Butterfly:

A satellite mission to reveal the oceans' impact on our weather and climate

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BACKGROUND: The ocean supplies the atmosphere with heat and moisture, dominating the global water and energy cycles while fueling weather and climate variability. Yet, these fluxes remain poorly sampled. Butterfly proposes to measure this air–sea exchange at previously unobserved spatial scales to unlock how the small-scale ocean "drives" the large-scale atmosphere, transforming predictability from mere days to weeks.

Current research using satellite winds and sea surface temperature indicates that air-sea coupling is remarkably different at smaller scales than at larger. The exchanges of heat and water at these scales are not available at the necessary resolution and accuracies to understand how these key fluxes may impact on this coupling. The atmosphere-ocean coupling in western boundary current regions like the Kuroshio and Gulf Stream from modeling results appear to help set storm tracks and influence storm evolution.

Butterfly Science: Local to Regional

Science Objective 1: Determine the degree to which < 25-km resolution turbulent heat and moisture fluxes influence midlatitude storm evolution and long-term weather.

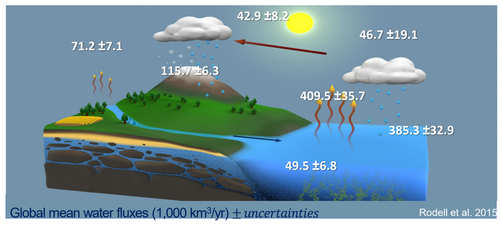
Addressing Decadal Survey Question W-3 *"How do spatial variations in surface characteristics modify transfer between domains and thereby influence weather and air quality?"*

Butterfly Science: Local to Global

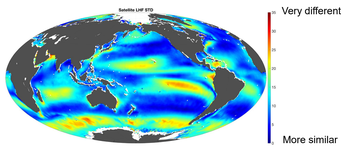
Science Objective 2: Balance the global ocean turbulent heat and moisture flux contributions to the energy and water cycles to within 5%.

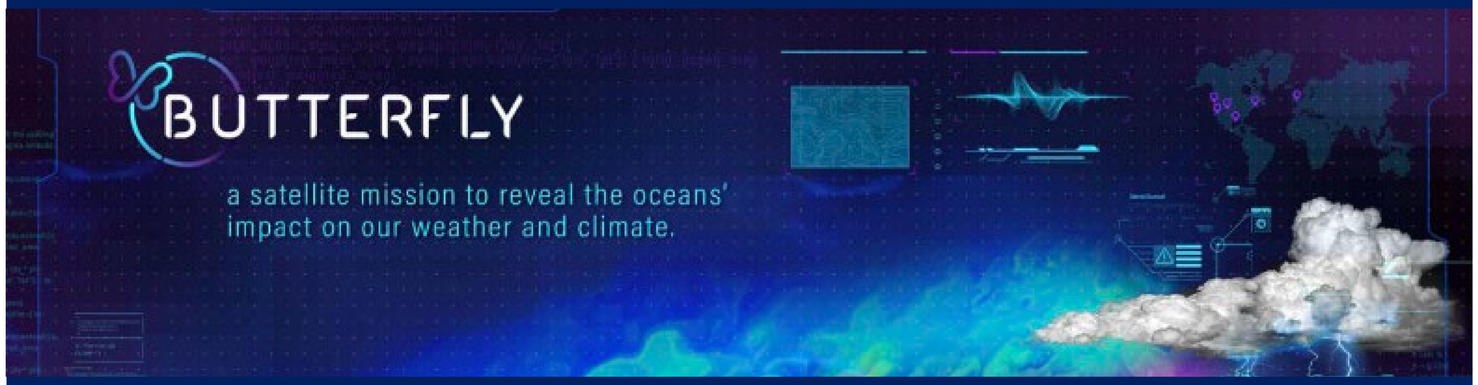
Addressing Decadal Survey Question C-4 *"How will the Earth system respond to changes in air-sea interactions?"*

Current satellite products of evaporation have the largest uncertainties in the global water cycle, with highest product differences in high sea surface temperature gradient areas.

