GLO-OBS reprocessing

Global hydrographic variability patterns from CMEMS global products

Stephanie Guinehut[1], Sandrine Mulet[1], Marie Drevillon[2], Jerome Gourrion[3], Nathalie Verbrugge[1], Gilles Garric[2], Charles Desportes[2], Yann Drillet[2], Simona Masina[4], Andrea Storto[4], Laura Jackson[5], Drew Peterson[5], Richard Wood[5], Hao Zuo[6], Magdalena Balmaseda[6]

[1]CLS
[2]Mercator Ocean
[3]CNRS/Coriolis
[4]CMCC, Bologna, Italy
[5]UK Met Office, Exeter, UK
[6]ECMWF, Reading, UK

PLAN

- Description of the CMEMS products intercompared
    1. ARMOR3D: MULTI-OBSERVATIONS (SATELLITES, INSITU PROFILES)
    2. CORA-OA : FROM INSITU PROFILES
    3. GREP: ENSEMBLE NUMERICAL MODEL
- Global time series of T and S
- North Atlantic signals
- Pacific signals

DESCRIPTION OF THE CMEMS PRODUCTS INTERCOMPARED:

1. ARMOR3D: MULTI-OBSERVATIONS (SATELLITES, INSITU PROFILES)

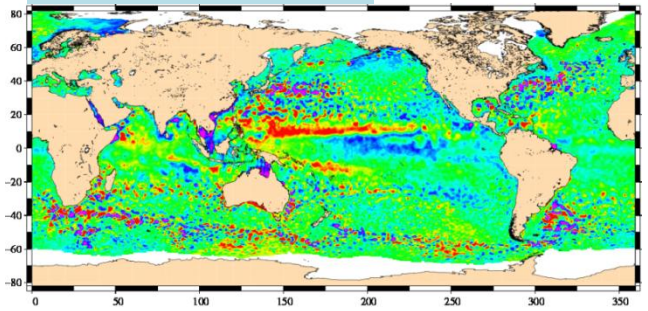
2. CORA-OA : FROM INSITU PROFILES

3. GREP: ENSEMBLE NUMERICAL MODEL

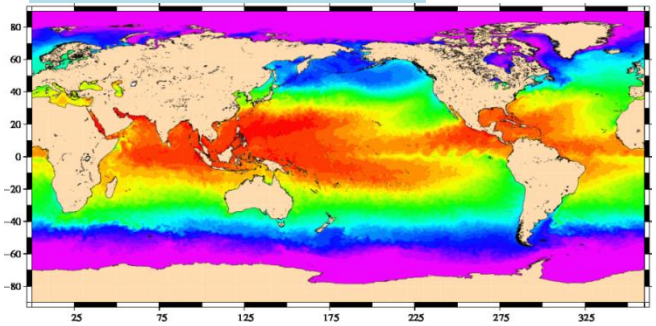
ARMOR3D : 3D T/S/UVg

Overview of the method / Step 1 REP

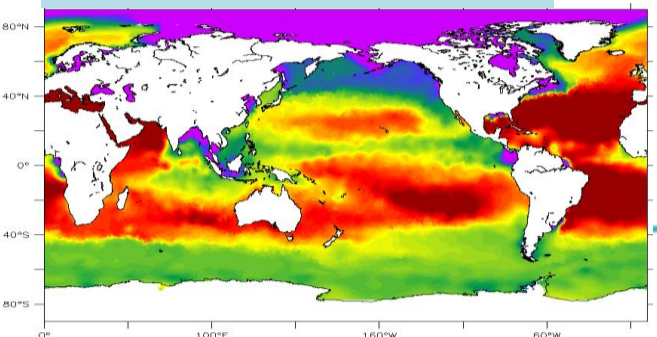
SLA [CMEMS]



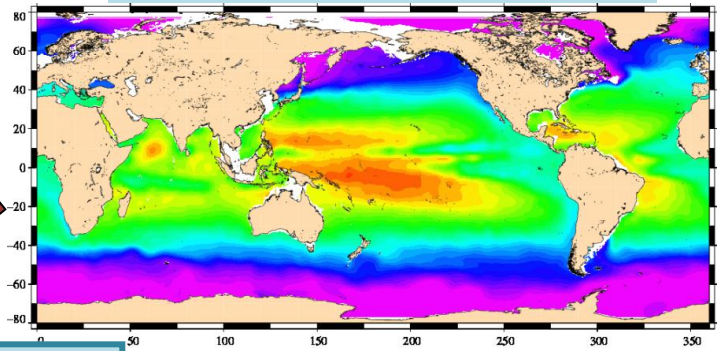
SST [Reynolds]



SSS [GLO-OBS/CMEMS]



Climatology T/S [WOA13]

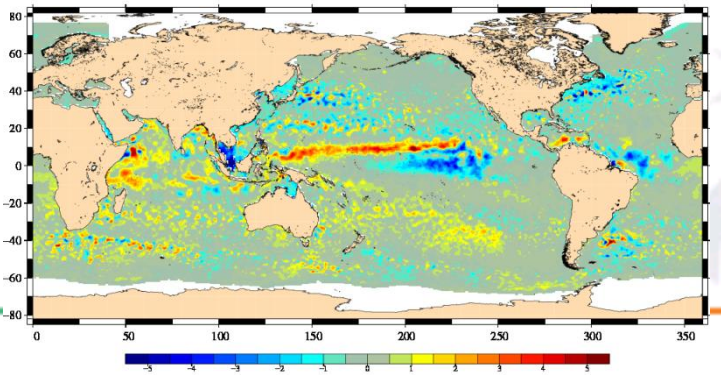


1

multiple linear regression

$$T = \alpha.SLA + \beta.SST' + Tclim$$
$$S = \gamma.SLA + \mu.SSS' + Sclim$$

Synthetic T'



1

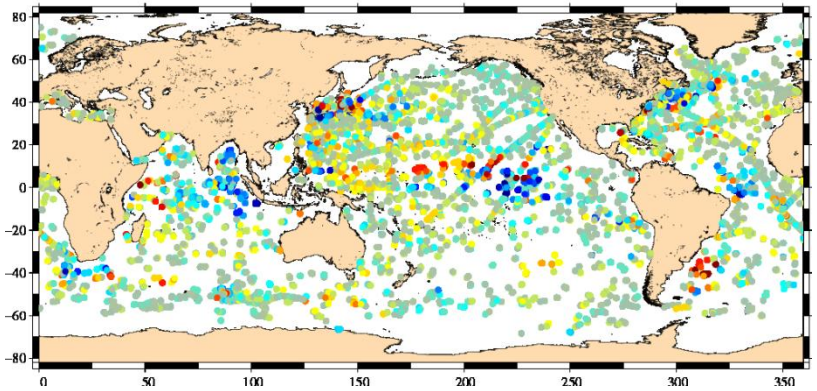
Synthetic T/S

➔ **Provides the mesoscale part of the signal**

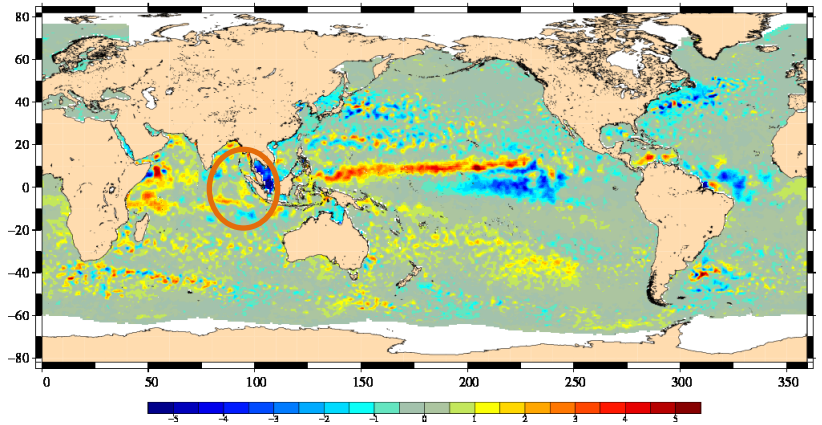
ARMOR3D : 3D T/S/UVg

Overview of the method / Step 2

In-situ T/S [CMEMS]

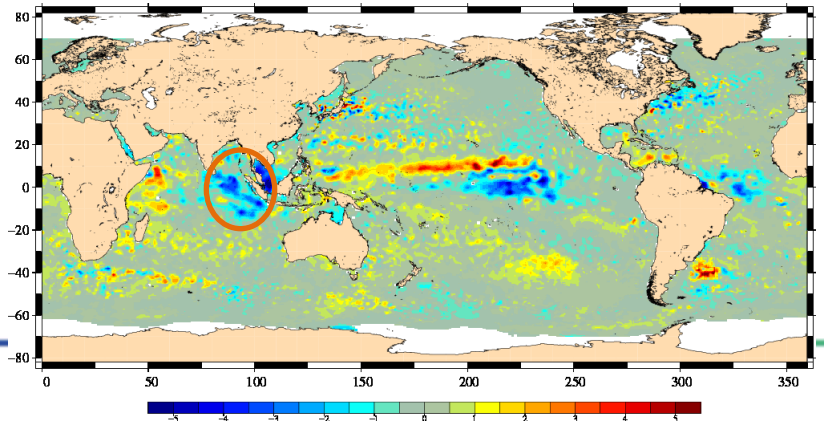


1 **Synthetic T/S**



2 optimal interpolation

Combined T'



