Ocean Predict

SYMPOSIUM OP'24

In partnership with unesco Intergovernmental Oceanographic Commission

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

The Copernicus Marine global "blue/white" ocean reanalysis: past, present, future

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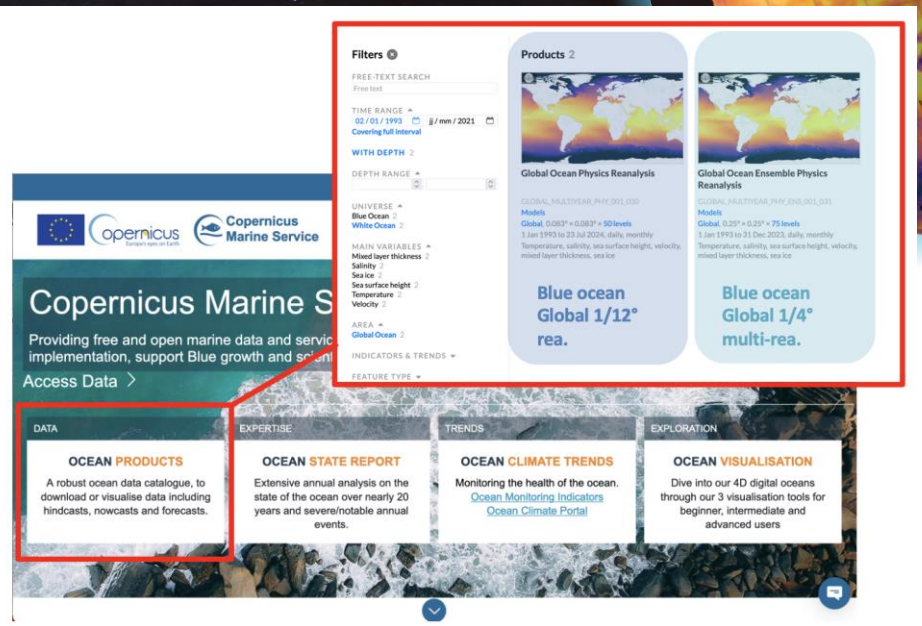
Outlines

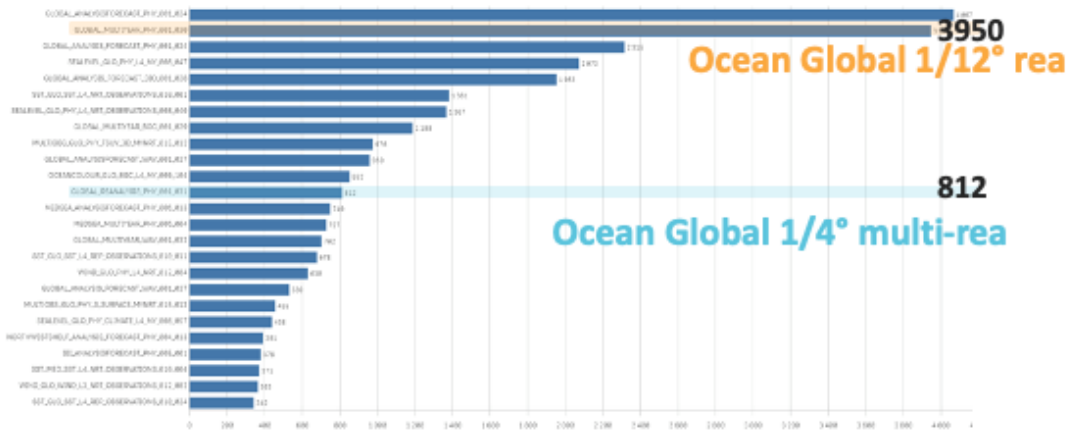
- Description and use of the global blue/white ocean reanalyses of Copernicus Marine
- Future evolution of the blue/white ocean reanalyses
- Example of preliminary result: Mass control of the system
- Conclusions/perspectives

Current Copernicus Marine global “blue/white” ocean reanalyses

- Copernicus Marine proposes 2 global “blue/white” ocean reanalyses:
  - **GLORYS12V1: High resolution at 1/12°**
  - **GREP: Multi-reanalysis at 1/4°**
- Both reanalyses products are free of charge and available on the Copernicus Marine portal
- Both reanalyses cover the “altimetric” period, called stream2 (1993-present).
- With more than 1.2 Peta octet downloaded and 5000 users in 2023 over last year, these reanalyses are ones of the most downloaded product of Copernicus Marine catalogue



