遥感科学国家重点实验室
State Key Laboratory of Remote Sensing Science
中国科学院遥感与数字地球研究所 • 北京师范大学
Institute of Remote Sensing and Digital Earth · Beijing Normal University

Introduction to Global Water Cycle Mission

Jiancheng Shi

The 10th GEO IGWCO COP Meeting

May 29 – 30, 2014

Tokyo, Japan

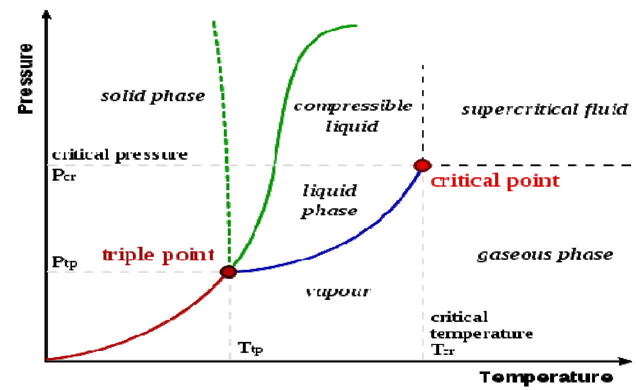
Water Cycle and Climate Change

Water Cycle /Climate Linkage

- One of the Earth system's major cycles
- The Clausius–Clapeyron equation governs the water-holding capacity of the atmosphere that increases by about 7% per degree Celsius.

Expectations: ↓ drizzles, ↑ storms, ET, speed of water cycle, therefore, hydrological extreme events

Clausius-Clapeyron_Equation



Application Linkage

Basic requirements for monitoring and prediction of water resource, flood, drought, agricultures

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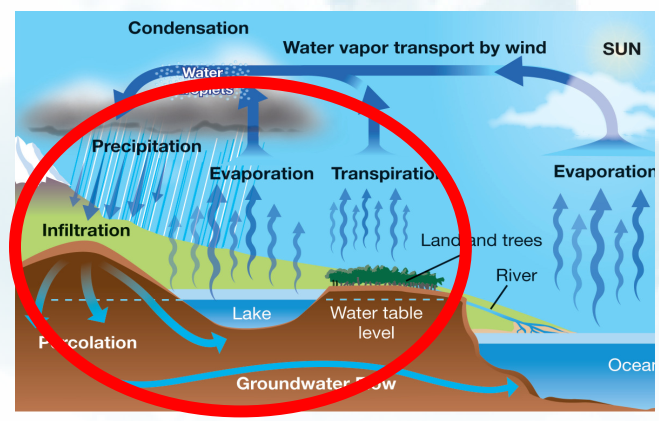
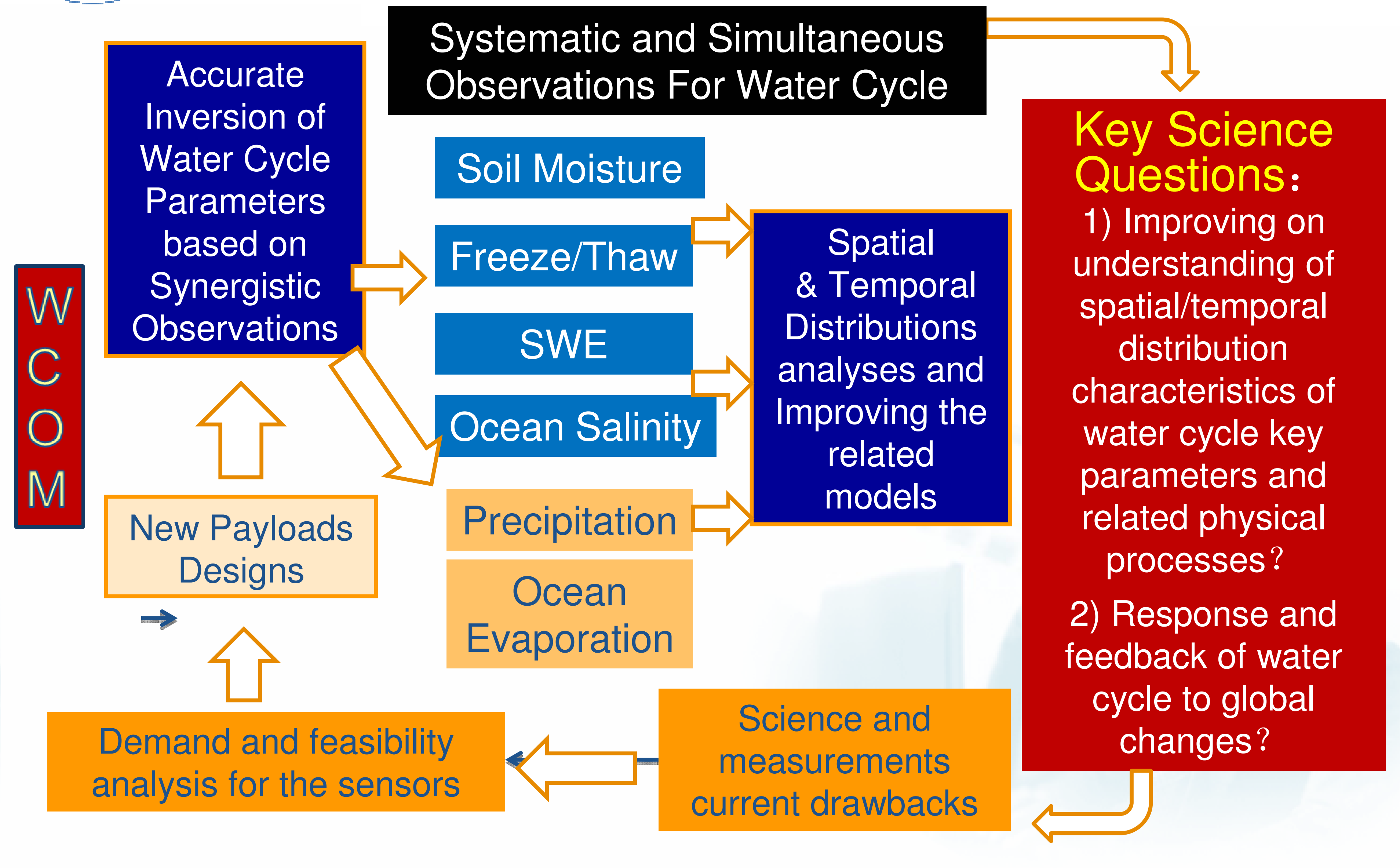
Water in the climate system functions on <u>all</u> time scales (from hours to centuries)



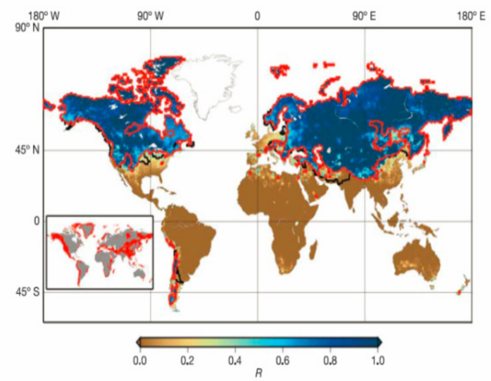
Key Science Questions

What are the spatial-temporal distribution characteristics of water cycle components and processes? Are the changing speeding up?

Global Water Cycle (WCOM) Mission Summary



Snow in Water Cycle



Global snow melting runoff dominating area

Energy and mass balance computations

Importance

1）Snow water equivalence: great importance to snowmelt runoff forecast, water resources management and flood prediction. Snowmelt is an important factor of water cycle and the main source of freshwater in many areas.