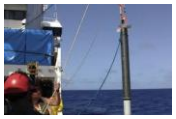
2 **Combined T/S**

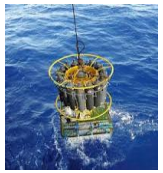
➔ **Correct the large-scale bias introduced during step 1**

ARMOR3D reprocessing

- **Method: multi-observations product**
  - **Start from a T/S climatology (WOA1/4°)**
  - **Step1: Vertical projection of variability and small scales from surface fields (SLA, SST, SSS)**
  - **Step 2: Correction of bias by combination with T/S in-situ profiles**
  - **Step 3: Thermal wind equation referenced at the surface: Estimation of geostrophic current and geopotential height**
- **DATA**
  - **3D In-situ temperature, salinity, geostrophic current, geopotential height**
  - **January 1993- December 2016**
  - **weekly/monthly**
  - **1/4° regular grid**
  - **33 levels (0 to 5500 m)**

REP CORA-OA



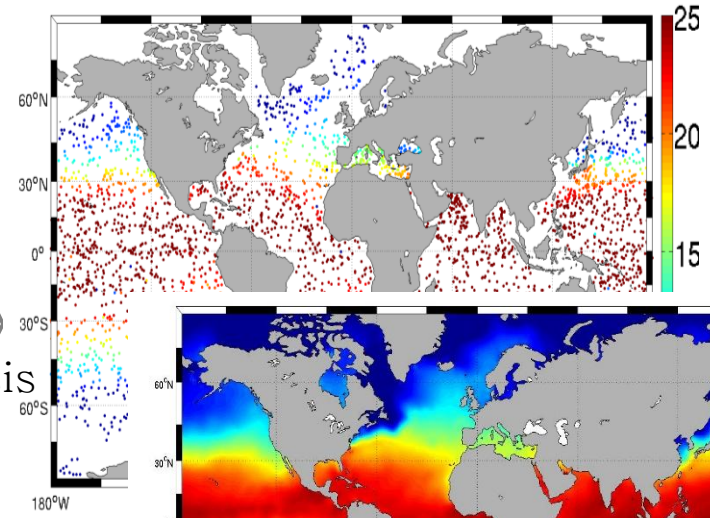

In-situ Measurements

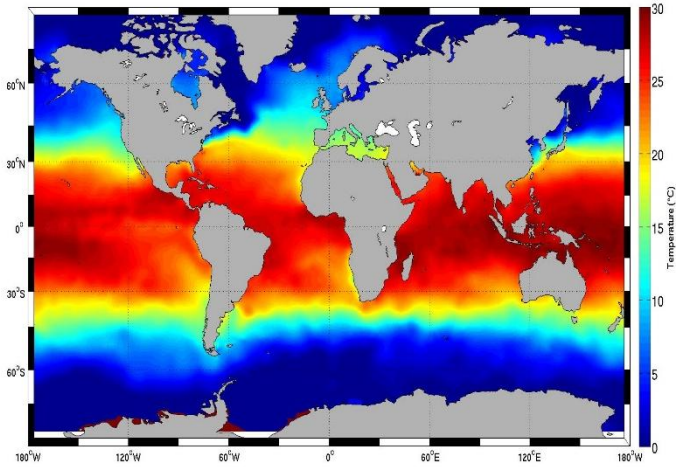
- Regional TAC
- ARGO
- Oceansites
- GTSPP
- Scientific campains
- GOSUD/EOG/..

ISAS Software

Formating
+ validation
+ Objective Analysis

In situ Dataset





CORA OA

- Objective analysis on a standard 3d grid
- Global coverage, 1990-2015
- 152 vertical levels
- 0.5degree x 0.5degree
- Easy to handle

GREP: Ensemble reanalysis

Reanalysis	Production centre	COMMON	Model version	Surface Forcing	ASSIMILATION
GLORYS2V4	**Mercator Océan**	**NEMO, ORCA1/4°** **75 vertical levels** **TKE** **Altimetry ERA : 1993-2015** **ERAinterim and bulk formulae** **Observations : SST, SLA, T/S profiles, SIC** **Multivariate assimilation, monovariate for the SIC**	NEMO3.1 LIM2	No surface nudging precipitation, flux correction Climatological runoff + ice shelf and iceberg melting	SAM2 (SEEK) Large scale bias correction 7-day assimilation window Merge MDT (obs+model) **Reynolds SST, CORA**
FOAM-GLOSEA5v13 (hereafter GLOSEA5)	**UK Met Office**		NEMO3.4 CICE4.1	SST, SSS surface nudging	NEMOVAR (3Dvar) Bias correction 1-day assimilation window **EN4**
C-GLORS	**CMCC**		NEMO3.4 LIM2	SST, SSS, SIC surface nudging	OceanVar (3Dvar) Large scale bias correction 7-day assimilation window Model MDT **Reynolds SST, EN4**
ORAS5	**ECMWF**		NEMO3.4.1 LIM2	Surface waves SST, SSS surface nudging	NEMOVAR (3Dvar) 5-day assimilation window **HadISSTv2 SST, EN4**

Status of the GREP product

Distribution:

GREP = 4 members + Ensemble Mean + Standard Deviation

Resolution 1°
Grid size 380x180
75 levels
Monthly files (223M):

- sea_water_salinity (PSU)
- sea_water_potential_temperature (deg C)

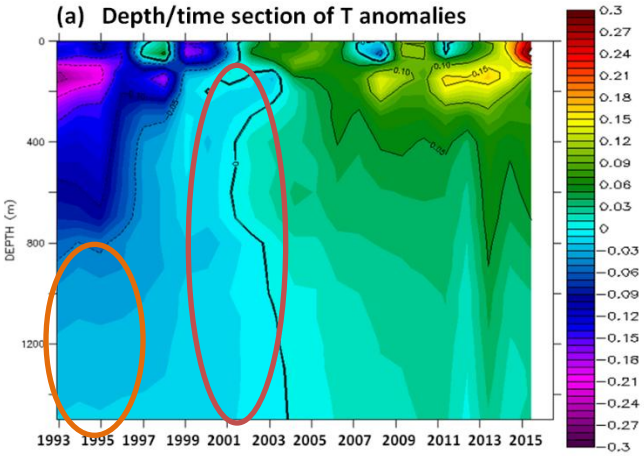
See http://marine.copernicus.eu

GLOBAL TEMPERATURE TIME SERIES IN THE DIFFERENT PRODUCTS:

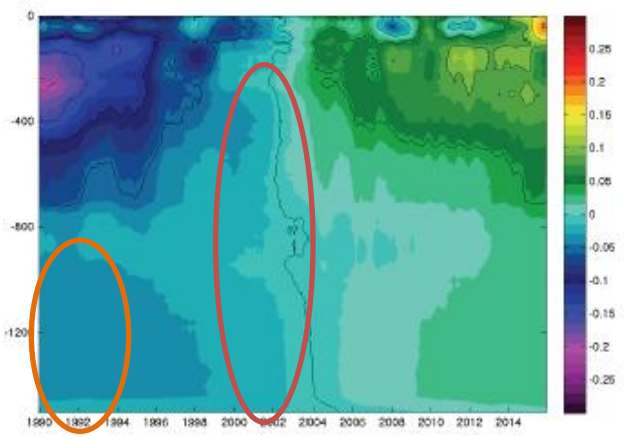
- **2 OBSERVED**
- **4 MODELS**
- **1 ENSEMBLE MEAN**