Copernicus marine offer for blue/white reanalysis



Number of download of CMEMS products for sept-2022 to sept-2023

Description of global “blue/white” ocean reanalyses

- For both reanalyses, 3D variables (temperature, salinity, zonal and meridian velocities) or 2D variables (sea surface height, mixed layer depth, sea ice concentration and sea ice thickness) are available.
- GLORYS12V1 (*Lellouche et al. 2021*) allows a better representation of mesoscale activity than reanalyses at coarser resolution
- GREP multi-reanalysis at ¼° resolution allows a first estimate of robustness/limitation of the ocean reanalyses e.g. transport (*Mayer et al. 2023), Sea Level (Storto et al. 2017), Steric and OHC (Storto et al., 2018), sea ice (Chevalier et al. 2017; Uotila et al. 2019; Iovino et al. 2022), AMOC (Jackson et al. 2019)).*

General characteristics of GLORYS12V1 (1/12°)

GLORYS12V1	
Ocean Models	
OGCM	NEMO v3.1 at 1/12; 50 vertical levels, LIM2 (mono category)
Atmospheric Forcing	ERAinterim 3h (Era5 hourly after 2019)
Runoff	Climatological runoff (Dai&Trenberth)
Assimilation characteristics	
DA scheme	SAM2V1 +BC
Analysis	SEEK
SSH trend	Imposed by SLA assimilation, no control mass/steric
SSS/SST	AVHRR
T/S	EN4 “weak” assimilation at depth
T/S profile	CORA data base
Assim. frequency	weekly

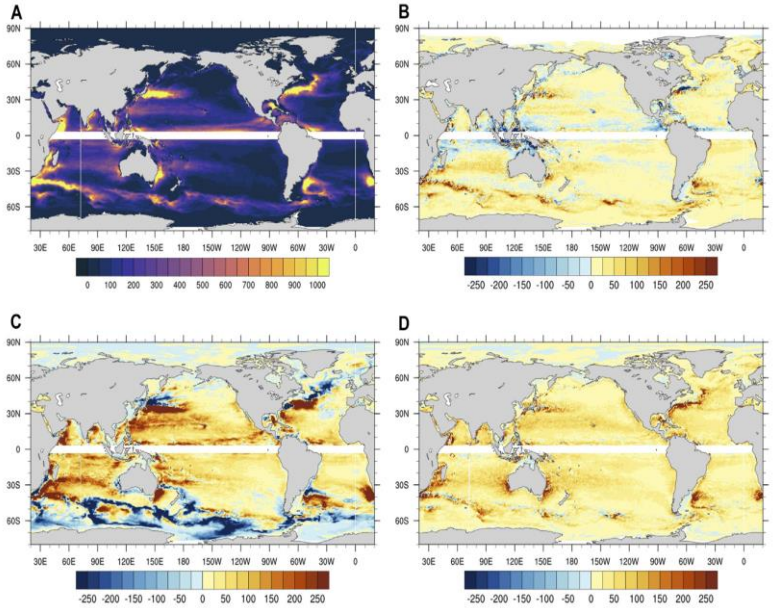
General characteristics of GREP (1/4°)

System name	CGLORS	ORAS	GLORYS
Ocean Models			
OGCM	NEMO at 1/4°, 75 vertical levels But different parameterizations		
Ice model	LIM2	LIM2	LIM2
Atmospheric Forcing	Era-Interim/Era5		
Time range	1993-2021		
Assimilation characteristics			
DA scheme	3DVAR	3D_NEMOVAR	SEEK
SLA assim	DT2014		
In situ	EN402	EN402	CORA
SSS/SST/3D relaxation	Flux-correction everywhere	Nudging	None
Sea-Ice DA	Nudging	L4 SIC	L4 SIC
Assim. frequency	weekly	weekly	weekly

Example of scientific studies based on GLORYS12V1

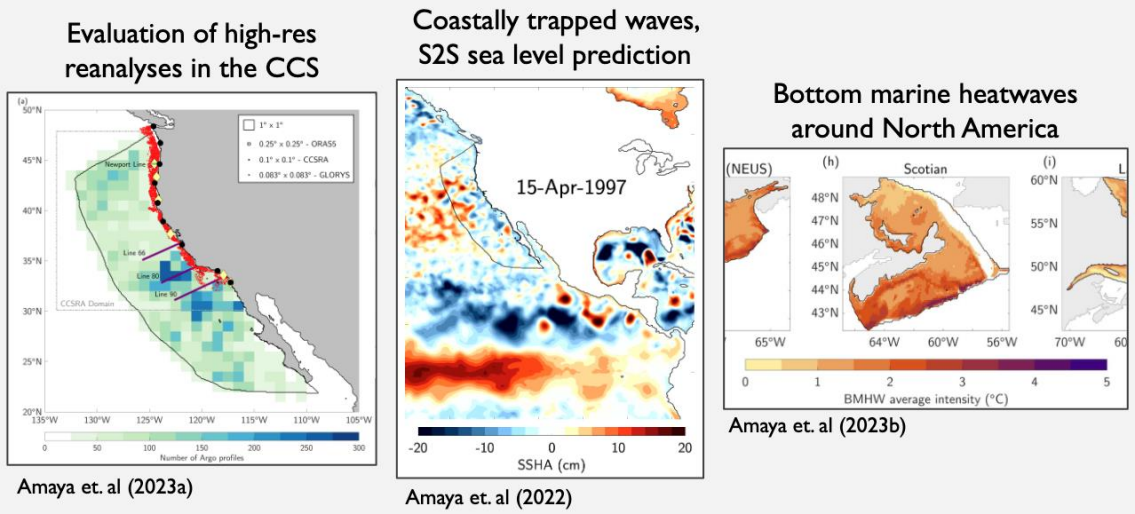
GLORYS12V1 is largely used for scientific studies: Lellouche et al. 2021 (reference paper, more 250 citations); *Artana et al. 2018b; Dimoune et al. 2022; Chafik et al. 2023; Amaya et al. 2022 & 2023; Alexender et al. 2023; du Pontavice et al. 2023; Cadima et al. 2024; …*

