Issues in identifying atmospheric and SST response to the Oyashio Extension Front variability

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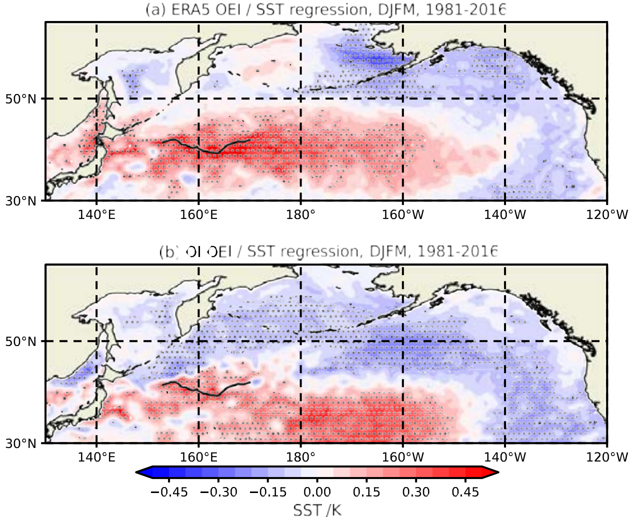
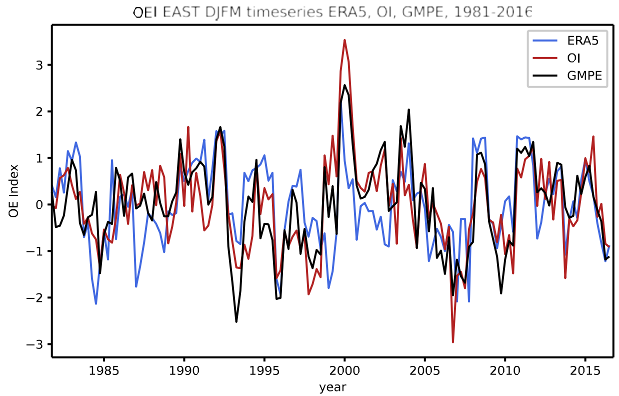
The Oyashio Index shows a north-south shift in the OE Front location. Indices vary according to the SST dataset used



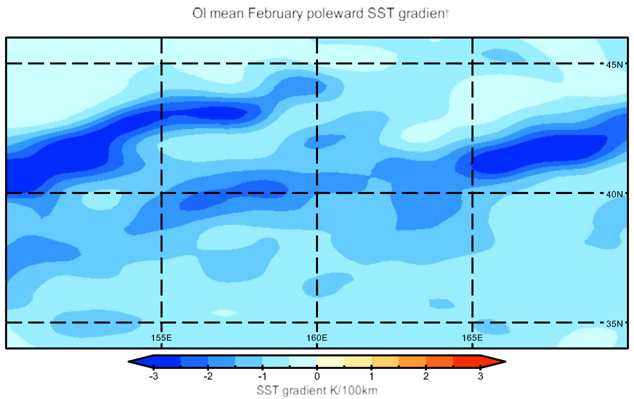
Regression of OEI against SST, DJFM, for ERA5 and

These look different too! What's going on?



The OEI indices for September-March, 1981-2016 Derived from different SST datasets

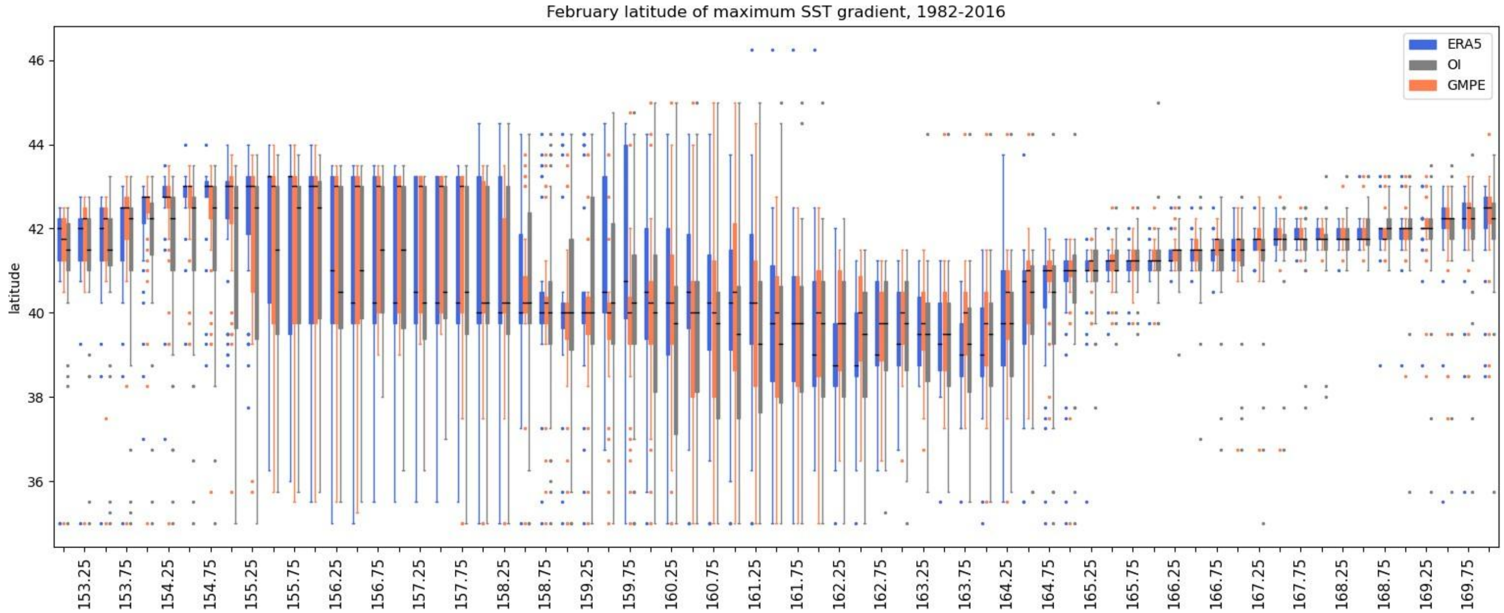
Imperial College London
WOODS HOLE OCEANOGRAPHIC INSTITUTION
NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH



The SST gradient is complex in the OE region

Conclusions

- Issues with front identification where SST gradients are complex
- Implications for interpretation of air-sea interaction results
- An ensemble approach can identify robust features
- GMPE is a possible way forward for deriving the indices:



Internal wave motions, precipitation variance, and spectral kinetic energy cascades in state-of-the-art high-resolution ocean and coupled ocean-atmosphere models

Brian Arbic, University of Michigan, arbic@umich.edu

The impacts of small-scale motions on air/sea coupling can be studied with high-resolution models, satellite missions, and in-situ measurements. Here we use high-resolution models to examine three topics of interest for satellite missions and models focused on air-sea interaction and mesoscale processes.

1) Simulation of near-surface internal gravity wave KE

Internal wave kinetic energy (KE) will be a source of "noise" in satellite missions such as Odysea that will focus on near-surface mesoscale KE. Models can be used to characterize near-surface internal wave KE. But, how accurate are these models? And, are they impacted by coupling to the atmosphere?

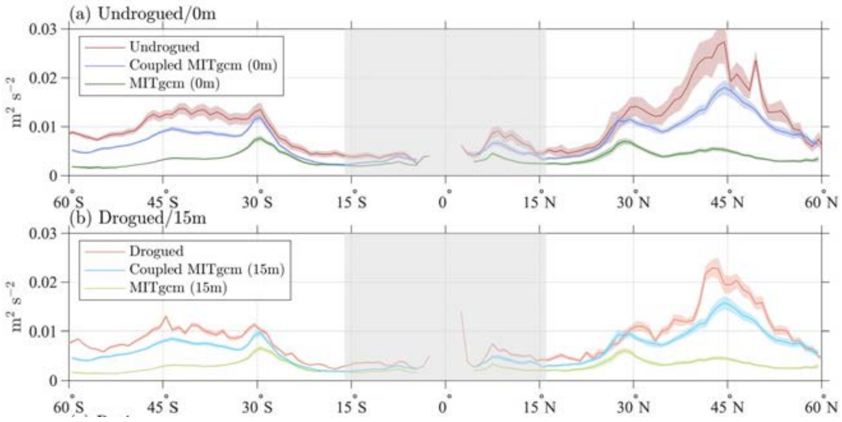
Arbic et al. (2022; JGR-Oceans; https://doi.org/10.1029/2022JC018551) compared the near-surface KE in two state-of-the-art global high-resolution ocean-only simulations:

–HYbrid Coordinate Ocean Model (HYCOM) simulations run by the US Navy

–Massachusetts Institute of Technology general circulation model (MITgcm) simulations run by NASA

with observations from undrogued and drogued drifters, in low-frequency (< 0.5 cpd), near-inertial, semi-diurnal, and diurnal bands.

