Update on CLIVAR GSOP

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With contributions from all GSOP panel members and
A. Bracco from CLIVAR SSG

CLIVAR New Scientific priorities

- **Mechanisms of climate variability and change** that require further investigation with the ultimate goal of better constraining the fluxes of energy and carbon in the climate system
- **Ocean processes** that modulate climate variability and change for which open questions remain
- **Climate predictability challenges** that exist over a broad range of space and time scales

WCRP World Climate Research Programme

CLIVAR

International cooperation is critical to grow the infrastructure that underpins all CLIVAR science:

- Climate and Ocean Process and **Sustained Observations**
- Global, Regionally Enhanced and Process Models
- **Ocean Data, Synthesis and Assessment**
- Capacity Development and Knowledge Exchange

WCRP World Climate Research Programme

CLIVAR

Global Synthesis and Observations Panel:

Terms of Reference

GSOP Terms of reference

1. Identify, develop and promote methods for climate reconstructions

2. Define requirements and promote the use of observational datasets for climate reconstructions

3. Develop assessment metrics for climate reconstructions

4. Provide advises and recommendations to CLIVAR about data and liaise with the other panels

GSOP Membership

Expertise include:

- DA methods for reanalyses
- Evaluation of Climate Reconstructions
- In-situ observation technology and processing
- Ocean, sea-ice and BGC modeling
- Seasonal to multi-annual predictability

Latest GSOP Meeting (10th session) Took place at the Woods Hole Oceanographic Institution, 5-6 Feb 2019

GSOP Panel Members

Name	Role		Institute	Country
Steven R. Jayne	Co-Chair	2020	Woods Hole Oceanographic Institution	USA
Andrea Storto	Co-Chair	2020	NATO STO CMRE	Italy
Matt Mazloff	Member	2021	Scripps Institution of Oceanography	USA
Nathalie Zilberman	Member	2021	Scripps Institution of Oceanography	USA
Isabella Ansorg	Member	2021	University of Cape Town, South Africa	South Africa
François Counillon	Member	2021	NERSC	Norway
Lijing Cheng	Member	2021	Institute of Atmospheric Physics, Chinese Academy of Sciences (IAP-CAS)	China
Yan Xue	Member	2019	NOAA/NCEP	USA
Yosuke Fujii	Member	2019	Meteorological Research Institute	Japan
Paulo Henrique Calil	Member	2019	Universidade Federal do Rio Grande,	Brazil
Ken Ando	Ex officio		Vice-Chair / Tropical Moored Buoy Implementation Panel	Japan
Uwe Send	Ex officio		Co-chair / OceanSITES	USA

The ICPO contact for the CLIVAR Global Synthesis and Observations Panel is Jose Santos.

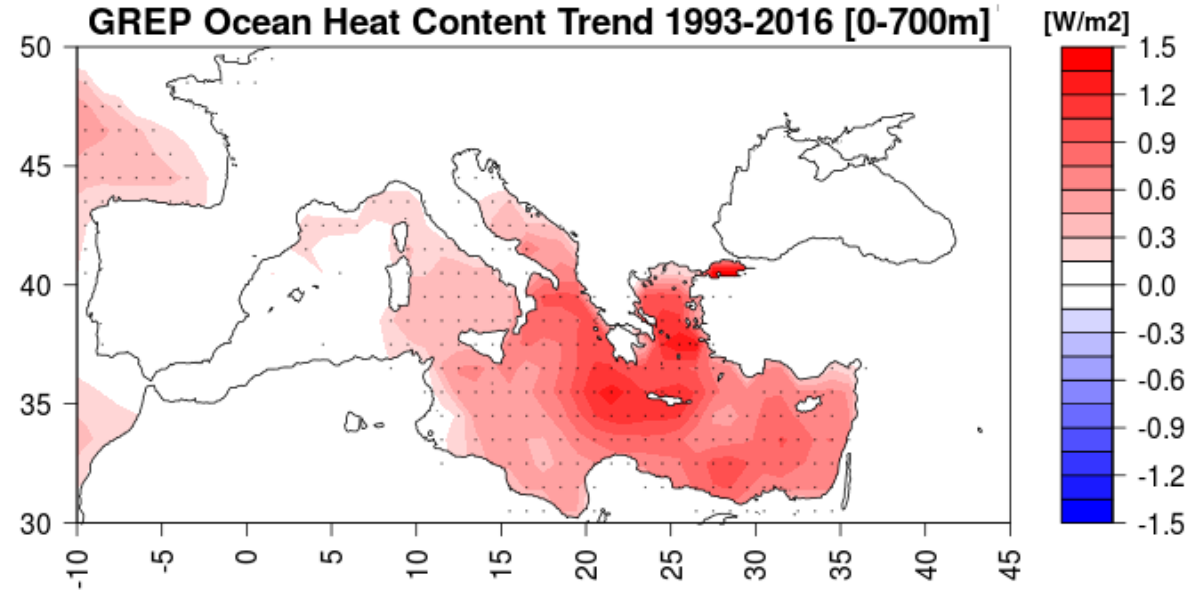
Activities endorsed by GSOP

(promoted by the Panel, fostering collaborations for the Advancement of climate reconstructions)

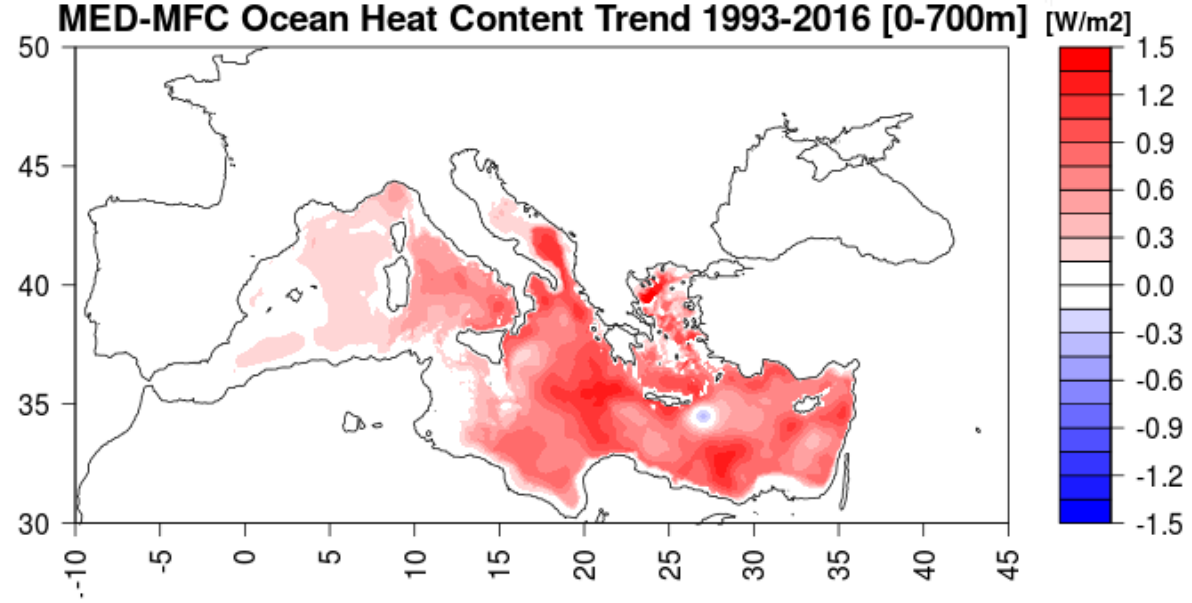
Promoting the use of multi-model ensemble reanalyses

