

A satellite mission concept to unravel small-scale ocean dynamics and air-sea interactions: ODYSEA (Ocean DYnamics and Surface Exchange with the Atmosphere)

ODYSEA Science Team

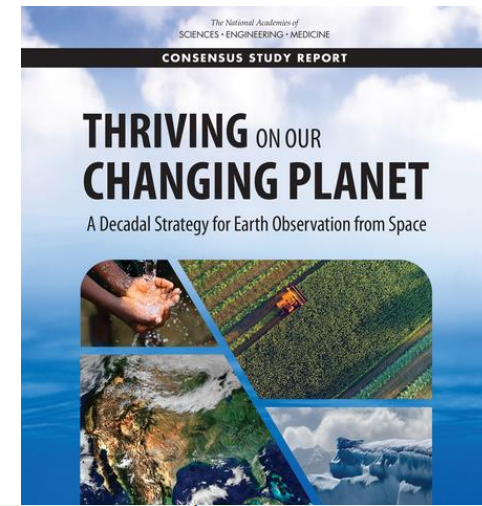
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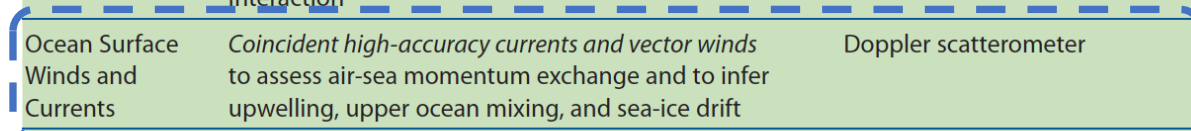


ODYSEA - a NASA Earth System Explorers (ESE) Mission concept

- ESE is a new NASA line of medium-class competed spaceflight missions, recommended by the 2017 Decadal Survey for Earth Science & Applications From Space
- Cost Cap \$310M FY24\$
- Seven solicited “Targeted Observable” categories
- ODYSEA responds to the “Ocean Surface Winds and Currents” observable category.
- 2-step campaign, 4 concepts into Step 1/Phase A; 2 selections to be announced ~mid-2025 (GHG a priority)
- AO on May 2, 2023; step-1 proposals due Aug. 2, 2023



Greenhouse Gases	<i>CO₂ and methane fluxes and trends</i> , global and regional with quantification of point sources and identification of sources and sinks	Multispectral shortwave IR and thermal IR sounders; or lidar*
Ice Elevation	<i>Global ice characterization</i> including elevation change of land ice to assess sea-level contributions and freeboard height of sea ice to assess sea ice/ocean/atmosphere interaction	Lidar*
Ocean Surface Winds and Currents	<i>Coincident high-accuracy currents and vector winds</i> to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift	Doppler scatterometer
Ozone and Trace Gases	<i>Vertical profiles of ozone and trace gases</i> (including water vapor, CO, NO ₂ , methane, and N ₂ O) globally and with high spatial resolution	UV/VIS/IR microwave limb/nadir sounding and UV/VIS/IR solar/stellar occultation
Snow Depth and Snow Water Equivalent	<i>Snow depth and snow water equivalent</i> , including high spatial resolution in mountain areas	Radar (Ka/Ku band) altimeter; or lidar*
Terrestrial Ecosystem Structure	<i>3D structure of terrestrial ecosystem</i> including forest canopy and aboveground biomass and changes in aboveground carbon stock from processes such as deforestation and forest degradation	Lidar*
Atmospheric Winds	<i>3D winds in troposphere/planetary boundary layer (PBL)</i> for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); or passive imagery or radiometry-based atmospheric motion vectors (AMVs) tracking; or lidar*



Motivation for ODYSEA



- Air-sea interactions (thermal & dynamical couplings) are important for weather and climate.
- The roles of dynamical (wind-current coupling) poorly quantified observationally, esp. on scales <200 km, <10 d.



- *Total surface currents are important for ocean dynamics, marine ecosystems and biogeochemical cycles.
 - Major knowledge gaps of total surface current dynamics, esp. in equatorial oceans & on scales < 200 km, <10 d.
- (*Total surface current = geostrophic + ageostrophic surface currents)



- NRT winds and currents are critical for operational monitoring and forecasting of the weather and ocean.
- Current capabilities are limited by observational coverage/sampling/resolution globally.

Urgent need for global high-resolution measurements of total surface currents & simultaneous vector winds to advance Earth system science, predictions, and operational applications that protect life, the environment, and the economy.

Models suggest dynamical coupling affecting thermal coupling, influencing storm tracks

South Indian Ocean example (Seo et al. 2021)

With and without considering the effect of Relative Wind (RW), RW-noRW, causes significant difference in meridional SST gradients, which impacts the atmospheric Eady growth rate σ_{BI} and thus storm track.

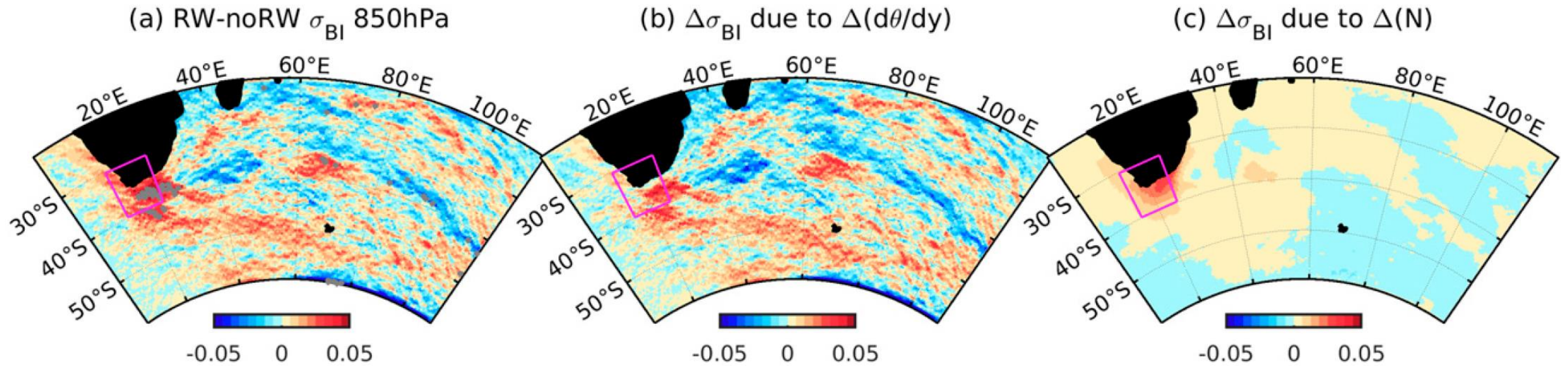


FIG. 10. (a) Annual-mean difference in σ_{BI} at 850 hPa (day^{-1}) between RW and noRW, and the differences (b) due to meridional temperature gradient only and (c) due to change in static stability only.