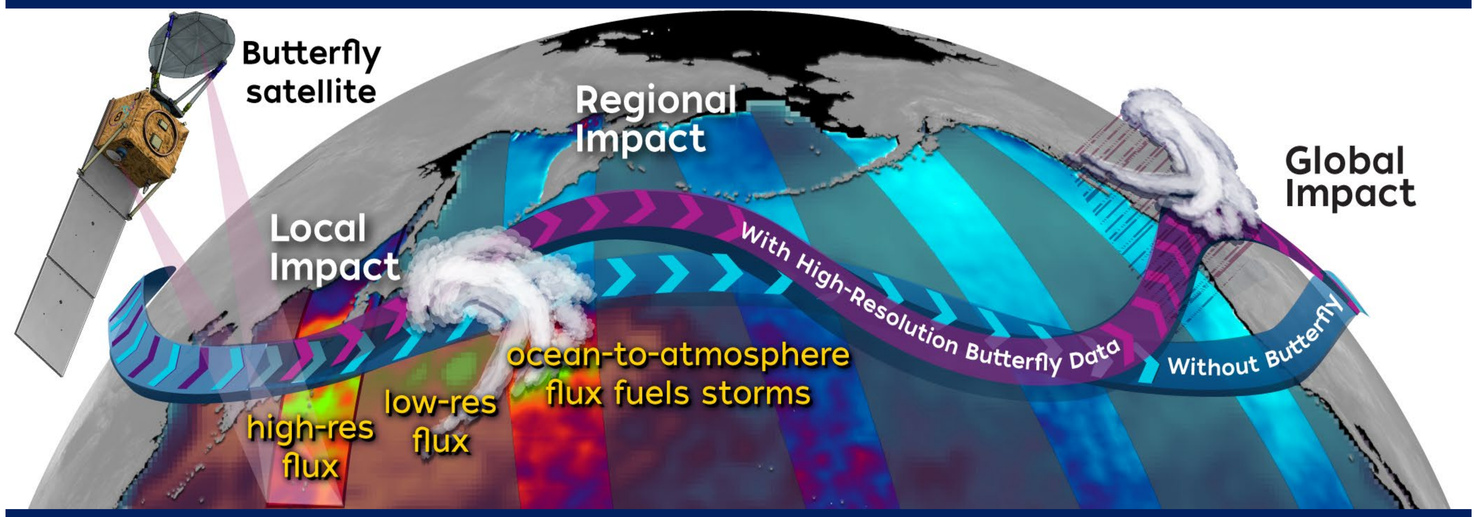


Differences between products:





Butterfly would be the first satellite mission to **simultaneously** measure sea surface temperature, wind, & near-surface air temperature & humidity in order to estimate air–sea turbulent heat and moisture fluxes at a spatial resolution and accuracy sufficient to resolve the impact of small-scale ocean features on large-scale weather and climate.



Butterfly was first proposed as an EVM3 Mission, receiving a Category 1 but not funded. We are planning on resubmission to EVM4, and are currently looking for adding several science team members with expertise in open science, application science, or other interests related to mesoscale air-sea interactions.

Take a picture to go to the Butterfly project page

EVM3 proposed configuration

Butterfly's single instrument combines:

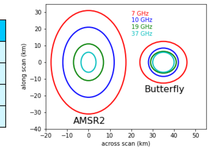
Passive MW channels: 7, 11, 19, 24, 37 GHz
Measures sea surface temperature & wind speed

Near-surface sounding channels: 109-117, 150-175 GHz
Measures near-surface air temperature & humidity

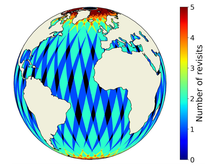
Two spinning reflectors: Achieves 20 km spatial resolution

Digital backend: Improves accuracy and provides RFI-robust data

Mission	Details
Length (minimum)	18-months
Orbit	>80° inclination
Swath Width	640 km
Resampled Footprint	20 km



2-Day coverage:



Turbulent heat flux = Sensible heat flux + Latent heat flux

$$Q_{sen} = \rho_a C_p C_H U(T_{sea} - T_{air}) \qquad Q_{lat} = \rho_a L_v C_E U(q_{sea} - q_{air})$$

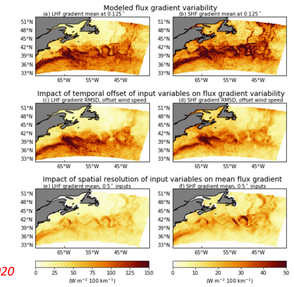
Air density · Air specific heat capacity · Turbulent exchange coefficient · Wind speed · Air-sea temperature difference

Air Density · Latent heat of vaporization · Turbulent exchange coefficient · Wind speed · Air-sea humidity difference

Data Sources: Butterfly Model Coefficients

The latent heat flux is directly related to moisture flux through evaporation.

Errors resulting from current mismatches in inputs derived from multiple satellites with different times of observation and resolution



Gentemann et al., 2020

Synergies with other community efforts:

- Possible synergy with CIMR (Copernicus Imaging Microwave Radiometer, conically scanning)
  - SST at 15 km (55 km salinity, 5 km sea ice concentration). Currently Phase B2.
  - Butterfly could fly in similar orbit, use this SST. Gain larger swath, could drop our other retrieval resolution to 10 km
- ESA Harmony, selected Earth Explorer mission
  - Multibeam thermal-infrared instrument, receive-only SAR, 2 satellites
  - Will provide cloud movements, SST, winds, waves, and currents
  - Simultaneous Winds and Surface Currents from Space: ODYSEA (Ocean Dynamics and Surface Exchange with the Atmosphere)
- NASA ODYSEA (Ocean Dynamics and Surface Currents from Space) mission concept (see poster)
- NASA Planetary Boundary Layer Incubation

Current Butterfly activities

- Hackathons/making code available on github
- Simulator development
- Additional science team members
- Putting out synthetic data for "early adopters"