Ocean Surface Current multiscale Observation Mission (OSCOM)

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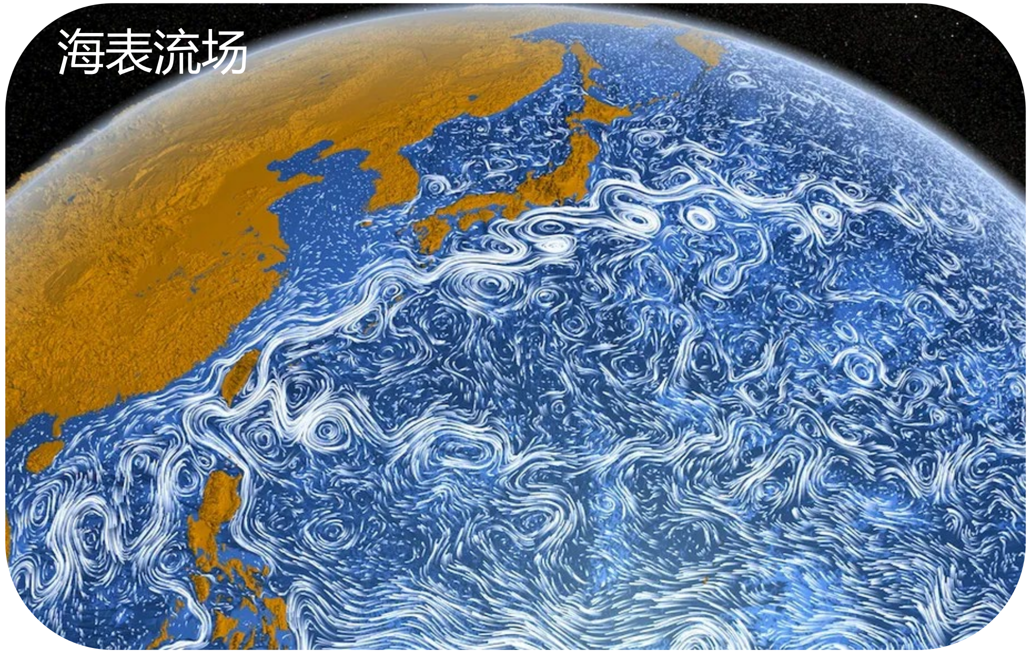
Major Scientific Issues

Ocean 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 (e.g., El Nino).

No direct observation of the global ocean surface current now.



By 2025, one additional measurement may become available—total surface currents.

(Freeman et al., 2010)


THE FUTURE OF OCEANOGRAPHY FROM SPACE

Ocean Measurements from Space in 2025

BY ANTHONY FREEMAN, VICTOR ZLOTNICKI, TIM LIU, BENJAMIN HOLT, RON KWOK, SIMON YUEH, JORGE VAZQUEZ, DAVID SIEGEL, AND GARY LAGERLOEF

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Progress: Ocean circulation theory

Navier-Stokes equation		$\rho\left(\frac{\partial \mathbf{u}}{\partial t}+(\mathbf{u}\cdot\nabla)\mathbf{u}\right)=-\nabla p+\mu\nabla^2\mathbf{u}+f$
Geostrophic balance		$fu=-\frac{1}{\rho}\frac{\partial p}{\partial y},\ fv=\frac{1}{\rho}\frac{\partial p}{\partial x}$
Theory of wind-driven circulation	**Ekman theory**	$-fu+A_z\frac{\partial^2 v}{\partial z^2}=0$
	Sverdrup balance	$\beta\int vdz=\frac{\mathbf{k}}{\rho}\cdot\nabla\times\boldsymbol{\tau}$

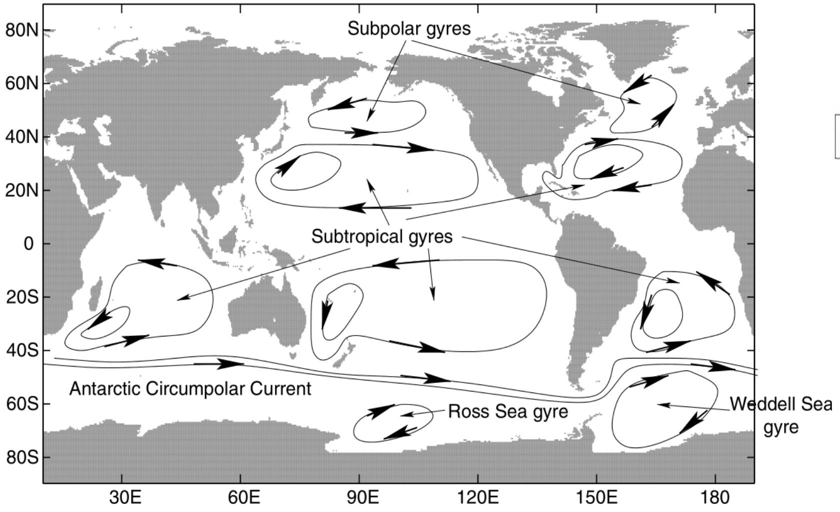
Considering the lateral friction and the westward intensification of ocean circulation can obtain the closed cell in each basins

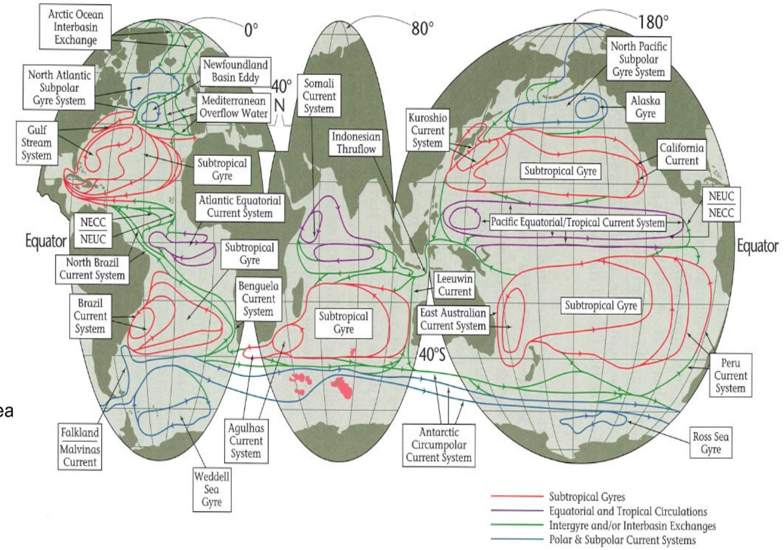
Unable to solve directly

Geostrophic current can be derived from satellite altimeter data

Ekman current can be derived from sea surface wind

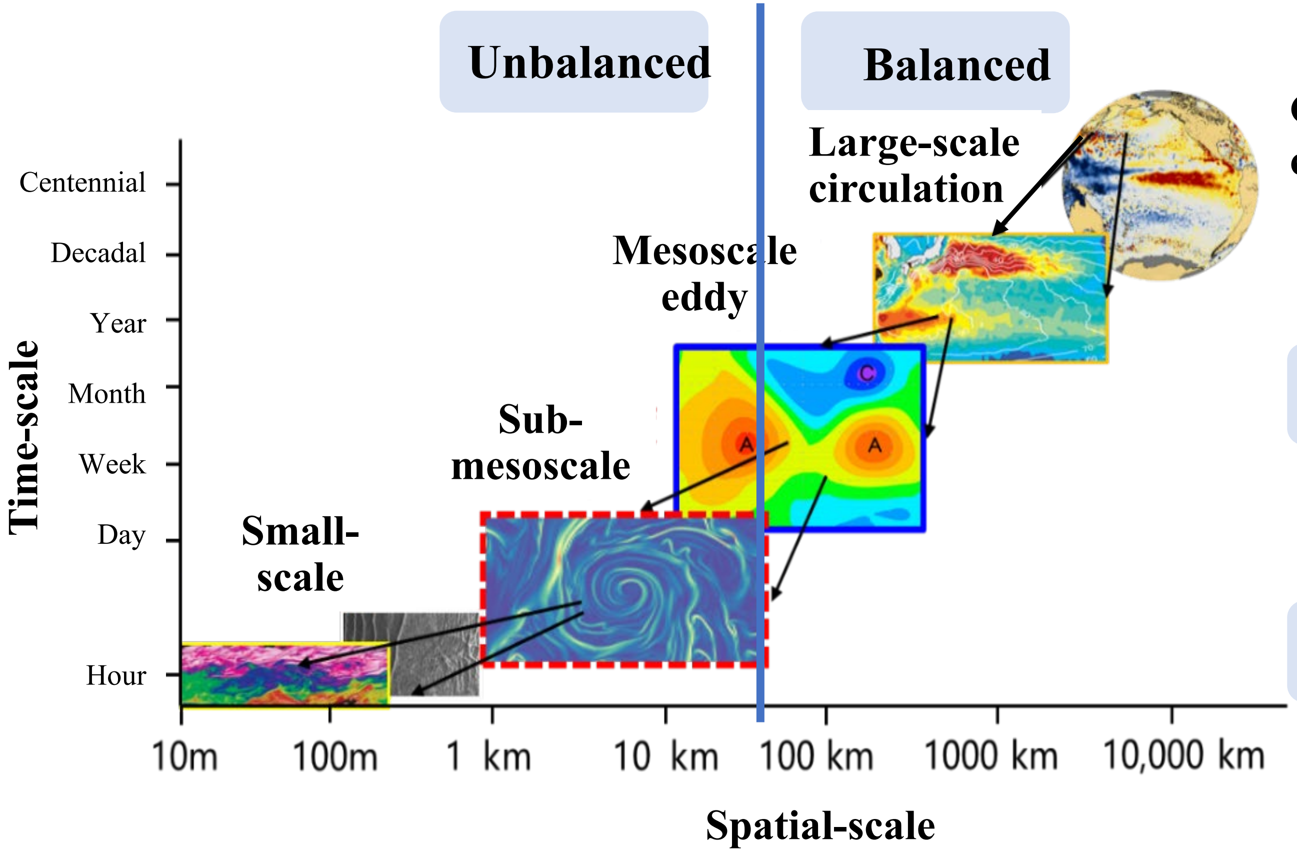
Mean circulation can be derived from wind stress curl

