An Update on Air-Sea Flux Activities for OOPC March 2021 Panel Meeting

Meghan Cronin (NOAA PMEL) with contributions from Tony Lee (JPL)

Since April 2019:

Sep 2019 OceanObs19

Mar 2020 COVID19. OOPC meeting canceled.

Sep 2020 Virtual Meeting Ocean Best Practices Systems “Surface Radiation” Community Consultation Workshop

Nov 2020 SCOR WG #162 Observing Air-Sea Interactions Strategy

Action Items from 2019 Joint Meeting

- ✓ Caterina Tassone (GCOS) liaison with WCRP to coordinate with existing WCRP ocean & land-base flux groups (WDAC, Surflux Task Team, GEWEX, SOLAS…).
- ✓ Liz Kent (AOPC) and Rainer Hollman (AOPC) will discuss with AOPC feasibility of remotely-sensed humidity & temperature profiles, optimized for surface boundary layer.
- ✓ Bob Weller (OOPC) will work with Christian Lanconelli (BSRN) to set up workshop on a global (ocean & land-based) radiation network, and develop best practices for surface radiation.
- ✓ Matt Palmer (OOPC) will liaison with WMO/WGNE & WCRP/WGCM
- ✓ Meghan Cronin (OOPC) will help coordinate a vision paper for broader community, beyond OceanObs19.
- ✓ Scoping of a SCOR Working Group Proposal for organizing/implementing near-term goals?

Slide from Joint Meeting April 2019

Surface Heat Flux Essential Climate Variables (ECVs)

Atmosphere

Surface

- Precipitation
- Pressure
- Radiation budget
- Temperature
- Water vapour
- Wind speed and direction

Upper-air

- Earth radiation budget
- Lightning
- Temperature
- Water vapor
- Wind speed and direction

Atmospheric Composition

- Aerosol and ozone precursors
- Aerosols properties
- Carbon dioxide, methane and other greenhouse gases
- Cloud properties
- Ozone

Land

Hydrosphere

- Groundwater
- Lakes
- River discharge

Cryosphere

- Glaciers
- Ice sheets and ice shelves
- Permafrost
- Snow

Biosphere

- Above-ground biomass
- Albedo
- Evaporation from land
- Fire
- Fraction of absorbed photosynthetically active radiation (FAPAR)
- Land cover
- Land surface temperature
- Leaf area index
- Soil carbon
- Soil moisture

Anthroposphere

- Anthropogenic Greenhouse gas fluxes
- Anthropogenic water use

Ocean

Physical

- Ocean surface heat flux
- Sea ice
- Sea level
- Sea state
- Sea surface currents
- Sea surface salinity
- Sea surface stress
- Sea surface temperature
- Subsurface currents
- Subsurface salinity
- Subsurface temperature

Biogeochemical

- Inorganic carbon
- Nitrous oxide
- Nutrients
- Ocean colour
- Oxygen
- Transient tracers

Biological/ecosystems

- Marine habitat properties
- Plankton

https://gcos.wmo.int/en/essential-climate-variables/ecv-factsheets

For global coverage of air-sea heat fluxes, we must:

Flux EOV/ECV	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Bulk SST	Partially met												Adequate
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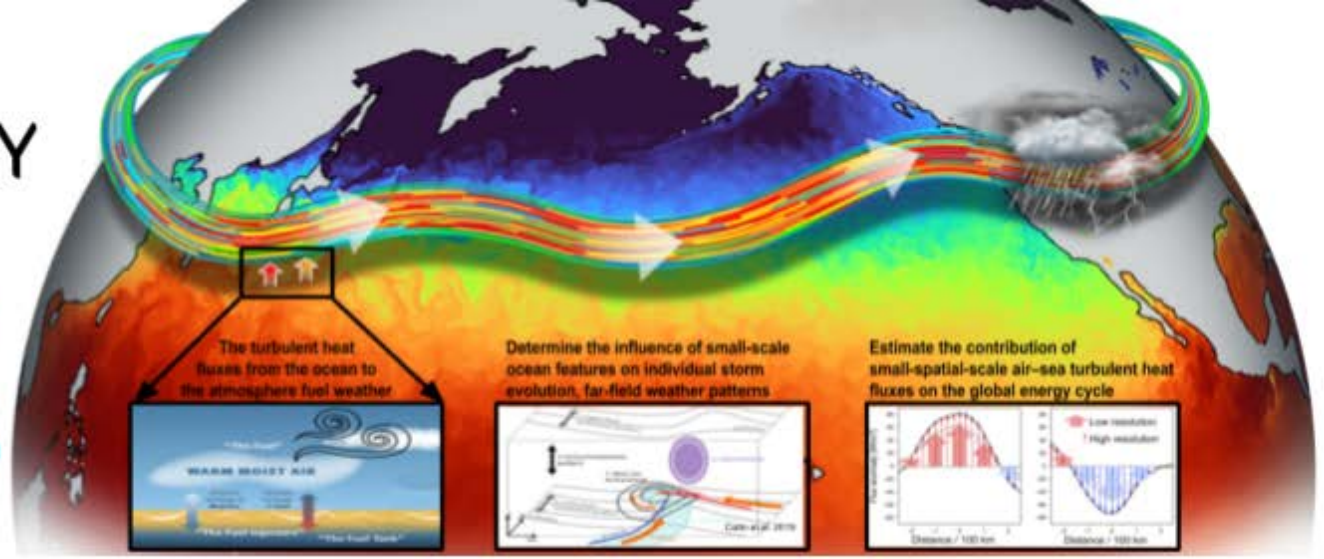
Cronin et al. (2019) **"Air-sea fluxes with a focus on heat and momentum"**

