The Cnr Ismar Global historicAl Reanalysis (CIGAR)

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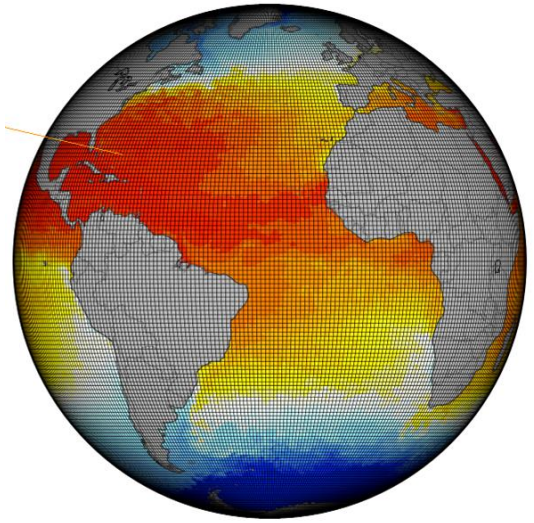
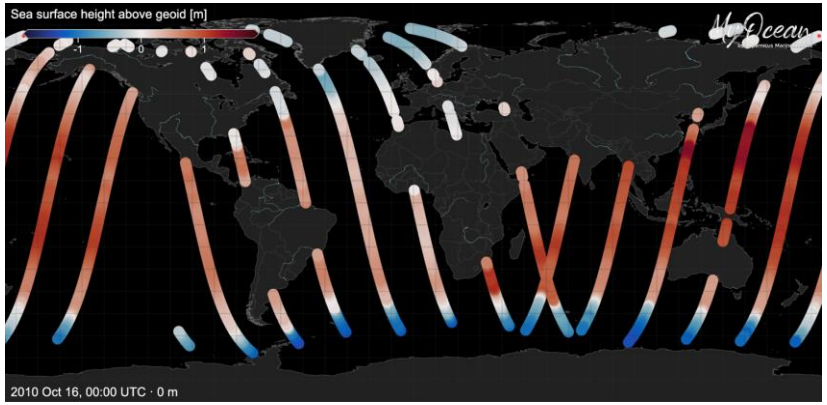
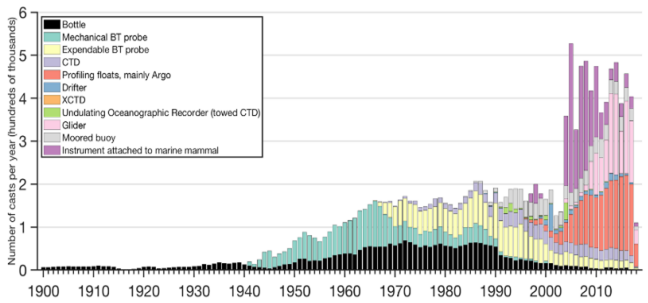
Ocean Reanalyses

Ocean reanalyses are reconstructions of the past ocean state combining ocean numerical models and earth observations through data assimilation techniques.



Ocean Models





Number of subsurface ocean temperature profiles yearly in the World Ocean Database, Meyssignac et al. (2019) **Measuring and Monitoring Global Ocean Heat Content to estimate the Earth Energy Imbalance** , Frontiers in Marine Science

Reanalyses

Image from Tim Boyer

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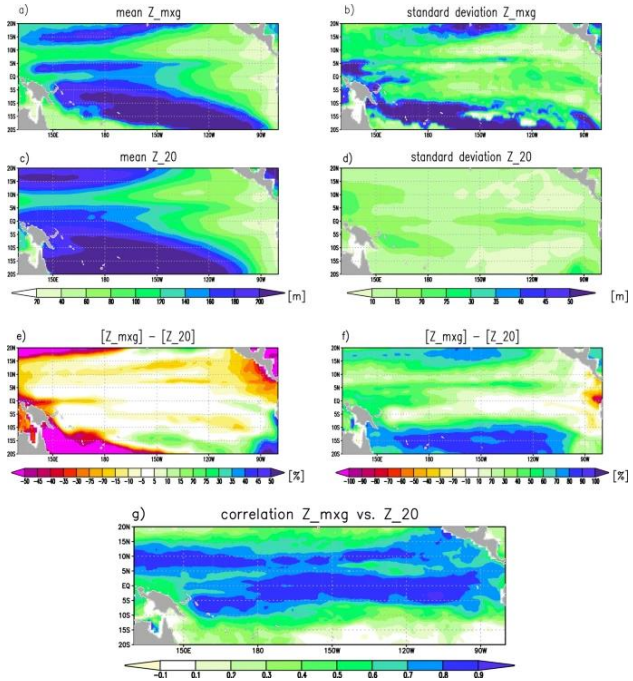
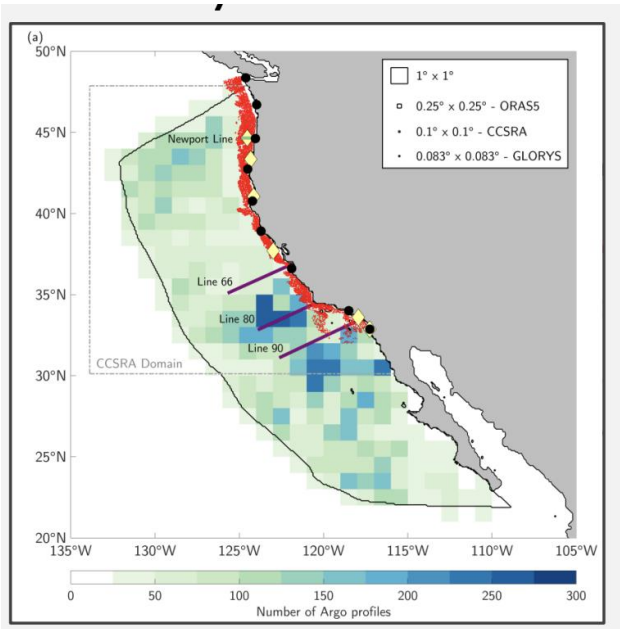
Ocean Reanalyses