2）**Snow cover area and SWE are important elements of hydrology, meteorology and climate monitoring, and the key variables for energy and mass balance in water cycle model.**

Terrestrial Snow: Spatial-temporal distribution characteristics and its change characteristics

Key Science Questions

1） What is the impact of snow on global and regional energy and mass balance and its response？

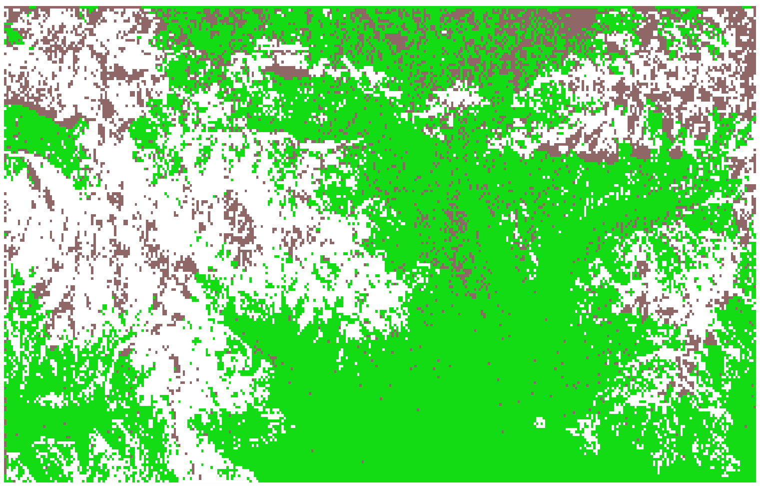
2）In the background of global changing, what is the spatial-temporal distribution characteristics and its change characteristics of snowfall？

3） what is the impact on global and regional water resources？

SAR Measurement Properties

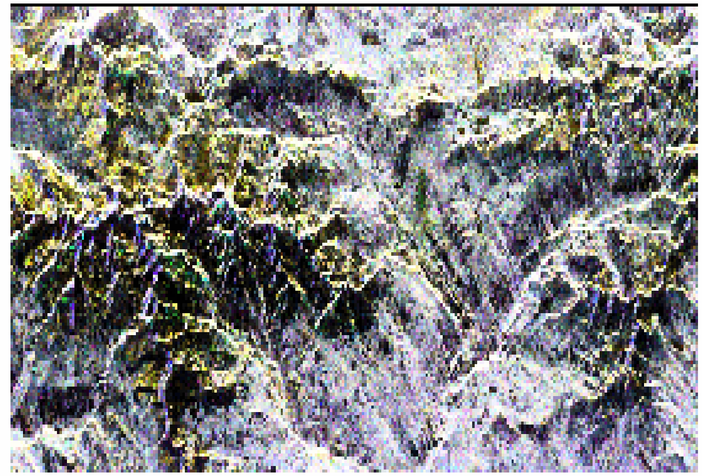
1. Backscattering intensity
2. Polarization or frequency ratio Properties
3. Interferometry

TM

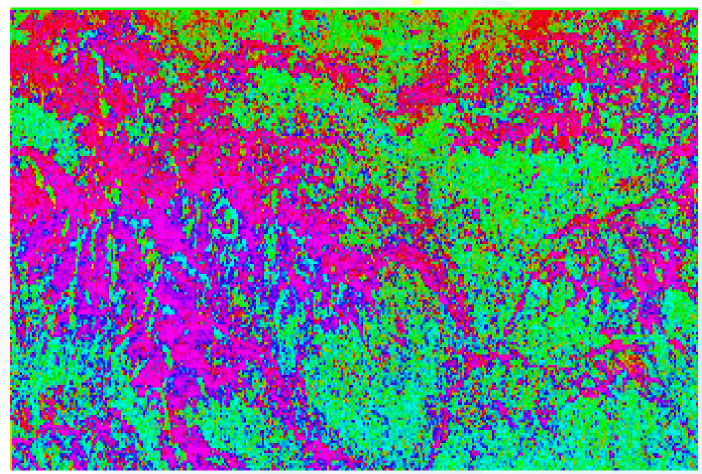


Ratio measurements between different frequency or polarization can significantly reduce the terrain effect