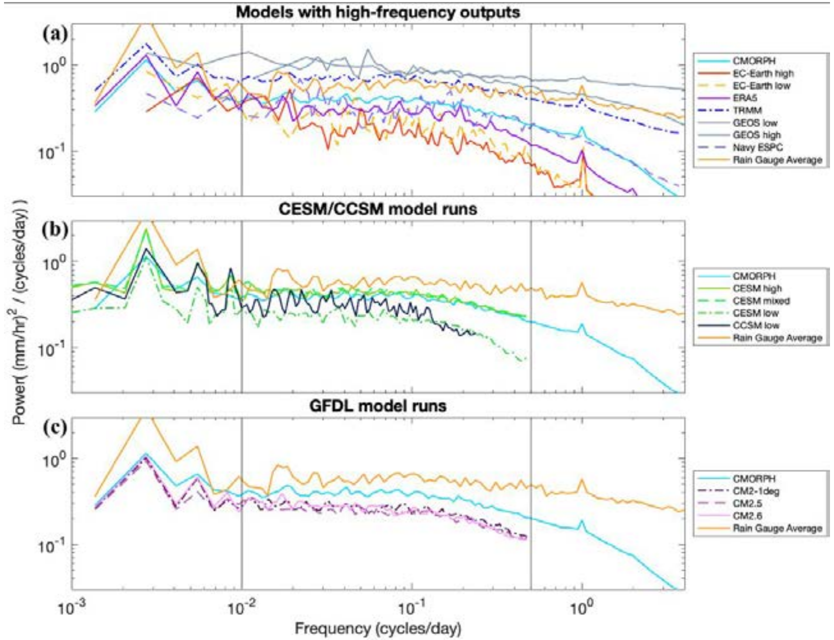
In a follow-on result (right), we have found that zonally averaged near-inertial KE in coupled ocean-atmosphere simulations with frequent coupling to the atmosphere lie much closer to drifter observations than ocean-only simulations with infrequent coupling. Thus an added benefit of high-resolution coupled ocean-atmosphere models, arising from the frequent coupling, is more accurate near-inertial motions.



2) High-frequency precipitation variance

Most precipitation variance is in sub-daily time scales, and low-resolution climate models do not capture this high-frequency activity (Covey et al., 2018).

Light et al. (2022; Climate Dynamics, https://doi.org/10.1007/s00382-022-06257-6) demonstrated that models with high-resolution in the atmosphere produce more high-frequency (subdaily) precipitation variance, as in observations, and that the ocean model resolution also matters, especially when the atmosphere model resolution is already high. The plot below shows high-frequency precipitation variance in the US Atlantic coast region. Higher-resolution models have greater high-frequency precipitation variance and ocean model resolution also matters.

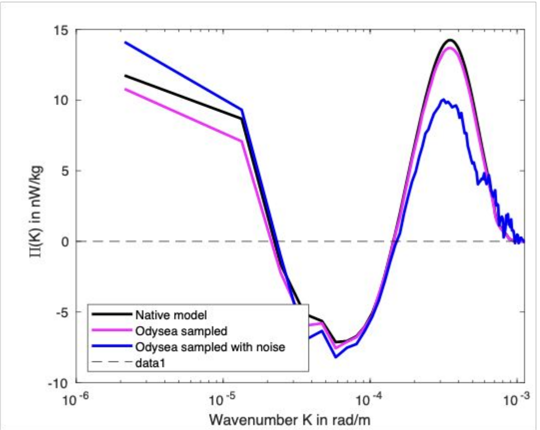


3) Will the Odysea mission be able to measure spectral kinetic energy cascades?

Spectral KE fluxes Π(K) measure the direction of spectral KE cascade as a function of wavenumber K. Spectral KE fluxes computed from altimetry (Scott et al. 2005; Scott and Arbic, 2007, Arbic et al. 2013, and others) apply the geostrophic assumption to sea surface heights. The proposed Odysea mission would enable the computation of spectral KE fluxes directly from velocities.

We computed spectral KE flux Π(K) from 1731 hourly snapshots of coupled MITgcm ocean/GEOS atmosphere in Kuroshio region, 2020-01-19 to 2020-03-29.

Also computed from 90 snapshots of “Odysea samples” of this region during the same time period, with and without noise, prepared by Alexander Wineteer of NASA JPL.

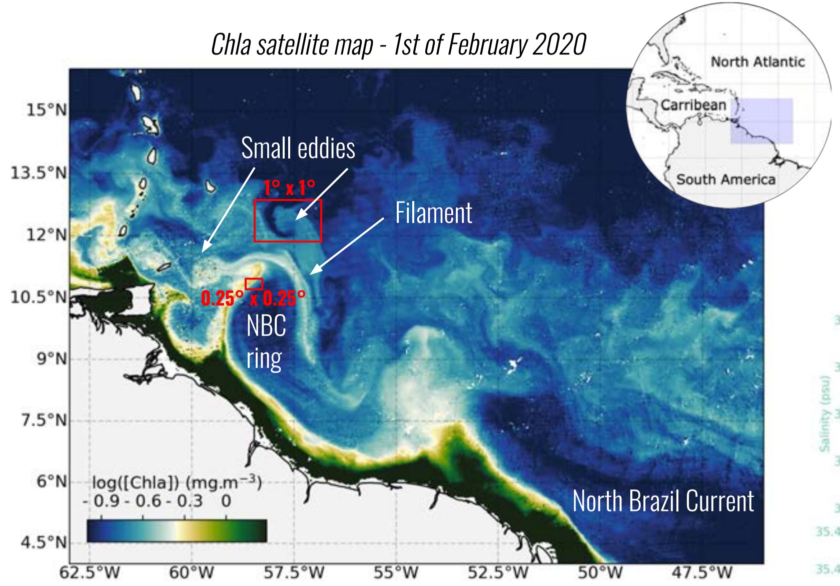


Ocean small-scale fronts in the Northwestern Tropical Atlantic:

Assessment from the EUREC4A-OA/ATOMIC field experiment

Solange Coadou, Sabrina Speich, Sebastiaan Swart, Chelle Gentemann, Dongxiao Zhang and Johannes Karstensen

Chla satellite map - 1st of February 2020



5 Saildrones deployed in Jan - Feb 2020

1-min sampling frequency ⇒ mean spatial resolution of 80 m

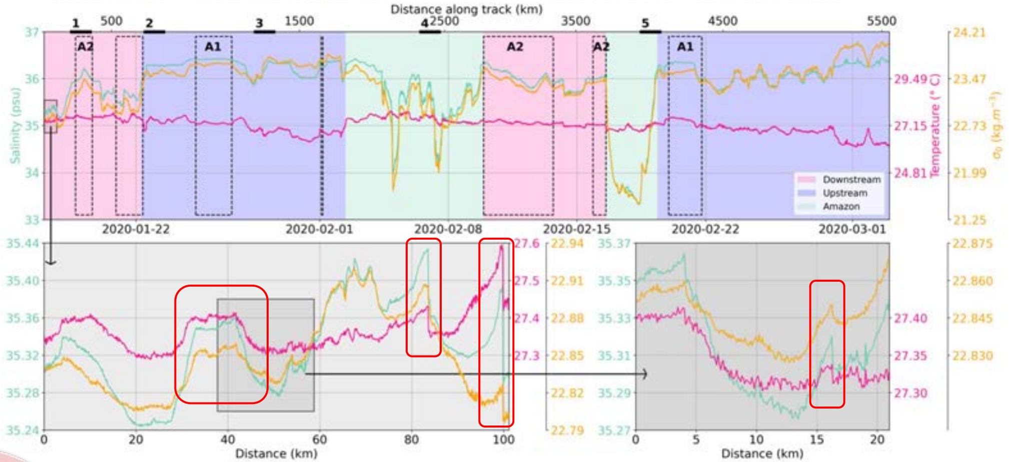
Salinity & Temperature are density-scaled

Strong thermohaline gradients occur at all scales, in particular close to the freshwater plume

Surface (0.5 m)

Wavelet transform analysis

At large scale density is salinity driven → But temperature tend to compensate salinity at small-scale