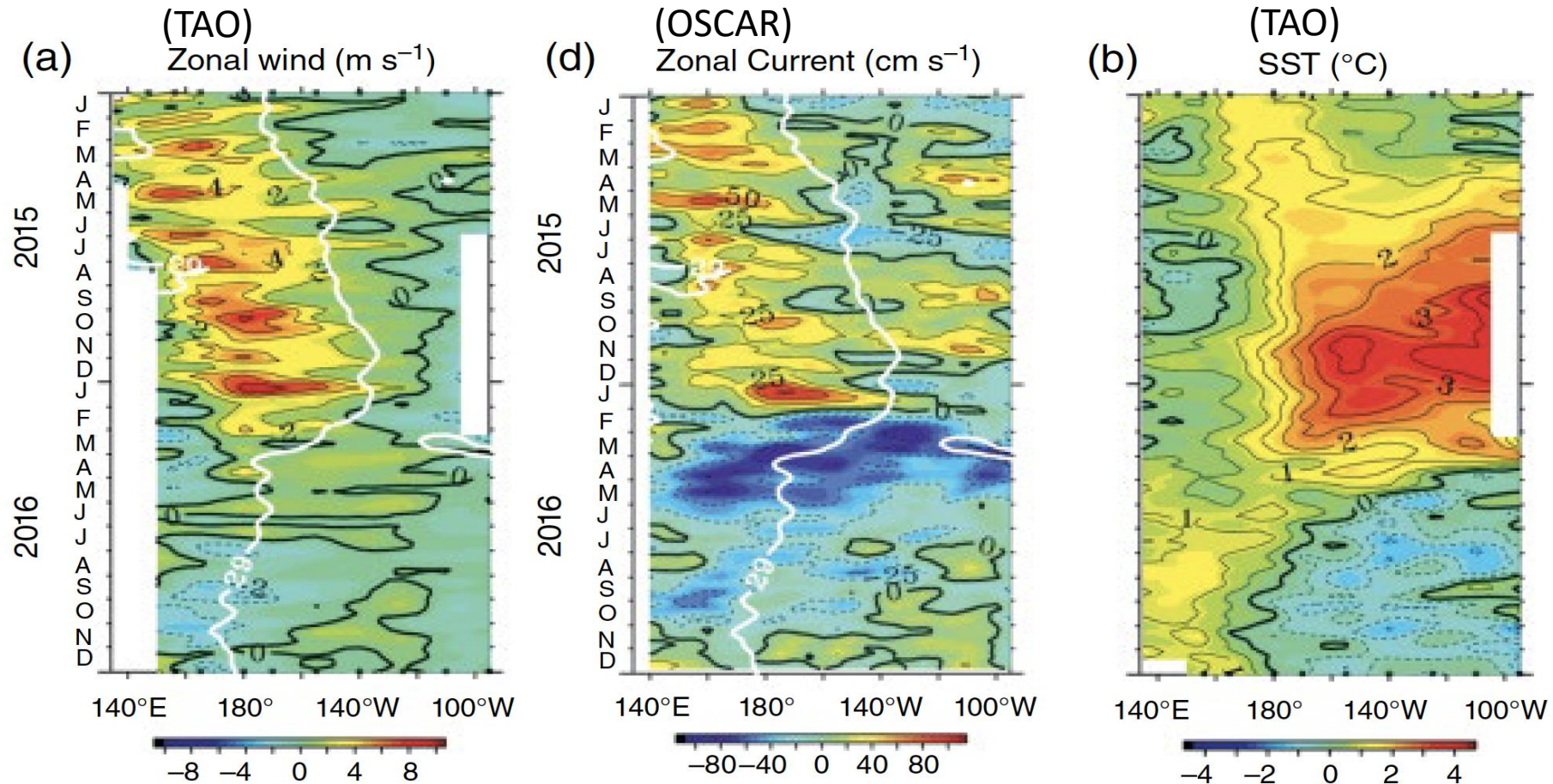
It's crucial to study dynamical (wind-current) & thermal coupling to understand air-sea interactions holistically, prompting the need for global simultaneous measurements of winds & currents to test model hypotheses (Seo et al. 2023, J. Clim. review).

The dynamics and roles of total surface currents in El Niño-Southern Oscillation (ENSO) are not well understood, affecting predictability study and prediction effort

- Tropical Pacific surface currents are fundamental to ENSO cycles (e.g., through zonal advective feedback).
- The relation of surface current anomalies and westerly wind bursts is not well understood.
- Stratification (MLD/BLT) effect? Error in surface current estimates? (geostrophic & Ekman theories not valid near equator)
- **Urgent need for direct measurement of total surface currents to advance understanding & improve mixing parameterization.**

Example for the 2015-16 extreme El Niño (McPhaden et al. 2020):

Longitude-time Hovmöller diagrams of zonal wind, current, and SST anomalies (1°S - 1°N average)





ODYSEA

Ocean Dynamics and Surface Exchange with the Atmosphere

Principal Investigator: Prof. Sarah Gille, Scripps Institution of Oceanography, UC San Diego

Connecting the ocean and atmosphere to advance science & applications that protect life, environment, & economy

ODYSEA provides the 1st-ever, near-daily global measurements of total surface currents and simultaneous high-resolution vector winds to reveal key processes underlying ocean dynamics and air-sea interaction that are important to marine ecosystems, weather, and climate, and to support operational applications.



SCIENCE OBJECTIVE 1:

Advance air-sea interaction science by revealing wind-current coupling processes.



SCIENCE OBJECTIVE 2:

Fill major knowledge gaps in the dynamics of total surface currents.

ODYSEA'S KA-BAND DOPPLER SCATTEROMETER

Simultaneously measures ocean vector winds and currents at 5-km posting. This measurement technique has been extensively validated by NASA's airborne DopplerScatt instrument (including by S-MODE).