(1) Optimize satellite-based boundary layer obs for near-surface air temperature & humidity, …

(2) Expand the global network of *in situ* air-sea interaction observations

BUTTERFLY

Butterfly's open science accelerates improvements in subseasonal-to-seasonal forecasts by revealing the influence of small-scale air-sea exchange on large-scale weather and climate

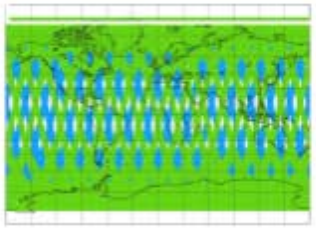


WHAT? Butterfly measures all the geophysical data needed to estimate the air-sea turbulent heat and moisture fluxes at unprecedented accuracy (~50% increase) and resolution (20 km) for 2 years.

HOW? Building on a decade of NASA technology developments, Butterfly combines a passive microwave radiometer, hyperspectral sounder, and digital backend to provide accurate, RFI-robust data.

Channel (GHz)	Footprint (km)
6.8	25x22
10.7	17x14
18.7	13x12
23.8	12x11
37	12x10
110-118	17x14
160-183	12x10
Swath width	562
Resampled	20

2-DAY COVERAGE



The ocean is the main source of heat and water to the atmosphere through air-sea temperature differences (the sensible heat) and evaporation (the latent heat), the turbulent heat fluxes. Near large, warm, ocean western boundary currents (WBC), small-spatial scale heat fluxes influence both local atmospheric variability and remote weather and climate. No past, current, or planned satellite carries the channel combination needed to estimate these fluxes. This observational gap has hindered our understanding of the underlying air-sea interaction processes as well as our ability to discriminate and improve models and enhance prediction skills. Butterfly fills this gap. Butterfly is an open-by-design mission. Open data, open software, open access, accelerating science return, maximizing community engagement, and increasing societal benefit.

WHO?  **Dr. Chelle Gentemann (PI)** and **Dr. Carol Anne Clayson (DPI)** lead an interdisciplinary team of expert meteorologists, oceanographers, and remote sensing specialists.

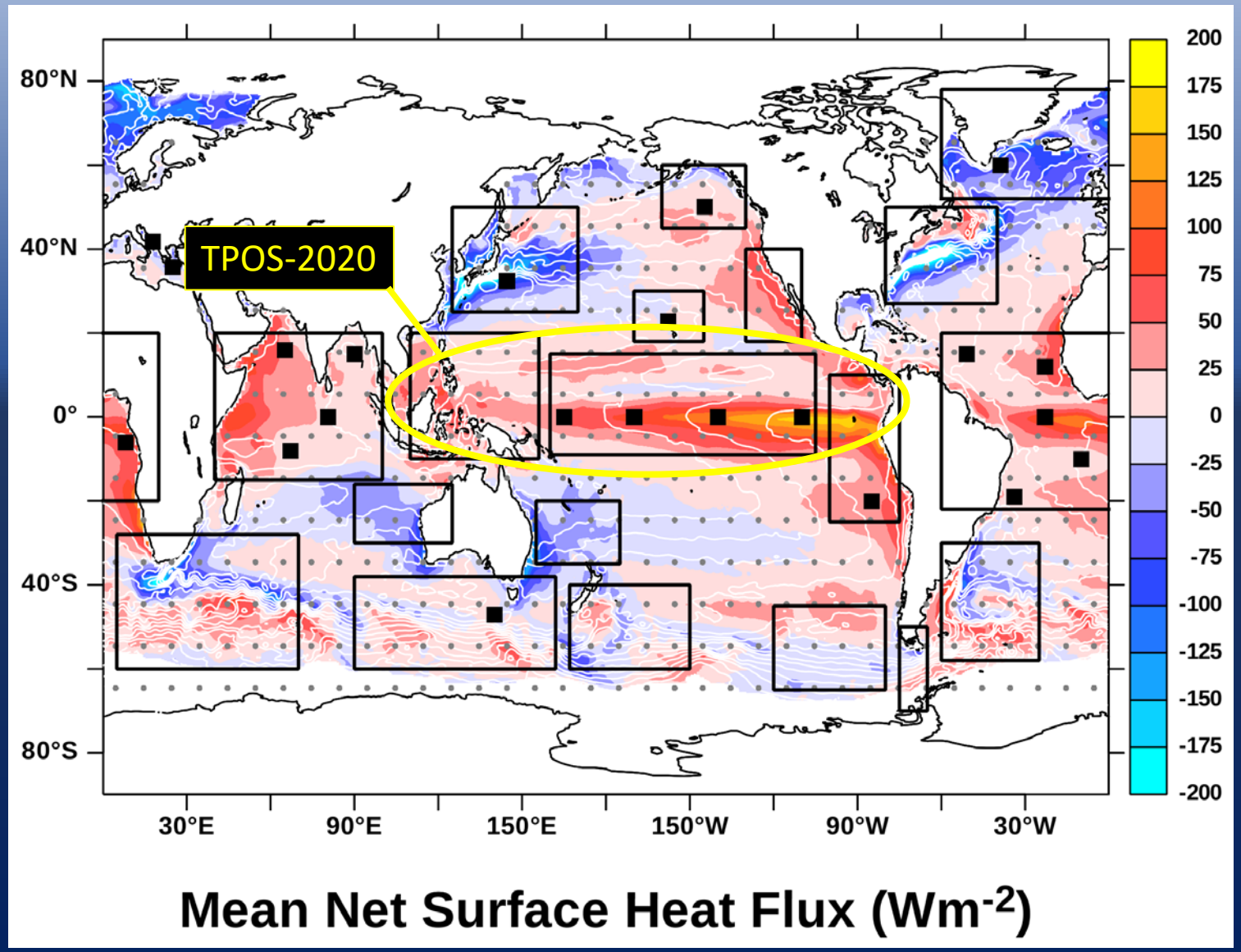
NASA Earth Venture Missions (EVMs) are science driven, competitively selected, low cost satellite missions