Intercomparaison: Temperature anomaly Time Series

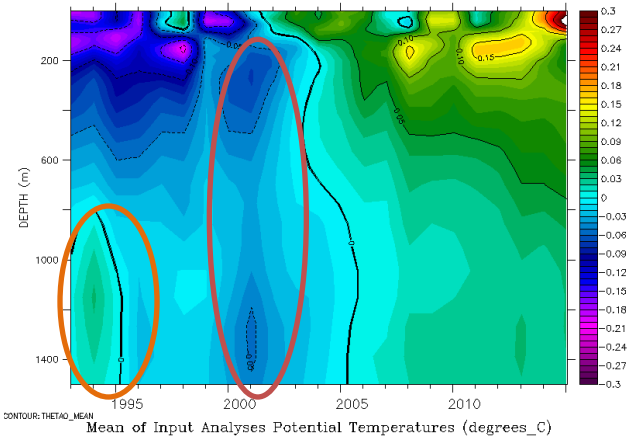
ARMOR3D



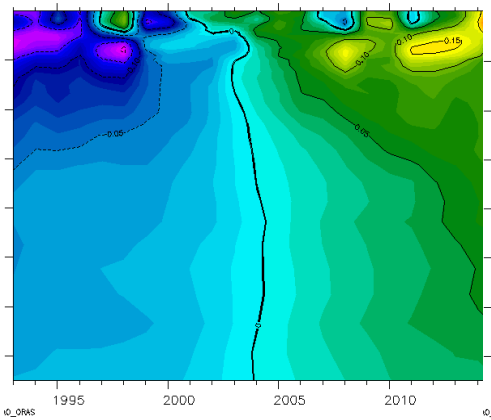
CORA-OA



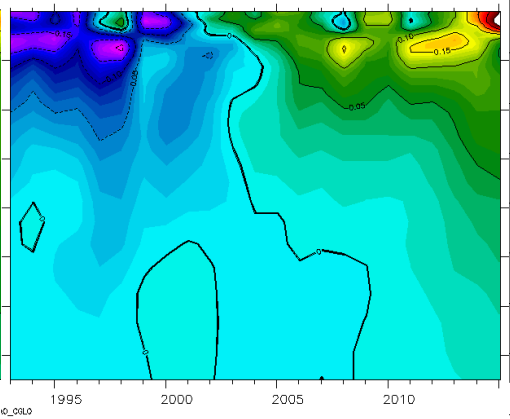
GREP



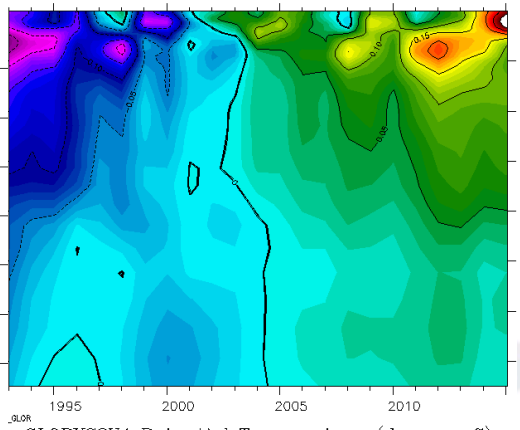
ORAS5



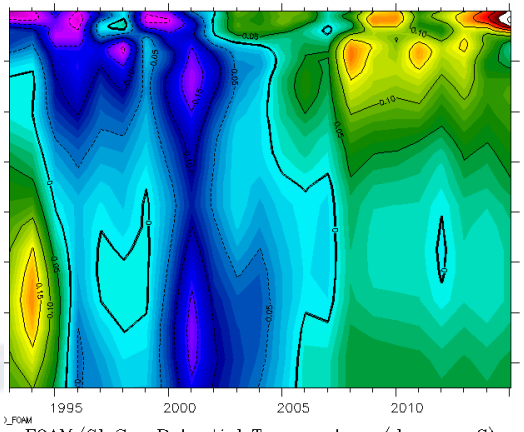
C-GLORS05



GLORYS2V4

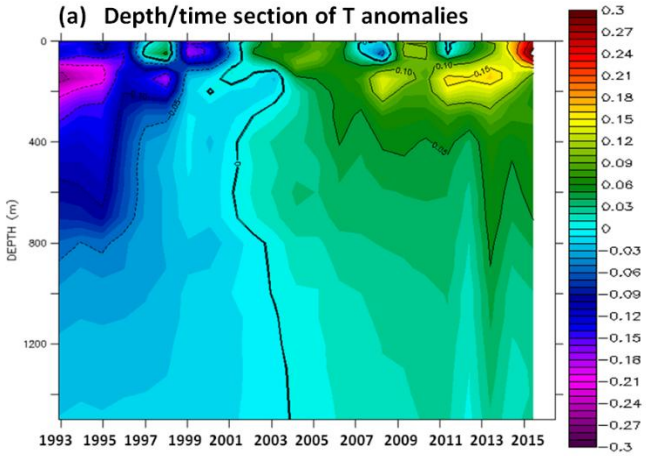


GloSea5

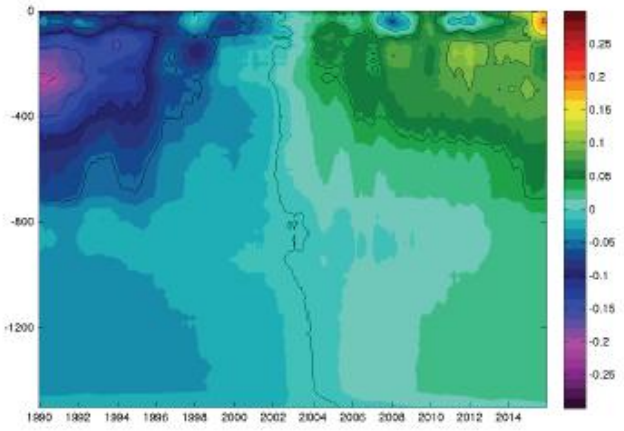


Intercomparaison: Temperature anomaly Time Series

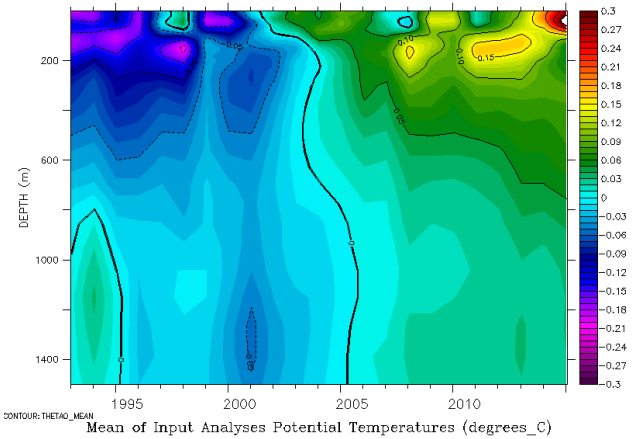
ARMOR3D



CORA-OA

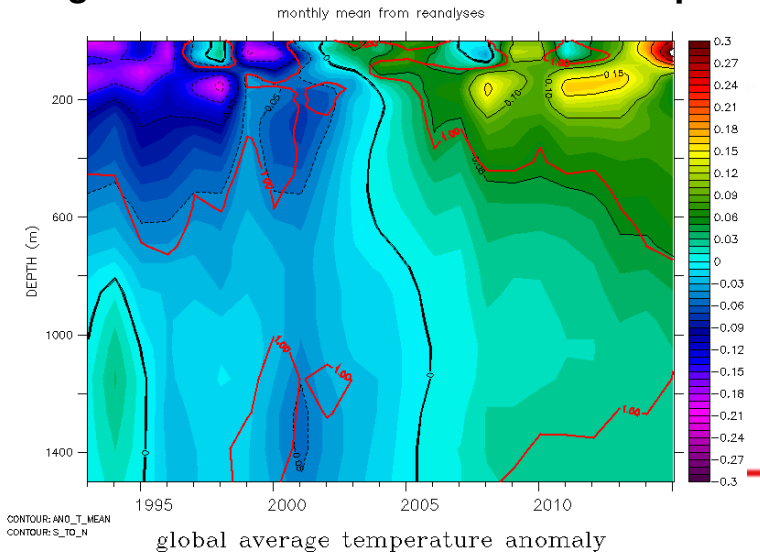


GREP



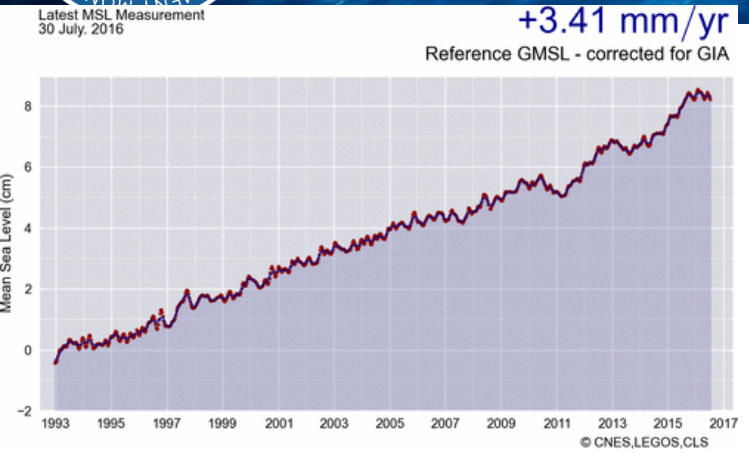
- → Consistent pattern, warming mostly in the first 200m depth
- → More differences deeper, especially at the beginning of the period (because of lack of observations…)
- → Compute signal/noise ratio to underline reliable pattern i.e. S/N>1 (Masina et al (2015) : Done with GREP only