Extending previous experiences from ORA-IP, CREATE, MyOcean/CMEMS

Comparison with regional reanalysis

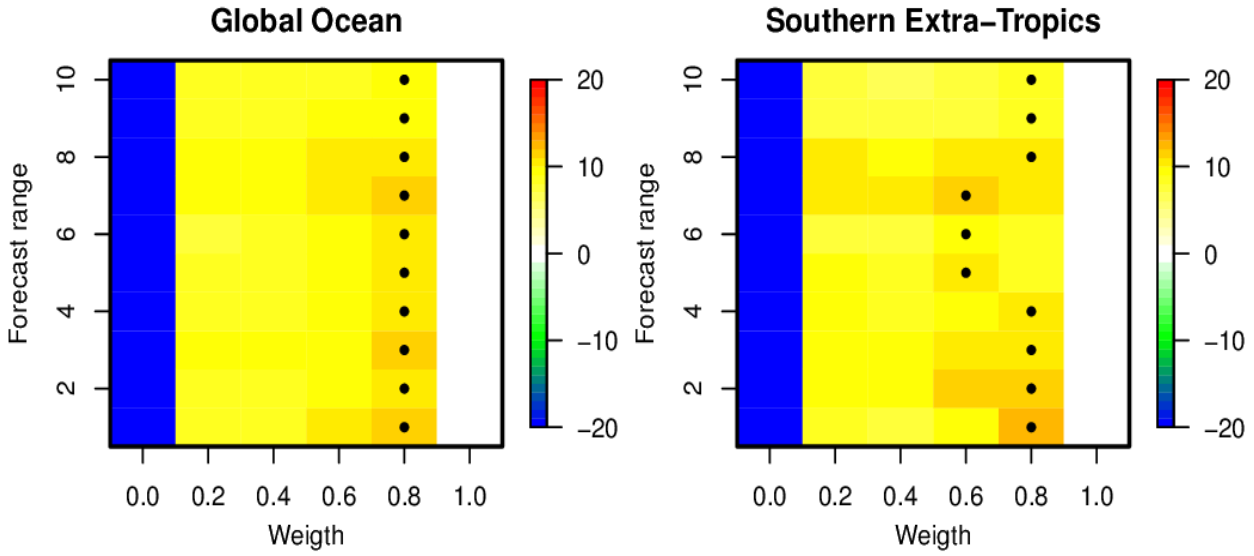


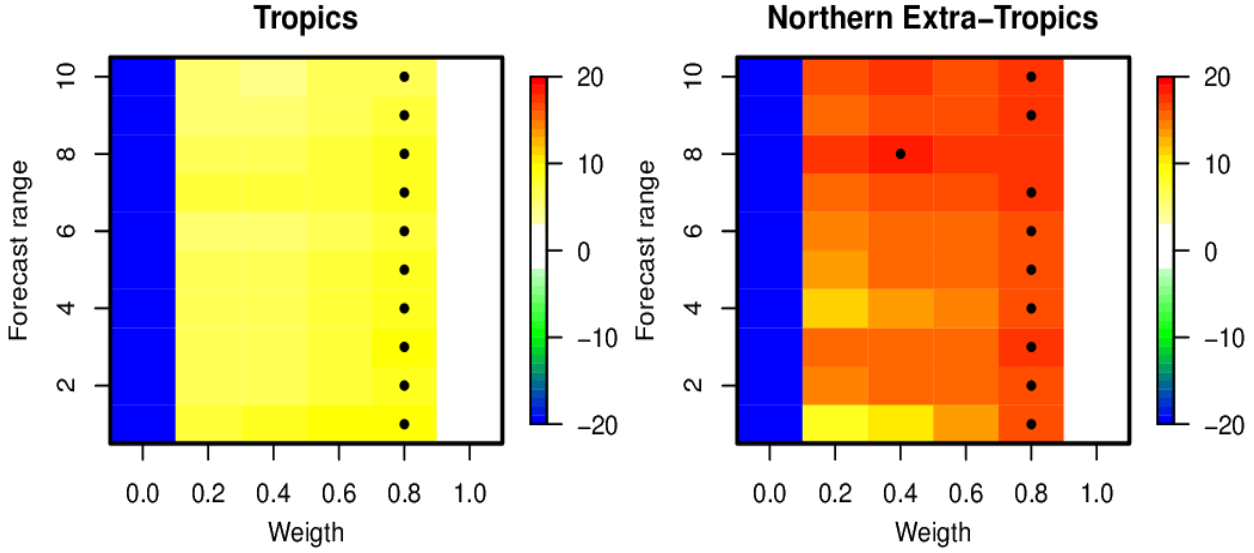
Similarly for the spatial Maps of OHC trend in the region, which highlight the potential complementarity between the two datasets



GREP ensemble is used to Determine the significance Of the trends (based on S/N ratio metrics)

Using GREP For retrospective hybrid-covariance Variational DA experiments





Background-error cov. Matrix:

$$\mathbf{B = w\ B_c + (1\text{-}w)\ B_e}$$

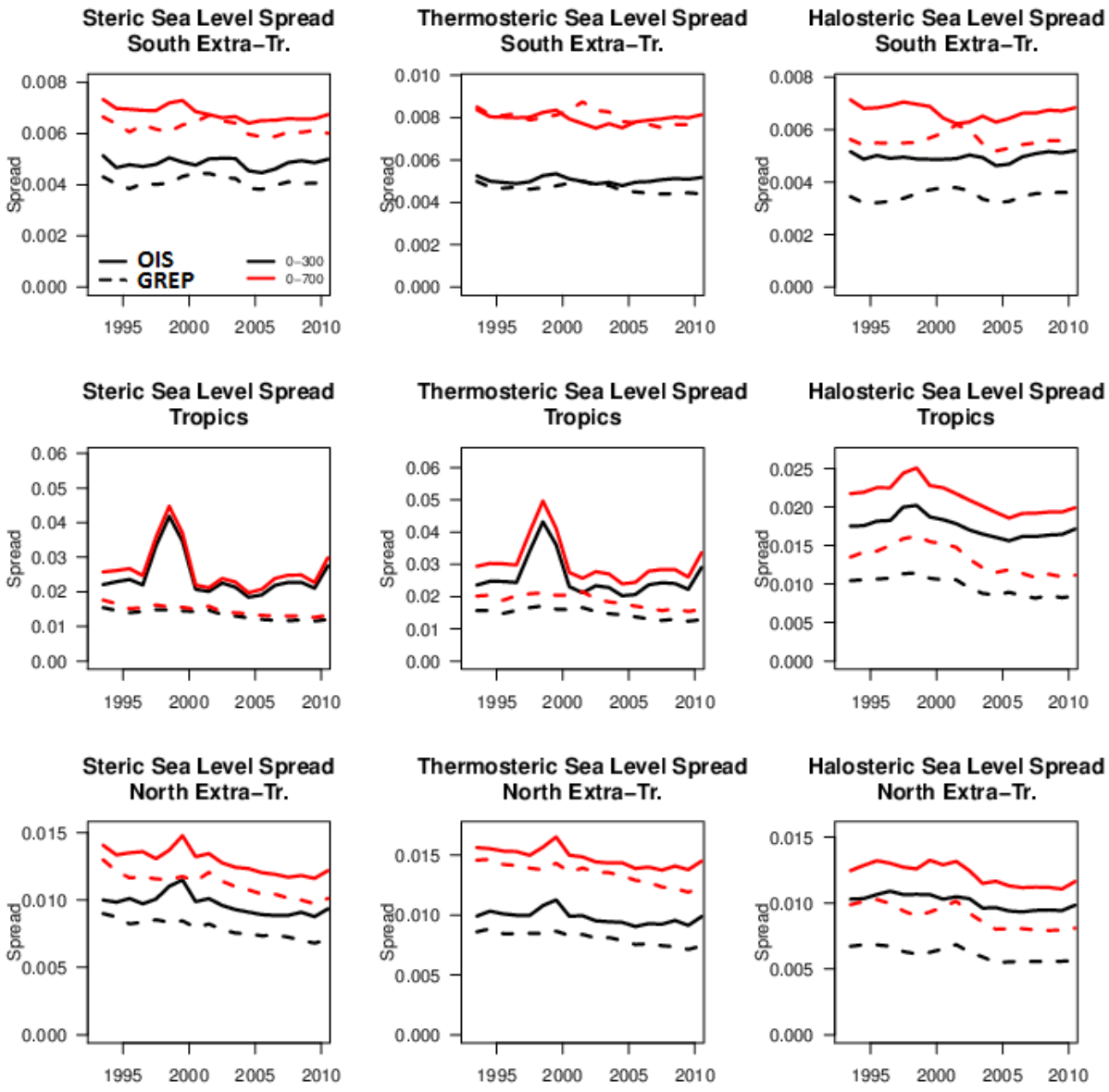
climatological

Ensemble-derived

Experiments with Low-resolution implementation of the CMCC reanalysis

Hybrid Weight:
0 → pure ensemble
1 → pure static cov. 3DVAR

Comparison with the previous vintage



★ ORA-IP: Ocean Reanalysis Intercomparison Project

Collaboration with GODAE Ocean View

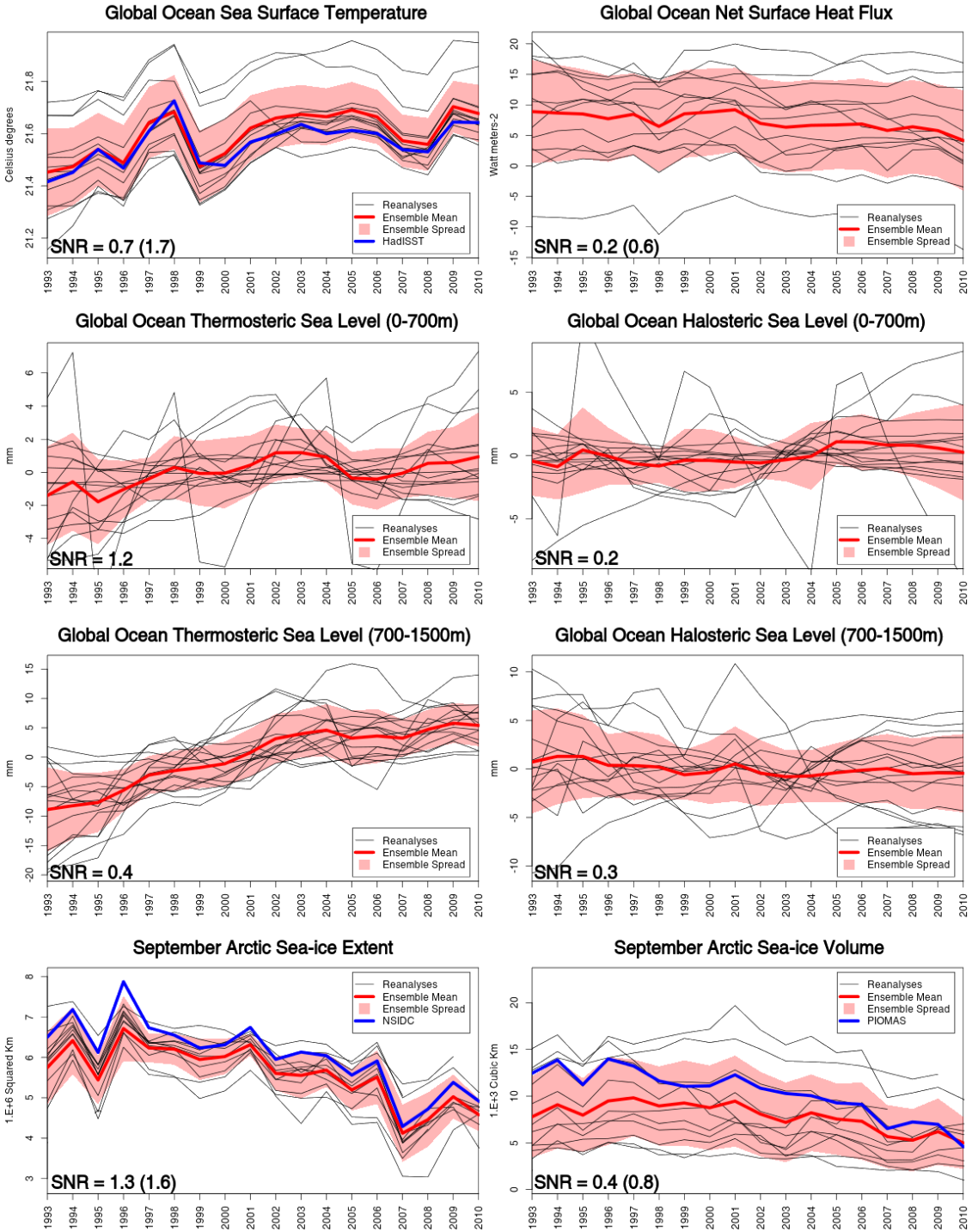
- **Objectives:**
  - To quantify signal/noise from Ensemble.
  - To gain insight into ocean variability and trends
  - To identify current system deficiencies, and to measure progress.
  - To exploit existing multi-ORA ensemble for real-time ocean monitoring
    for climate indicators
    for model validation
    for initialization of coupled models
- **Members:** 6 observation only products, 13 low resolution models, 8 high resolution models, 4 coupled DA products.
- **Summary Paper:** **Balmaseda et al. 2015, J. Oper. Oceanogr.**
- **Special Issue in Climate Dynamics (Vol. 49, Issue 3, August 2017)**
- **Data Archive** (with version control)
  - ✓ ICDC (Integrated Climate Data Center; University of Hamburg)
    http://icdc.zmaw.de/1/daten/reanalysis-ocean/oraip.html

ORA-IP

Timeseries of global ocean sea surface temperature, net surface heat flux, thermo and halo steric sea level (0-700 m and 700-1500 m), September Arctic sea-ice extent and volume from the ORA-IP inter-comparison project.

Each plot shows the ensemble mean and standard deviation and the individual ocean reanalyses. Reference datasets are shown in blue for selected parameters.

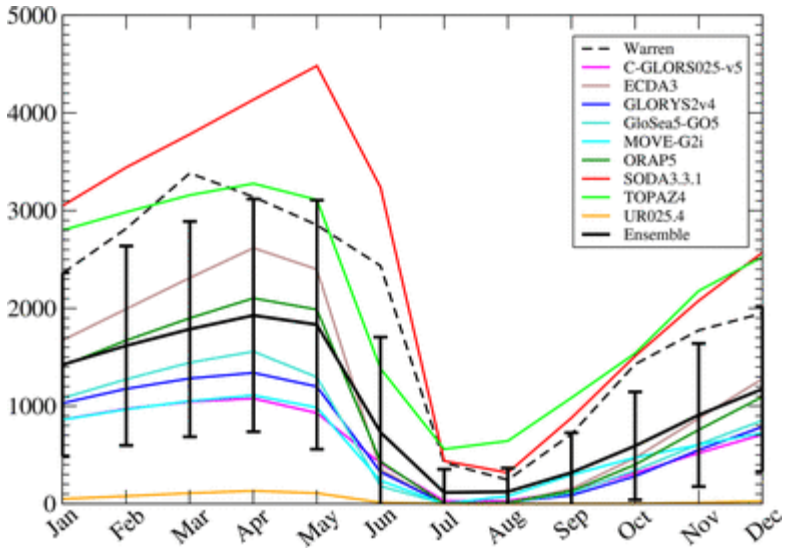
Each plot reports also the Signal-to-noise ratio (SNR), defined here for simplicity as the ratio between the temporal standard deviation of the ensemble mean divided by the temporal mean of the ensemble standard deviation. Numbers in parentheses refer to the SNR ratio computed from anomalies rather than full field data, except for thermo and halo steric sea level data that are already anomalies by construction.