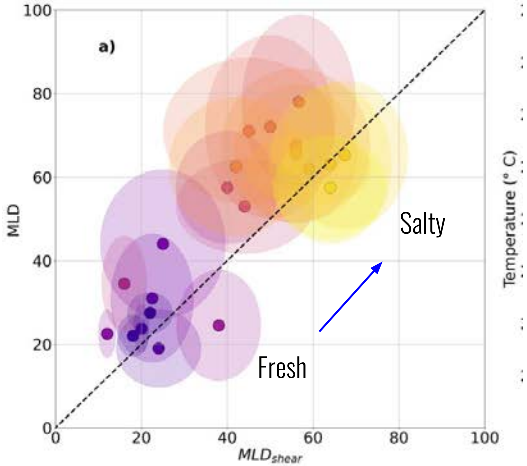


One Saildrone SSS, SST and potential density time series

solange.coadou-chaventon@lmd.ipsl.fr

Relate maximum velocity vertical shear level with MLD based on TS clustering

Computed from Argo floats, CTDs, gliders, MVPs and uCTDs



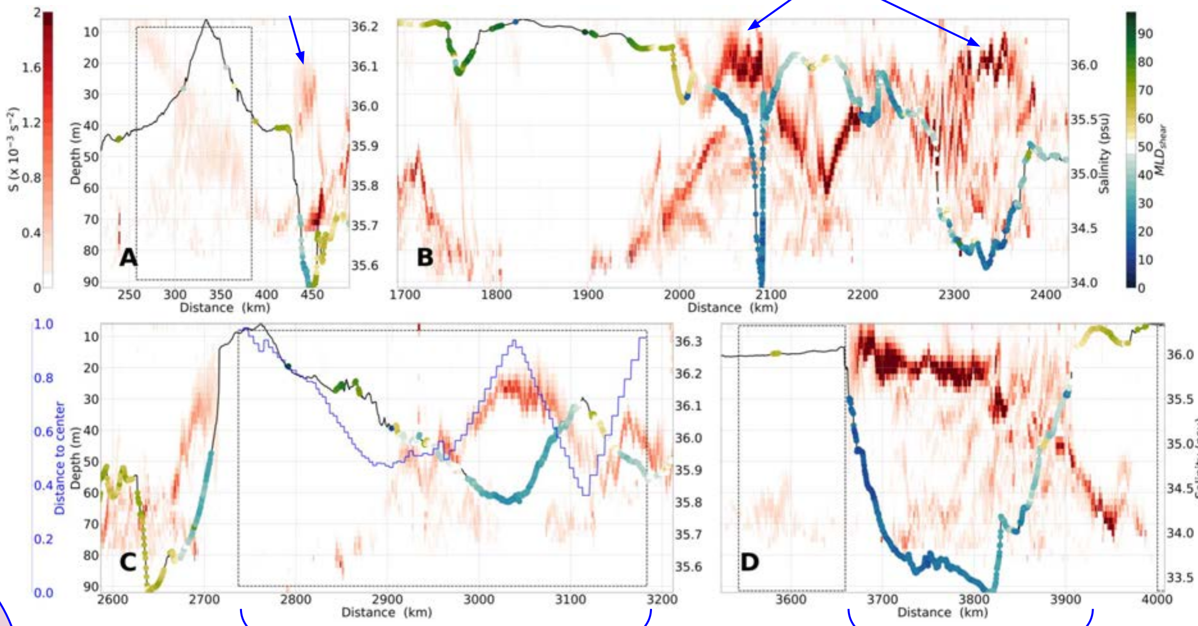
Computed from the Saildrones ADCP

Fronts associated to the fresh water signal are coincident with a sharp increase of the maximum velocity vertical shear level, related to a shallow MLD

Upper ocean (6 - 100 m)

Filament

Plume



NBC ring

Plume

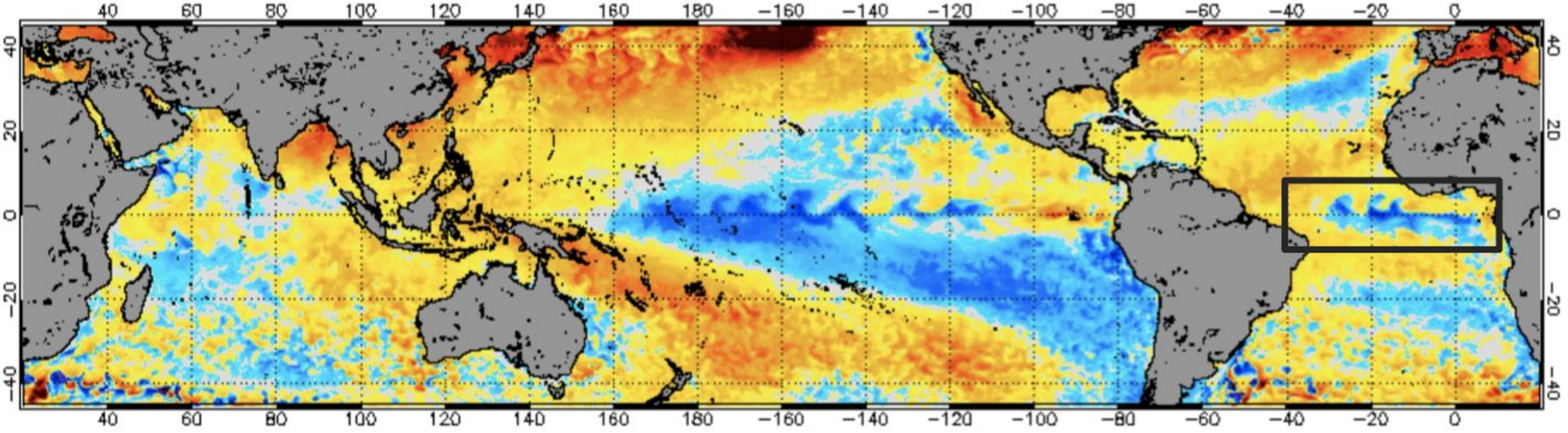
Detailed picture of the fronts at the meso and submesoscale,
revealing particularly strong gradients in the freshwater plume area
Increasing T compensation at the submesoscale, but strong salinity gradients remain uncompensated

Strong salinity fronts are associated with the rise of the maximum velocity vertical shear level, which indicates a shallower MLD

<u>Red shading:</u> velocity shear computed from the saildrone ADCP, <u>color dots:</u> Depth of the maximum velocity shear, <u>black line</u>: Salinity time series, <u>black dash line</u>: indicates eddy crossing, <u>blue line:</u> distance between the saildrone and the eddy center

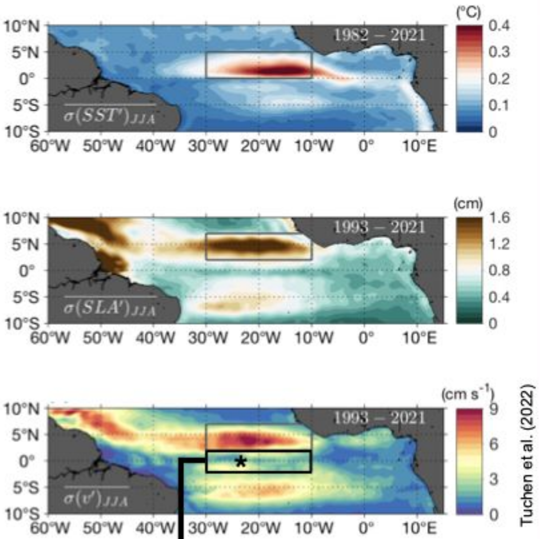
solange.coadou-chaventon@lmd.ipsl.fr

Investigating long-term variability and trends of Atlantic **Tropical Instability Waves** with multidecadal **satellite observations** and **mooring data**



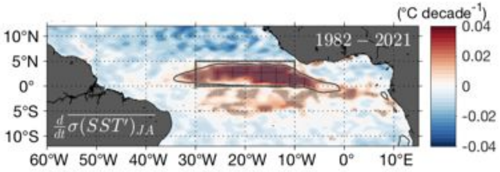
Franz Philip Tuchen (NOAA/AOML, Miami, USA) | franz.philip.tuchen@noaa.gov |
US CLIVAR Mesoscale and Frontal-Scale Air-Sea Interactions Workshop (March 6-8, 2023)

Tropical Instability Wave (TIW)-induced variability patterns

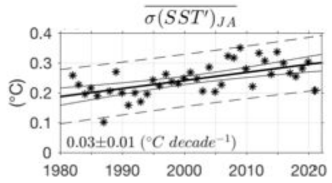


something is missing at the equator …

Observed long-term intensification of TIW activity



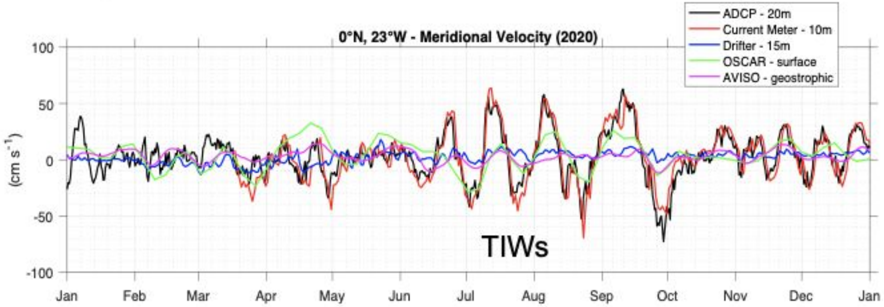
TIW-induced SST variability increased by 43% over the last 40 years



Pronounced interannual modulation (likely associated with Niño mode)

Why?

