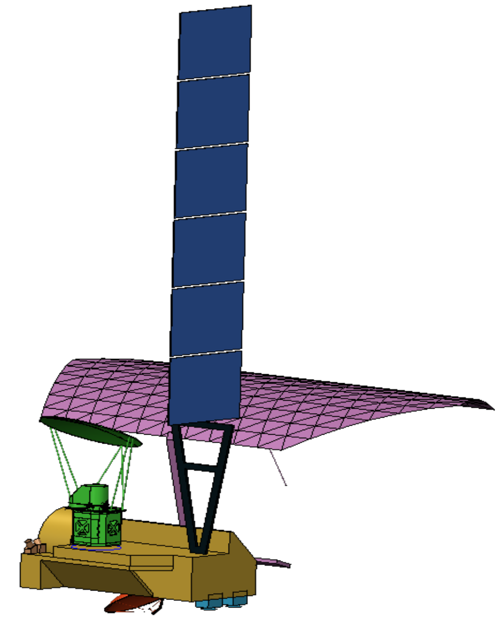
Water Cycle Observation Mission (WCOM) and Its Potentials for Ocean Surface Wind Vector Measurement



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WCOM: Briefs

- Science mission supported by the **Strategic Priority Project on Space Space** of Chinese Academy of Sciences
- Jointly proposed by State key Laboratory of Remote Sensing Science (SKLRSS) in the Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences (RADI, CAS) and MiRS in NSSC, CAS
- Co-PIs: JC Shi, XL Dong
- 2013: selected as one of 8 candidate science missions to be implemented in the 13th five-year-plan (2016-2020)
- 2014: mission definition-science objectives and mission design, payload configuration and design
- 2015-2016: intensive pre-study: mission design, development and verification of key enabling technologies

Outline

- Objectives and mission concept
- Payload configurations and mission design
- Potentials for ocean surface wind vector measurement
- Future development and implementation plan

Scientific Significance of Water Cycle

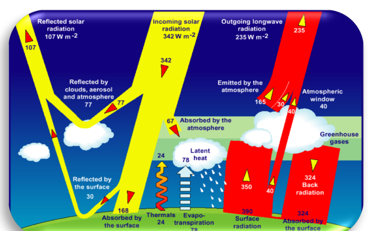
Roles of water in earth system:

1) Phase changing affects energy cycle
2) Major carrier and forces of mass cycles
3) Vital role for ecology system

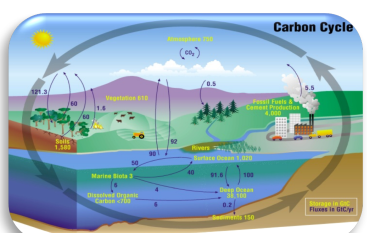
Water cycle global and regional distribution changes

changes of landscapes, ecosystems and human activities and also affect interiority of the earth

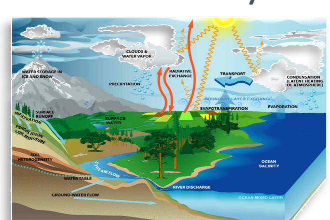
Energy cycle



Bio-chemical cycle



Water cycle

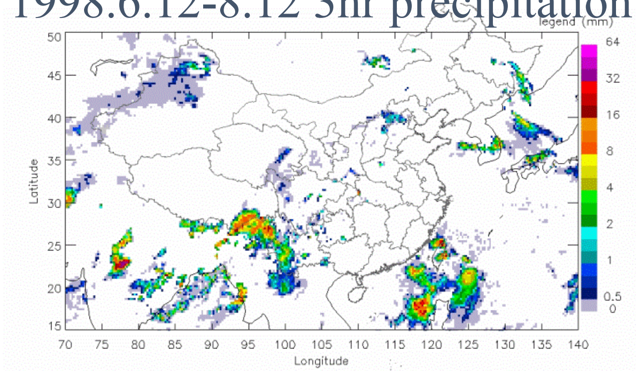


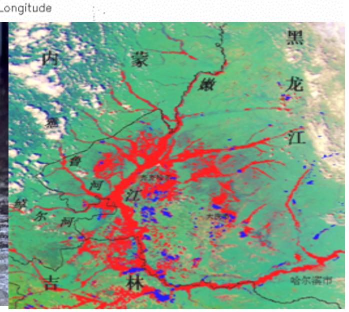
Application Significance of Water Cycle

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

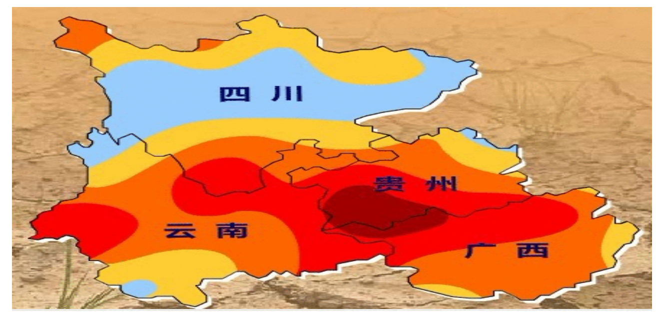
1998 flood event in China

1998.6.12-8.12 3hr precipitation





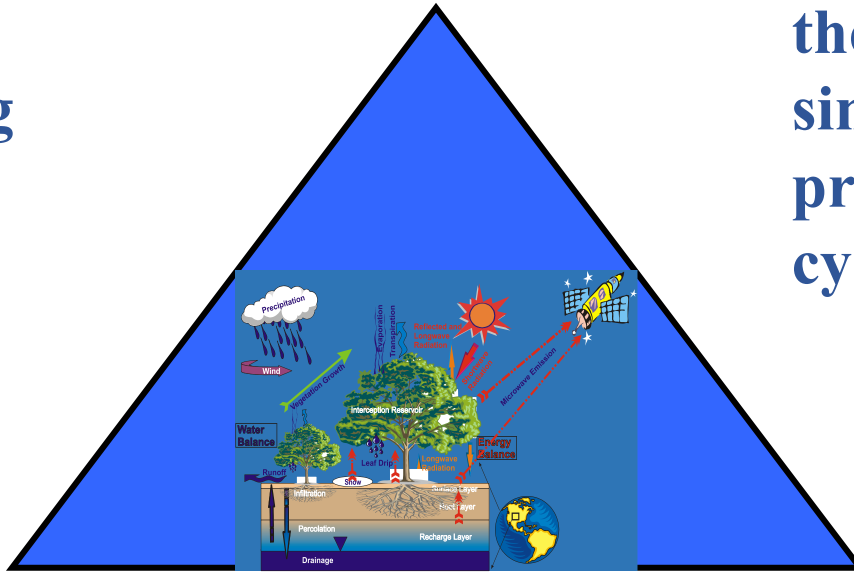
2010 drought monitoring in South West China