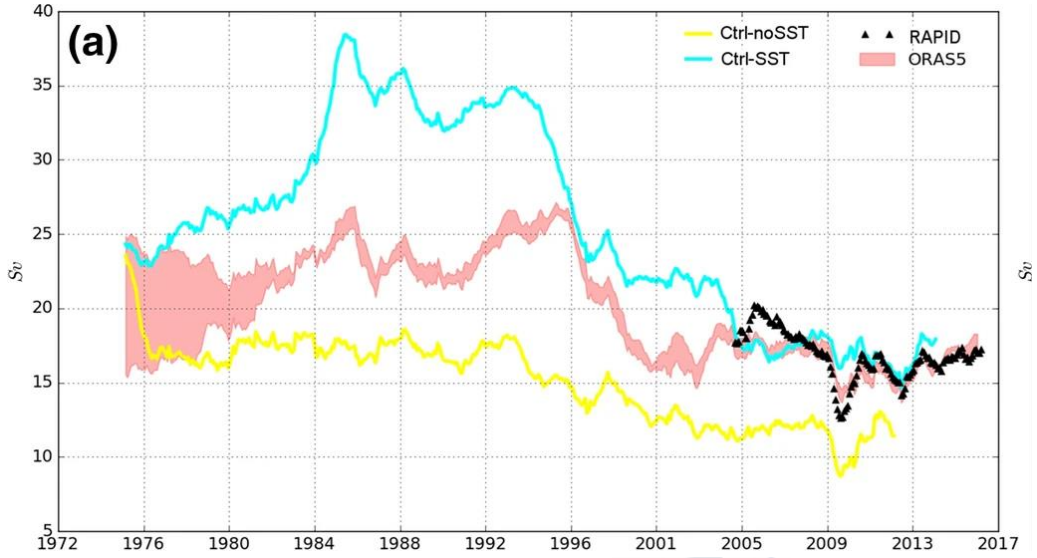
- Ocean and Climate process studies
- Ocean and Climate Monitoring
- Initial conditions for seasonal and decadal predictions



Dommenget et al., 2023



Amaya et. al (2023a)



Tietsche et al., 2020

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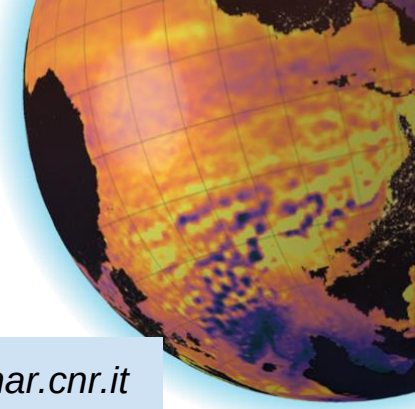
Reanalyses System



The ensemble historical reanalysis system (CIGAR)

- Moderate resolution (ORCA1, 1° with 1/3° increase in the Tropics, 75 levels)
- Relatively large ensemble (**32** to 48 members)
- State-of-the art modelling system (NEMO4.0.7)
- Variational data assimilation of all in-situ observations with VarQC
- Monthly background-error covariances from long-term anomalies, modulated with EN4 obs sampling (1st iter)
- Air-sea flux corrections (nudging to SST, SSS)
- Deep-ocean large-scale bias-correction w.r.t. AI-based yearly mean reconstructions (ARANN)
- Model tendency correction with climatological analysis increments
- Realistic discharge into the ocean (daily discharge from JRA55-do)

http://cigar.ismar.cnr.it

ORCA1 → ORCA025: 4^3=64 CPU increase

Perturbation of SST, input data, Ics, bulk-f. + stochastic physics

Contemporary period
1960-2022
(ERA5 reanalysis forcing)

Completed (published)

Storto, A., Yang, C. Acceleration of the ocean warming from 1961 to 2022 unveiled by large-ensemble reanalyses. Nature Commun. 15, 545 (2024).