APPLICATIONS OBJECTIVE:

Provide **essential NRT** wind & current measurements to advance operational applications for

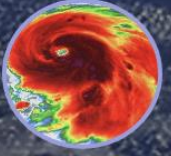
Maritime safety and transport efficiency

Fisheries management, marine pollutant tracking, blue economy

Weather warning & forecast up to 1-2 km of the coast

Sailor & pilot safety of U.S. Navy/Air Force

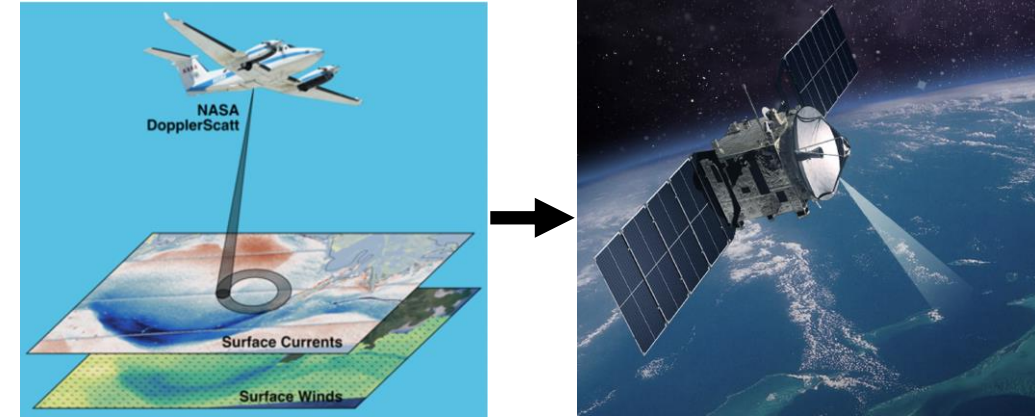
Maritime Search and Rescue



ODYSEA's strong foundation and partnerships

ODYSEA builds on:

- NASA's long heritage in satellite scatterometry for ocean-surface vector wind measurements;
- strong foundation of Doppler scatterometry for simultaneous measurements of vector winds and currents, matured by NASA's Earth Science and Technology Office and demonstrated by NASA's Earth Venture Suborbital Mission-3 S-MODE.

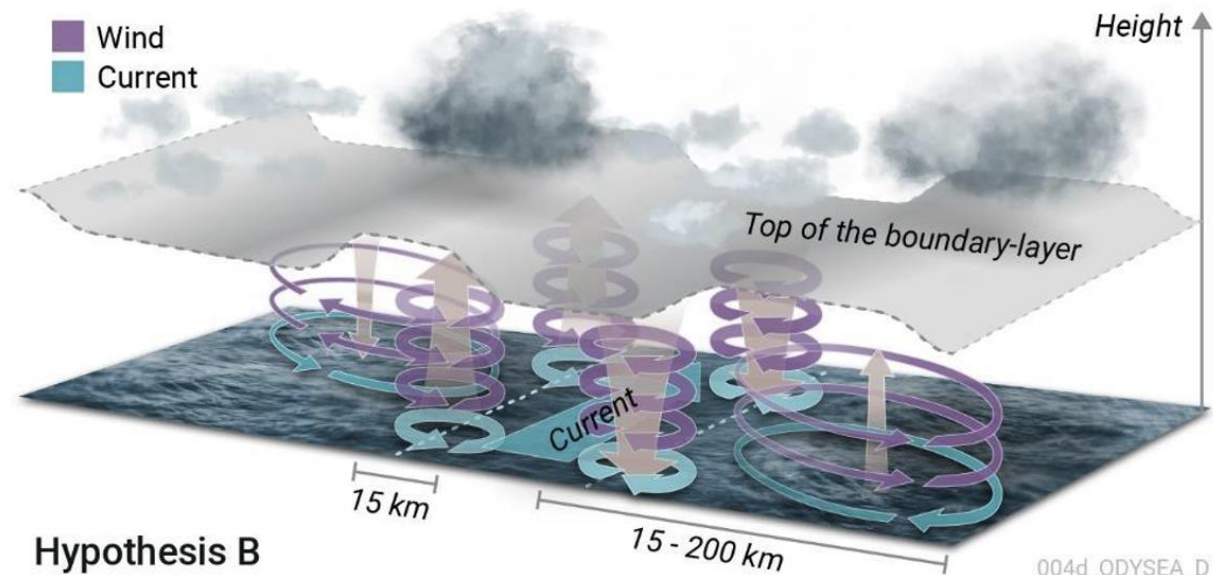
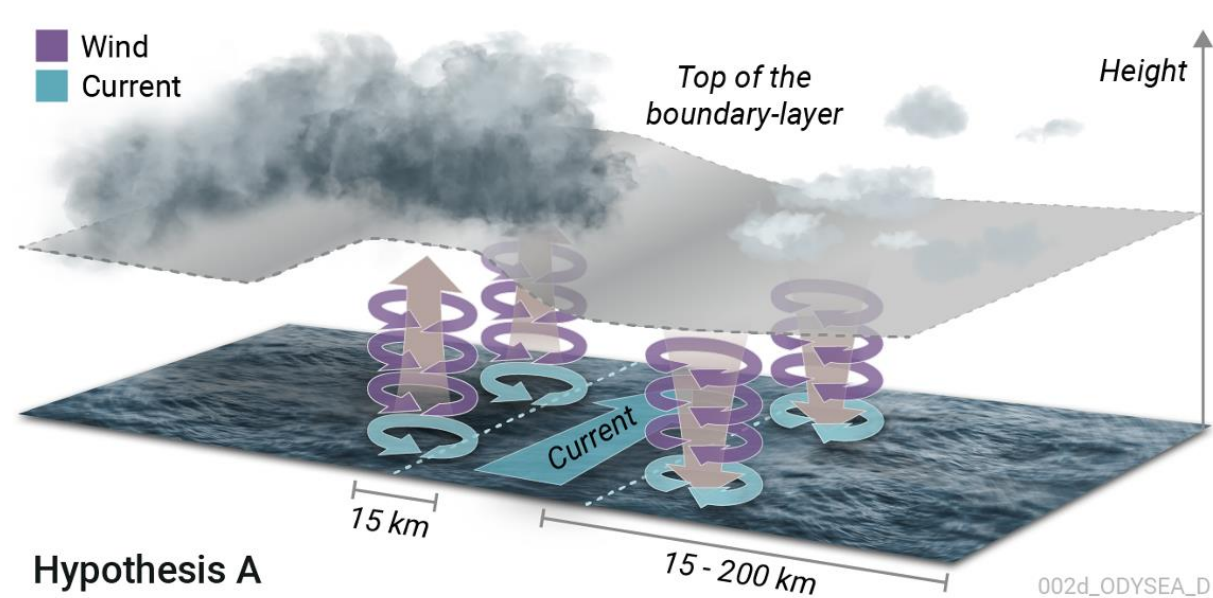


ODYSEA leverages strong partnerships including with **CNES** and U.S. Space Force, as well as operational organizations NOAA, U.S. Navy, and Mercator Ocean International.

SCIENCE OBJECTIVE 1:

Advance air-sea interaction science by revealing wind-current coupling processes.

- Is small-scale wind-current coupling strong enough to impact major ocean currents?
- Does wind-current coupling affect only local winds or remote winds as well?
- To what extent the proximity to coastlines affects wind-current coupling?

