Science I: Climate data records for understanding the causes of global and regional sea level variability and change

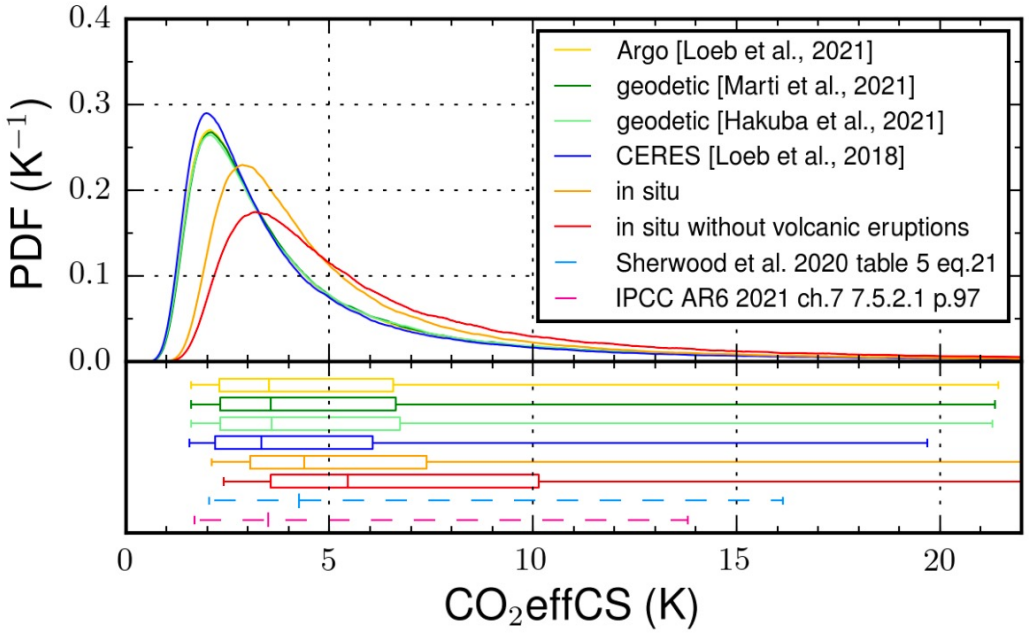
Session chairs: Benjamin Hamlington, Benoit Meyssignac

(Mon, Oct 31 2022, 16:15 - 18:00)

SCIENCE I session summary

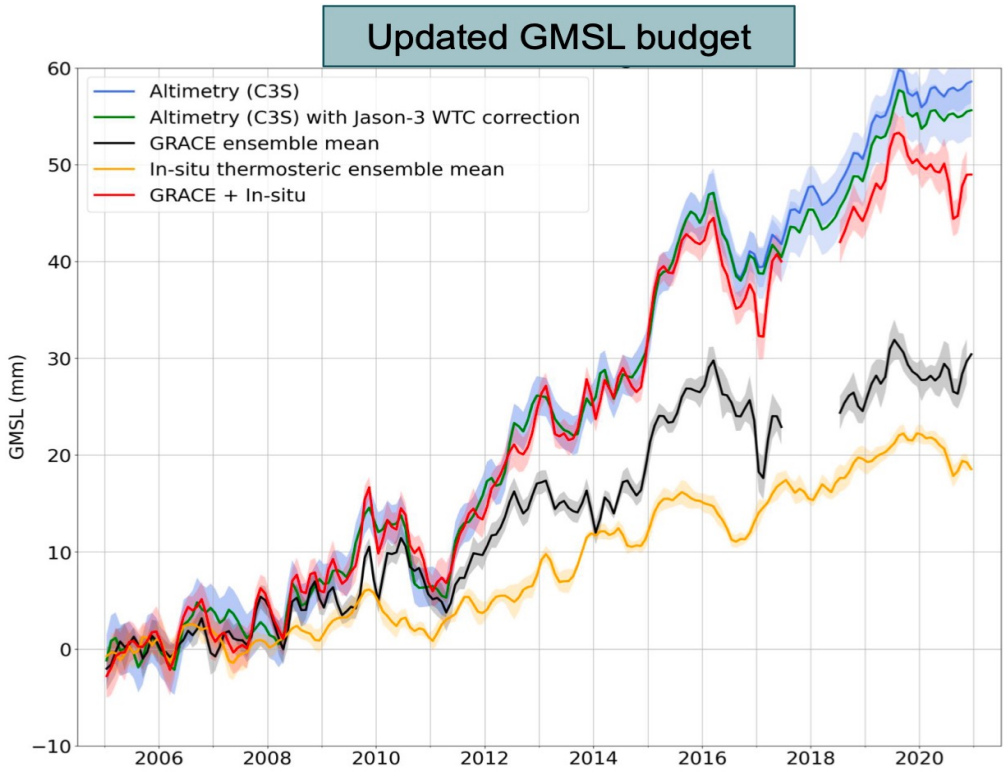
- Argo on one side and Satellite altimetry sea level combined with space gravimetry data on the other side enable to estimate indepedently the mean and time varying Earth energy imbalance that is responsible of current climate change. With these consistent estimates we can derive the global climate feedback parameter and its time variations over the past decades which further provides an observational constraint on the climate sensitivity

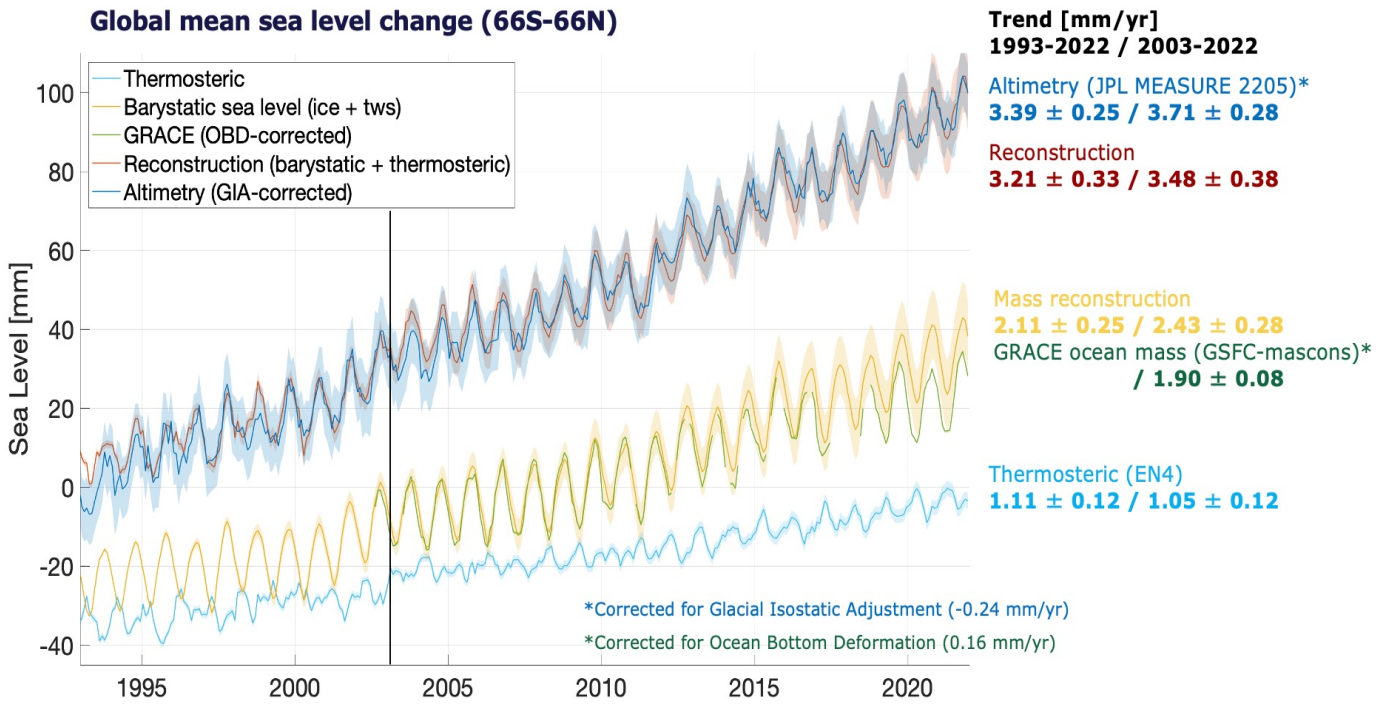
		Median [5%,95%] (K)
Argo [Loeb *et al.*, 2021]	(2005-2018)	3.5 [1.6 ; 21.4]
Geodetic [Marti *et al.*, 2022]	(2002-2016)	3.6 [1.6 ; 20.8]
Geodetic [Hakuba *et al.*, 2021]	(2005-2015)	3.6 [1.6 ; 21.3]
CERES [Loeb *et al.*, 2018]	(2006-2018)	3.3 [1.5 ; 19.7]
In situ	(1971-2017)	4.4 [2.1 ; 24.5]
In situ (without volcanic eruptions effect)* [Chenal *et al.*, 2022]	(1971-2017)	5.4 [**2.4** ; 35.6]
[Sherwood *et al.*, 2020]	(2006-2018)	4.3 [2.0 ; 16.1]
IPCC AR6 [Forster *et al.*, 2021]	(2006-2019)	3.5 [1.7 ; 13.8]