signal/noise ratio: ensemble mean/spread

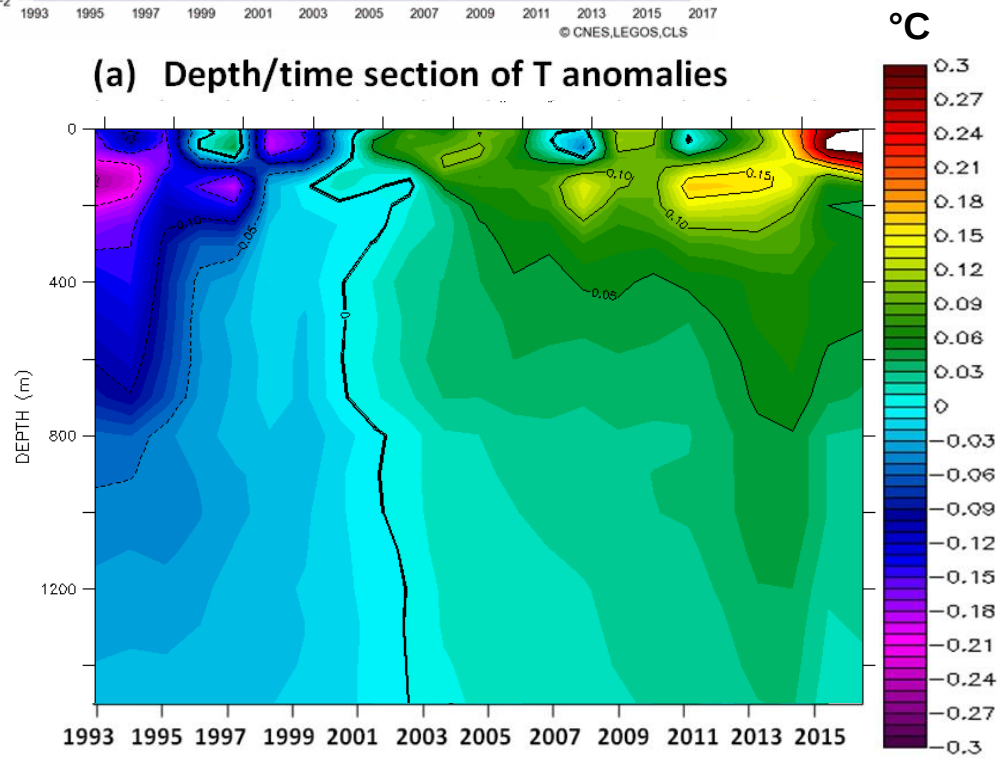


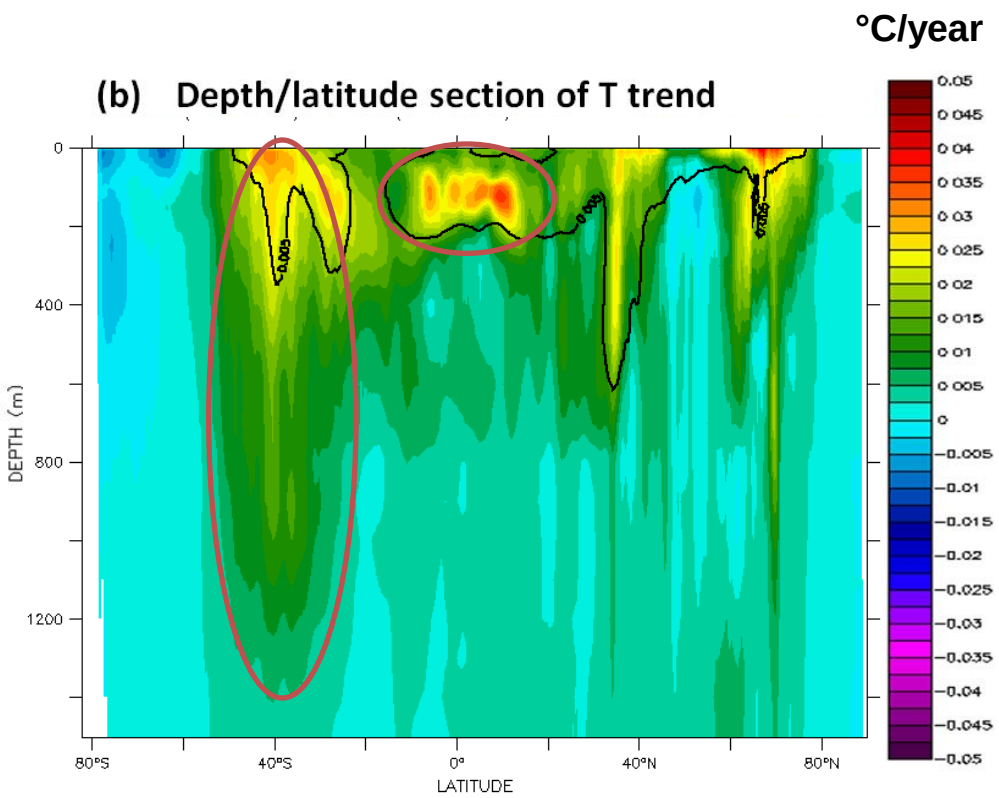
Ocean State Estimate

Hydrographic variability pattern – 1993-2016



- Global Mean Sea Level rise
- 3D evolution for the Temperature field ➔ warming
  - The amplitude of the warming is not spatially uniform
  - Southern Ocean: strong trend down to 1400 m
  - In the Equatorial band, the signal in the thermocline is linked to ENSO events





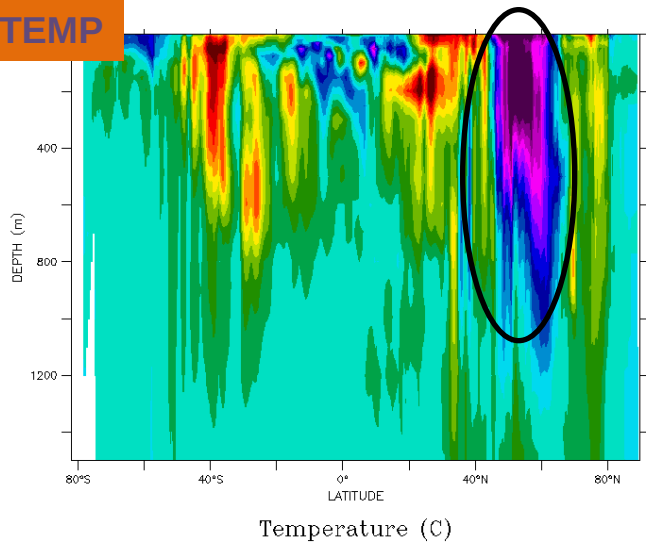
THERMOHALINE SIGNAL ANALYSIS IN THE ATLANTIC OCEAN:

2015-2016

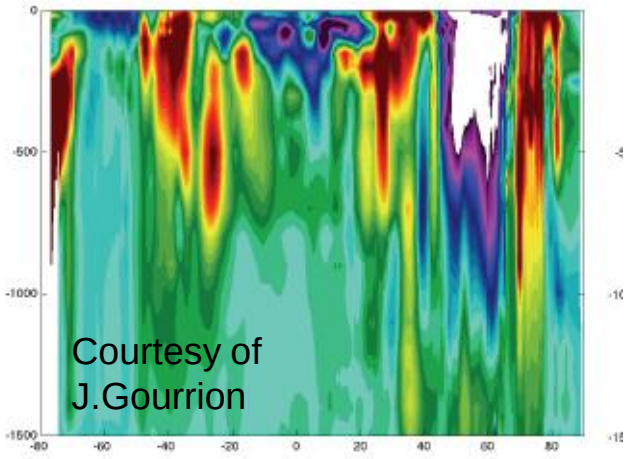
Intercomparaison: temperature/salinity anomaly in 2015 in the Atlantic