"Butterfly" is a proposed NASA EVM that would lead to significant improvement in satellite-based air-sea heat fluxes by 2027

Courtesy Tony Lee

Global network: 500-1000 drifting or mobile platforms and more reference stations (squares) in key (boxed) regions

Drifting and Mobile Flux Platforms (examples)



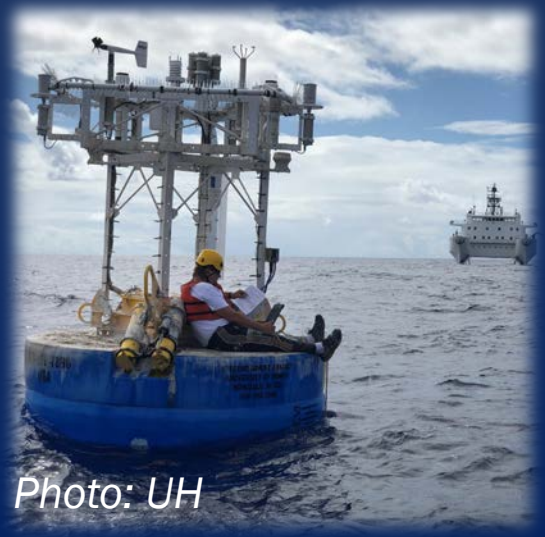
Cronin et al. (2019) **"Air-sea fluxes with a focus on heat and momentum"**

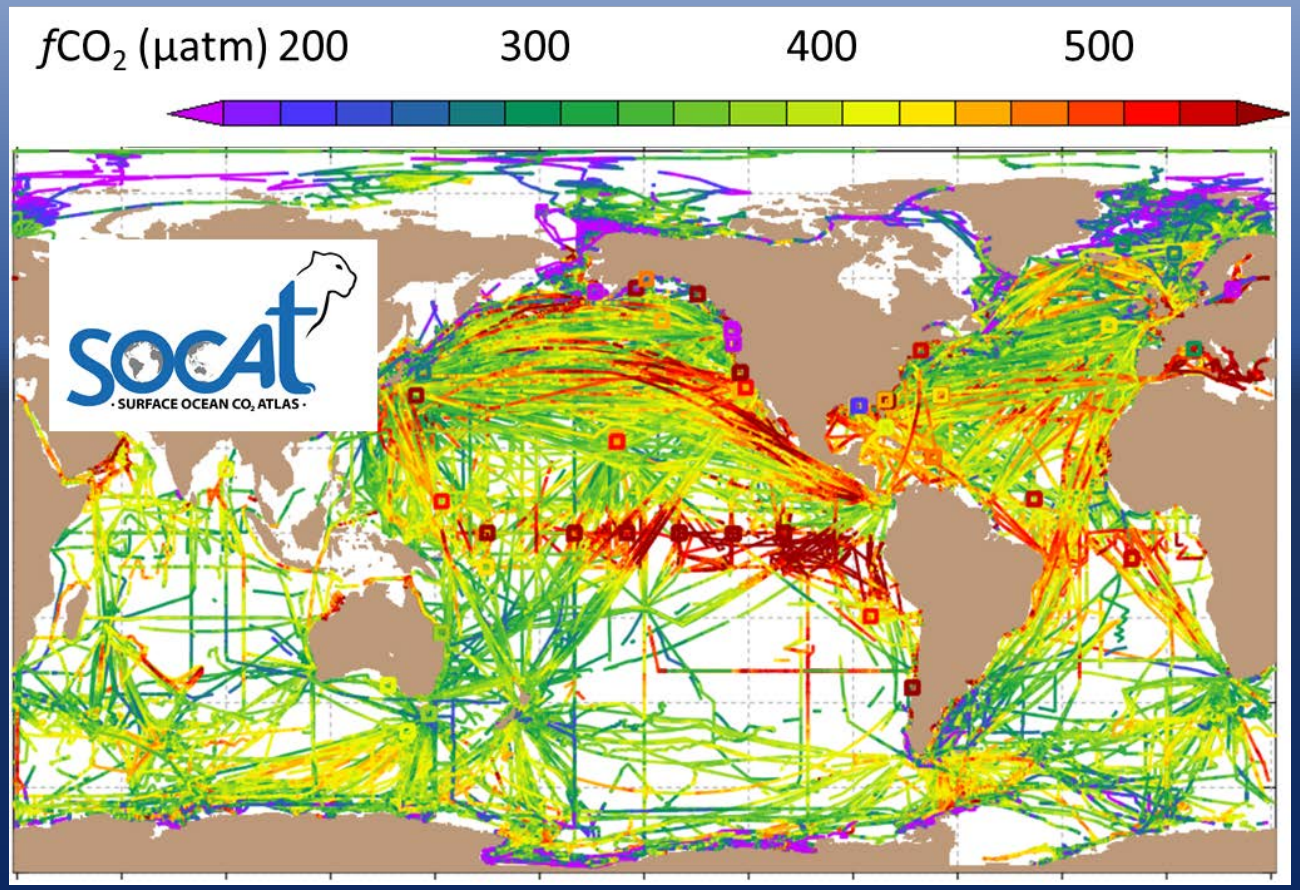
Reference Stations (examples)

