中国科学院遥感与数字地球研究所
Institute of Remote Sensing and Digital Earth ,CAS

8th GEWEX Open Science Conference – Extremes and Water on the Edge
6-11 May 2018, Canmore, Alberta, Canada

Challenges and progress towards understanding the energy and water exchanges in high mountain Asia by remote sensing observations

Li Jia
(jiali@radi.ac.cn)

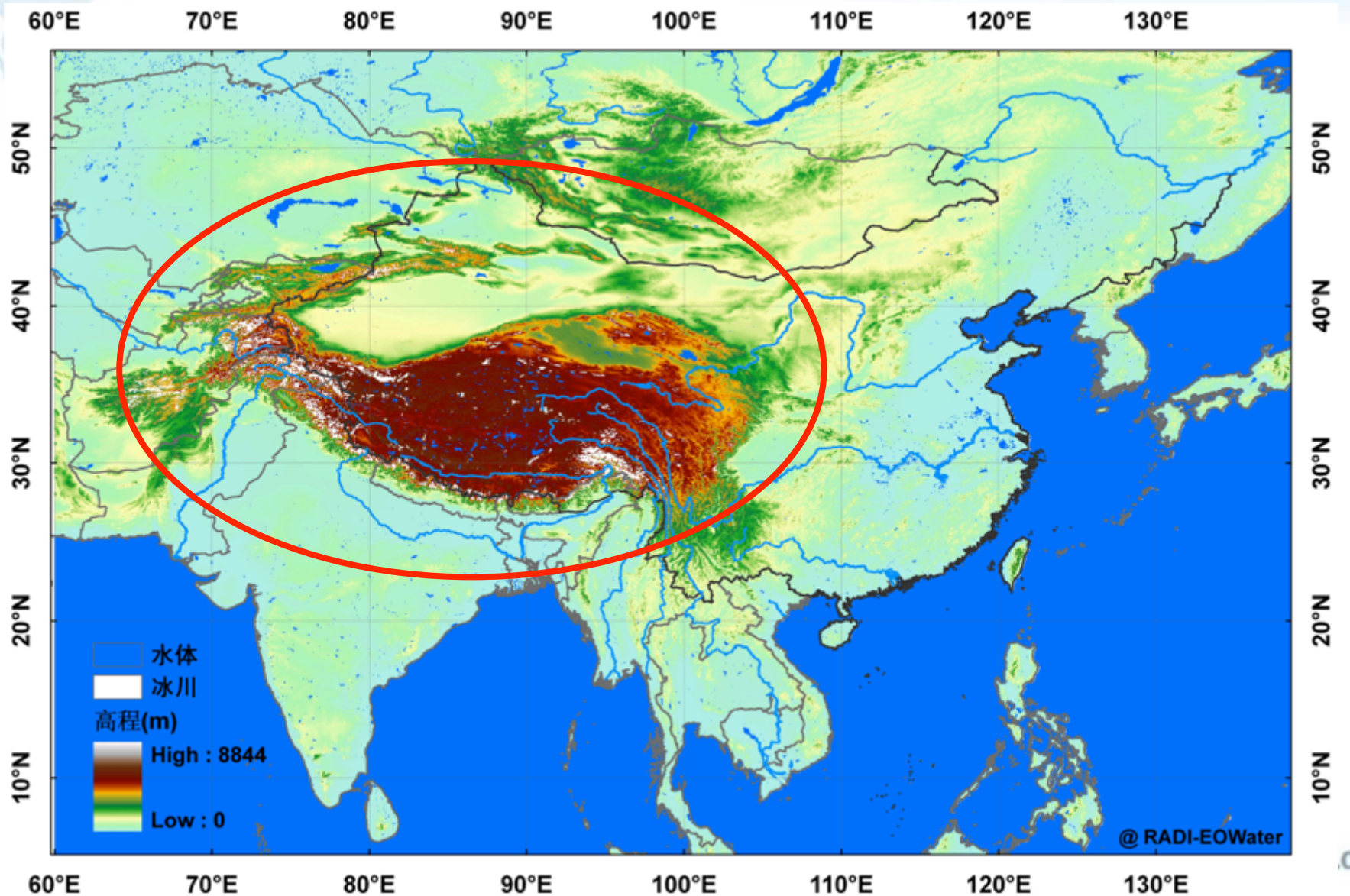
Institute of Remote Sensing and Digital Earth (RADI), Chinese Academy of Sciences (CAS)

Contributors:
Chaolei Zheng, Guangcheng Hu, Xinyu Mo (RADI)
Lingmei Jiang (BNU)

10 May 2018, Canmore, Canada

HMA Region Background

DEM



Key Issues

High Mountain Asia (HMA)

- **What & How**: Location, status and changes
- **Why**: Forcing factors
- **Which**: Impacts & Feedbacks

Issues

- Area
- Volume
- Mass balance

- Climate (T & P)
- Radiative Forcing
- Human Activities

- Local & Plateau & Regional & Global Hydro/Climate/Eco conditions
- Local & downstr. Hazards

Determinant Processes

Energy balance and Heat exchanges

Water / Mass balance

Data/ Tools/Methods

- Satellite / Airborne Observations
- Meteo / Climate Data
- Modelling
- Field Survey / Measurements

Know Enough?

Understand Clearly ?

Quantity / Quality Sufficient ?

Variables/Parameters relevant to Energy and Water Balance from Remote Sensing

- **Forcing:**
  - Net Radiation
  - Precipitation
- **Surface status and processes:**
  - Glacier area and thickness change
  - Lake area change
  - Albedo (energy)
  - Land Surface Temperature (LST)
  - Soil Moisture
  - Snow Cover
  - Freeze/Thaw
  - Evapotranspiration

Objective: Towards more accurate and higher resolution data products over HMA and its surrounding regions.

Challenges in HMA

Lessons/experiences learnt:

- Impact of cloud coverage is a big problem for all the products derived from optical satellite sensors (e.g. downwelling radaiton fluxes, surface albedo, LST, snow cover fraction, vegetation cover, etc.);
- Topography effect needs to be corrected;
- Large difference exists in different soil moisture satellite data products, frozen status impact on SM need to be studied;
- Validation of remote sensing and model results are challenging in particular in regions with complex terrain due to lack of proper ground measurements, or of good quality long time series data;
- Needs better precipitation and evapotranspiration datasets
- More….

Outline

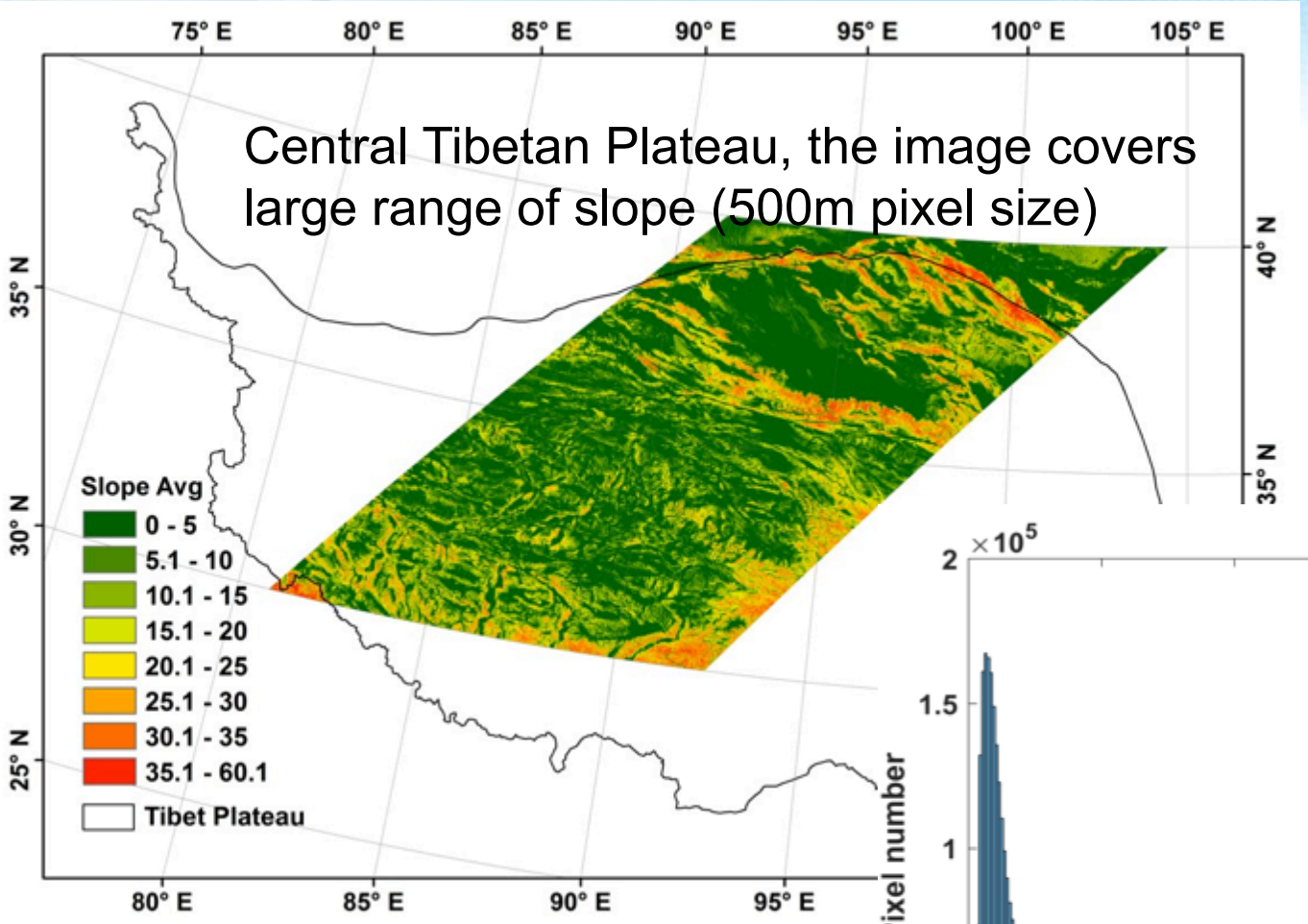
- Radiation: albedo

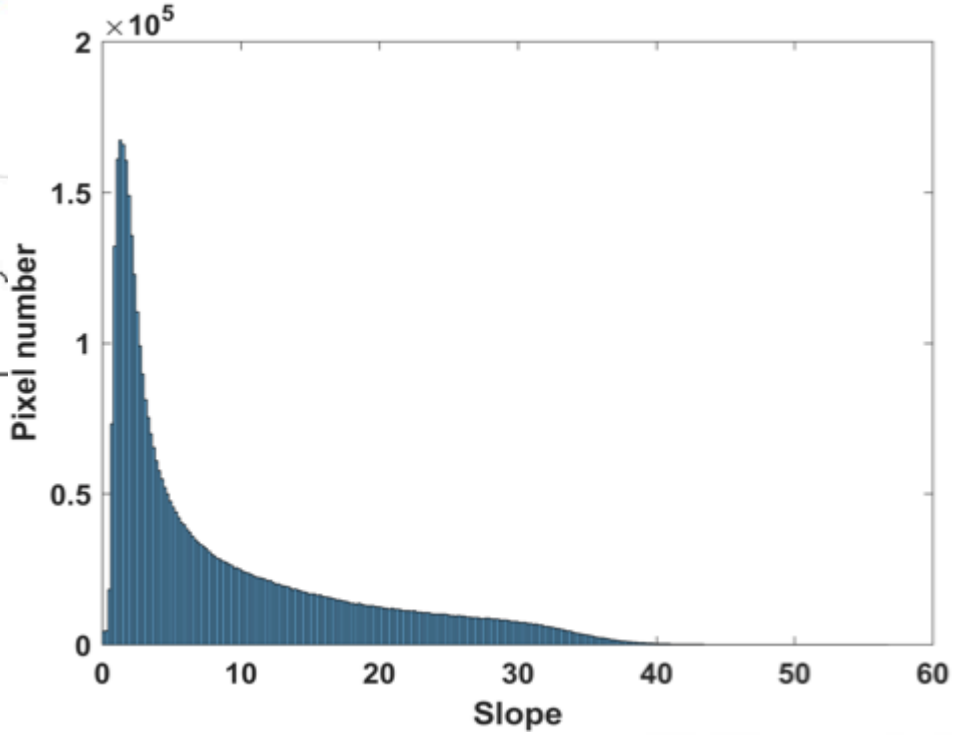
how (much) do the topography and snow cover affect the surface albedo ?

- Evapotranspiration:

how lake area dynamics and snow cover influence evapotranspiration estimation?

Surface Albedo: Topography Impact





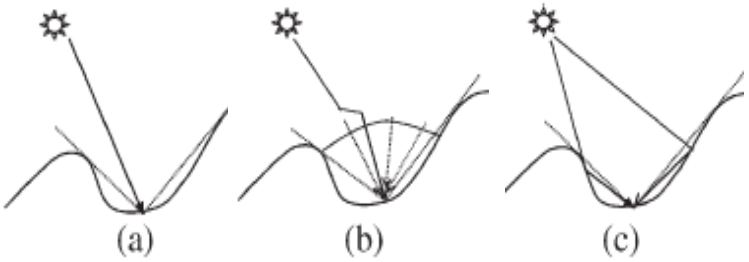
There is no terrain correction in most existing albedo datasets derived from satellite data ➔ flat surface albedo

Surface Albedo: Topography Impact

How topography influence surface radiation balance ?