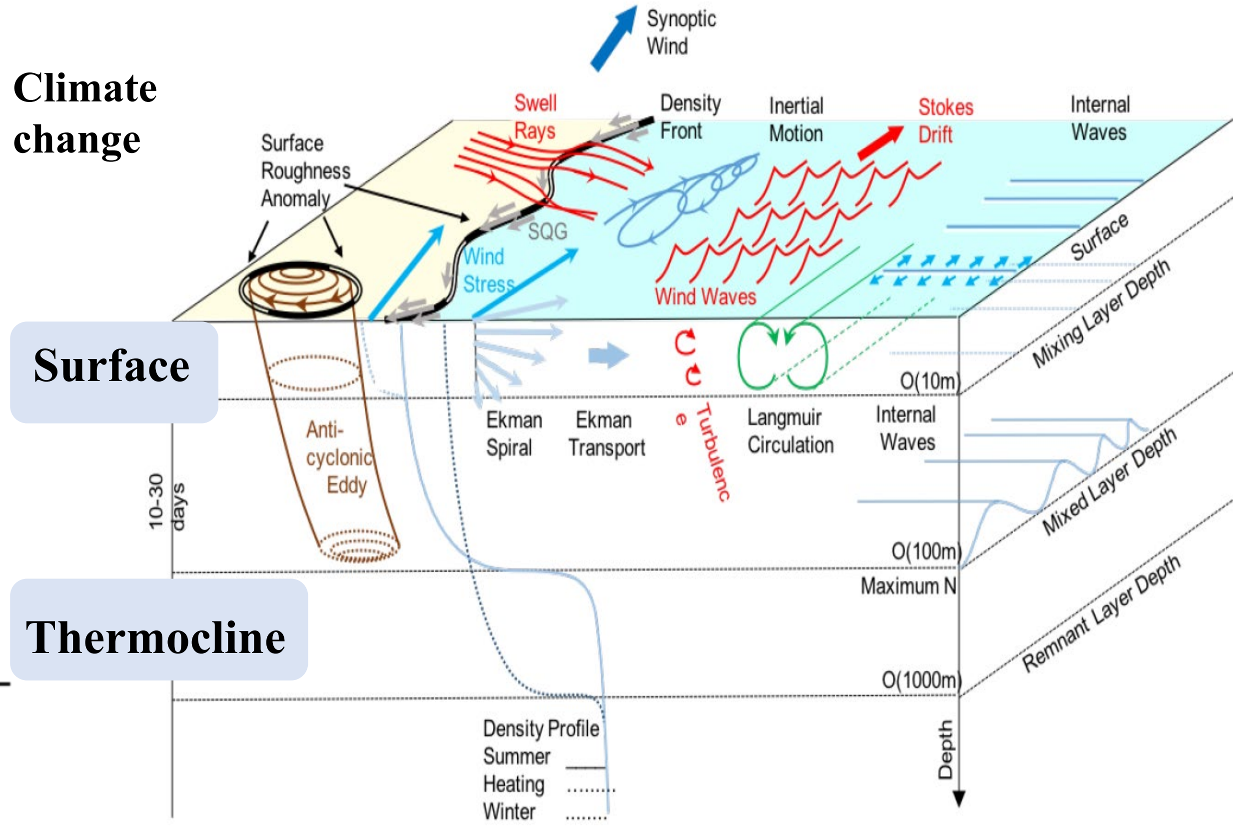




Theory of wind-driven circulation solved the issues of large-scale circulation (>1000 km), which is confirmed by the World Ocean Circulation Expedition.

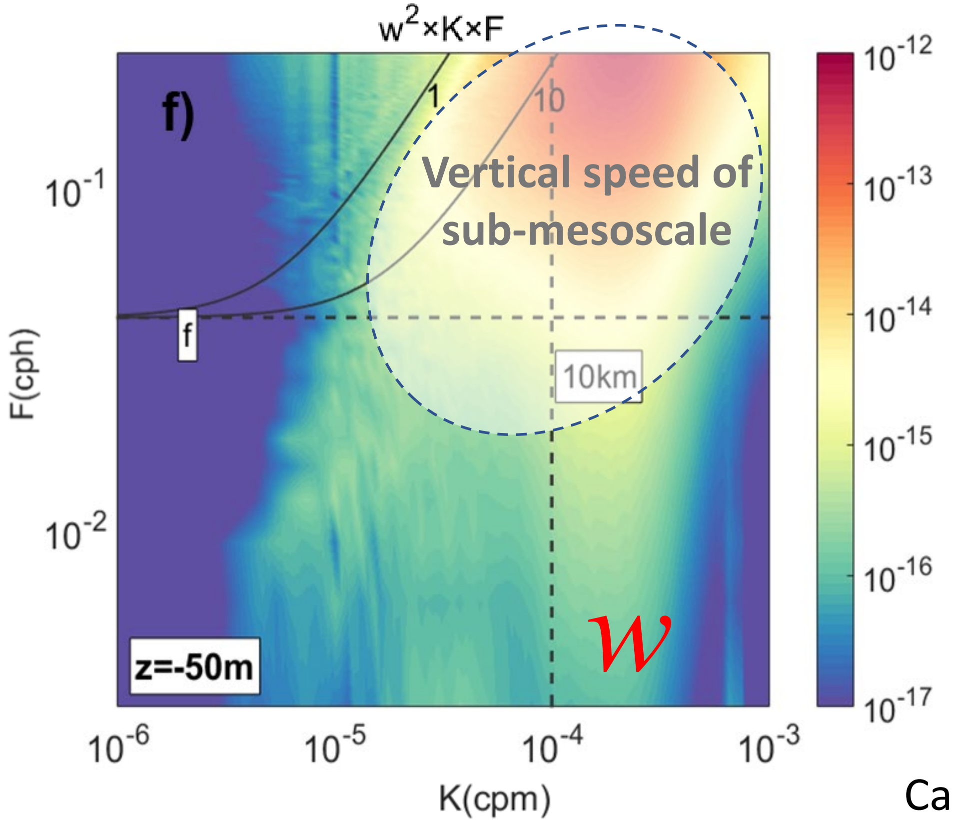
Progress: Multiscale ocean circulation structure in the upper ocean





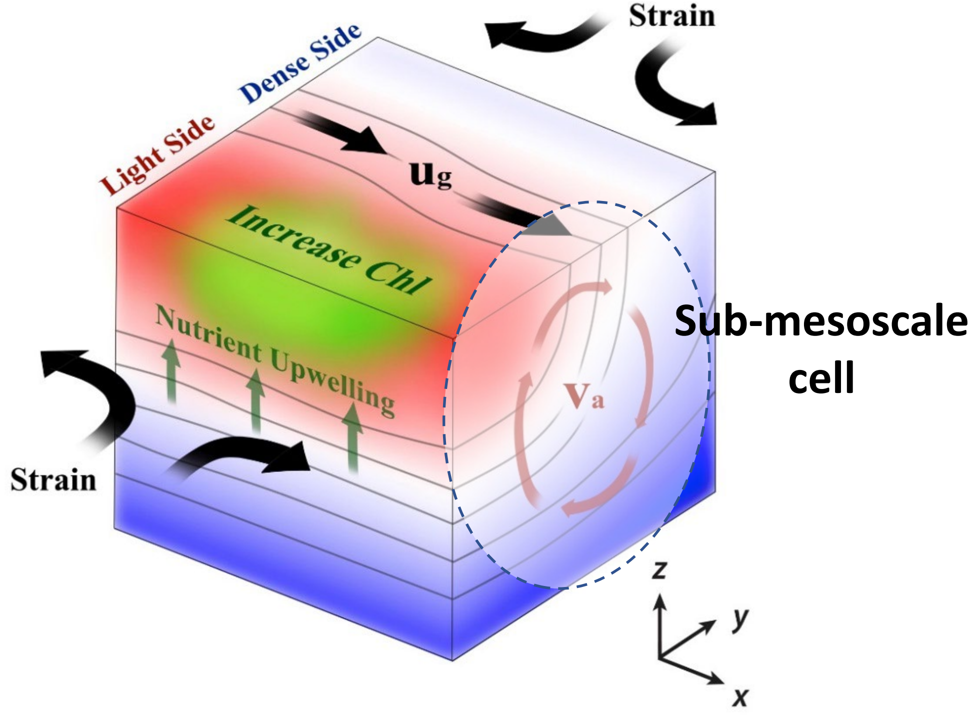
- Ocean dynamics involve processes in multiple spatial and temporal scales with the balanced component associated with the large- and meso-scale processes and the unbalance component is corresponding to mesoscale and sub-mesoscale； The unbalanced dynamics typically occur in the upper ocean, accounting for the 80% of ocean motions.
- Previous studies focused on geophysical current that is dominated by thermocline processes, while the sub-mesoscale processes are difficult to study and observe