- The sea level budget evaluated with satellite altimetry, space gravimetry and Argo does not close from 2015 on, by 2.0±1 mm/yr if estimated using the trend since 2015. The salinity drift in Argo floats and a drift in Jason 3 WTC explain respectively ~40% and ~20% of this non-closure. ~40% of the of the non-closure, which correspond to a significant signal of 1.0±05mm/yr that remains unexplained

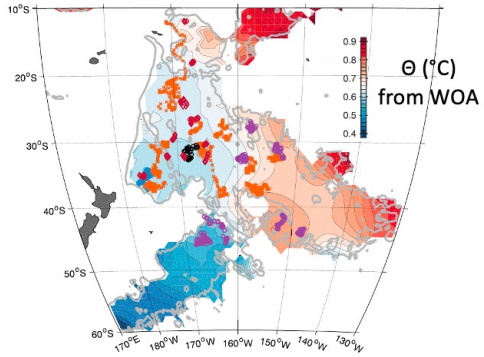
- A monthly reconstruction in a 0.5-degree grid of every individual contribution to sea level change from 1992 does close the sea level budget after 2015. The reconstructed mass-driven sea level show large variations with GRACE after 2015

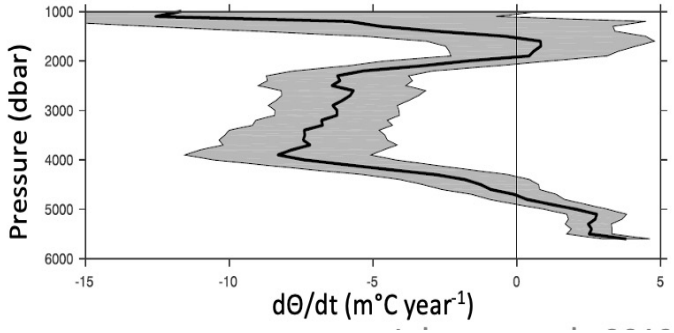




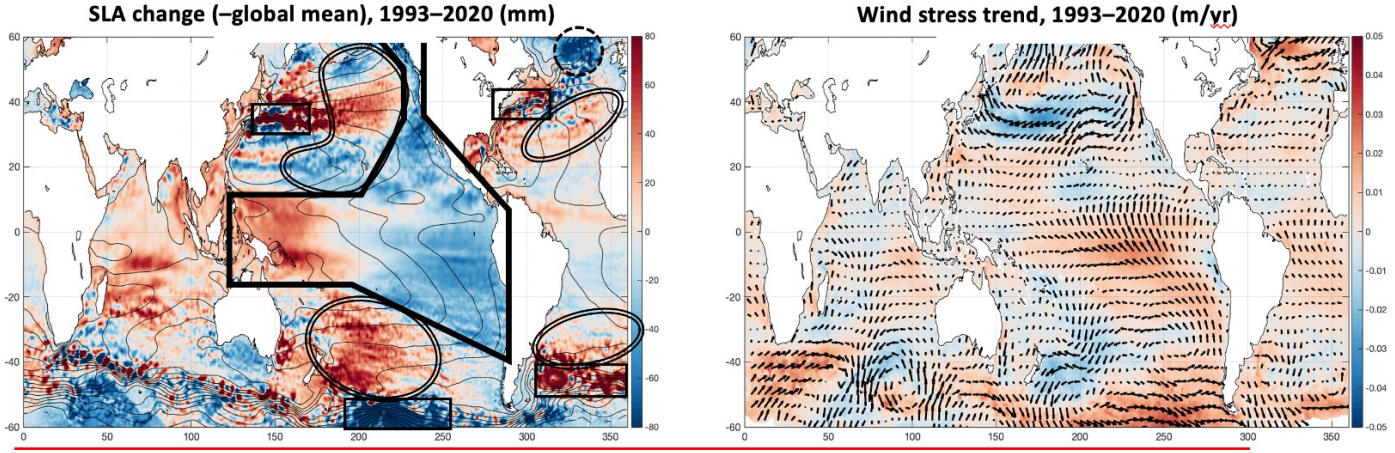
- Part of the non-closure could be due to the deep ocean contribution that has been only partially been accounted for, so far. The Deep-Argo network is growing and is already measuring significant changes in bottom water properties. The deep Argo network suggests an acceleration of previously reported long-term abyssal warming trends in the south west Pacific ocean