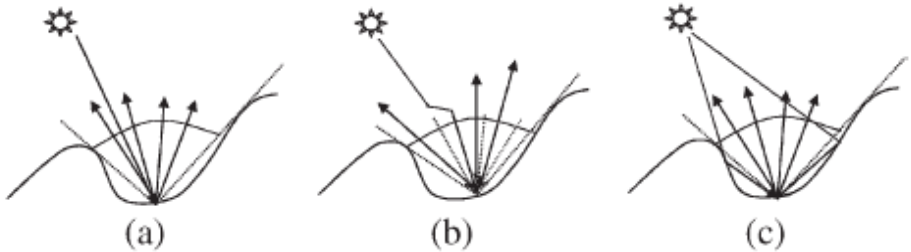
$$R\downarrow n = R\downarrow n\uparrow s + R\downarrow n\uparrow l = R\downarrow d\uparrow s\,(1-\alpha) + \varepsilon R\downarrow d\uparrow l - \sigma\varepsilon T\uparrow 4$$

Incident shortwave radiation



(a) direct solar irradiance
(b) diffused solar irradiance
(c) terrain-scattering irradiance from the adjacent terrain

Surface albedo



(a) Directional hemispheric albedo
(b) Sky-diffused albedo
(c) Terrain-scattering albedo

(Gao, Jia et al;, 2014)

- **Topography**
  - **(shadow, sunlit aspects)**
- **Surface properties**
  - **(veg., soil, snow, glacier, water,…)**

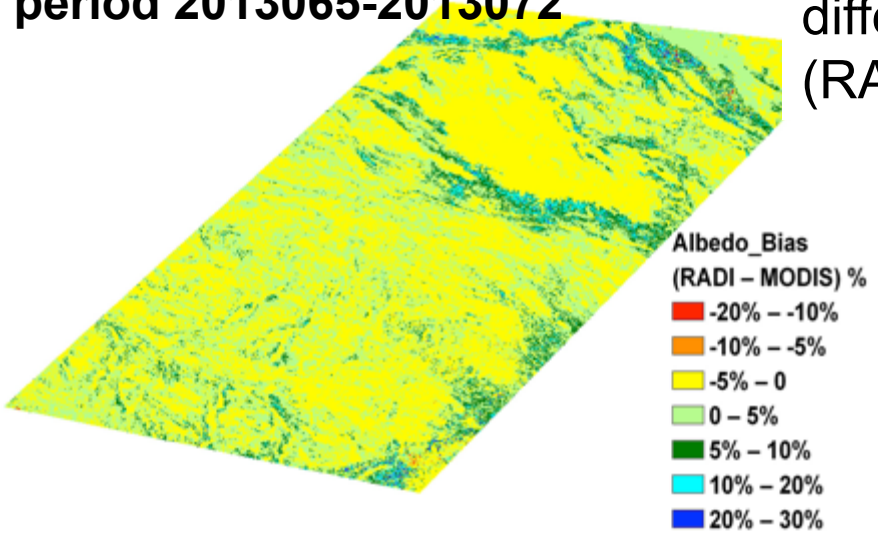
Surface Albedo: Topography Impact

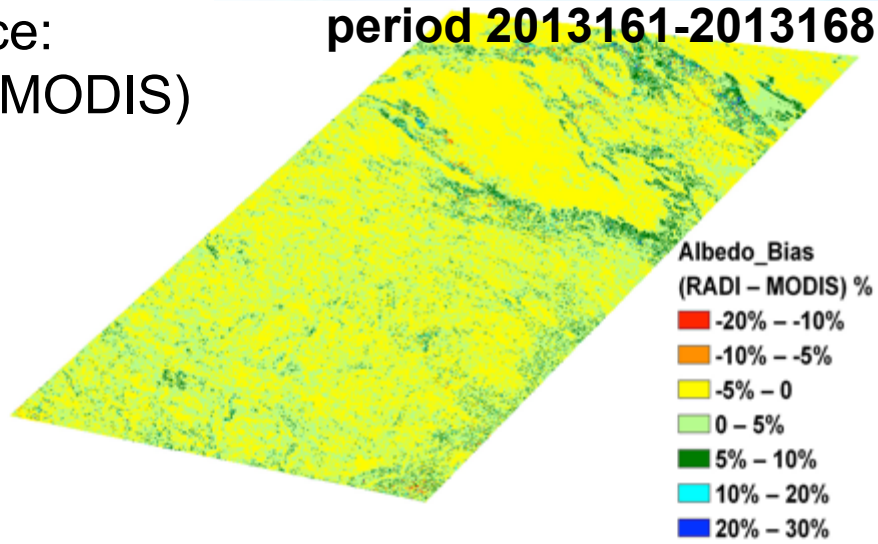
Albedo retrieval: Improved algorithm @RADI v.s. MODIS product

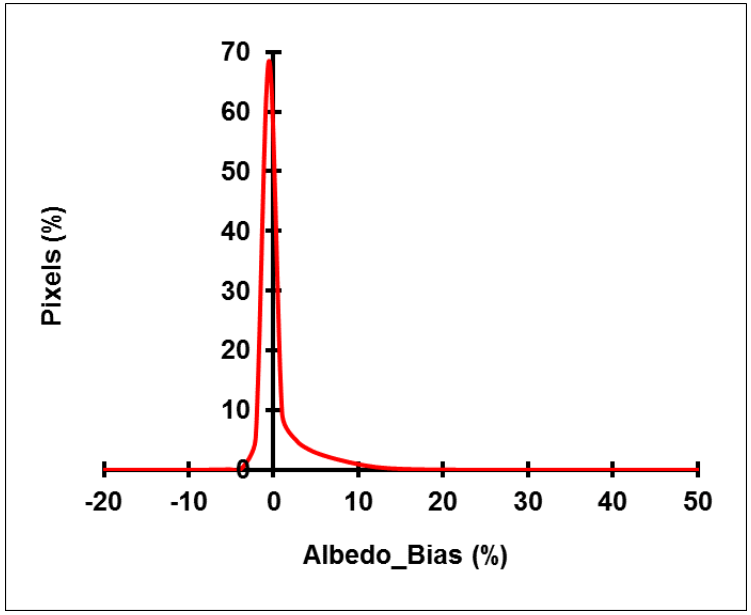
period 2013065-2013072

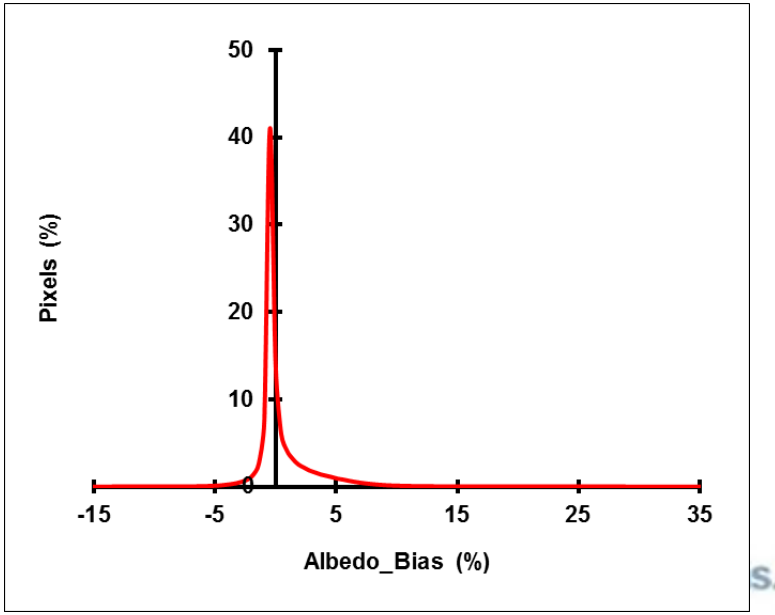
difference:
(RADI - MODIS)

period 2013161-2013168



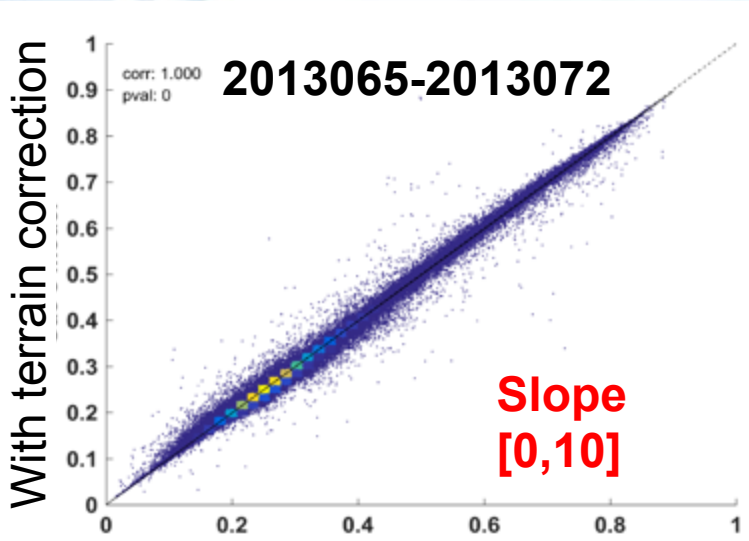


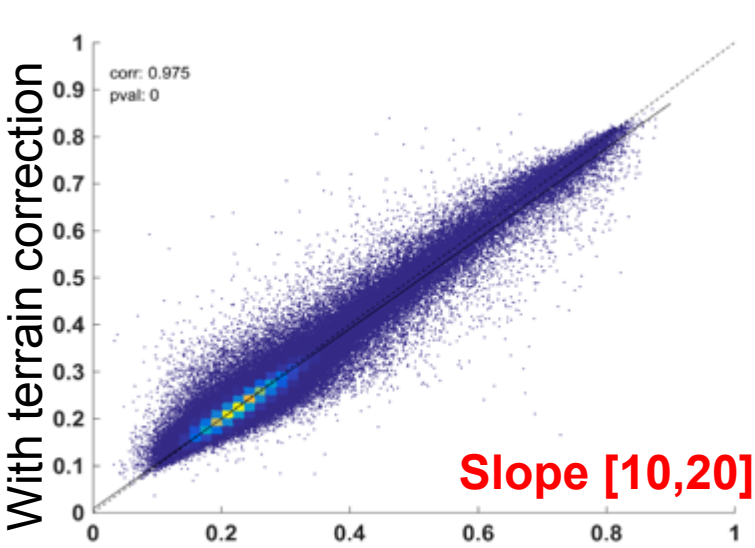


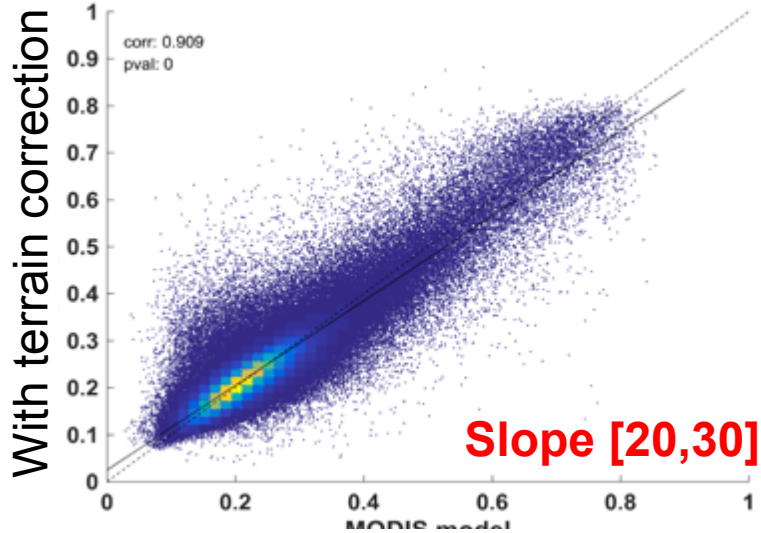


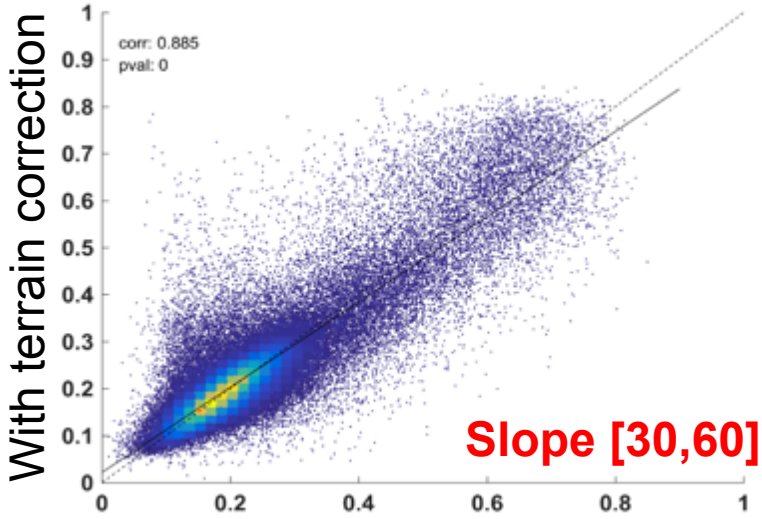
Surface Albedo: Topography Impact

Albedo retrieval: dependence of topography correction on slope

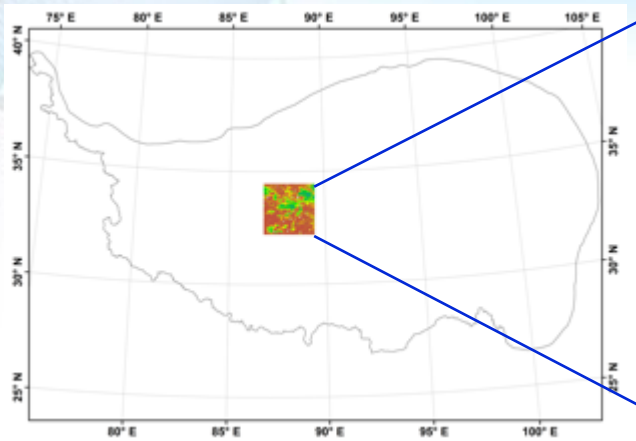


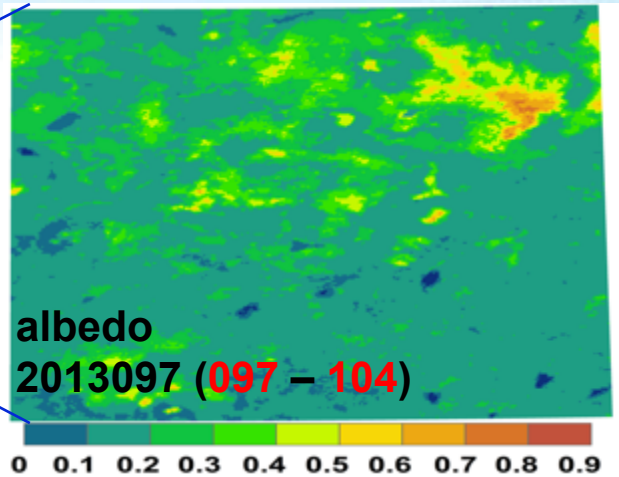






Surface Albedo: Snow cover impact

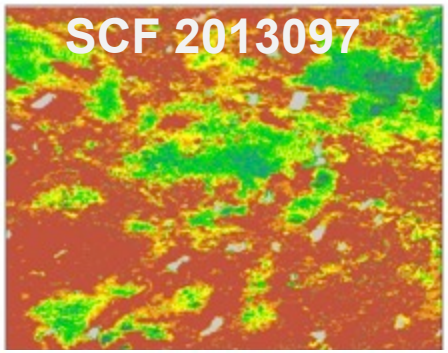


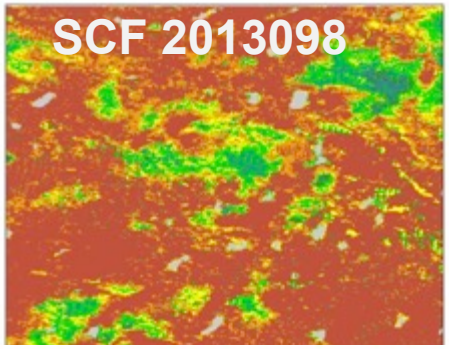


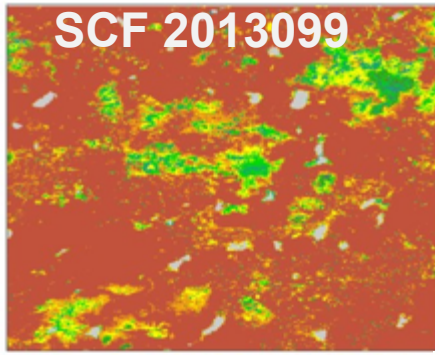
GLASS 8-day Albedo product (MODIS based)