Surface ocean CO_2 flux: all seawater pCO_2 measurements collected since 1957

SOCONET
• SURFACE OCEAN CO_2 OBSERVING NETWORK •

Established Platforms:





Wanninkhof et al. (2019) **"A Surface Ocean CO_2 Reference Network, SOCONET and Associated Marine Boundary Layer CO_2 Measurements"**

New Technology:

Surface ocean CO_2 flux: all seawater pCO_2 measurements collected in 2015

SOCONET
• SURFACE OCEAN CO_2 OBSERVING NETWORK •

Established Platforms:

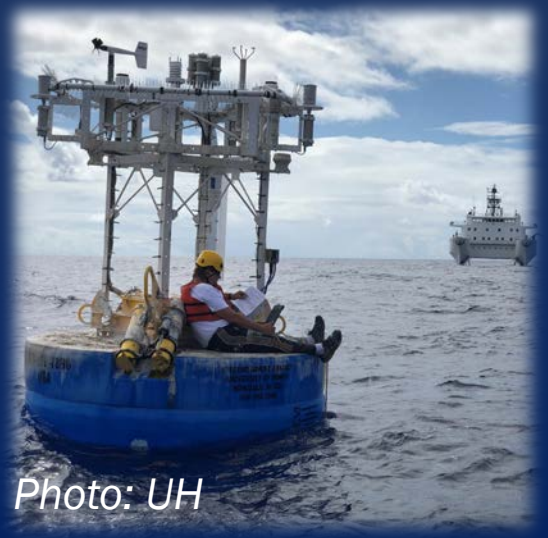
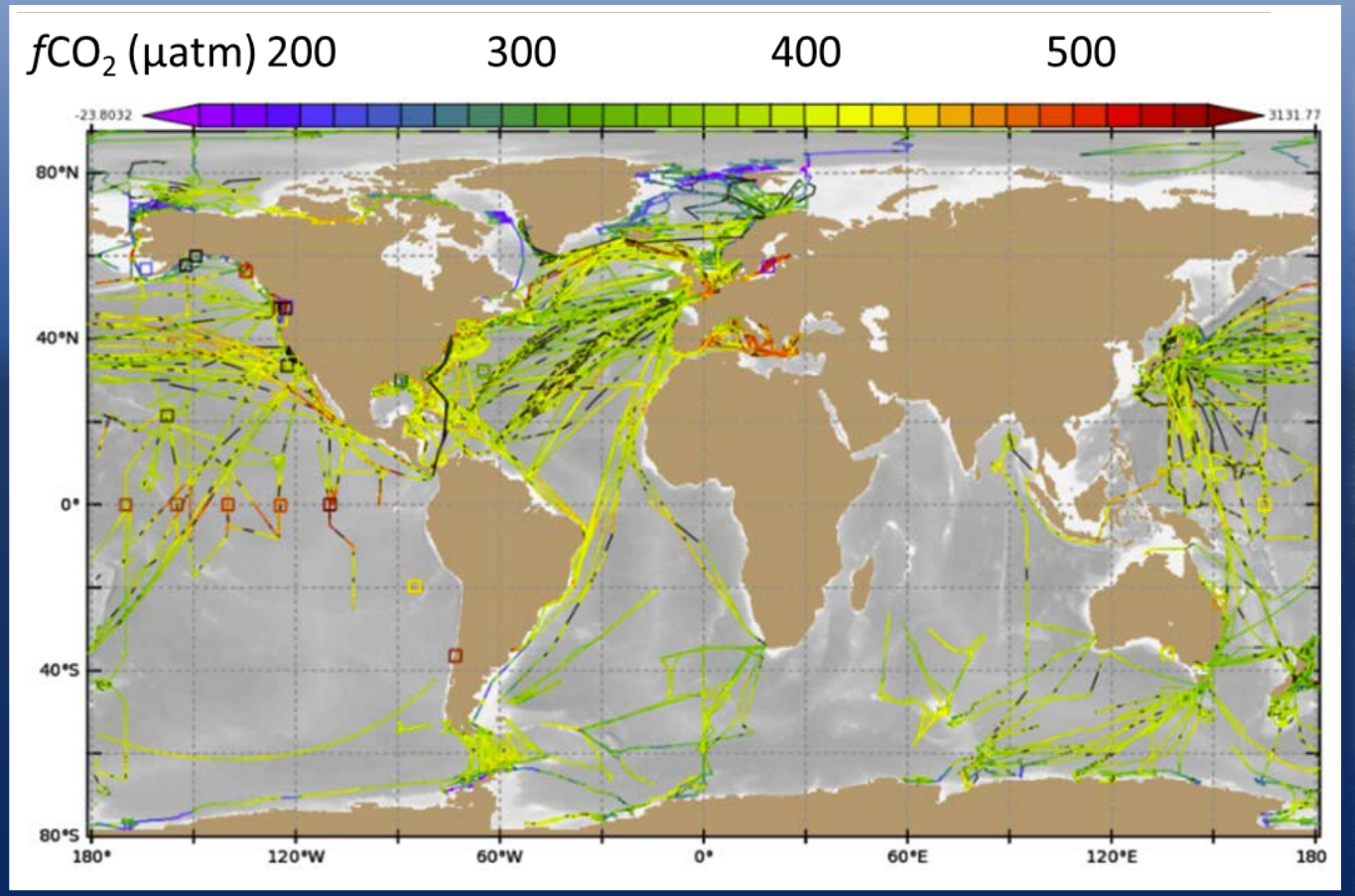