Geostrophic EKE of Global 1/12° (A) and differences with AVISO L4 (B); free 1/12° (C); global 1/4° (D)



- EKE pattern in good agreement in experiments with DA (1/12° & 1/4°)
- Higher EKE value everywhere with the increase of resolution
- Higher level of energy in global 1/12° compared to AVISO L4 product (consequence of higher spatio-temporal resolution in the reanalyse)

Regional process studies



- GLORYS12V1 can be used in various regional studies, for example:
  - Current in California system
  - Tropical wave propagation
  - Bottom temperature around north America

Evolution of GLORYS12 planed in 2026

- New Reanalyse at 1/12° is broadly based on the new global real time Mercator system at 1/12° (see Lellouche's presentation for bias correction, analysis kernel,…)

- Main differences compared to the real time system:
  - Extended ORCA grid (Antarctica ice shelves) + 75 vertical levels
  - Forced by ERA5/1H atmospheric reanalysis
  - Interannual river discharge of 13 major rivers from GloFAS (Copernicus Emergency Mgt Service)
  - Assimilation of reprocessed data (SLA, OSTIA, CORA, OSI SAF)
  - **Add Sea Ice mass in the controlled mass budget**

GLORYS12V1	
Ocean Models	
OGCM	NEMO v3.1 at 1/12; 50 vertical levels, LIM2 (mono category)
Atmospheric Forcing	ERAinterim 3h (Era5 hourly after 2019)
Runoff	Climatological runoff (Dai&Trenberth)
Assimilation characteristics	
DA scheme	SAM2V1 +BC
Analysis	SEEK
SSH trend	Imposed by SLA assimilation, no control mass/steric
SSS/SST	AVHRR
T/S	EN4 "weak" assimilation at depth
T/S profile	CORA data base
Assim. frequency	weekly

General characteristics of GLORYS12V1 reanalysis

New release in 2026

GLORYS12V2	
Ocean Models	
OGCM	NEMO **v3.6** at 1/12; **75 vertical levels**, **LIM3 (multi-category)**
Atmospheric Forcing	**Whole Era5 (hourly)**
Runoff	**Interannual** runoff (GloFas debiased for 13 major rivers)
Assimilation characteristics	
DA scheme	SAM2V**2** + **New BC**
Analysis	SEEK with **4D analysis**
SSH trend	**Mass imposed (GRACE, ISBA,…); global steric only diagnosed**
SSS/SST	**OSTIAv2 reprocessed SST**
T/S	EN4 "weak" assimilation at depth
T/S profile	CORA data base
Assim. frequency	weekly

General characteristics of GLORYS12V2 reanalysis

Construction of SLA model equivalent in GLORYS V2

Products available to estimate Sea Level variations:

- GRACE :
  mass = liquid water + Sea Ice ! (Not only ”sea water” !!!)
  No Steric info
  No MSSH/GIA info
  No atmo Pressure info