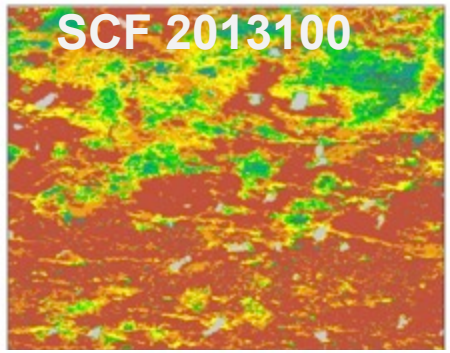
8-day albedo

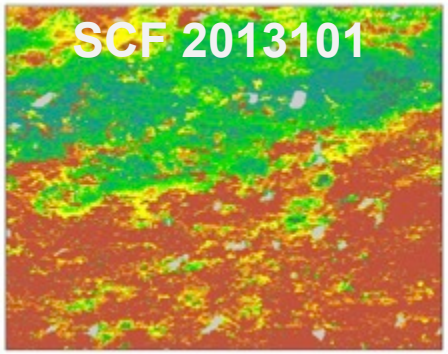
cannot capture the fast snow process

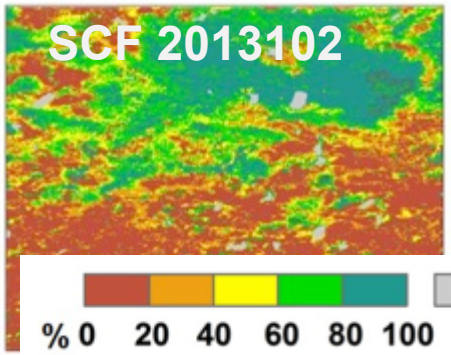


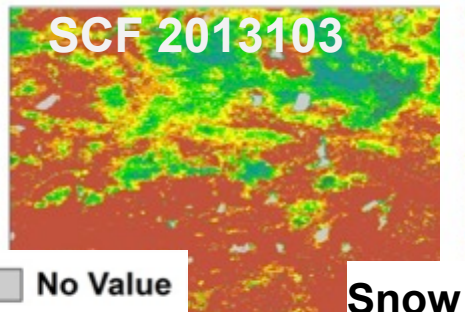


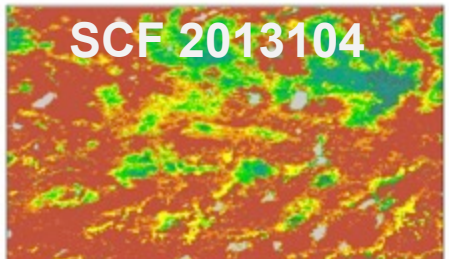






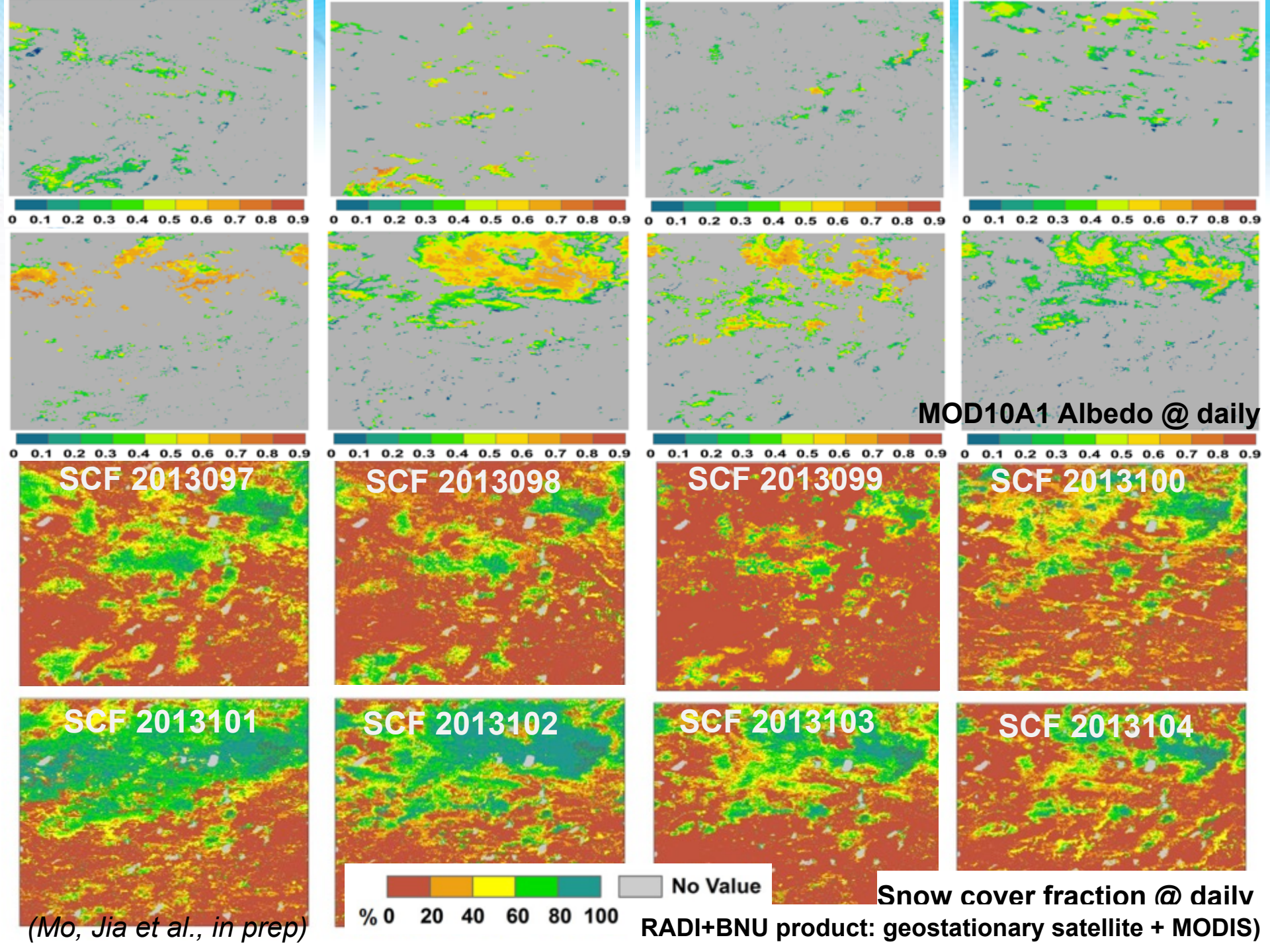




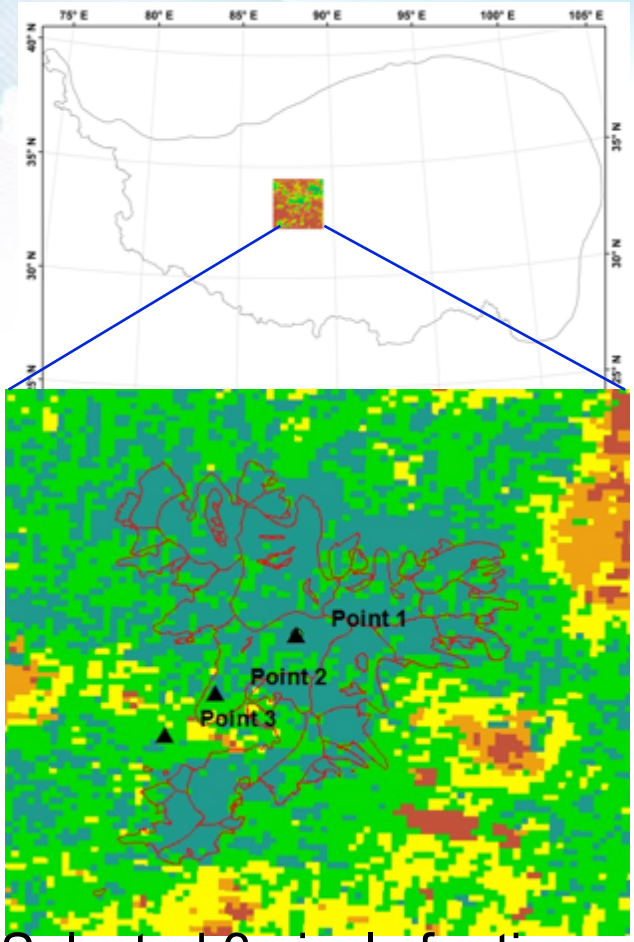


Snow cover fraction @ dailv

RADI+BNU product: geostationary satellite + MODIS)

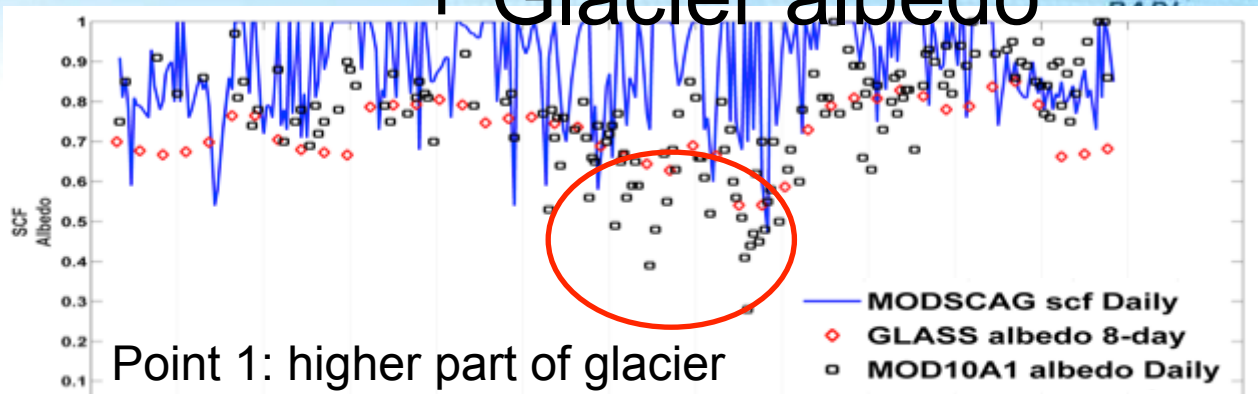

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
MOD10A1 Albedo @ daily
SCF 2013097
SCF 2013098
SCF 2013099
SCF 2013100
SCF 2013101
SCF 2013102
SCF 2013103
SCF 2013104
No Value
% 0 20 40 60 80 100
Snow cover fraction @ dailv
RADI+BNU product: geostationary satellite + MODIS)
(Mo, Jia et al., in prep)

Surface Albedo: Snow cover impact + Glacier albedo

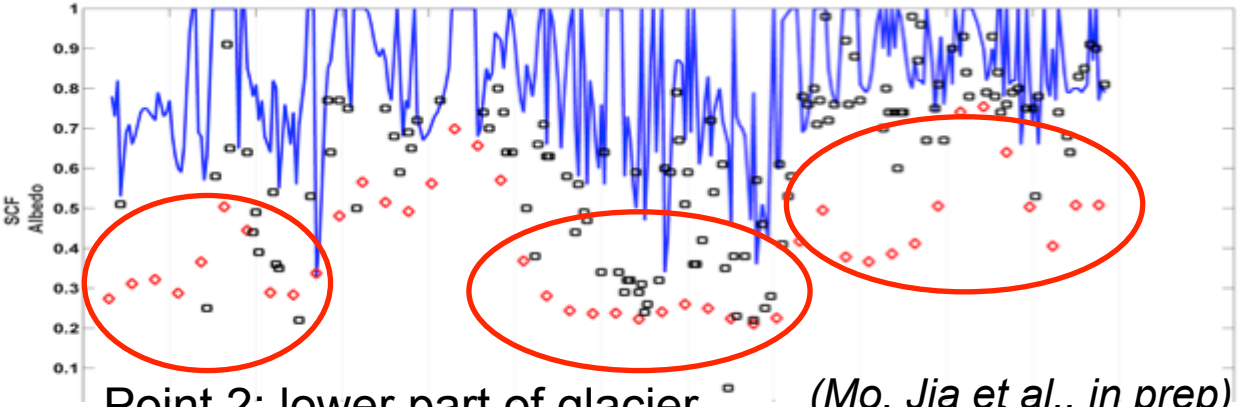


Selected 3 pixels for time series analysis:

Point 1: higher part of glacier
Point 2: lower part of glacier
Point 3: non-glacier area

