The 9th GEOSS Asia-Pacific Symposium
Earth Observations Supporting the Implementation of the SDGs in the Asia Pacific Region

A Water Cycle Observation Mission （WCOM）

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Outline

1. Background
2. Payloads Design
3. Phase A research
4. Cooperation and Expectation

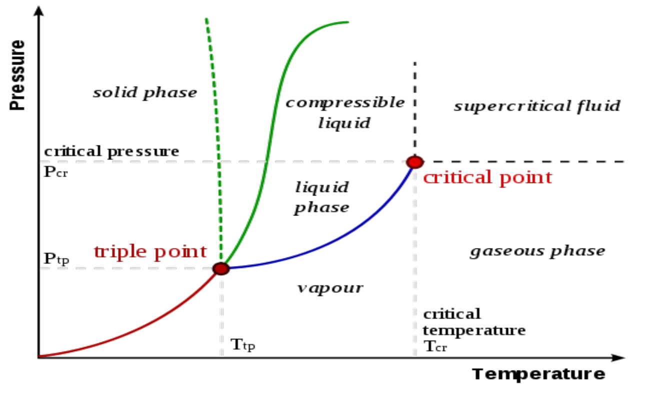
Water Cycle & Climate Change

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.

Clausius-Clapeyron_Equation

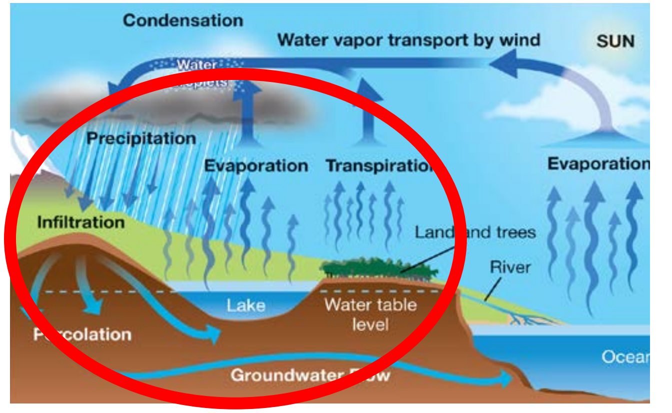


Expectations: ⇩ drizzles, ⇧ storms, ET, speed of water cycle, therefore, hydrological extreme events

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?



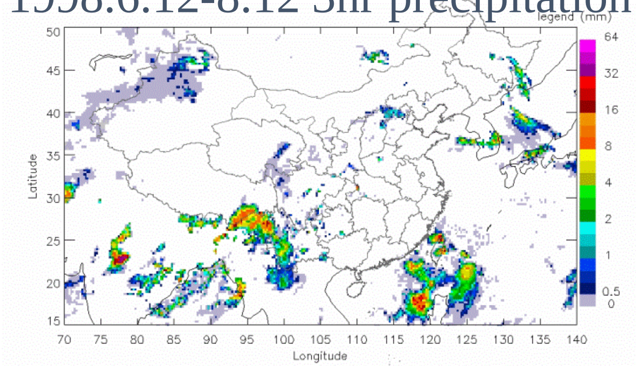
Importance of Water Cycle

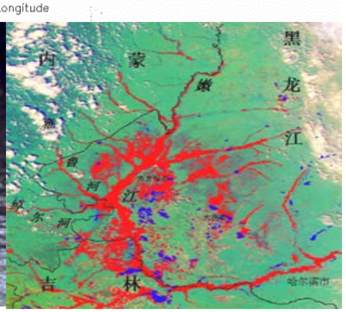
Application Linkage

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

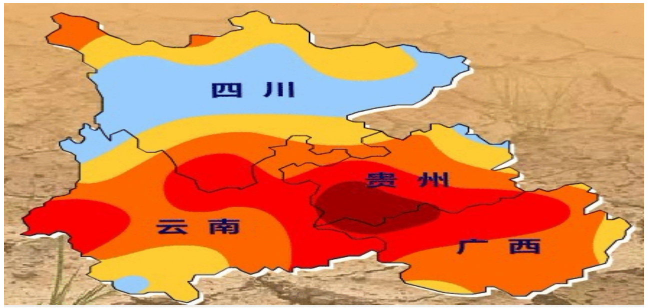
1998 flood event in China

1998.6.12-8.12 3hr precipitation





2010 drought monitoring in South West China



Available Sensors for Water Cycle

	Sensor	Frequency (GHz)	vapor	Preci.	Temp.	Soil Moisture	Freeze Thaw	SWE	Sea Salinity	Sea Surface wind
Multiple Frequency Sensor	AMSR-E	6.925;10.65;18.7;23.8;36.5;89	√	√	√	√	√	√		√
	GCOM/AMSR2	6.9;7.3;10.65;18.7;23.8;36.5;89	√	√	√	√	√	√		√
	FY-3/MWRI	10.65;18.7;23.8;36.5;89	√	√	√	√		√		
	SMMR	6.6;10.7;18;21;37	√		√		√	√		√
	SSM/I	19.35;22.235;37.0;85.5	√	√	√		√	√		√
	TRMM/TMI	10.65;19.35;21.3;37;85.5		√						√
	WindSat	6.8;10.7;18.7;23.8;37	√	√						√
	SSMIS	19.35;22.235;37;50-60;91.655;150;183.31	√	√	√			√		√
Single Frequency Sensor	ASCAT	5.255								√
	ERS	5.3								√
	QuikSCAT	13.4								√
	Aquarius	1.413							√	
	SMOS	1.41				√			√	
	SMAP	1.26; 1.41				√	√			