SAR

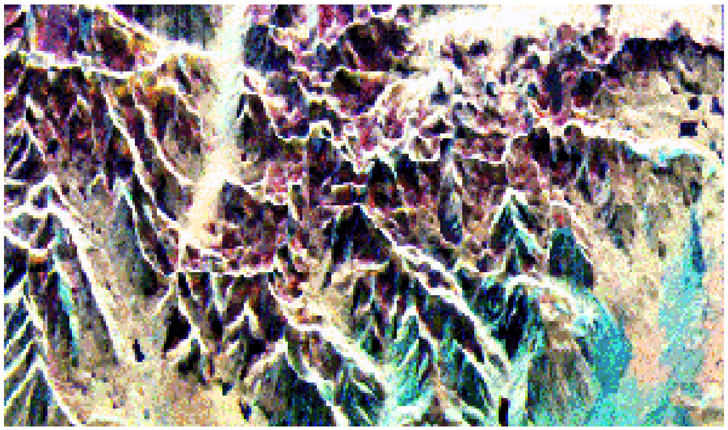


Intensity

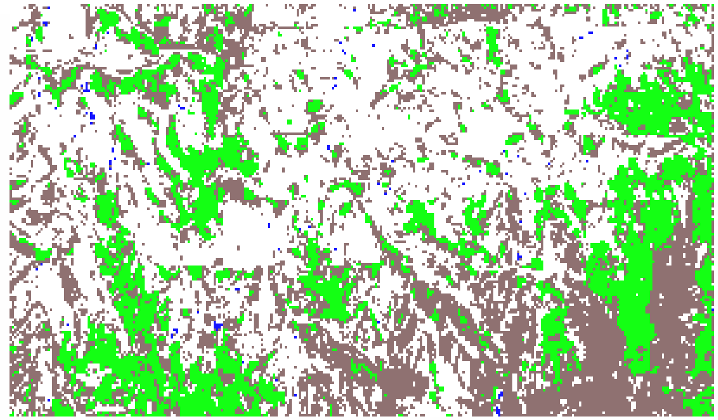


Polarization ratio

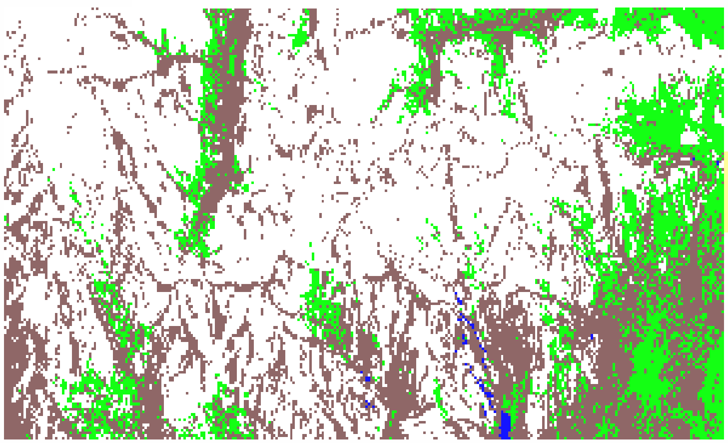
Wet Snow Map Derived by SIR-C/X-SAR



L-Span, C-Span, X-VV

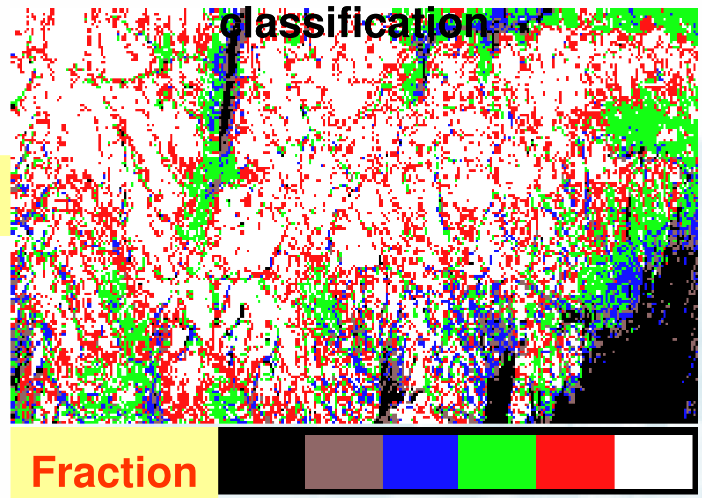


SIR-C/X-SAR binary classification



Binary: Snow Lake, Forest, Range Land

TM



Fraction

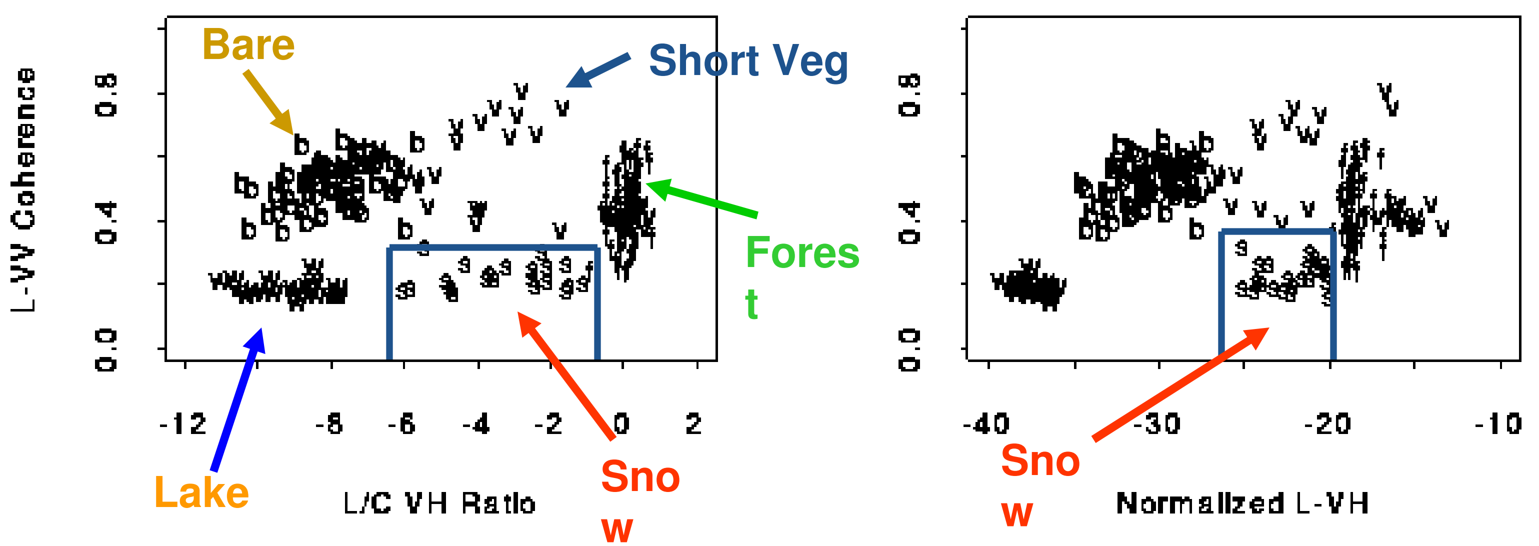
0 20 40 60 80 100 %

Coherence Measurements from SIR-C's L-band Two Mission Image data

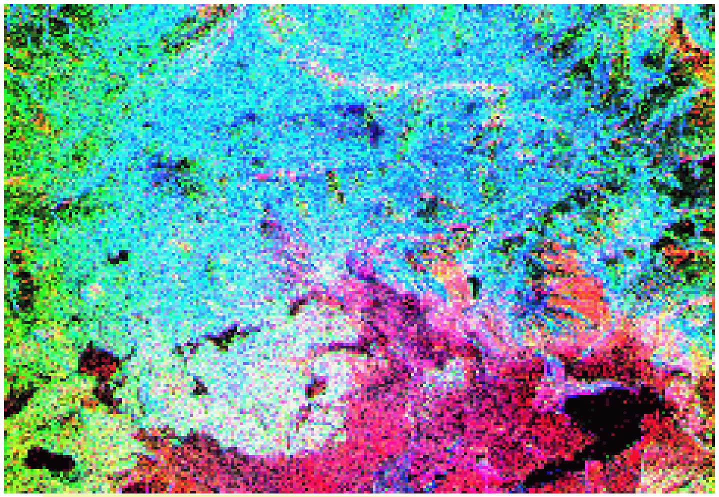
1.Bare & short vegetation have higher coherence