Photo: UH



Wanninkhof et al. (2019) **"A Surface Ocean CO_2 Reference Network, SOCONET and Associated Marine Boundary Layer CO_2 Measurements"**

New Technology:

Photo: Saildrone

SCOR WG #162 for developing an

Observing Air-Sea Interactions Strategy (OASIS) for 2030

airseaobs.org

Expected lifetime as a SCOR Working Group: November 2020 – October 2023

A "system-as-a-whole" approach for making surface and boundary layer observations relevant to the Earth's energy, water, and carbon cycles, including their physical, biological, and geological components.

Integrating recommendations from

>40 OceanObs19 community strategy papers &

>400 authors

SCOR WG Member	Institution
Meghan Cronin*	NOAA Pacific Marine Environmental Laboratory, **US**
Sebastiaan Swart*	University of Gothenburg, **Sweden**
Nadia Pinardi	University of Bologna, **Italy**
R. Venkatesan	National Institute of Ocean Technology, **India**
Phil Browne ^	ECMWF, **UK**
Warren Joubert ^	South African Weather Service, **South Africa**
Ute Schuster	University of Exeter, **UK**
Christa Marandino	Geomar, **Germany**
Shuangling CHEN ^	Second Institute of Oceanography, **China**
Clarissa Anderson	Scripps Institution of Oceanography, **US**
Jim Edson	Woods Hole Oceanographic Institution, **US**
Zhaohui CHEN	Ocean University of China, **China**
Juliet Hermes	South African Environmental Observation Network, **South Africa**
Fabrice Ardhuin	University Brest, CNRS, IRD, Ifremer, LOPS, IUEM, **France**
Oscar Alves	Bureau of Meteorology, **Australia**
Hiroyuki Tomita	Institute for Space-Earth Environmental Research (ISEE), Nagoya University, **Japan**

* Cochairs ^ Early Career

OASIS SCOR WG #162 DELIVERABLES:

1. Consolidated recommendation report (TOR #1; 6-months).
    a. **OASIS "Programme" for UN Decade Call for Action (due Jan 15, 2021)**
    b. **OASIS "Ocean Shots" for Ocean Decade US Call (due Dec 1, 2020)**
    c. **Consolidated OO19 OASIS Recommendations Report**
2. Observing Air-Sea Interaction Strategy publication (TOR #1-6; 36-months)
3. Best practice papers (TOR #2-5; 18-36-months)
4. Air-sea flux toolbox (TOR #2, 4-6; 12-36-months)
5. Air-sea flux curriculum (TOR #2, 4-6; 12-36-months)
6. Website, webinars and newsletter (TOR #1-6; Ongoing)

Air-sea exchanges of energy, moisture, and gases drive and modulate the Earth's weather and climate, influencing life, including our own. These air-sea interactions fuel the hydrological cycle and affect precipitation across the globe. Air-sea interactions affect the distribution of carbon dioxide between the atmosphere and ocean, how seawater flows and winds blow, and how pollutants floating on the ocean surface move – information critical to policymakers, industry, and civil society.

The Observing Air-Sea Interactions Strategy (OASIS) PROGRAMME will provide observational-based knowledge to fundamentally improve weather, climate and ocean prediction, promote healthy oceans, the blue economy, and sustainable food and energy.

