



AOMSUC-15 2025 FYSUC

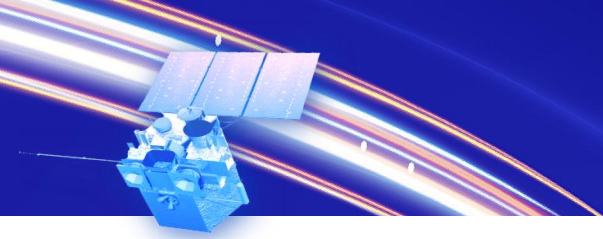
THE 15TH ASIA-OCEANIA METEOROLOGICAL SATELLITE USERS' CONFERENCE (AOMSUC-15)
2025 FENGYUN SATELLITE USER CONFERENCE (2025 FYSUC)

Toward Improved Observations of Air-Sea Coupling by Microwave Remote Sensing

Xiaolong DONG, Jieying HE, Hao Liu, Feixiong Huang

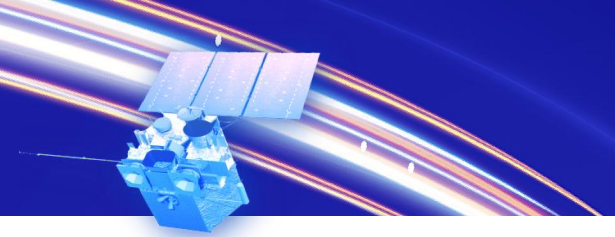
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- Introduction
- New developments for the microwave remote sensing of air-sea coupling
- Summary



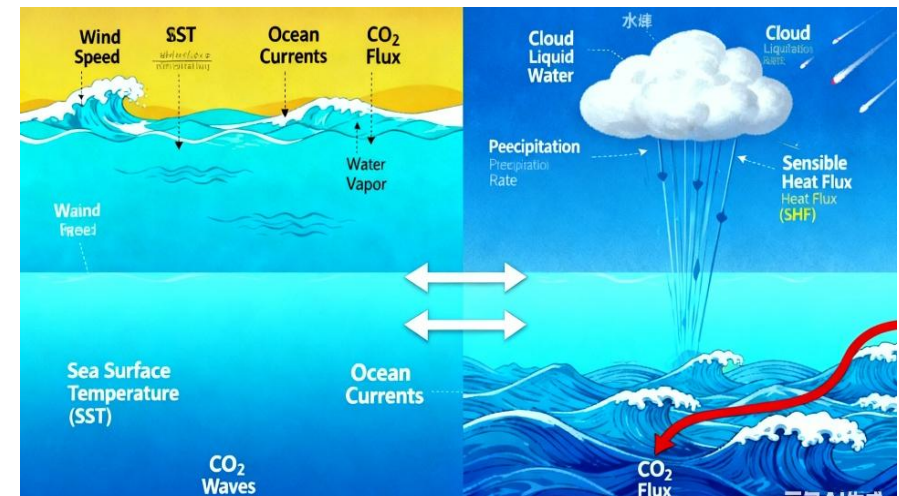
Introduction

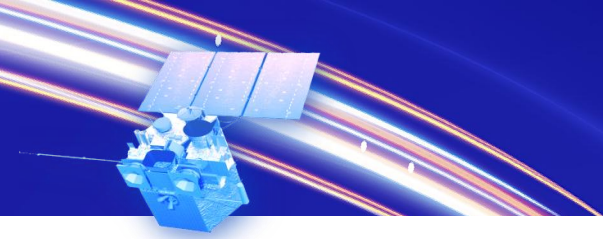
Air-Sea Coupling:

- The complex exchange of **momentum, heat, moisture, and gases** between the ocean and atmosphere
- Profoundly impacts global climate and weather systems

Scientific Significance:

- Critical for global water-heat balance maintenance, climate change monitoring, and extreme weather prediction





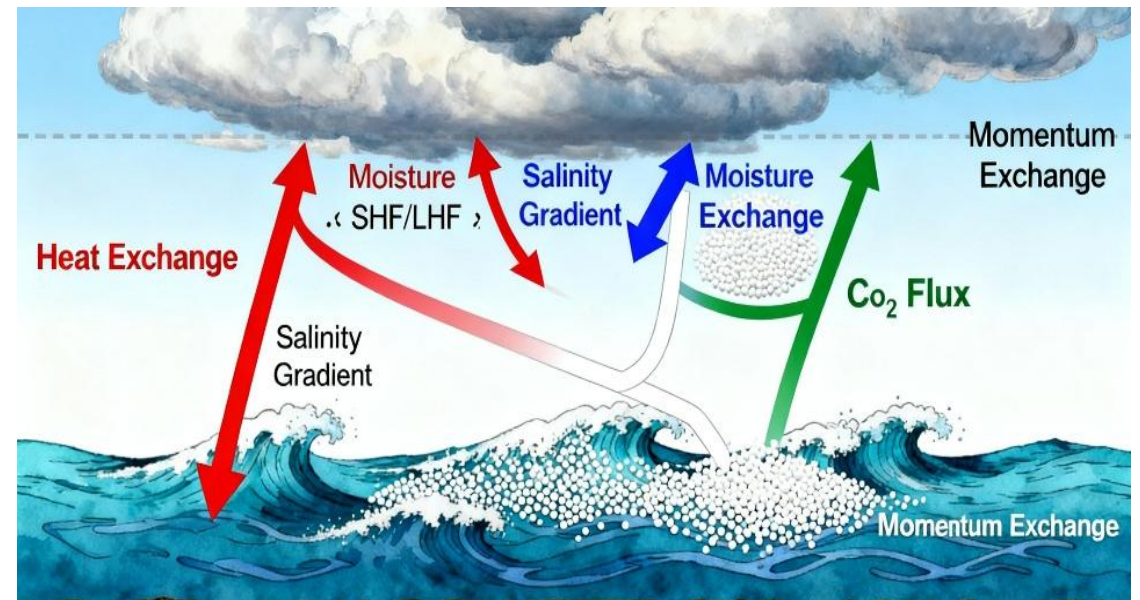
Observation Variables by microwave RS:

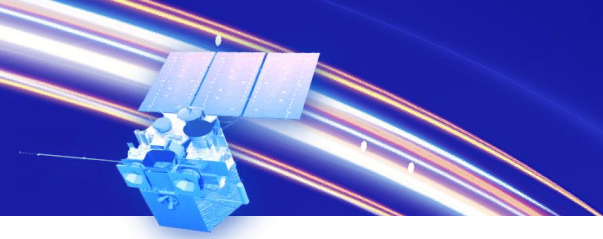
- Sea surface temperature (SST): heat
- Wind speed, current and waves: momentum
- Sea surface salinity (SSS): emission

} Sea surface variables

- Vapor
- Temperature
- Cloud liquid water
- Precipitation rate
- CO₂ fluxes: IR observation
- air-sea heat fluxes (SHF/LHF): derived

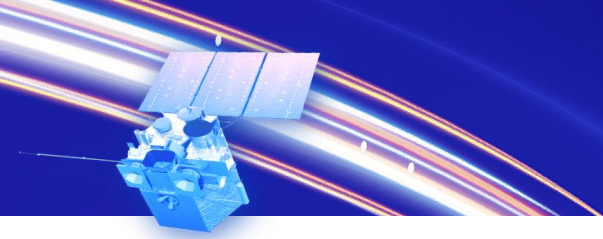
} Atmospheric variables





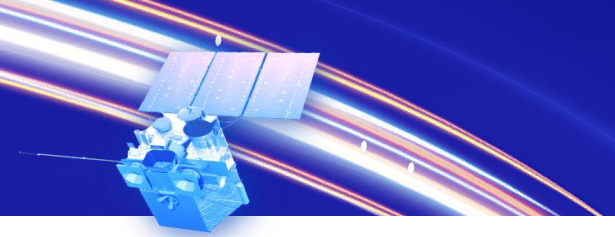
Main challenges and development requirements:

- **Data Gaps** caused by satellite orbit coverage gaps and cloud, leading to incomplete observation sequences.
- **Low Precision** of lower/near surface atmospheric variables;
- **Spatial-Temporal Restrictions** with poor representation of mesoscale/sub-mesoscale processes and sparse data in extreme regions like the Southern Ocean .
- **Single-Source Limitation** leading to difficulty in integrating multi-platform data for comprehensive analysis.



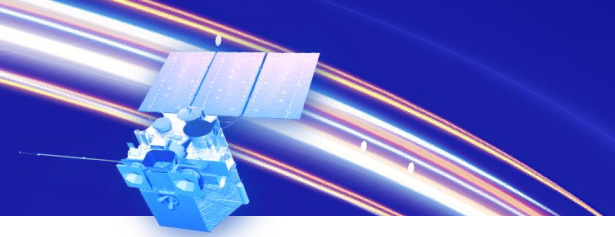
How to meet the development requirements:

- **Improvement of Observation Techniques:**
 - wind speed, current and waves, SSS, SST, etc., with higher precision and finer resolutions;
 - Atmospheric temperature and humidity for lower atmosphere (PBL).
- **High-Precision Inversion Models:**
 - Improvement of models;
 - AI techniques.
- **Multi-Source Data Fusion:** Integrates microwave remote sensing data and in-situ observations, enhancing spatial generalization ability .
- **Flux Observation Advancement:** New parameterization techniques for air-sea turbulent fluxes and sea spray fluxes, improving hurricane intensity research

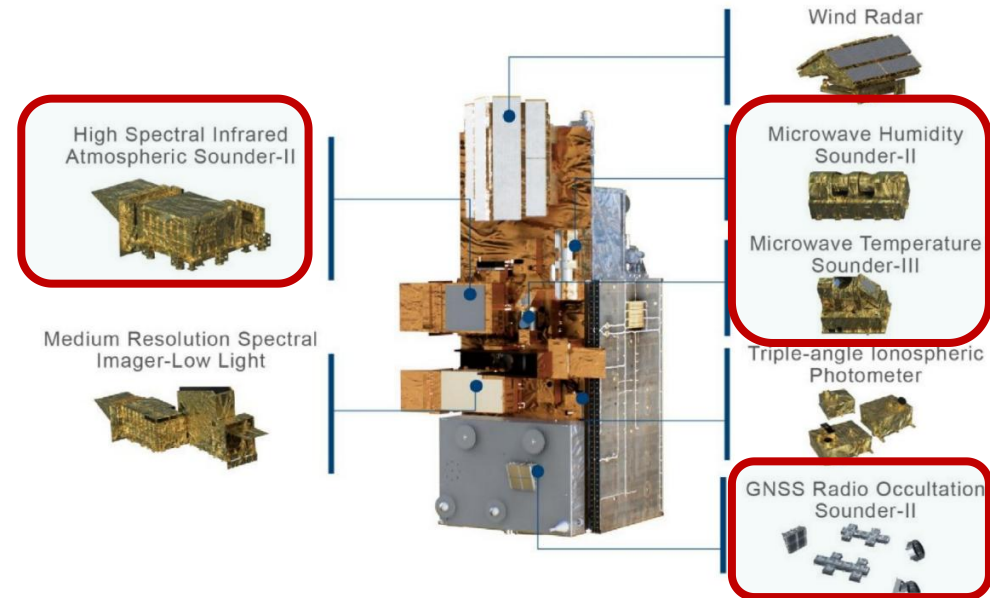
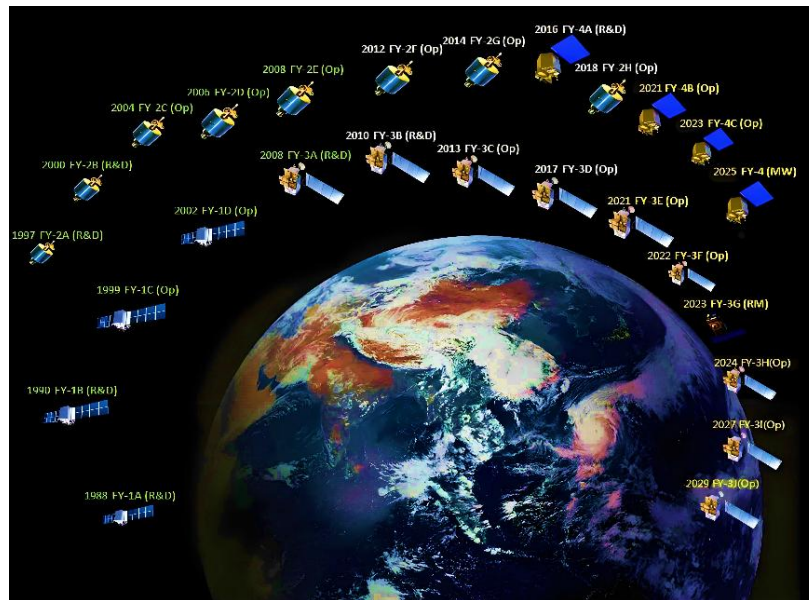