Observations and Modeling of Water Cycle

Observation is the key part for understanding sophisticated water cycle processes

Modeling represents the ability of simulation and prediction of water cycle processes



Observation **Model**

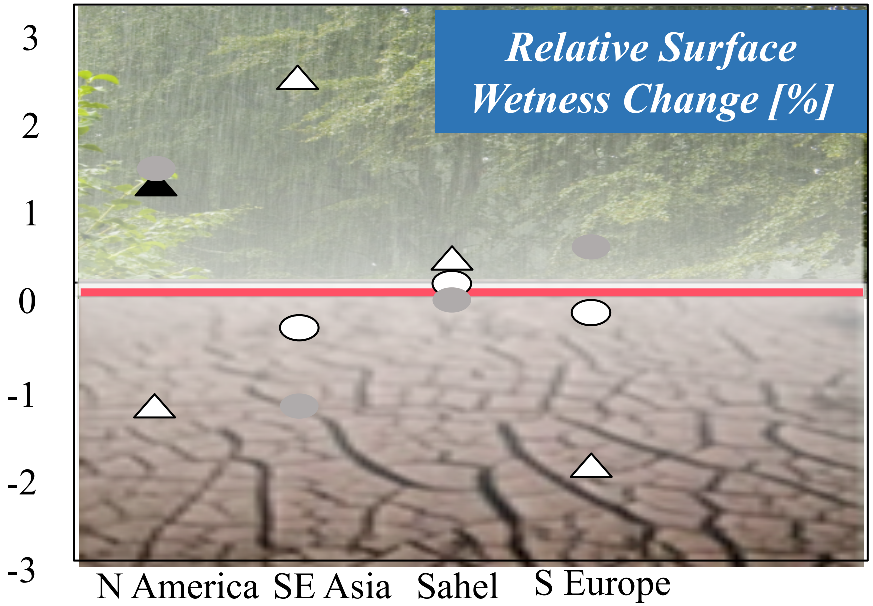
To support model improvement requires:

Accurate measurements of water cycle components and synergetic balanced observations of water cycle system

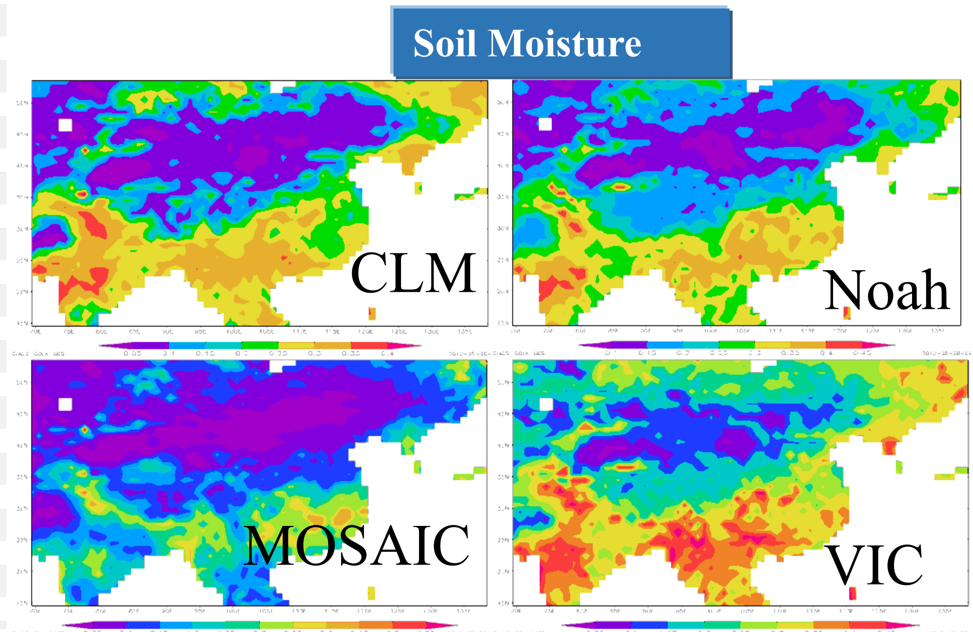
Capability of Model Prediction

Large uncertainties exists in the model Simulations on Water Cycle

Comparison of Regional Climatic Models in Intergovernmental Panel on Climate Change (IPCC) AR4

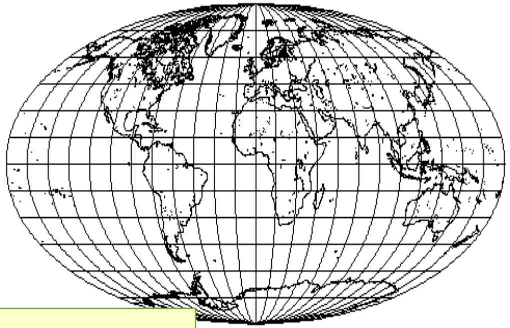


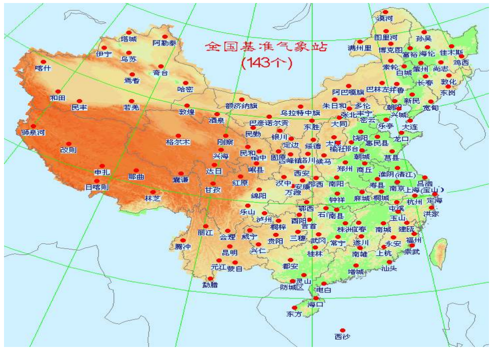
Model Simulations with the Same Driving Data



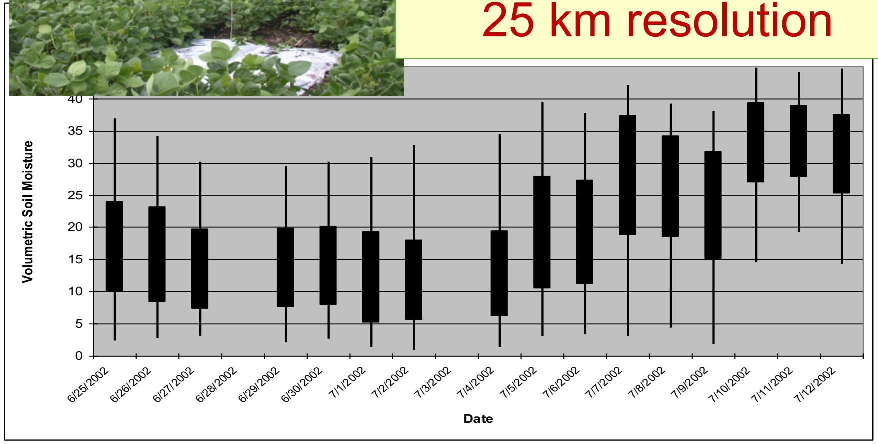
Problems in Modeling & Observation

Grids in prediction model represents average status and physical processes at a given scale in water cycle