Jun 2014-Nov 2018

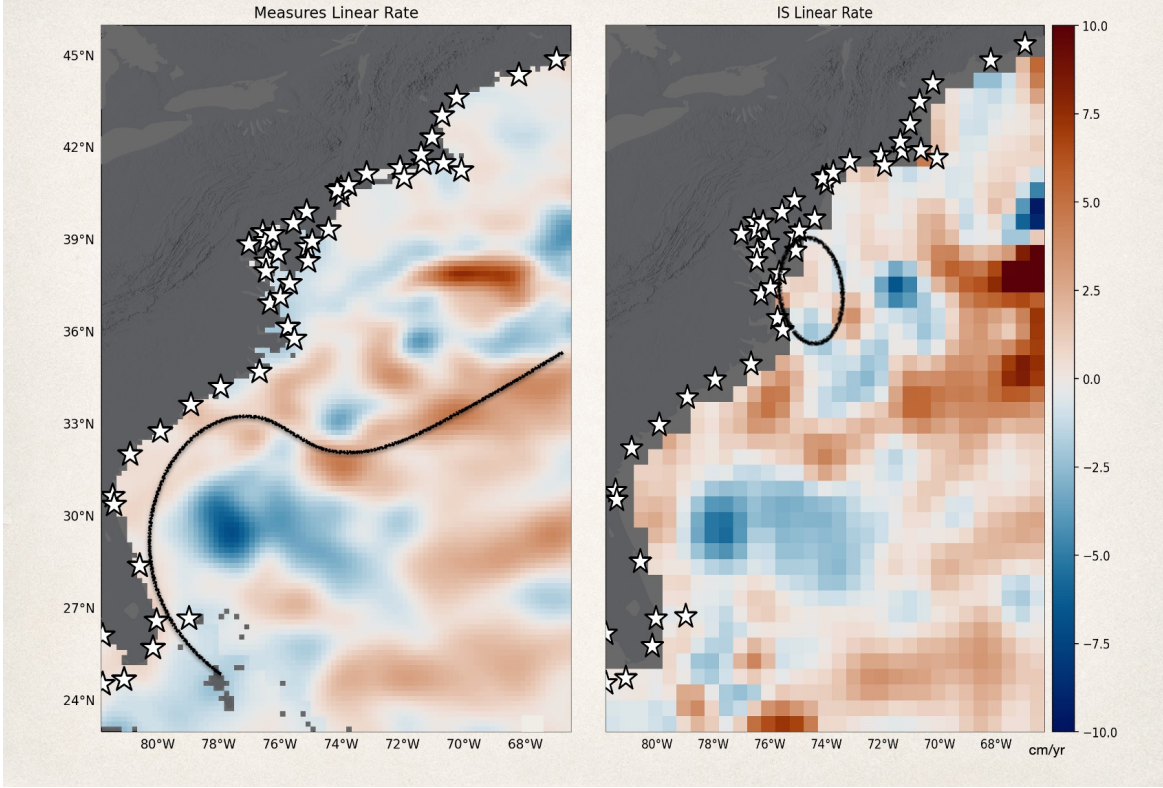




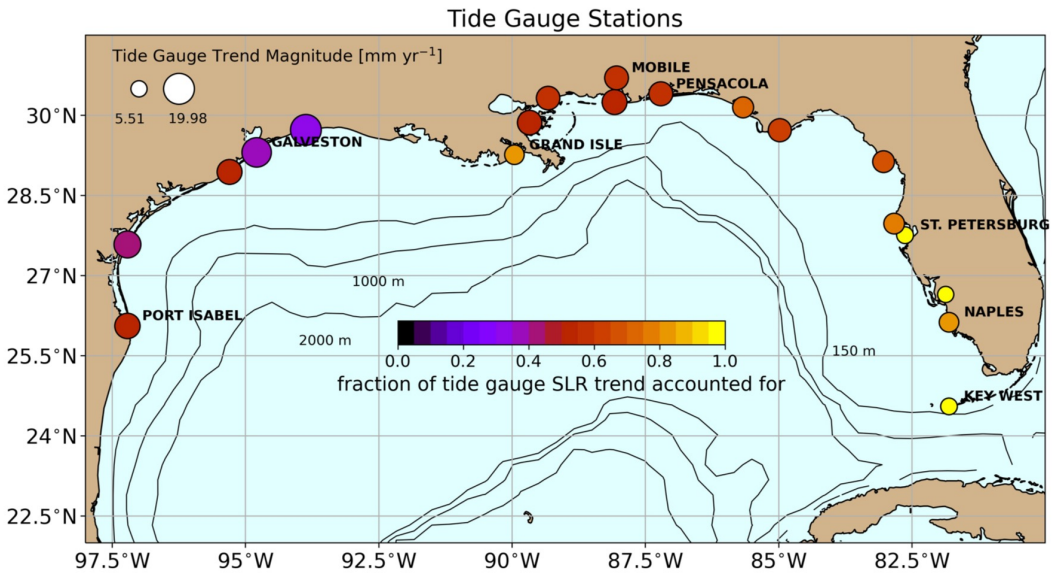
- Large parts of the global pattern of sea level rise since 1993 are explained by changes in the wind-driven ocean circulation and their influence on sea surface height via ocean heat transport. These patterns are largely thermosteric in origin – they will fundamentally change in the future as the ice sheets (and their sea level fingerprints) start to dominate regional sea level change.



- ICESat-2 shows consistent sea level estimates with satellite radar altimeters in terms of trends and variability. ICESat-2 is filling data gaps in the radar altimetry record especially close to the coast where altimeter's data is of lesser quality



- Decadal trends in gulf of Mexico coastal sea level can largely be explained by import of mass to the Gulf of Mexico (due to land ice melt & terrestrial water storage loss) and subsurface warming driven mass redistribution onto the continental shelf



Science II: Large Scale Ocean Circulation Variability and Change

Session chairs: Weiqing Han, Thierry Penduff, LuAnne Thompson and Nathalie Zilberman

(Wed, Nov 02 2022, 14:00 - 15:45)

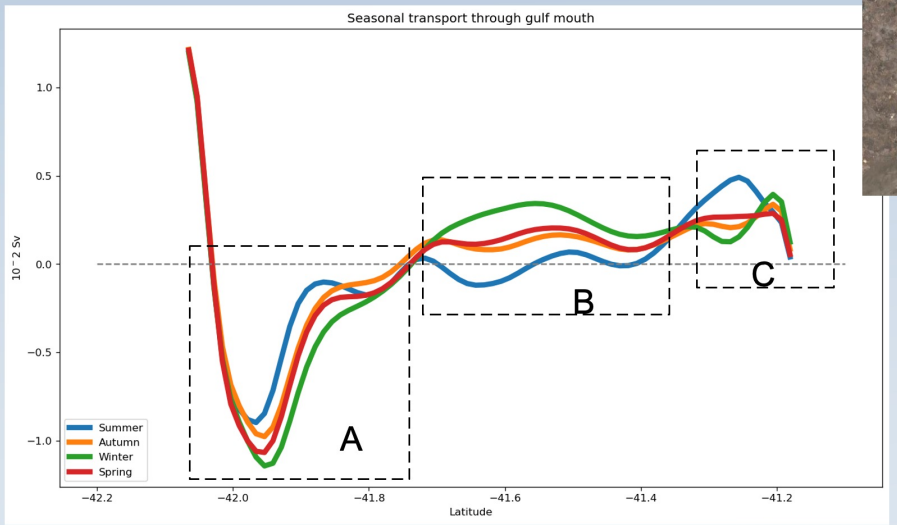
This session presented various uses of remote data combined with *in situ* observations and ocean models to improve our understanding of large-scale ocean circulation, associated heat and salinity transports, and links to changes in ocean-atmosphere interactions. 6 research projects were presented showing some interesting results summarized below.

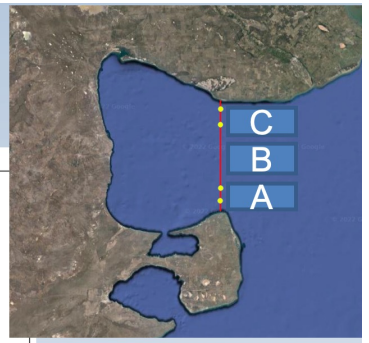
TWO MODELING STUDIES (1/2):

Martin Saraceno et al: Heat and salt fluxes in the San Matias Gulf, Argentina

- Objective: to improve estimates of the heat and salt exchanges (having strong impact on local fisheries) between the San Matias Gulf off Argentina and the ocean interior using a high-resolution (1.3km) setup of the CROCO model.
- Model comparisons with independent sea surface temperature and sea surface salinity observations in the study region show consistent results.
- Future work will consist of (1) Calibrating the model using in-situ and remote data (coastal satellite altimetry and moored observations) , (2) study transport and associated SST and SSS variations at interannual time scales, and (3) add a biogeochemical model to monitor primary biological tracers inside the gulf.