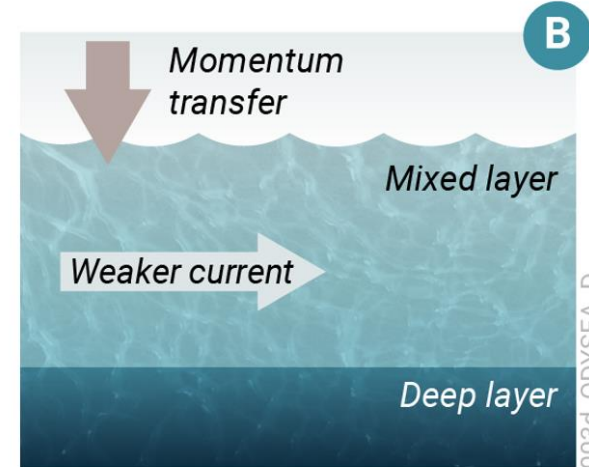
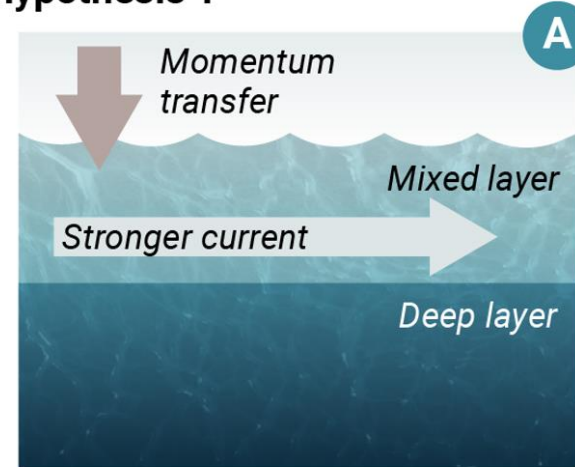


SCIENCE OBJECTIVE 2:

Fill major knowledge gaps in the dynamics of total surface currents.

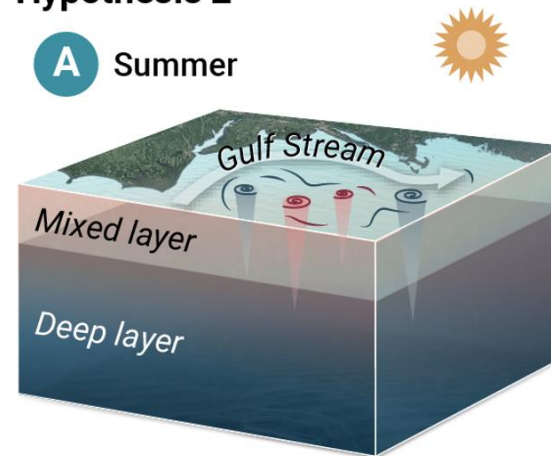
- To what extent the strength of total surface currents is modulated by mixed layer depth?
- Are small-scale total surface currents more energetic in winter than in summer? Does the answer depend on open- vs. coastal oceans?
- What are the direction and magnitude of kinetic energy transfer between small- & large-scale total surface currents?

Hypothesis 1

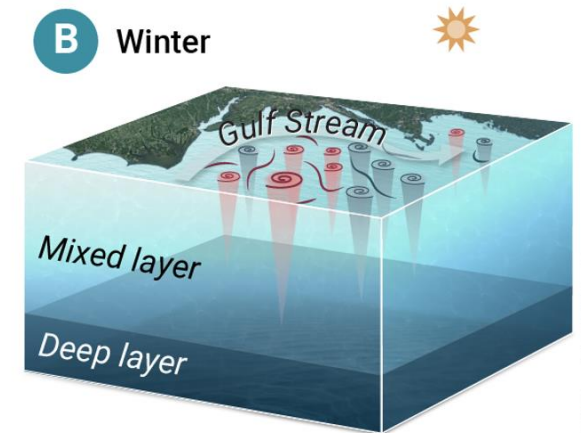


Hypothesis 2

A Summer



B Winter



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APPLICATIONS OBJECTIVE:

Provide essential NRT wind & current measurements to improve the monitoring and forecasting of the weather and ocean that are important for protecting life, environment, and economy:

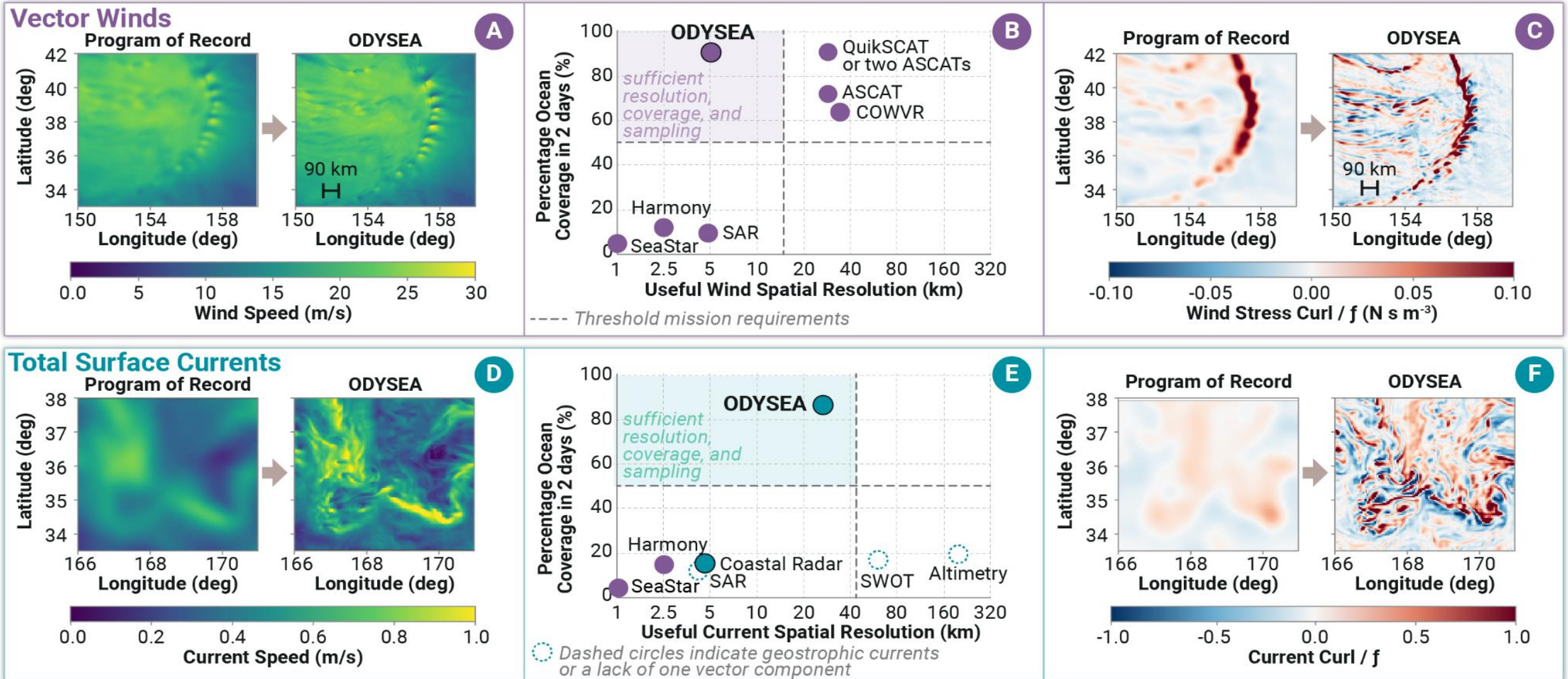
- Maritime navigation and transport efficiency
- Safety of human activities at sea (civil and military)
- Search and rescue
- Optimization of fisheries management
- Transport pathway of marine pollutants (e.g., oils spills, plastics, debris, sargassum)