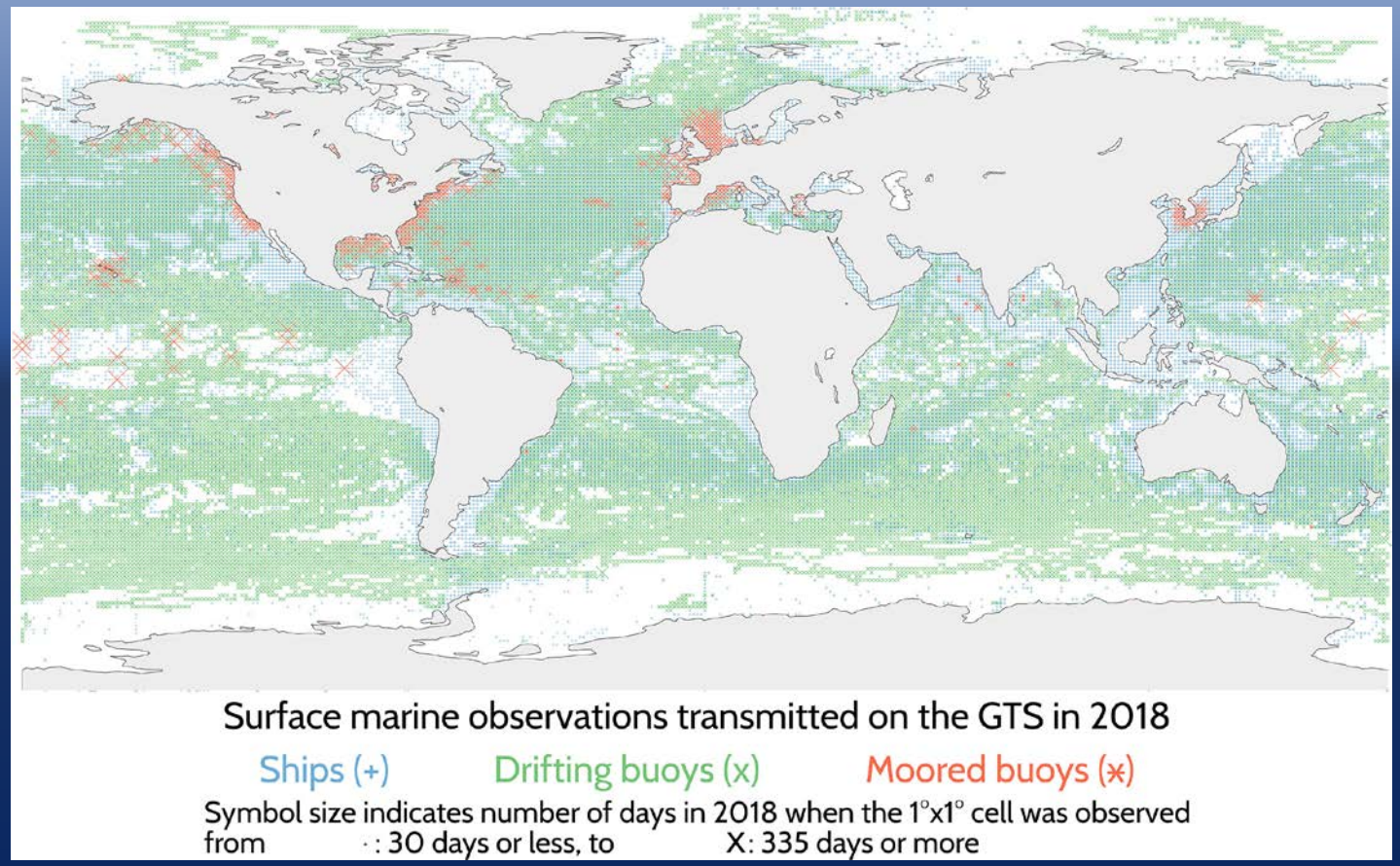
-- Summary Statement for the UN Ocean Decade OASIS Programme proposal

OASIS partnerships for implementing Programme

Partner Organization	Role of Partner in OASIS Programme	Point of Contact	Contact Info
GOOS Ocean Observations Physics and Climate (OOPC) panel	Help coordinate & integrate air-sea interaction observations within the GOOS for physics and climate	Sabrina Speich & Weidong Yu (co-chairs)	sabrina.speich@lmd.ipsl.fr, yuwd@mail.sysu.edu.cn
GOOS BGC panel / International Ocean Carbon Coordination Project (IOCCP)	Help coordinate & integrate biogeochemical air-sea interaction and carbon flux observations within the GOOS	Kim Currie (co-Chair), Véronique Garçon (co-chair), Rik Wanninkhof (former member)	Kim.Currie@niwa.co.nz, veronique.garcon.legos@gmail.com Rik.Wanninkhof@noaa.gov
GOOS Biology-Ecosystem panel	Help coordinate & integrate OASIS biological and ecosystem observations within the GOOS	Frank Muller-Karger (member), Lavenia Ratnarajah (international project officer)	carib@usf.edu, L.ratnarajah@unesco.org
Ocean Best Practice Systems	Help formalize ocean best practices needed for high-quality observations and interoperability within the OASIS network	Jay Pearlman (co-chair)	jay.pearlman@fourbridges.org
CoastalPredict	Help bridge open ocean and coastal OASIS observations with stakeholders	Nadia Pinardi (co-chair)	nadia.pinardi@unibo.it
Marine Life 2030	Help design and integrate biological and ecosystem observations within the OASIS network	Frank Muller-Karger (co-chair)	carib@usf.edu
Deep Ocean Observing Strategy (DOOS)	Help connect surface OASIS observations with deep ocean observations and processes to inform interaction of the surface and deep ocean (e.g. GHG and elemental fluxes, animal migrations, etc.)	Lisa Levin (co-chair)	llevin@ucsd.edu
Ocean Corps	Help develop OASIS knowledge partners and users in developing countries	Brian Arbic (co-chair)	arbic@umich.edu
EquiSea	Help develop resources and build capacity for OASIS activities in developing countries	Alexis Valauri-Orton (co-chair)	avalauriorton@oceanfdn.org
Consortium for Ocean Leadership	Provides administration and communication support (see airseaobs.org)	Sheri Schwarz (Program Associate)	sschwartz@oceanleadership.org
NSF Regional Coordination Network	Help connect to OceanObs19 community recommendations for ocean observing in 2030	Jay Pearlman (co-chair)	jay.pearlman@fourbridges.org