Inter-comparison of ocean-sea-ice reanalyses, follow-up from the ORA-IP initiative (GSOP-GODAE):

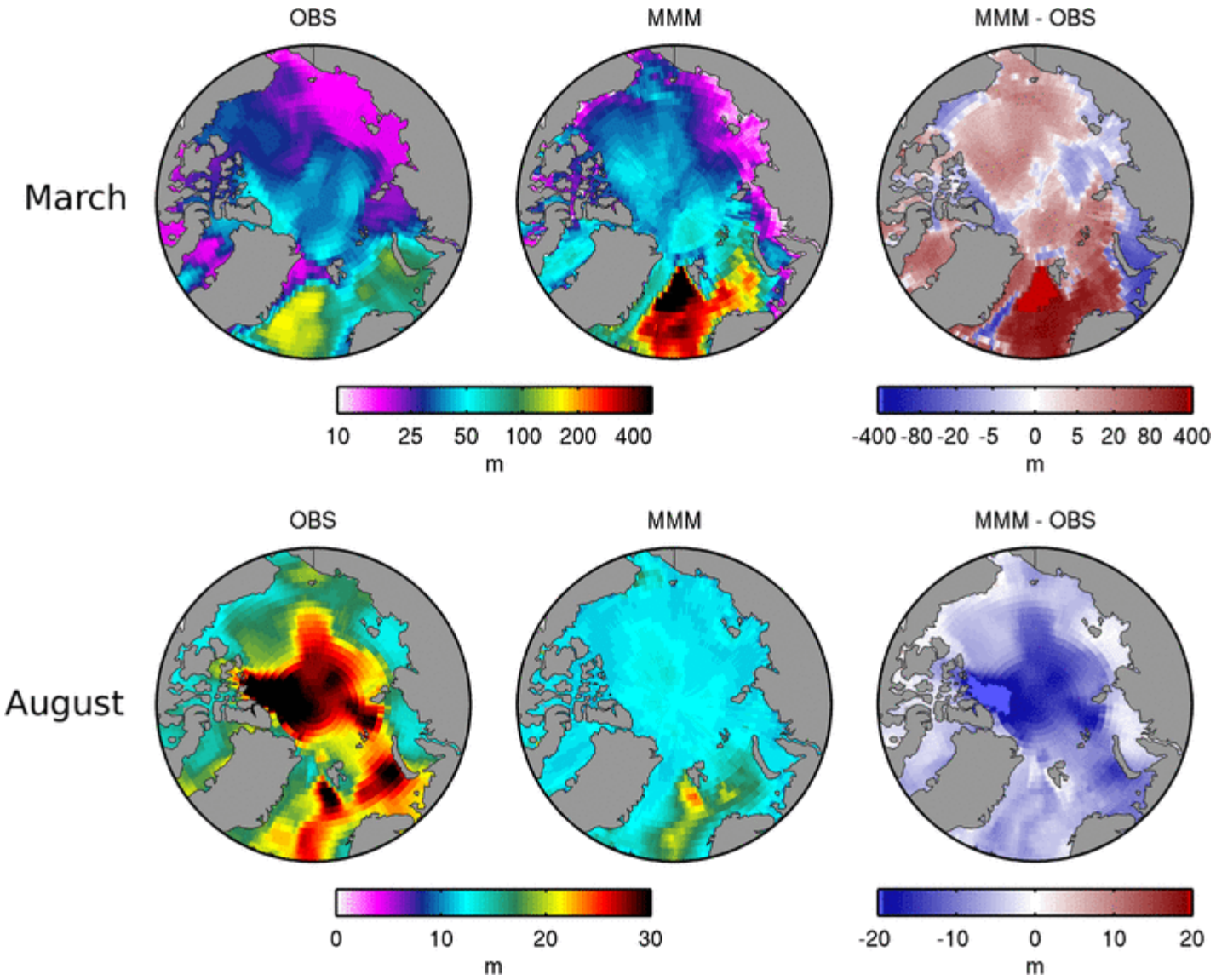
- ***Polar regions inter-comparison (PORA-IP) led by FMI***
- ***North Atlantic Ocean inter-comparison (NA ORA-IP) led by UKMO & Mercator***
- ***Real-time inter-comparison (RT ORA-IP) led by NCEP & BoM***

Selected results from PORA-IP: importance of inter-comparison to identify observational requirements



Top: Climatology of Arctic snow volume (mostly under-estimated, large uncertainty)

Right: Mixed layer depth in ice-covered areas (under-estimated in summer, over-estimated in winter)



From Uotila et al., 2019 (Clim. Dyn.)

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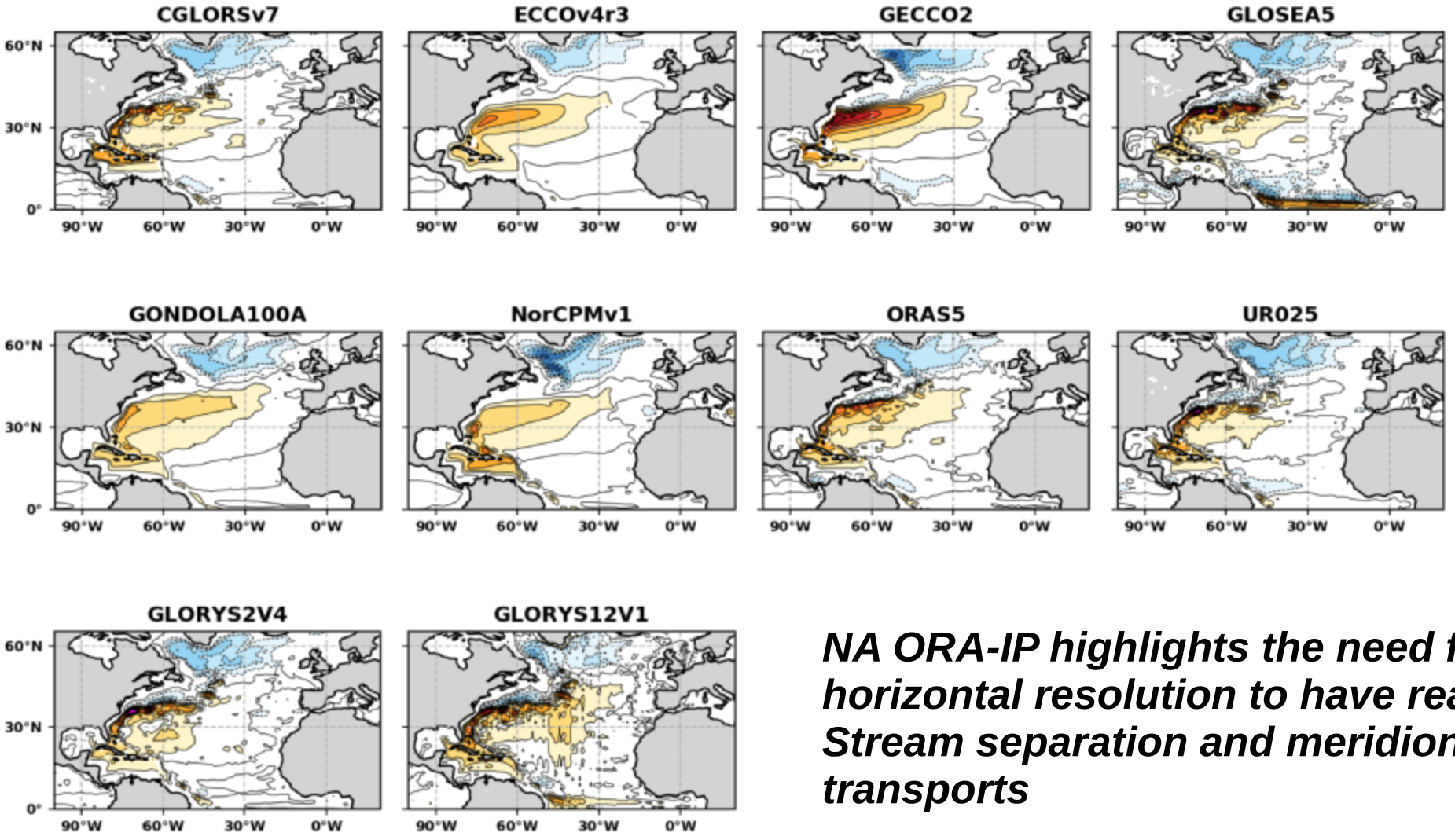
Time-mean Barotropic stream-function in the North Atlantic