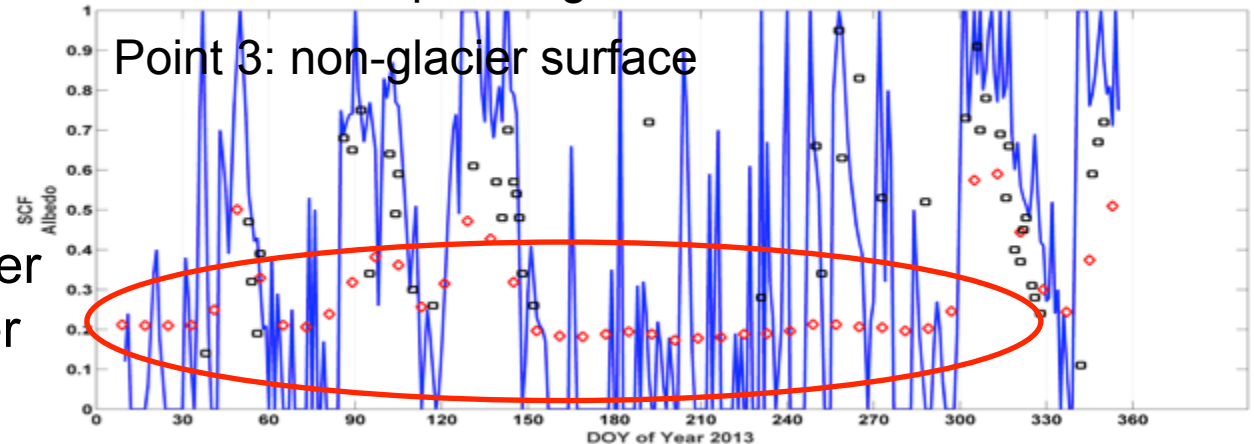


Point 1: higher part of glacier

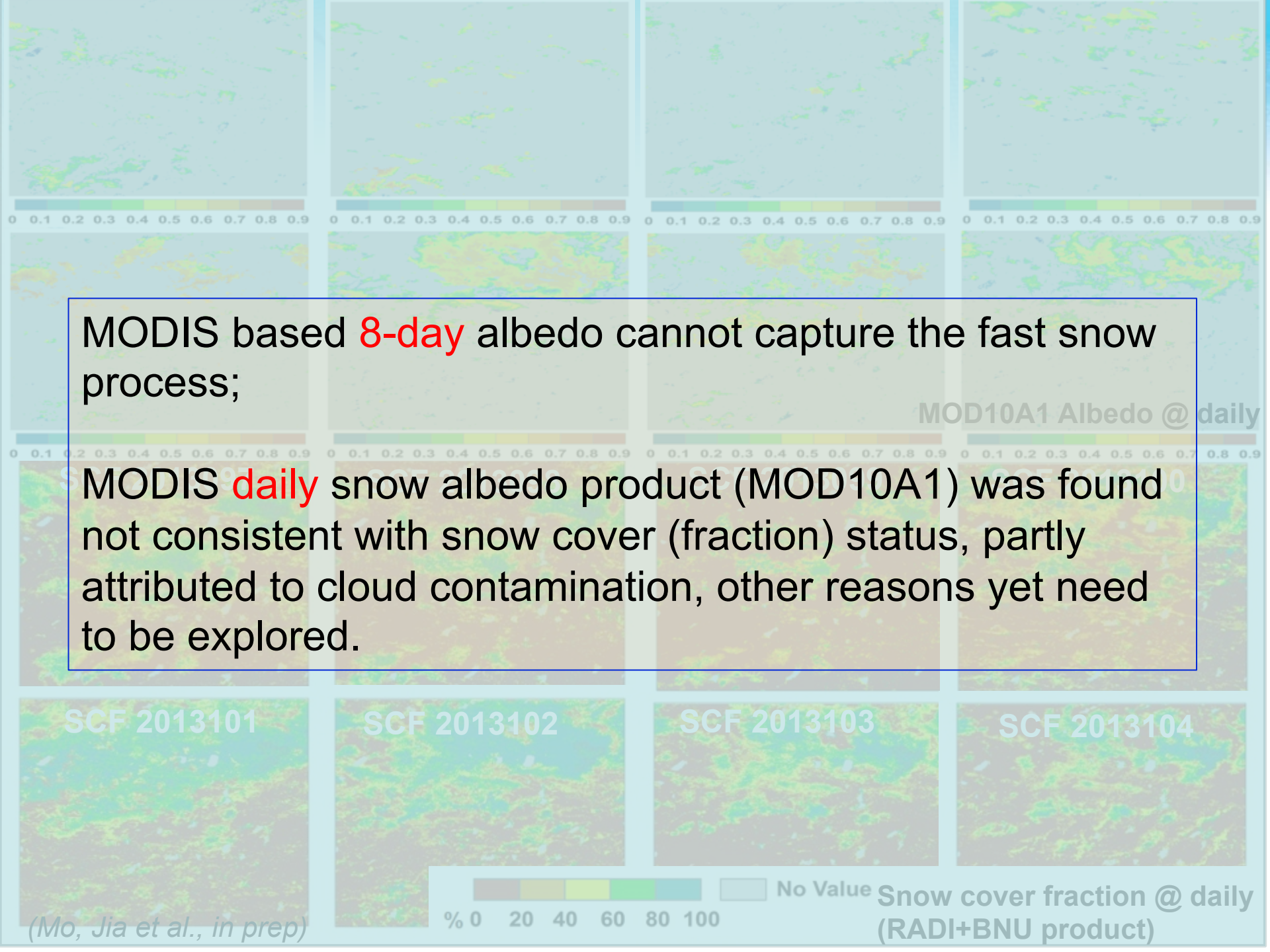


Point 2: lower part of glacier

(Mo, Jia et al., in prep)



Point 3: non-glacier surface



MODIS based 8-day albedo cannot capture the fast snow process;

MODIS daily snow albedo product (MOD10A1) was found not consistent with snow cover (fraction) status, partly attributed to cloud contamination, other reasons yet need to be explored.

Outline

- Radiation: albedo

how (much) do the terrain and snow cover affect the surface albedo ?

- Evapotranspiration:

how lake area dynamics and snow cover influence evapotranspiration estimation?

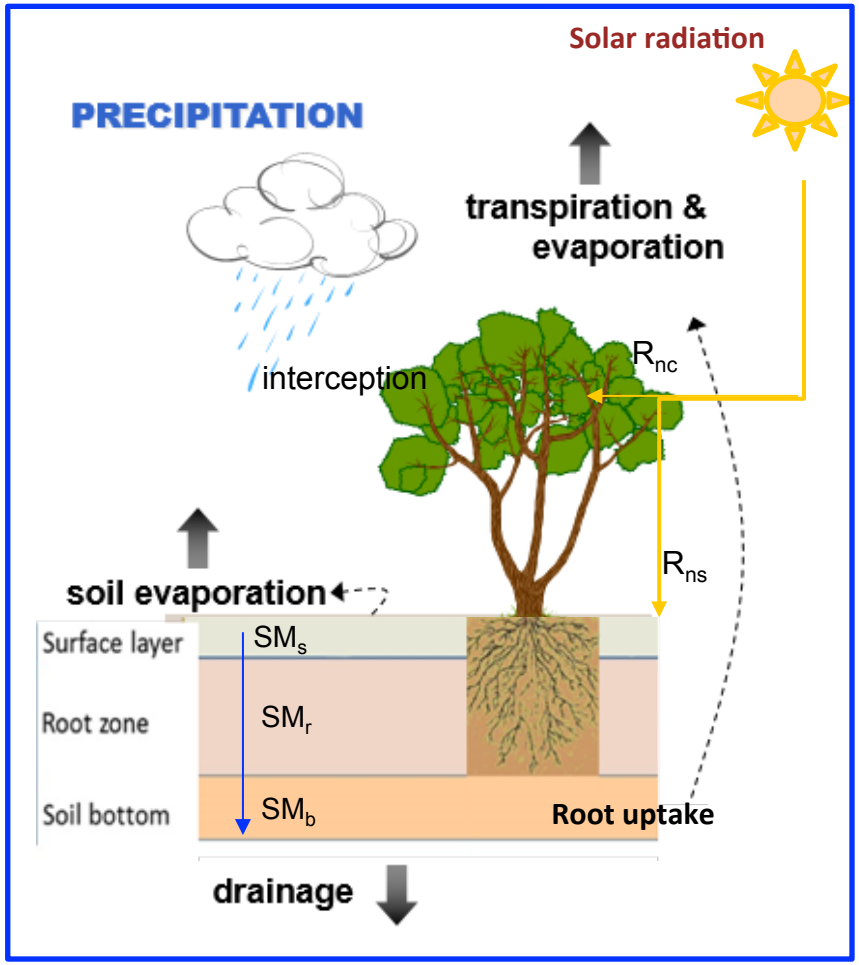
Evapotranspiration: ETMonitor

A process based model that implements processes of

- energy balance,
- plant physiology and
- soil water balance

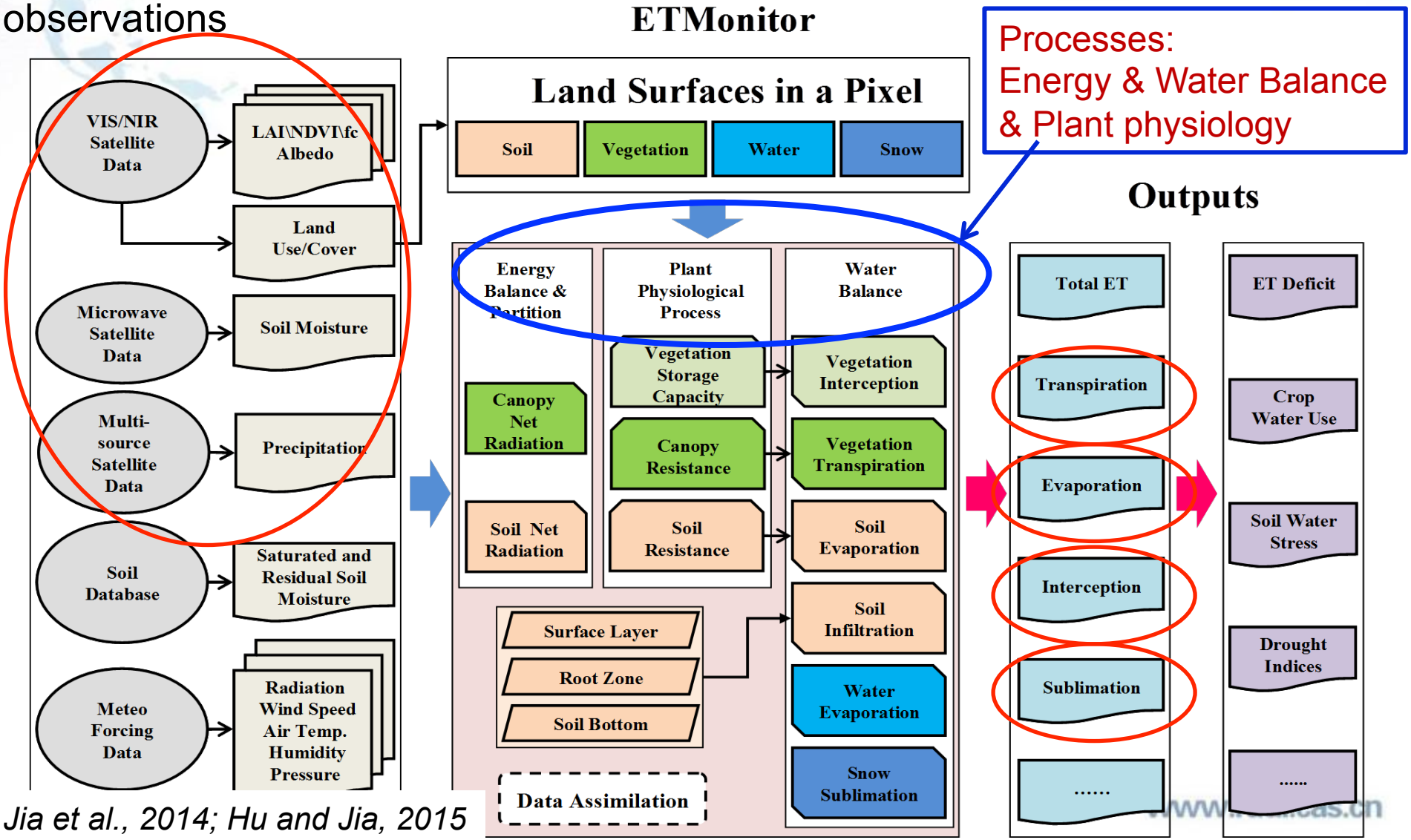
developed by EOWater Lab at RADI-CAS.

- Combined optical and microwave remote sensing observations.
- A pixel is composed by:
  - soil
  - vegetation
  - water body
  - snow



Evapotranspiration: ETMonitor

ETMonitor: a process based model involving energy balance, water balance and plant physiology and combining optical and microwave remote sensing observations