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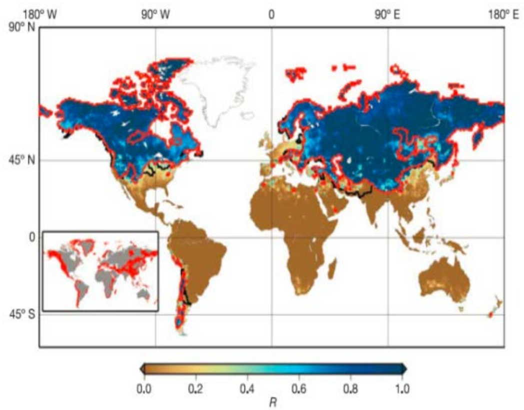
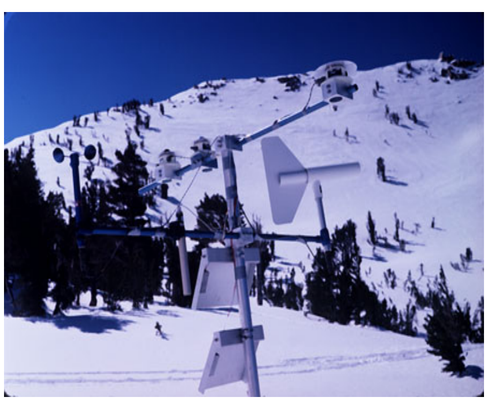
Importance of snow in water cycle research



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 ?

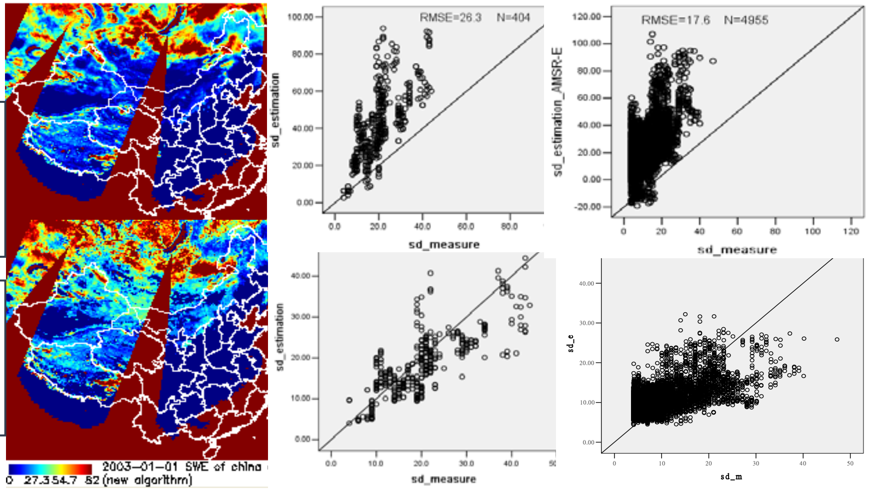
3） what is the impact on global and regional water resources ?

Problems in SWE inversion

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

AMSR-E B04 product (no pixel mixing decomposition)

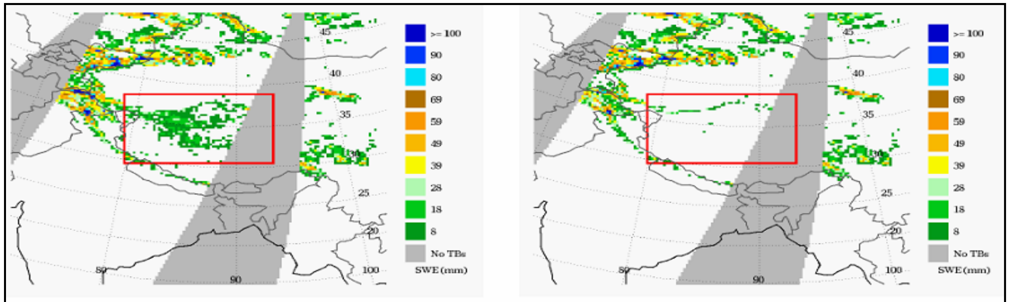
Our algorithm (with pixel mixing decomposition)



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

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).

<u>Need:</u> **Spatial observation capacity**

Problems of Current Techniques

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	Disadvantages in Observations	Disadvantages 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 of 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

Characteristics of the Spatial-Temporal Distribution of Water Cycle Components

Hydro-climatology 50-100km，Hydro-meteorology 4-15km resolution

Strong Variability in Time:

- Precip./vapor
- Ocean Evaporation

Strong Variability in Space:

- FT
- SWE
- Soil Moisture

Weak Variability :

- Sea salinity
- Polar Ice

Water Cycle	Temporal Resolution	Ideal Spatial Resolution	Minimum Requirement	Obs, Error
Precip./vapor	1-2hour	1km	25km	1 mm hr-1
Sea Evap.	1-2hour	10km	25km	15 W m-2
Soil moisture	2-3day	100m-1km	50km	0.04 m^3/m^3
Sea salinity	10-30day	10km	100km	0.1-0.2 psu
FT	2-3day	100m-1km	50km	10-20 %
SWE	2-3day	100m-1km	50km	10 %
Water body	3-7day	30m	1km	1000 m2
Underground water	1month	50km	300km	~
Land ET	1-2hour	30m-1km	5km	30 W m-2
runoff	1-2hour	~	~	~