San Matías Gulf – Zonal Volume Transport





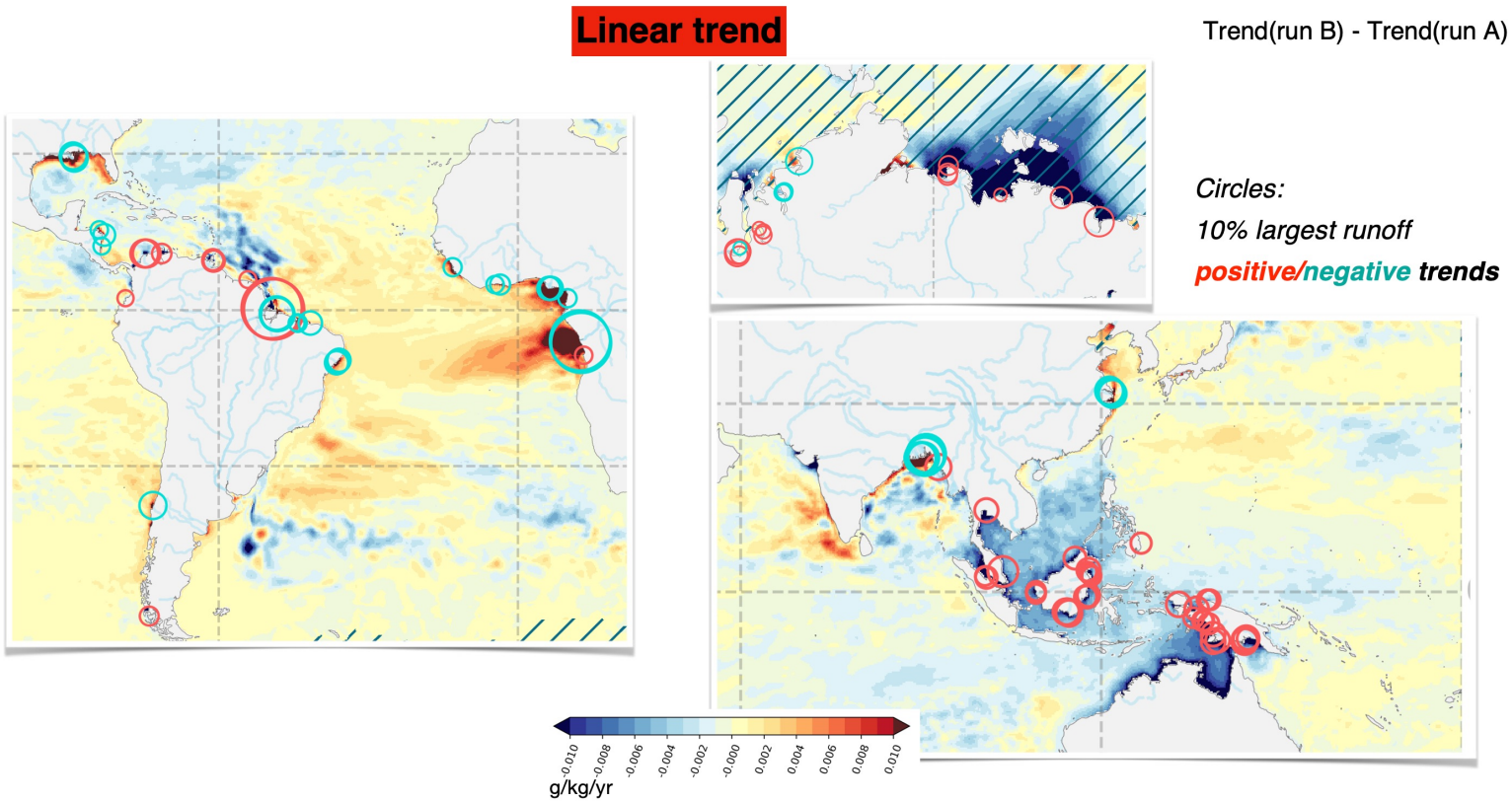
- The volume transport in the mouth shows that water enters the gulf through a narrow south section as part of the permanent anticyclone gyre seen before in the circulation figures (A). Maximum values in winter.
- In the middle of the mouth section, water mainly exits the gulf, with a few exceptions in summer (B).
- Gulf waters exits in the northern part towards the adjacent platform all year round (C). Maximum values in summer.

TWO MODELING STUDIES (2/2):

Thierry Penduff et al: Toward a probabilistic assessment of the global ocean response to fully-varying river runoffs.

- This modelling study investigates the various impacts of fully-varying freshwater discharges from rivers and the Greenland ice sheet in the global ocean using NEMO sensitivity experiements. This talk presented the sea surface salinity response to these fluctuating runoffs at interannual to multi-decadal time scales.
- Ongoing activities aim to extend this methodology and assess the impact of fully-varying runoffs on sea surface height, sea surface temperature, water mass characteristics, volume transports, Atlantic Meridional Overturning circulation, etc. Ensemble simulations are now adopted to filter out the imprints of chaotic intrinsic variability on these fields.

Model SSS: impact of fully-varying runoffs (1980-2018)



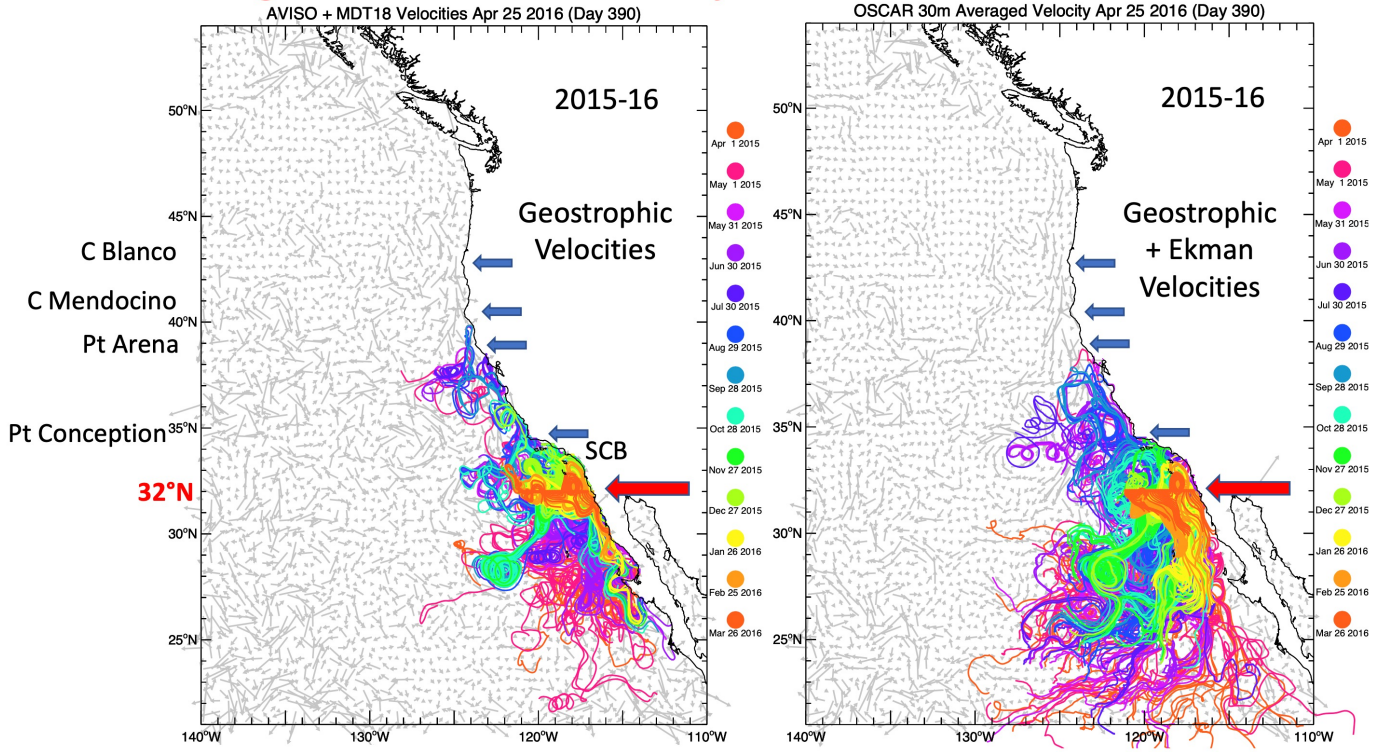
TWO LAGRANGIAN ANALYSES (1/2):

Ted Strub et al: Altimetric Studies of the Oceanic Pathways in the Northeast Pacific Ocean

- Use of the Parcels software to analyze lagrangian trajectories in the California Current System based on satellite-derived geostrophic velocities with and without Ekman velocity estimates.
- Large capes (such as Point Arenas, Mendocino cape and Blanco cape between 39-43°N) on the west coast act as a seasonal barrier to poleward zooplankton migration (that influences the salmon populations).
- The interannual fluctuations of this migration are still poorly understood although results indicate an increase in the past 10 years.