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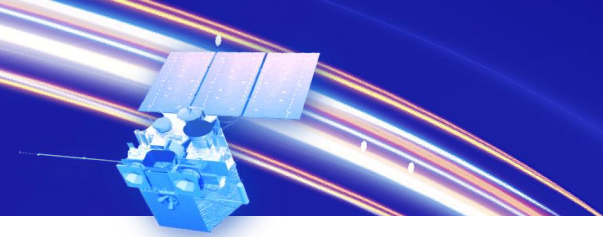
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Atmospheric sounding Missions-----FY-3 satellite series



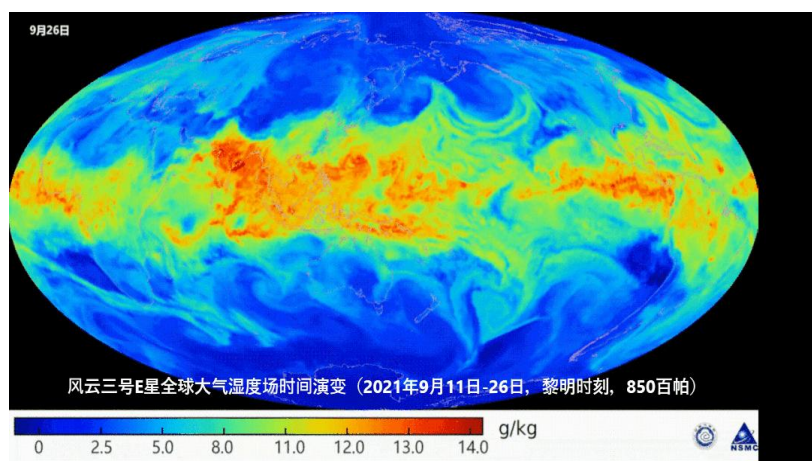
- ✓ **Multi-spectral sounding:** MWHS, MWTS, GNSS...
- ✓ **Retrieved Variables:** atmospheric temperature and humidity profiles, precipitation, rainfall, sea ice, soil moisture, sea surface wind, snowfall, etal.



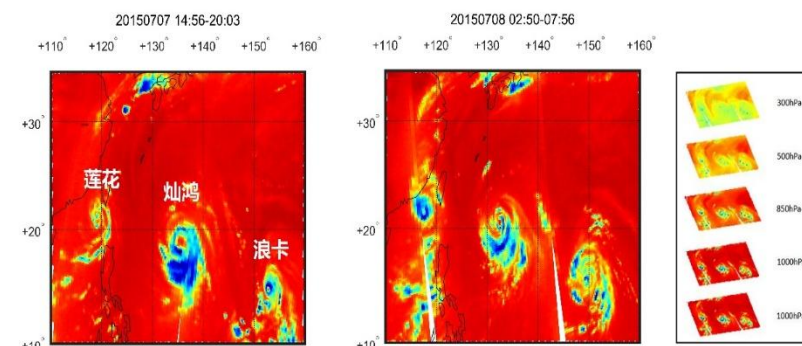
Microwave remote sensing onboard FY-3

MWHS-II onboard FY-3 (Long-life, high-performance in-orbit operation):

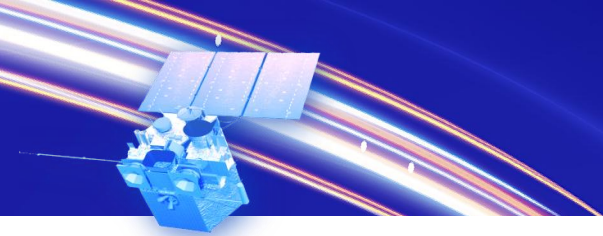
- Four payloads are operating in a constellation, achieving full global coverage in 3-4 hours.
- Realizing global meteorological monitoring of catastrophic weather.



FY-3E MWHS Global Atmospheric Humidity Field Evolution
(Dawn , September 27, 2021)



MWHS successfully monitored typhoon “Chanhong”, “Lotus”, “Langka” together, clearly shows the localization, strong convective rainfall area
(End of June, 2015)

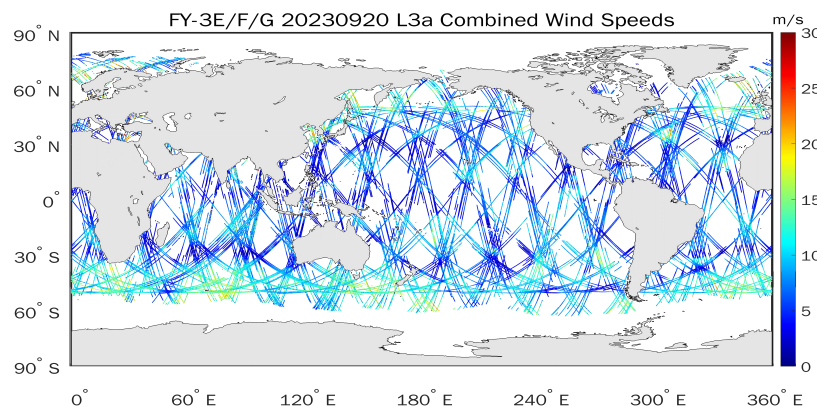


GNSS Remote Sensing Missions

GNOS-II onboard FY-3:

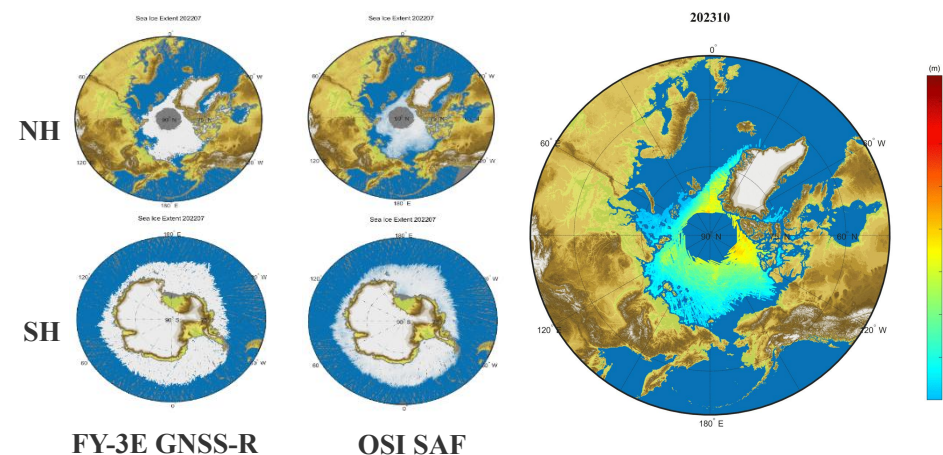
- Four payloads on FY-3E/F/G/H.
- Integrates the functions of GNSS radio occultation and GNSS-R.

Combined FY-3E/F/G wind speeds in one day

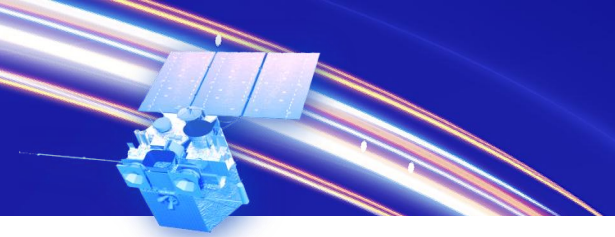


FY-3 GNSS-R winds have already been operationally assimilated into the CMA-GFS global NWP model, and have positive impact.

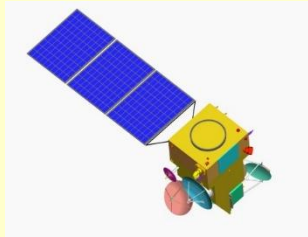
Sea Ice



FY-3E GNSS-R sea ice cover product (July 2022) with an accuracy of 98.5%.

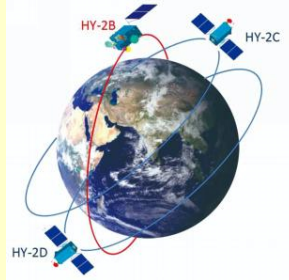


Chinese Ocean Dynamic Environment Missions



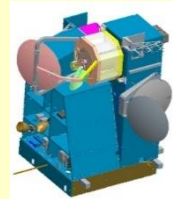
HY-2A, 2011.08.16

- Radar altimeter
- Atmospheric Correction Microwave Radiometer



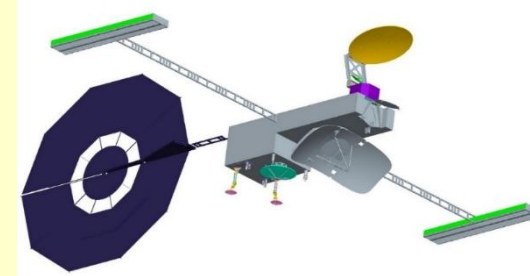
HY-2B/C/D, 2018~2021

- Radar altimeter
- Atmospheric Correction Microwave Radiometer



HY-2E/F (in development)

- Synthetic Aperture Radar Altimeter
- Atmospheric Correction Microwave Radiometer



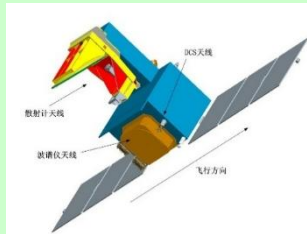
HY-2/New Generation (approved)

- Synthetic Aperture Radar Altimeter
- Wide-Swath Radar Altimeter
- Multi-Beam Atmospheric Correction Microwave Radiometer



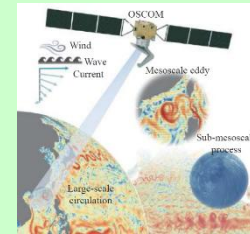
CFOSAT, 2018.10.29

- Rotating Fan-Beam Scatterometer



Wind and Wave Mission (in development)

- Ku-band Multi-beam Doppler Scatterometer



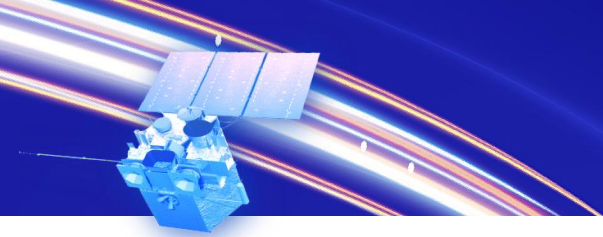
CFOSAT-NG (under Study)

- Ku/Ka Dual-Frequency Multiple-Pencil-Beam Doppler Scatterometer



COSM 2024.11.14 (salinity)

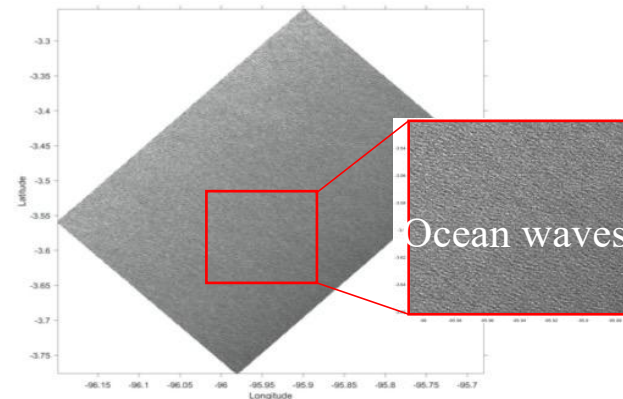
- Combined Active-Passive microwave Imager