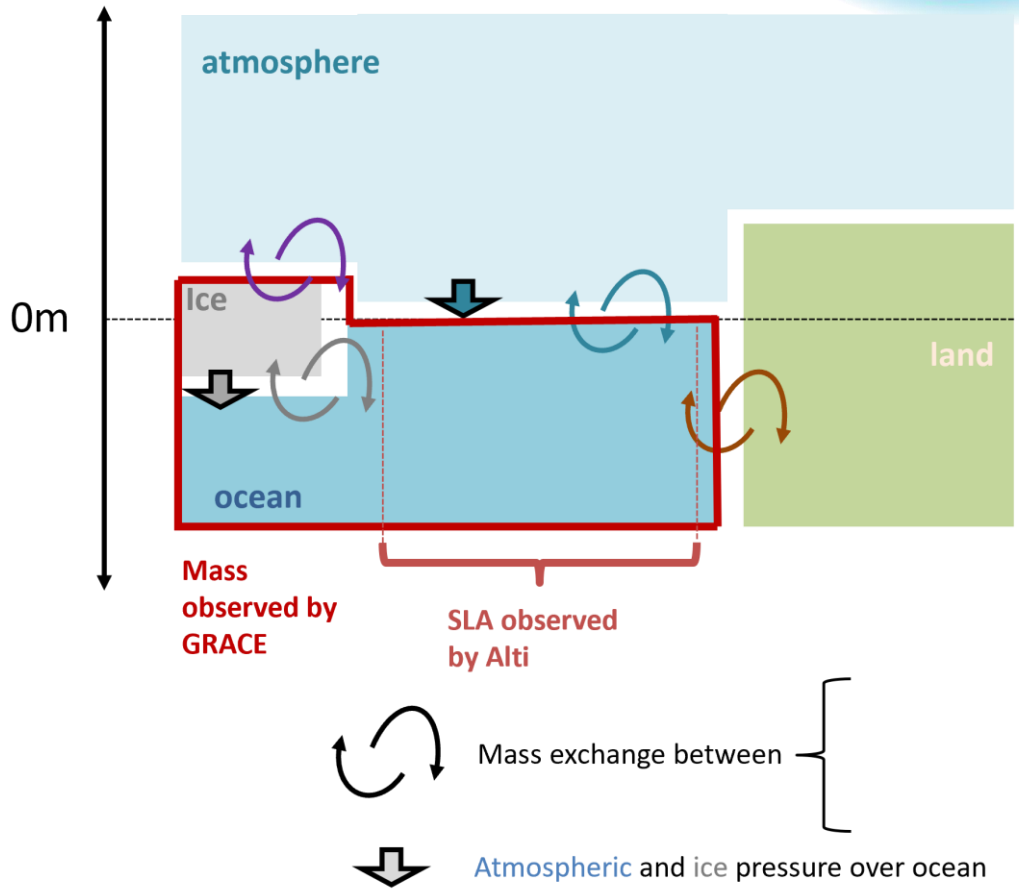
- AVISO SLA L3:
  Total MSL: Mass (ocean/SeaIce) + Steric variations
  No MSSH/GIA info
  No atmo Pressure (filtered)

- NEMO, Bousinesq approx. + SeaIce levitating (not embedded):
  Liquid mass + SeaIce mass + local steric gradient
  No global steric
  No SeaIce pressure effect
  No atmo Pressure (in this version)

=> SSH equivalent construction with NEMO:

SSHeq = SSH_nemo + SSH_steric_1D + SSH_SeaIce(_1D) - GIA

Exchanges and Pressures between Atmo/Ocean/SeaIce/Land



Construction of SLA model equivalent in GLORYS V2

NEMO GMSL = Mass only, SSH due to Sea Ice pressure and steric effect are diagnosed
(assumption: uniform isostatic response of pressure induced by Sea Ice mass variations)

Mass Imposed

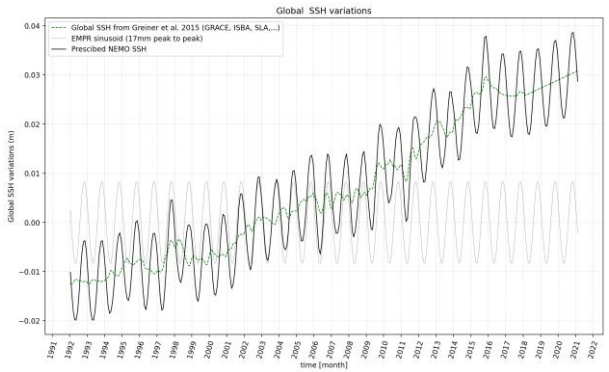
$$SLA\_model\_equivalent = SSH + SSH\_SeaIcePressure\_1D + SSH\ steric\_1D - (MSSH + GIA)$$

NEMO | Diagnosed | Diagnosed | Input

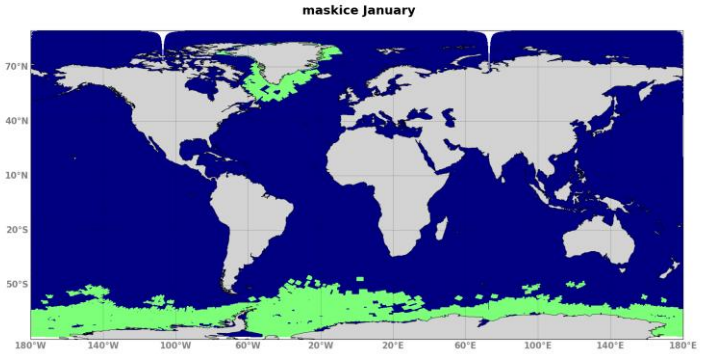
Mass (Ocean/SeaIce) forced through EMP budget toward an estimated deduced from observation (GRACE+ISBA,..).