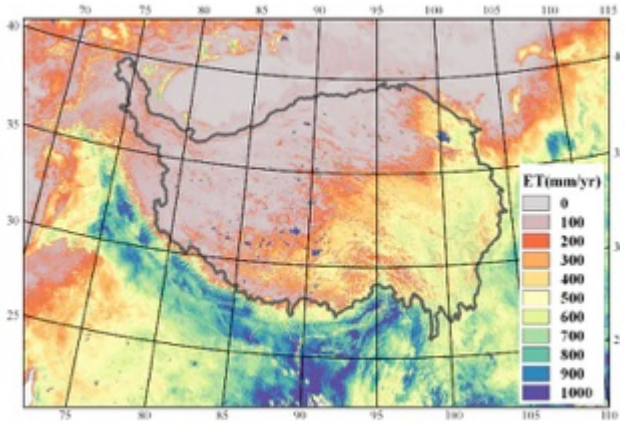


Jia et al., 2014; Hu and Jia, 2015

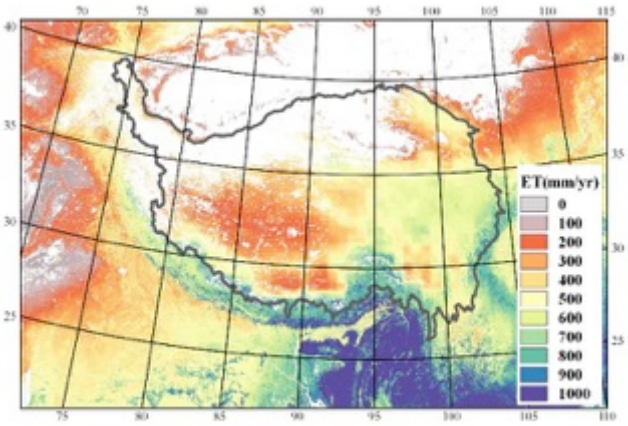
Inter-Comparison of ET products in HMA

2001-2011 mean annual ET

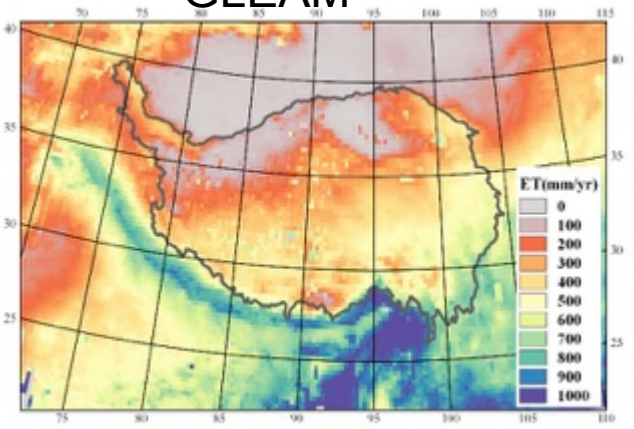
ETMonitor



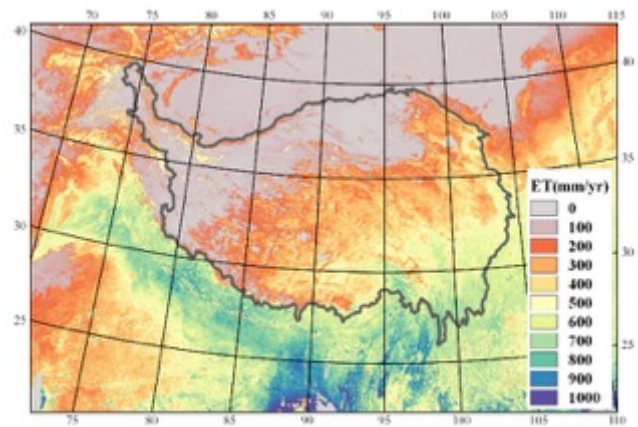
MOD16



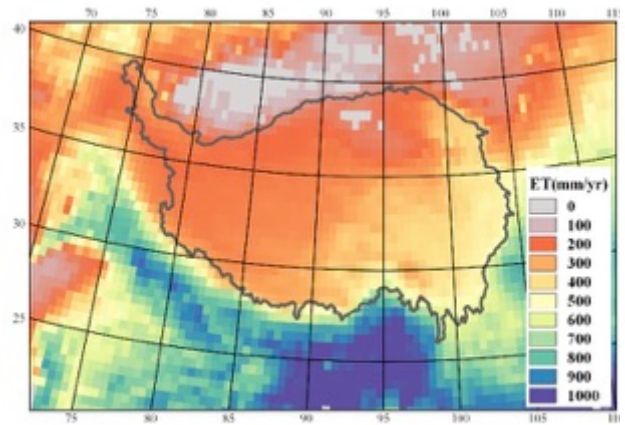
GLEAM



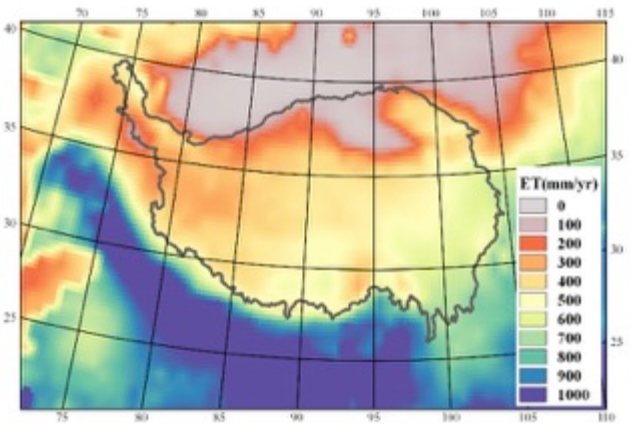
SEBS



Jung2011 ET

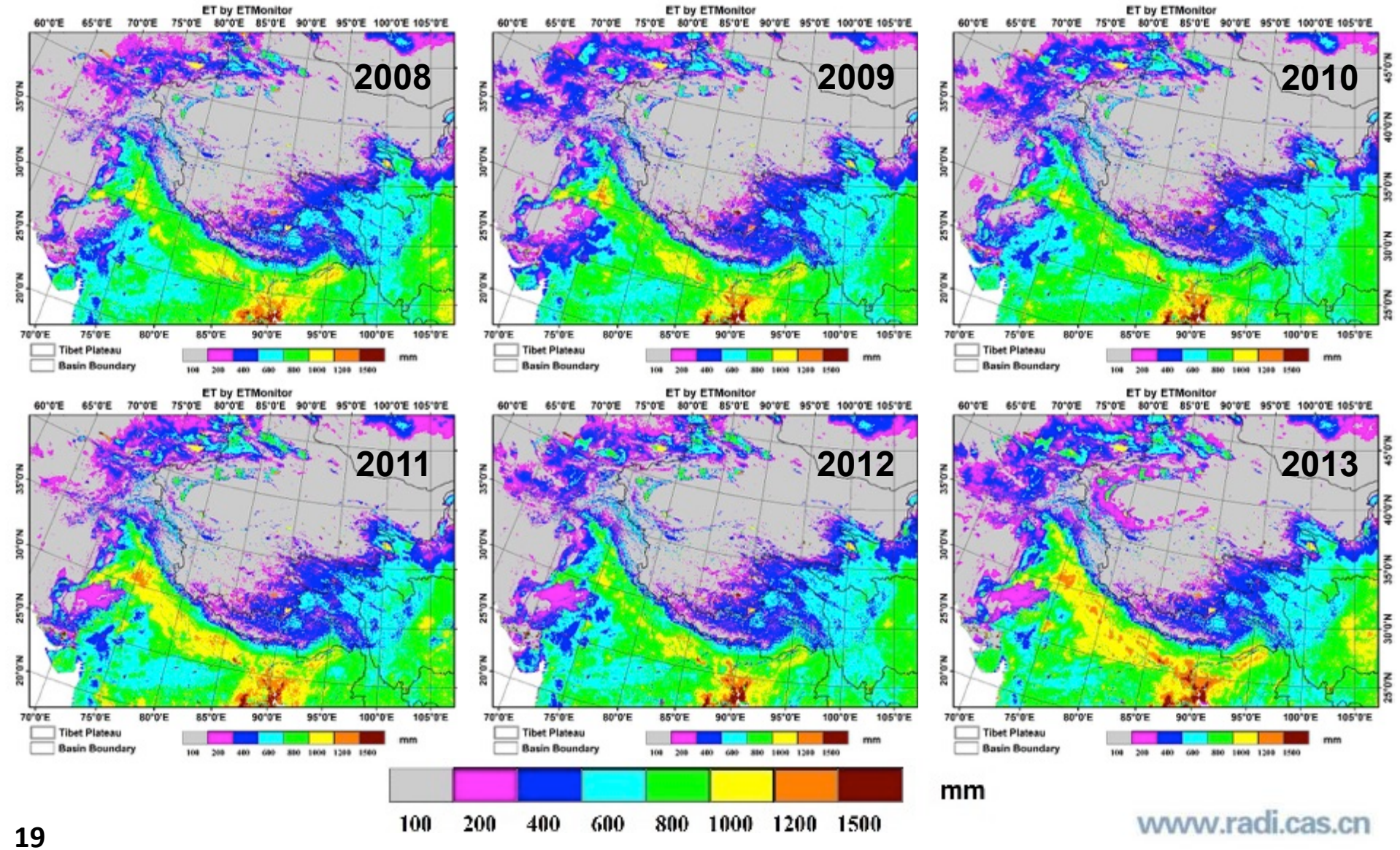


ERA-Interim



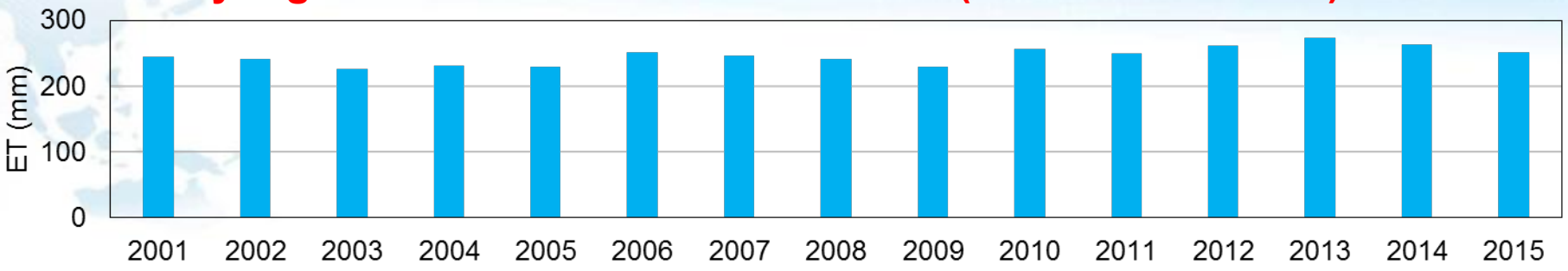
Annual variability of Evapotranspiration over HMA

Yearly Evapotranspiration in HMA (ETMonitor Product)

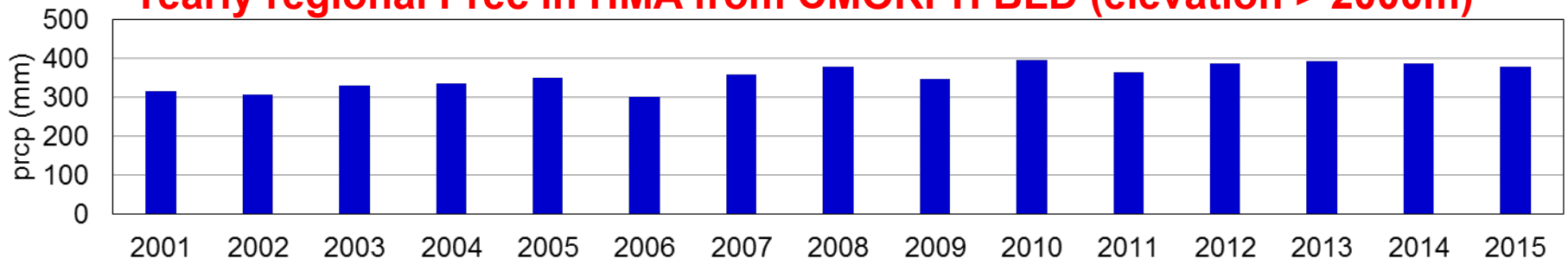


Water budget over HMA

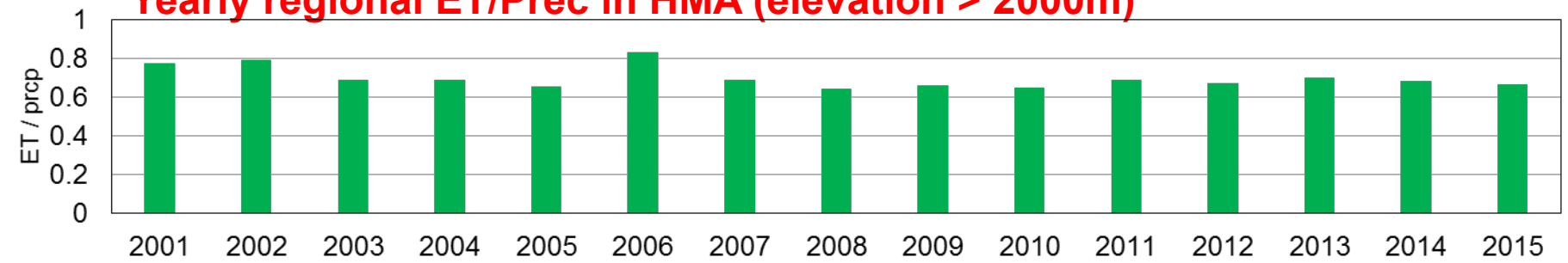
Yearly regional ET in HMA from ETMonitor (elevation > 2000m)



Yearly regional Prec in HMA from CMORPH BLD (elevation > 2000m)

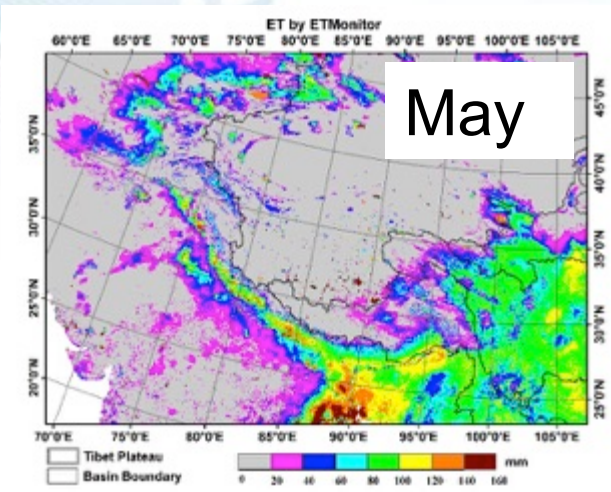


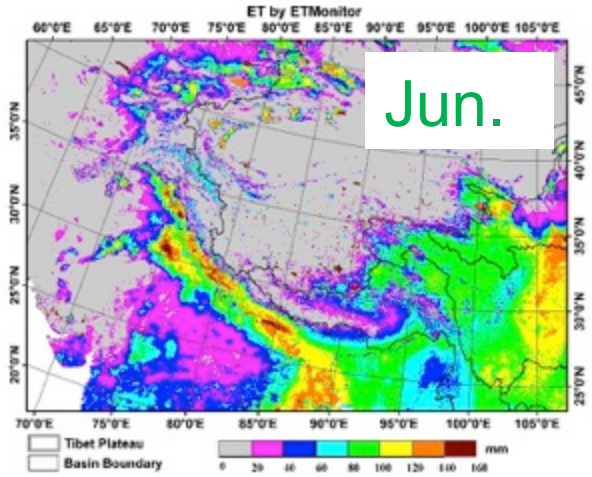
Yearly regional ET/Prec in HMA (elevation > 2000m)

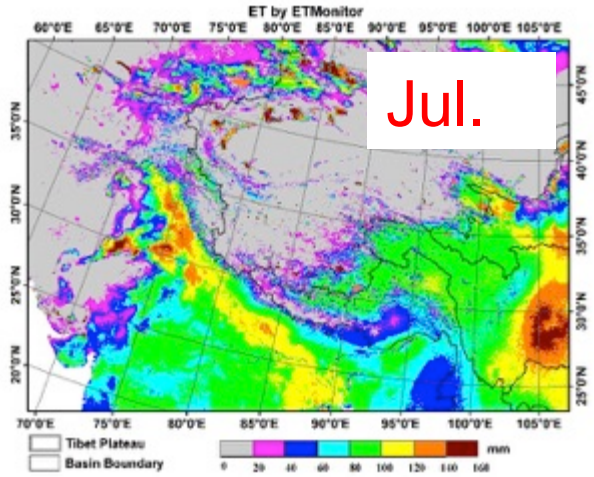


Need to understand the controlling process: energy or water limits spatially and seasonally