TEMP

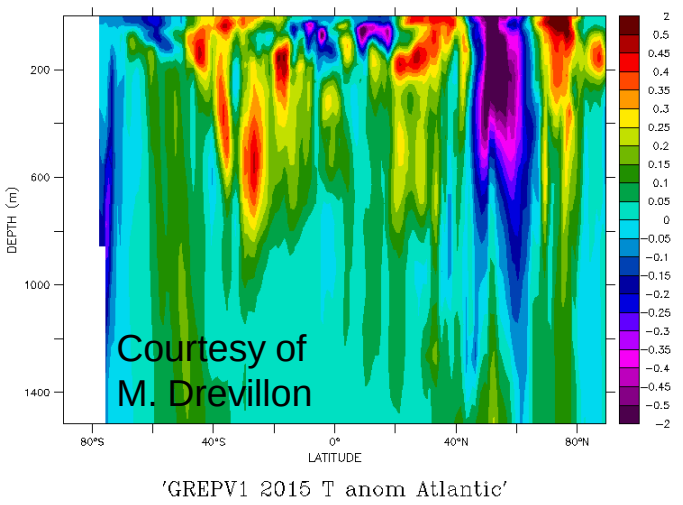
ARMOR3D ref 1993-2014



CORA-OA ref 1993-2014

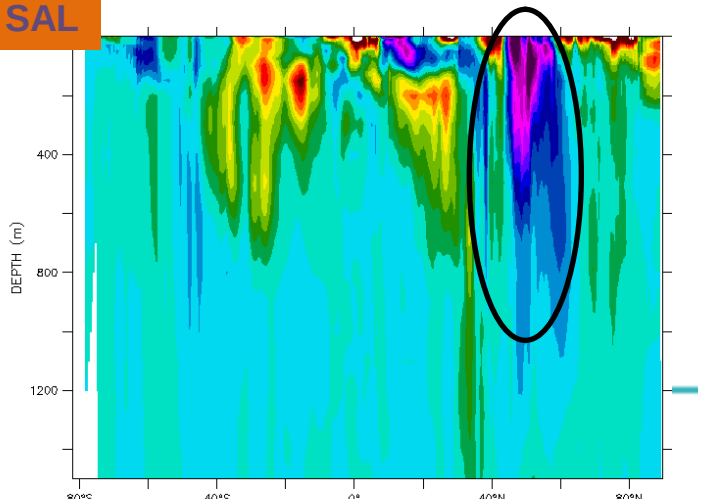


GREP-V1 ref 1993-2014

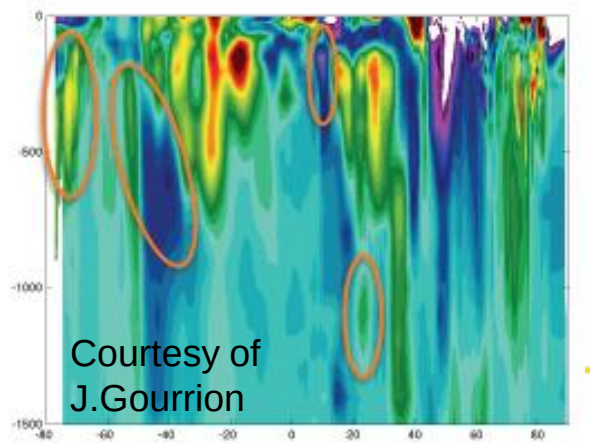


SAL

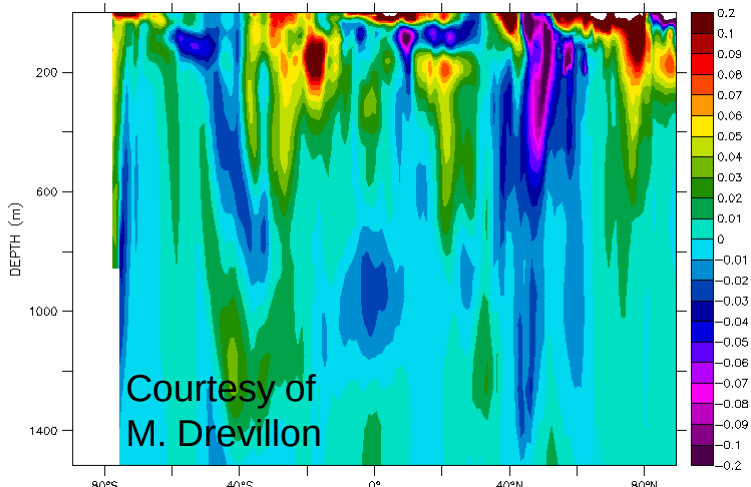
ARMOR3D ref 1993-2014



CORA-OA ref 1993-2014

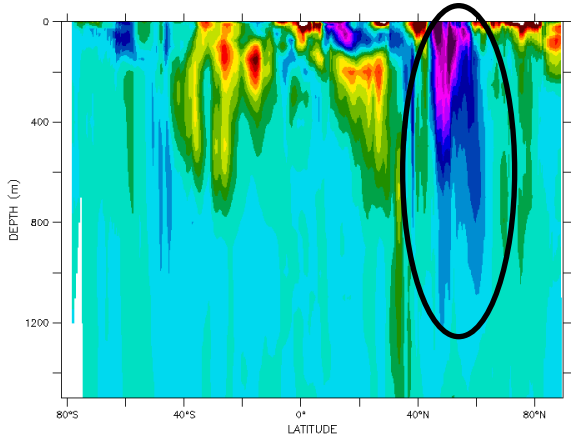


GREP-V1 ref 1993-2014

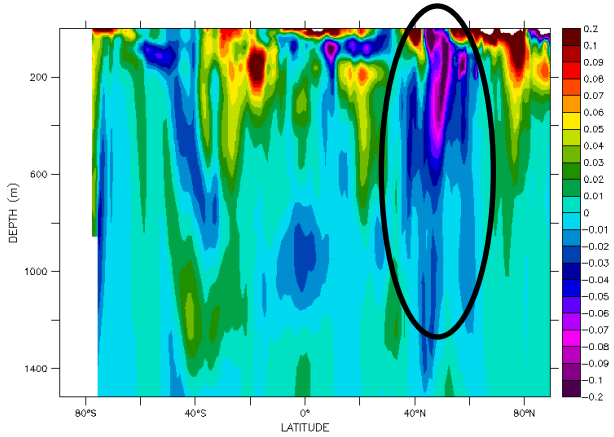


Intercomparaison: salinity anomaly in 2015 in the Atlantic

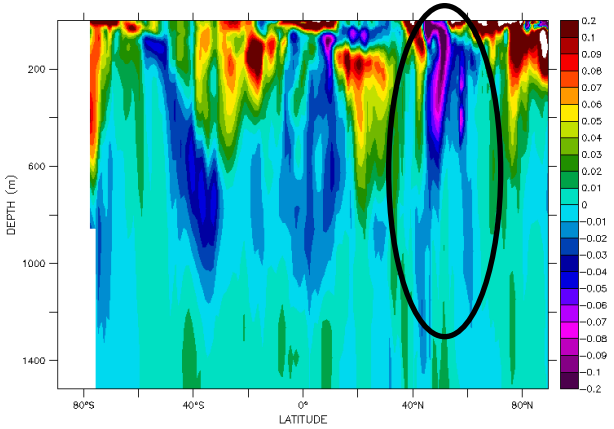
ARMOR3D ref 1993-2014



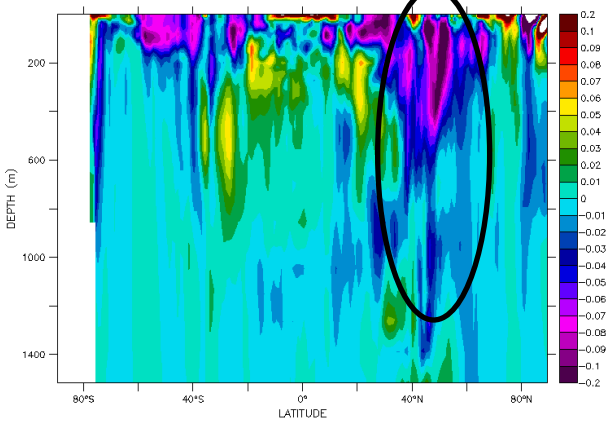
GREP-V1 ref 1993-2014



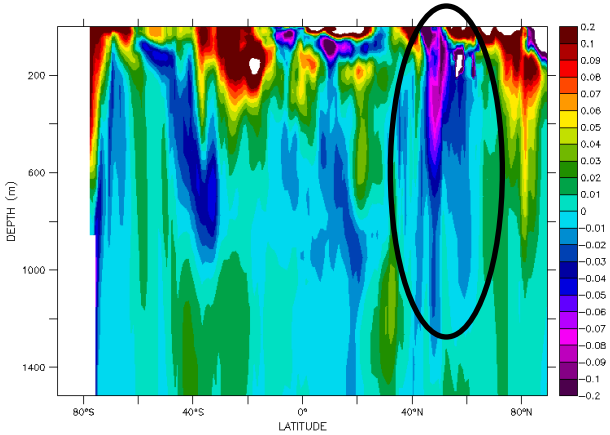
C-GLORS05 ref 1993-2014



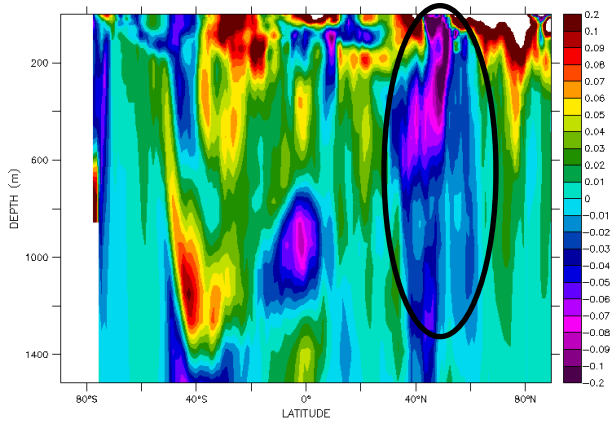