=> Total mass evolution (black) = Greiner and Meyssignac (2015) estimate (green) + Seasonal EMP cycle (grey) with 17mm peak to peak (Chandanpurkar et al. 2021)

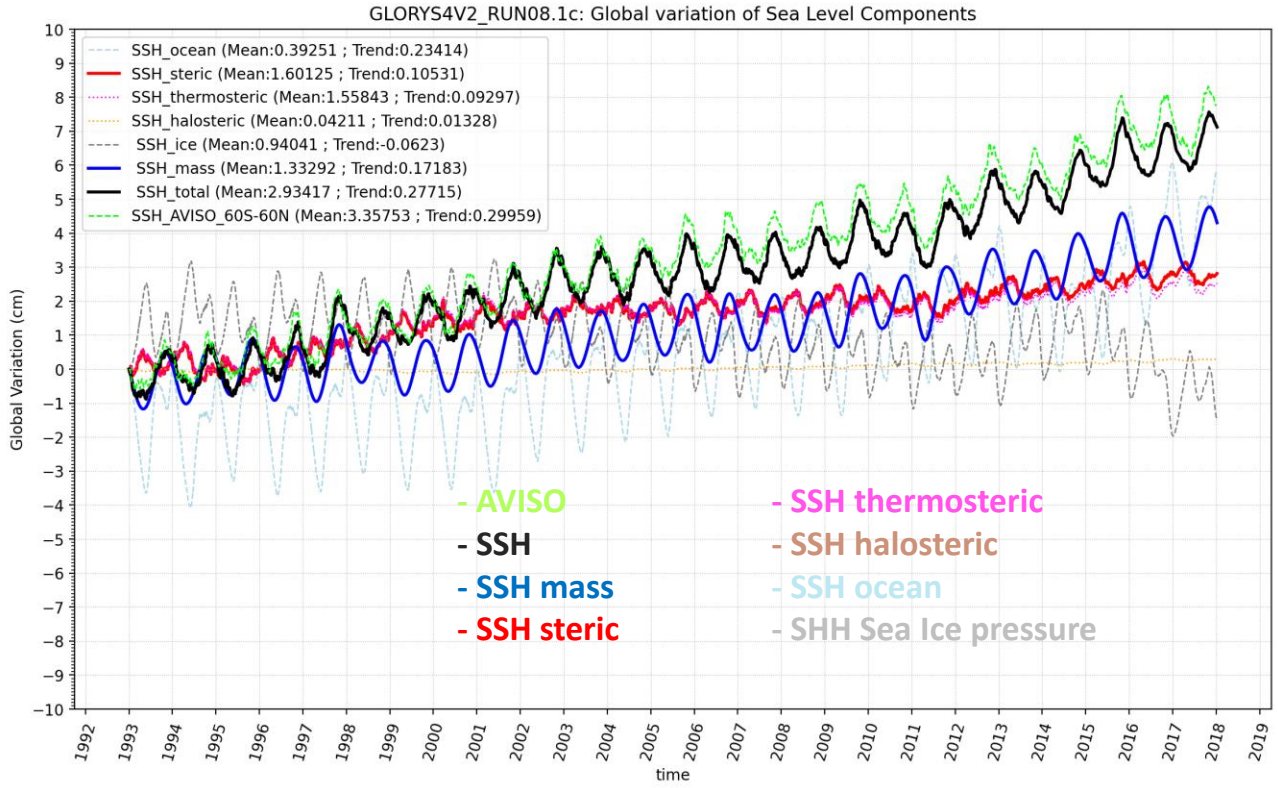
Mass evolution in GLORYS v2



Example of the Iceberg climatology (January) where interannual mass adjustment is distributed



GMSL components evolution vs AVISO in test at ¼° resolution

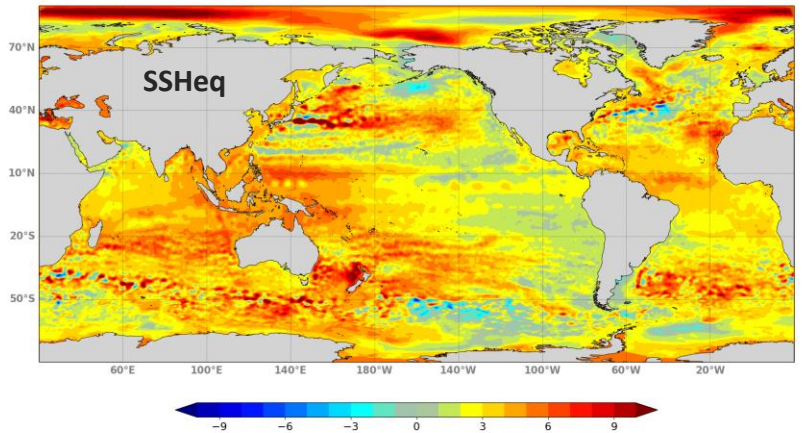


- GMSL trend in good agreement with AVISO estimate.
- Mass trend prescribed (60% of the total); steric trend at 1mm/year.
- Corrected repartition thermo/halo steric
- Importance of (negative) Sea Ice trend in the global budget.