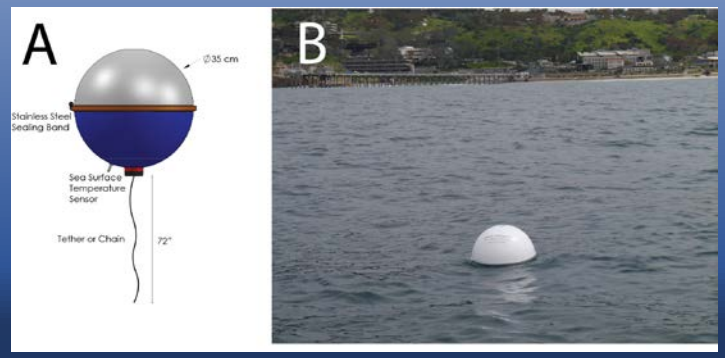
EXTRA Slide

OceanObs'19 Recommendation: Create an Integrated Surface Ocean Observing System

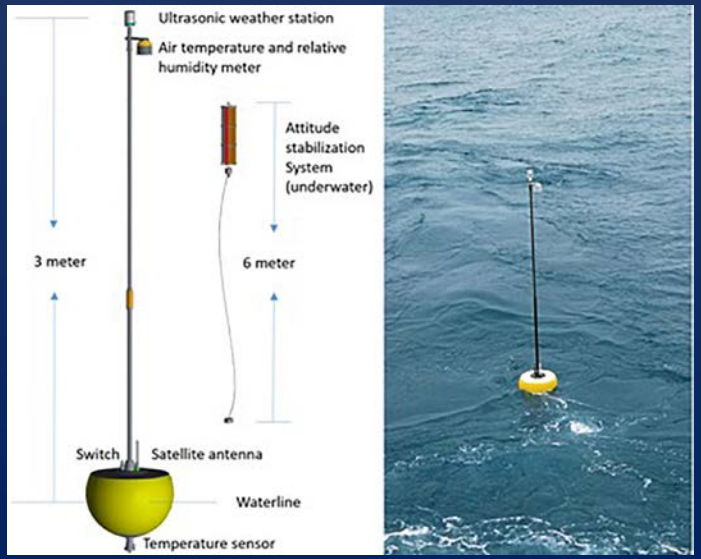


Centurioni et al. (2019) **"Global in situ Observations of Essential Climate and Ocean Variables at the Air-Sea Interface"**

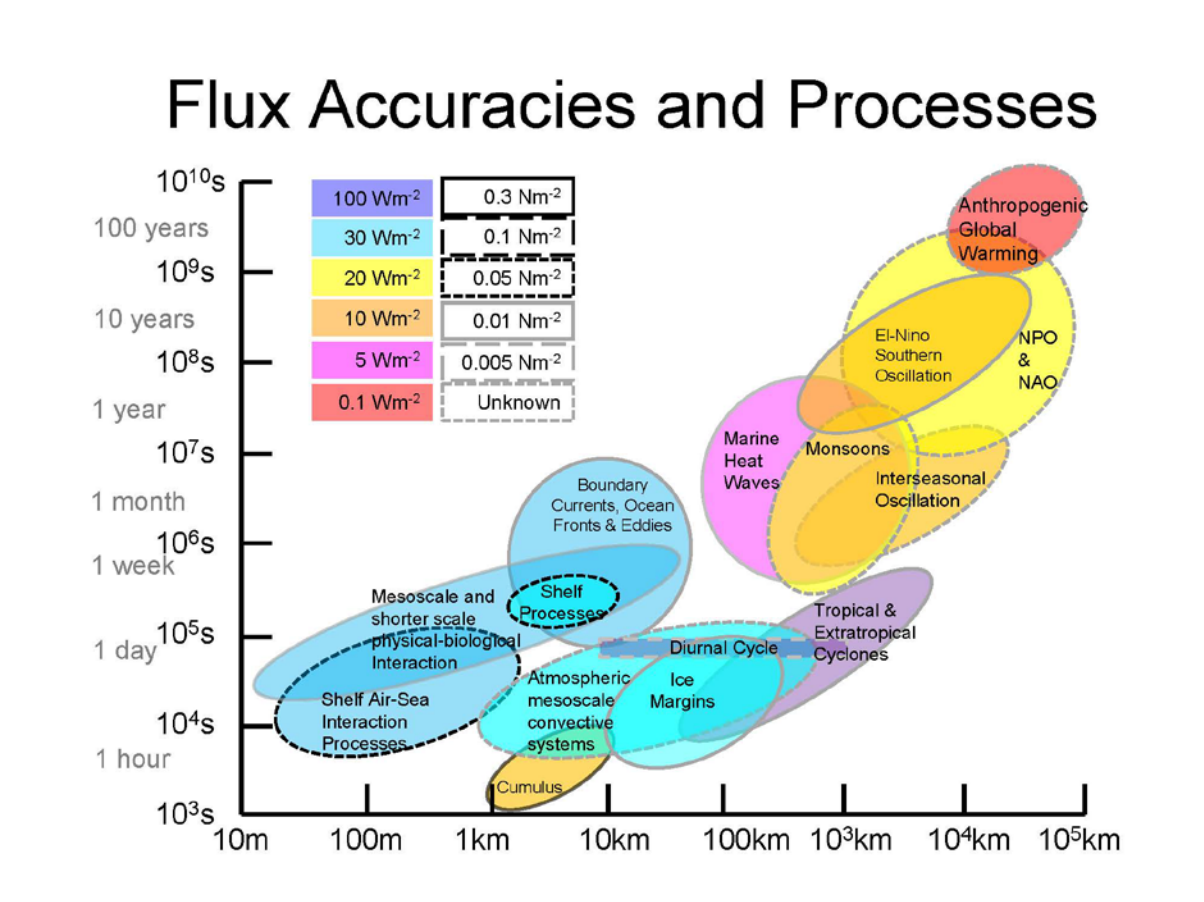
New technology for measuring directional waves