NA ORA-IP highlights the need for >1/4° horizontal resolution to have realistic Gulf Stream separation and meridional heat transports

From L. Jackson et al. (in preparation for JGR-O)

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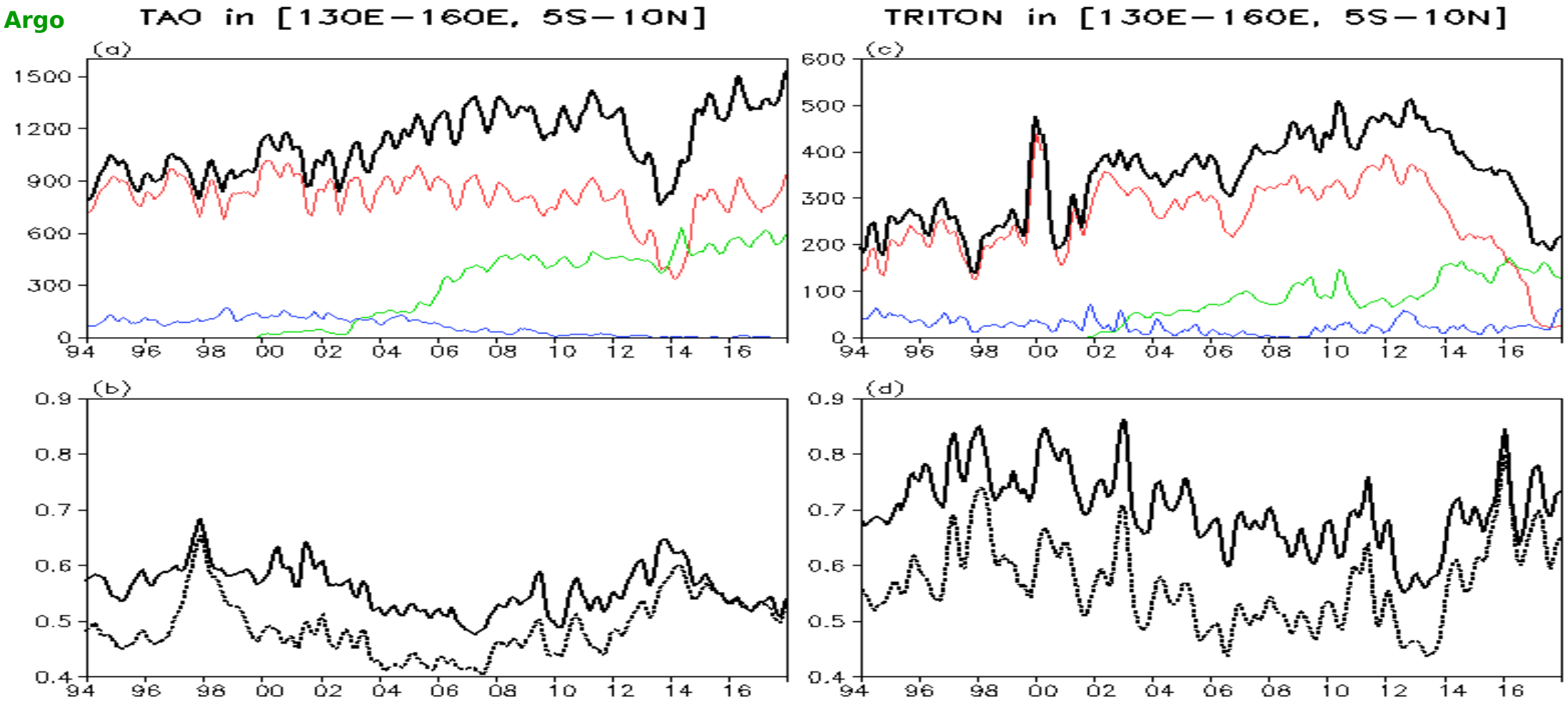
Black: All data
Red: TAO/TRITON
Blue: XBT
Green: Argo

Ensemble Spread vs. TPOS

OceanObs19 White Paper Fujii et al.



Time variations of the number of daily temperature profiles per month accumulated in the (a) TAO and (c) TRITON array region from the moorings (red line), Argo (blue line), XBT (green line) and all together (black line) from January 1994 to January 2018. Time evolution of the ensemble spread of total temperature (solid lines) and anomalous temperature (dash lines) calculated in the upper 300 m for the (b) TAO and (d) TRITON array region from January 1994 to January 2018.

RT ORA-IP would benefit from uptake and external funding to further evolve!