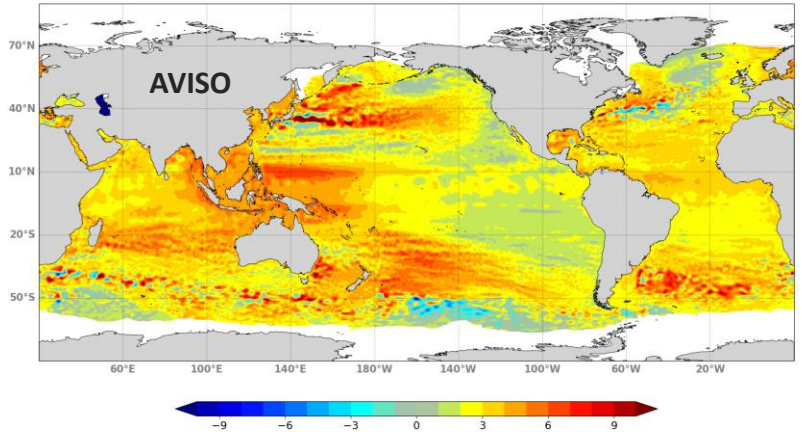
Components	Trend (mm/year)
AVISO	3 ± 0.3
SSH total (mass+steric)	**2,8**
SSH mass	**1.7**
SSH ocean	2.3
SSH SeaIce	-0.6
SSH steric	**1**
SSH thermosteric	0.9
SSH halosteric	0.1

Mean Sea Level trends (1993-2017)

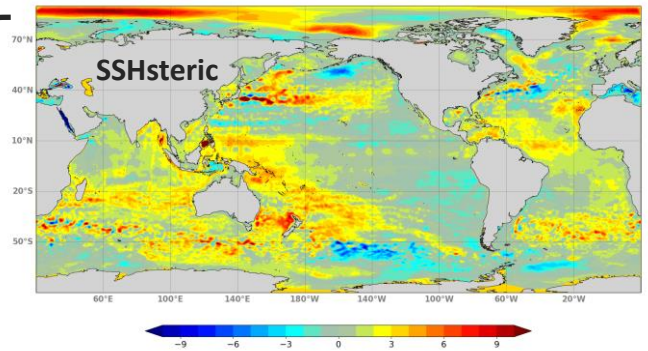
GLORYS4_RUN08.1c Trend ssh_pgr (mm/year) 1993-2017



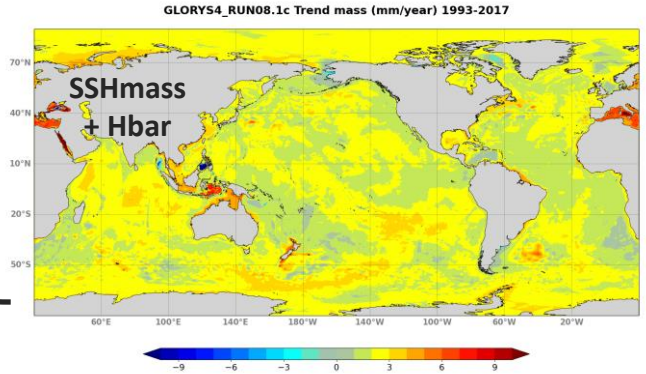
AVISO Trend sla (mm/year) 1993-2017



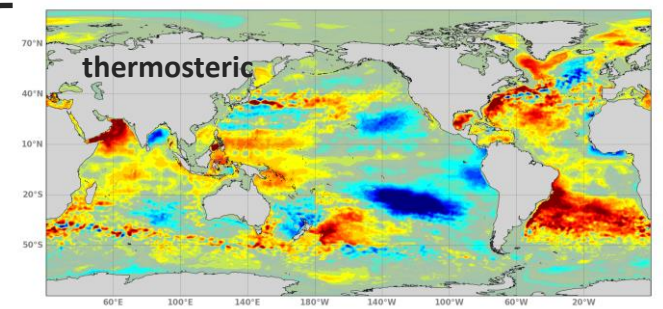
GLORYS4_RUN08.1c Trend st (mm/year) 1993-2017



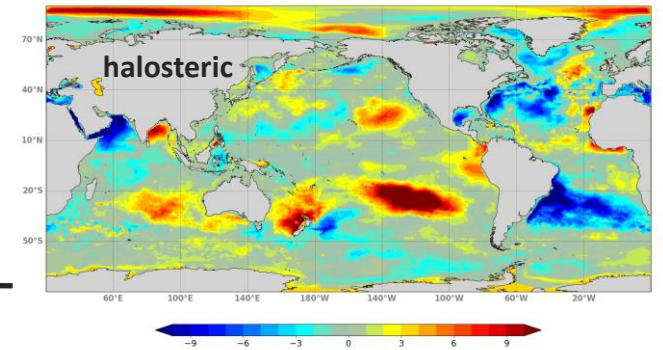
GLORYS4_RUN08.1c Trend mass (mm/year) 1993-2017