Progress: Sub-mesoscale processes



Vertical speed of multiscale processes

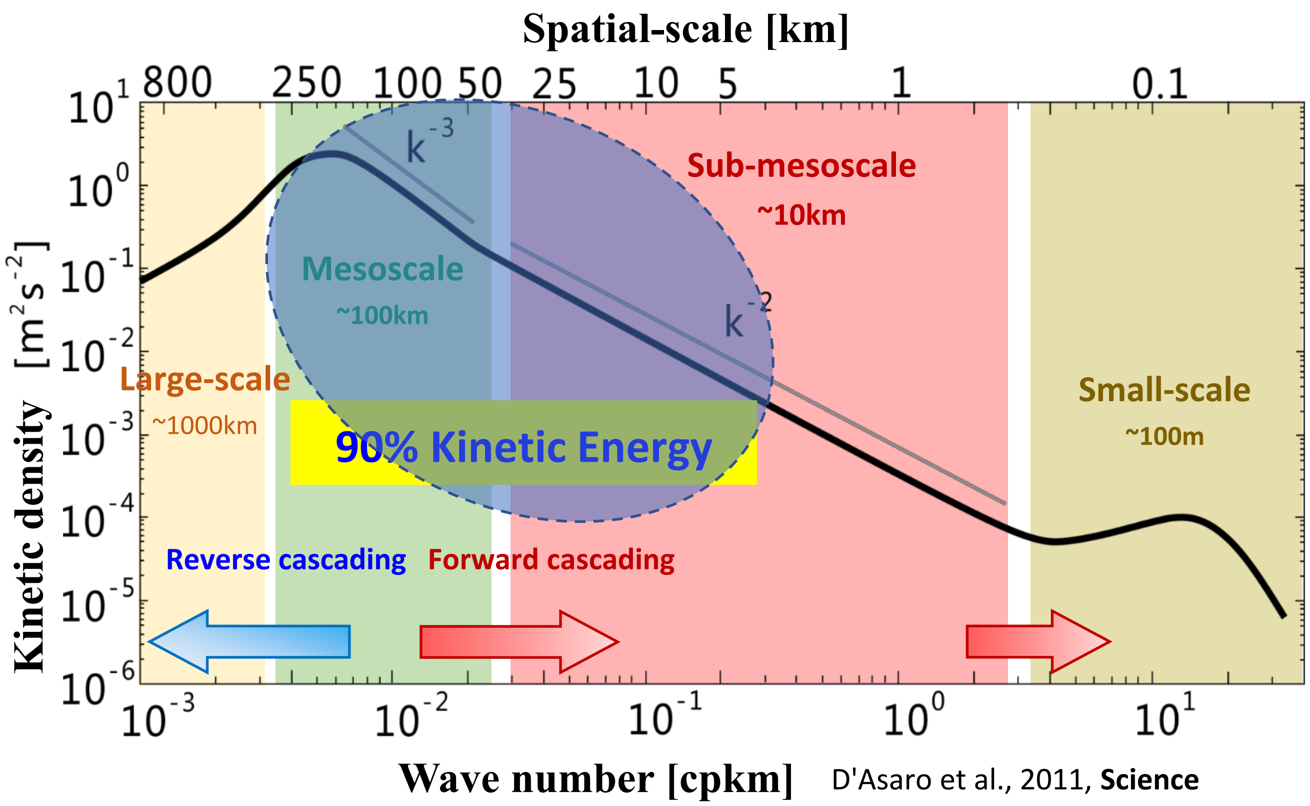
Cao, 2021 JPO;
Zhang, 2019 NC



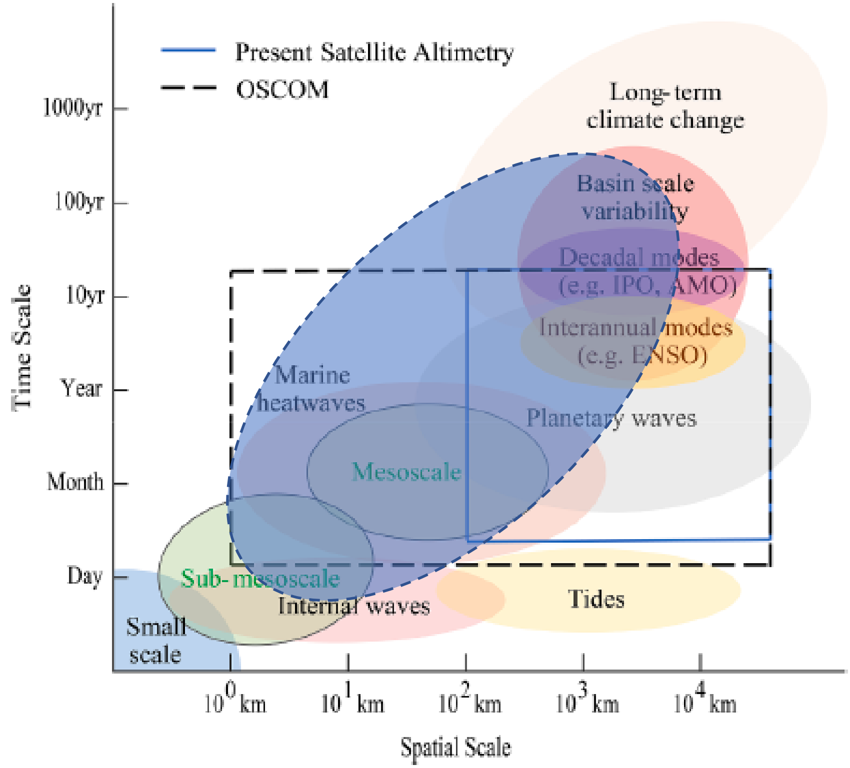
Sub-mesoscale frontogenesis

- The sub-mesoscale dynamics vary rapidly, typically with a time scale of O (1 day), which is an indispensable key pathway for positive ocean energy cascading and is the most dominant dynamical process for oceanic vertical material exchange and sea-air fluxes.
- Sub-mesoscale processes are at the forefront of oceanography and are key to the study of unbalance ocean dynamics.

Scientific issues: ① Multi-scale dynamical process interaction and energy cascades

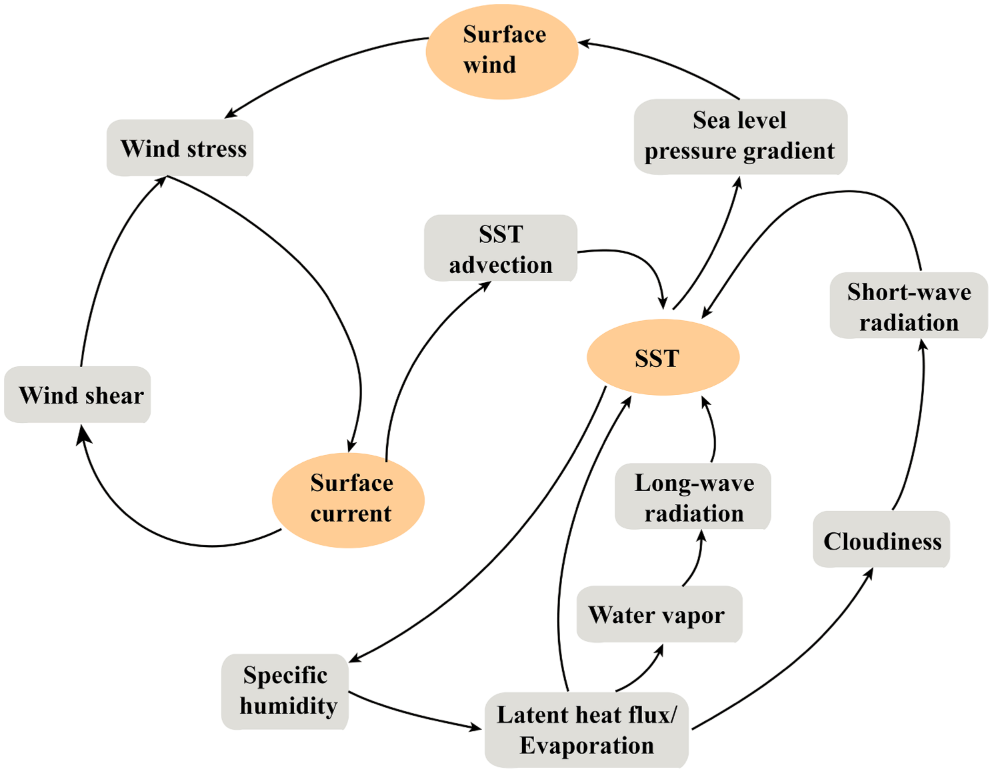


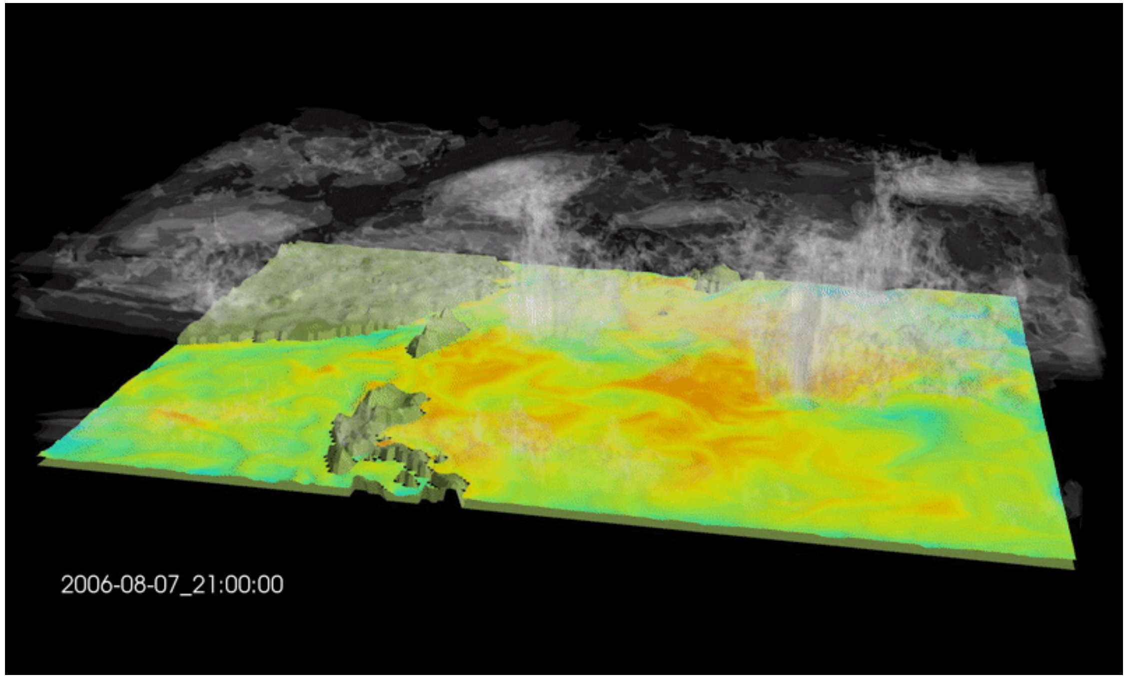
D'Asaro et al., 2011, **Science**



- How to separate multi-scale processes in the global ocean surface total currents?
- What constitute the unbalanced ocean dynamic processes?
- How do mesoscale and sub-mesoscale processes in the ocean interact with each other and transform energy?
- How does the energy of surface wind input and convert to ocean currents and waves?

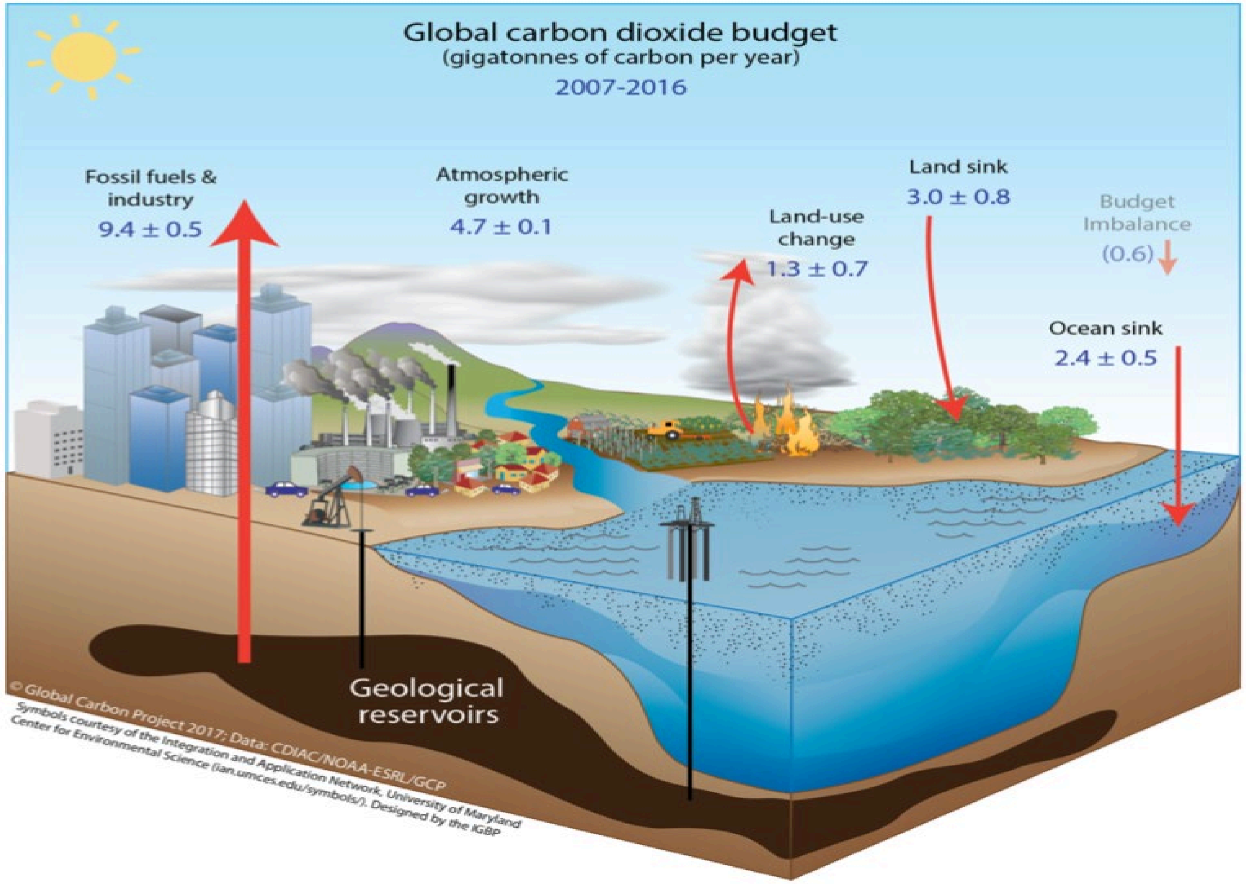
Scientific issues: ② Ocean-atmosphere exchanges and their climate effects