Process model improvement from observations

1、Parameter optimization using single-element observation

Case	Changes in model performances			
	Soil temperature	Soil moisture	Sensible heat flux	Latent heat flux
soil temperature observation	21. 99%	−41. 87%	11. 13%	−46. 08%
Soil moisture observation	−0. 46%	10. 85%	1. 15%	1. 29%

Test experiments by CoLM demonstrate that: the model error will transfer to another state variables when only one state is optimized by using single-element observation

2、 Parameter optimization using multi-element observation

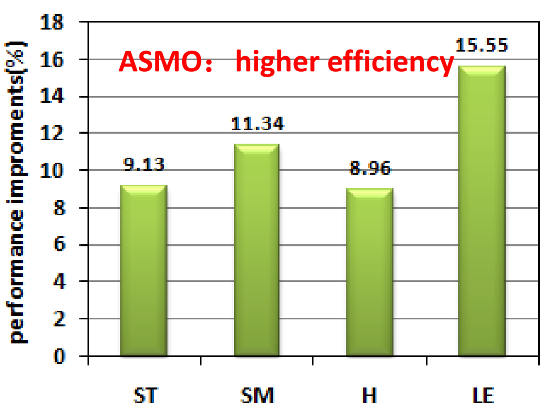
Parameter Selection
Select the most sensitive and controlling parameters

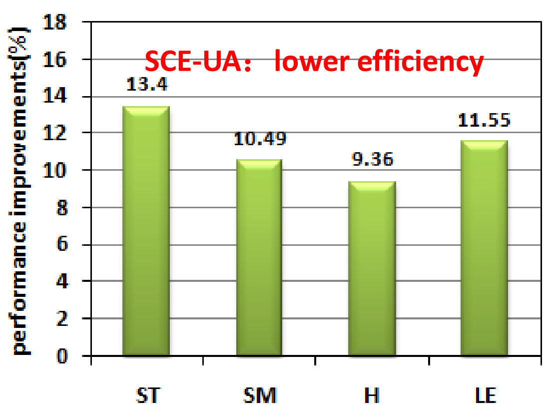
→

Building Surrogate Models
Building statistical models to surrogate the physical models

→

Multi-Object Optimization

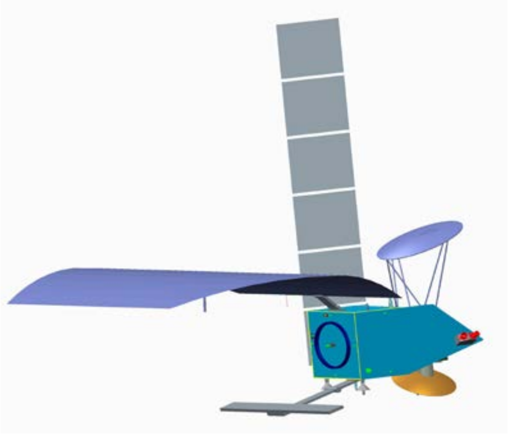




Simultaneous multi-parameters optimization provide a much better chance for the model improvement

Payloads and Configurations

- 1. IMI， Full Polarized Interferometric Radiometer： Soil Moisture and Sea Salinity
- 2. DPS, Dual Frequency Polarized Scatterometer： SWE and FT
- 3. PMI, Polarimetric Microwave Imager， 6.8～89GHz： Temperature, rain, water vapor , atmosphere correction, and bridge to historical data



Payloads	IMI	PMI	DPS
Frequency（GHz）	L, S ,C (1.4,2.4,6.8)	C~W (7.2,10.65,18.7,23.8,37,89)	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 of WCOM Payloads Design

	IMI	PMI	DPS
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.

Vital major help

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

Outline

1. Background
2. Payloads Design
3. Phase-A research
4. Cooperation and Expectation

Phase-A Objectives

Science part

1）Further evaluation of science objectives; further optimization of payloads, to achieve higher precision water cycle parameters observation than any existing satellites;

2）Based on the simultaneously multi-sensor observation, to achieve joint key water cycle parameters and environmental parameters retrieval, and the preliminary algorithm validation;

3）The study of the method to calibration of historical observations of other satellites based on WCOM observations; Water cycle models parameter optimization;

Technology part

1）Design and evaluation of payloads: FPIR, PMI and DFPSCAT

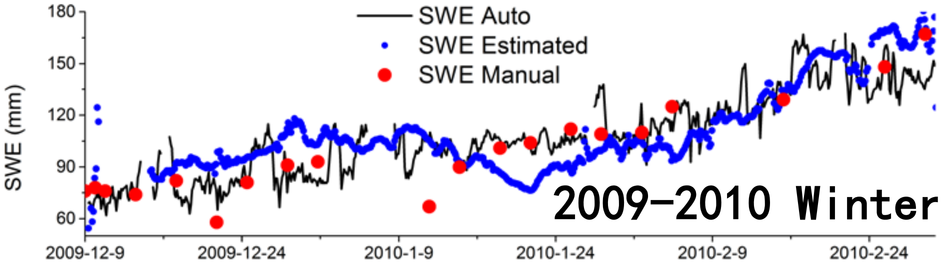
2）To make breakthroughs in key technologies in payloads, and the experimental validation of the key technologies ;