Historical period
1860-2015
(20CRV3 reanalysis forcing)

Completed (under evaluation)

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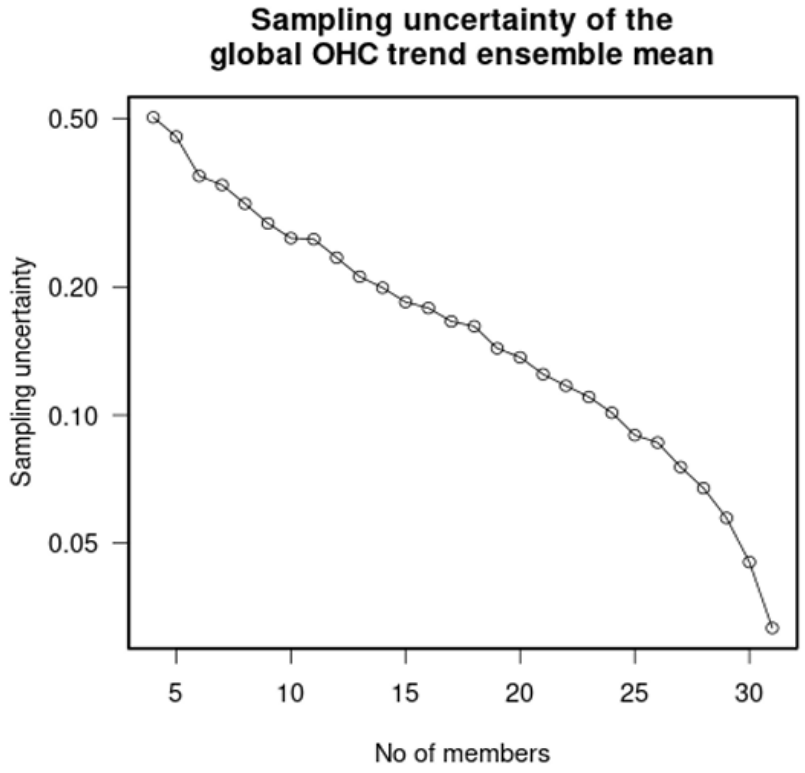
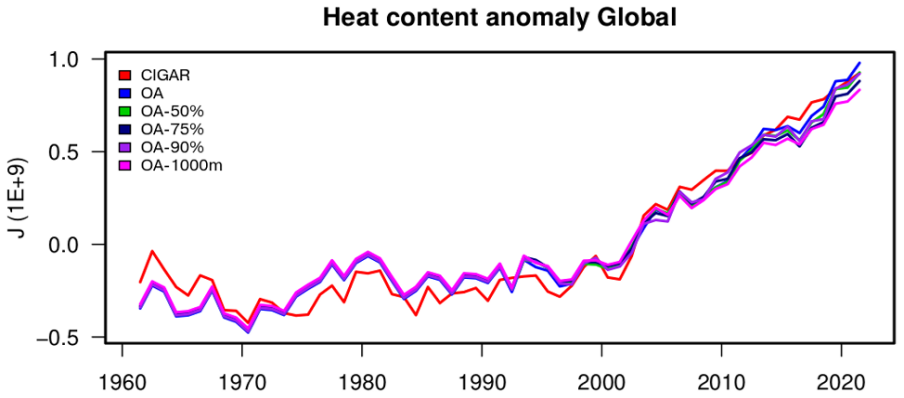
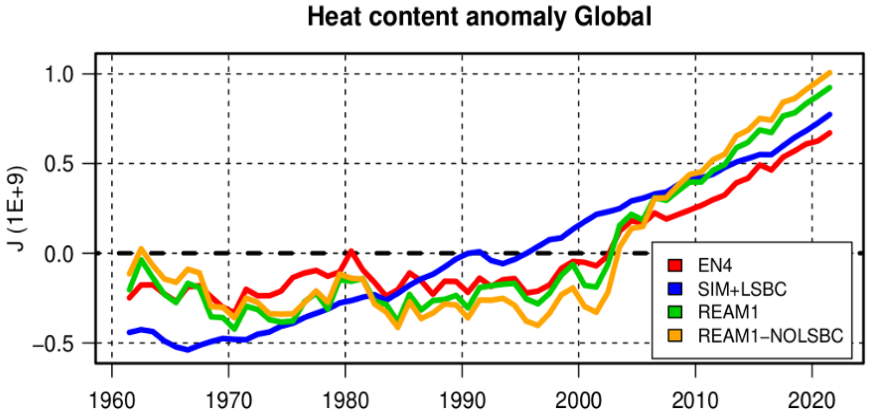
Robustness of the estimates



32 members reduces by about 90% the sampling noise compared to 10 members



The OHC trend estimates are found robust w.r.t. observation withholding (top) and LSBC scheme (bottom)