Gridded products underestimate current velocity variability



Recommendations:

- Mesoscale TIWs are important components of the tropical heat and freshwater budgets and yet their net effect is not well understood
- Maintaining (or better expanding) in-situ observations of current velocities at established equatorial mooring sites (i.e., PIRATA buoys)
- Validation and comparison of (future) satellite missions or gridded surface current products with near-surface moored velocities

The Mesoscale Ocean Contribution to Sea Surface Temperature Distribution

Andrew Delman[1], Tong Lee[2]
[1]Joint Institute For Regional Earth System Science & Engineering (JIFRESSE), University of California Los Angeles
[2]Jet Propulsion Laboratory, California Institute of Technology

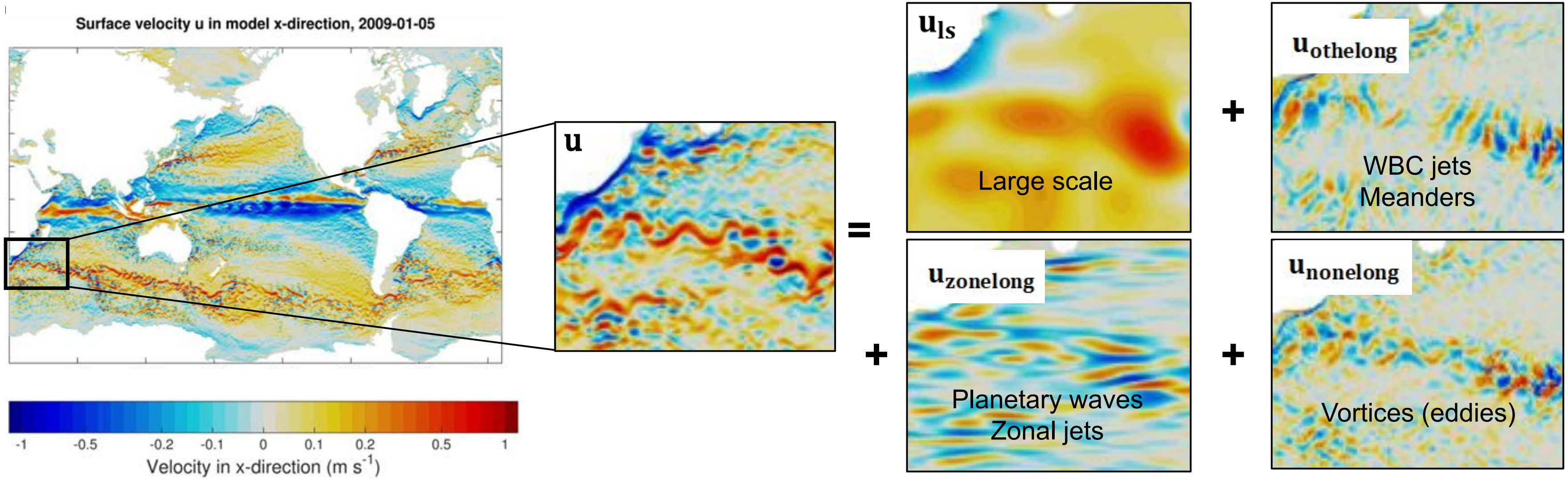
What are we doing?

- Developing a framework by which the contributions of different types of mesoscale dynamics to surface variability can be quantified, focusing on the mixed layer temperature budget (i.e. SST variability)

Temperature Budget

$$\frac{\partial T}{\partial t} = -\nabla \cdot \mathbf{u}T - \nabla_h^2\left(A_h \nabla_h^2 T\right) + \frac{\partial}{\partial z}\kappa\left(\frac{\partial T}{\partial z} - \Gamma\right) + \frac{1}{\rho C_\rho} Q_{net}$$

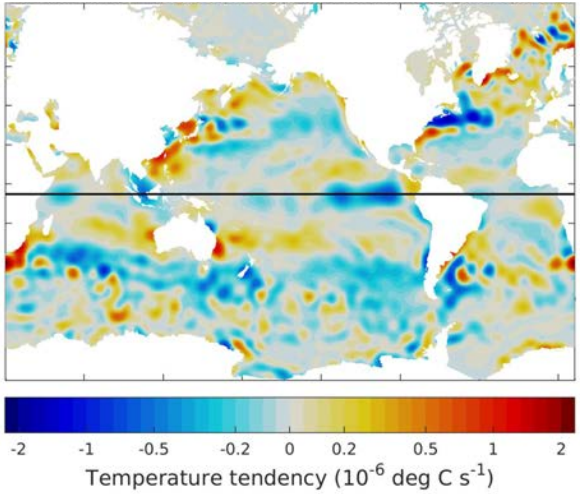
Decompose advection term **u** (3D velocity) and *T* (temperature) using two-dimensional spectral filters, in 0.1° forced ocean CESM simulation



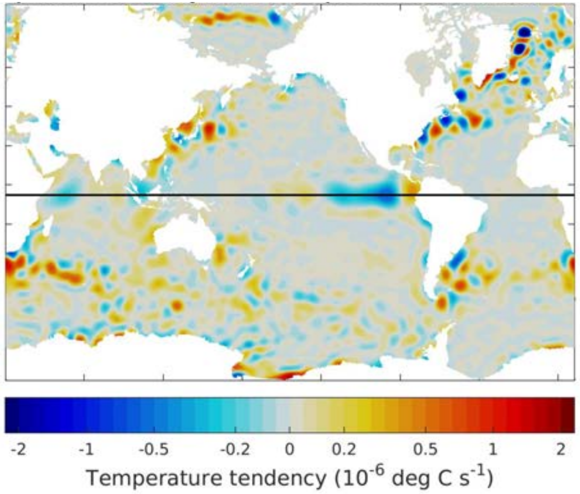
What is the effect of the mesoscale on temperature tendency?

- These are for a 5-day mean (2009 Jan 1-5). Low-pass spatial filter also applied after tendency computation to smooth patterns

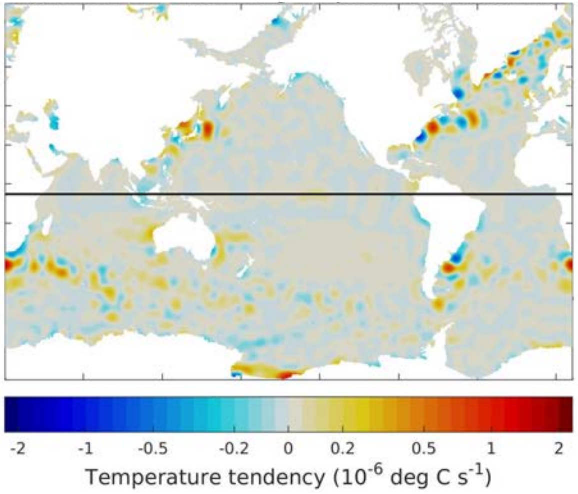
Temperature tendency – all advection



Excluding large-scale term



Only terms with "eddy" component



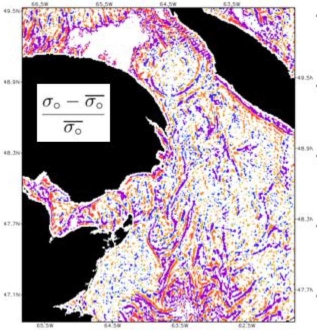
Work in progress/planned

- Extend this analysis to quantify seasonal/interannual/decadal timescale contributions of mesoscale ocean dynamics to SST
- Adapt budget and filtering code for use with Arakawa C-grid models (e.g., MITgcm)

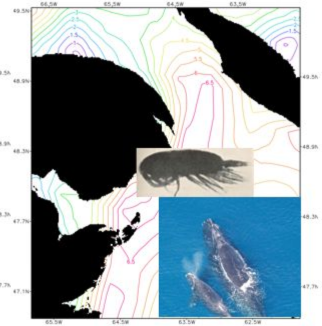
- Thanks to NASA Physical Oceanography for support, and Ben Johnson and Frank Bryan for running the model simulation and assisting with obtaining output.