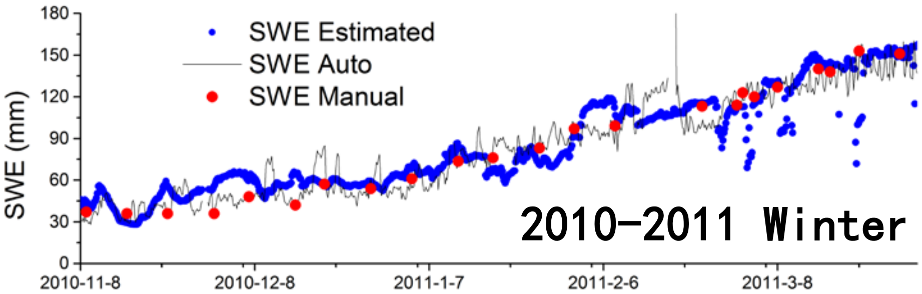
3）WCOM satellite platform design and evaluation based on the requirement of payloads and their observation; Design and evaluation of interface between satellite system and other systems

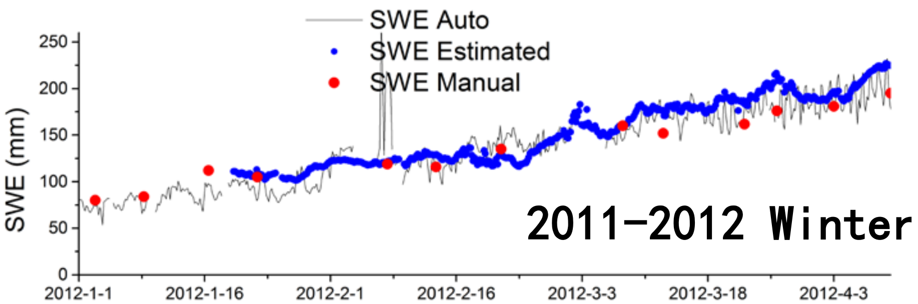
SWE retrieval and Validation

SWE inversion algorithm for DPS scatterometer is developed based on Bicontinuous+VRT model .

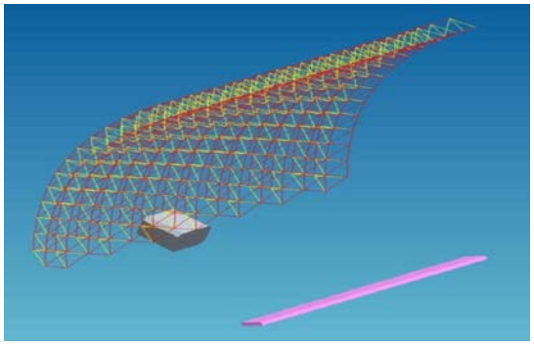
Three-year time series measurements at dual-polarization X and Ku bands in Finland Nosrex campaign.

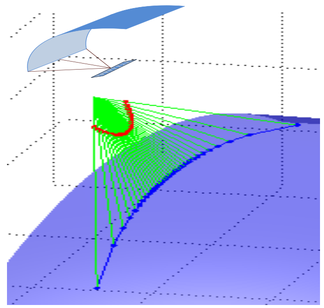






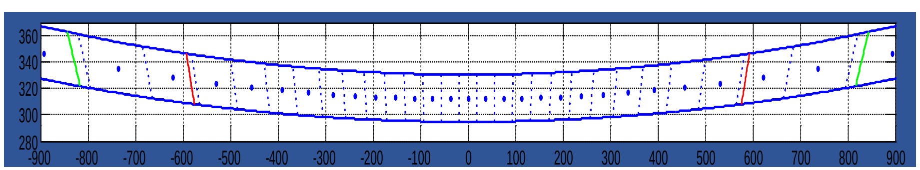
L/S/C Microwave Interferometric Radiometer





Instrument Concept：1D Microwave Interferometric Radiometer with parabolic cylinder reflector antenna

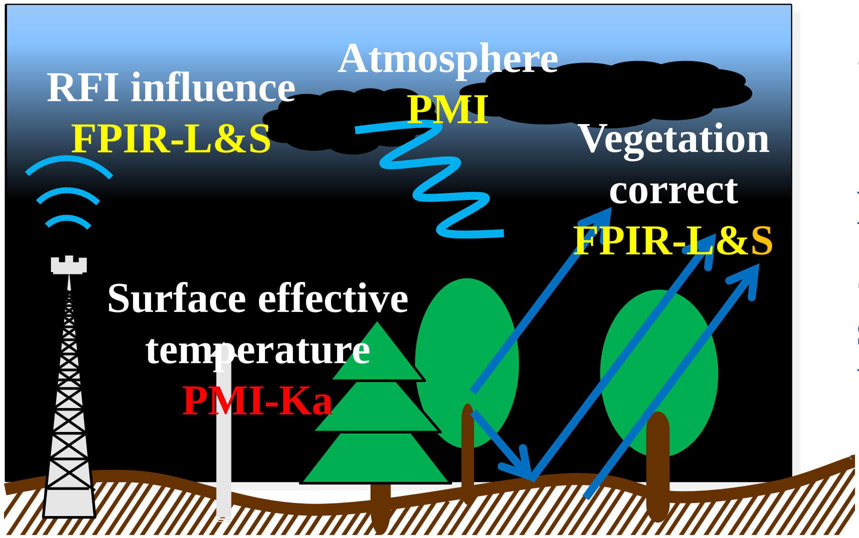
- **Use parabolic cylinder reflector and interferometric technology to achieve High spatial resolution**
- **Patch feeds and shared reflector to achieve the multi-frequency ability**
- **Dual-size feeds to enhance the system sensitivity performance**