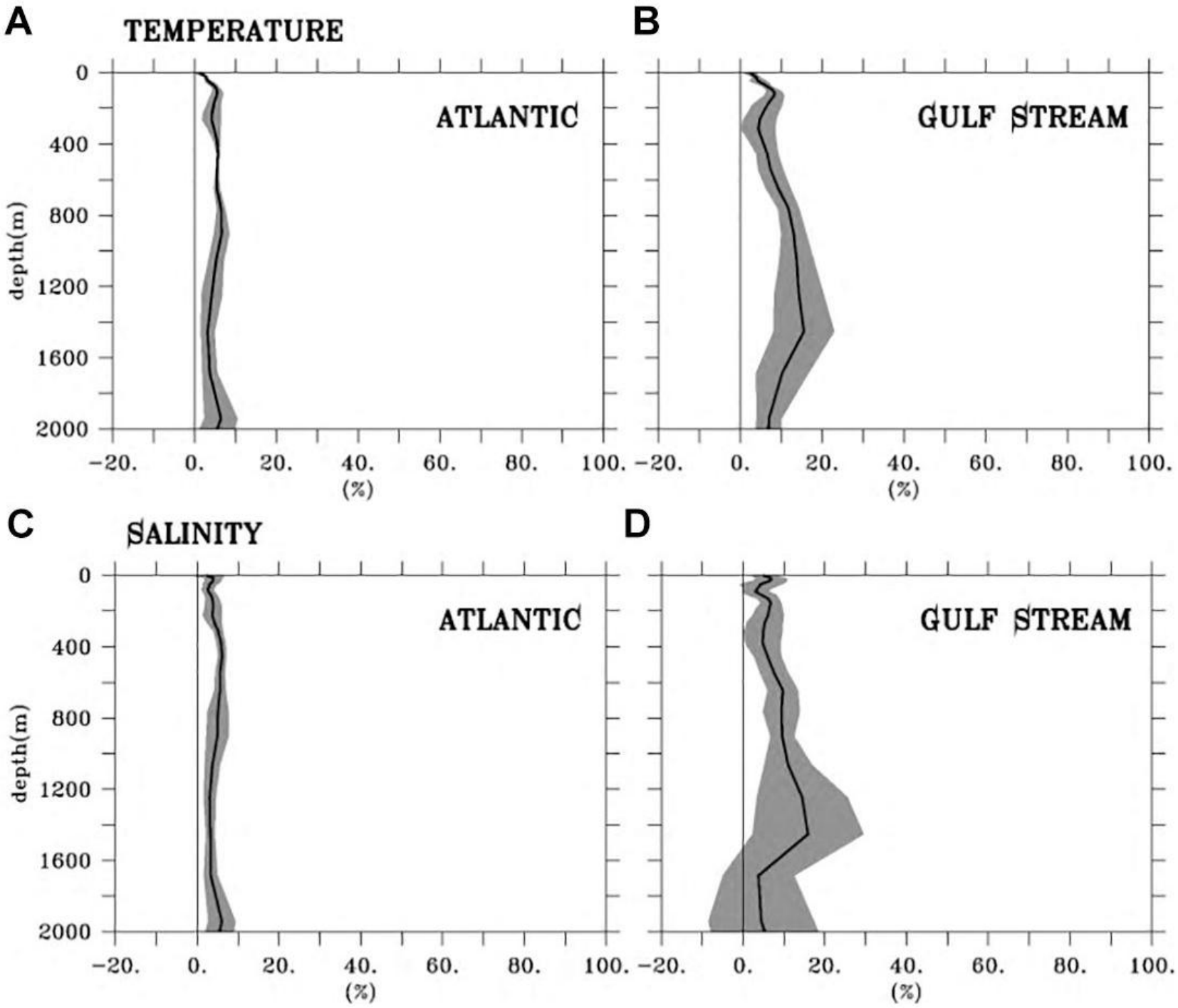
Assess the impact of observations

- ***Collaborating with OSEval TT (GODAE transitioning towards OceanPredict)***

  - *Supporting multi-model OSE/OSSE*
  - *Building a common NR (e.g. from eddy-resolving simulation)*

- ***Synthetic observation experiments (CAS/IAP)***

  - *Use of synthetic obs from eddy-permitting reanalyses for OHC objective analyses (i.e. reconstructions without dynamic models) to understand the impact of mapping methods and observational sampling*



Multi-model OSSE provide robust results through the spread of impact

Example:
Impact of doubling Argo in the Equatorial region and WBCs in terms of RMSE reduction

From AtlantOS project:
Gasparin F, Guinehut S, Mao C, Mirouze I, Rémy E, King RR, Hamon M, Reid R, Storto A, Le Traon P-Y, Martin MJ and Masina S (2019) Requirements for an Integrated in situ Atlantic Ocean Observing System From Coordinated Observing System Simulation Experiments. Front. Mar. Sci. 6:83. doi: 10.3389/fmars.2019.00083

Assess the impact of observations

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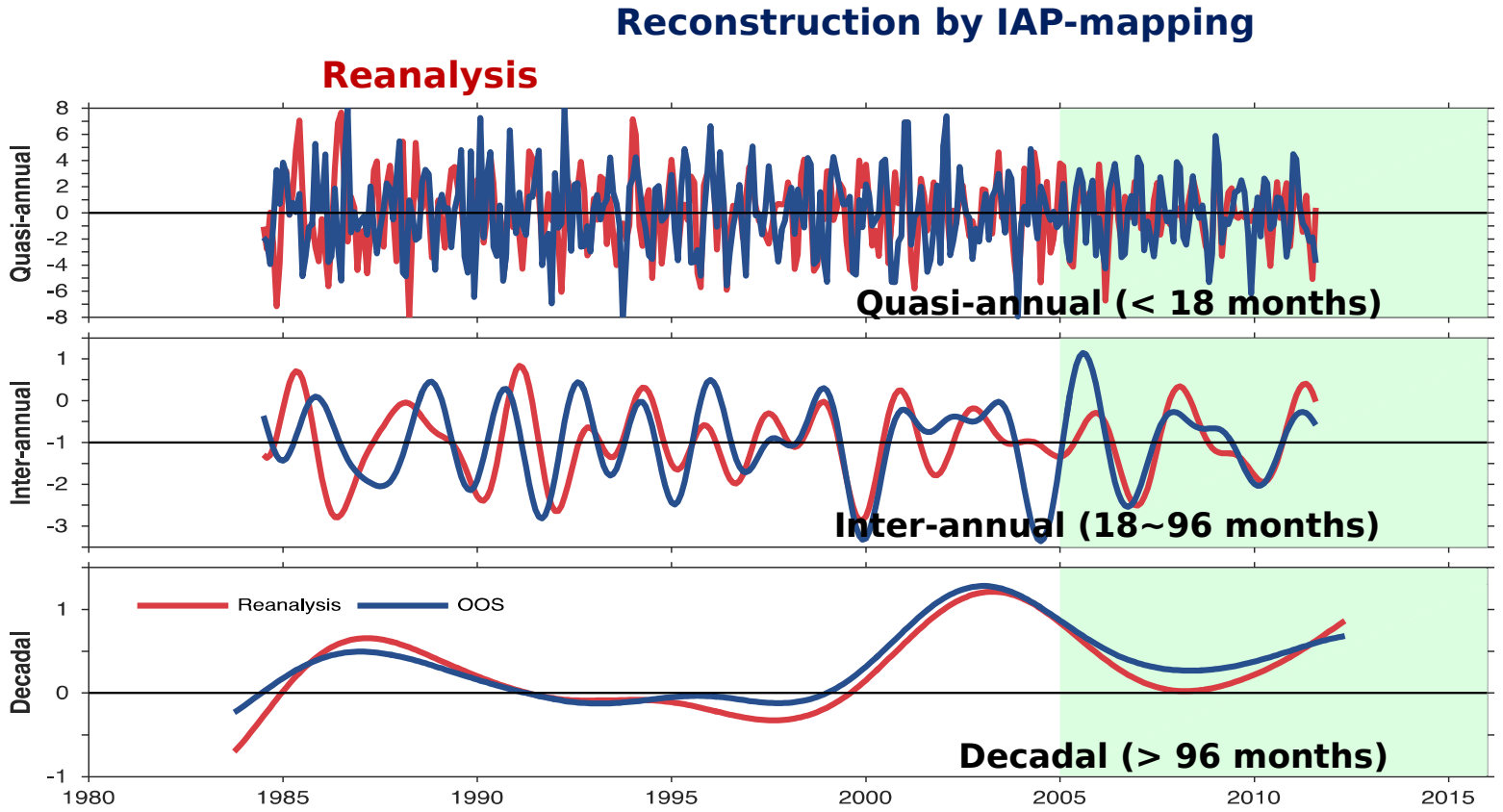
Synthetic observations

Truth (full coverage): Argo data; Reanalysis data; High-resolution Model outputs



The error is scale—dependent:

Total OHCT RMSE (1980-2015):

- Quasi-annual (3.36 W m^{-2}).
- Inter-annual (0.90 W m^{-2})
- Decadal (0.15 W m^{-2})

Quantifying the scale-dependent error of the global OHCT (~EEI) through synthetic observation exercises