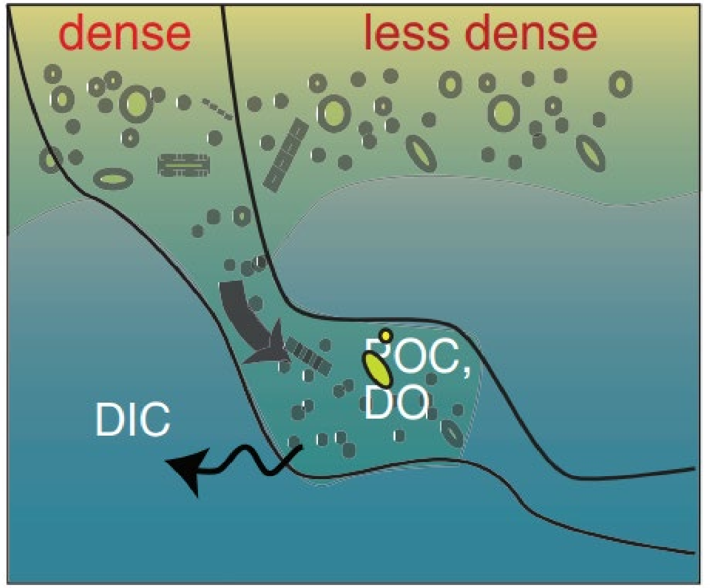




- How does the ocean surface dynamic affect the exchange of ocean-atmosphere momentum, heat and mass?
- How does the ocean surface dynamic modulate the global heat balance, and then influence global and regional climate?
- What is the contribution of sub-mesoscale and mesoscale ocean-atmosphere thermal coupling to climate change?
- How to quantitatively estimate CO_2 exchange at the ocean-atmosphere interface?

Scientific issues: ③ Ocean carbon budget and biogeochemical cycle





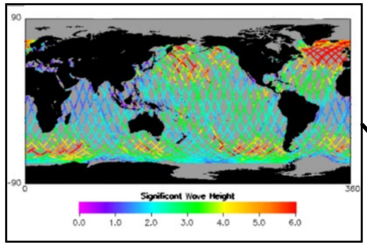
>50% from scale smaller than mesoscale processes

Omand et al., 2015, Science

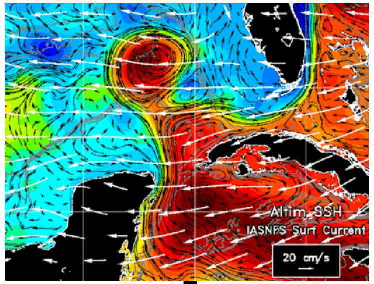
- ➢ How to understand the ocean internal processes through surface currents?
- ➢ What is the vertical dynamic structure of the upper ocean and its mass transport?
- ➢ How do ocean vertical transport and horizontal transfer affect nutrient and biogeochemical cycling?

Scientific issues: ④ Development and improvement of ocean numerical models

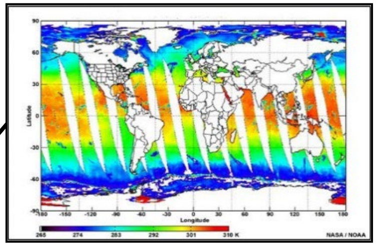
SSH
(~14 km)



Absence of
current
observations



Microwave
SST
(~25 km)

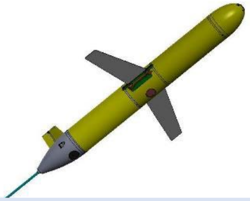


Argo T/S profiles：
(~10 km-1000 km)

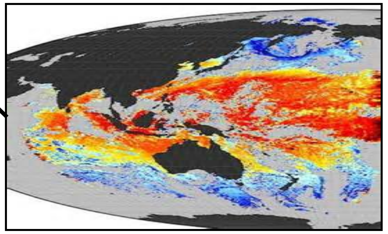
Data
Simulations

Subsurface buoy
(~10 km-1000 km)

Underwater Glider
T/S profiles
((~10 km-1000 km)



OGCM



Infrared SST
(~1 km)

- How to assimilate non-equilibrium sea surface current into coupled ocean circulation and ocean-atmosphere models?
- How to optimize the estimation of momentum fluxes between ocean and atmosphere?
- How to improv the forecast accuracy of ocean circulation models?

OSCOM Scientific Objectives

(1) To accomplish the **direct satellite observations of the global ocean surface current**, and the **current-winds-wave spectrums** integrated observations, fill the gap in sub-mesoscale observations of ocean surface current

(2) To reveal the **interactions between meso- and small-scale processes and energy cascade** in the upper ocean through simultaneous high-resolution observation of ocean surface current, vector wind, and wave spectrums, elucidate **the mechanism of mass and energy balance between A-O** with the SST/Chla observations, and

(3) provide a **dynamic basis for the improvement of OGCM and ESM**

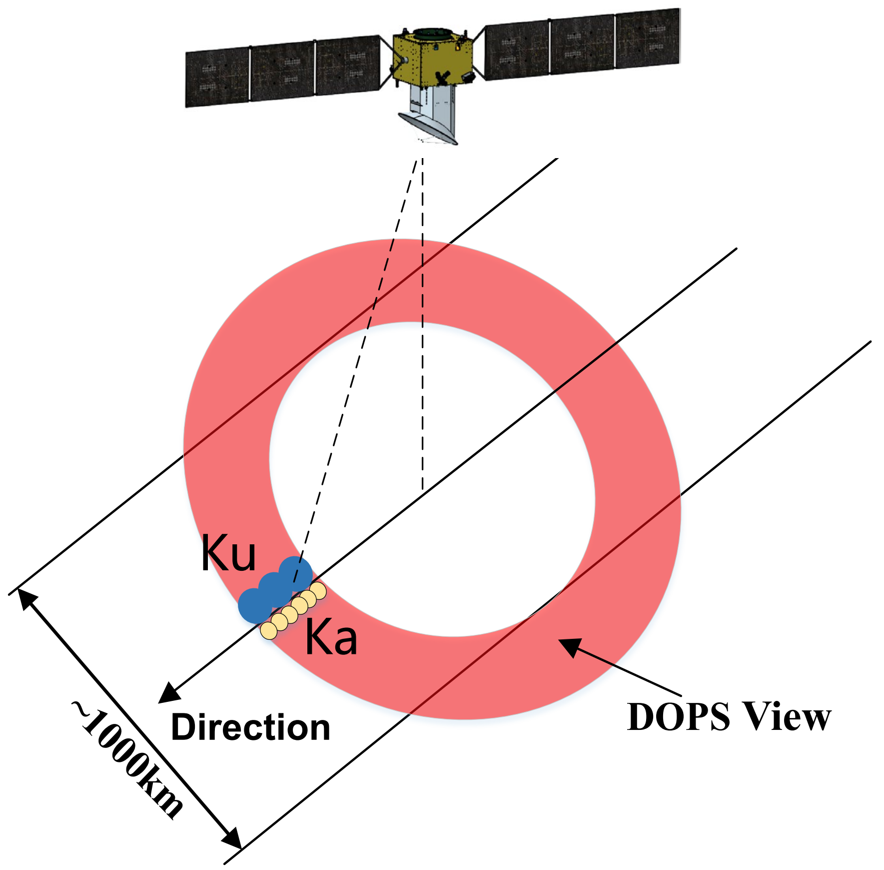
Configurations and measurement principles

Payload: Doppler Scatterometer (DOPS)

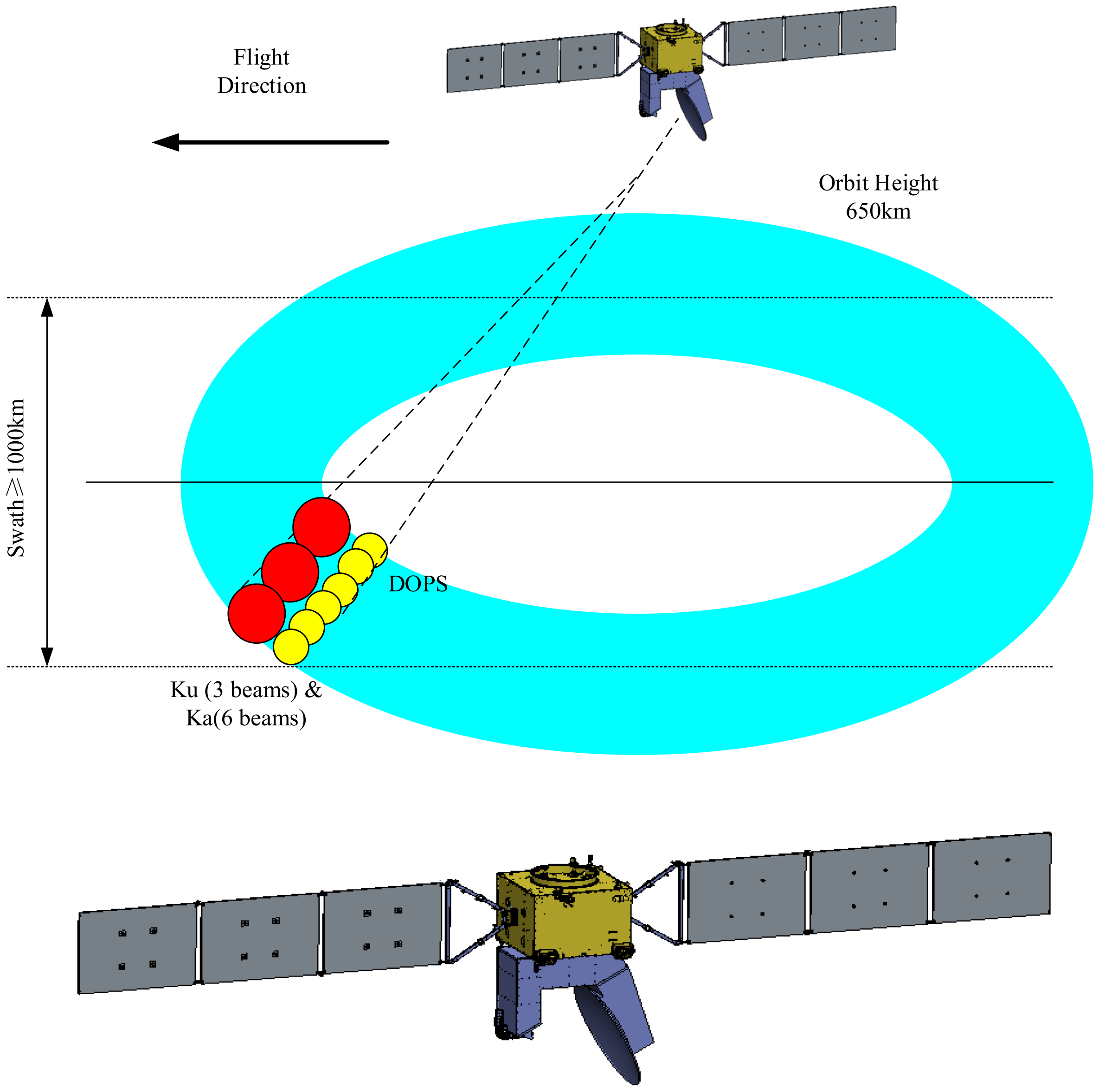
Variables:

Ocean surface currents (OSC),
Ocean surface vector winds (OSVW),
Ocean surface wave spectrums (OSWS)

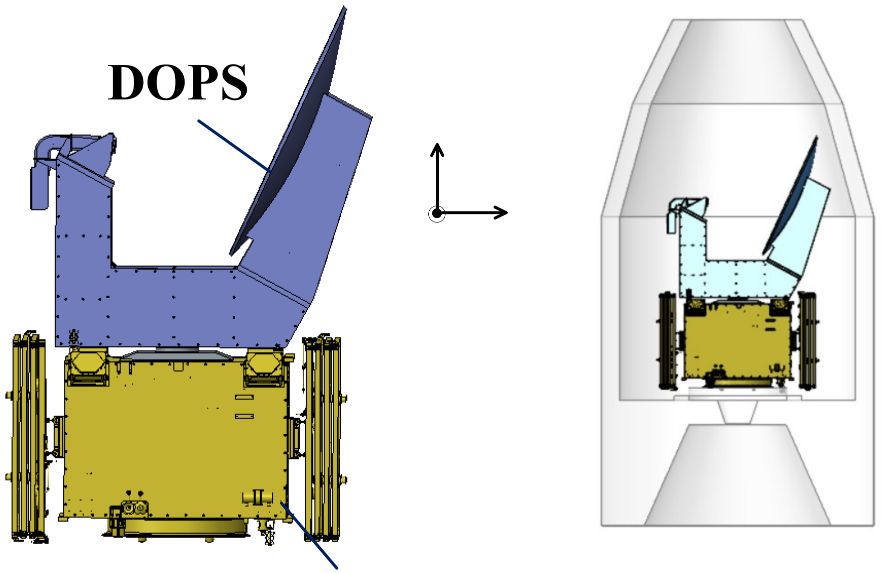
Parameter	Values
Wave band	Ka+Ku
Polarization mode	Ka： VV Ku： HH、VV
Swath	＞1000km
Resolution	5km（OSC, OSVW） 10km（OSWS）
Accuracy	0.1m/s（OSC） 1.5m/s（OSVW） 15°（OSC，OSVW）
Rotating speed	~15rpm
Antenna diameter	1.5m



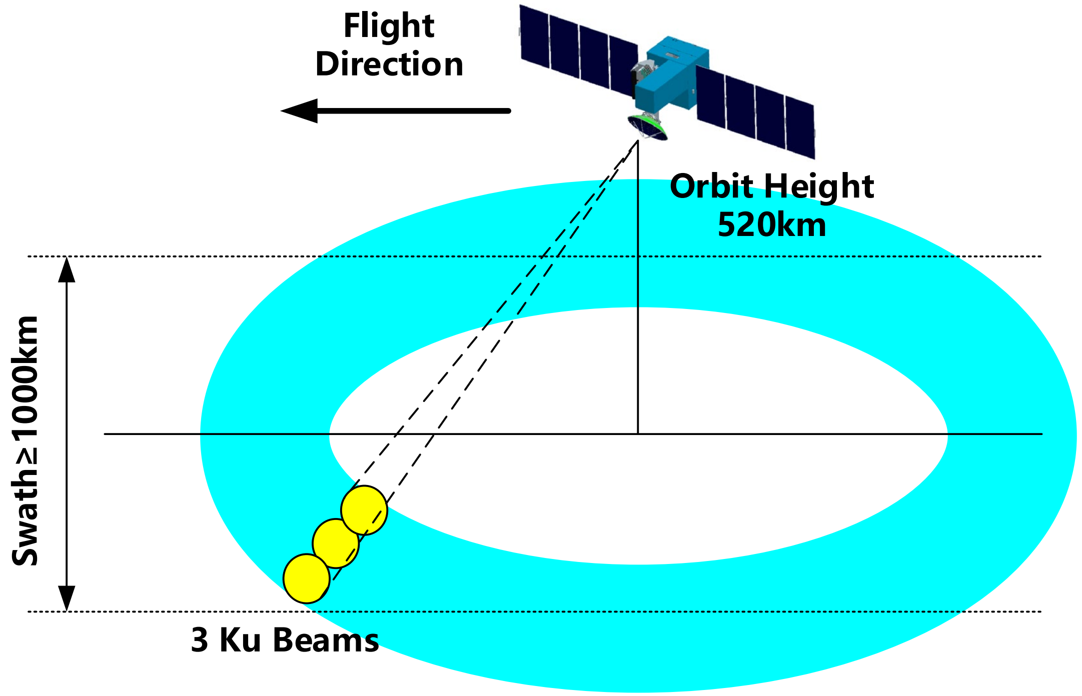
Ka & Ku Dual Frequency Doppler Scat onboard OSCOM



Payload	Payload Parameter	Technical Indicator
Ka+Ku DOPS	**Dual Band： Ka+Ku; incidence: 46°-49°; Polarization: Ka-band: VV, Ku-band: HH & VV;**	**Resolution：** 5 km (OSC, OSVW) **Swath：** >1000 km **Accuracy:** 0.1m/s (OSC) ≤15° (OSC, OSVW)



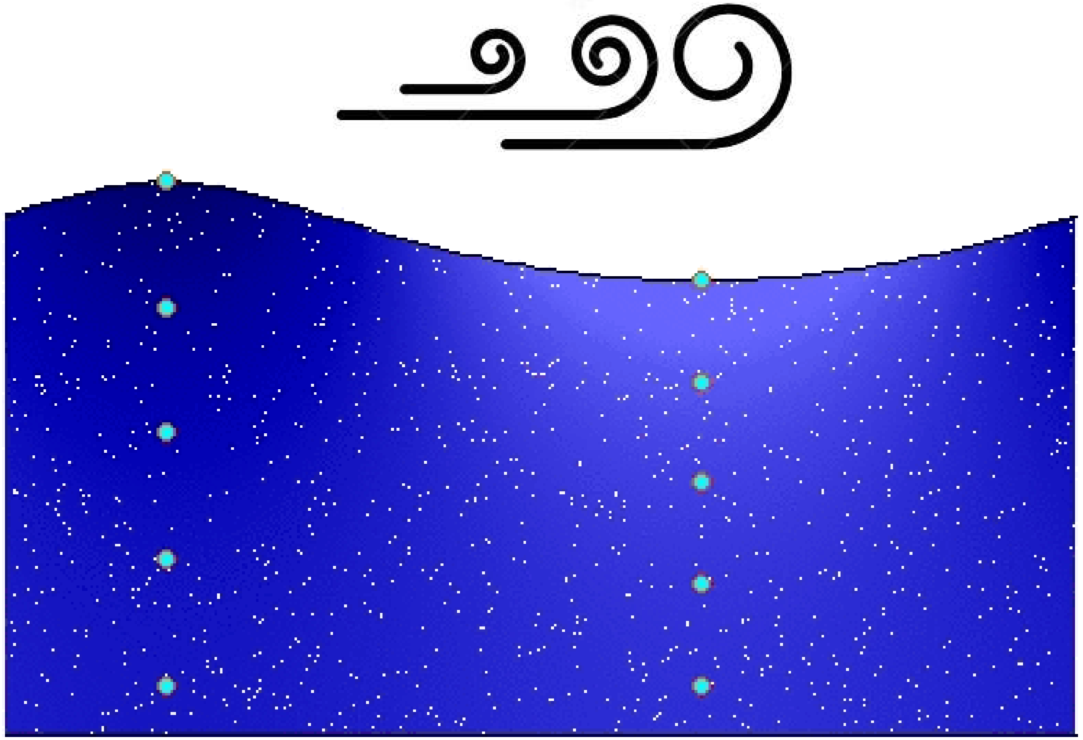
Ku band Doppler Scat onboard Wind-Wave Satellite



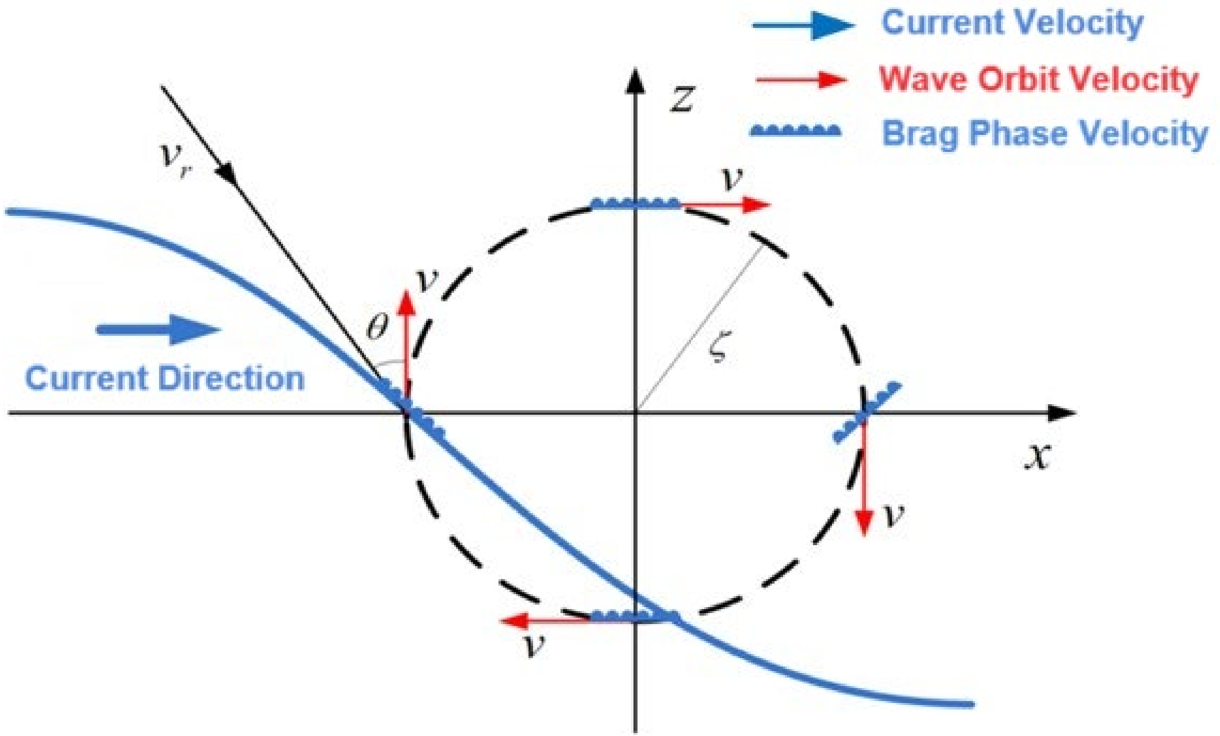
Payload	Payload Parameter	Technical Indicator
Ku-DOPS	**Frequency**： **13.256GHz (Ku);** **incidence: 46°-49°;** **Polarization: HH &VV;**	**Resolution** ： 12.5 km (OSC, OSVW) **Swath**： >1000 km **Accuracy:** 0.2m/s (OSC) 1.5m/s (OSVW) ≤15° (OSC, OSVW)

- **Wind-wave Satellite** is the follow-on missions of CFOSAT.
- The Scatterometer will upgrade to Ku band Multi-beam Doppler Scatterometer for the Ocean Surface Current observation.
- Ocean Surface Current accuracy: 0.2m/s
- Resolution, Wind vector accuracy will be improved.