2.Snow & lake have low coherence

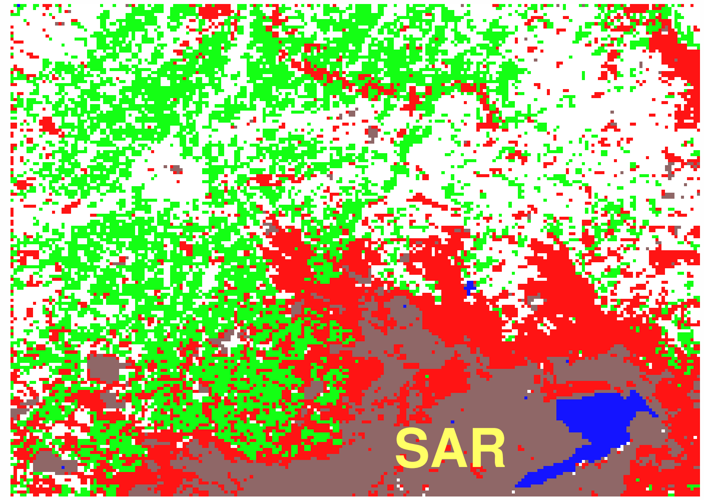
3.Forest has wide range of coherence



Snow Map Derived from Repeat Pass SAR Measurements

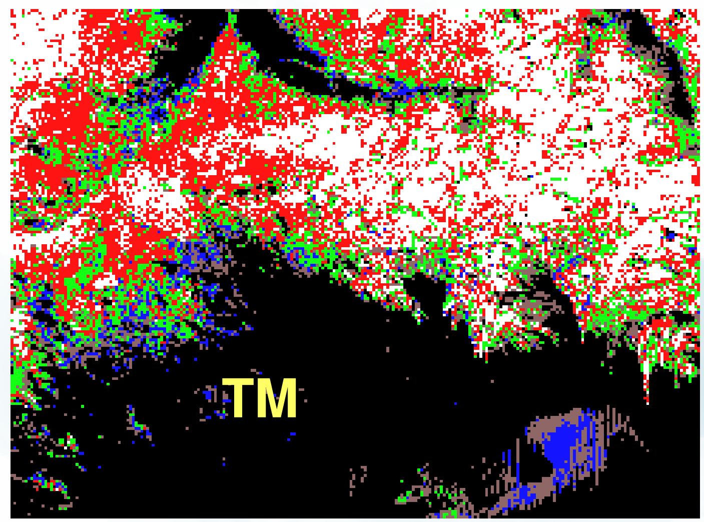


L-VV cor C/L HV L-VV



SAR binary classification

Snow | Forest | Short Veg | Lake | Bare



TM percent classification

Snow free 20 40 60 80 in %

Mapping Snow with Optical Sensors

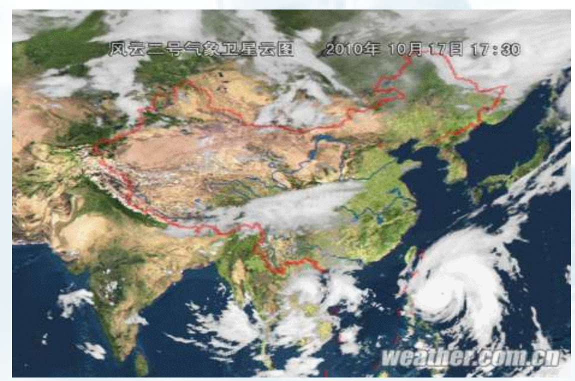
Seasonal snow cover in many places has highly spatial-temporal variability

Snow cover change in 10 days

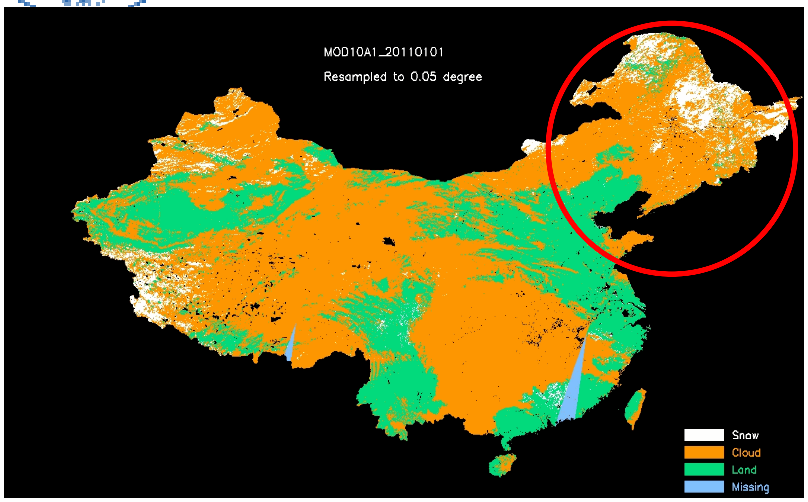
Most widely used snow cover products is from MODIS by 8 day composites. It does not match the needs of water cycle study of hydrological applications

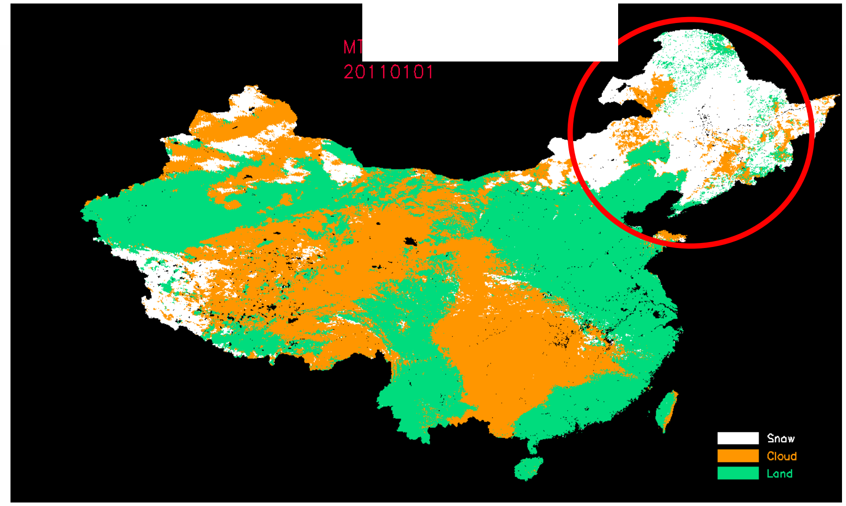
FY-2E VISSR(Visible and Infrared Spin Scan-Radiometer)

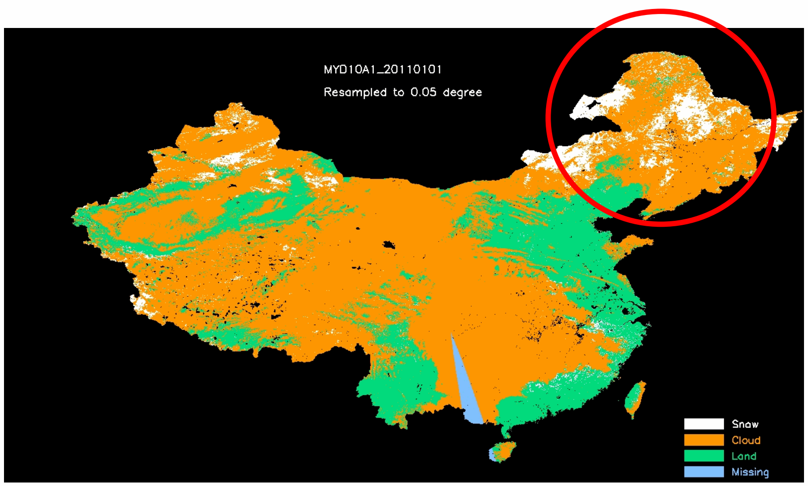
Band	Wavelength range (μm)	Spatial resolution(km)
VIS	0.55 - 0.90	1.25
IR1	10.3 – 11.3	5
IR2	11.5 – 12.5	5
IR3	6.5 – 7.0	5
IR4	3.5 – 4.0	5

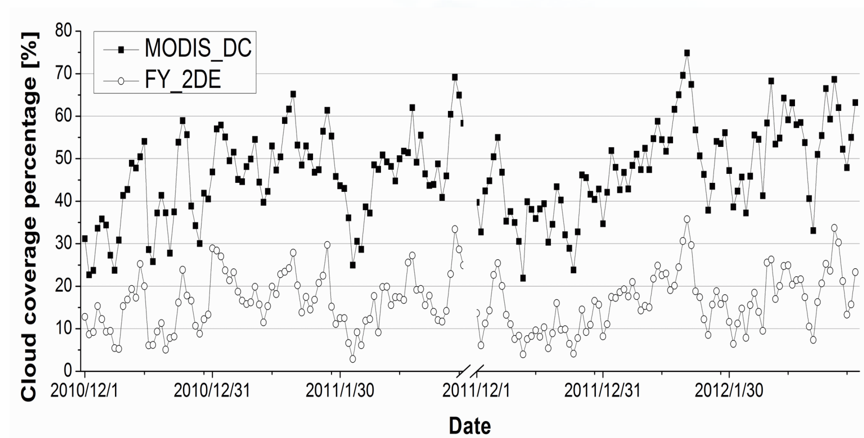


FY-2DE Imager vs. MODIS snow cover









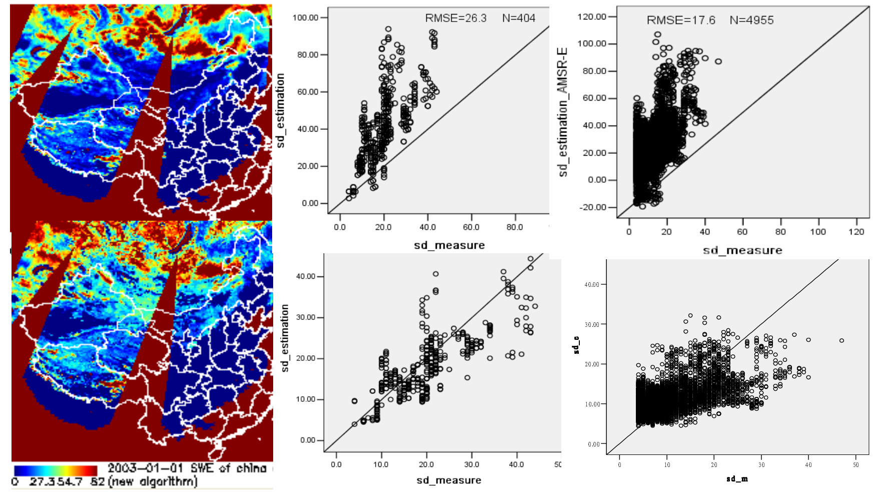
Cloud coverage percentage: MODIS: 46.8%; FY-2DE: 16.3%