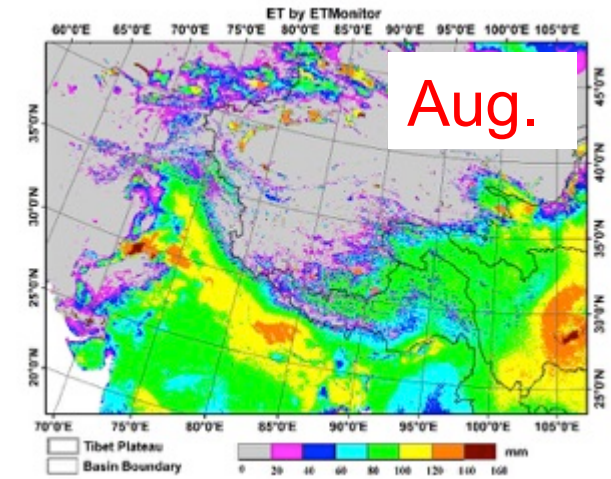
Seasonality of ET in HMA

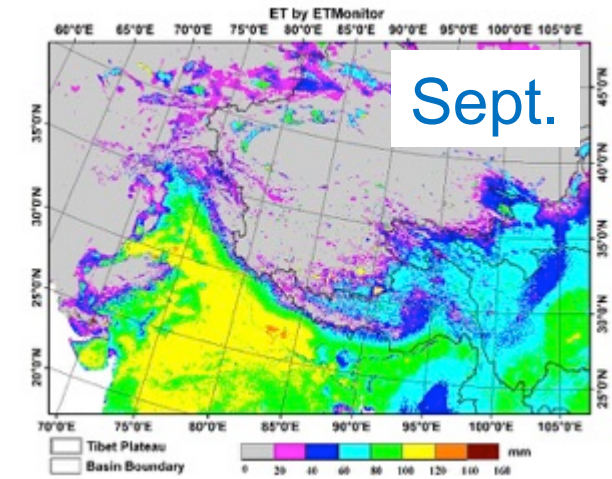


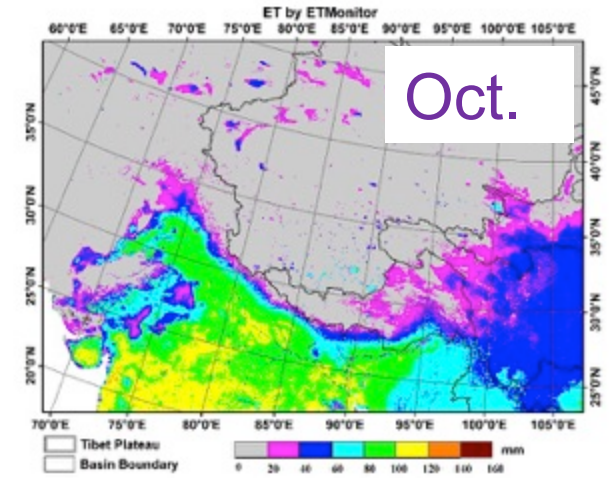




Pre monsoon	Transition	Monsoon season
Monsoon season	Transition	Post monsoon

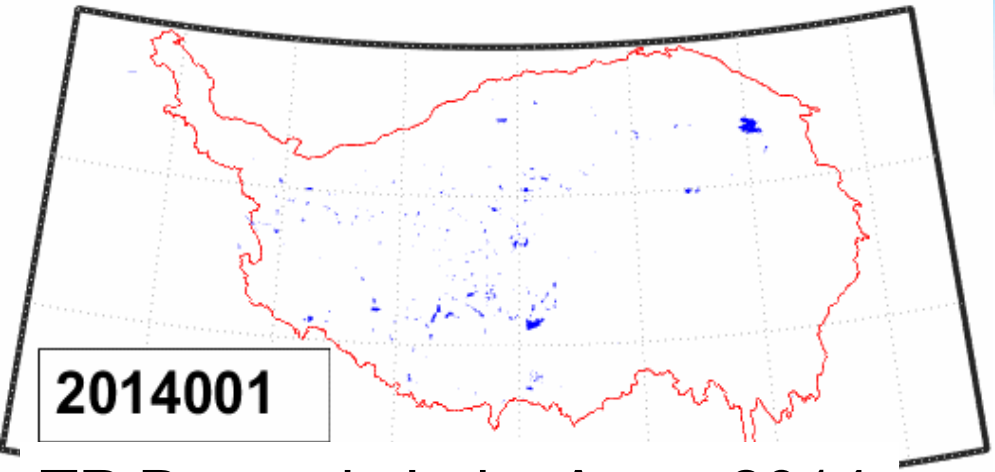




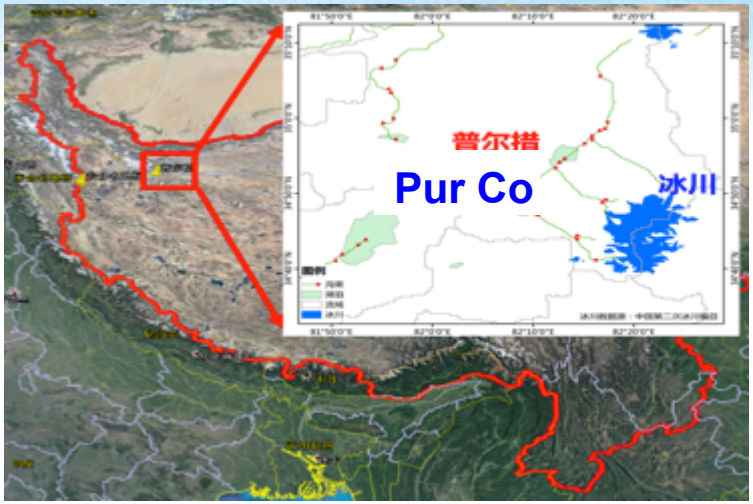


2008-2013 mean

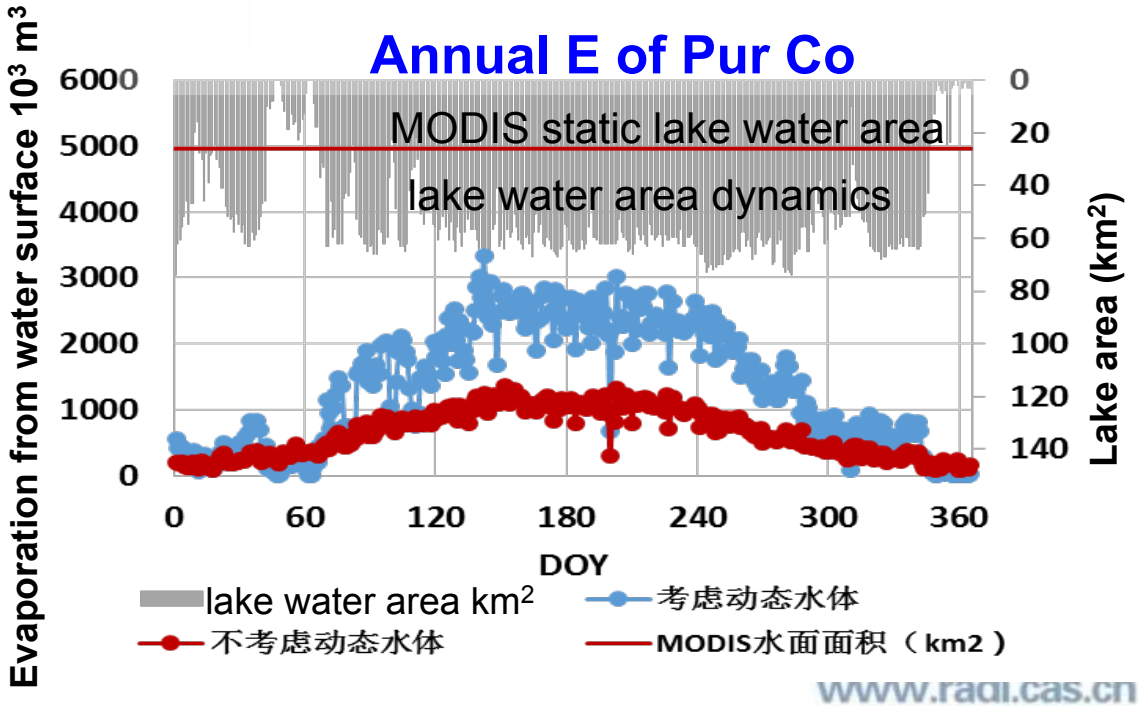
Impact of lake area dynamics on total ET



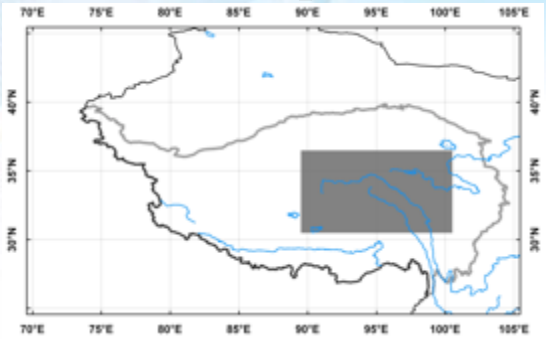
TP Dynamic Lake Area, 2014



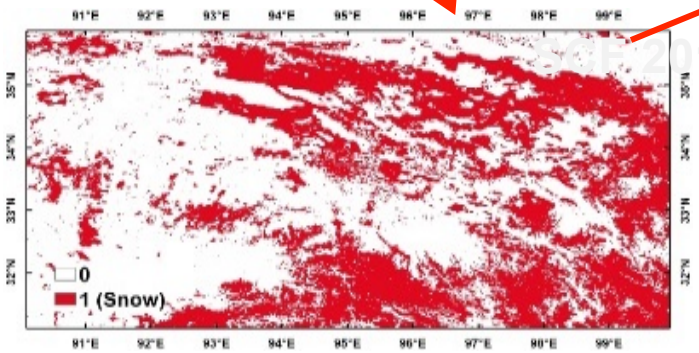
E: 5x10^8 m^3 (dynamic);
E: 2.4x10^8 m^3 (static).
Relative error 53%.



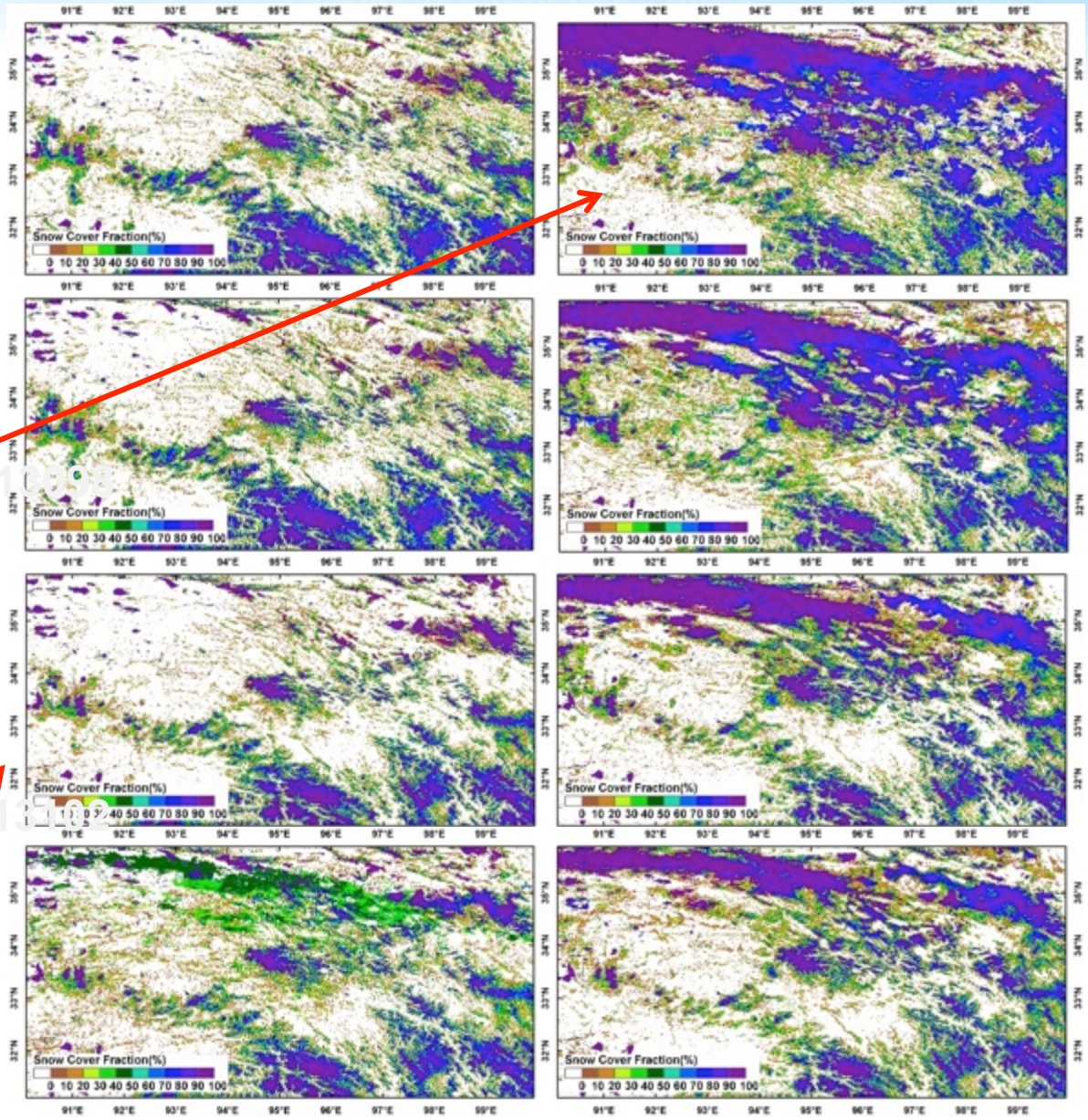
Impact of snow cover on total ET



MOD10A2, 8-day binary snow cover classification (1-8 Jan. 2010)