ODYSEA operational partners:

NOAA, U.S. Navy, Mercator Ocean International.

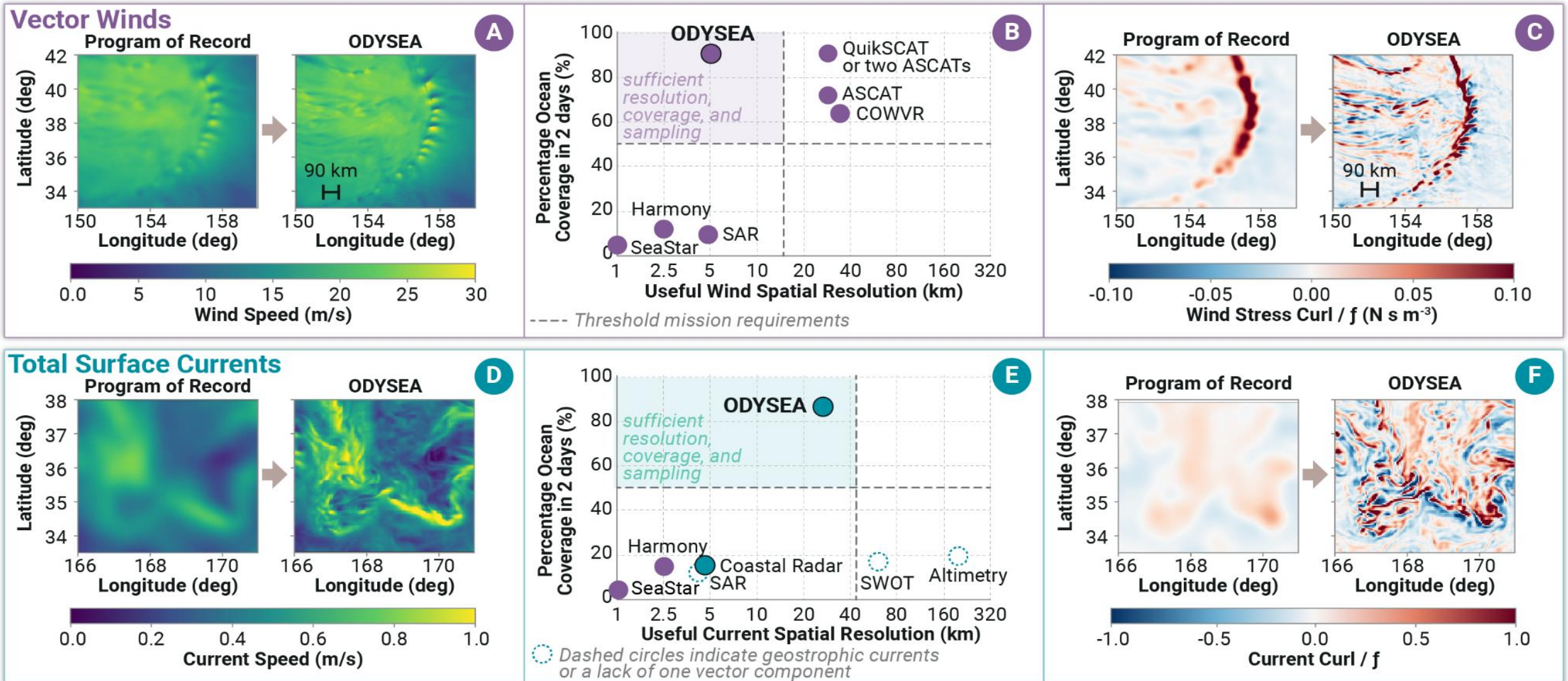
ODYSEA's objectives will be achieved with near-daily global measurements of total surface currents & simultaneous vector winds: 5 km posting, up to 1-2 km from coastline, 1700-km swaths, 4:30am/pm orbit

ODYSEA wind & current capability relative to the Program of Record (past/present/committed mission)



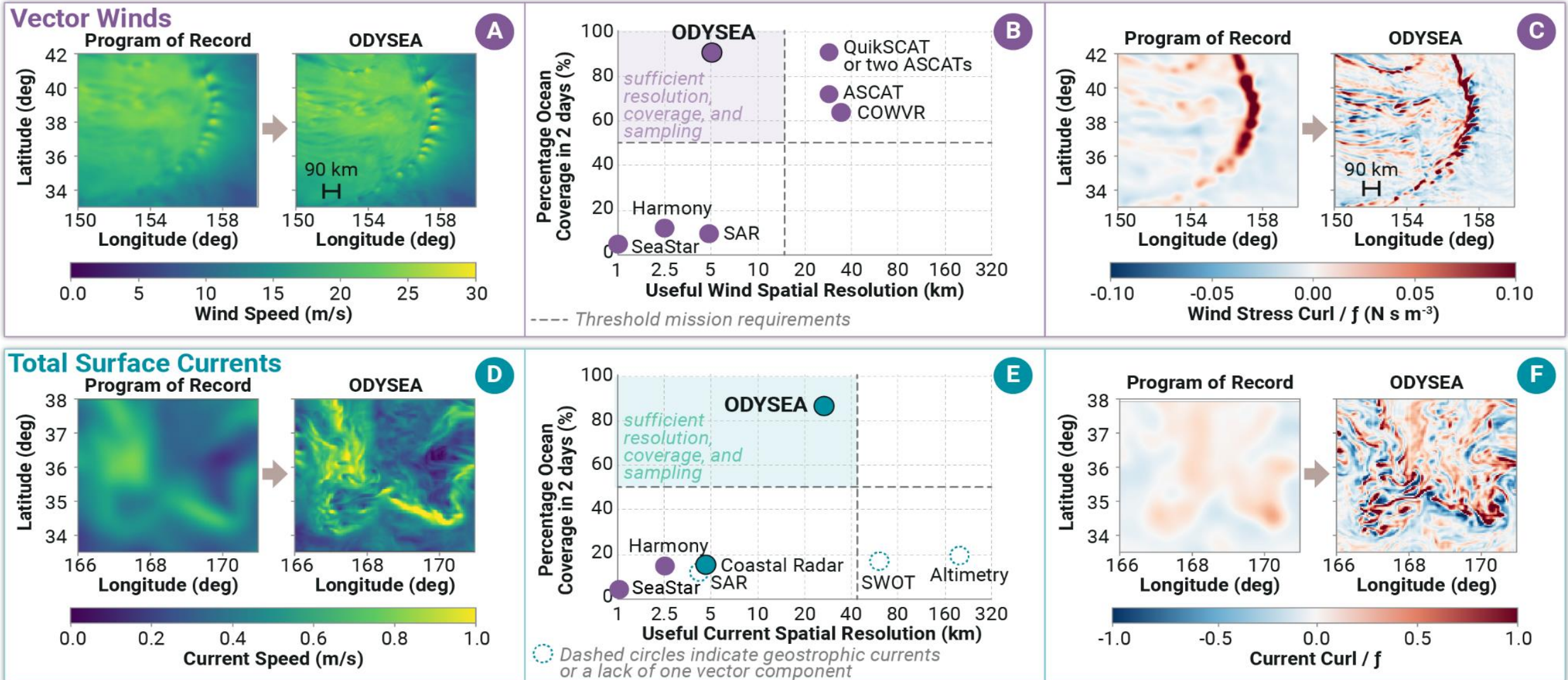
ODYSEA's objectives will be achieved with near-daily global measurements of total surface currents & simultaneous vector winds: **5 km posting**, up to 1-2 km from coastline, 1700-km swaths, 4:30am/pm orbit
(enable detailed view of the wind field, including between patchy rain cells)