… and meteorological variables



To predict weather and climate influenced by the ocean, we must accurately resolve air-sea heat fluxes



Cronin et al. (2019) **"Air-sea fluxes with a focus on heat and momentum"**

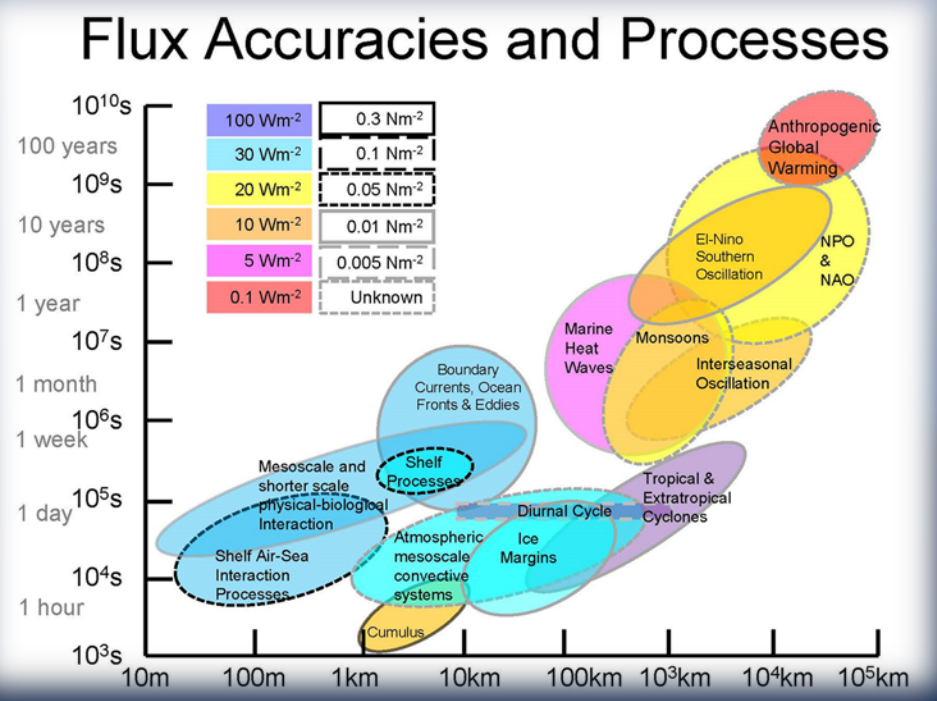
How accurate?
What resolution?
Where are these observations needed?
How can this be done?

An Observing Air-Sea Interactions Strategy (OASIS) for 2030

OASIS Decade Outcomes

OASIS observations will lead to improved prediction of the **ocean's influence on global weather and climate** on timescales of days-seasons-years → *"A predictable ocean" & "a safe ocean"*

OASIS observations will lead to improved quantification of **air-sea carbon exchange, ocean acidification, oceanic deoxygenation, and nutrient gradients** → *"A healthy & resilient ocean" & "a sustainable productive ocean"*



OASIS will improve understanding of **oceanic and atmospheric processes and feedbacks** that modulate surface fluxes of energy, moisture and carbon dioxide, and that interact with the ecosystem → *"A healthy & resilient ocean", "a sustainable productive ocean", "a predictable ocean", "a clean ocean", "an accessible ocean", and an "inspiring ocean"*

To predict weather and climate influenced by the ocean, we must accurately resolve air-sea heat fluxes. For global coverage of air-sea heat fluxes, we must:

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