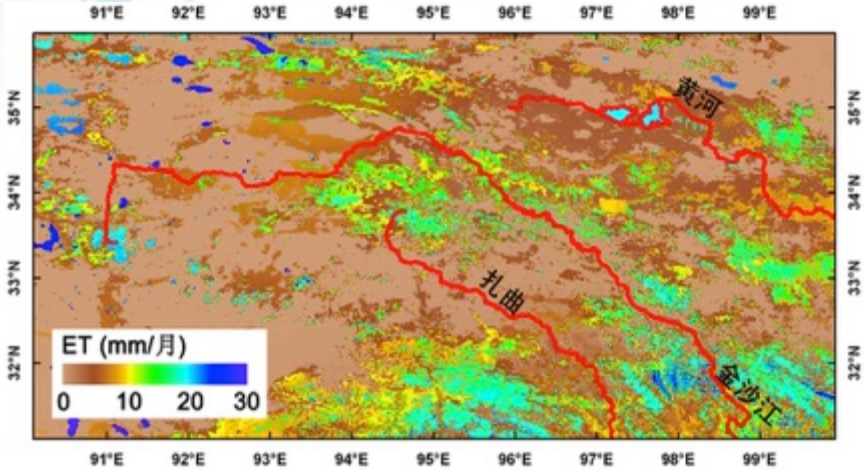


1-day **snow cover fraction** (%)
RADI+BNU product: geostationary satellite + MODIS

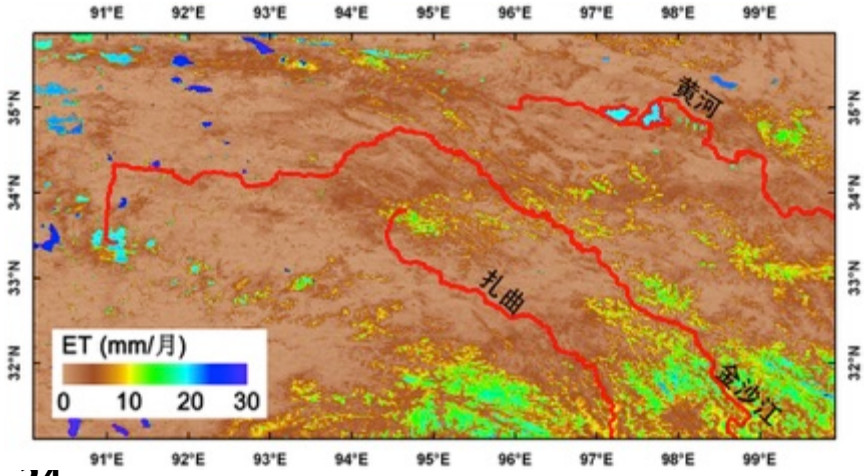


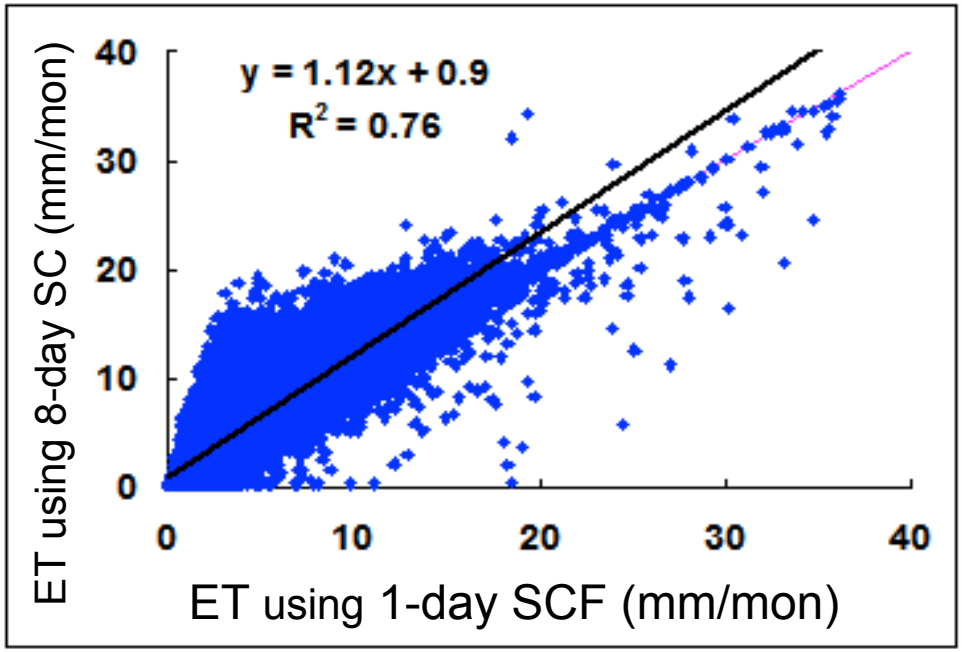
Impact of snow cover on total ET

Total ET in January 2010
(using 8-day SC binary class)



Total ET in January 2010
(using 1-day SCF)





Implications:

- 8-day binary SC data overestimate actual snow cover condition, leading to overall higher ET (mainly as sublimation);
- Frozen soil almost has no contribution to total ET.

Hu, Jia, et al., in prep

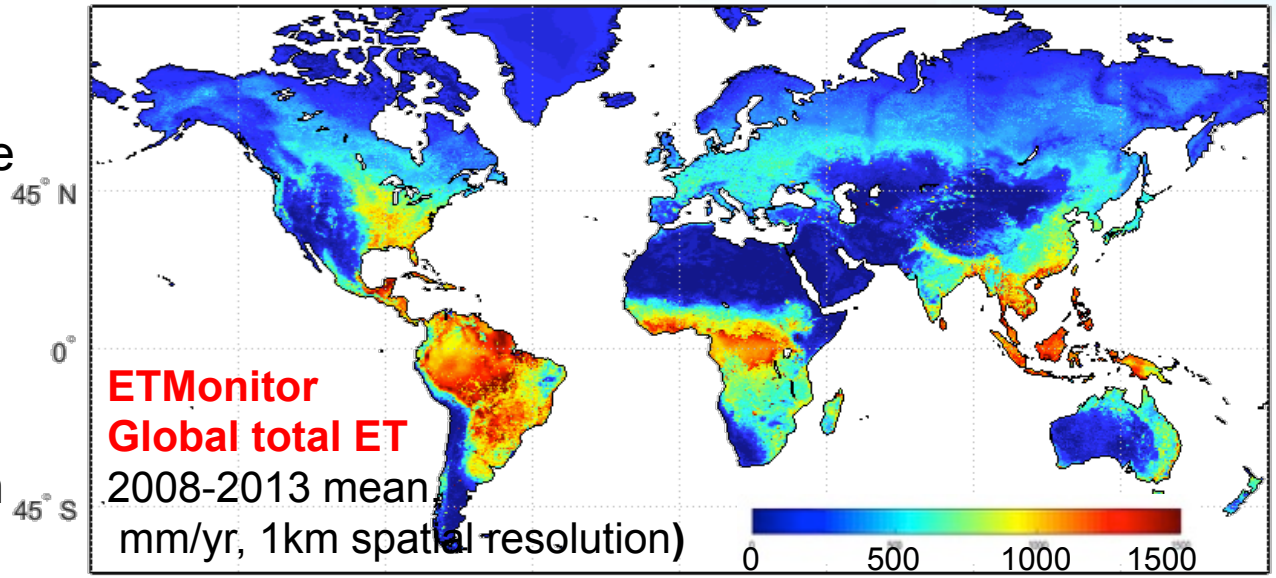
Summary

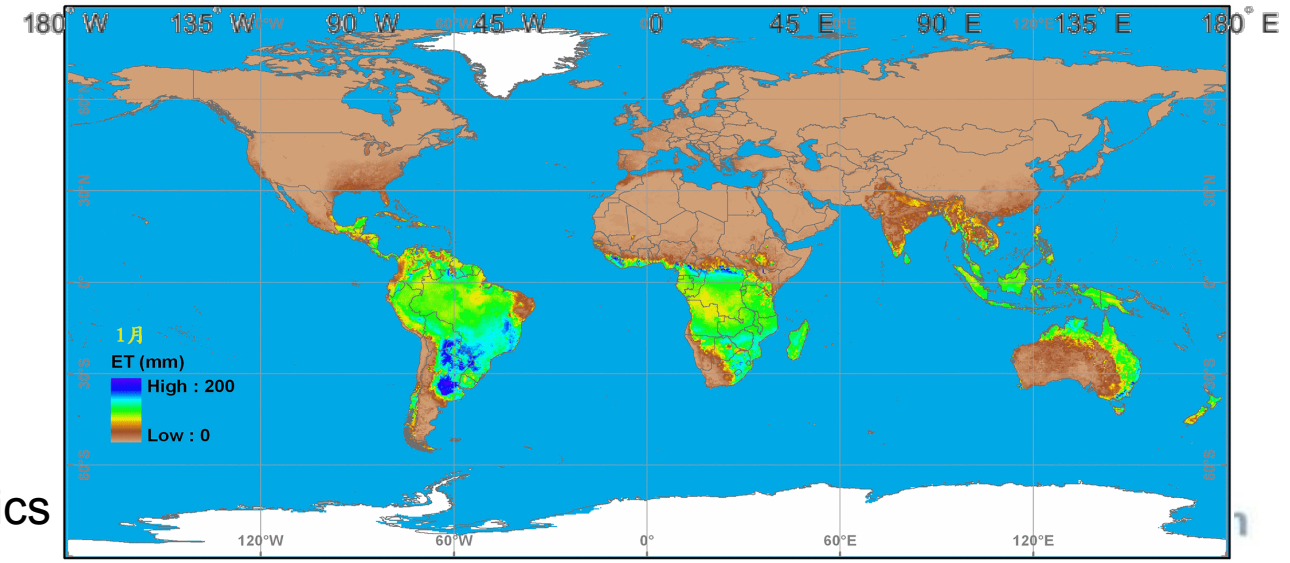
- Satellite data with high temporal resolution help to increase the reliability and accuracy (e.g., snow cover fraction, albedo).
- Snow/glacier albedo is still a important issue to work at in HMA;
- Accuracy and spatial resolution of soil moisture are critical for ET estimate at corresponding scales;
- Impact of topography yet needs to be understood;
- Validation of remote sensing and model results are challenging in particular in regions with complex terrain due to lack of proper ground measurements, or of good quality long time series data;
- Consistency among different land surface parameters needs more attention (e.g. albedo vs snow cover);
- Systematic analysis are necessary for better understanding and quantifying terrestrial water cycle processes over TP region, e.g. relations between forcing and response.

Beyond HMA:
Global Evapotranspiration Product by ETMonitor

ETMonitor ET product:

- Daily step, 1km grid size
- China: 2001 – 2016
- Global coverage: 2008-2015
- Plans:
  - Currently at validation stage (using 150 flux tower station data)
  - V1.0 to be released by the end of 2018





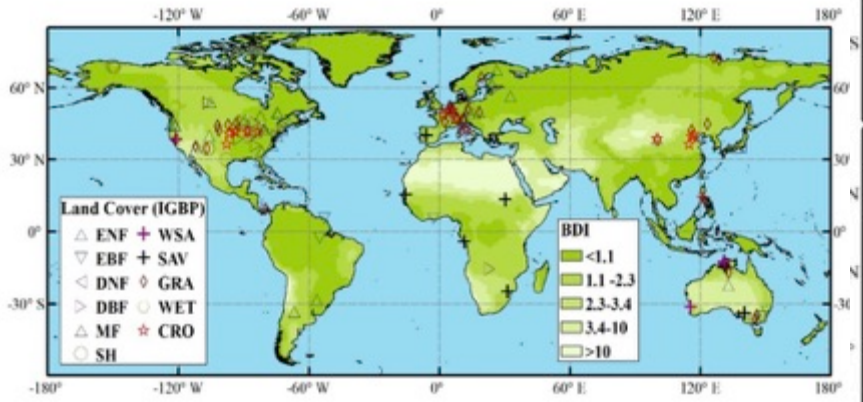
ETMonitor
ET monthly dynamics

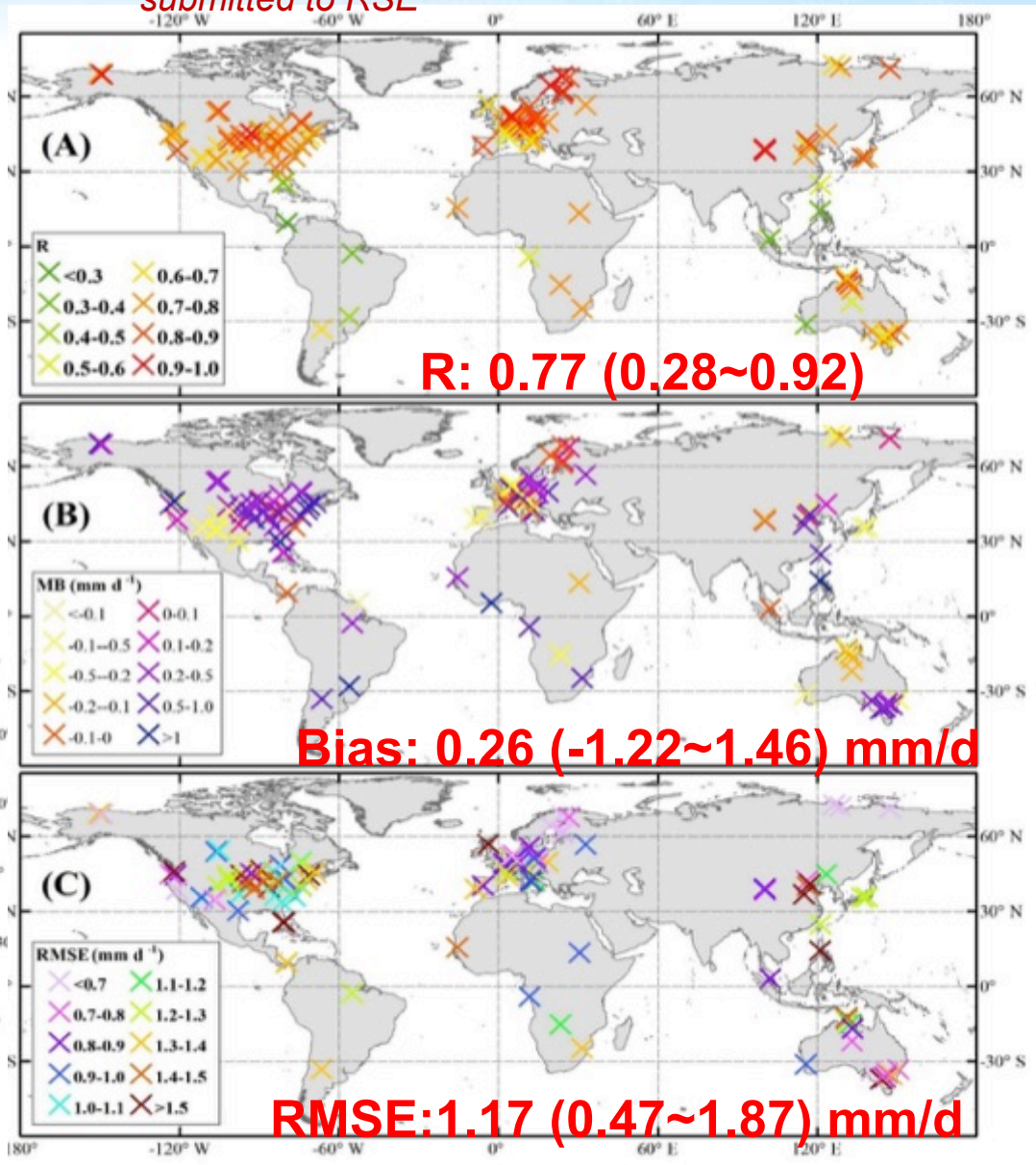
ET from ETMonitor: Validation and Comparison