Simulated footprints on the ground

system	1D Interferometry + parabolic cylinder reflector
frequency	L：1.4～1.427GHz，S：2.64~2.70GHz，C：6.6～6.9GHz
Sensitivity	L-band：0.1K；S-band：0.4K；C-band：0.4K
Polarization	Full pol（H,V,Q,R）
Antenna size	Reflector:6.0m×6.0m（after deployment）Feed array：4m×0.5m
FOV	>1000km
Incidence	30~55º
Spatial resolution	L-band：50km，S-band：30km，C-band：15km
revisit	2-3 days
weight	250kg
Data rate	< 1Mbps

Advantages in soil moisture retrieval



- **PMI :** Surface effective temperature

- **IMI**

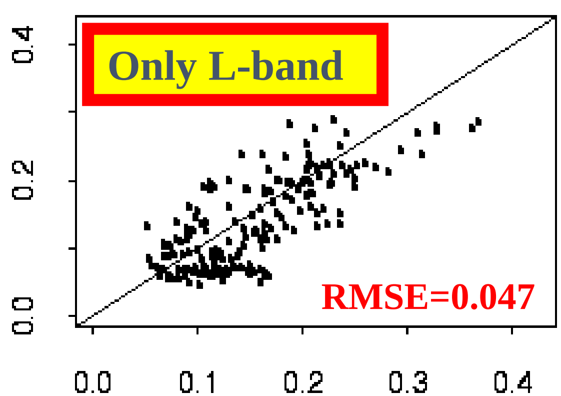
1）Combination of L- and S-band can solve the polarization effects in vegetation correction.

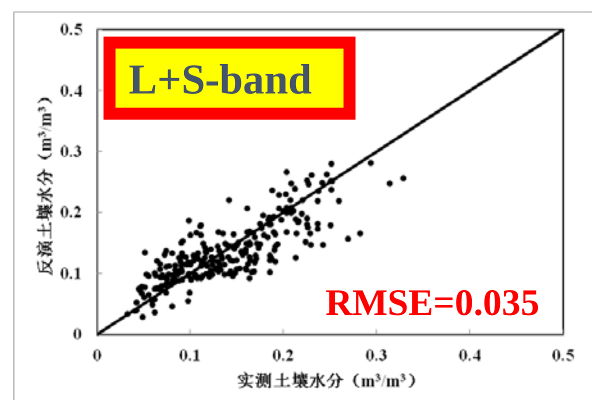
2）The probability of RFI occurrence at the same area and frequency is vary small. RFI can be avoid by switching L- and S-band .

- **DPS**

Vegetation information of high resolution

Various vegetation types





Soil moisture Products

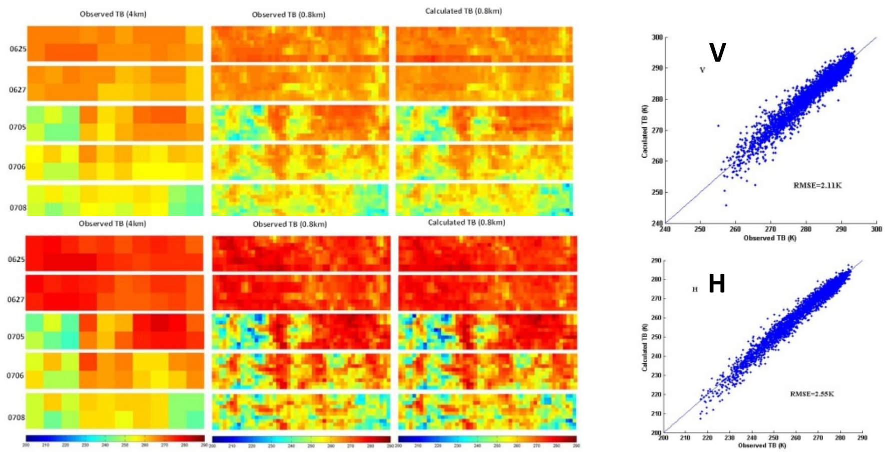
A） Passive microwave (FPIR)

L/S/C-bands: 50/30/15 km

Experiment with Airborne data：

Downscale the L-band Tb (4km) at a scale of 800m using higher resolution Tb of S-band, and its validation with original L-band data

Spectral analysis downscaling method for passive microwave



Passive： Sensitive to soil moisture but low resolution

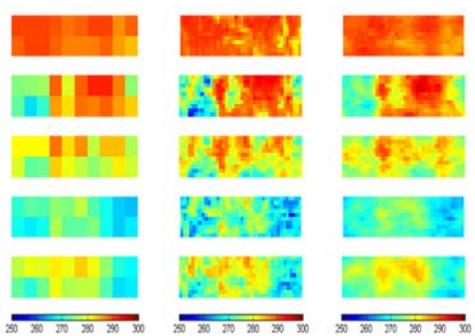
Active： High resolution but sensitive to vegetation and roughness

B） Active/passive microwave (FPIR/PMI+DFPSCAT)

$$T_{Bp} = A + C\frac{\sigma_{vh}^{t}}{\bar{\sigma}_{vh}^{t}} + \left(B + D\frac{\sigma_{vh}^{t}}{\bar{\sigma}_{vh}^{t}}\right)\sigma_{pp}^{t}$$

Active /passive combination of C and X band：

Downscaling using both active and passive



Products： Soil moisture estimates at a scale of both 15km and 5km (research) over nominal areas and 30km over forests.