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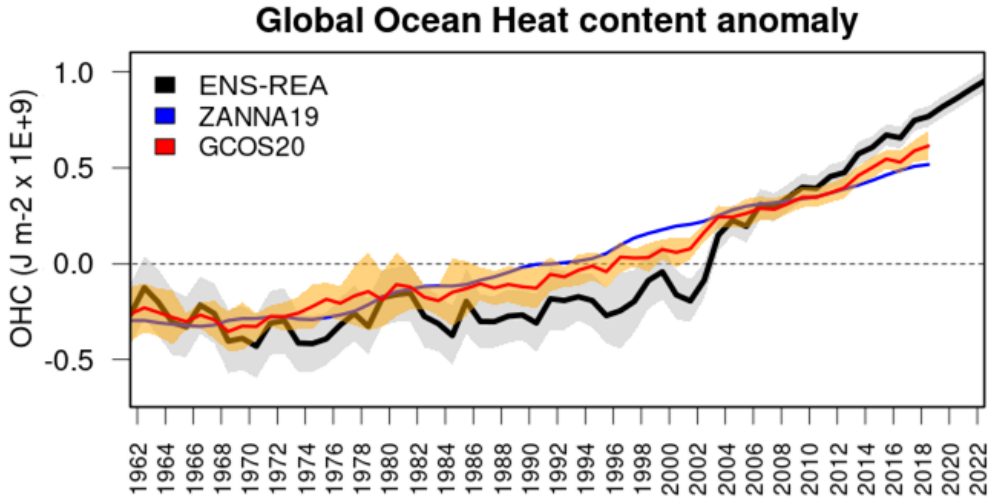
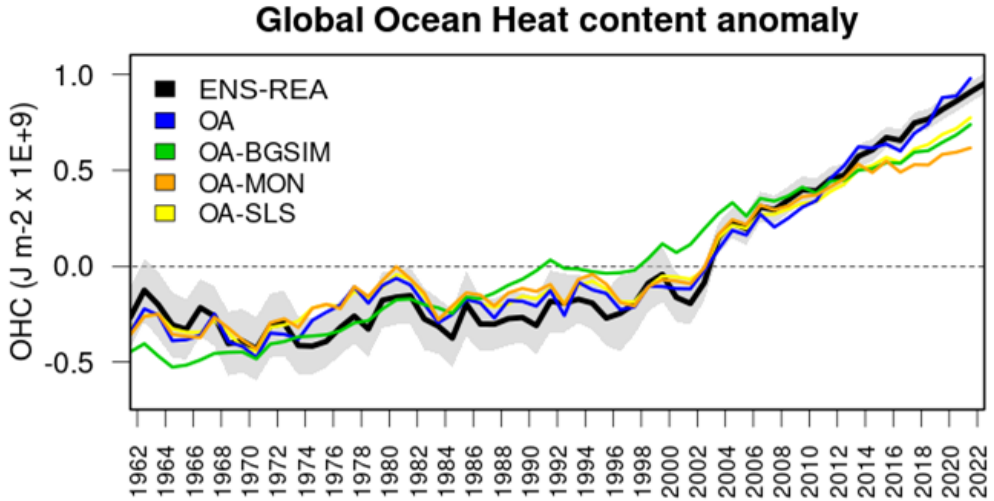
Climate monitoring (1961-)





Dataset	Global warming ($W\ m^{-2}$) 1961-2022	Global warming ($W\ m^{-2}$) 1961-2020	
ENS-REA	0.43 ± 0.08	0.41 ± 0.09	
GCOS22	NA	0.41 ± 0.10	
Dataset	**OHC Trend ($W\ m^{-2}$) (1961-2018)**	**Interannual Variability ($1E9\ J\ m^{-2}$) (1961-2018)**	**Acceleration ($W\ m^{-2}\ dec^{-1}$) (1961-2018)**
ENS-REA	0.42	0.20	0.13
GCOS20	0.34	0.09	0.07
OA	0.41	0.19	0.12
OA-BGSIM	0.44	0.07	0.04
OA-MON	0.36	0.12	0.07
OA-SLS	0.37	0.14	0.09

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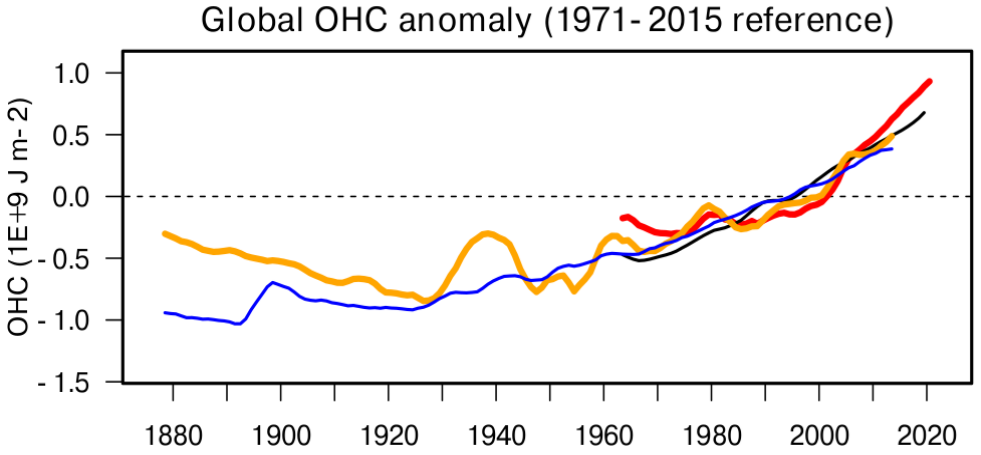
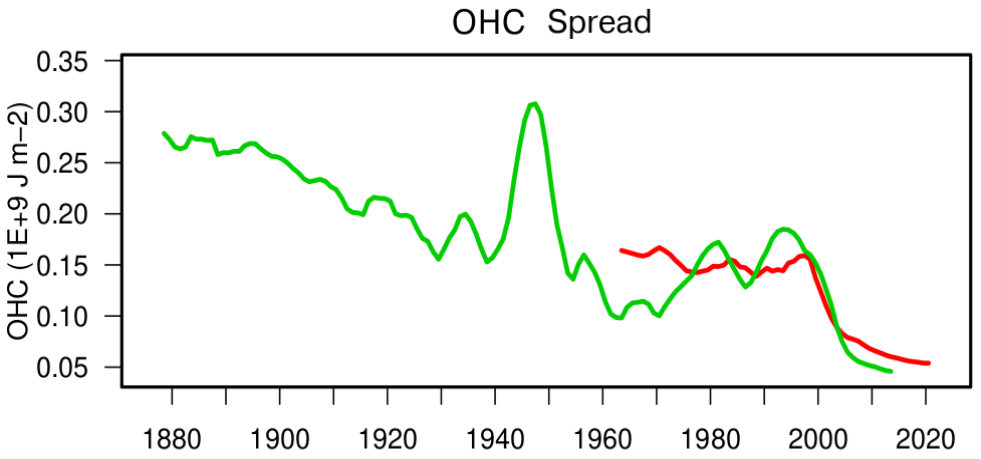
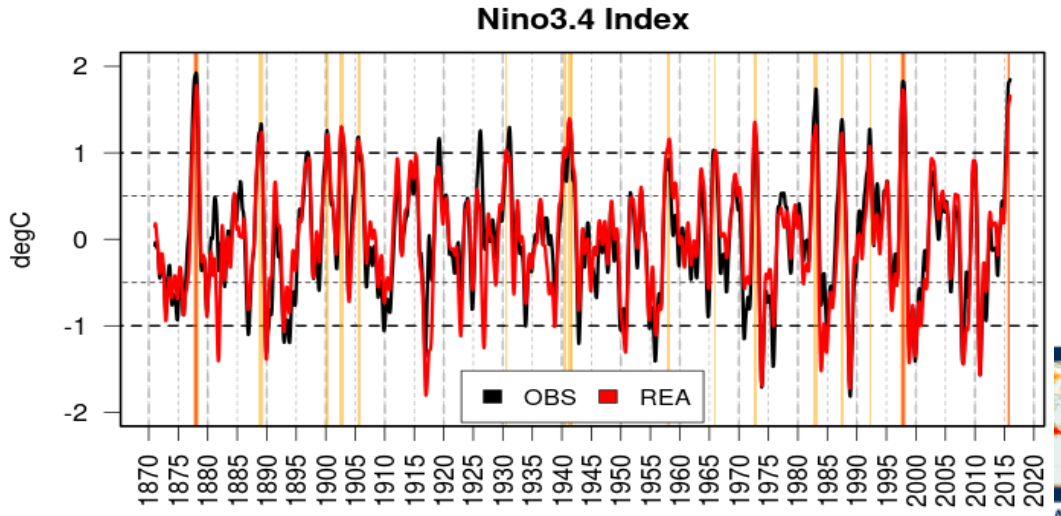
CIGAR-HS Preliminary assessment