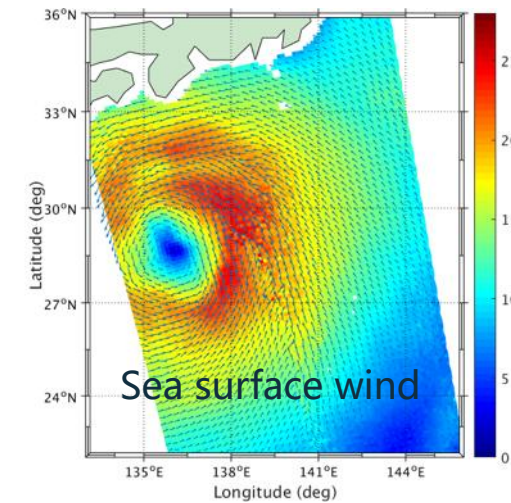
eg. Satellite ocean products



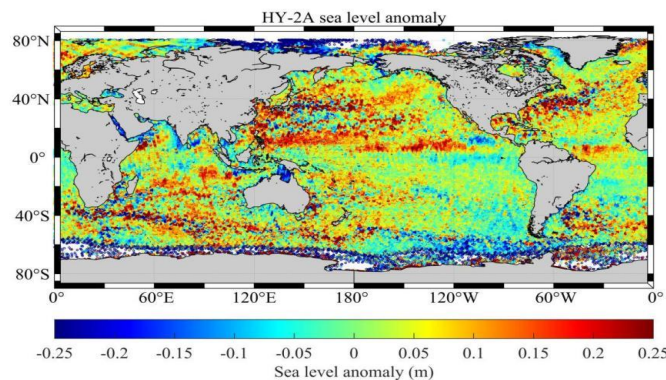
Radar altimetry



Ocean waves

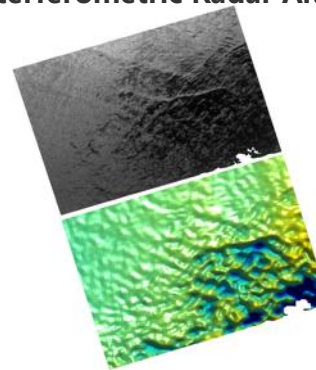


Sea surface wind

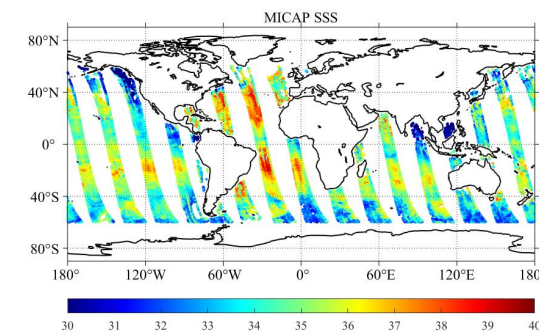


Sea level anomaly

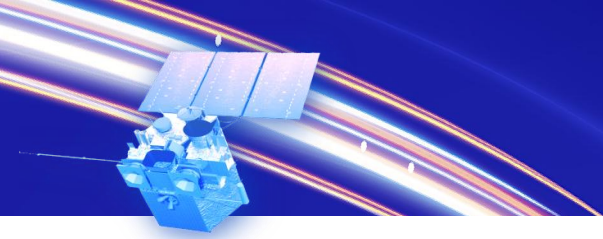
Wide Swath interferometric Radar Altimeter



Retrieved wave spectra



Sea surface salinity



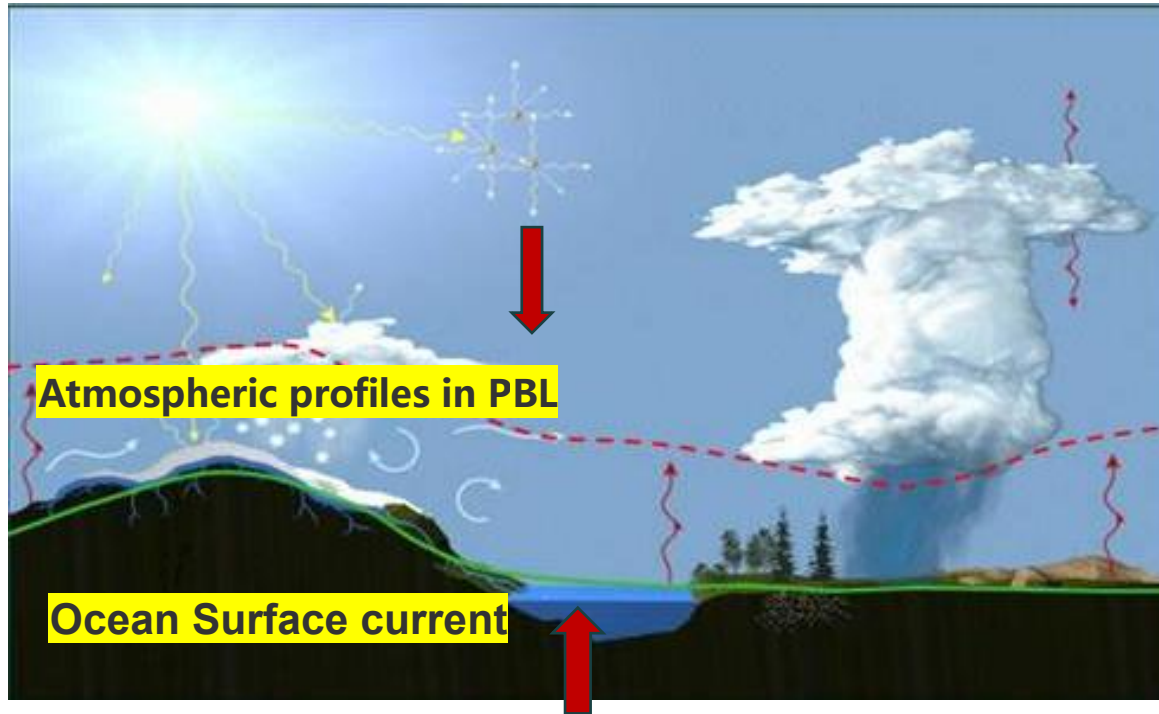
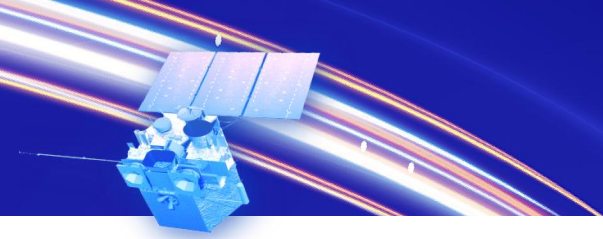
Overview of Microwave Remote Sensing of Sea-Air Coupling