ODYSEA wind & current capability relative to the Program of Record (past/present/committed mission)



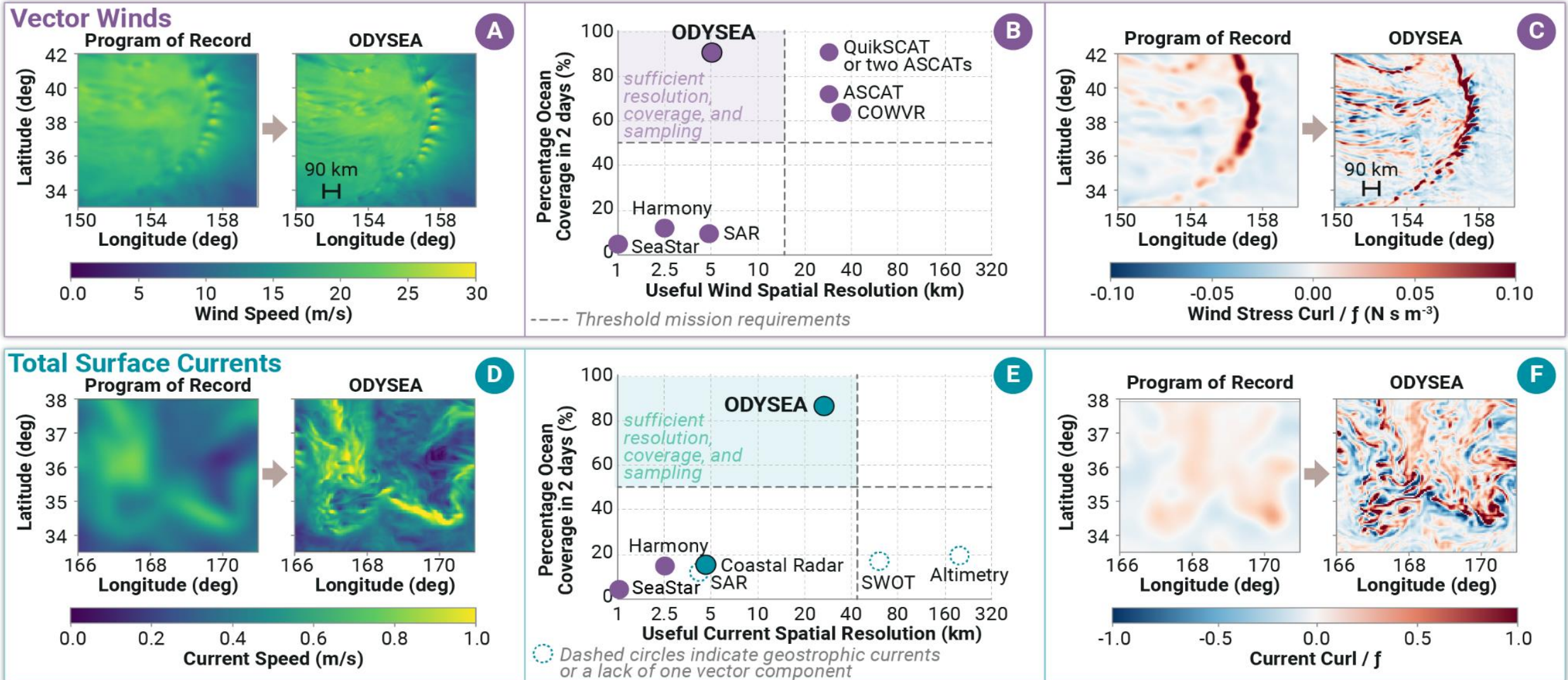
ODYSEA's objectives will be achieved with near-daily global measurements of total surface currents & simultaneous vector winds: 5 km posting, **up to 1-2 km from coastline**, 1700-km swaths, 4:30am/pm orbit
(important for coastal science & applications)

ODYSEA wind & current capability relative to the Program of Record (past/present/committed mission)