WCOM data simulator

Dynamic forcing data module

WCOM payloads configuration

Land/Ocean/Atmosphere radiative transfer and backscatter modelling

1. FPIR/PMI Brightness temperature
2. DFPSCAT Backscatter coefficient

Satellite orbit, Sensor gain function, footprints and resampling

Initial WCOM data

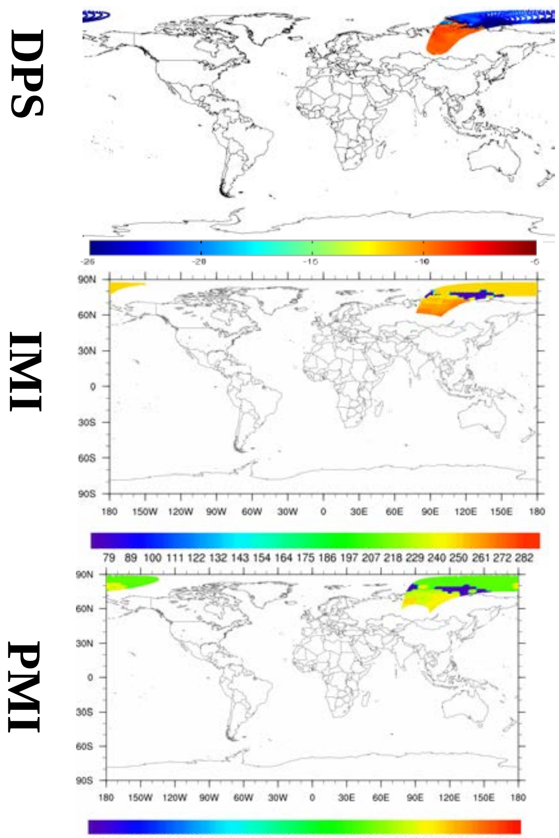
Calibration with current satellites (SMOS/SMAP, AMSR2, etc)

Final WCOM data

2) Evaluate instrument error on science requirements

3) Parameter optimization of hydrologic model

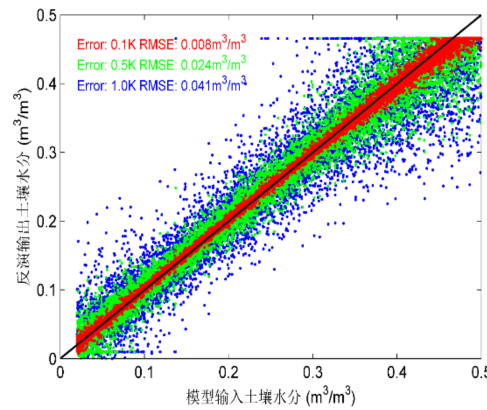
1）Retrieval algorithm development and validation



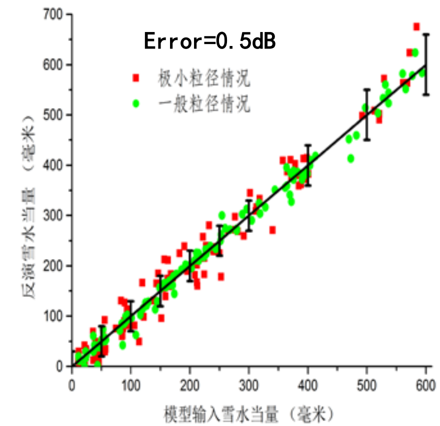
Science Requirements for Instrument Error

Analysis of Effect of Payload observational error on parameters inversion accuracy

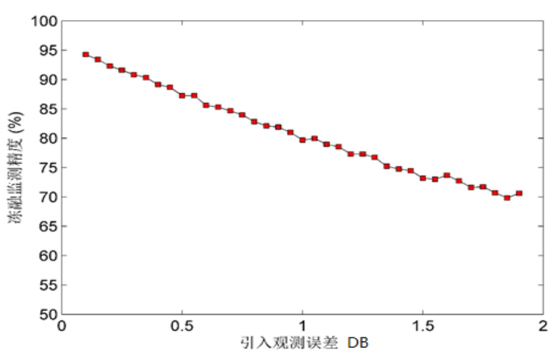
Parameters	Instrumental error	Retrieval RMSE
SWE	<0.5dB	<10%
Soil Moisture	Observed Tb <1K	<0.04m3/m3
SSS	observed Tb: L band <0.2K, S band<0.5K, C band<0.4K	< 0.2psu/week
Freeze-thaw State	< 1-0.5dB	classification accuracy>80-90%
Precipitation	observed Tb <3K	<0.4mm/hr



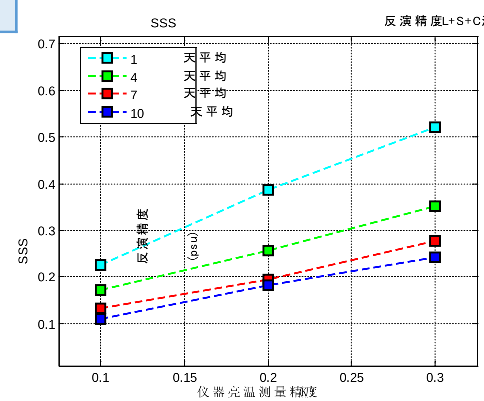
Analysis of the effect of instrument observation error on soil moisture inversion accuracy