ORAS5 ref 1993-2014



GLORYS2V4 ref 1993-2014



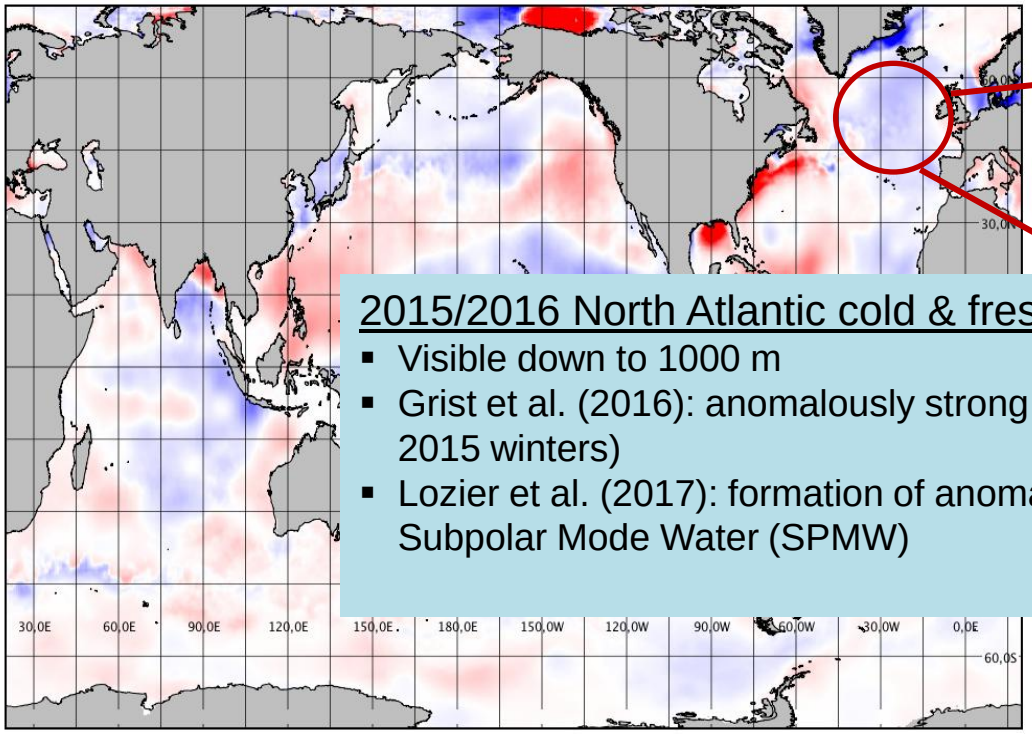
GloSea5 ref 1993-2014



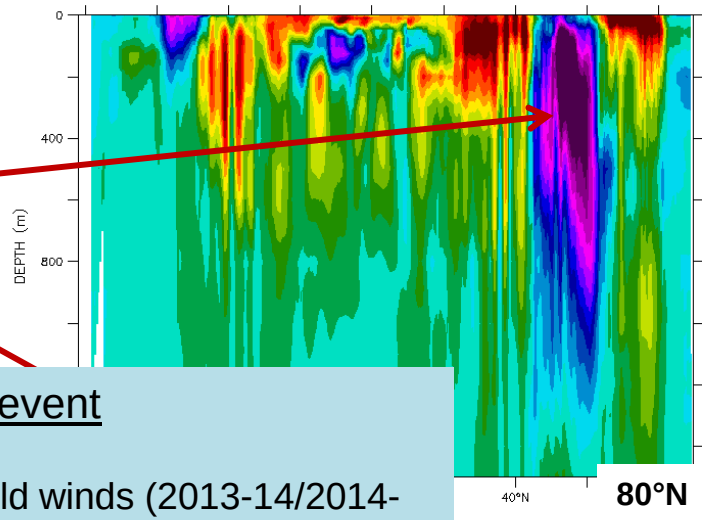
Ocean State Estimate

2016: SSS & cold/fresh event in Atlantic Ocean

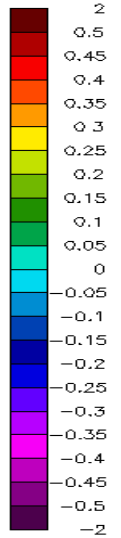
SSS - **2016** anomalies



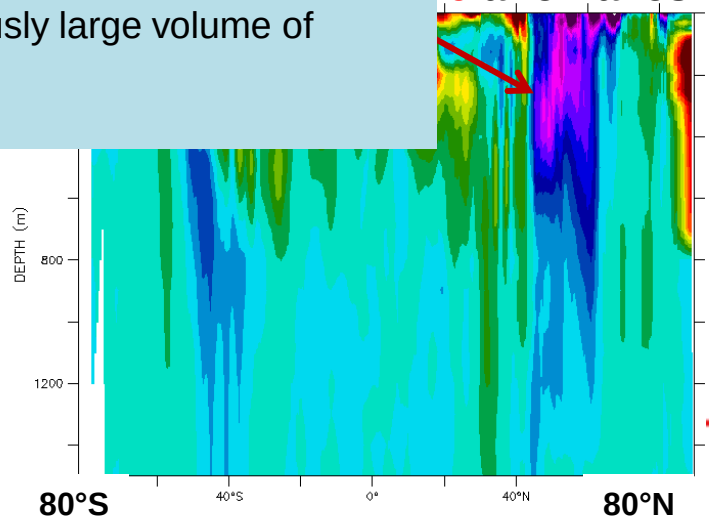
Atlantic - TEMP - **2016** anomalies



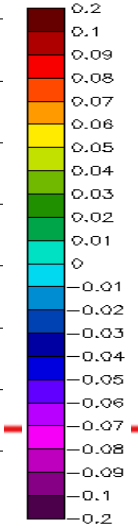
°C



2016 anomalies



psu



2015/2016 North Atlantic cold & fresh event

- Visible down to 1000 m
- Grist et al. (2016): anomalously strong cold winds (2013-14/2014-2015 winters)
- Lozier et al. (2017): formation of anomalously large volume of Subpolar Mode Water (SPMW)