Zheng, Jia, et al., 2017, manuscript to be submitted to RSE

Global Validation

- 153 flux sites **(FLXUXNET2015 data)**
  - 98 from Fluxnet2015
  - 6 from HiWATER
  - 37 from AmeriFlux
  - 8 from EuroFlux
  - 4 from AsiaFlux



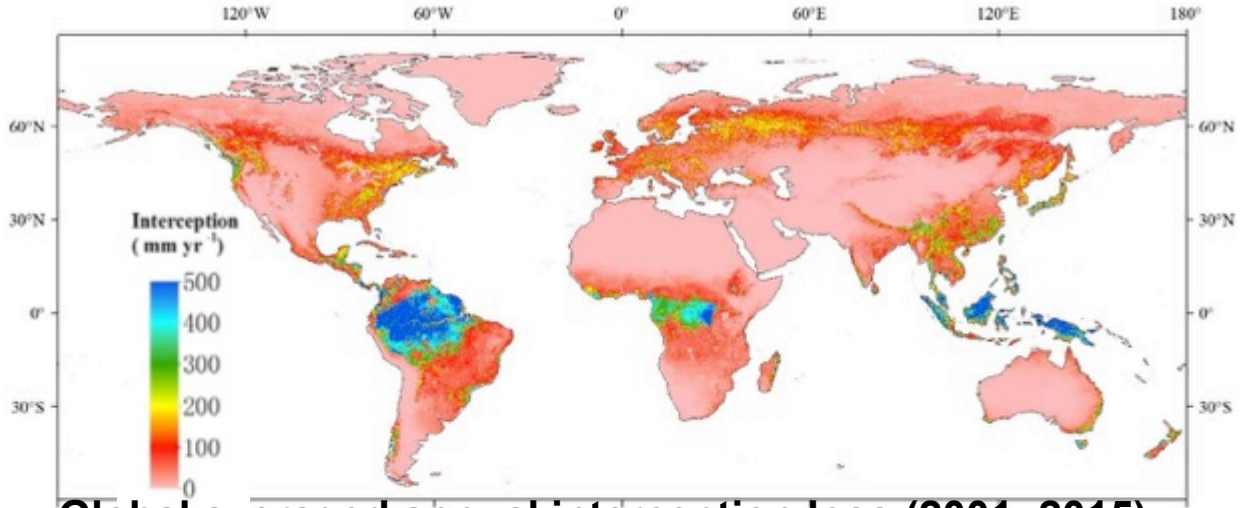


Zheng, Jia, et al., JH, manuscript

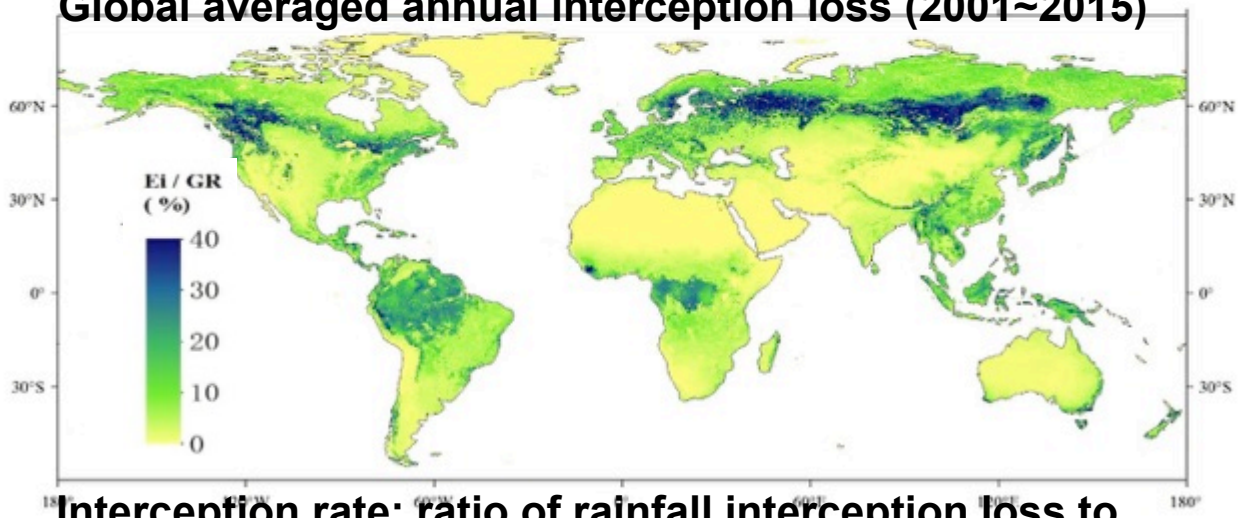
Global ET by ETMonitor

Global interception loss

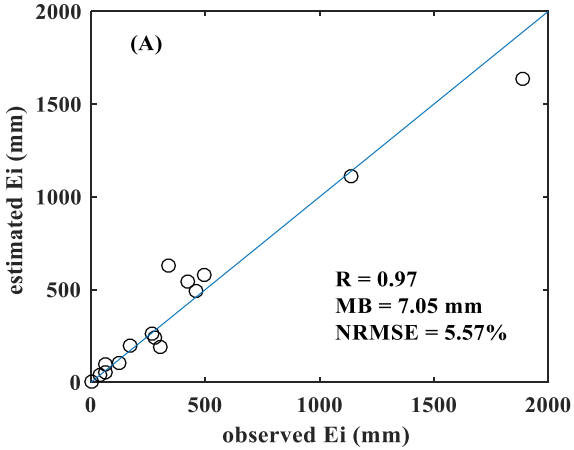
(2001-2015 mean, mm/yr, 1km spatial resolution)

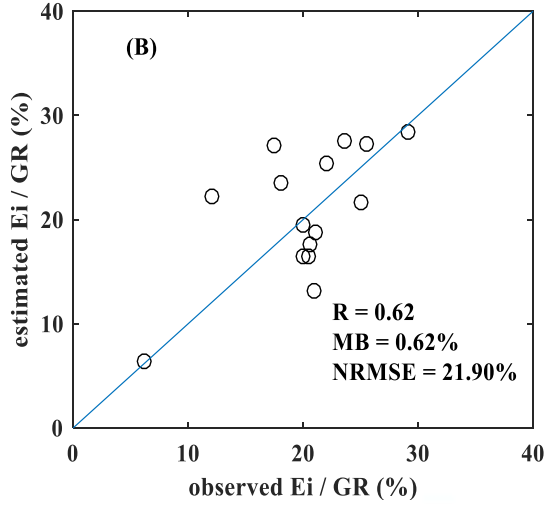


Global averaged annual interception loss (2001~2015)



Interception rate: ratio of rainfall interception loss to total rainfall (2001~2015)





Zheng, Jia, et al., JH, in review

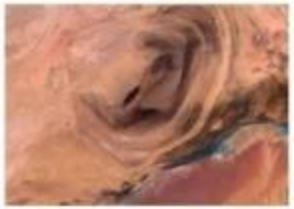
Li JIA

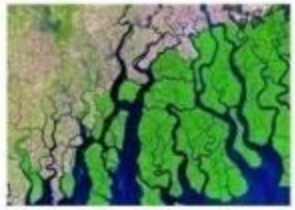
(jiali@radi.ac.cn)

Institute of Remote Sensing and Digital Earth (RADI),
Chinese Academy of Sciences (CAS)

谢 谢 ！








中国科学院遥感与数字地球研究所

地址：北京市海淀区邓庄南路9号（100094）

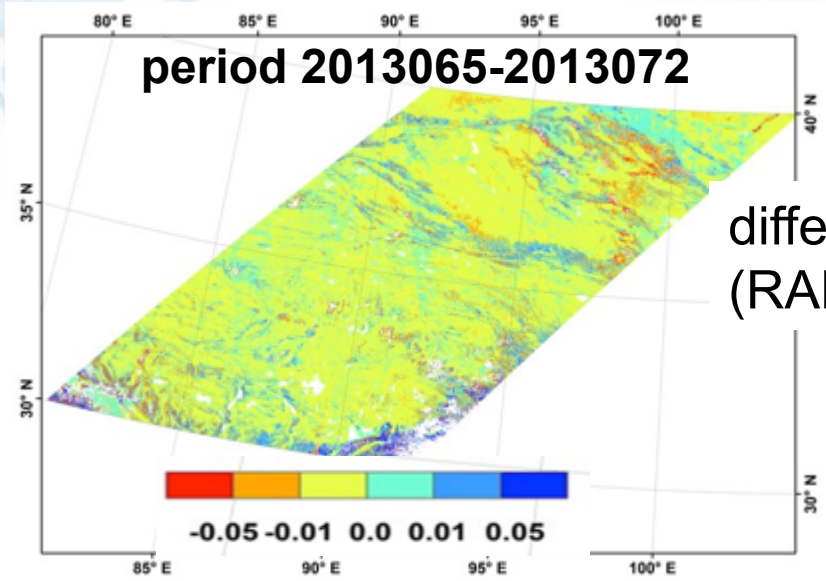
电话：86-10-82178008　传真：86-10-82178009

邮箱：office@ceode.ac.cn

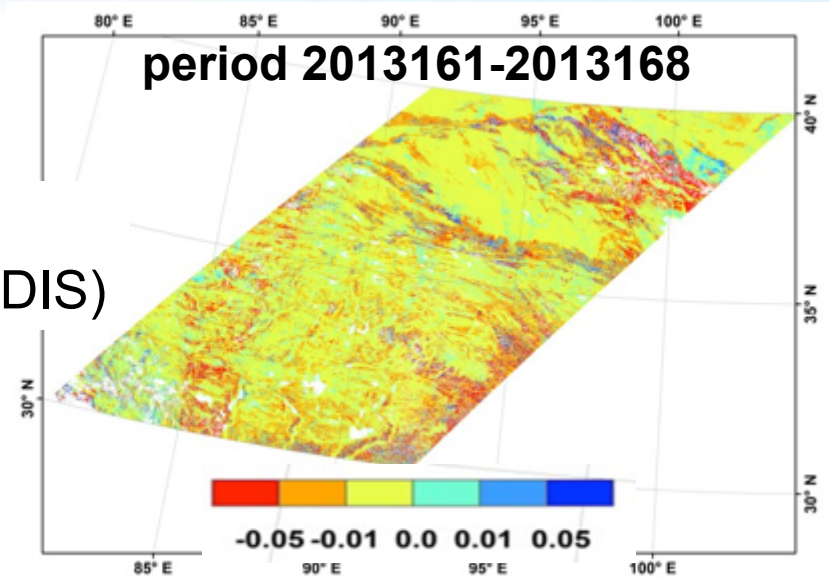
网址：www.radi.cas.cn

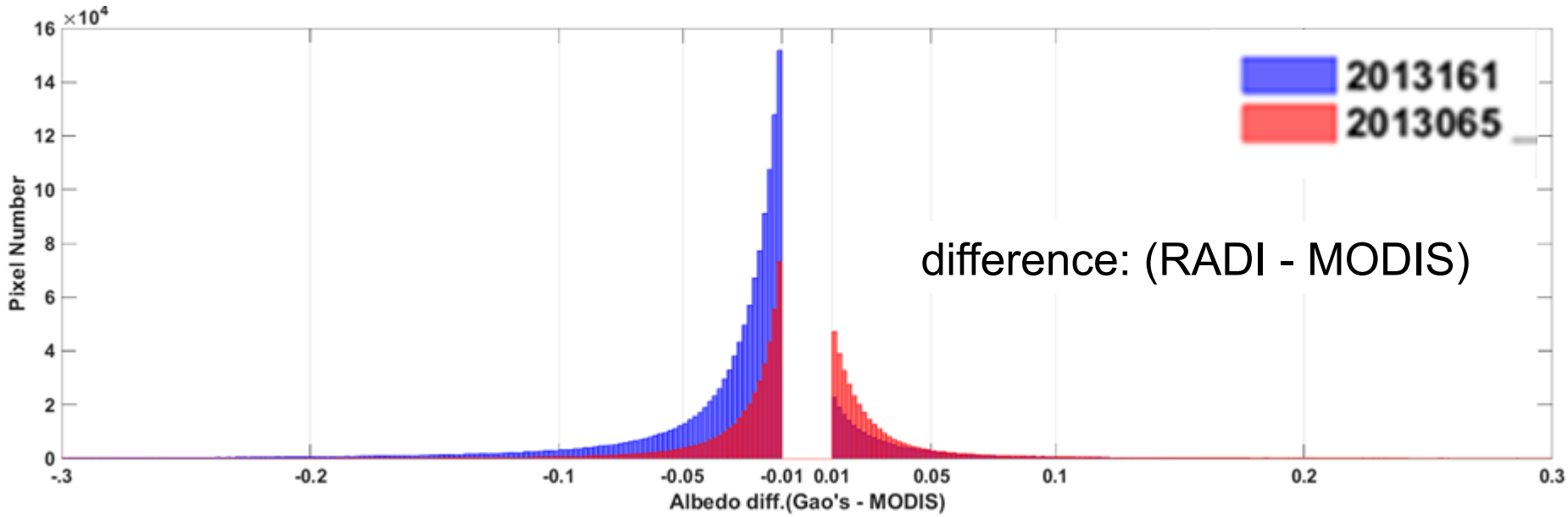
Surface Albedo: Terrain Impact

Albedo retrieval: Improved algorithm @RADI v.s. MODIS product



difference:
(RADI - MODIS)





difference: (RADI - MODIS)