Climate oriented high-quality datasets

- ***IQuOD***

Use of reanalyses for validation

- *Ana4MIPs (CREATE-IP)*

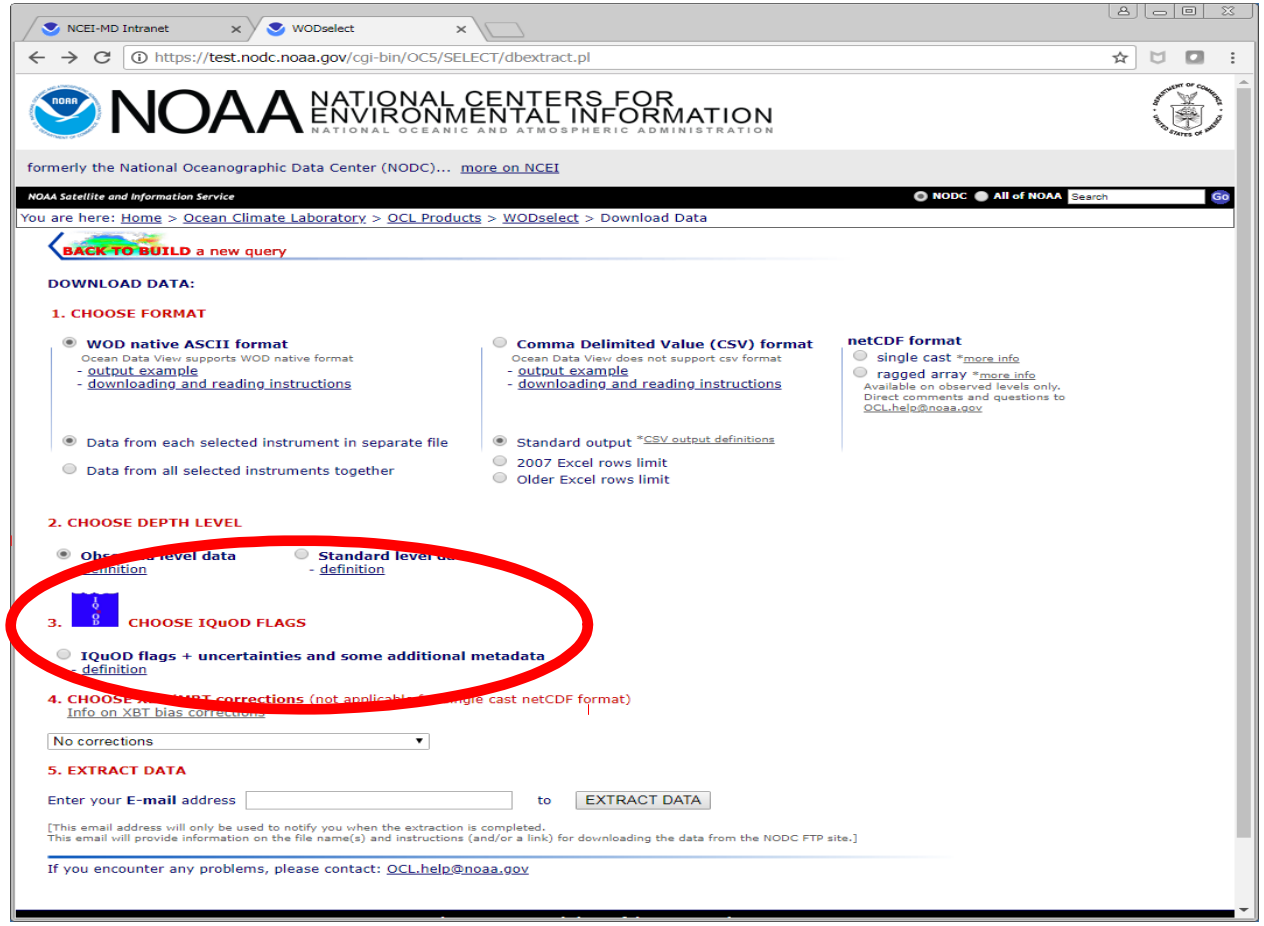
Data quality

- **IQuOD Team: v0.1 data released**

IQuOD (The Internationally Quality Controlled Oceanographic Database): Primary focus is to produce and freely distribute the highest quality and complete single ocean profile repository for use in ocean climate research applications

Who?
- Organized by the oceanographic community
- Includes experts in data quality and management, climate modelers and the broader climate-related community

What?
- Quality controls
- **Intelligent metadata**
- **Assigned uncertainties**
- **Emphasis on temperature**
- **Best practice XBT corrections**



References:
IQuOD version 0.1 Information
Palmer et al. 2017
Leahy et al. 2018

Climate oriented high-quality datasets

- *IQuOD*

Use of reanalyses for validation

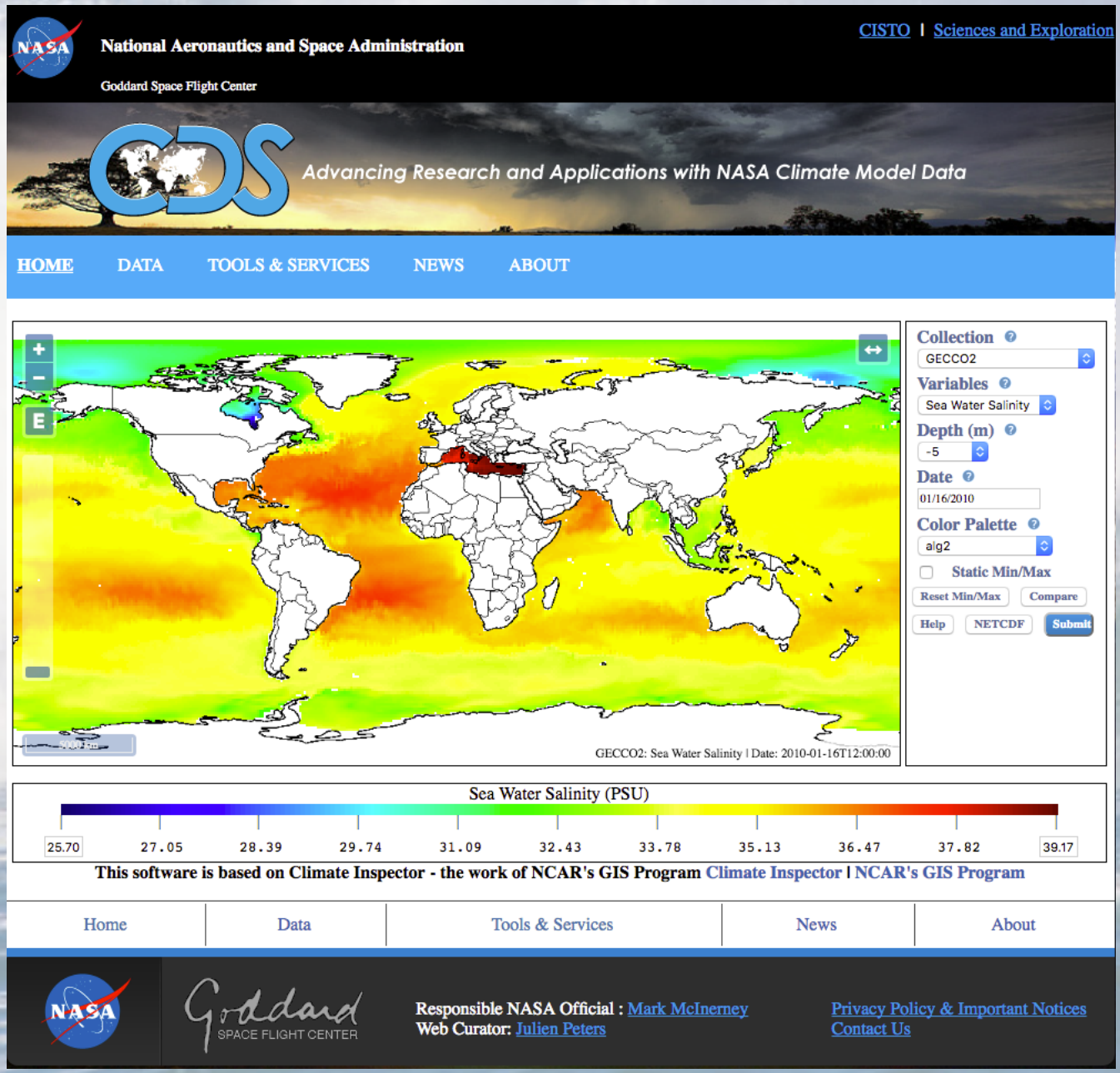
- ***Ana4MIPs (CREATE-IP): how to evolve to routine tools?***

★ An Extension of the ORA-IP: **CREATE-ORA**

Providing multi-system ensemble ocean reanalysis products on common Earth System Grid for climate model evaluation

- Under NASA **C**ollaborative **REA**nalysis **T**echnical **E**nvironment (**CREATE**) Project (ana4Mips)
- Part of a larger project to reformat major atmos. reanalyses (NASA Funding)
- Convert 8 ocean reanalysis products to the standard CMIP format to facilitate intercomparison & evaluation of climate models
  - CFSR (NOAA NCEP)
  - GECCO2 (Univ. Hamburg)
  - GDFL CDA (NOAA GFDL)
  - GODAS (NOAA NCEP)
  - MRI (JMA)
  - ORAS4 (ECMWF)
  - ORAP5 (ECMWF)
  - C-GLORS (CMCC)
- resolution of the common grid: 1^{o}x1^{o}, 33-level grid
- Time range: 1980-2010 (to be extended upon available funding)