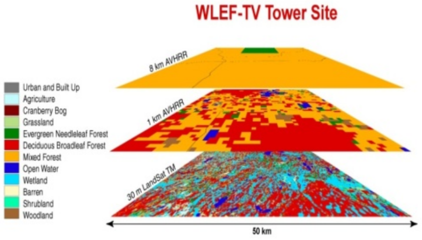
e.g.： soil moisture at 25 km resolution

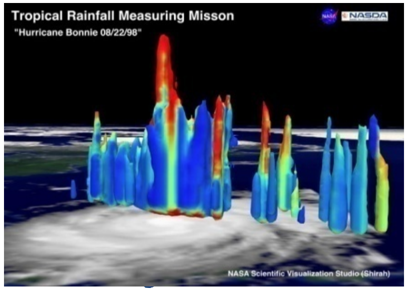


1. In situ observations – point and sparse
2. Point observations at different scale with prediction model
3. Needs for spatial and temporal observations

➔➔Satellite Observations

Great uncertainties in the parameterization of prediction model





Characteristics of the Spatial-Temporal Variabilities of Water Cycle Components

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

Strong Temporal Variability

- Precipitation /vapor
- Ocean Evaporation

Strong Spatial Variability

- Freeze/Thaw
- Snow Water Equivalent
- Soil Moisture

Weak Variability

- Sea Surface Salinity
- Polar Ice

Water Cycle Parameters	Temporal Resolution	Ideal Spatial Resolution	Minimum Requirement	Observation 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
Ground water	1month	50km	300km	~
Land ET	1-2hour	30m-1km	5km	30 W m-2
Run-off	1-2hour	~	~	~

Available Observation Capability for Water Cycle

	Sensor	Frequency（GHz）	vapor	Preci	Temp	SM	Freeze Thaw	Snow	SSS	OSW
Multiple Frequency Sensor	Aqua /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	√	√	√	√		√		
	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				√	√			

Problems of Current Observations

1. Lack of synergetic observations on environmental factors affecting the retrieval of water cycle parameters

2. Lack of systematic observations on the water cycle parameters related to each other for water cycle modeling

Parameters	Disadvantages in Observations	Disadvantages in Retrievals
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 temperature and roughness correction
Sea Evaporation	Lack of simultaneous observations on both sea surface and atmospheric factors	Uncertainties in the inversion of related parameters
Precipitation	Insufficient cloud 3D properties	Need to Discern rain and snow

Perspectives of WCOM

China's 1st science driven mission for EO with combined active and passive, multiple frequency microwave measurements on key water cycle components of land, ocean and atmosphere

Systematic Observations

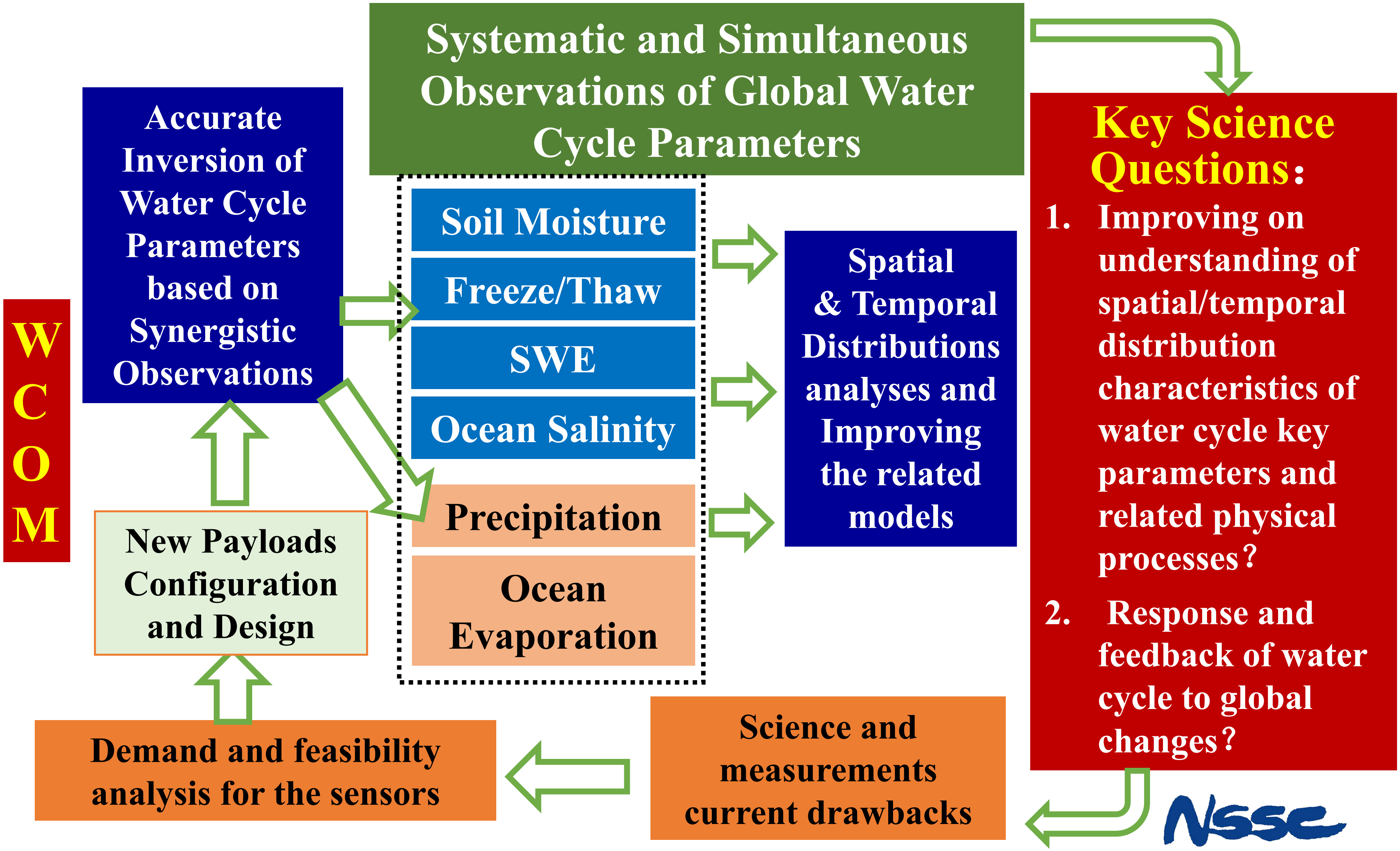
1. **Advanced Sensors**
2. **Accurate Inversion**
3. **Systematic observations**