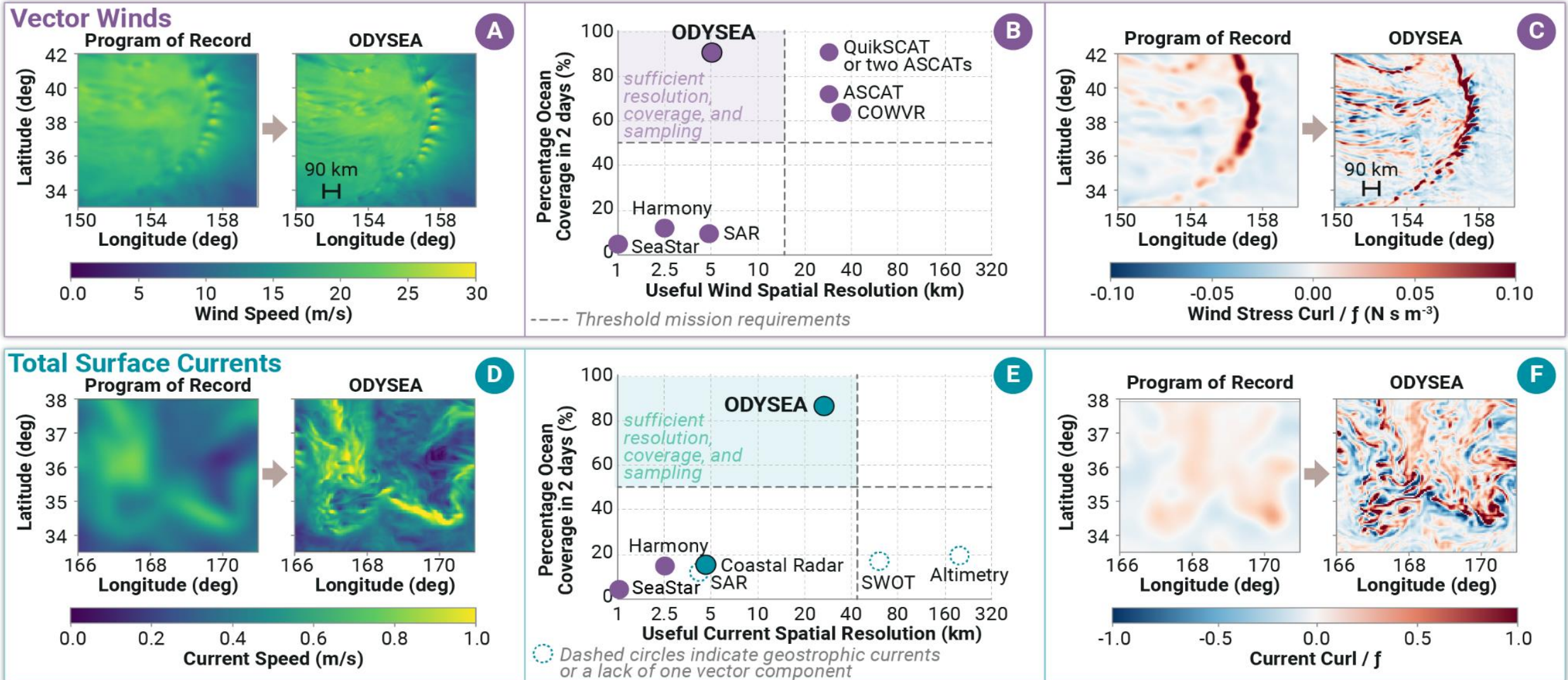
ODYSEA's objectives will be achieved with near-daily global measurements of total surface currents & simultaneous vector winds: 5 km posting, up to 1-2 km from coastline, **1700-km swaths**, 4:30am/pm orbit
(improve synoptic monitoring of storm evolution, estimation of 2-D kinetic energy spectra)

ODYSEA wind & current capability relative to the Program of Record (past/present/committed mission)



ODYSEA's objectives will be achieved with near-daily global measurements of total surface currents & simultaneous vector winds: 5 km posting, up to 1-2 km from coastline, 1700-km swaths, **4:30am/pm orbit (fills the longest time gap in scatterometer coverage, important for monitoring diurnal winds & storms)**

ODYSEA wind & current capability relative to the Program of Record (past/present/committed mission)

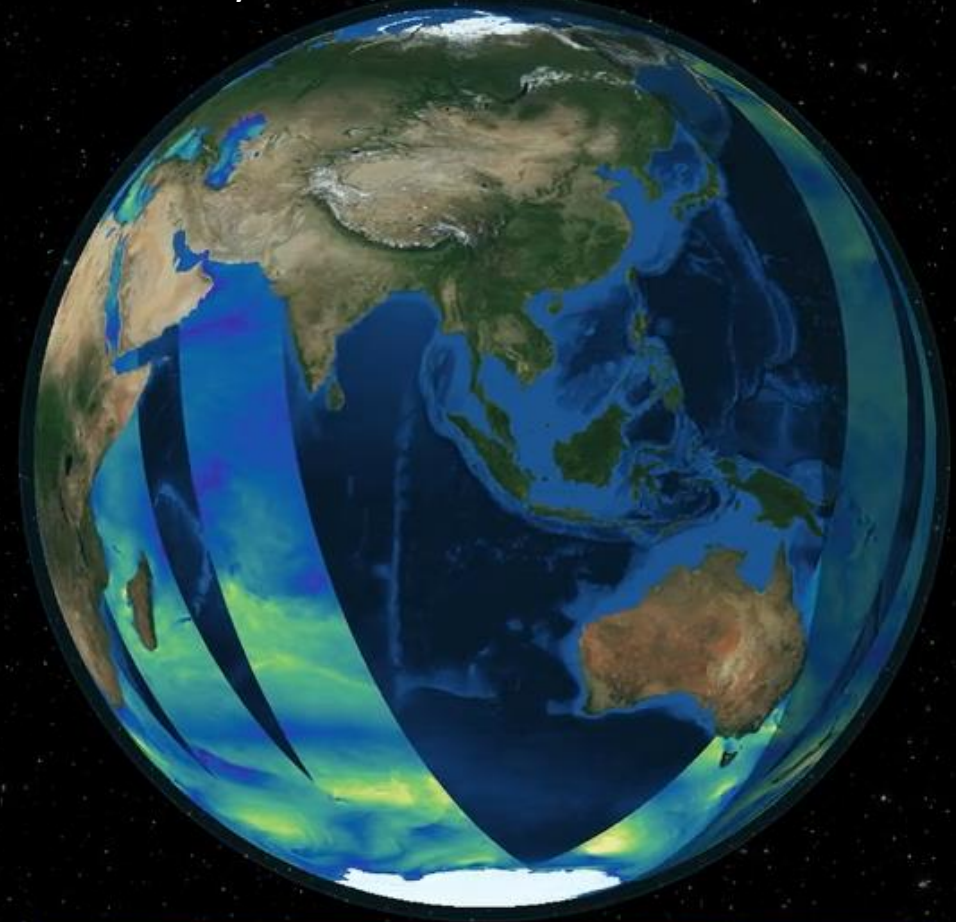
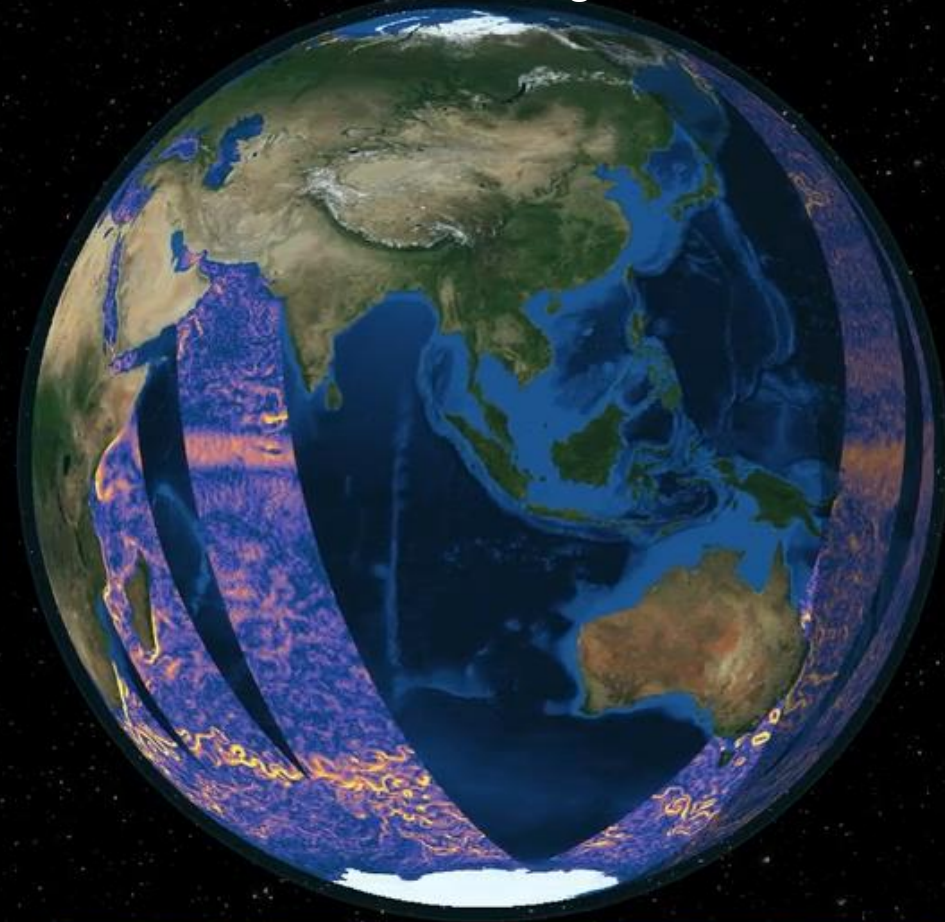