Problems in SWE inversion

- **Passive microwave（~25km):**
  - **SMMR**
  - **SSM/I**
  - **AMSR-E**
  - **AMSR2**
  - **FY-3**

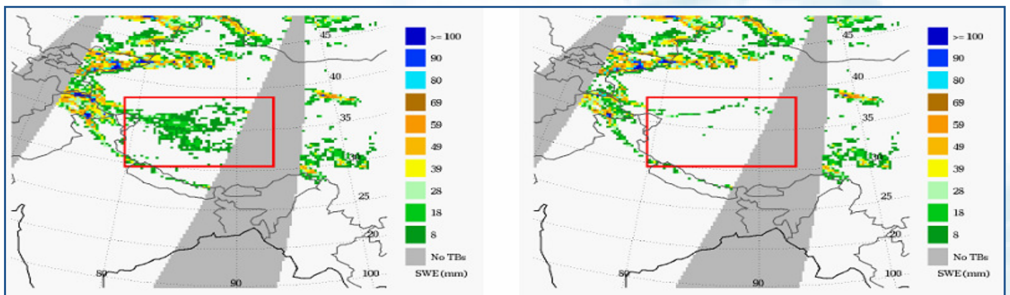
AMSR-E B04 product (no pixel mixing decomposition)

Our algorithm(with pixel mixing decomposition)



$$SD(SWE) = a + b \cdot \left(T_{Bp}(18) - T_{Bp}(37)\right)$$

1. Semi-empirical algorithm: Regional differences, inconsistent accuracy globally
2. Vertical inhomogeneous (layered snow), changes in snow characteristics
3. Atmospheres
4. **Insufficient spatial resolution, horizontally in homogenous of snow (mixed pixel)**



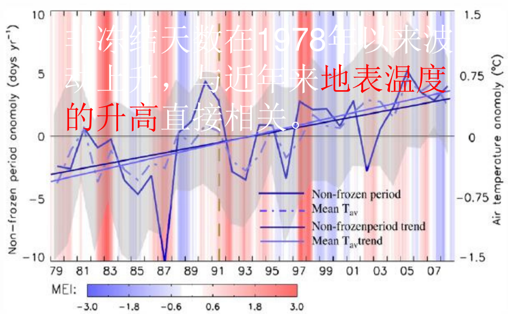
Result of atmospheric correction, November 29, 2003. SWE derived from uncorrected AMSR-E (left) and corrected AMSR-E (right).

Need : The improvement of snow observation

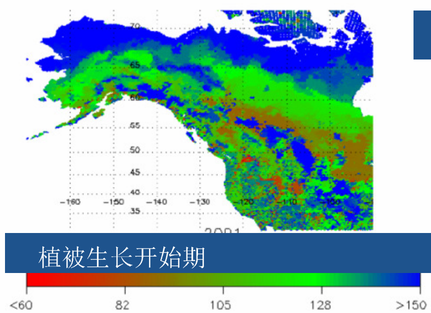
Freeze-Thaw Process in Water Cycle

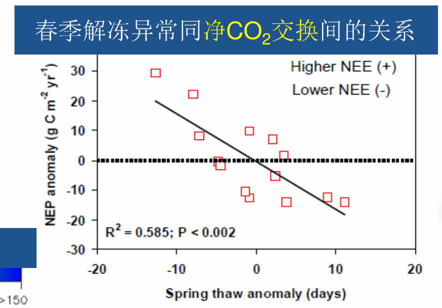
Freeze-Thaw: Sensitive factor of climate change; Great amount of latent heat changes during Freeze-Thaw process, and have impacts on land-atmosphere interactions (evapotranspiration and carbon release); Frozen soil: Increasing runoff due to rainfall and snowmelt.

1. Climate change research

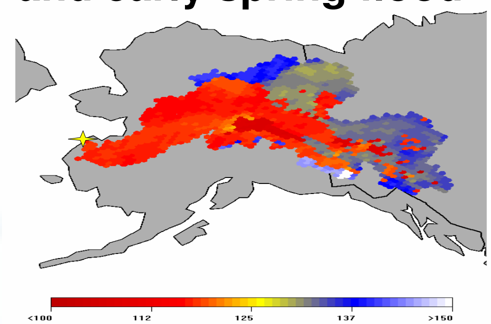


2、Carbon cycle research





3、Hydrological forecast and early spring flood



Permafrost in high latitude areas: determinational impacts on water and greenhouse gasses storage and release

Key Science Questions:

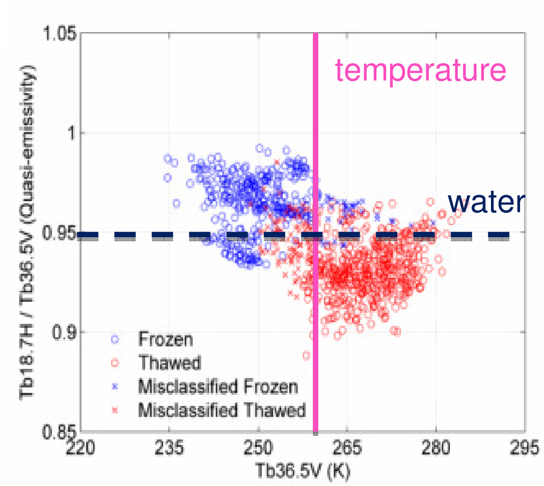
Global Freeze-Thaw spatial-temporal distribution →

1）Its spatial-temporal distribution characterstics?

2） How does it influences the strength of land evapotranspiration and runoff? Does it change?