Scientific questions ：

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

Improvement on understanding of global water cycle for global changes and Earth system science

WCOM: a synergetic water cycle observation mission



:ientific objectives of WCOM

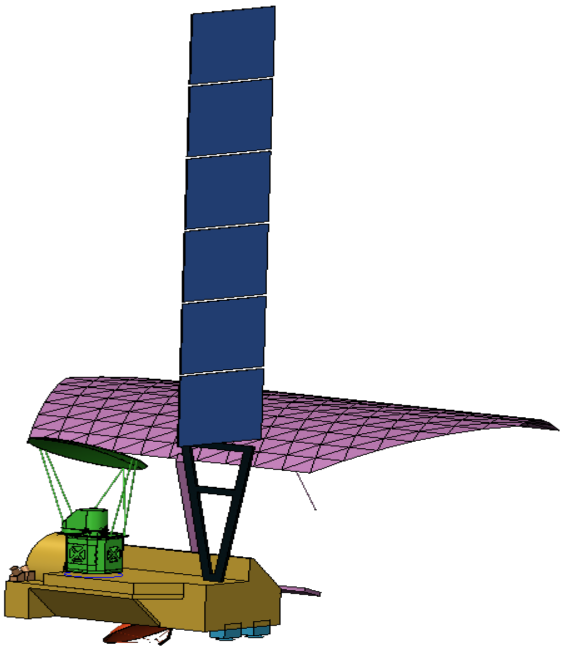
- To significantly improve the accuracy and synchronization of measurements for spatial and temporal distribution of global water cycle key parameters and system
- To refine the long-term satellite observations over past decades by improving water cycle models with improved observations

Mission Overview

- **Observation requirements:**

Synergetic **observations of global water cycle**

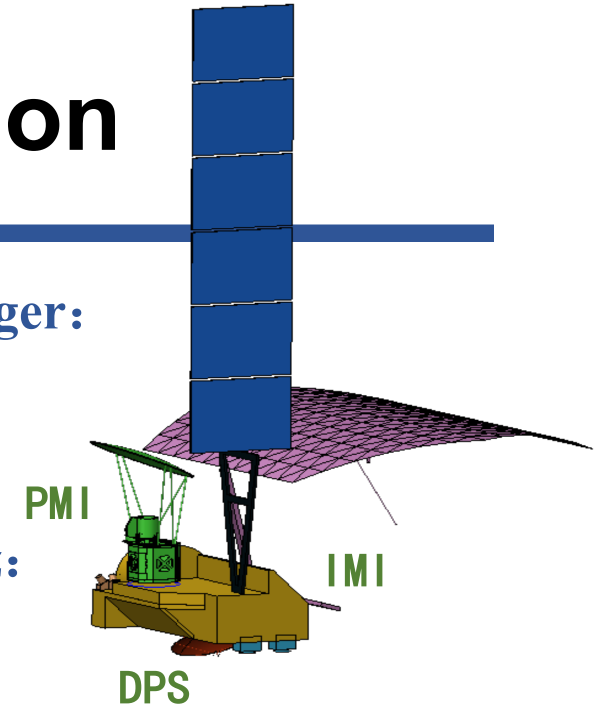
- **Synergetic:**
  - **Systematic observations of water cycle variables of land, ocean and atmosphere**
  - **Simultaneous observation of sensitive parameters and auxiliary parameters (atmospheric and surface corrections) for retrieval**



- **Payloads**
  - **Combined active passive, multiple frequency, polarized microwave instrument**

Payloads Configuration

- **IMI, Interferometric polarimetric Microwave Imager: Soil Moisture and Sea Salinity**
- **DPS, Dual-frequency Polarized Scatterometer: SWE and FT**
- **PMI, Polarimetric Microwave Imager, 6.8～89GHz: Temperature, rain, water vapor , atmosphere correction, and bridge to historical data**

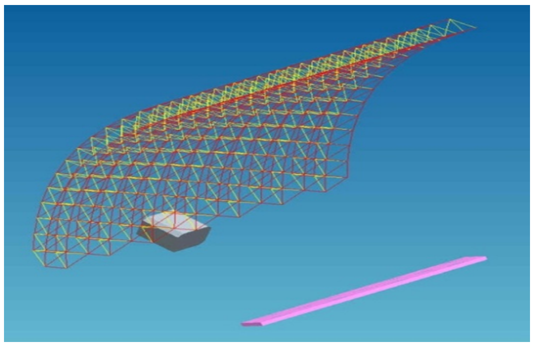


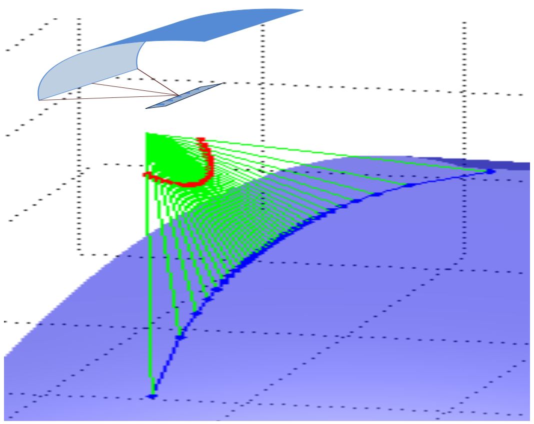
Payloads	IMI	PMI	DPS
Frequency （GHz）	L, S ,C (1.4,2.4,6.8)	C~W (6.8,10.65,18.7,23.8,37,89)	X, Ku (9.6,17)
Spatial Resolution （km）	L: 50, S: 30, C:15	4~50 （frequencies）	2~5 （processed）
Swath Width （km）	>1000	>1000	>1000
Polarization	Full-Pol	Full-Pol	Full-Pol
Sensitivity	0.1~0.2K	0.3～0.5K	0.5dB
Temporal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