Feel free to contact me at andrewdelman@ucla.edu

What can synthetic aperture radar (SAR) filaments tell us about North Atlantic right whales and their prey?



Radarsat-2 SAR contrast



ERA5 wind speed (ms^{-1})

An Observational Study of the Dependence of Ocean Surface Filaments on Wind Speed

Rick Danielson, Hui Shen, Jing Tao, Will Perrie, Fisheries and Oceans Canada

Please see https://arxiv.org/abs/2302.01533 or reach out rick.danielson@dfo-mpo.gc.ca

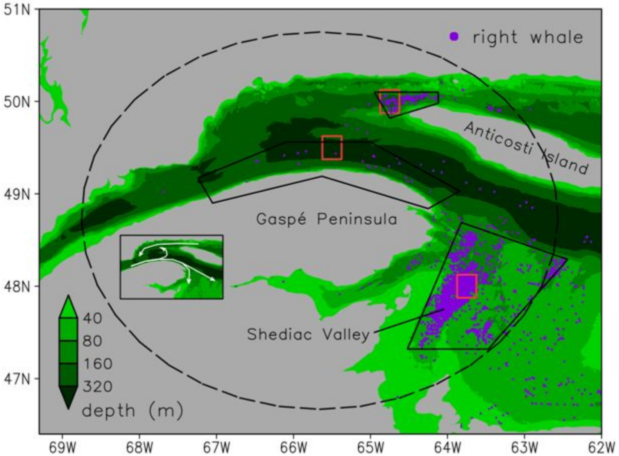
$$
\begin{aligned}
\text{SAR} \quad C &= t + \epsilon + \epsilon_C \\
\text{ERA} \quad U &= \alpha_U + \beta_U t + \epsilon + \epsilon_U \\
Var(C) &= \sigma_t^2 + \sigma_\epsilon^2 + \sigma_C^2 \\
Var(U) &= \beta_U^2 \sigma_t^2 + \sigma_\epsilon^2 + \sigma_U^2 \\
Cov(C,U) &= \beta_U \sigma_t^2 + \sigma_\epsilon^2
\end{aligned}
$$

a) define *specific* measurements of interest

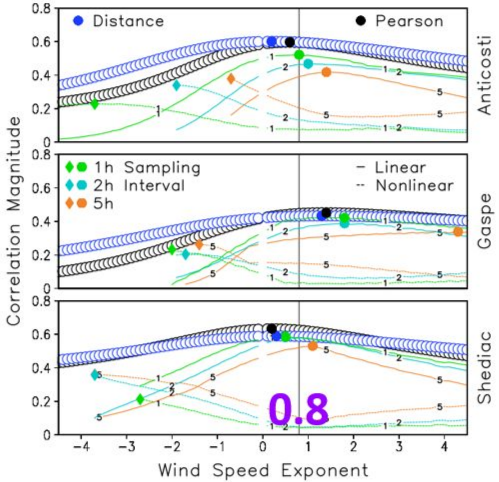
b) ask how these measurements are associated

$$\left[\frac{\text{ERA5 wind speed}}{6\ ms^{-1}}\right]^{0.8}$$

c) scale SAR contrast to reduce-wind enhance-ocean dependence



- **Pearson correlation** $\rho = Cov(C,U)/\sqrt{Var(C)Var(U)}$ with linear ($\beta_U \sigma_t^2$) and nonlinear (σ_ε^2) components
- **Distance correlation** is a measure of nonlinear/nonmonotonic dependence (Székely et al. 2007, Székely and Rizzo 2009) that is comparable to Pearson correlation (Edelmann et al. 2021).

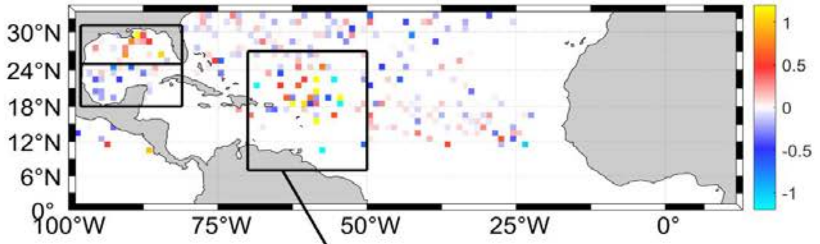


Investigation of the surface and subsurface salinity wakes of tropical cyclones

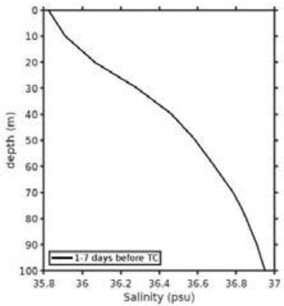
Aurpita Saha[1,2] (aurpita.saha@noaa.gov), Gregory R. Foltz[2], Claudia Schmid[2]

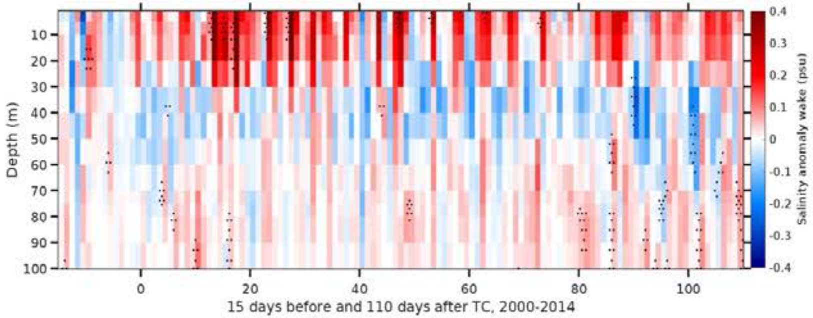
[1] Cooperative Institute for Marine and Atmospheric Studies, University of Miami, Miami, FL, USA
[2] NOAA/Atlantic Oceanographic and Meteorological Laboratory, Miami, FL, USA

Sea Surface Salinity wakes (psu) of tropical cyclones (TC) using Argo floats



A saline surface salinity wake and subsurface freshening dominate at the Amazon plume region. Predominantly fresh surface waters from river runoffs in this region mixes down to greater depths. Salinity maximum water at the subsurface is mixed to shallower depths.





Using SAR to diagnose boundary layer stratification change at the ocean sub-to-mesoscale

D.Vandemark, R. Foster, J. Stopa, C. Wang, B. Chapron, A. Mouche

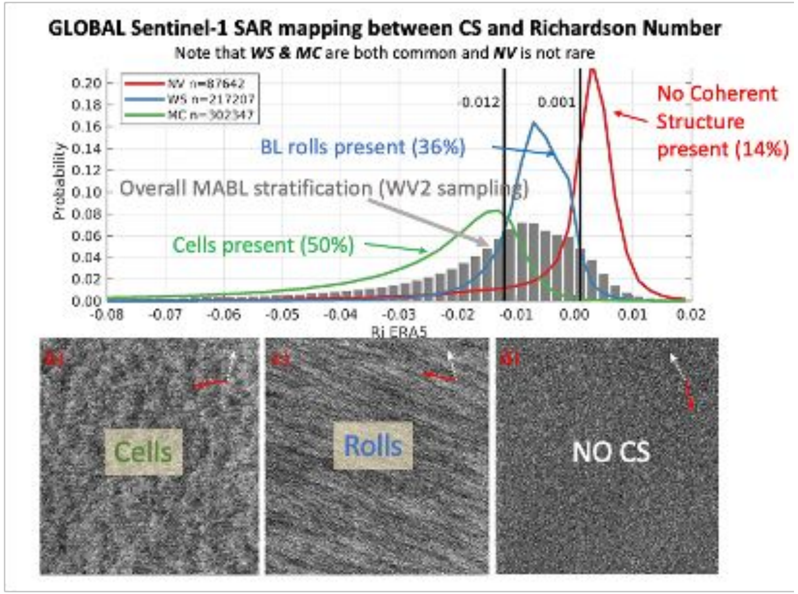
Workshop question 4:
What are key analysis approaches and diagnostics of air-sea coupling which could guide modeling and observational strategies, including time and space scale dependencies and specific variables and processes?