Oceanic Remote Sensing techniques

- **Radar altimetry** for ocean surface topography, wind speed and wave height
- **Radar scatterometry** for ocean surface vector wind and current
- **Microwave radiometry** for ocean surface temperature, salinity, wind and air pressure
- **GNSS-R** for ocean surface wind and waves

Atmospheric Remote Sensing techniques

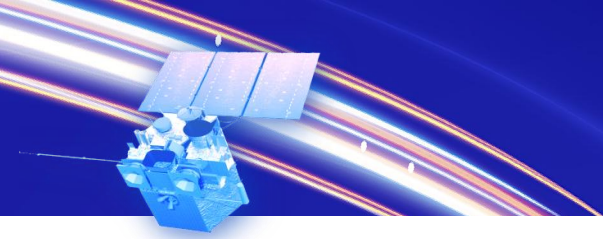
- **Microwave radiometry** for atmospheric humidity/temperature profiling
- **Microwave/Millimeter wave radar** for cloud, precipitation and atmospheric wind
- **GNSS-Occultation** for atmospheric sounding



Planetary Boundary Layer (PBL)

- **Different** kinematic characteristics from free atmosphere (friction)
- **Varying** with time and location, meteorological conditions, climatic changes, surface roughness and human activities, etc.
- The **water vapour exchanges** occur between the earth/sea surface and free troposphere

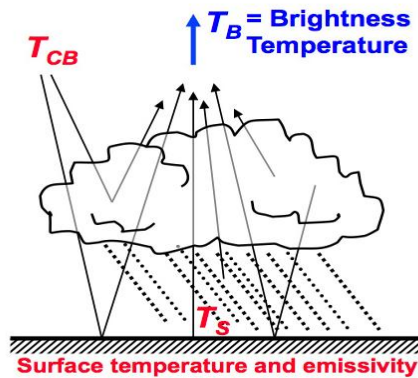
Ocean Surface current is one of the major drivers of water mass, energy, and biogeochemical cycles in the global ocean-atmosphere boundary layer and also a key variable in the formation of extreme climate events



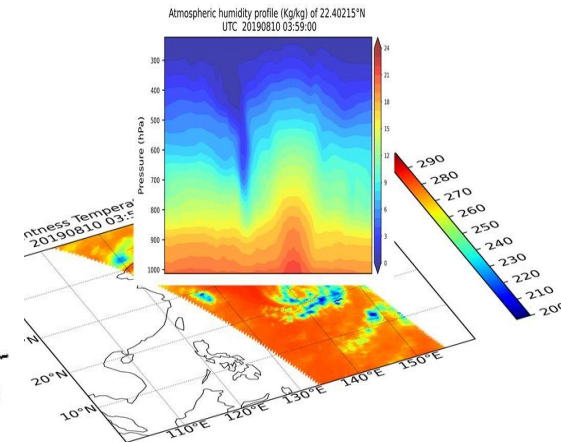
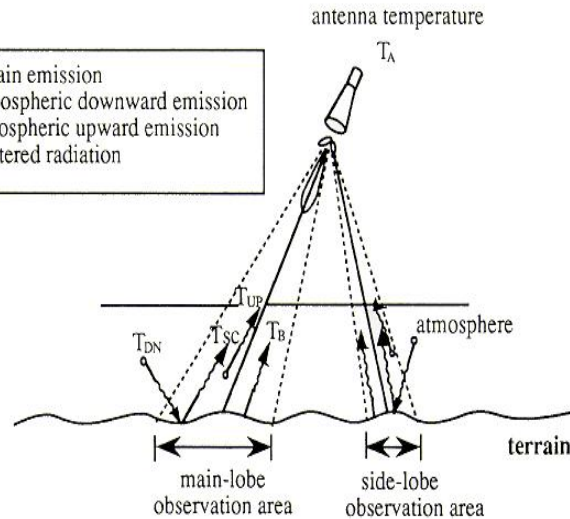
Upgrading from FY-3 to FY-5 satellite

Passive Remote Sensing

Sources: surface emission, cosmic background, rain emission

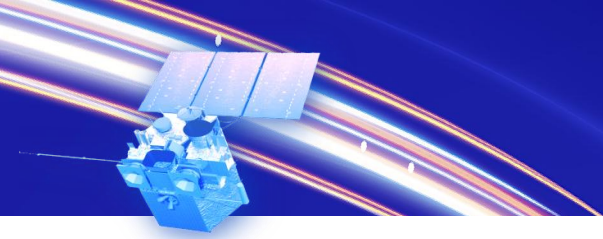


T_B : terrain emission
T_{DN} : atmospheric downward emission
T_{UP} : atmospheric upward emission
T_{SC} : scattered radiation

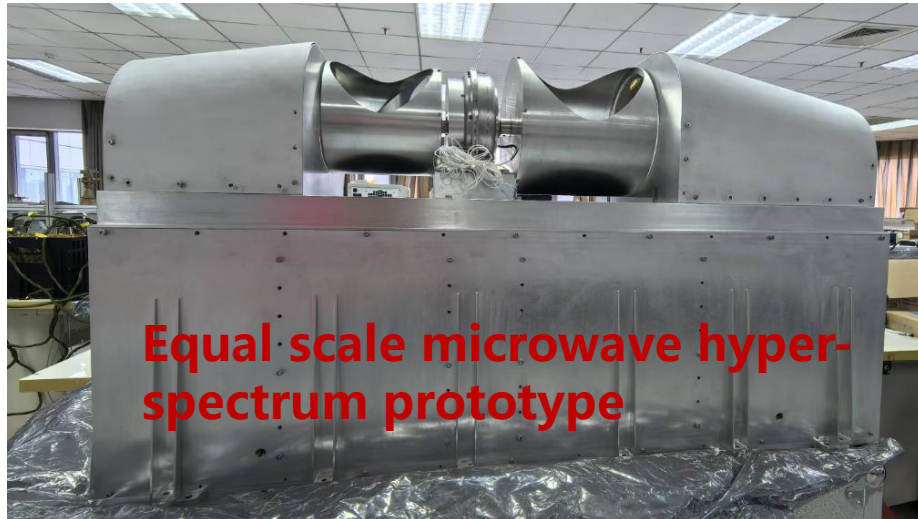


Satellite-based MR: able to penetrate the ABL (current capacity of MR is limited)