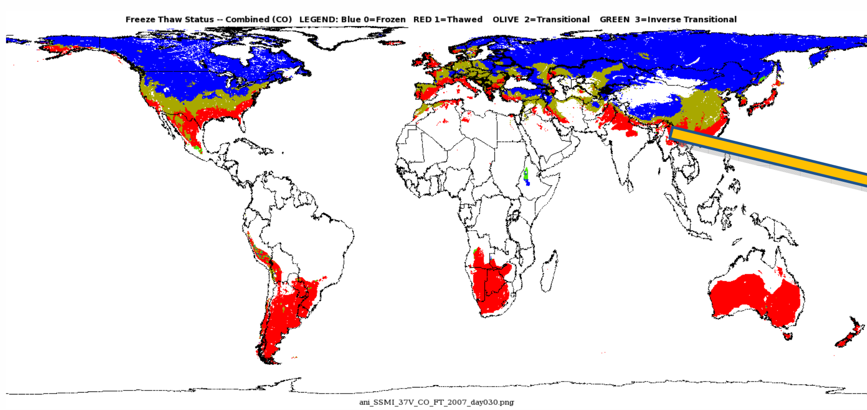
Problems in Freeze-Thaw monitoring

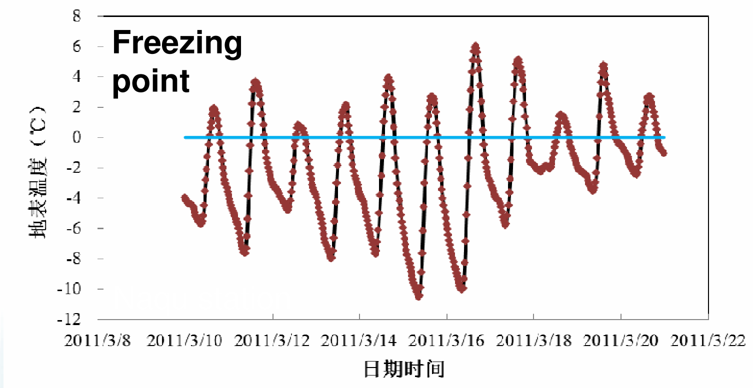
- **Ka band radiometer:**
  - **SMMR (1978-)**
  - **SSM/I (1987-)**
  - **AMRS-E (2002-2011)**
  - **AMSR2 (2012-)**



1. Rely on the indication of temperature using Ka band; Insufficient indication of water-state transition: Need L band for more sensitivity

Freeze-thaw state monthly
SSM/I (37GHz, 25km Res.) 2007





2. Problem of resolution: in seasonal frozen soil area, land surface temperature is not consistent in passive microwave scale, need higher resolution observations

Need: high resolution observations!

Problems of Current Observations

1、Lack of synergistic observations on the other affecting factors the retrieval of water cycle components

2、Lack of systematical observations on the water cycle components that are related to each other

Parameters	Weakness in instrument capability	Weakness in Inversion
Soil Moisture	Weak penetration for high freq.; lack of temperature for low freq. ; RFI	Lack of valid inversion technique on vegetation and surface roughness
SWE	Low spatial resolution for passive microwave	More considerations needed for snow process and atmosphere conditions
FT	Low spatial resolution for passive microwave	Limited validity for using fixed Threshold values
Sea Salinity	Lack of temperature and atmosphere observations	Lack of surface roughness correction
Sea Evaporation	lack of simultaneous observations on both sea surface and atmosphere	Uncertainties in the inversion of related parameters
Precip.	Cloud 3D properties	Need to Discern rain and snow

Payloads and Configurations

1. FPIR, Full Polarized Interferometric Radiometer: Soil Moisture and Sea Salinity

2. DFPSCAT, Dual Frequency Polarized Scatterometer: SWE and FT

3. PMI, Polarimetric Microwave Imager, 6.8～150GHz: Temperature, vapor, precipitation and atmosphere correction, bridge to current & historic data

Payloads	FPIR	PMI	DFPSCAT
Frequency（GHz）	L, S ,C (1.4,2.4,6.8)	C~W (6.8,10.65,18.7,23.8,37, 89,150)	X, Ku (9.6,14/17)
Spatial Resolution（km）	L: 50, S: 30, C:15	4~50（frequencies）	2~5（processed）
Swath Width（km）	>1000	>1000	>1000
Polarization	Full-Pol	Full-Pol	Full-Pol
Sensitivity	0.1~0.2K	0.3～0.5K	0.5dB
Temporal Resolution（Day）	2～3	2～3	2～3

Advantages for SWE inversion

- **DFPSCAT**

Dual-frequency full-polarizations: Different sensitivity of snow scattering in X and Ku; Co-pol and Cross-pol backscattering's different sensitivity to volume scattering and surface scattering

High spatial resolution: Reducing the effect of horizontal inhomogeneous

High temporal resolution: short re-visit cycle for fast snow changing monitoring

- FPIR

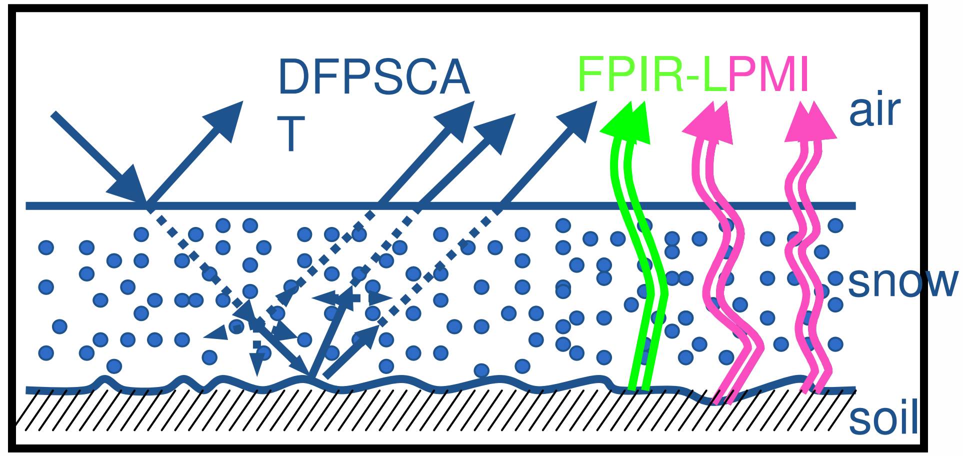
Soil information from low frequency radiometry

- PMI

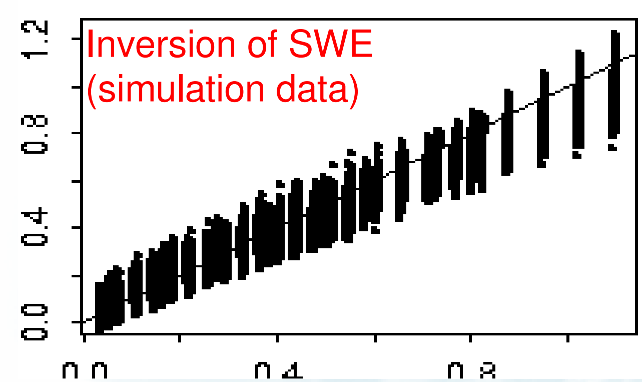
1）SWE inversion from multi-frequency polarized brightness temperature;

2）PMI + DFPSCAT : active and passive

3) Atmospheric correction

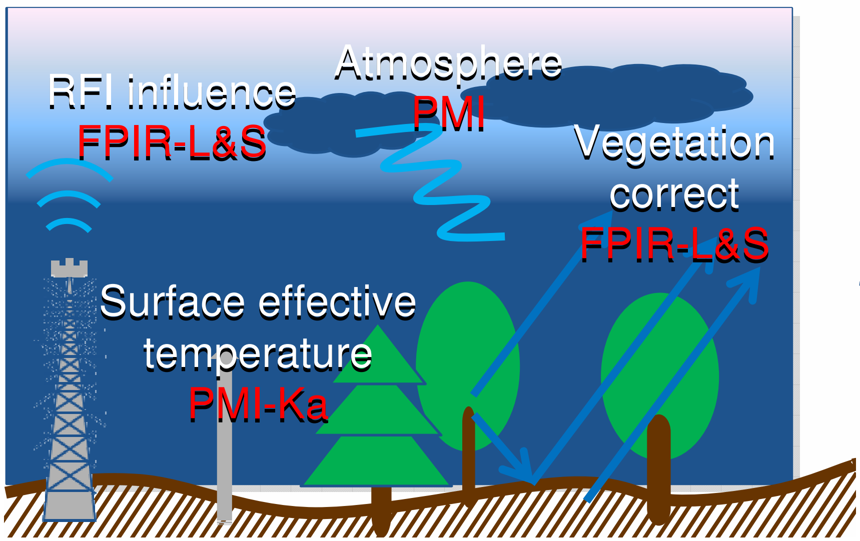


Proposed sensor configuration and quantitative inversion algorithm



No satellite for SWE monitoring for now

Advantages in soil moisture retrieval



- FPIR

1）Combination of L- and S-band can solve the polarization effects in vegetation correction.