- Consistency between Historical (H) and Contemporary (C) reanalyses in terms of trends and difference w.r.t. their corresponding control run and yearly OHC correlation (**0.93** over 1961–2015)
- Early peaks partly linked to new observations / ICs
- Century-long trend of **0.18+/-0.07** W m-2



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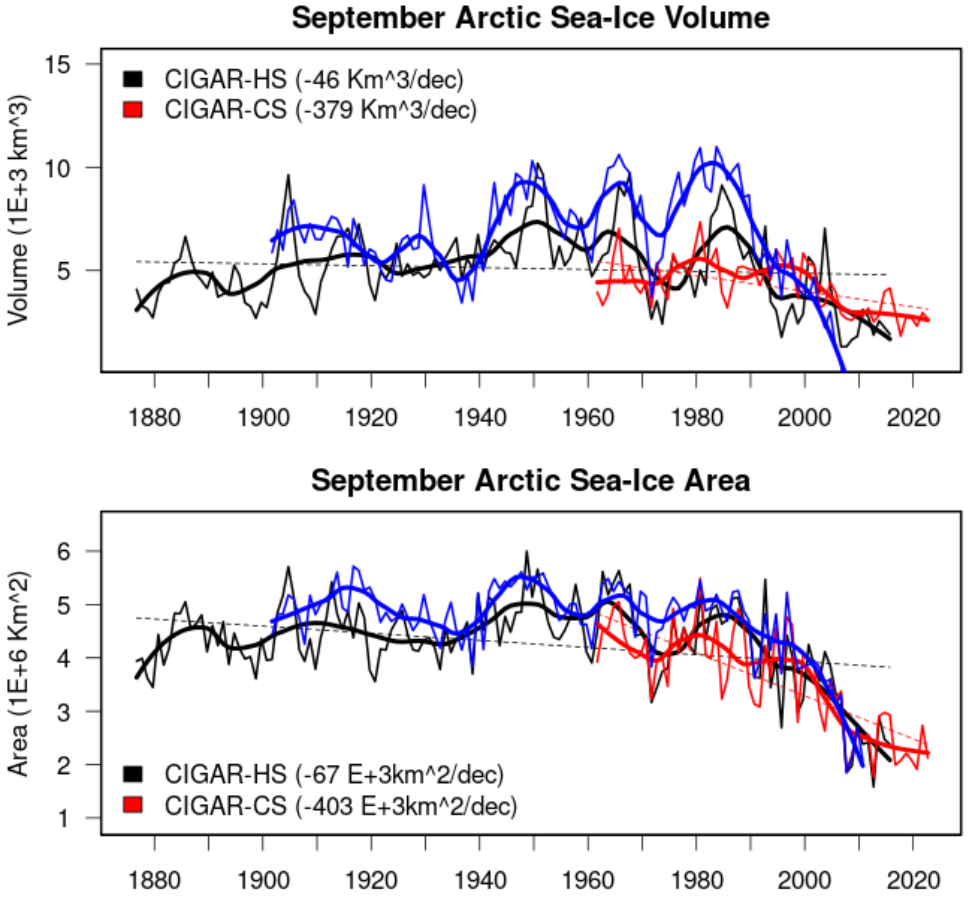
Arctic Sea-ice