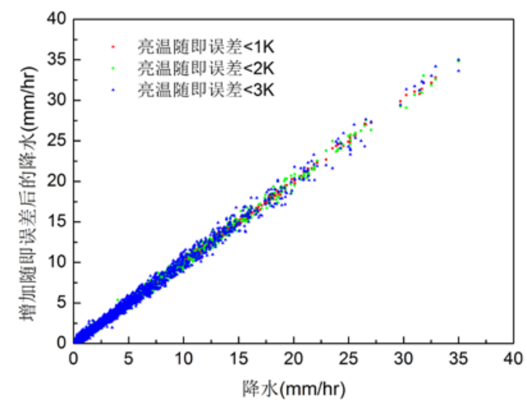
Analysis of the effect of instrument observation error on SWE inversion accuracy



Analysis of the effect of instrument observation error on freeze-thaw monitoring inversion accuracy



Analysis of the effect of instrument observation error on SSS inversion accuracy



Analysis of the effect of instrument observation error on precipitation inversion accuracy

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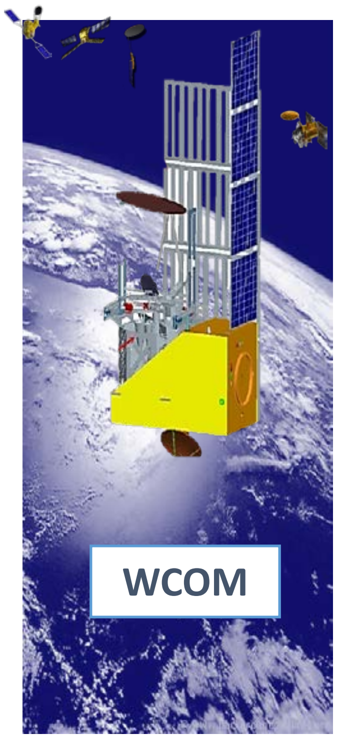
Progresses of WCOM

- 2013, WCOM was selected as one of 8 candidate science driving missions to be launched before 2020; It is only one that for EO in China.
- 2014-2015： Phase-A to study key technologies;
- In Feb., 2015, 3 from 8 candidate missions were selected as the key support missions with full funding for 2014-2015. WCOM is one of them;
- WCOM is now under the engineering defense;
- Launch date 2019-2020

International Collaborations



WCOM,SMOS,SMAP

FY-3 Preci Sat

GPM

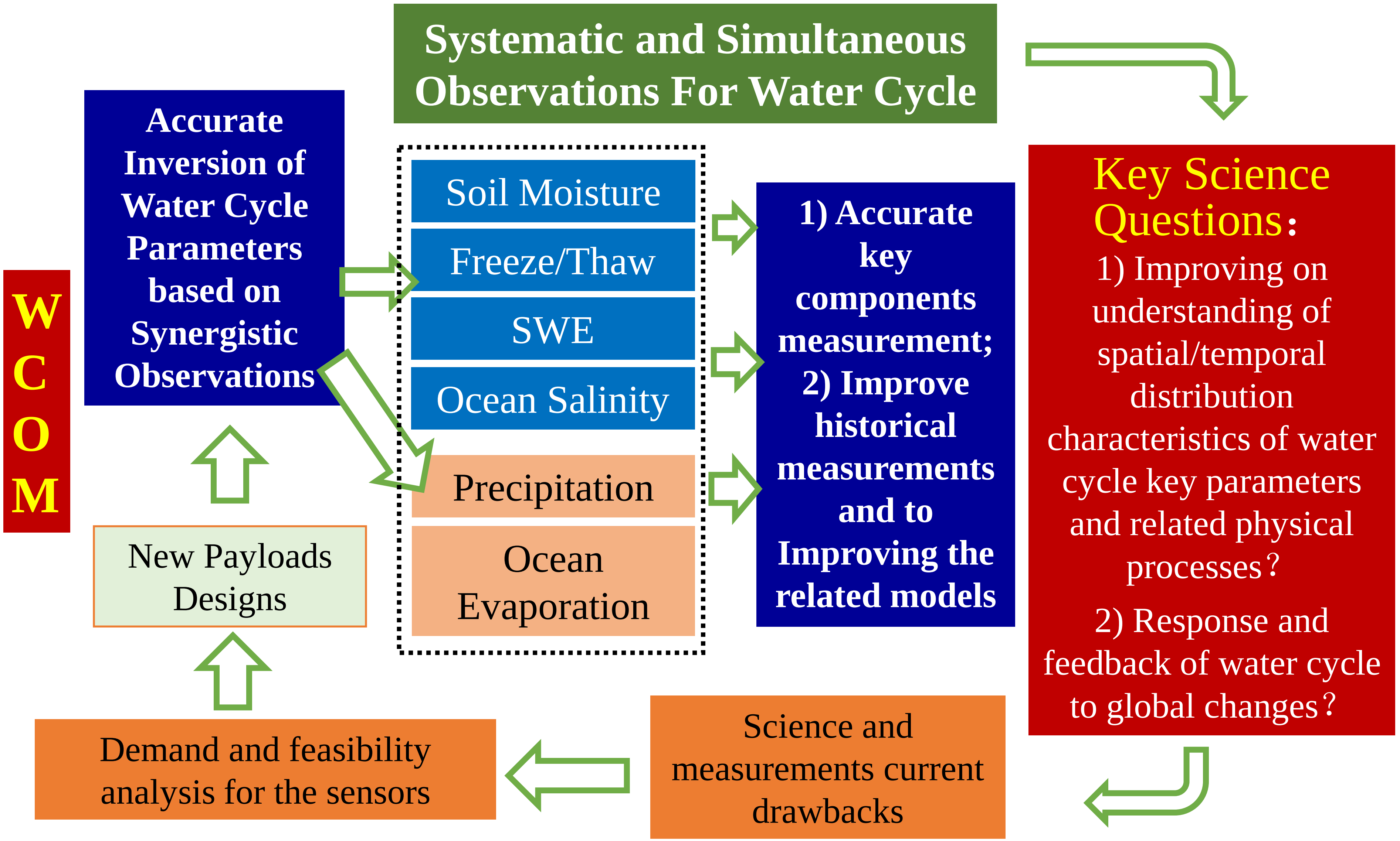
Global Water Cycle Observations

Ocean Salinity, Water Resource Sat(s)