Start April 1, 2015 (Strong El Niño). Release 40 parcels along 32°N every 30 days.

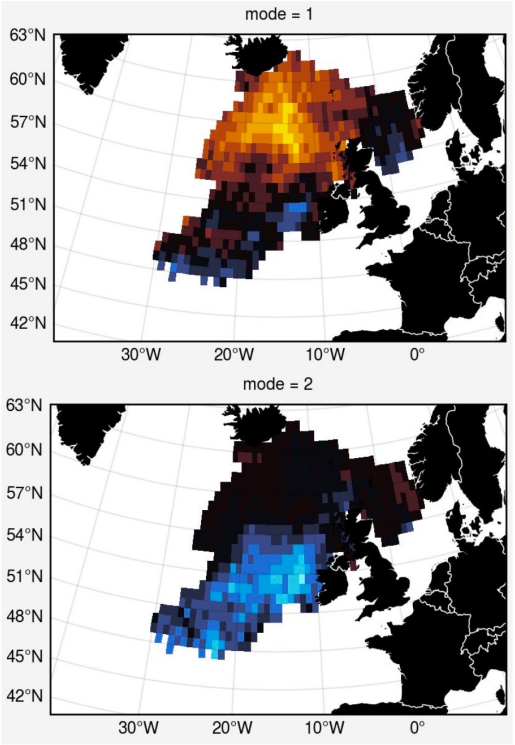
Parcels released from within the Southern California Bight have a difficult time reaching north of 39°-40° during 2015-16 and most other years.

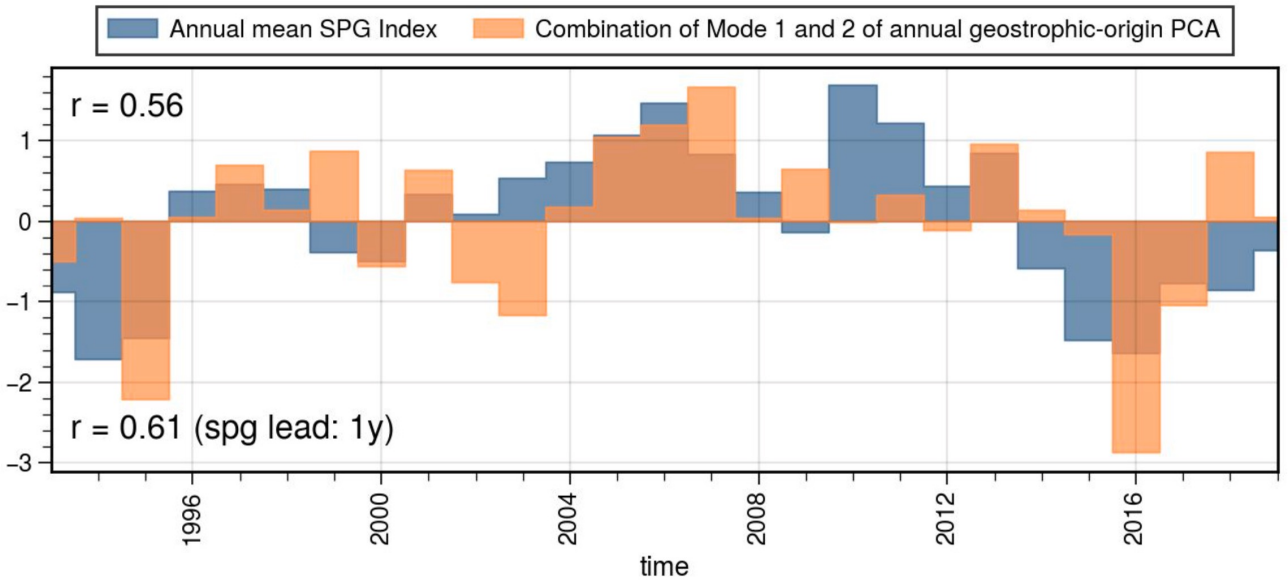


TWO LAGRANGIAN ANALYSES (2/2):

Ezra Eisbrenner et al: Lagrangian properties of on-shelf satellite-geostrophy between the North Atlantic and the North Sea

- Lagrangian analysis of the geostrophic transport between the North Atlantic and the North Sea using satellite-derived geostrophic velocity fields.
- A new index characterizing oceanic pathways from the Subpolar Gyre and the northern European shelf exhibits two preferred source regions, north and south of the Rockall Plateau.
- The fluctuations of this index shows significant relationship with the strength of the Subpolar Gyre and will be further studied in future work.





1-year-origin PC 1+2 vs. SPG strength index

A STUDY BASED ON REMOTE AND IN SITU OBSERVATIONS:

Bo Qiu et al: Surface ocean eddy kinetic energy trend from 3-decade satellite altimetry missions: observations and causes

- Global study of eddy kinetic energy shows overall increasing trends in most of the interior oceans over the last 3 decades that have spatial patterns different from regional sea level.
- In the subtropical eastern Pacific Ocean, the EKE increase is associated with an increase in the angle between surface and subsurface currents, itself related to (1) the upper-ocean stratification sensitive to ocean warming, (2) Ekman pumping linked to the PDO, and (3) near surface current speed.
- Ongoing work concerns other regions of the ocean interiors where EKE increase has been observed.

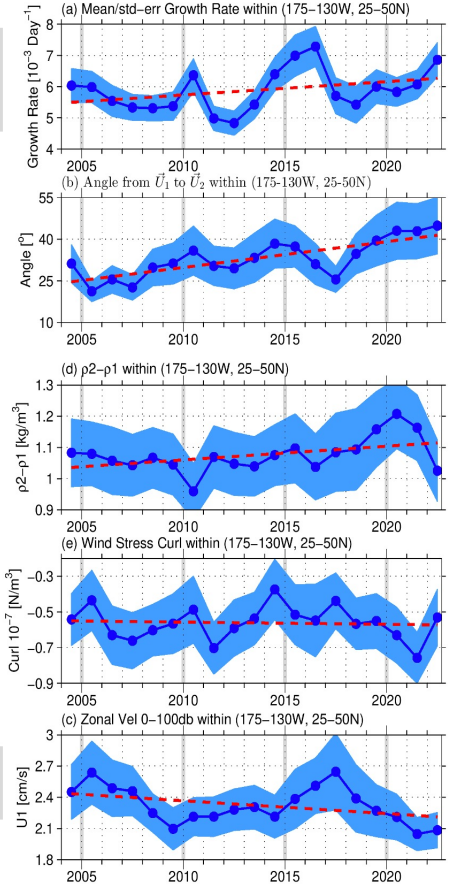
growth rate averaged in NE Pacific

angle θ between U_1 & U_2

stratification $\rho_2 - \rho_1$

wind stress curl

magnitude of U_1



- Sensitivity study reveals the increased instability is largely due to the increase in angle θ between surface & subsurface flow vectors in the past 2 decades

Question: What caused the angle in the upper ocean velocity field to increase during the past 2 decades?