2）The probability of RFI occurrence at the same area and frequency is vary small. RFI can be avoid by switching L- and S-band .

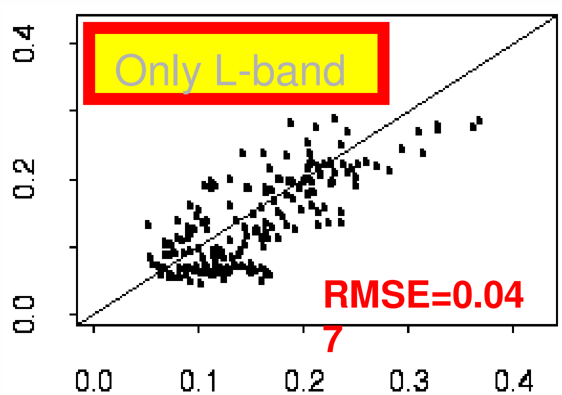
- PMI

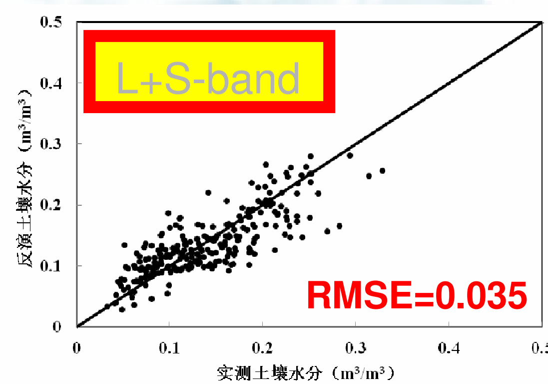
Surface effective temperature

- DFPSCA

Vegetation information of high resolution

Various vegetation types





Summary on Advantages of Payloads Design

	FPIR	PMI	DFPSCAT
Soil Moisture	1 More sensitive to land surface 2 Minimizing vegetation effects 3 Mitigating RFI	1 Sensitive to temperature 2 Observing large-scale surface roughness	1 Surface Roughness and vegetation 2 high resolution soil moisture
Sea Salinity	1 More sensitive to sea surface 2 Faraday rotation correction	1 effective correction on atmosphere 2 ensitive to sea temperature	High resolution Wind Vector
Sea Evaporation	Corrections on sea surface roughness	Sensitive to temperature	High resolution Wind Vector
FT	Obtaining Soil Surface Parameters	Sensitive to temperature changes	1 Time series techniques for FT detection 2 Downscaling techniques for FT inversion
SWE	Obtaining Soil Surface Parameters	Obtaining SWE by scattering effects	1 Estimating SWE 2 Mitigating Mixed pixel effects
Vapor and Precip.	Helping determine land surface emissivity	1）obtaining Water Vapor 2）Precip. Rate 3）Discerning Rain and snow	High resolution observations on precip.

The Payloads Design: 1）Optimal channels for inversion，2）Effective corrections on affecting factors，3）Simultaneous observations

Vital

major

help

Precipitation Satellite of FY-3 Series

For the FY-3 precipitation satellite, the main objective is to improve the observation of precipitations and the monitoring and forecast of floods for disaster mitigation purpose. It also aims to provide precipitation data for climate change research.

Orbit: non sun-synchronous circular

- **Altitude: 407km**
- **Inclination: 50degree**

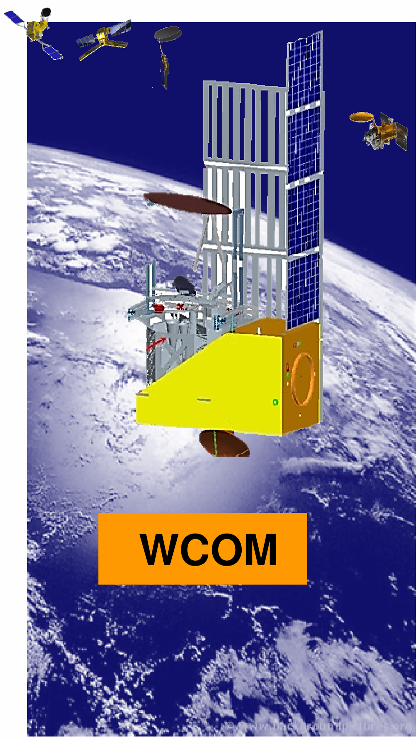
5 Payloads

- **Precipitation Radar (PR)**
- **Microwave Radiometric Imager (MWRI)**
- **Microwave Temperature Sounder (MWTS)**
- **Microwave Humidity Sounder (MWHS)**
- **Optical Imager (0.6-12.5um, 7 channels)**