ODYSEA simulator enables community efforts to advance ODYSEA science & applications

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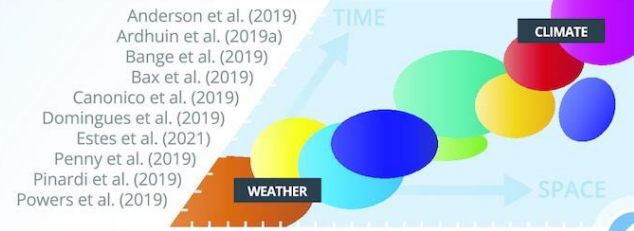
<https://github.com/awineteer/odysea-science-simulator>

ODYSEA looks forward to enhancing collaborations with the broad community, incl. assimilation of total surface currents.

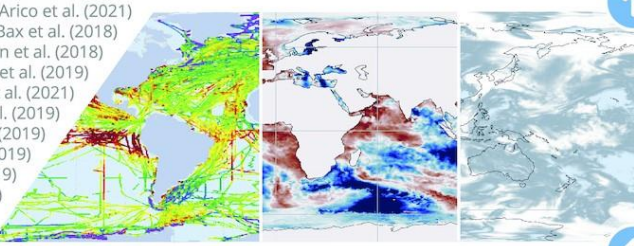


Observing Air-Sea Interactions Strategy (OASIS) is harmonizing community recommendations from OceanObs'19 and UN Decade Laboratories...

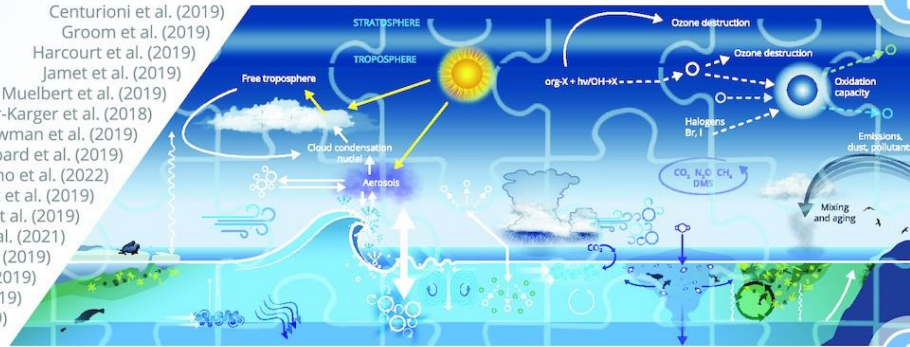
...into three **Grand Ideas**



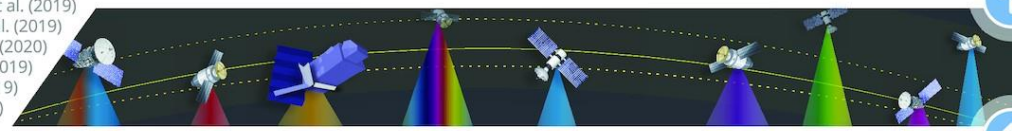
Improved Earth system (including ecosystem) forecasts for a predicted, clean, accessible, healthy, safe & productive ocean



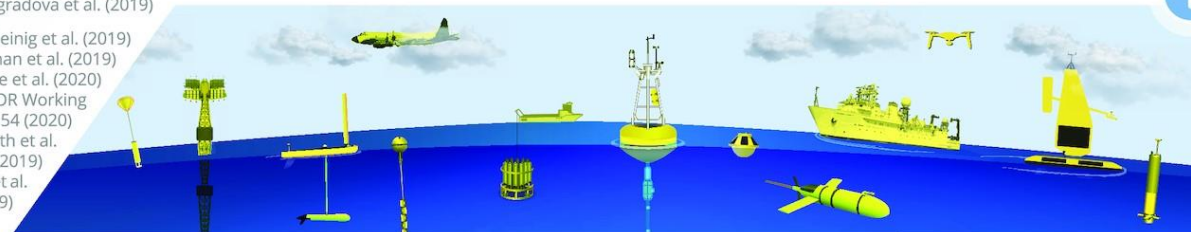
Improved ocean information serving stakeholders around the world



Grand Idea #3
Improved models & understanding of air-sea interaction processes



Grand Idea #2
Satellites optimized for air-sea fluxes



Grand Idea #1
A globally distributed in situ air-sea observing network built around an expanded array of time series stations

ODYSEA supports OASIS and UN Decade's goals for "safe ocean" & "predicted ocean"

← **Satellites**

Cronin et al, 2022.
ICES J Mar Sci, fsac149
<https://doi.org/10.1093/icesjms/fsac149>

JPL



Question?

Toulouse