- Dynamically, θ change with depth is given by

$$\frac{\partial \theta}{\partial z} = \frac{gw}{fU^2}\frac{\partial \rho}{\partial z}$$

where w is vertical velocity (~ $w_{Ek} < 0$ in NE Pacific), & U is flow speed

- In past 2 decades, amplitudes of w & $\partial\rho/\partial z$ increased while that of U decreased

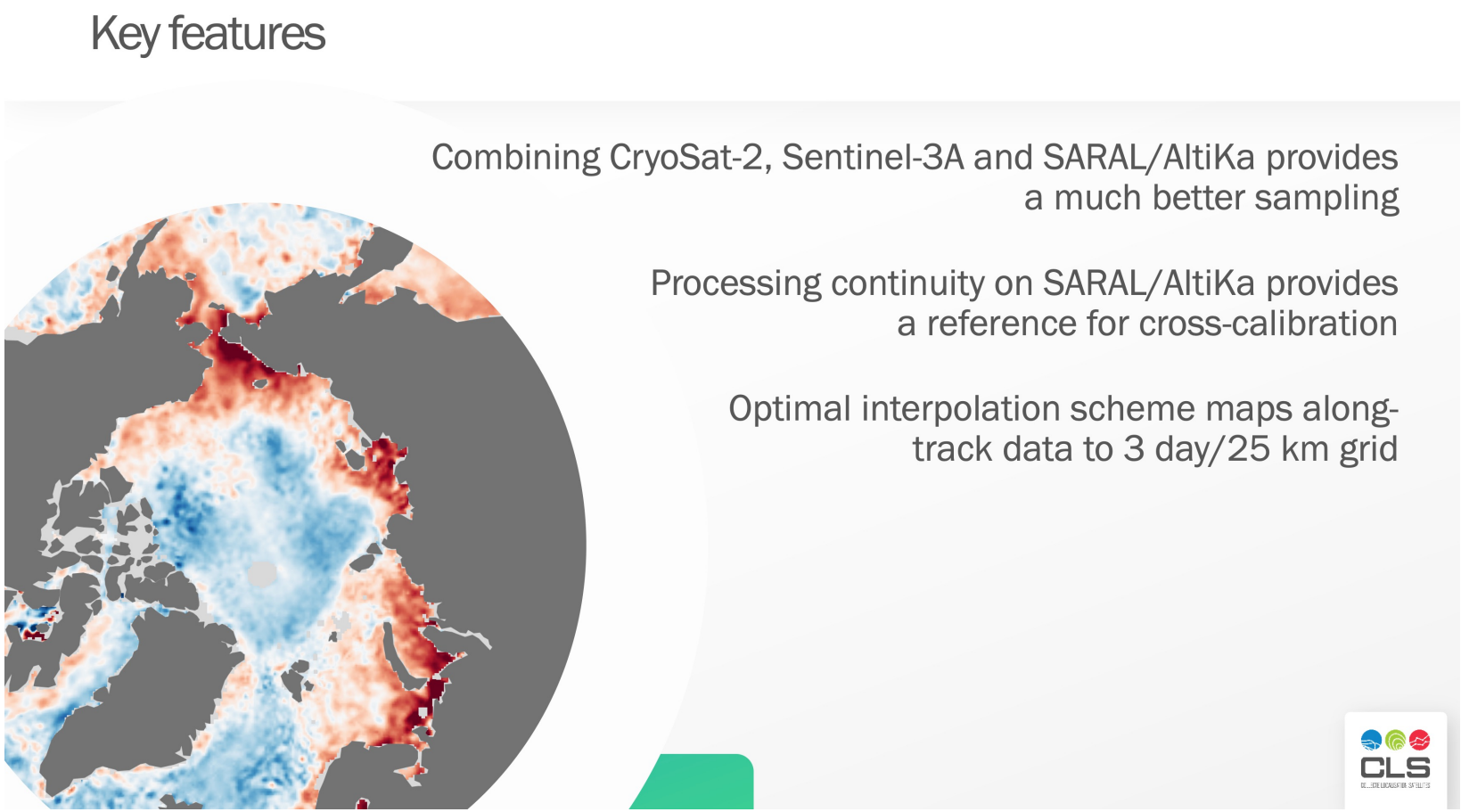
→ all of which contributed to the increase in $\partial\theta/\partial z$, hence the regional instability

- Increase in $\partial\rho/\partial z$ is related to the upper ocean warming

A NEW OBSERVED SEA LEVEL PRODUCT:

Pierre Prandi et al: CMEMS Next-gen polar sea level products

- CryoSat-2, Sentinel-3A and SARAL/AltiKa altimeter data were combined to generate maps of sea level time series (25-km gridded, 3-day averaged) in the Arctic and Southern Ocean in continuity with the lower-latitude ice-free ocean
- These products have higher spatial and temporal resolution than previously available, and show much better agreement with local in situ data including bottom recorder and tide gauges.
- Two versions were generated: poleward of 50°N and of 50°S. Feedback from the scientific community is welcome.



Science III: Mesoscale and sub-mesoscale oceanography

Session chairs: Lee-Lueng Fu, Rosemary Morrow, Heather Roman-Stork, Clément Ubelmann, Jinbo Wang

(Wed, Nov 02 2022, 16:15 - 18:00)

Science III: Mesoscale and sub-mesoscale oceanography

7 talks & 22 posters

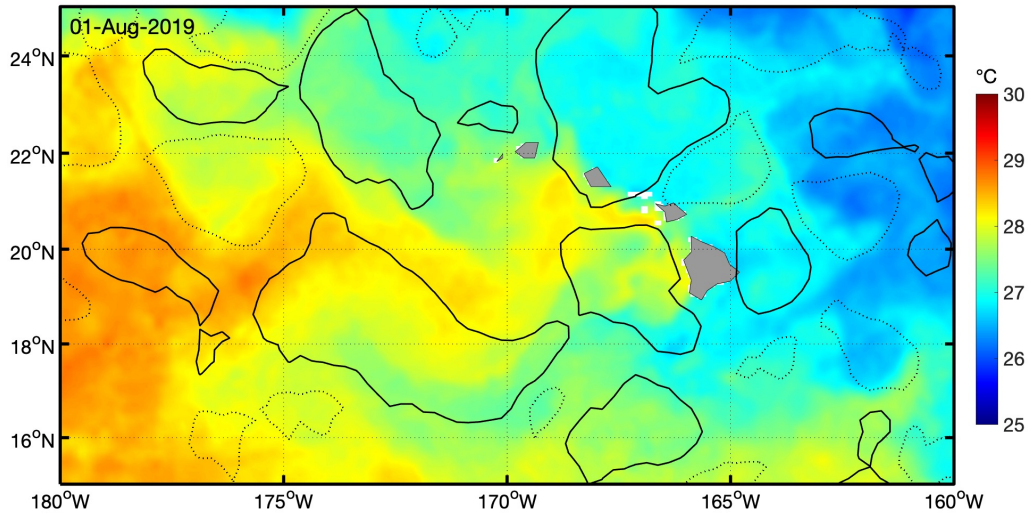
Session chairs: Lee-Lueng Fu, Rosemary Morrow, Heather Roman-Stork, Clément Ubelmann, Jinbo Wang

(Wed, Nov 02 2022, 16:15 - 18:00)

Highlight 1: New global mesoscale eddy tracking products

- **Antoine Delepouille, CLS.** New version of AVISO+ eddy tracking trajectory atlas for mesoscale applications : META3.2 using ADT, based on Mason et al methodology. Developing META4.0 with improved splitting & merging