GLORYS4_RUN08.1c Trend termost (mm/year) 1993-2017



GLORYS4_RUN08.1c Trend halost (mm/year) 1993-2017



- Very good agreement between AVISO and model SSH_equivalent
- Steric/mass repartition reasonable
- Sulu, Med and Black Seas: suspicious signals in mass trend. Should be compared with others estimates
- High spatial variability in thermos/halo trends

Arctic sea ice volume and thickness

- Great validation effort on Sea ice thickness (in situ, satellite).
- Large uncertainties in reanalyses and in the observations
- All reanalyses agree that Arctic sea ice volume has declined, but not by how much

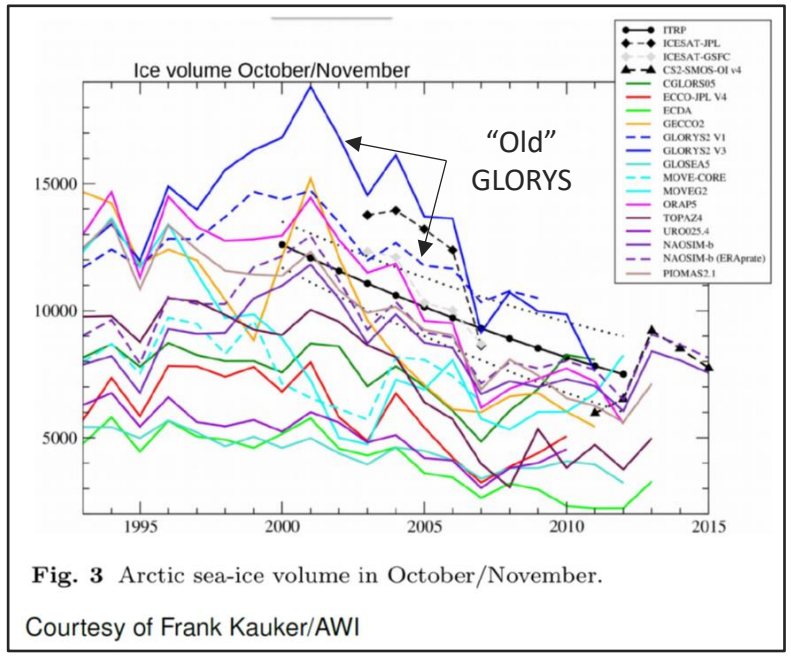
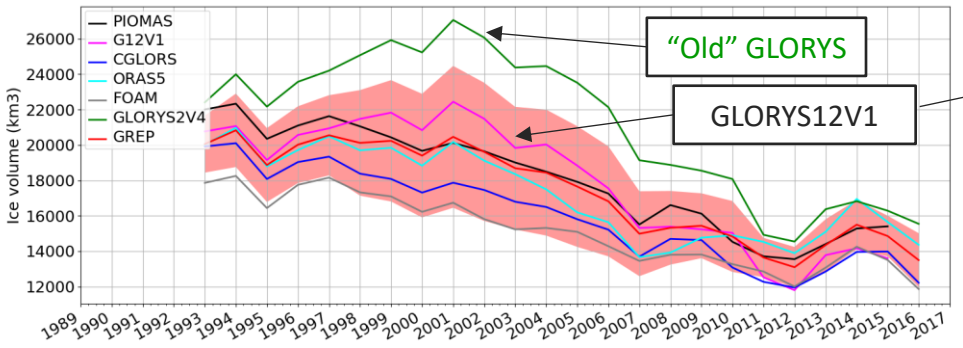


Fig. 3 Arctic sea-ice volume in October/November.

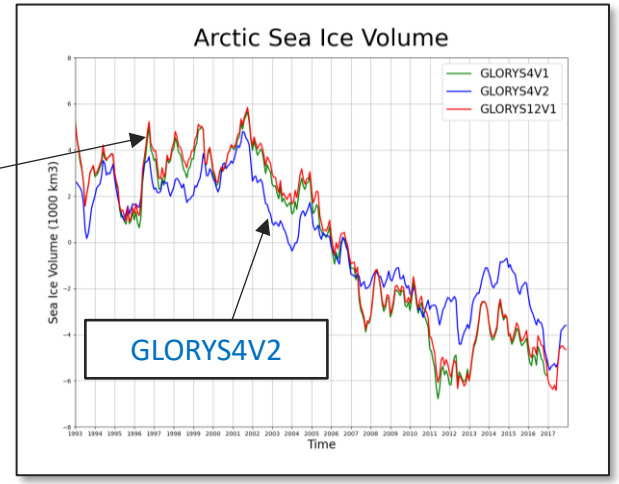
Courtesy of Frank Kauker/AWI

Also see Uotila et al. 2019 – POLAR ORA-IP

Annual mean sea ice volume



- Already large reduction of sea ice volume with GLORYS12V1 → more in accordance with others reanalyses. No changes with resolution



- Reduction of the negative trend with the upcoming GLORYS2V4
- No changes with resolution