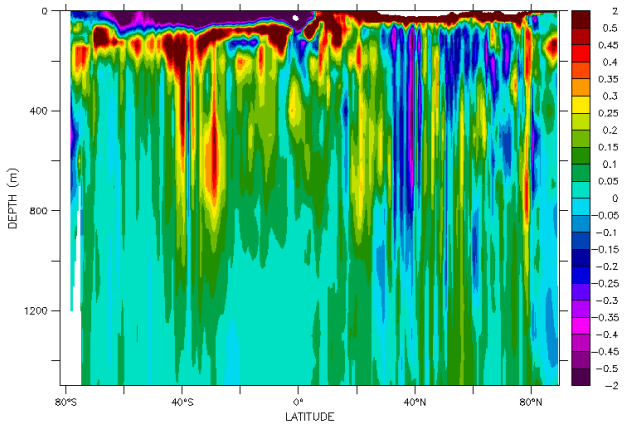
SPMW formation in ARMOR3D : 2014-2015

> TEMPERATURE

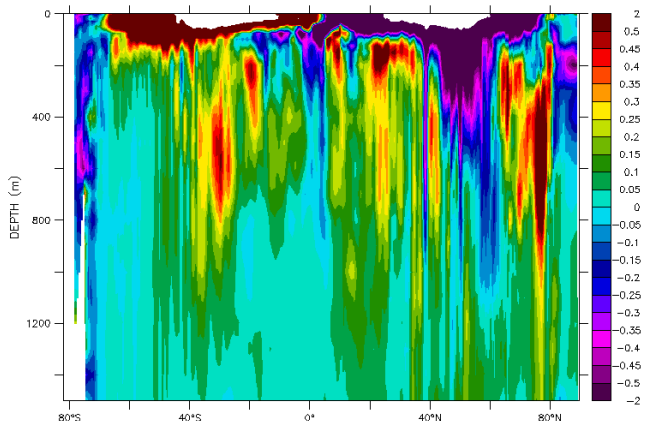
Winter (march) : mixing

Summer (july): Stratification

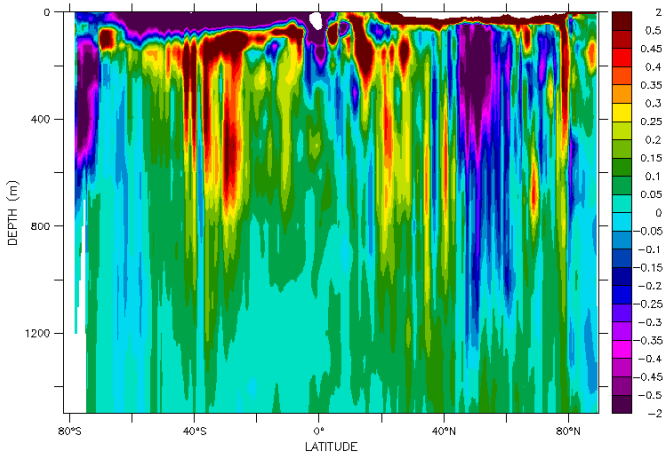
July 2013



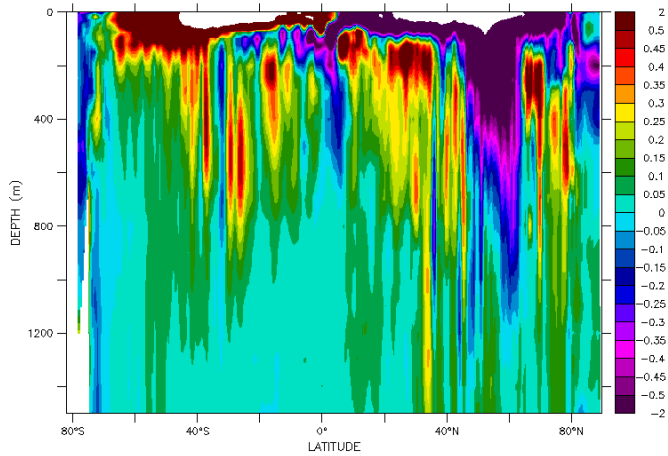
March 2014



July 2014



March 2015



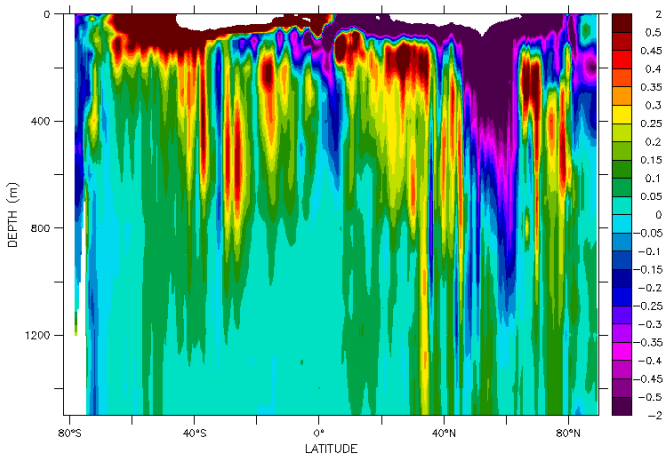
SPMW formation in ARMORD3 : 2015-2016

> TEMPERATURE

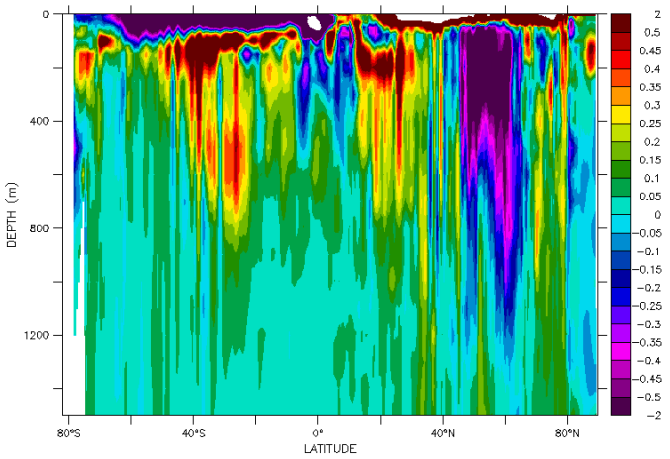
Winter (March) : mixing

Summer (July): Stratification

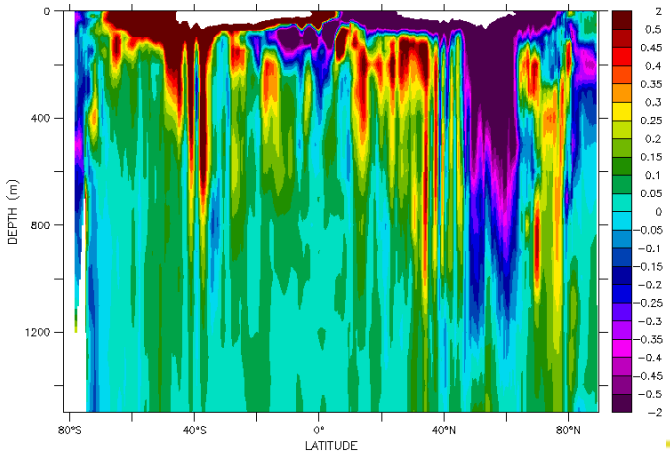
March 2015



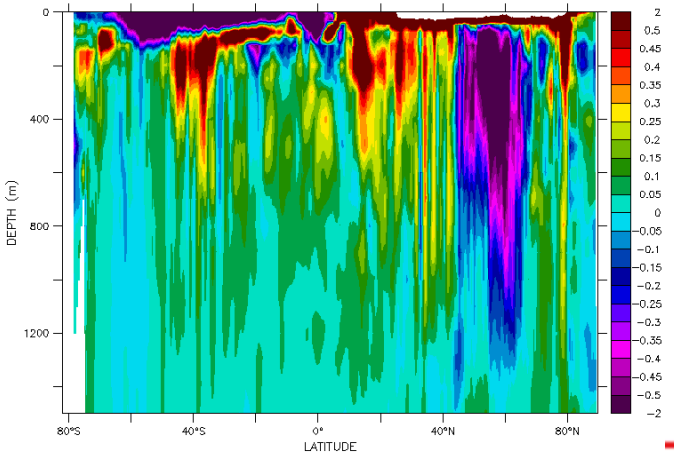
July 2015



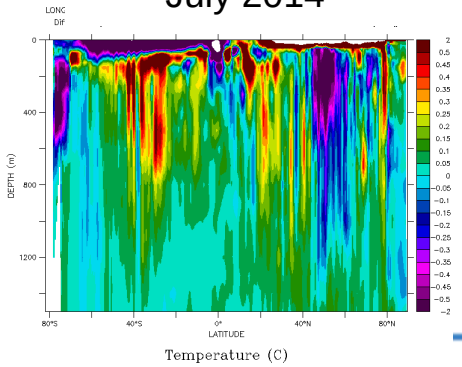
March 2016



July 2016



July 2014

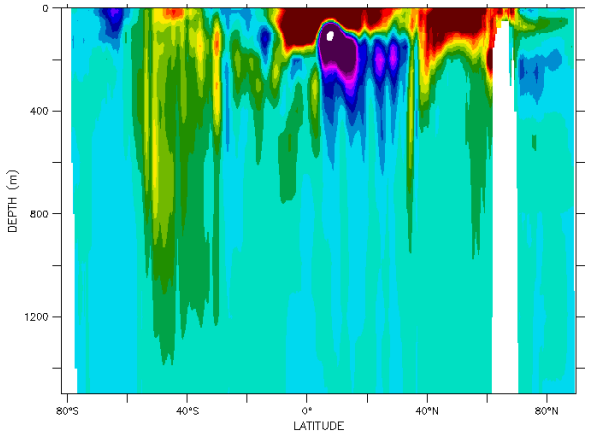


THERMOHALINE SIGNAL ANALYSIS IN THE PACIFIC OCEAN:

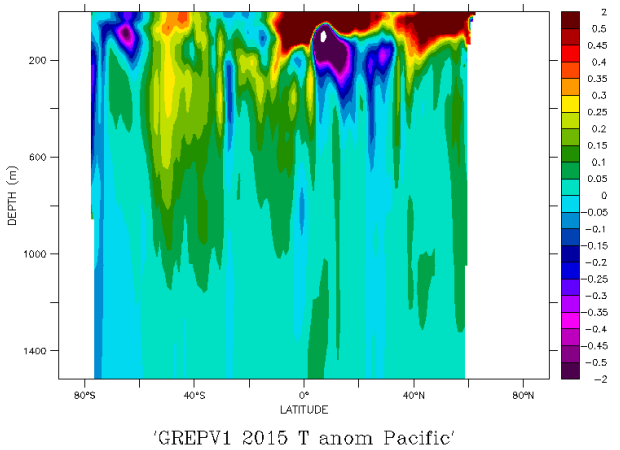
- SOUTHERN OCEAN
- EL NINO SIGNATURE

Temperature anomaly in 2015 relative to 1993-2014 in the Pacific

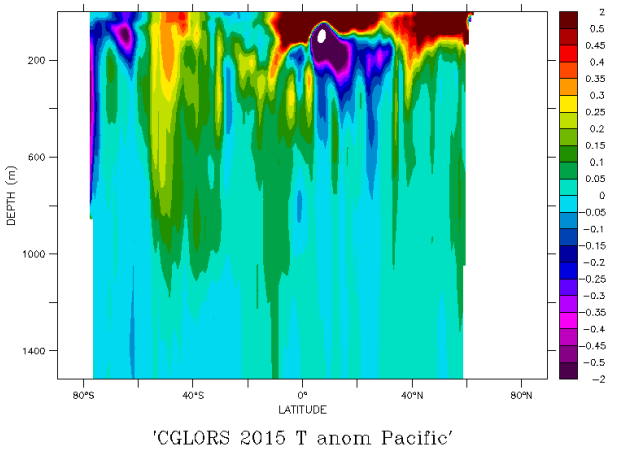
ARMOR3D ref 1993-2014



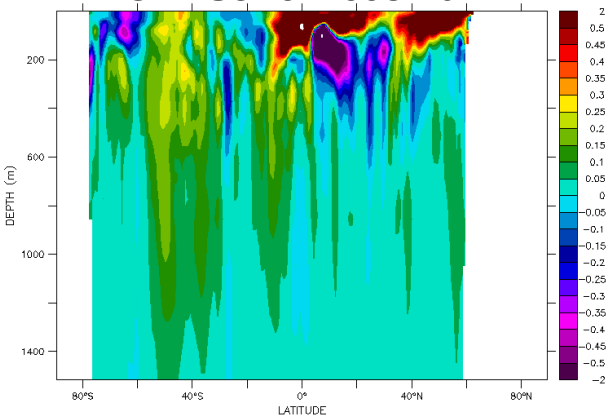
GREP-V1 ref 1993-2014



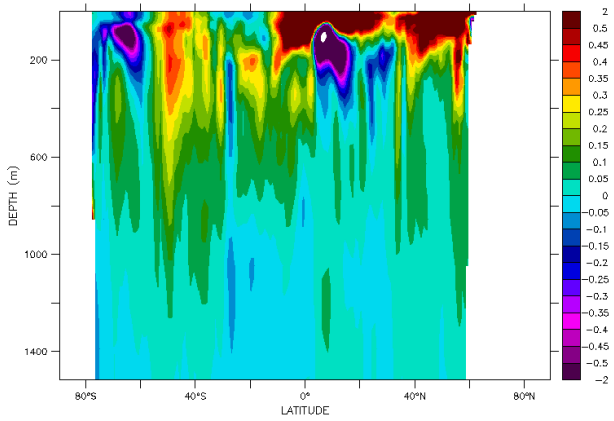
C-GLORS05 ref 1993-2014



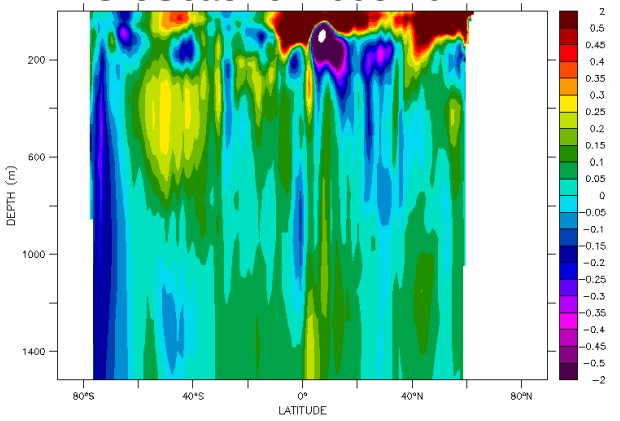
ORAS5 ref 1993-2014



GLORYS2V4 ref 1993-2014



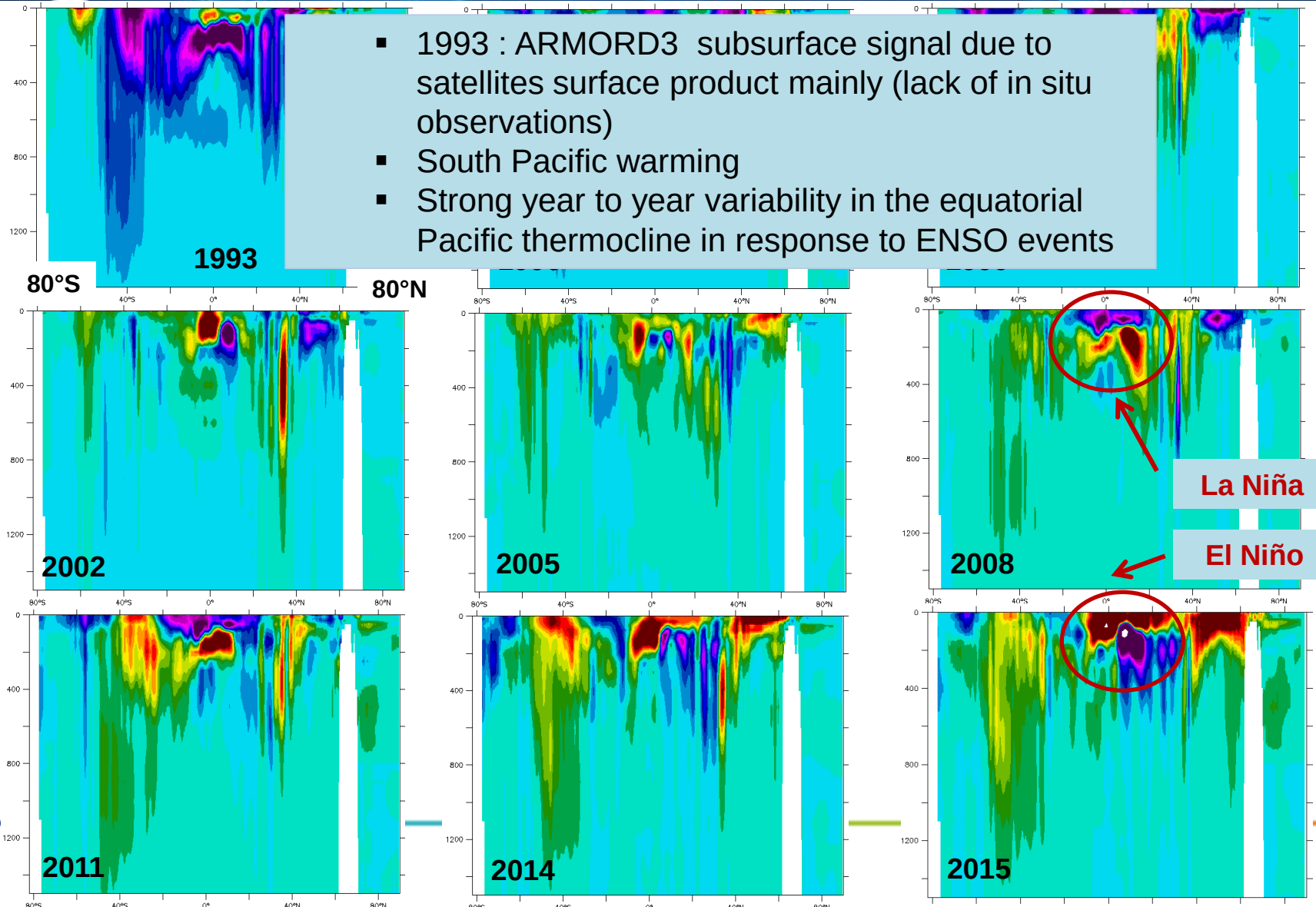
GloSea5 ref 1993-2014



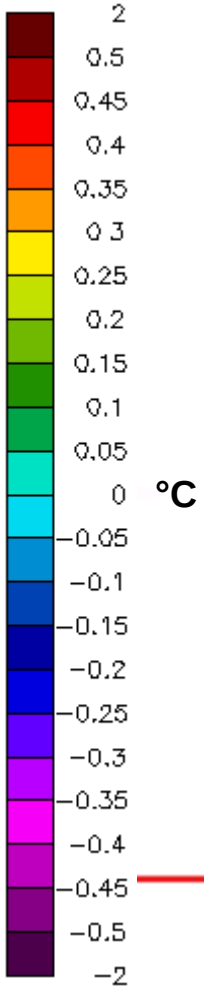
Ocean State Estimate

TEMPERATURE: Year to year variability in the Pacific Ocean

- 1993 : ARMORD3 subsurface signal due to satellites surface product mainly (lack of in situ observations)
- South Pacific warming
- Strong year to year variability in the equatorial Pacific thermocline in response to ENSO events



Depth/latitude section of T anomalies



Conclusions and perspectives

- Common and consistent patterns appear in this intercomparaison work
  - Global warming from 1993 to 2015
  - Fresh and cold event in the subpolar Atlantic region in 2015 and 2016
  - El Nino/La Nina events
  - South Pacific warming up to 1400-m depth

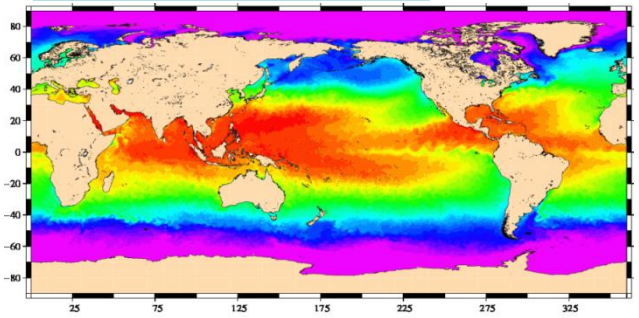
- Need to add signal/noise ratio for all the products to confirm…

SSS (& SSD)

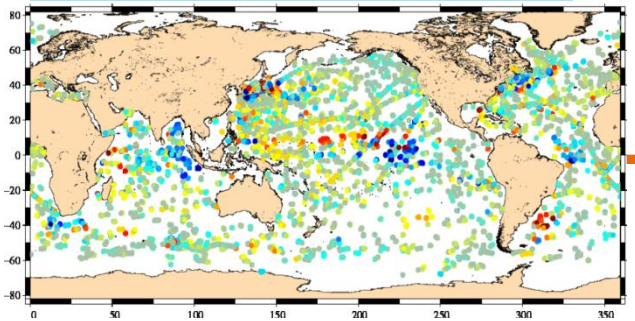
Overview of the method

SSS is an input data for ARMOR3D step 1

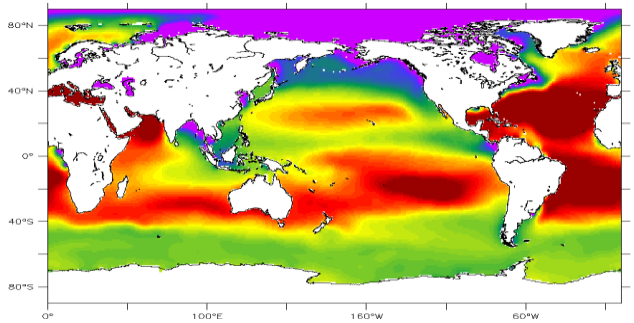
SST [Reynolds]



In-situ SSS/SSD [CMEMS]



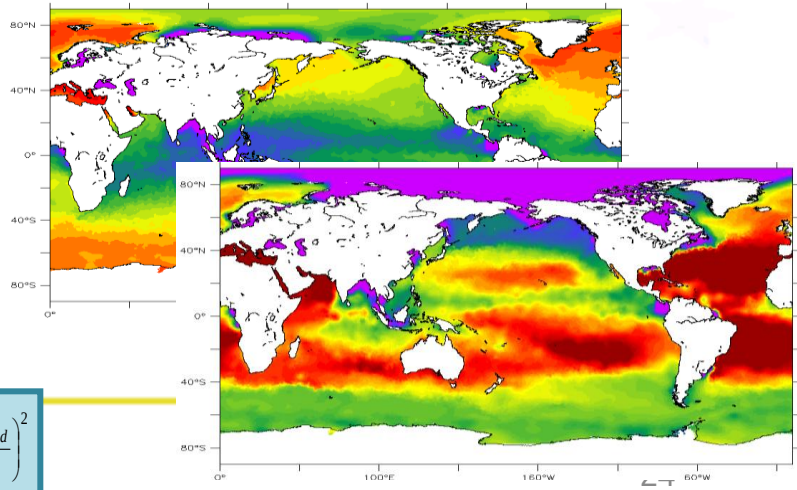
Background **CORA-OI** [CMEMS]



multivariate optimal interpolation

$$x_{analysis}=x_{bckg}+C(R+C)^{-1}(y_{obs}-x_{bckg})$$

SSS & SSD 1/4° regular grid



Hypothesis:

sea surface temperature (SST) and **sea surface salinity (SSS)** variations are correlated at scales smaller than the ones dominating atmospheric variability (in the open ocean)

→ **T and S** pairs identify **water masses**, thus **basically modified only by advection and mixing once large-scale variations are filtered out**

➔ **multi-dimensional covariance model:**

$$C(\Delta r,\Delta t,\Delta SST)=e^{\left(-\frac{\Delta t}{\tau}\right)^2}e^{\left(-\frac{\Delta r}{L}\right)^2}e^{\left(-\frac{\Delta SST_{filtered}}{T}\right)^2}$$