Payload specifications

Payload/Specs	IMI	DPS	PMI
Frequency （GHz）	L, S ,C (1.4135, 2.695, 6.9)	X, Ku (9.6,17)	6.8/7.2,10.7,18.7,23.8,37,90
Resolution （km）	L: 50, S: 30, C:15	2~5 (after processing)	50,30,20,15,10,5
Swath （km）	≥1000	≥1000	≥1000
Polarization	Full-polarimetic	HH,VV,HV/VH	Full-pol for 10.7/18.7/37
Radiometric sensitivity	0.2~0.4K	0.5dB	0.3～0.5K
Calibration accuracy/stability	L ：0.12K/3 day ；S,C ：0.4K/3 day	0.15dB	Better than 0.5K

IMI: Interferometric polarimetric Microwave Imager



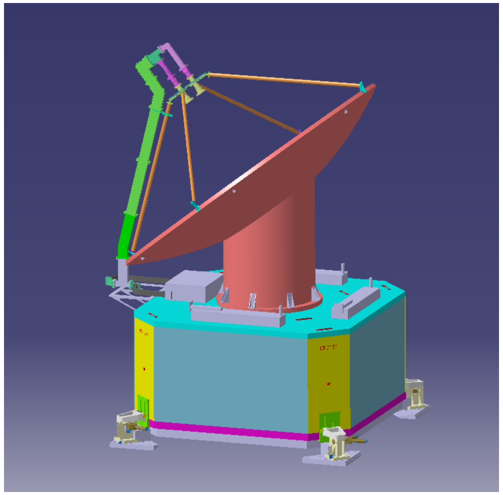


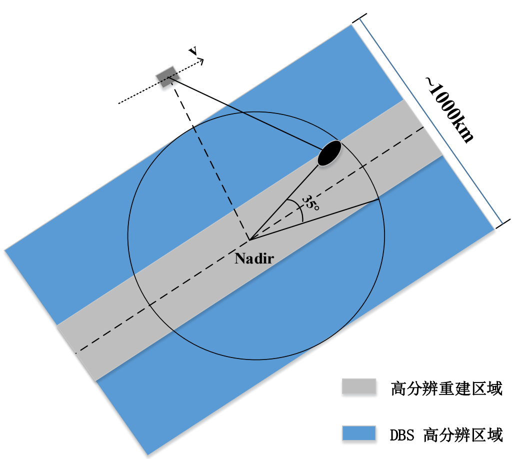
Cylindrical reflector +

1D interferometric synthetic aperture

- **Deployable large mesh reflector (6mX9m) to minimize the launch dimension**
- **Multiple frequency (L/S/C) share the reflector**
- **High precision thermal control of the integrated <u>feed+RF-front</u>, to implement radiometric precision and stability**

DPS: Dual-frequency Polarized Scatterometer





Rotating Pencil-Beam Radar Scatterometer

- X-Ku dual-frequency polarized (HH, VV, HV/VH)
- Rotating pencil-beam for higher antenna gain and SNR (cross-pol)
- Dual frequency share the reflector;
- Antenna aperture dimension: ~1.5m to adapt to the launch contour and scanning loss;
- Co-pol and cross-pol;
- Spatial resolution

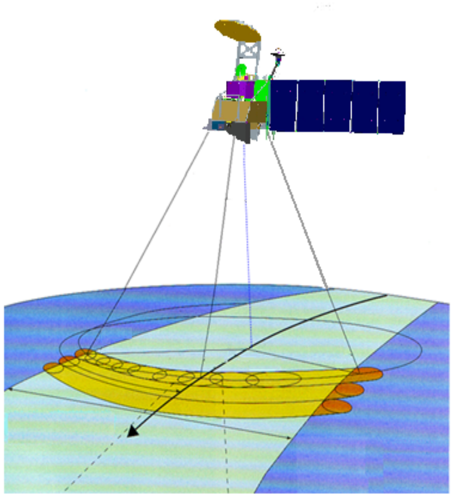
  Elevation: LFM and pulse compressio

  Azimuth:

  Outer swath (>30deg)➔SAR

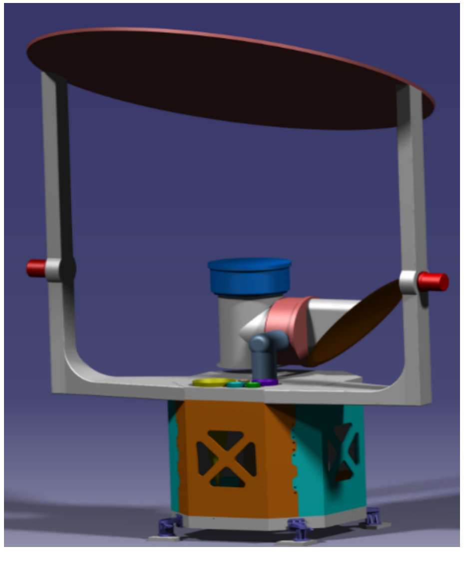
  Center swath (<30deg)➔oversampling and super-resolution reconstruction