New 'Routine' Observational Tool:

- Satellite SAR detects boundary layer coherent structure (CS) type
- CS relates to state of surface layer stratification (unstable-to-stable)
- Spatial scales of 1-1000 km including seasonal mapping capability

Possible Discussion question:
Could such stratification information provide a new useful diagnostic for model/data comparisons and improved flux prediction?

Implies model BL flux parameterization and predictions change with SST gradients, stability, and CS… including LES.



20 x 20 km Sentinel 1 SAR "imagettes"

Research supported by NASA Physical Oceanography grants: NNX17AH17G and 80NSSC20K0822

Example global multi-year mapping to illustrate SAR detected diversity in surface layer stratification (Ri) (Stopa et al. 2022)

SAR CS

ERA5 Ri

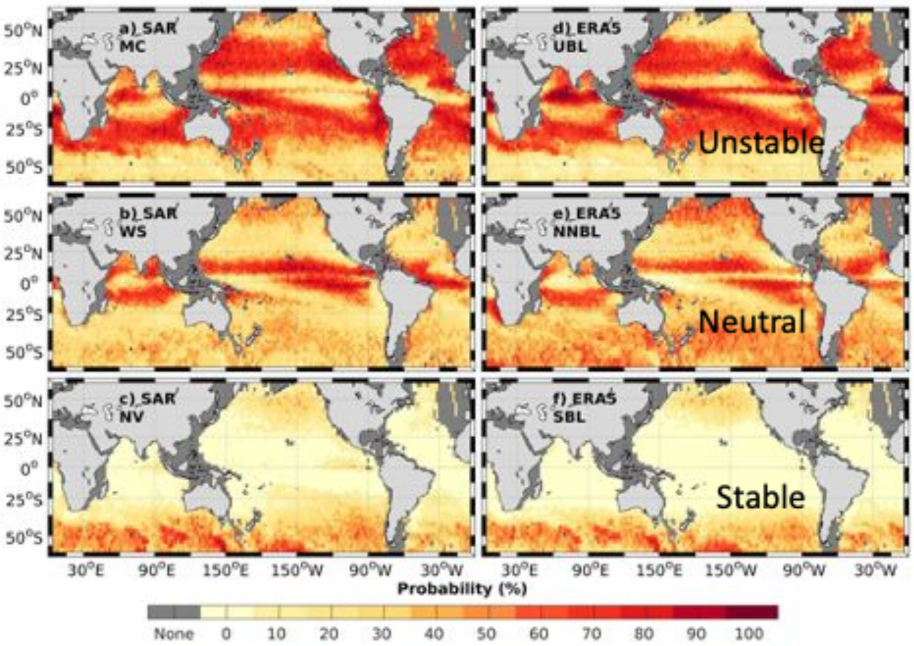


Figure 3. Relative occurrence rate between SAR-detected MC, WS, and NV events, left panels (a–c), using selected 2016–2019 S-1 data. Results are calculated for 2° bins. Panels d–f show the same events but mapped using ERA5 unstable, near-neutral, and stable boundary layer stratification classes based on *Ri* as defined in the text.

CS information tied to Ri holds even when sub-20km variability exists (atm and ocean fronts)

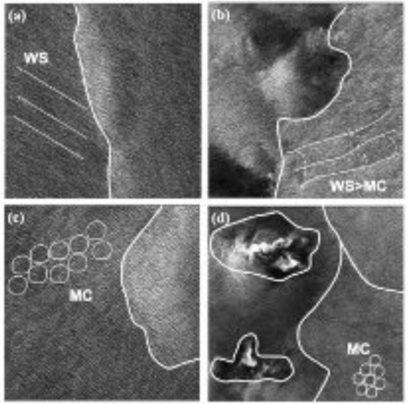


Fig. S7 The sea surface roughness SAR image examples with coherent structures coexisting with other localized MABL phenomena such as fronts in (a)-(d), cold pools in (b) and rains in (d).

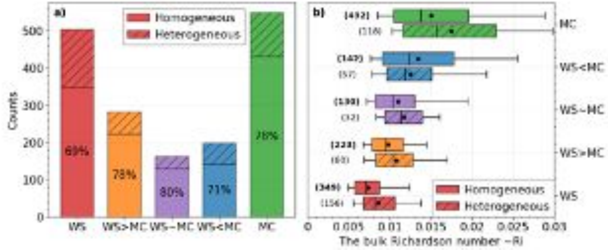


Fig. S8 Variations due to SAR image homogeneity. (a) Image count of each WS/MC class separated for homogeneous and heterogeneous cases, i.e., whether or not the coherent structures coexist with atmospheric fronts, rains or cold pools. (b) comparison of -Ri between homogeneous and heterogeneous for each WS/MC class.

Using scatterometer observations to correct for persistent biases in modelled ocean surface winds

Copernicus Marine Service
Royal Netherlands Meteorological Institute
Ministry of Infrastructure and Water Management

Rianne Giesen, Evgeniia Makarova, Zhixiong Wang, Ad Stoffelen and Marcos Portabella

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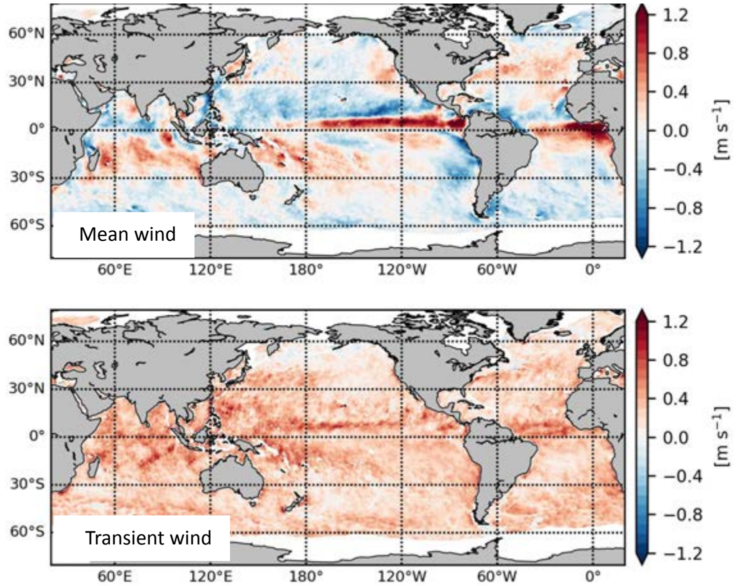
Institut de Ciències del Mar

- The ocean surface wind plays a key role at the atmosphere-ocean interface
- Persistent biases are found between scatterometer observations and ECMWF NWP model winds
- Lack of small-scale variability in ECMWF model winds

- Use temporally-averaged differences between scatterometer observations and collocated NWP model winds to correct for persistent local NWP wind vector biases:

$$SC(i,j,t_f) = \frac{1}{M}\sum_{m=1}^{M} u_{10s}^{scat}(i,j,t) - u_{10s}^{NWP}(i,j,t)$$

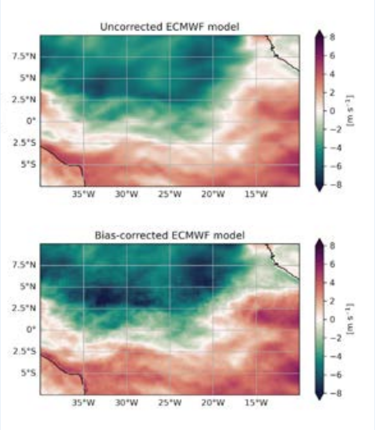
Metop-A ASCAT – ECMWF ERA5 [2018]



Meridional wind bias

Application 1:
Bias-corrected wind products for the Copernicus Marine Service

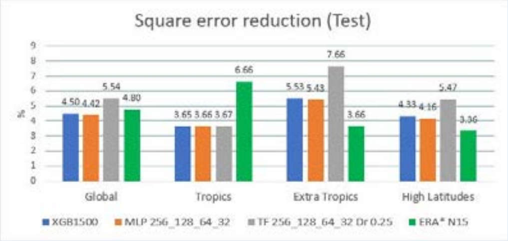
Products providing ECMWF surface wind and stress fields, corrected for persistent biases using scatterometer observations (hourly and monthly temporal resolution, 0.125° and 0.25° horizontal grid)



Application 2:
Using machine learning to correct NWP surface wind biases

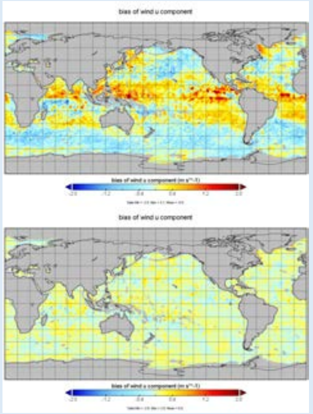
Machine learning setups are explored to find functional relationships between oceanic and atmospheric variables and the persistent NWP biases.