- Affected by atmospheric attenuation (absorption and scattering) and complex subsurface
- The vertical resolution and sounding accuracy cannot meet the requirements for ABL research



HyMAS prototype for FY-5



Equal scale microwave hyper-spectrum prototype

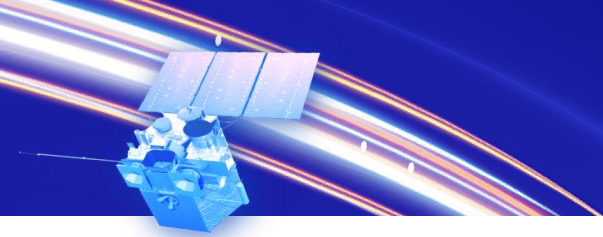
- Improve vertical resolution
- Improve PBL capacity (lower atmosphere)
- Improve stratospheric capacity

Top-level design concept:

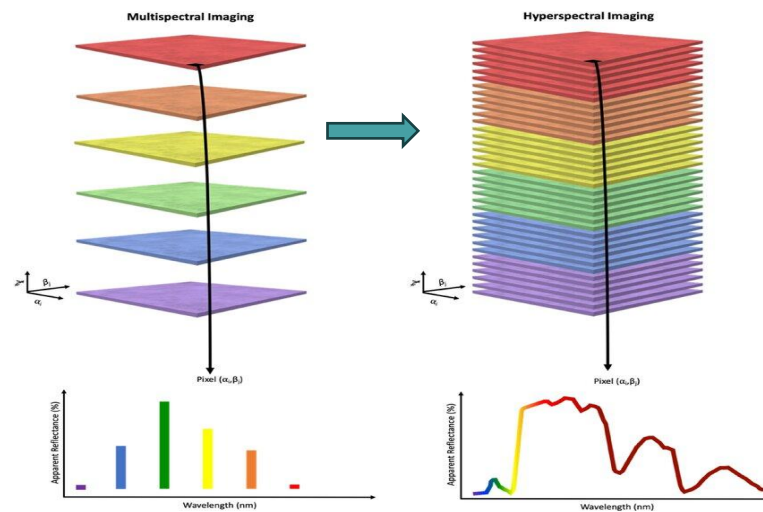
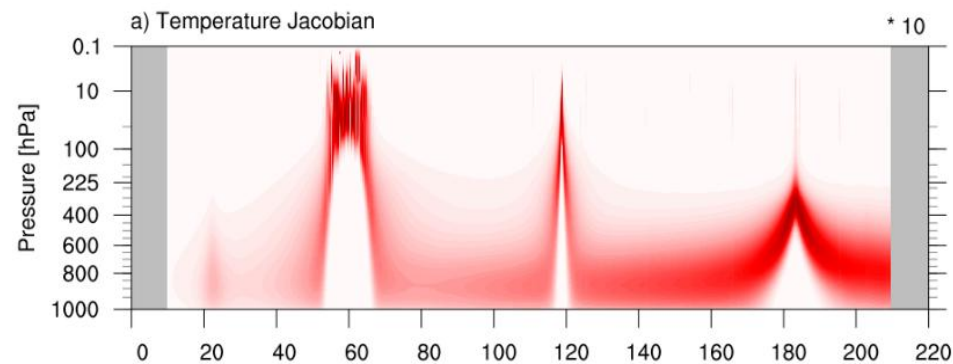
- New system: effective combination of analog and spectrometer
- Flexibility: Programmable Spectrometer Modular Configuration
- New element: pressure condensate, Cloud hydrometeors

Technical advancement:

- Center frequency: 20~229GHz
- Detection accuracy: 1K scale up to 0.4K
- Spectral resolution: hundreds of MHz upgraded to MHz
- Vertical resolution: kilometer scale to hundred meter scale



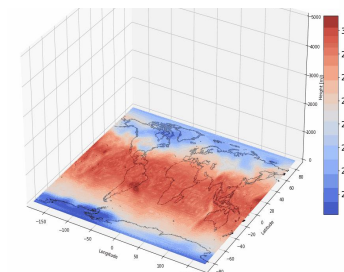
Field campaigns: hyperspectral MR



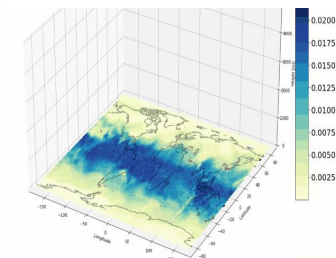
Peaks distribution of Jacobian



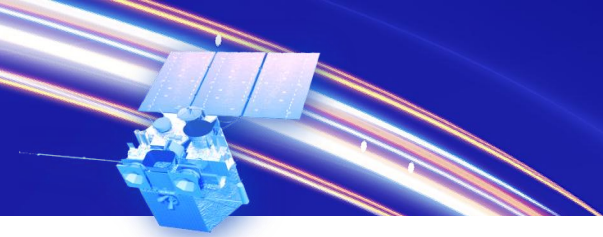
temperature



humidity



The key technology of hyperspectrum has been validated, and the detection advantages have been initially confirmed.