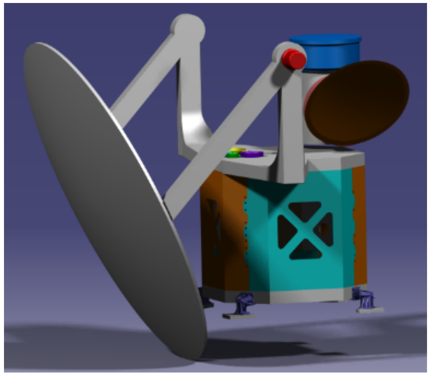
PMI: Polarimetric Microwave Imager



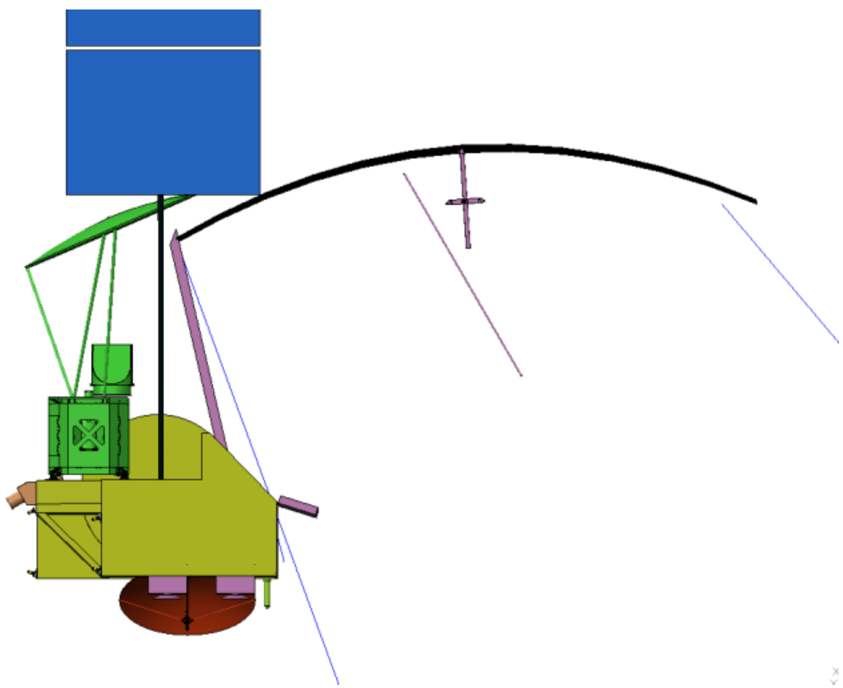
Multi-frequency Conically Scanning Radiometric Imager

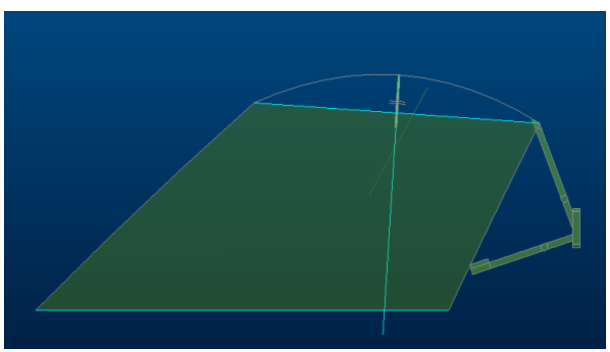
- Reflector dimension: 1.8m;
- Multiple frequency (6.8/7.2~90GHz)
- Full-polarimetric for surface imaging (10.7, 18.7, 37GHz)
- Width swath: >1000km
- Calibration: on-board two-point
- Stowed antenna during launch and deploy after in orbit