SWOT, GRACE

Form a global water cycle consolidation

Water Cycle Observation Mission (WCOM) Summary



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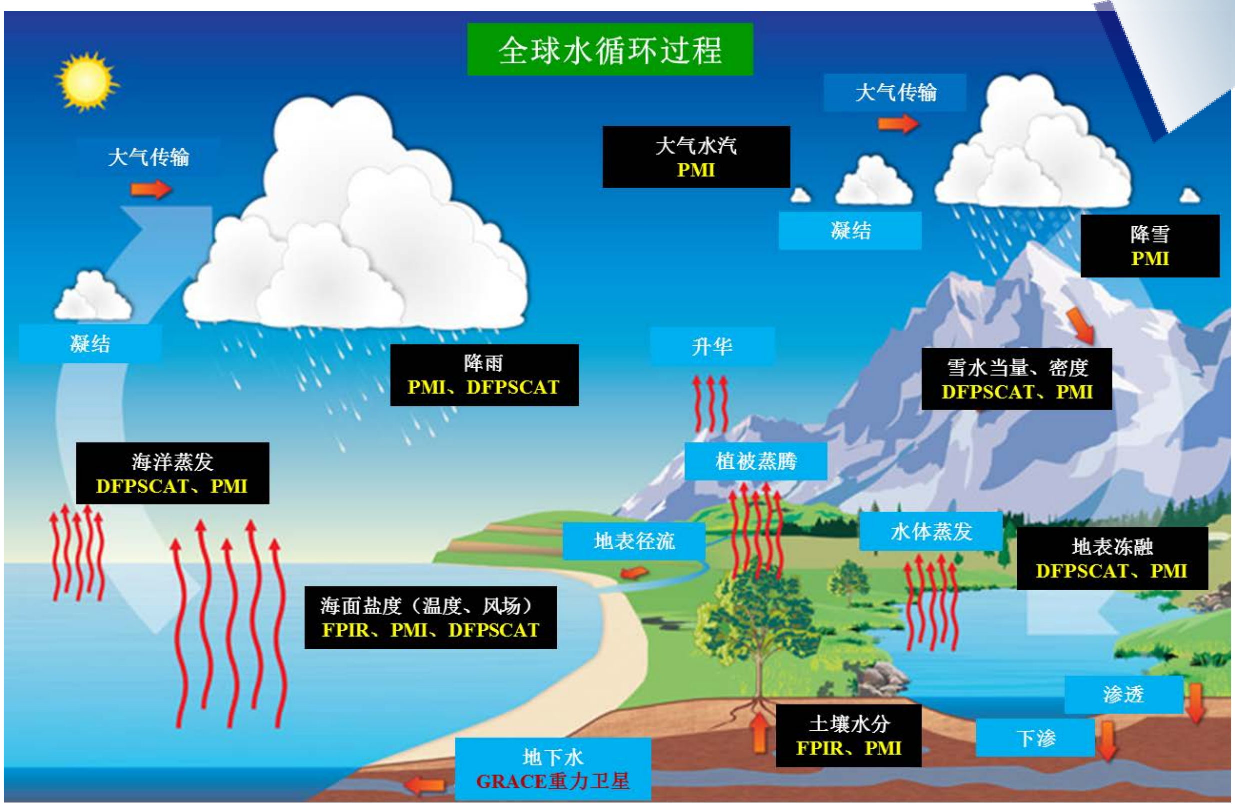

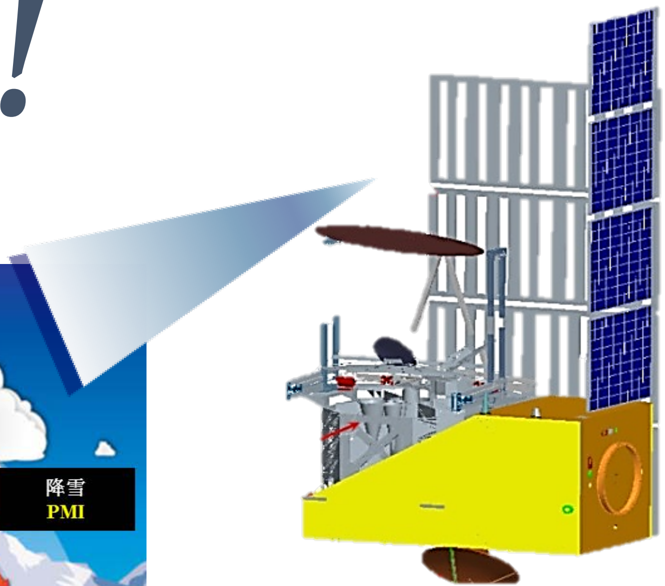

WCOM
(Welcome)