NASA Climate Data Services has developed web tool for visualizing these products



https://cds-cv.nccs.nasa.gov/CREATE-V/

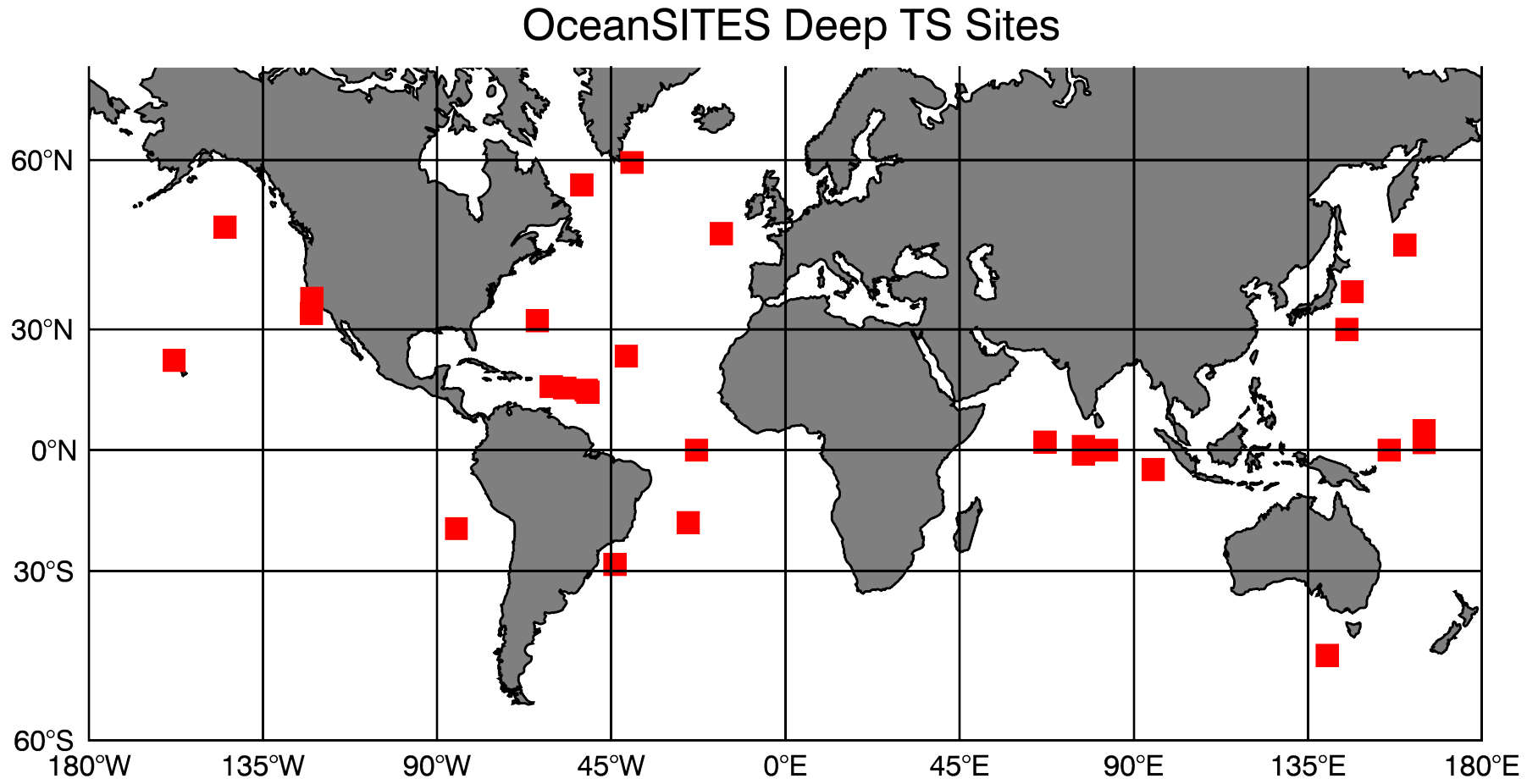
Endorsing the vision of

- ***TPOS2020, but with several recommendations:***
  - ***Stronger link with OSSE community to assist the "staged deployment"***
  - ***Stronger link with DA to make new/enhanced obs (ADCP, fluxes, etc.) readily exploitable in real-time context***
  - ***Needs specific thoughts about climate monitoring requirements***
  - ***Model evolution: bias and drifts***

- ***Argo2020 (2025): doubled core Argo in selected regions + deep Argo + BGC Argo***
  - ***Stronger link with OSSE community to assess the gradual deployment***

Recommendations from GSOP (from last GSOP session)

1) There is ***lack of climate data assembly center*** *capable to integrate different projects (e.g. OceanSites for deep T/S, GO-SHIP, and others, including repeated hydrography data), but also additional datasets such as e.g. current / ADCP measurements, glider and marine mammals for Argo-poor regions. The lack of standard format and common repository emerges as clear weaknesses, preventing these data to be widely utilized in climate monitoring studies and reanalyses, in spite of their high value. [Having uncertainty estimates will be a plus for assimilation/validation/analysis applications.]*



Jump from research activities to service products.

<u>Risks</u>:
- Data not capitalized
- Loosing the reanalysis diversity

2) Coordinated OSE/OSSE activities (in a multi-system context) should be strengthened. A possible way consists in the creation of a publicly available "nature run" for OSSEs (e.g. from an eddy-resolving model simulations) from where all participants may extract synthetic observations for specific studies. To this end, the link with OceanPredict and the OSEval TT should be reinforced.

3) Bias in reanalyses is still a major concern. Some actions envisaged by GSOP:

i) a stronger link with OMDP (e.g. inter-comparison of control runs from reanalysis realizations without using a strict protocol as in CORE, e.g. having a joint workshop);

ii) inter-comparison of time-averaged and time-varying analysis increments (as in TPOS), which implies that reanalysis producers need to store analysis increments in real-time and observation innovation/feedback files;

iii) promotion of inter-comparison and monitoring tools that mimic NWP standards (e.g. tools for real-time monitoring of ocean observations in prediction systems (this could be checked with Mercator Ocean, UKMO, US Navy HYCOM, and with GODAE Inter-comparison and validation and the OSEval Task Teams);

iv) survey of state-of-the-art methods for bias-correction.

4) There have been significant advances in ***air-sea flux gridded products, i.e. their maturity has increased in the recent years (e.g. wind products in TP, etc.). It is recommended to have systematic comparison with atmospheric and oceanic reanalyses, perhaps involving also atmospheric reanalysis community (TIRA Task Team), and foster their use for coupled ocean-atmosphere data assimilation (tuning and validation).***

5) Sea-ice thickness data have reached a reasonable maturity in the Arctic Ocean, which is testified by a large number of scientific publications successfully ingesting those data in the past few years. Studies and projects devoted to building sea-ice thickness datasets in the Antarctic Ocean shall be initiated and supported.

6) Climate Indexes from reanalyses, e.g. based on ORA-IP and RT ORA-IP experience should be promoted routinely and formulated to respond to stakeholder's requirements (e.g. fisheries, hurricane, ocean heat waves, etc.). CMEMS is taking already care of some of that, but relying mostly on European products: it is desirable that this approach is extended to include all available real-time global products.

Summary

GSOP is concerned with promotion of activities for the advancement of climate reconstructions, including methods, observational requirements and best practices (e.g. use of multi-model ensemble)

At the moment, the prioritized recommendations include

- **User-friendly dissemination of key climate ocean dataset**

- **Strengthening the link between reanalyses/DA communities with the observational one to optimize deployment plans**

Thank you