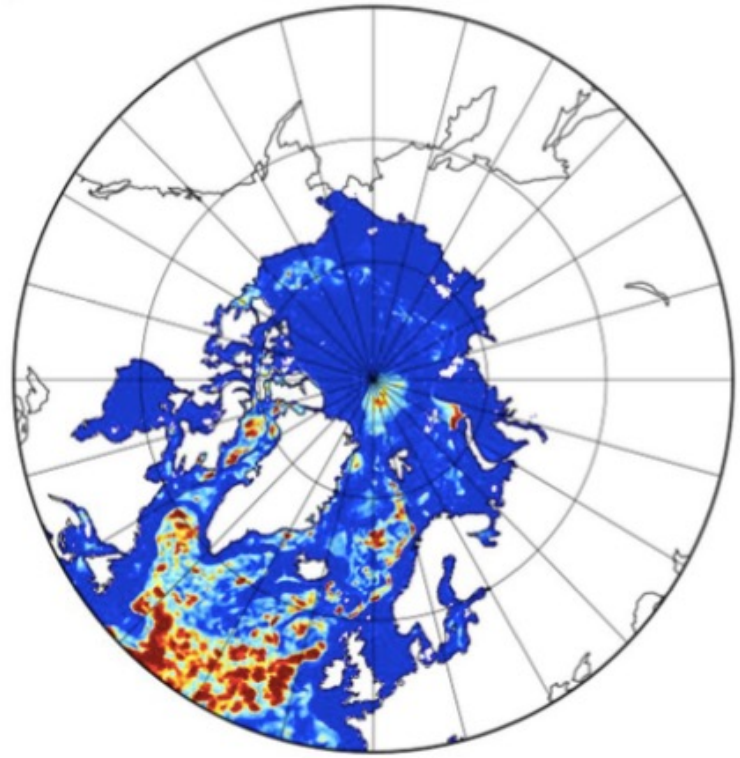
- **Heather Roman-Stork, NOAA/GST.** NOAA multi-parameter eddy product, incorporates collocated SST, SSS, Chl-A. Develops Multiparameter Eddy Significance Index (MESI), first-look impact on upper ocean & BGC dynamics



Highlight 2: Multi-satellite & in-situ analyses

- **Clement le Goff, eoDyn.** Blending ship AIS surface current data & altimetry, in the Agulhas & Gulf of Mexico. Separating rotational and divergent AIS currents, improves current estimates in shipping lanes

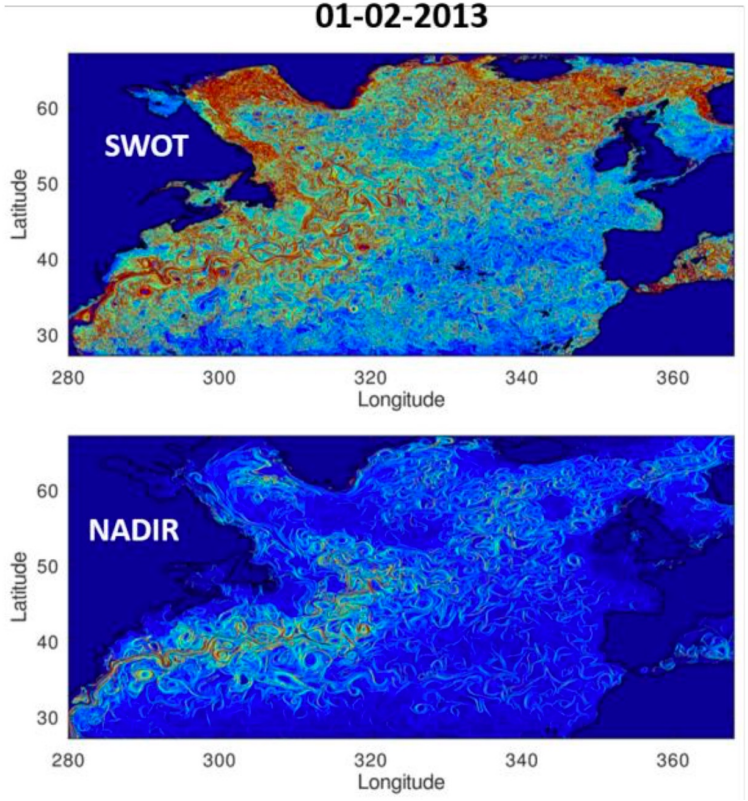
- **Antionio Bonaduce, NERSC**. High-resolution datasets for sea-level budget in the Nordic Seas & Arctic. Study uses NEMO/ERA5 models, altimetry, Argo, & 3D-VAR. Isolate the role of mesoscale eddies in the heat transport into the Arctic



Highlight 3: In preparation for SWOT

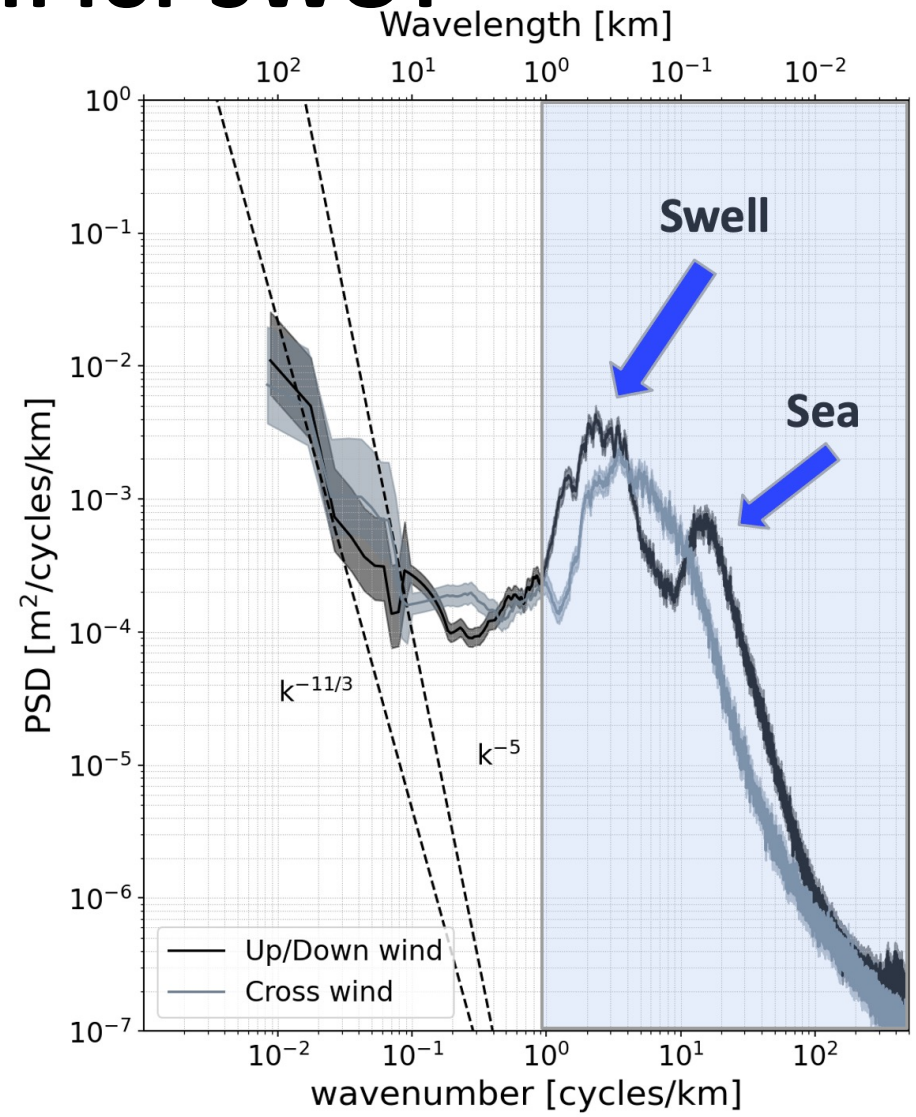
- **Florian Le Guillou, IGE/ESA.** Joint estimation of mesoscale balanced motions and internal tides in 2D maps using simple dynamic models (QG & linear shallow water). Successful separation of BM/ITs both coherent and incoherent – no noise included. Test case in California Current with realistic nadir & SWOT sampling.