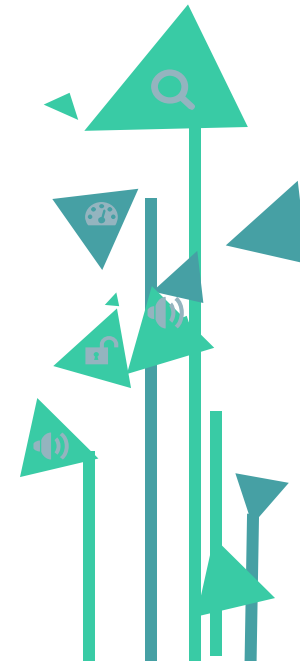


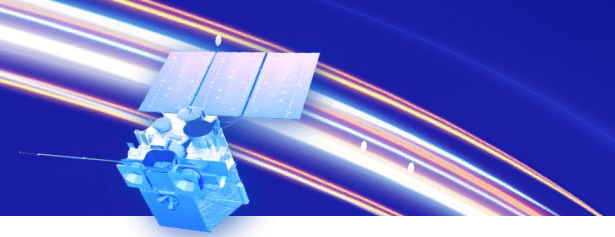
Microwave sounding--Key technologies

To be developed:

- Accurate Radiation Spectra and Cloud and Rain RTM for Physical Conditions
- Weak signal detection technique based on fine spectral tracking with multi-frequency multi-polarization
- Automatic Tracking Inversion Algorithm for Weak Signal Dynamic Changes
- Exact solution from the multi-source fusion and high singularity radiative transfer equation

- **Team research:** Research on key thermodynamic processes in the atmospheric boundary layer and satellite microwave remote sensing techniques
- **Supported** by Pandeng Program of National Space Science Center, Chinese Academy of Sciences

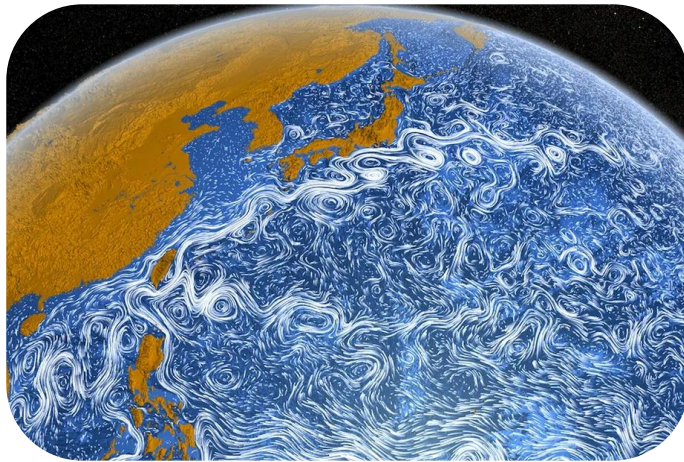




Ocean observing upgrading:

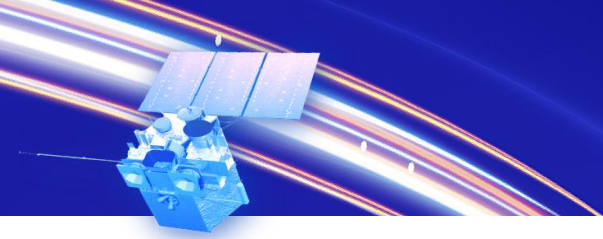
Simultaneous measurement of ocean surface wind,
waves and currents

Till now, there is no directly
observation of global Surface Current!



Ocean Surface Current multiscale Observation Mission (OSCOM):

hoped to launch a satellite equipped with a
Doppler Scatterometer (DOPS) to directly
measure ocean surface currents with a
very high horizontal resolution of 5–10 km
and a 3-day global coverage.



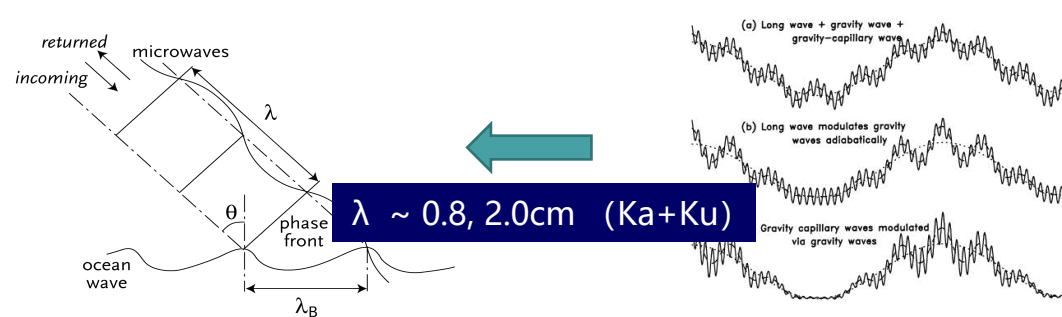
Simultaneous Measurement of Wind and Current

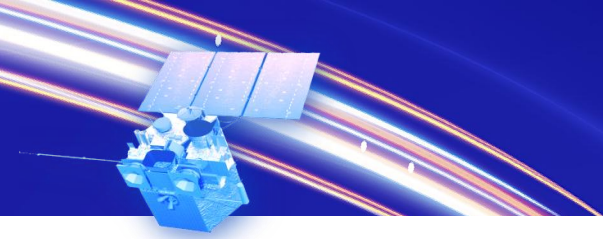
Ocean surface winds

- Achieve the vector winds by combining the multi-angle measurements of **Backward scattering coefficient** at different incident azimuth angles on the same cell at the sea surface with geophysical model inversion

Sea surface current

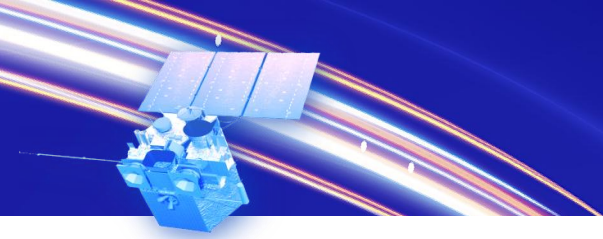
- Obtained high-precision sea surface Doppler velocities by Ka-band pulse clusters
- Eliminate platform Doppler errors with high-precision attitude and velocity measurement of satellite
- Eliminate the effects of capillary wave Bragg phase speed and gravity wave orbit speed using wind and wave models





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Summary

- ✓ Air-sea coupling is important for weather prediction, climate monitoring, and environment management.
- ✓ Improvement of satellite remote sensing, especially for lower atmosphere and mesoscale/sub-mesoscale sea surface observations is important to overcome the challenges;
- ✓ New generation of satellite mission will contribute and promote the development, both for scientific research and applications.

Thank you!