Better accordance of GLORYS Arctic sea ice volume with ensemble of reanalysis with time being …

Evolution of GREP

- Future GREP reanalyse (at 1/4°) will be based on upgrade version of each member
- ERA5 forcing, general use of multi-category of sea ice model, upgrade of assimilated observations.
- New member(s) will be added to enrich the uncertainty estimate

System name	CGLORS	ORAS	GLORYS
Ocean Models			
OGCM	NEMO at 1/4°, 75 vertical levels But different parameterizations		
Ice model	LIM2	LIM2	LIM2
Atmospheric Forcing	Era-Interim/Era5		
Time range	1993-2021		
Assimilation characteristics			
DA scheme	3DVAR	3D_NEMOVAR	SEEK
SLA assim	DT2014		
In situ	EN402	EN402	CORA
SSS/SST/3D relaxation	Flux-correction everywhere	Nudging	None
Sea-Ice DA	Nudging	L4 SIC	L4 SIC
Assim. frequency	weekly	weekly	weekly

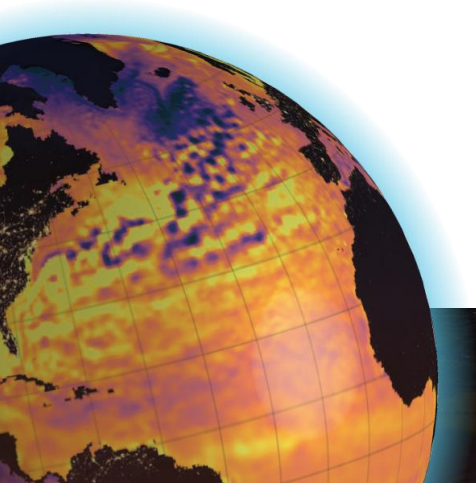
General characteristics of current GREP

New release end of 2025

System name	CGLORS	ORAS	GLORYS	New member
Ocean Models				
OGCM	NEMO at 1/4°, 75 vertical levels But different parameterizations			
Ice model	CICE	SI^3	SI^3	
Atmospheric Forcing	ERA5			
Time range	1993-2024			
Assimilation characteristics				
DA scheme	3DVAR	3D_NEMOVARv6 Revised R and QC	SEEK	
SLA assim	DT2021 + new MDT + spatial unbias	DT2021	DT2021 + Mass imposed (GRACE, ISBA,...); global steric only diagnosed	
In situ	EN422	EN422	CORA	
SSS/SST/3D relaxation	Flux-correction everywhere	OSTIAv2 reprocessed SST WOA18 climatology for 3D nudging + new BC	OSTIAv2 reprocessed SST new BC	
Sea-Ice DA	Bivariate (SIC/SIT)	L4 SIC	L4 SIC	
Assim. frequency	weekly	weekly	weekly	

General characteristics of future GREP

- **Conclusion:**
  - GLORYS12V1 and GREP are broadly used in the community
  - New versions are under development
  - Promising results on new treatment of GMSL (Mass/steric separation) and Arctic sea ice volume
- **Perspectives:**
  - 2025 production of new global 1/12° (and twin ¼°) reanalysis covering 1993-present. 1 year is needed to produce Global 1/12° and release of products in 2026
  - Production of a new version of GREP based on upgraded global ¼° reanalyses, release end of 2025.
  - New Global ¼° reanalysis will be ready in 2025 and GLORYS12V2 in 2026 for new intercomparison exercises: MER-EP (Drévillon's talk on monday)



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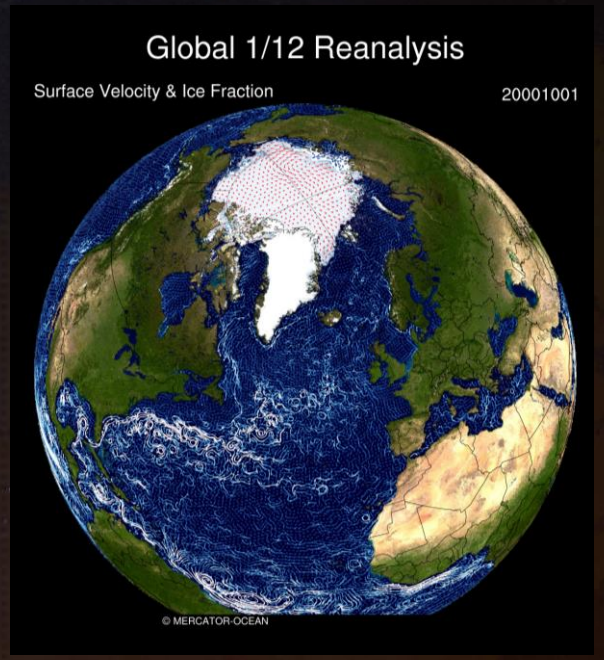
Thank you!



Snapshot of surface velocity and Sea Ice fraction

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