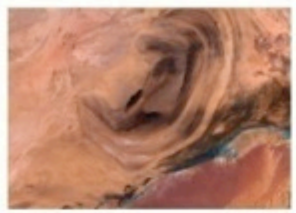
2) Geostationary satellites have both spatial and temporal capabilities to measure clouds, cloud type, cloud physical properties, and short wave radiation at the surface. They provide an important tool to improve our understanding on spatiotemporal distribution of radiation forcing;

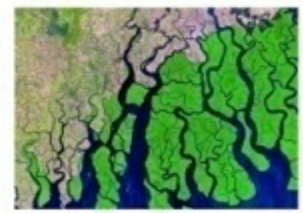
3) Downward shortwave radiation is mainly controlled by clouds. It has great daily (clouds increase from morning to early evening) and seasonal (different seasons) variations;

4) Our study on surface radiation balance is underway

Thank you!





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