Configurations and measurement principles



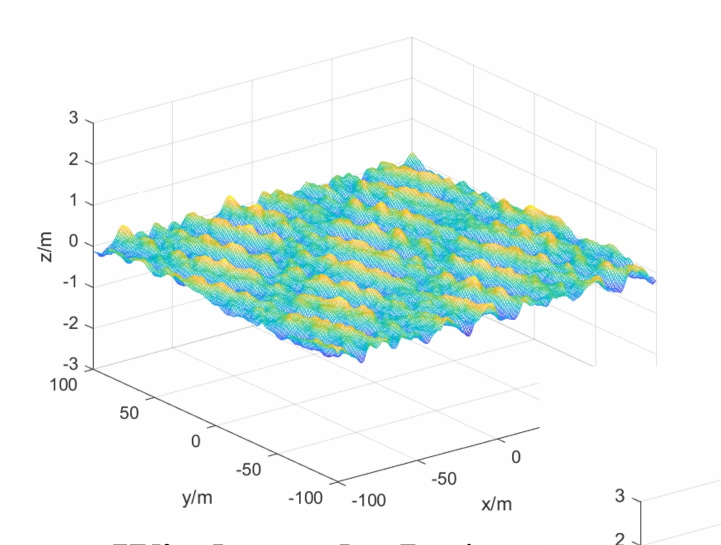
Velocity distribution of sea surface



Sea Surface Velocity = Current Velocity + Wave Orbit Velocity + Bragg Phase Velocity

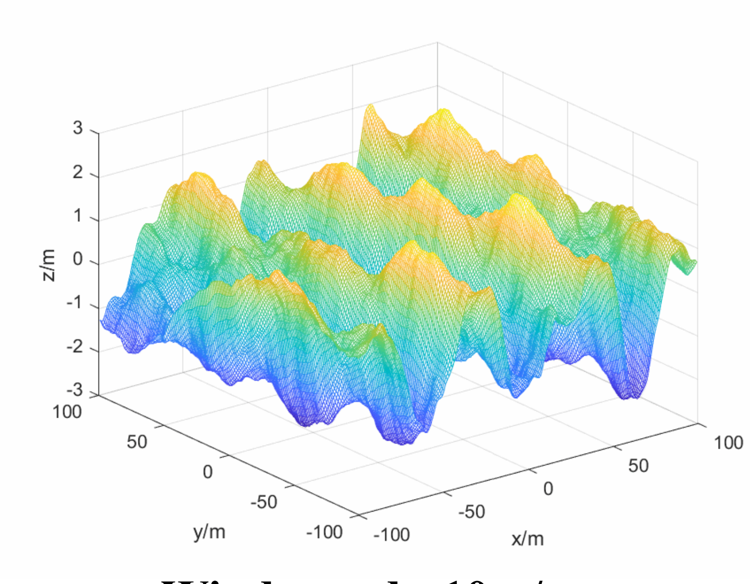
Configurations and measurement principles

① Doppler spectrum



Wind speed : 5m/s

Wind direction forward along the x-axis

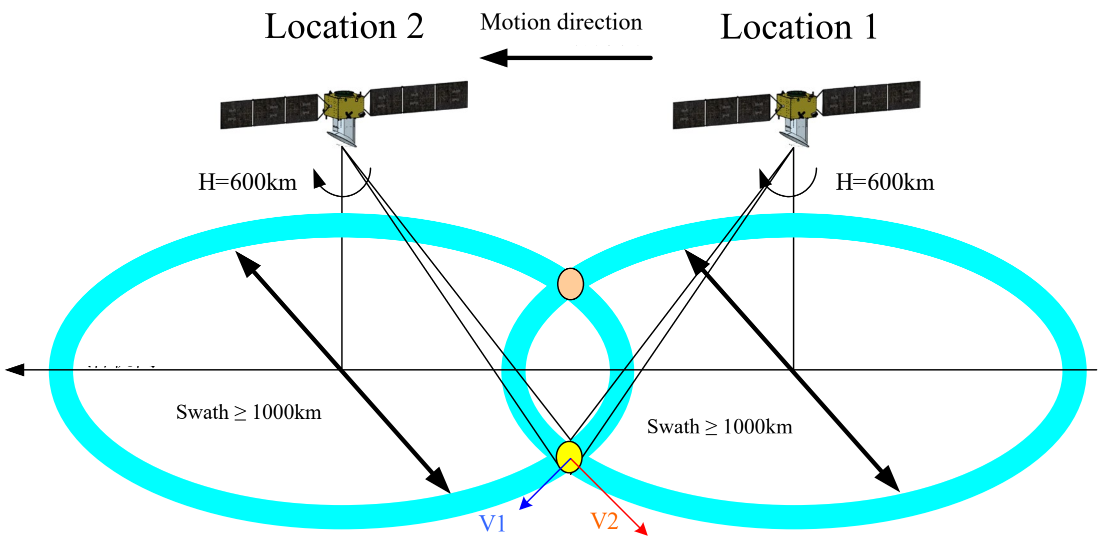


Wind speed : 10m/s

Simulation of of sea surface Velocity

② Doppler speed measurement

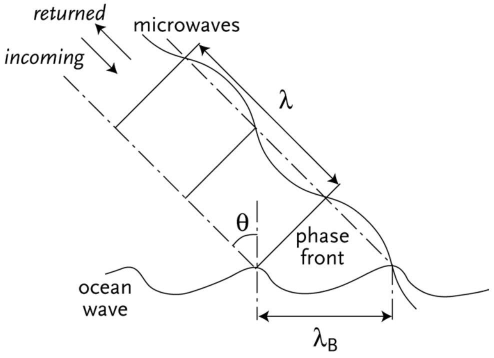
- Obtained the relative velocity of the satellite to the sea surface by the method of electromagnetic **pulse pair interference**
- Inverted the velocity vector by multi-azimuth observation of the sea surface using antenna cone scanning