- Consistency between the two streams regarding SIA; poor agreement on SIV
- SIA minima in 2000s and 2010s well captured by both
- Sea-ice data not assimilated (because of lack of consistent record throughout the period)
- Low-frequency consistency (both SIA, SIV) with reconstructed timeseries

PIOMAS-20C (forced by ERA-20C)
Schweiger, et al., 2019

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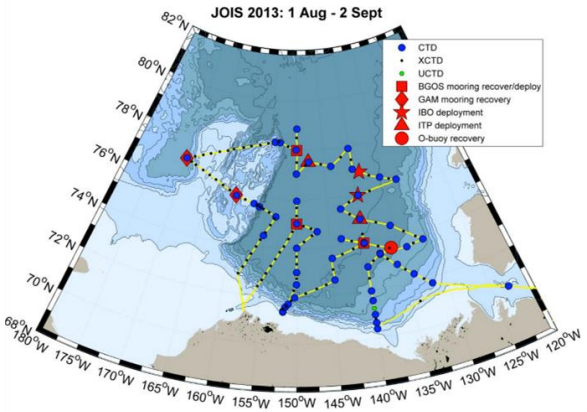
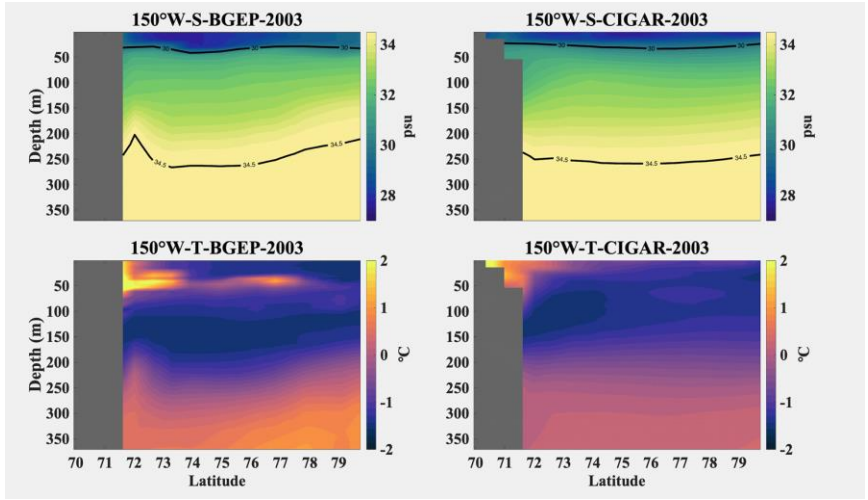
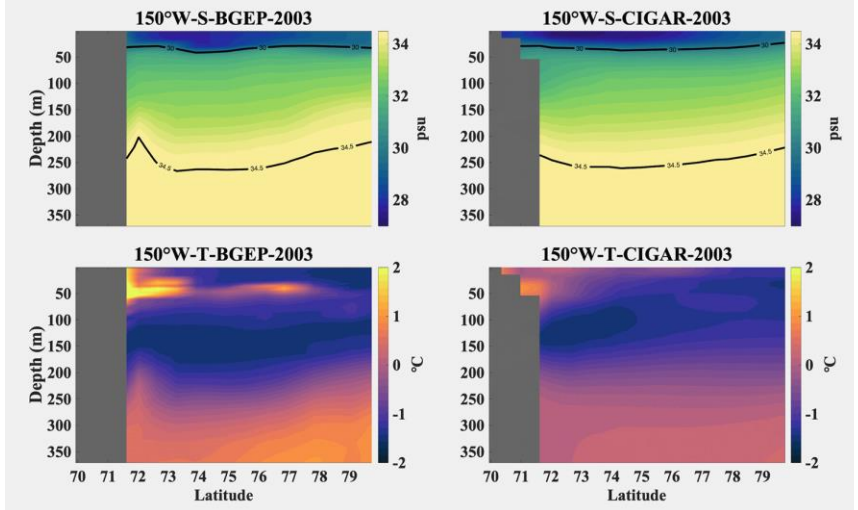
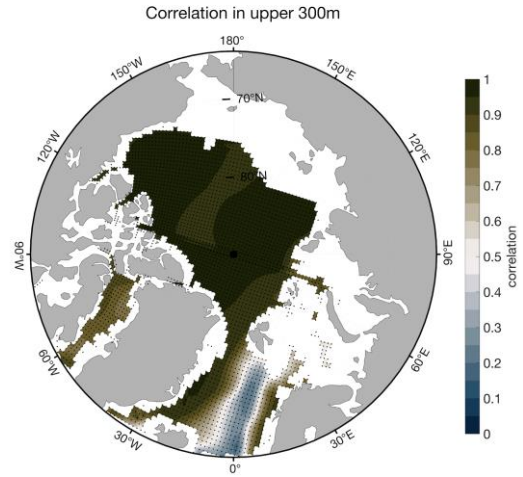
Changes in Arctic stratification



- Validation of the model at high latitudes
- Correlation of stratification and FWC during 1961–2022
- Investigating the drivers of FWC changes (ice melting versus Atlantification and transports)