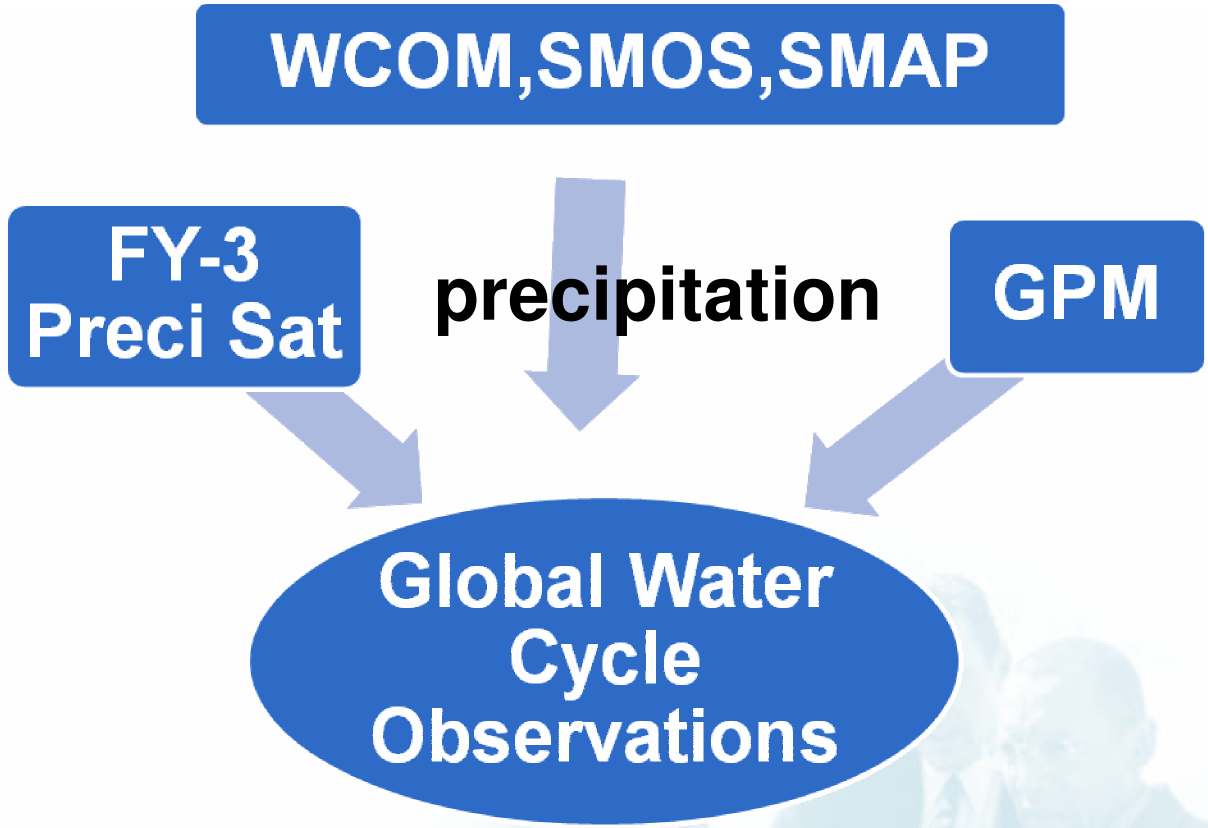
Dual-Frequency Precipitation radar

Parameters	Specifications	
Frequency	Ku	Ka
Polarization	HH	HH
One-way -3dB beamwidth	0.7° ± 0.02° (for 5km nadir resolution	
Range resolution (-6dB)	⩽ 250m	
Scanning mode	Across-track one dimensional	
Mininum detectable preciptation rate	0.5 mm/h (18dBZ)	0.2 mm/h (12dBZ)
Dynamic range	⩾ 70 dB	

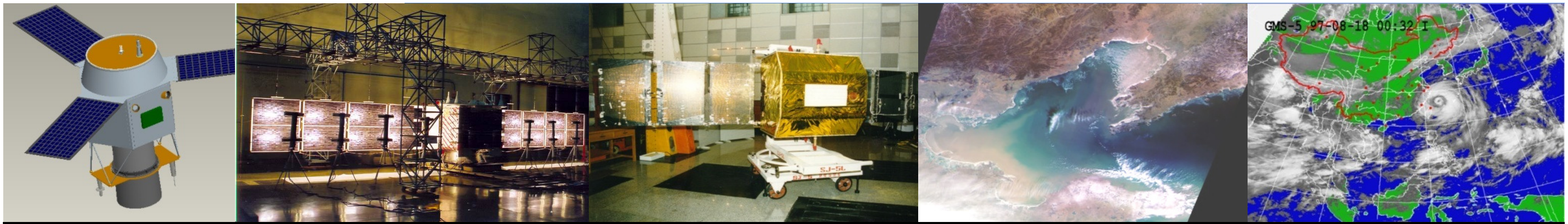
GEOSS : International Collaborations



Earth surface components



Form a global water cycle consolidation



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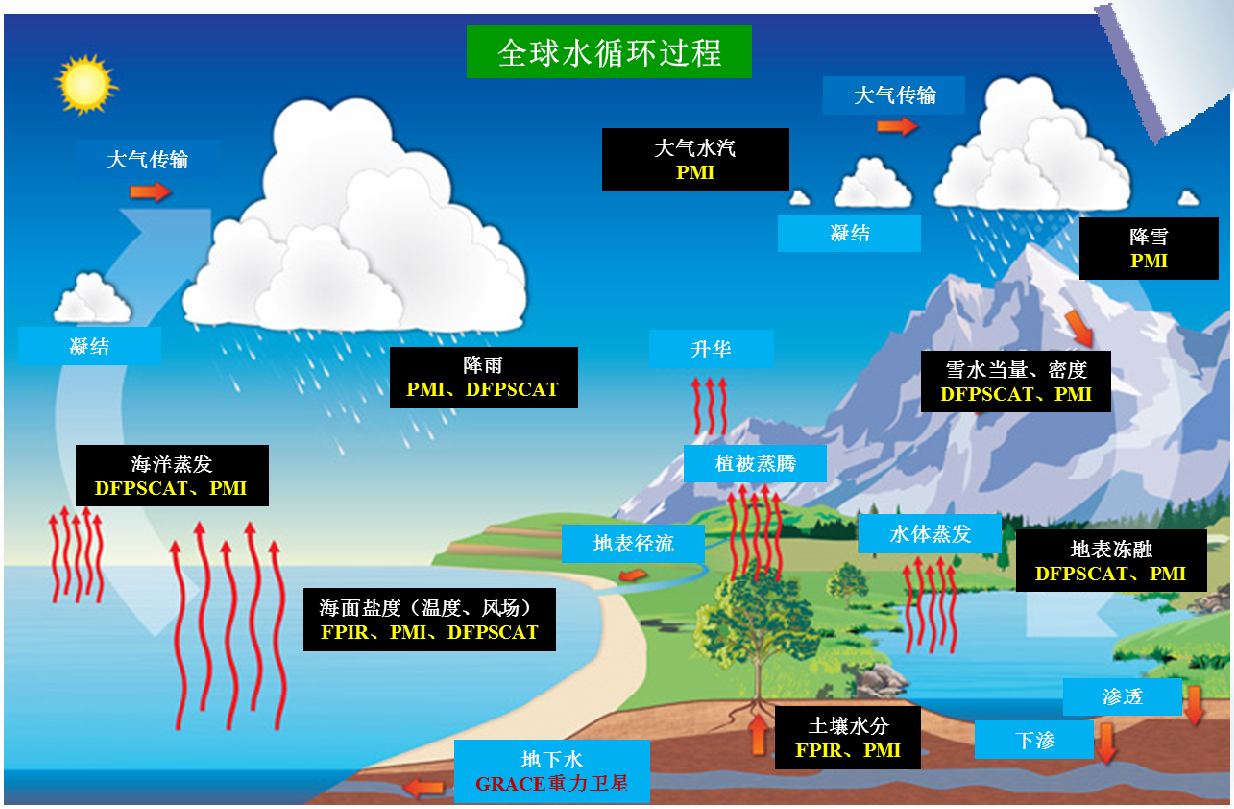

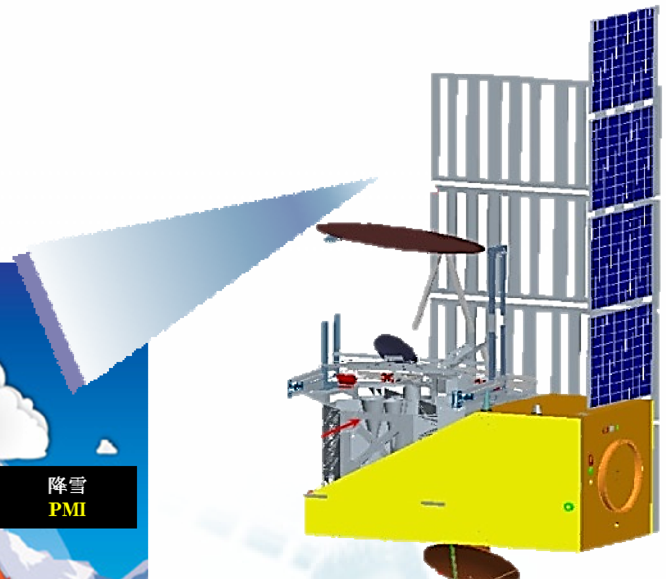

WCOM

Innovations

The first mission for combined active and passive microwave measurements on key water cycle components of land, sea and atmosphere

Systematic Observations

1. Advanced Sensors
2. Accurate Inversion
3. Systematic observations

Scientific questions:

The coupling of key water cycle components and the feedbacks to global changes

Improvement on understanding of global changes and Earth system science