Predictions can be used to correct ocean forcing forecasts or NWP biases for periods before scatterometers existed.



Application 3:
Bias-adjusted scatterometer observations for NWP data assimilation

The large systematic errors in NWP model winds inhibit effective assimilation of scatterometer winds. Using bias-adjusted scatterometer observations is expected to be beneficial for data assimilation.



Characteristics and Trends of the Campbell Plateau Meander in the Southern Ocean: 1993-2020

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Xinlong Liu (IMAS); Dr. Amelie Meyer (IMAS); Dr. Chris Chapman (CSIRO)

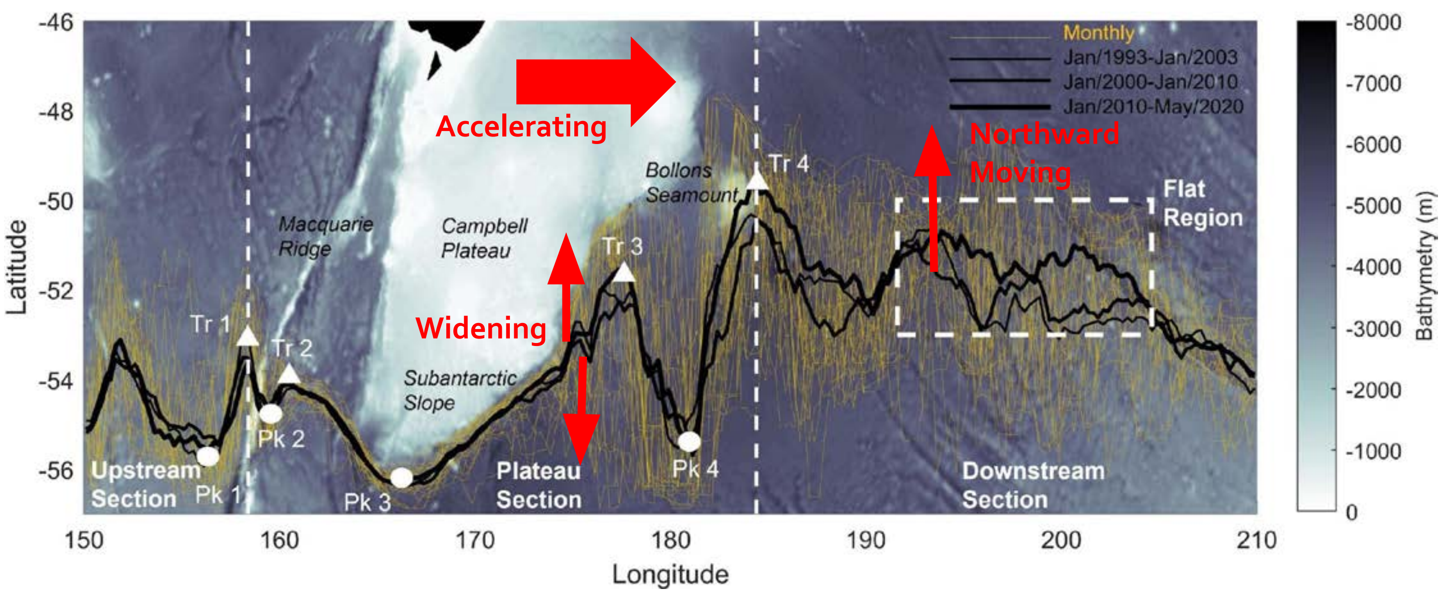

Figure 1: The Campbell Plateau meander's mean positions over three different decades. Adapted from Liu et al . (in prep).

The Campbell Plateau meander has clear trends over the past 27 years:

- *Position*: overall spatially fixed, but downstream part shifting northward.
- *Amplitude*: flattening upstream from the Plateau; flexing downstream from the Plateau.
- *Width & speed*: widening and accelerating, particularly downstream from the Plateau.
- *Similar* trends compared to the Agulhas-Kerguelen standing meander (Meyer et al. in prep).

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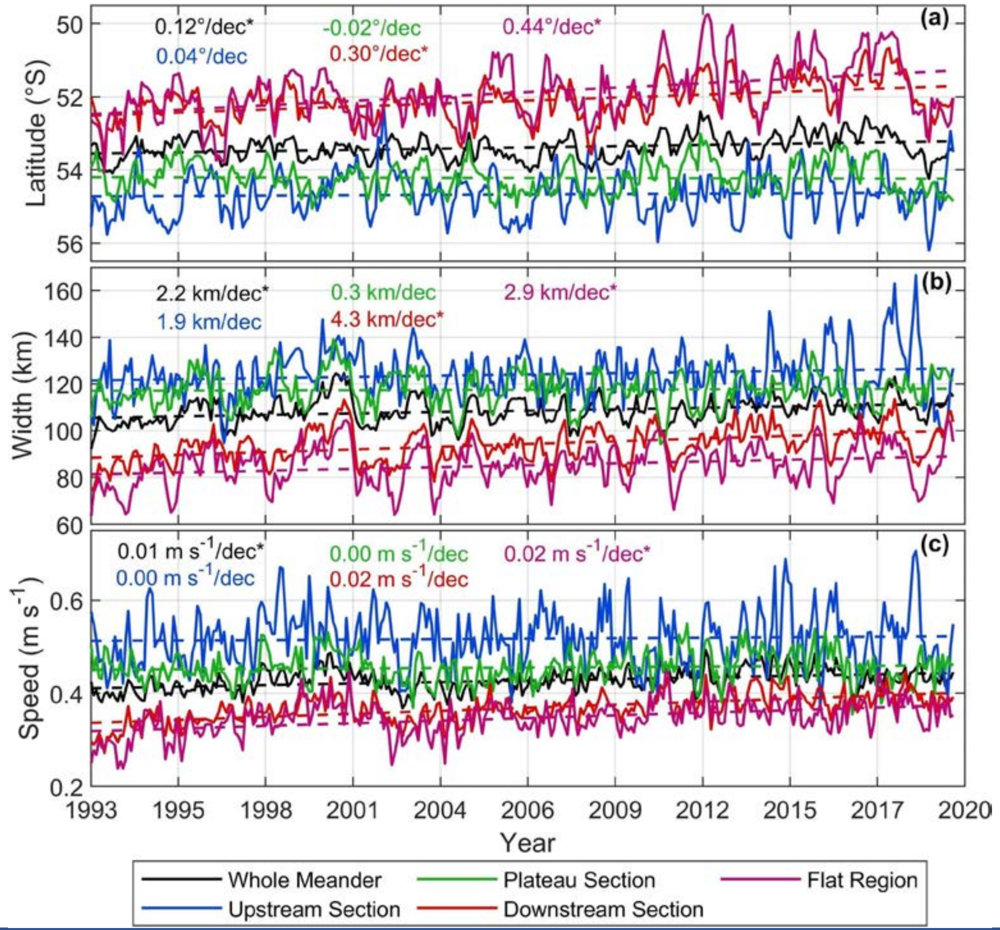
Results & Implications



Discussions

- *Downstream Section significantly moving northward*:
  - Hypotheses: 1. Changes in the stability properties of the downstream jet [Youngs et al. (2017); Barthel et al. (2022)]; 2. Interaction between the South Pacific gyre and Antarctic Circumpolar Current jets [Roemmich et al. 2007].
- *Increasing width*:
  - Consistent with Gille (1994) & Shao et al. (2015).
  - Hypothesis: Changes in the meander's volume transport.
- *Increasing speed*:
  - Consistent with recent Southern Ocean studies [e.g., Shi et al. (2021)].
  - Hypotheses: 1. Increased wind forcing; 2. Increased buoyancy forcing [Shi et al. (2021); Peng et al. [2022)].

Figure 2: Monthly time series and corresponding linear trends over the 1993-2020 period of the Campbell Plateau meander's position, width and speed. From Liu et al . (in prep).