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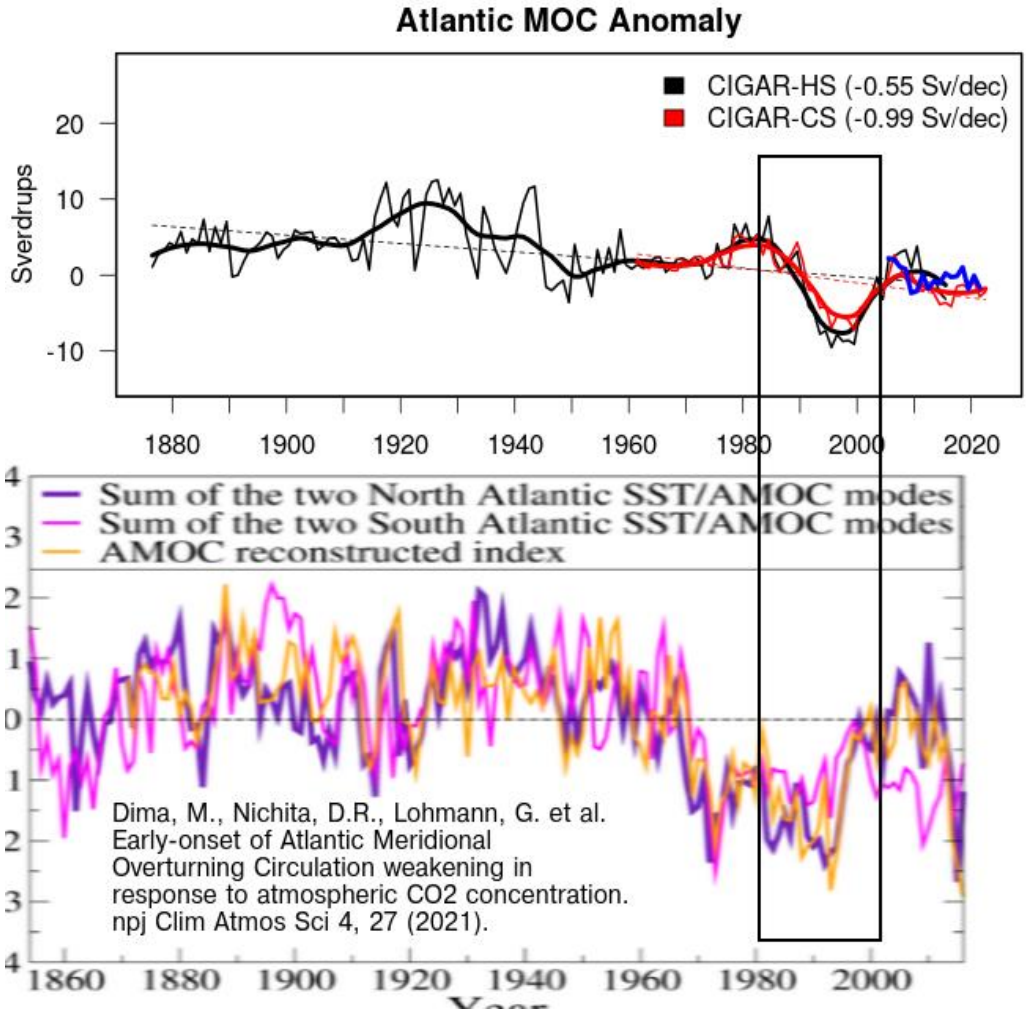
AMOC consistency



- Consistency between streams
- Decreasing trend
- Decreasing uncertainty
- Short observed time series
- Qualitative consistency with fingerprint–based reconstructions