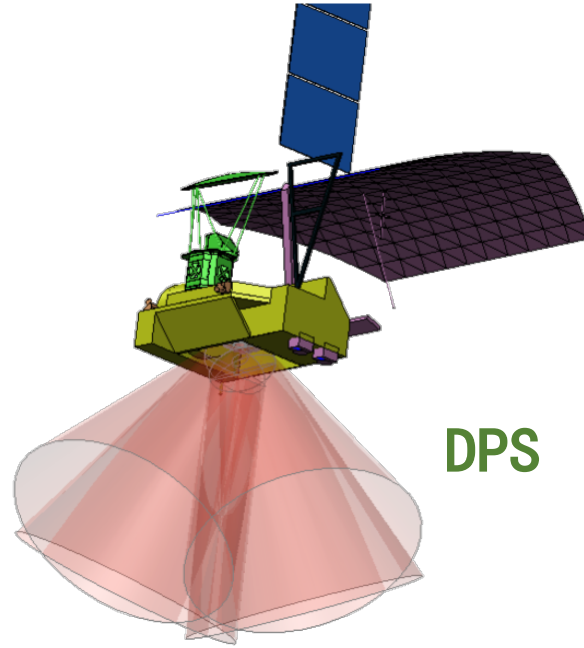


Payload Accommodations and FoV

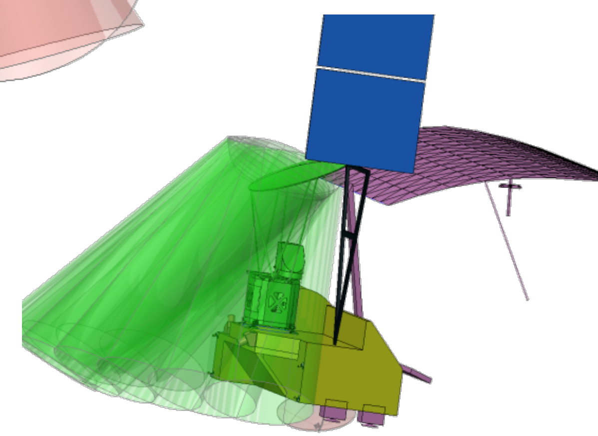




IMI

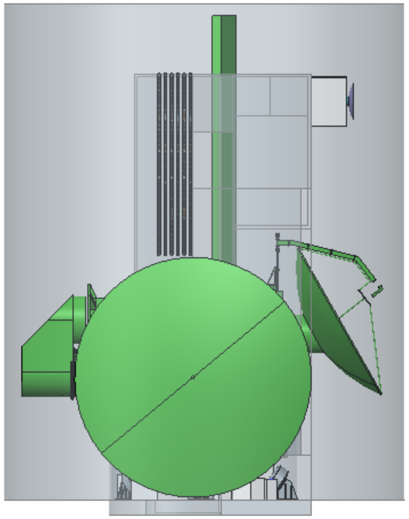


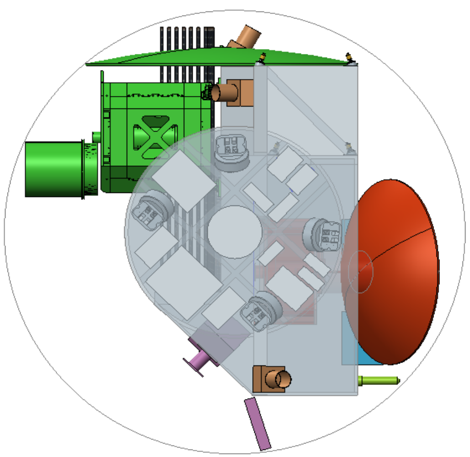
DPS



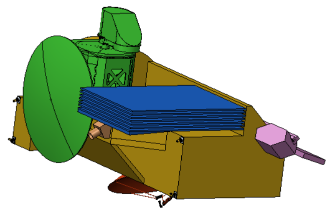
PMI

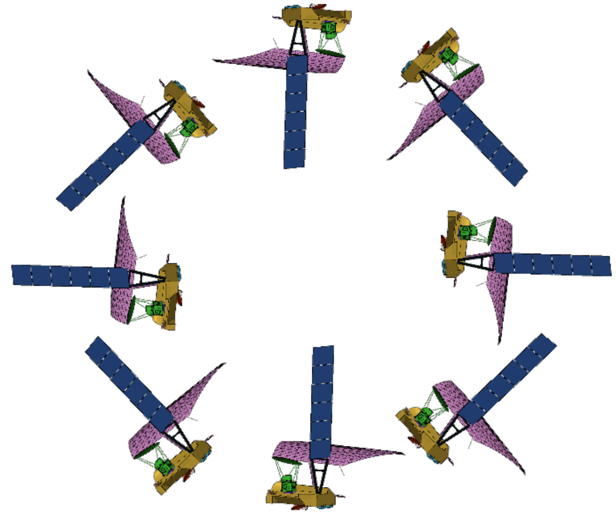
Deployment and observation mode



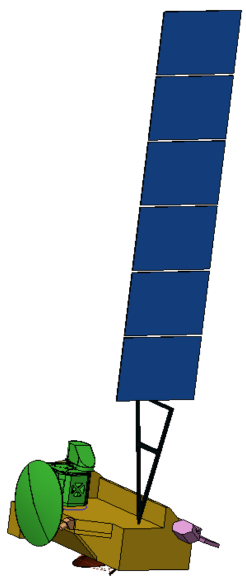


Launch

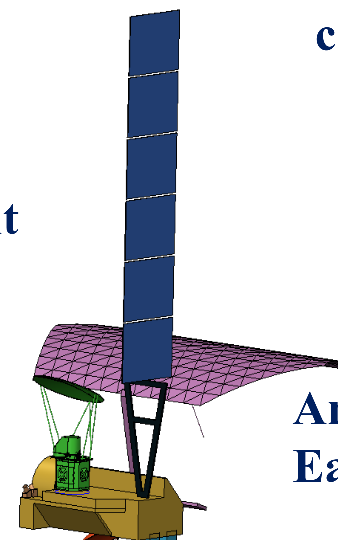




Attitude Maneuver for cold sky calibration



Solar wing deployment



Antenna deployment for Earth Observation

Orbit

■Orbit design

- Observation requirements (stable for retrieval)
- Resolution and swath
- Power supply

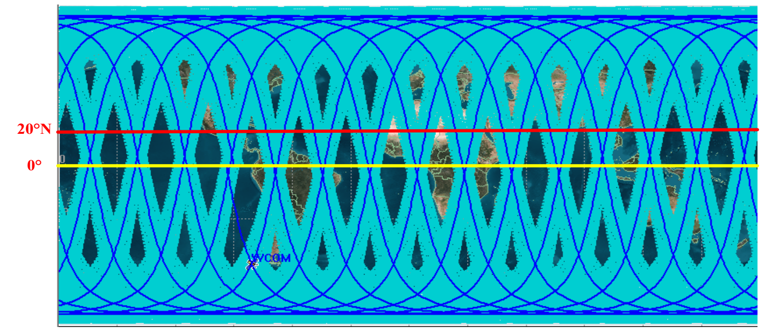
■Orbit parameters (preliminary)

- Orbit altitude： 645km
- Orbit return： every 4 days
- Payload swath: >1000km
- 6:00am dawn/dusk SSO

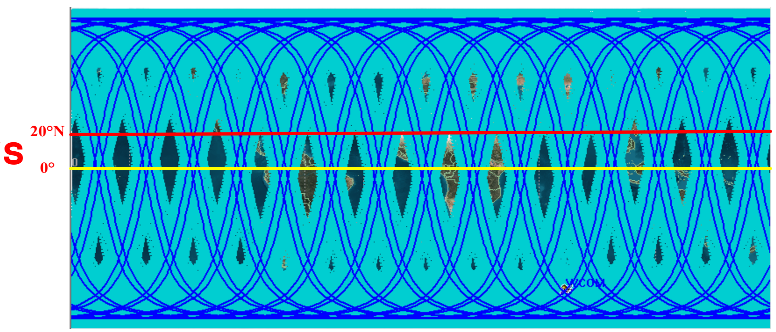
■Surface coverage:

- Coverage between N/S 20~90deg: 99.79%
- Global coverage: 96.15%/3day.

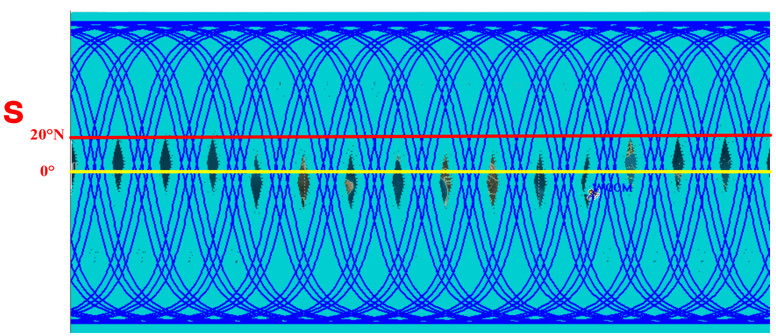
1day



2days



3days



Advantages of WCOM Payloads Configuration and 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. Sensitive to sea surface 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 Precipitation	Helping determine land surface emissivity	1. Obtaining Water Vapor 2. Precipitation Rate 3. Discerning Rain and snow	High resolution observations on precipitation

Vital Major Helpful

Payloads Configuration: 1）Optimal sensitive frequency for retrieval，2）Effective corrections on affecting factors，3）Simultaneous observations

Potentials for Ocean Surface Vector Wind Measurement

- **OSVW measurement capabilities**
  - Active microwave: DPS-dual frequency polarized scatterometer
    - X and Ku band (9.6, 17GHz)
    - HH, VV, HV/VH
  - Passive microwave: PMI-polarimetric microwave imager
    - 6.9, 10.7, 18.7, 23.8, 37, 89GHz
    - Full-polarimetric: 10.7, 18.7, 37GHz

- **Potentials for improvement**
  - Higher wind speed capability
    - Cross-polarization observations
    - Combined active/passive with lower frequency observations
  - Mitigation of rain contamination
    - Combined active/passive

DPS specifications

Specifications	Parameters
Frequency	9.6GHz， 17GHz
Bandwidth	5MHz
Swath	>1000km
Peak Power	200W/150W
Polarization	HH， VV， HV， VH
Antenna aperture	1.5m×1.5m
Incident angle	～39°
sigma 0 range	HH， VV: ＋15～－25dB HV， VH: ＋5～－35dB
sigma 0 precision	优于0.5dB
Raw resolution	50m (azimuth)×15km (elevation)
Reconstructed resolution (for SWE)	2～5km