- **Robin Rolland, LOCEAN.** Analyzing lagrangian structures at 10-100 km from a model data. Reconstruction using nadir sampling and future SWOT sampling. SWOT scales have 2-3x more stirring and higher strain rate, and greater retention of particles within eddies. Strong impact of small-scale dynamics in winter and at higher latitudes, and on biology.



Highlight 3: In preparation for SWOT

- **Sarah Gille, Scripps.** Observations of SSH spectral energy cascade from mesoscale (red) to waves (blue). SWOT Airborne MASS Lidar campaign able to resolve SSH down to 10s metres: surface wave band can be very energetic. SWOT onboard filtering at 500m wavelength should remove most surface wave energy in California Current. Potential for aliasing on other areas will depend on dominant wavelength, height and direction



OSTST Discussion topics not addressed in our Mesoscale session

Science IV: Altimetry for Cryosphere and Hydrology

Session chairs: Charon Birkett, Jérôme Bouffard, Jean-Francois Crétaux, Sinead Farrell, Karina Nielsen

(Thu, Nov 03 2022, 16:15 - 18:00)

Science IV: Altimetry for Cryosphere and Hydrology

Summary

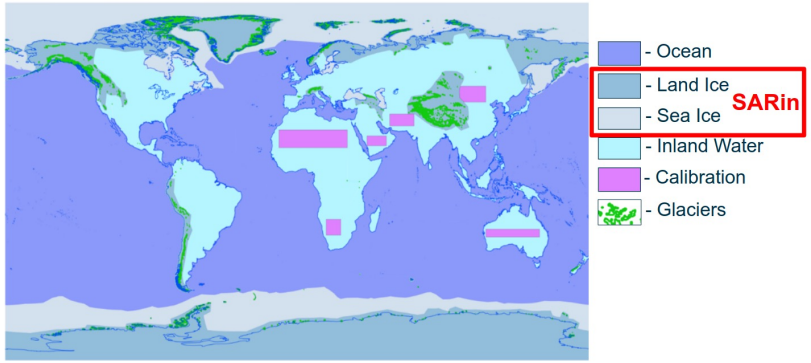
Karina Nielsen and Jérôme Bouffard

Highlights from the sessions

- Successful session and fruitful discussion with 7 presentations (2 cancellation) and 26 posters.
- Always complicate to accommodate time for presentations in combining both Hydrology (i.e. river and lake) and Cryosphere (i.e. land ice, sea ice, polar ocean (?) ...) in a single session
- Very nice poster sessions providing an overview of several innovative studies on Lake ice thickness, applications of FFSAR for iceberg detection and inland water, swath processing over inland water, innovative retracking
- .... and also include smmary of R&D activities of several ESA and/or Copernicus projects such as St3TART, CryoTempo, S3 MPC, SIN'XS, STREAMRIDE. Most of these project concern the issue of uncertainty, Cal/Val and FRM which key to address Climate.
- ... All relevant for current missions (Icesat2, CryoSat.. S-3/S6 ...) and also

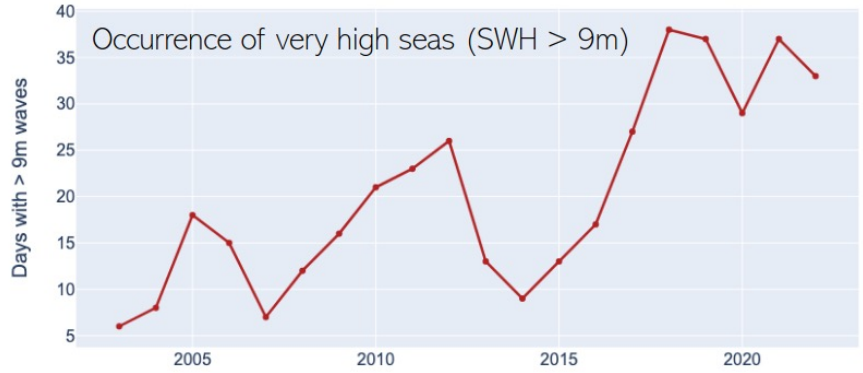
Highligths from presentations

- **Paolo Cipollini presented an overview and status of the Crystal mission**
  - Dual band Ku/Ka band
  - Strong Heritage from CS2 with more SARIN and open burst over SI, increased precision 3 times (many echoes) + focused processing



- **Elodie Da Silva provided an overview of the St3TART project**
  - Objective to build an FRM compliant in-situ network for validation of S3 altimetry over Inland water, sea ice and land ice, and provide fully traceable uncertainty estimates
  - Drone as a new tools for cal/va
  - Need to focus on robust approach heritate from metrology

- **Reint Fischer investigated the correlation between decline in sea ice and SWH in the Bering Strait**
  - Detect cyclones using satellite altimetry (increased coverage thanks to S3)
  - More stormy weather in recent years



Highligths from presentations

- **Sara Fleury presented different strategies to calculate the SIT**
  - Important to account for snow on the sea ice (and density …)
  - Currently monthly maps can be generated from C2 and AltiKa
  - Can be done right-away with CRISTAL due to dual altimeter Ku/Ka

- **Ferran Gibert presented the use of Sentinel-6 FFSAR data to estimate lake level and an inovative approach for lake extent**
  - For lake level a nadir track is need, and for extent an off-nadir track is needed.
  - The method was tested for small reservoirs in Spain.
  - When compared to gauge data std of 2-4 cm whas achieved

- **Karina Nielsen estimated the spatial and temporal lake level signals on lake Tanganyika (Africa) using ICESat-2**
  - The spatial signal represent may reprents residue geoid signals and can be used to correct e.g. Cryosat-2 to improve the water level time series

- **Stine Kildegaard Rose presented a (almost) 30 years time series of the Arctic Ocean from ERS1/2, Envisat, and CryoSat-2**
  - ERS1 (noisy butO still provides valuable information
  - EOF analysis of the winter month was performed
  - Detailed study of the Russian Shelf

Seed questions and points of discussion

- OK Sentinel is operational … well… but need resources for developing / fine tuning processing algorithms and next generation product during all the operational life time of the mission. These even more true over challenging surfaces such as sea ice, land ice , river an lake
- Lack of in situ data / FRM over the Cryosphere (in particular Snow Depth and Antarctic) and inland …. Need infrastructures/maintenance for long term Cal/Val and monitoring (key for climate) during all the operational life time of the mission.
- How to attract new/more downstream users and get feedback from them ? How to make data more easy to use to non altimetry experts ?
- What about synergy of SWOT with other nadir missions ? What can we learn in terms of processing algo and cross Cal/Val ? How can it be used in preparation to S3-NG for hydro and cryosphere ?
- Mask frozen for CRISTAL over inland ? What are the needs ? What about SARIN over sea ice ? Also for hydrology …. Do we need more SARIN from CryoSat ?
- Develop assimilation in sea ice / hydrological / hydrodynamic models and climate models for reanalyses, forecast and climate projection.
- Geodetic or long orbit cycle " a la cryosat/AltiKa" important for hydro ?
- FF perspective for hydro and cryosphere ? Selected area to process "on demand" FF ? What

PLEASE GO TO THE ONLINE FORUM TO COMPLEMENT … REACT… DEBATE….