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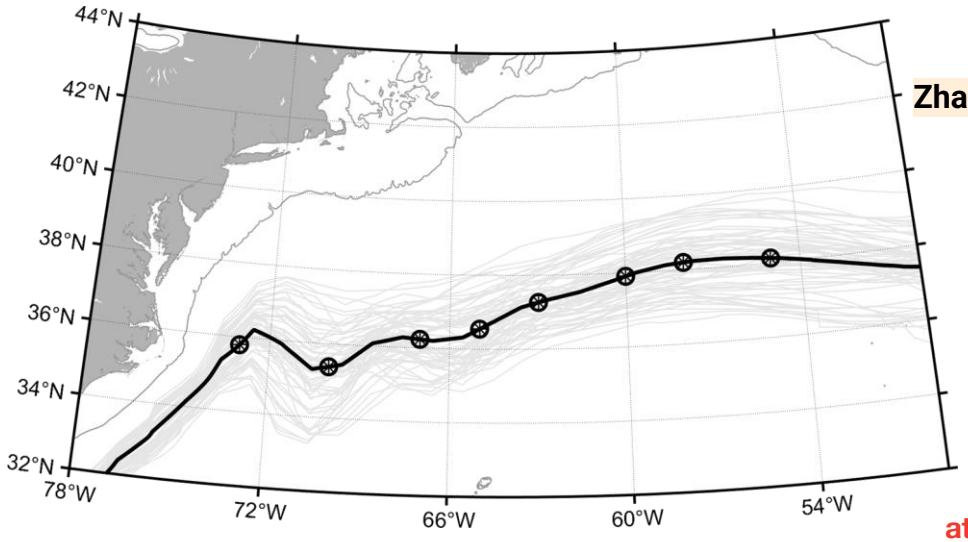
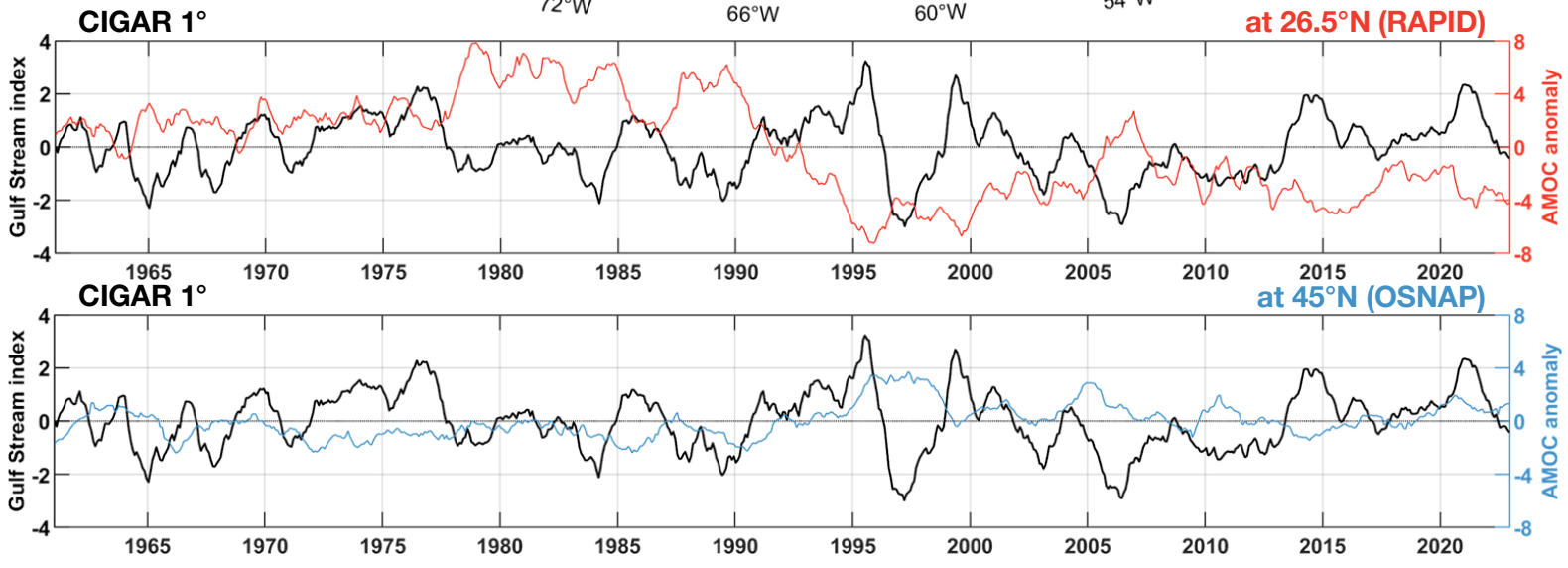
AMOC consistency

Indices calculations



Zhang et al. (2008) – 15°C isotherm at 400m depth, the “North Wall index”



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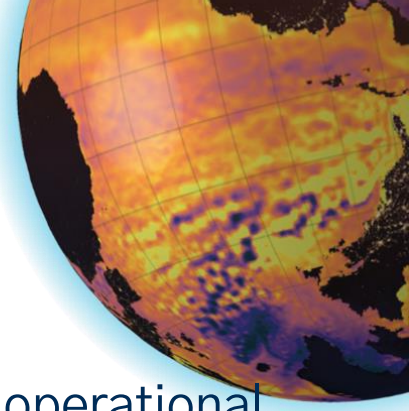
Concluding Remarks



- Long-term reanalyses enable robust monitoring of the ocean climate, and can benefit operational oceanography as well (e.g. through AI-based forecasting and bias-correction)
- For long-term applications, transitioning towards a fully probabilistic approach show large benefits (towards reliability and credibility)
- Complementarity with high-resolution systems to go further back in the past and allow for uncertainty estimates

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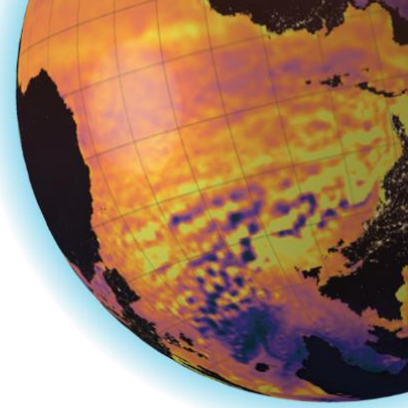
Challenges



- Sparse observing networks (AI, non-conventional, uncertainty specific)
- Biases and drifts (3 BC schemes + AI + model enhancements)
- Temporal consistency leads to conservative choices for input observations (e.g. no sea-ice, use of nudging)
- Production is heavy (resolution versus ensemble size): difficulty with online BEC's estimation
- Reliable uncertainty is crucial for long-term applications (stochastic physics, input data)
- Verifying dataset are scarce and mostly proxy-based estimates
- Initial conditions at the beginning of reanalyses

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Ocean Predict
In partnership with
unesco
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2021 2030 United Nations Decade of Ocean Science for Sustainable Development
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