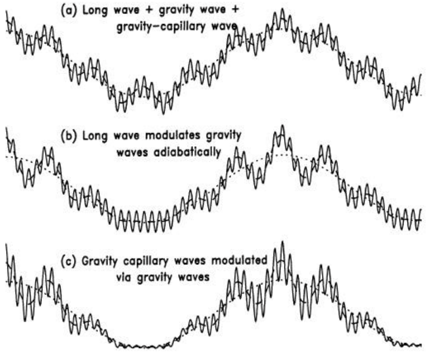


Configurations and measurement principles

③ 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

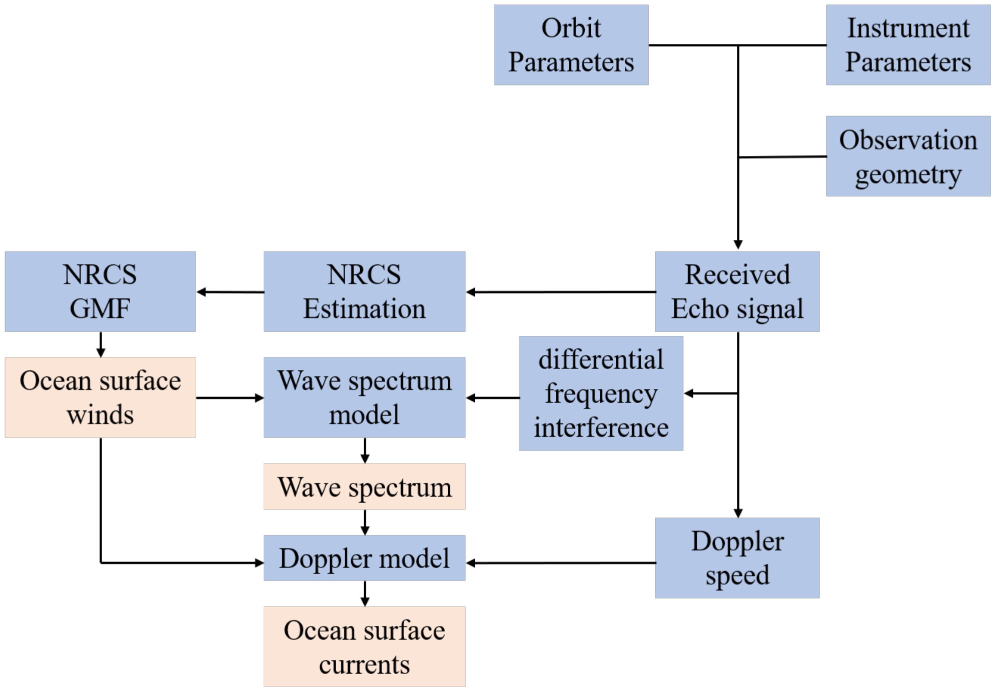




λ ~0.8, 2.0cm （Ka+Ku）

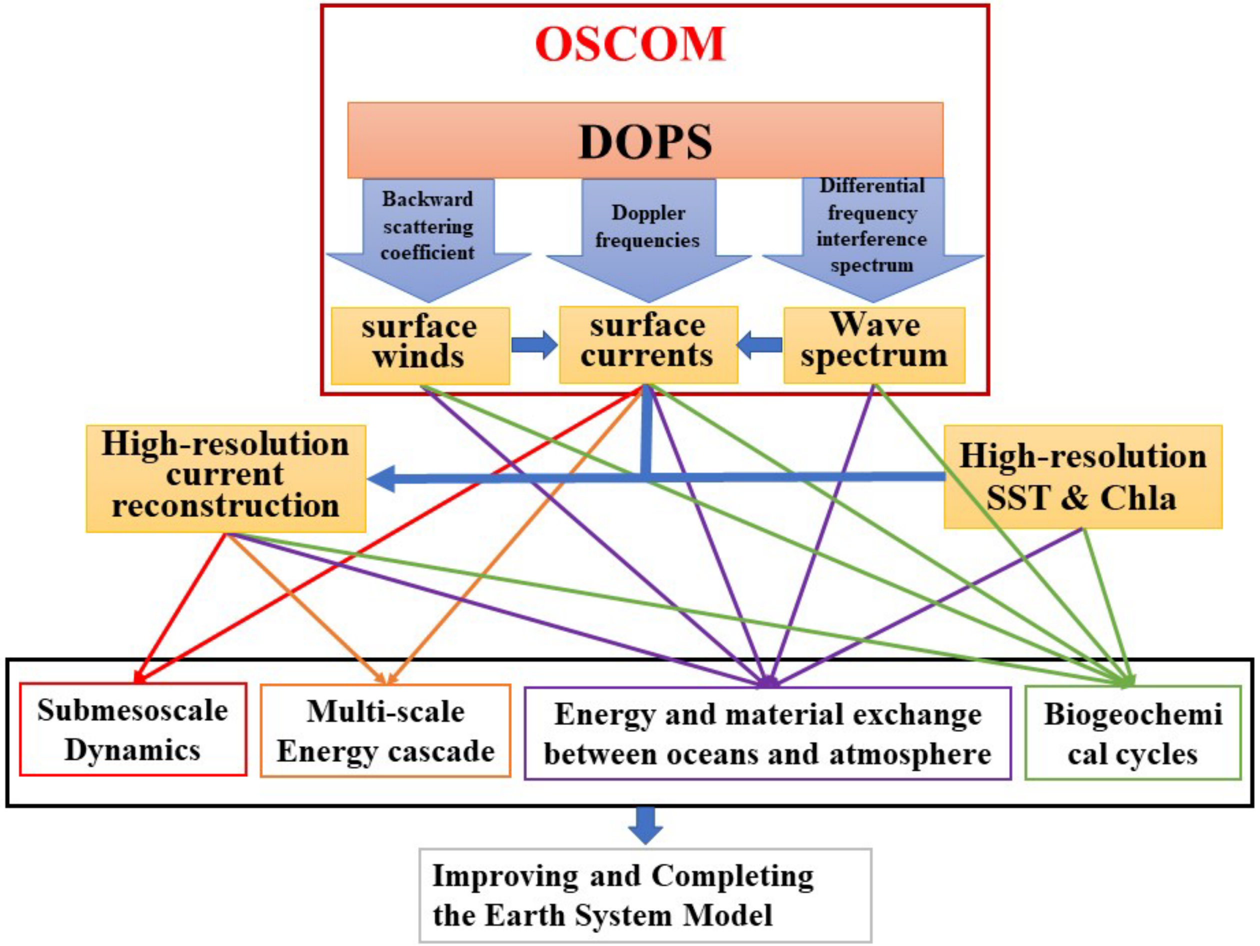
④ Sea surface current

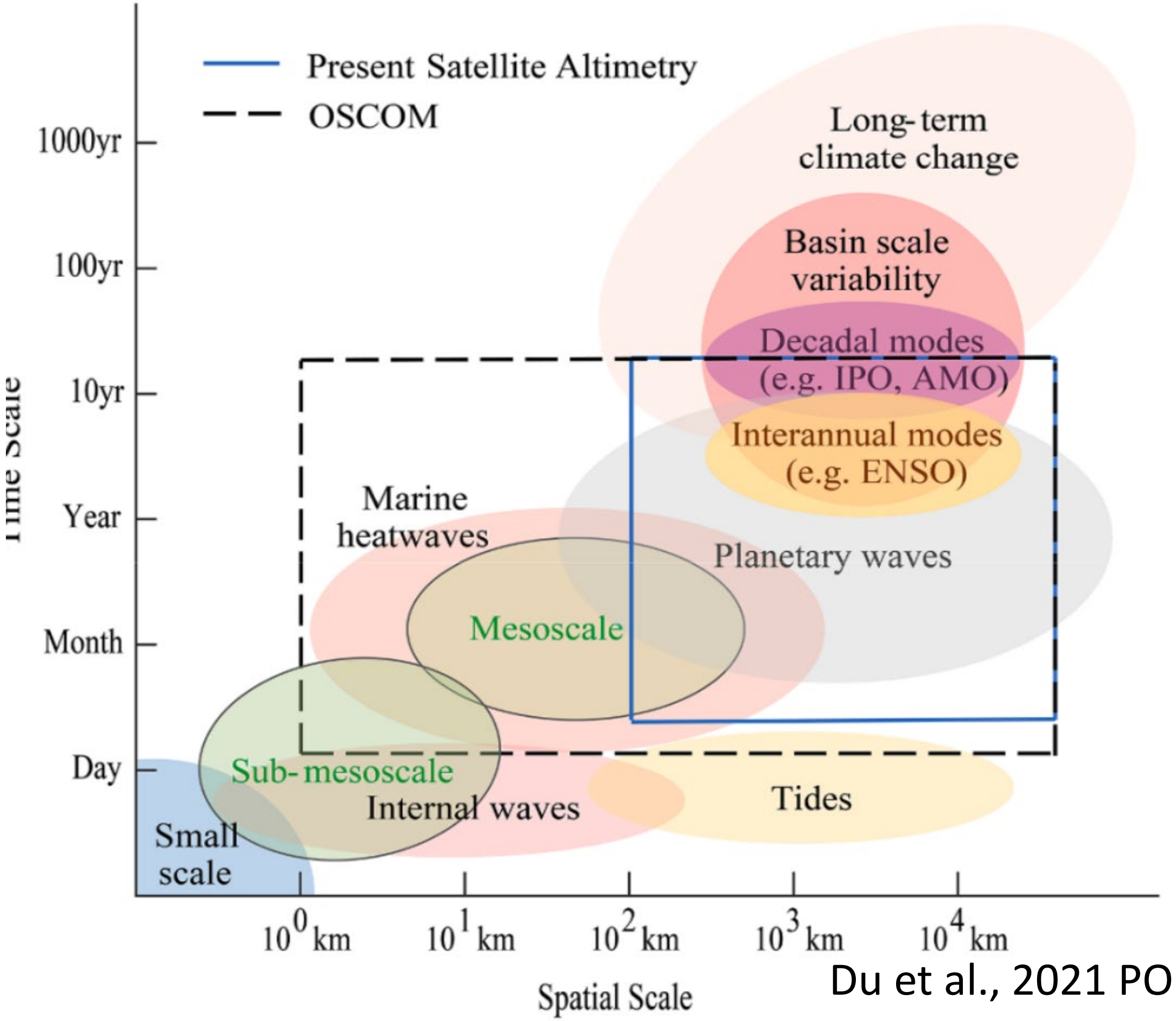
- Obtained high-precision sea surface Doppler velocities by Ka-band pulse clusters
- Eliminate platform Doppler errors with high-precision attitude and velocity measurement of satellite
- Eliminate the effects of capillary wave Bragg phase speed and gravity wave orbit speed using wind and wave models



Requirement and Achievement

OSCOM will directly measure ocean surface currents with a very **high horizontal resolution of 5–10 km and a 3-day global coverage**. The **accuracy of currents is 0.1m/s** in speed and 15° in direction.

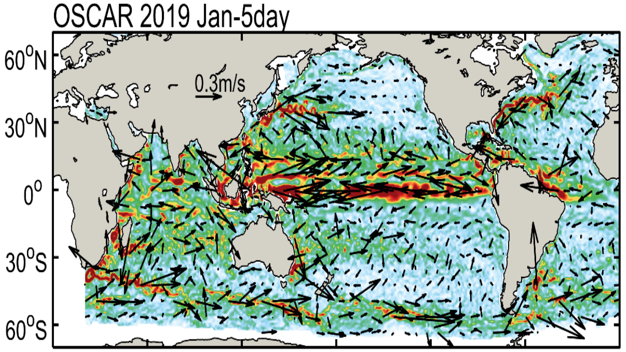


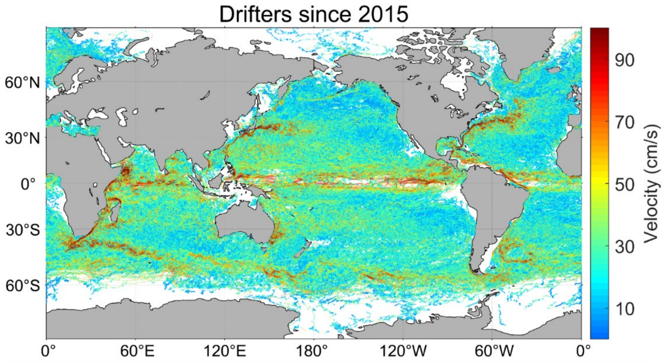


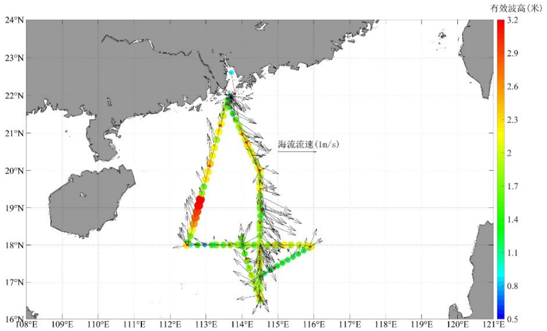
Du et al., 2021 PO

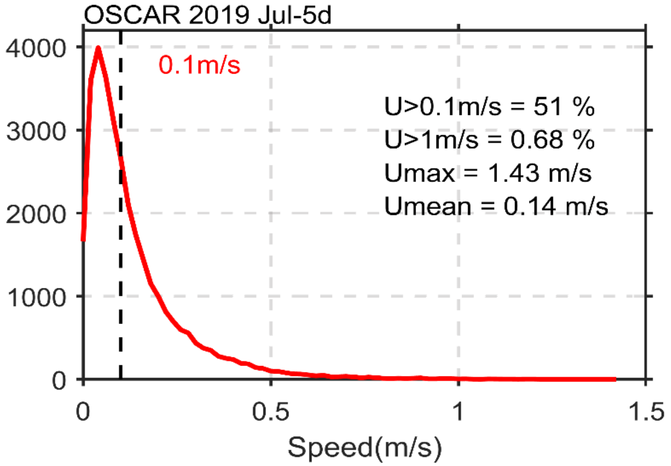
Global ocean surface velocity: OSCAR, Argos, ADCP, Radar

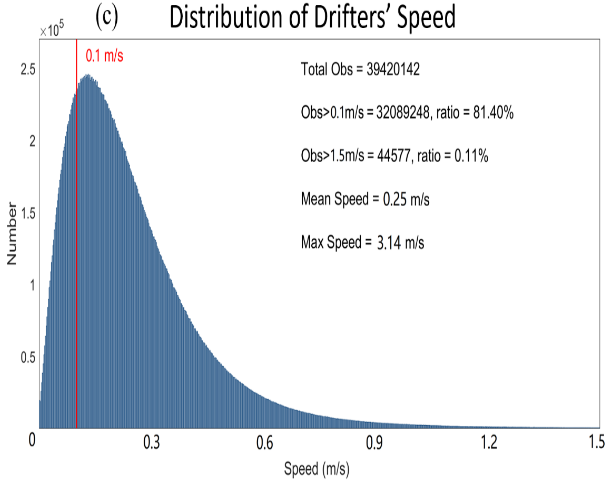
- 5-day mean OSCAR currents: Currents with speed ≥0.1m/s account for 51% of the global currents
- 6-hour mean Argos currents: Currents with speed ≥0.1m/s account for 81% of the global currents
- **In-situ observed currents (2021): Currents with speed ≥0.1m/s account for 95% of the currents**