Regional Coupled System Development at the UK Met Office

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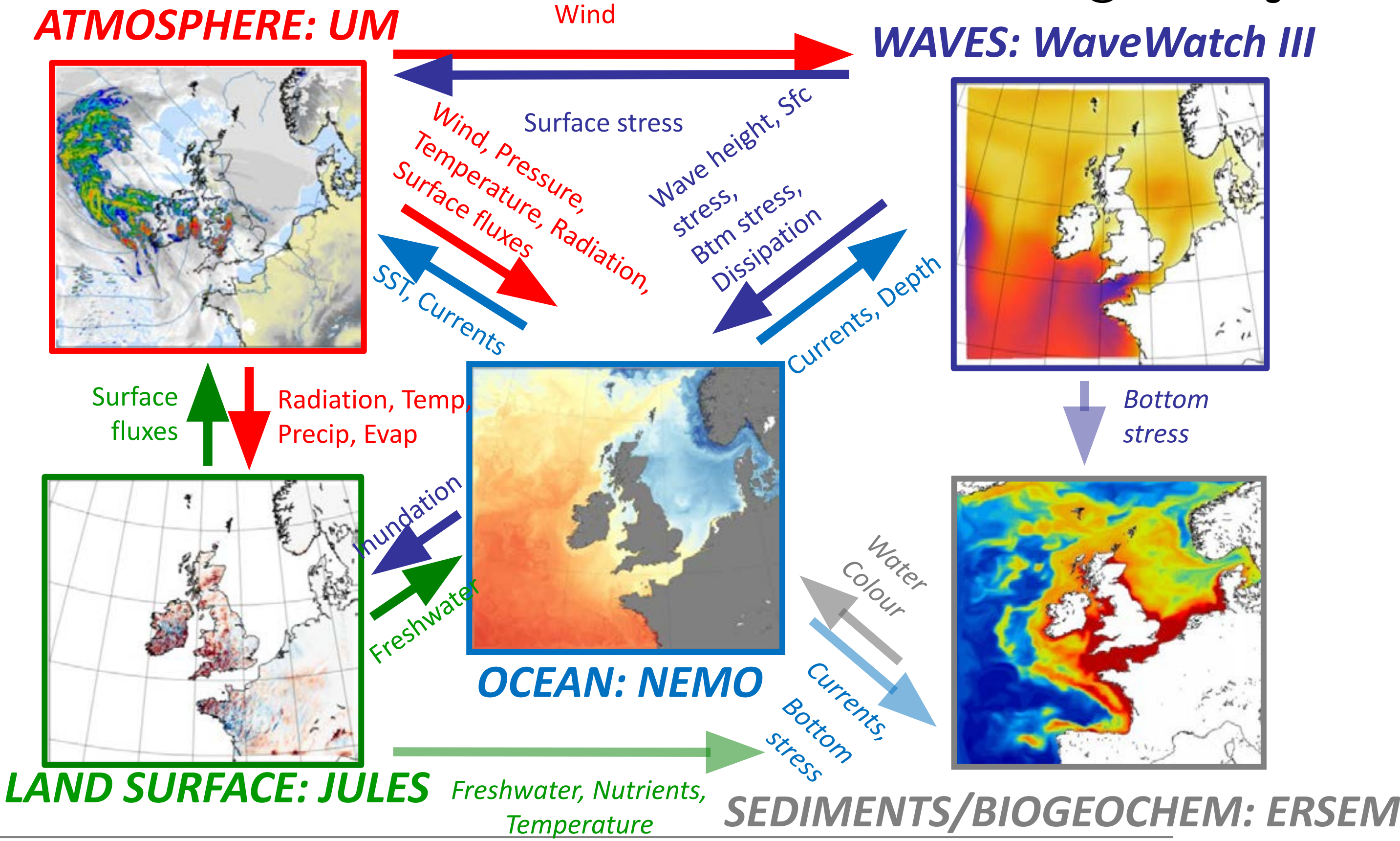
UK domain (1.5km):

Numerical weather prediction: **A/O/W**
- Deterministic forecast
- Ensembles

(Case studies)

Climate:
Atmosphere-Ocean

Under development:
- Modelled river outflow into the ocean (Lewis et al. 2021)
- Biogeochemistry: ERSEM



Met Office

Some highlights

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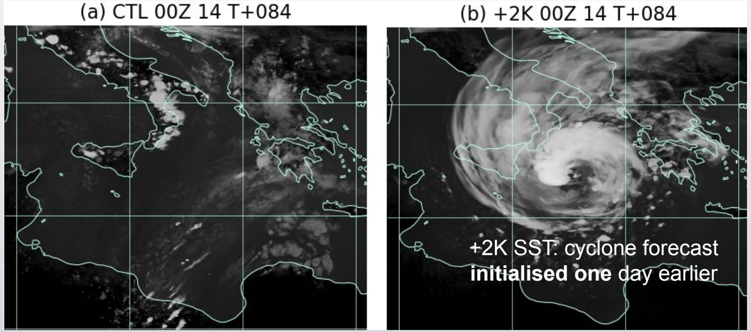
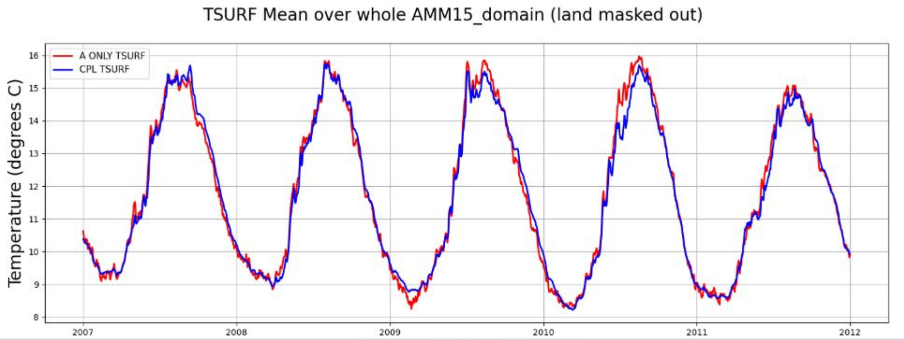
Medicane forecast: importance of SST perturbations



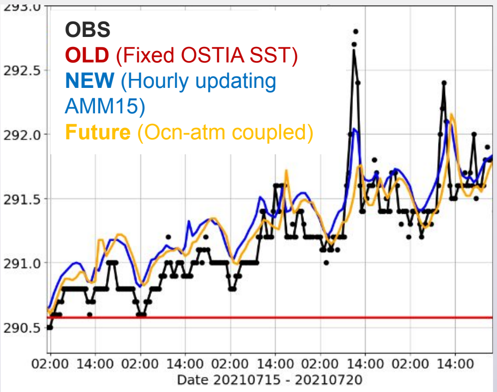
Claudio Sanchez

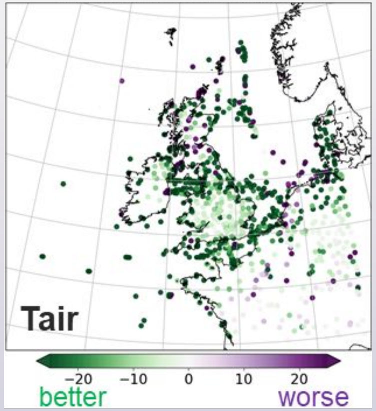
On-going developments of climate capability



Alex Arnold

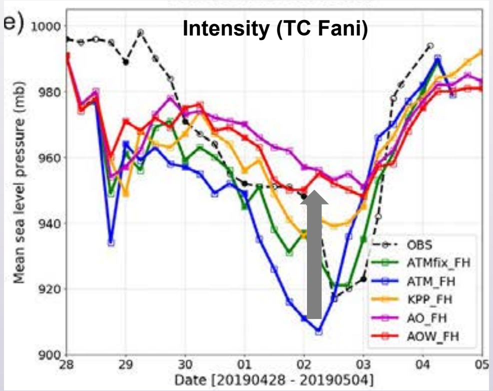
Heatwaves + light winds: importance of SST evolution

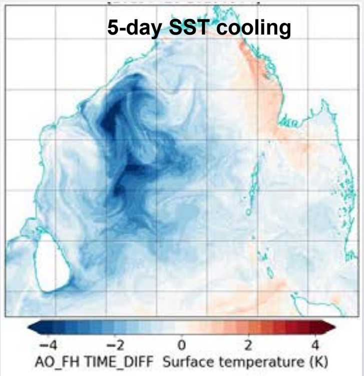




Mahmood et al. (2021)

Tropical cyclones: importance of ocean coupling





Castillo et al. (2022)