Ocean surface current measurement capability is under consideration, main challenge is the satellite attitude determination precision (<0.001deg)

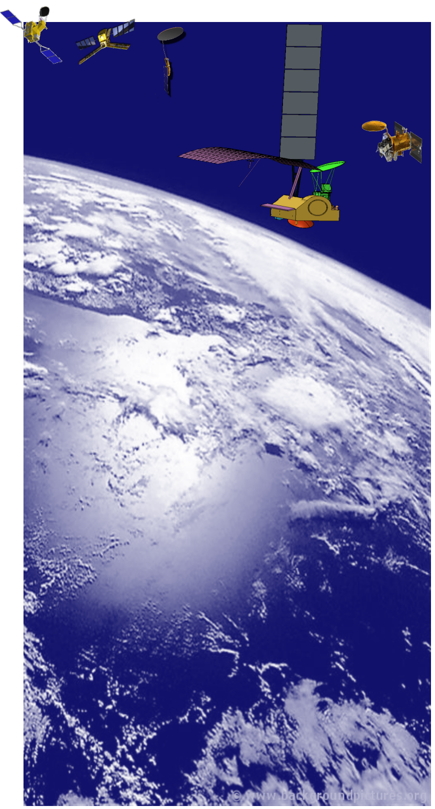
PMI specifications

Frequency (GHz)	Bandwidth (MHz)	Polarization	Radiometric Resolution (K)	Spatial Resolution (along track × cross track) (km)
6.8/7.2	350	V, H	0.3	53×31
10.7	300	FULL	0.4	34×19
19.1	750	FULL	0.3	19×11
23.8	500	V, H	0.5	15×9
37.0	2000	FULL	0.3	10×6
90	2000	V, H	0.5	4×2

WCOM: Future development and implementation plan

- 2017: preparation for implementation, satellite and payload development to be kicked-off before October
- 2017-2018: detailed design
- 2019: engineering model and test
- 2020: flight model and test
- 2021: launch and in-orbit commissioning

International Collaborations



WCOM

FY-3
HY-2

WCOM

SMOS
SMAP

GPM

Global Water Cycle Satellite Observations

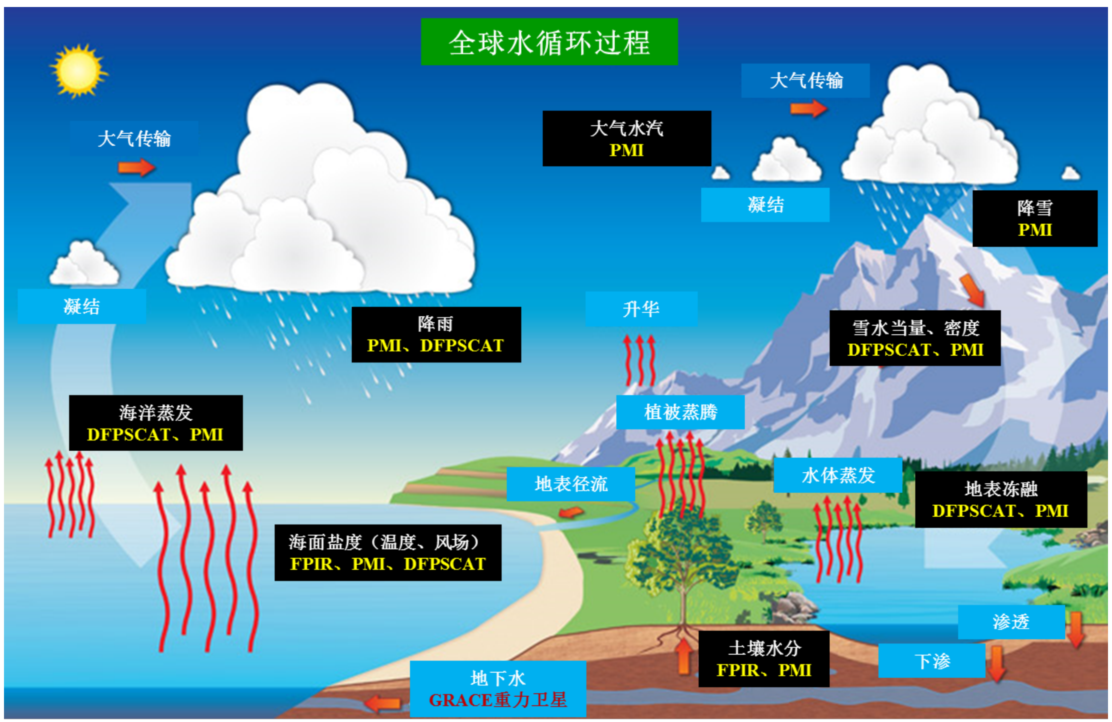
Chinese Ocean Salinity Mission

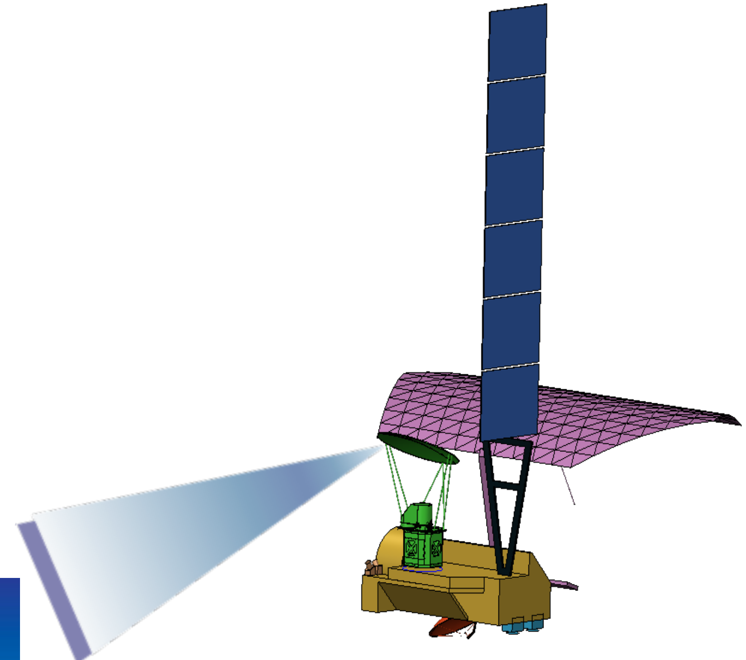
Water Resource Mission

SWOT
GRACE

A global water cycle consolidation

Thank You!





WCOM:
International collaborations are Welcome!