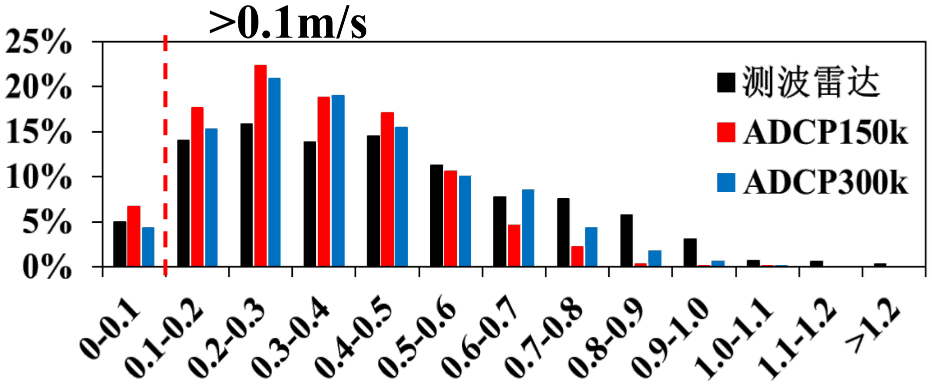




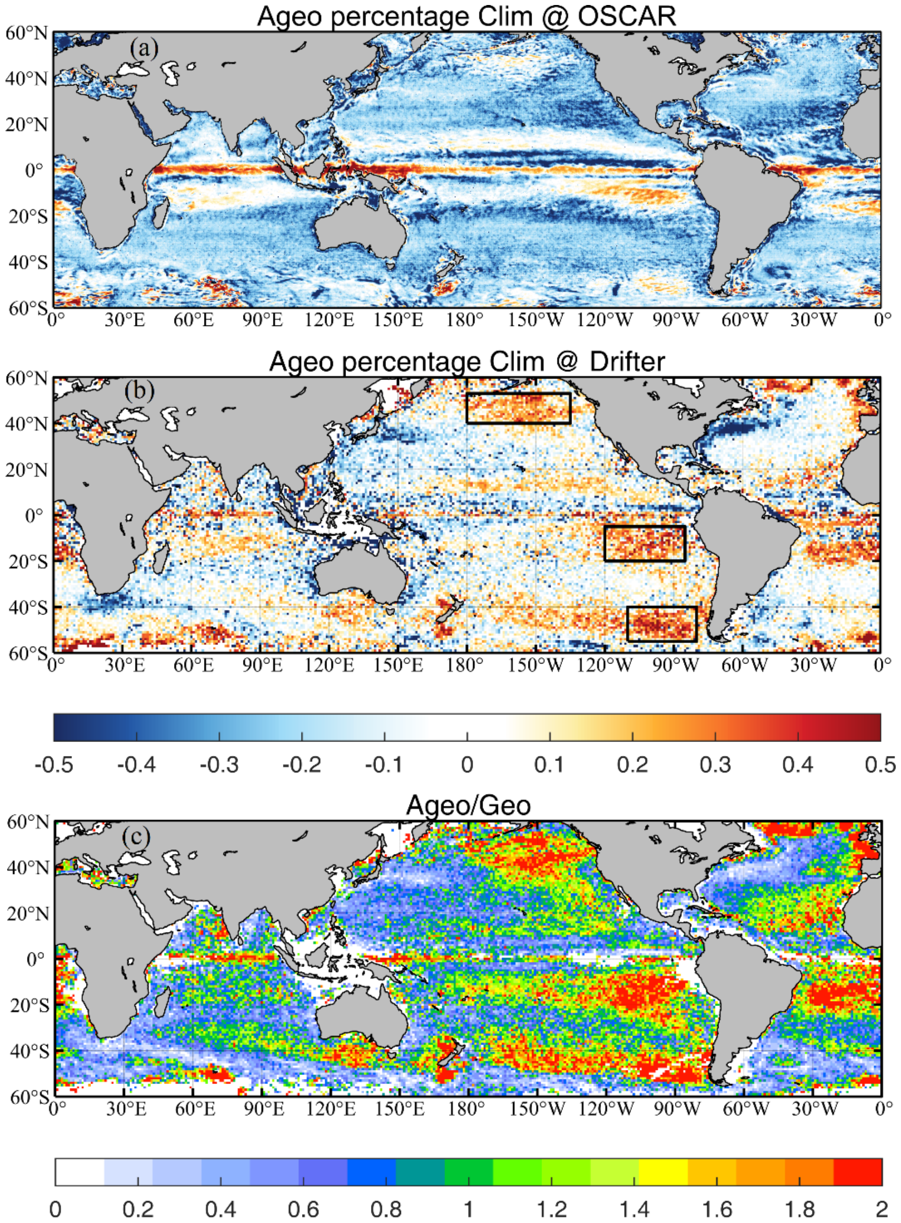




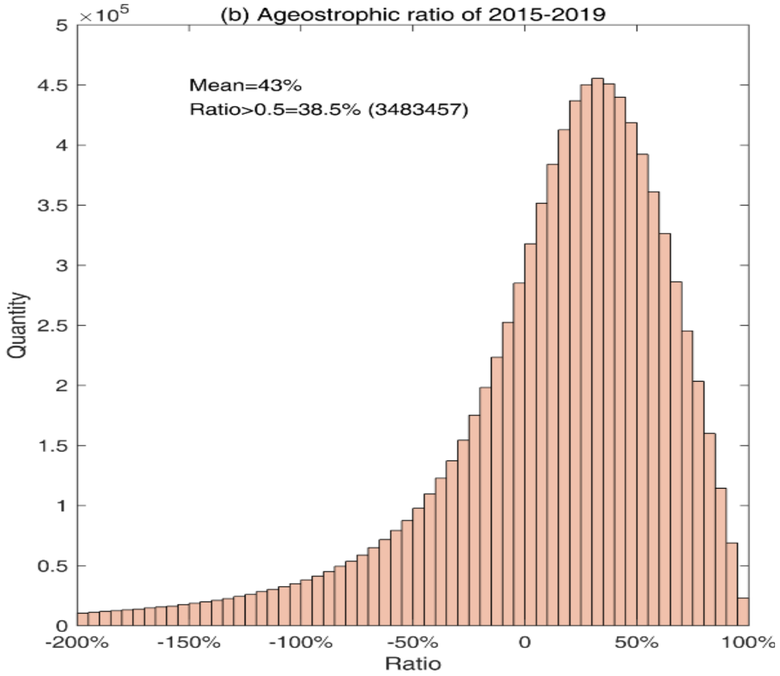




Importance of the non-geostrophic currents



- The non-geostrophic currents determine the directions of the total currents in the near-equatorial trade winds and mid-latitude westerly winds prevailing regions, where the maximum non-geostrophic speed can reach twice the geostrophic speed and exceed 60% of the total current.
- The OSCAR data cannot reveal the non-geostrophic processes in these regions and underestimate the weakening effect of the non-geostrophic process in the strong western boundary currents and the Antarctic Circumpolar Current.



- **The non-geostrophic currents in the global ocean account for ~43% of the total current**

$$P_1 = \frac{|S| - |S_G|}{|S|}, P_2 = \frac{|S| - |S_G|}{|S_G|}$$

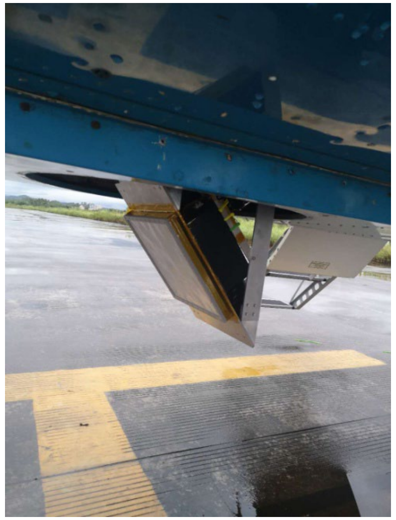
Flight experiment of Ka-band Doppler scatterometer calibration

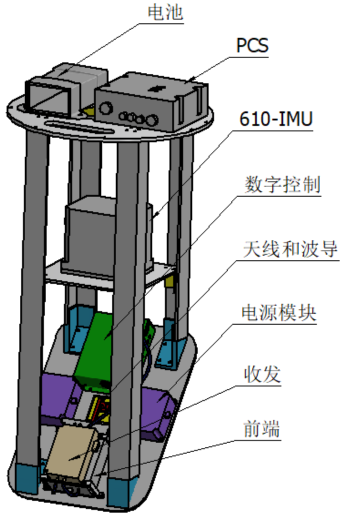
CARAVAN -208B

In-situ observations

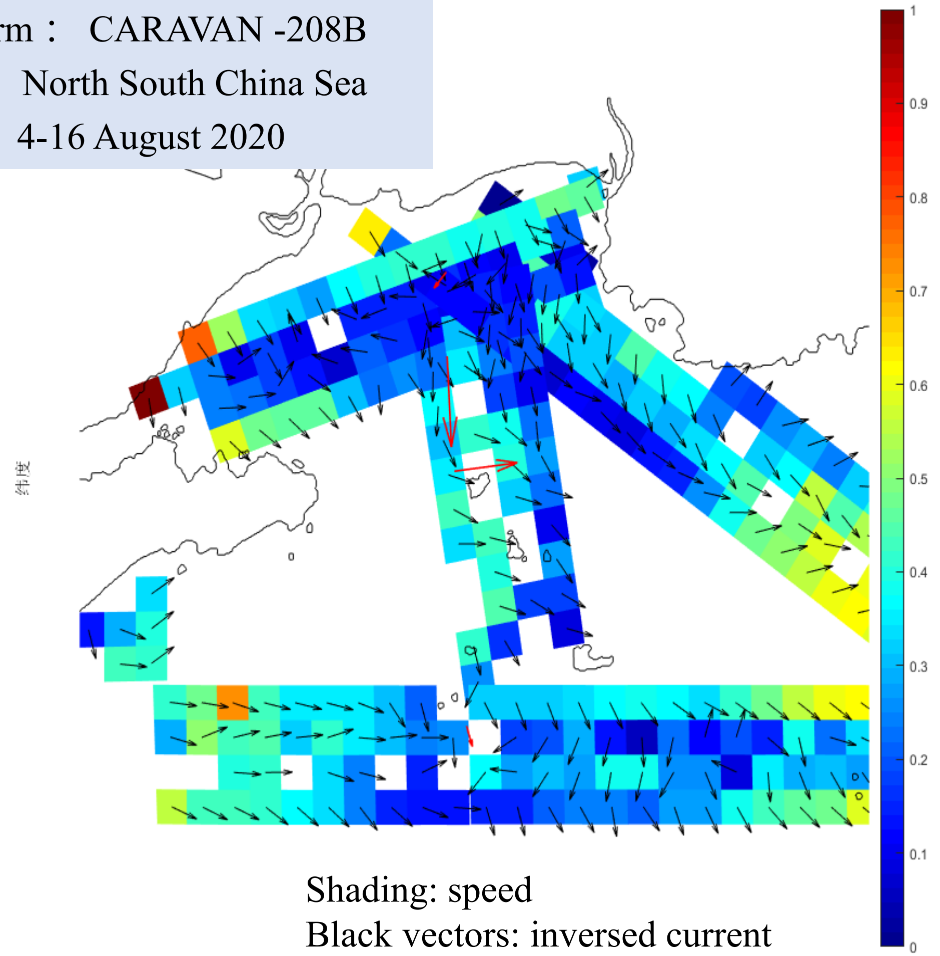
The currents inversed from Ka-band DOPS are **consistent with the in-situ observations**

- Platform： CARAVAN -208B
- Area： North South China Sea
- Time： 4-16 August 2020





Installation and commissioning of Airborne antenna



Shading: speed
Black vectors: inversed current
Red vectors: in-situ current

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