



**MERCATOR
OCEAN**
INTERNATIONAL

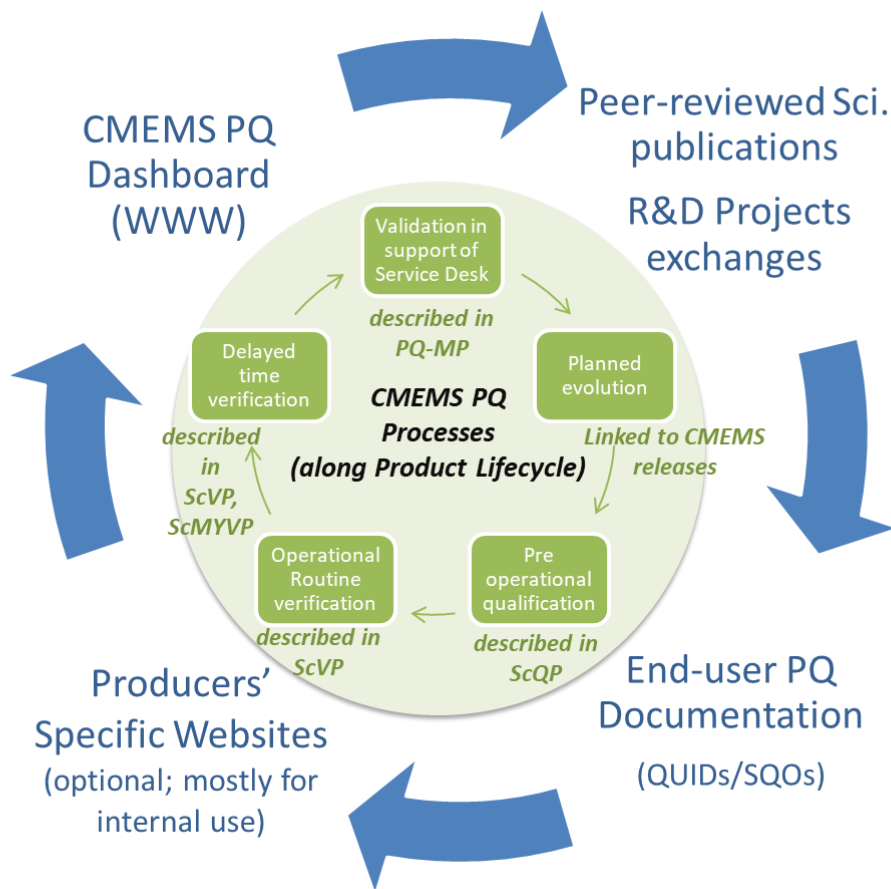
Verification of Mercator Ocean global ocean forecasts

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Mercator Ocean international team

Verification process

in the following, a short description of the verification process

CMEMS operational context



The validation is performed with metrics agreed within the international community (OceanPredict, CMEMS)

CMEMS PQ Documentation

Internal PQ Docs:

PQ-MP: PQ Management Plan
ScQP: Scientific Qualification Plan
ScVP: Scientific Validation Plan
ScMYVP: Sci. MultiYear Prod. Val. Plan.

End-User Docs (for each product):

QuID: Quality Information Doc
SQO: Synthesis Quality Overview **(New!)**

- Data assimilation performance, error tunings
- Models: what phenomena do we reproduce?
 - Water masses
 - Currents and transports
 - Variability
 - Mesoscale
 - high frequencies, tides
 - Waves
 - Biogeochemical phenomena
- Stability over time
- Forecast skill
- QC on assimilated data -> feedback to TACs
- Non regression with respect to previous versions

many plots produced every day
-> human check performed using internal website

Delayed time verification results

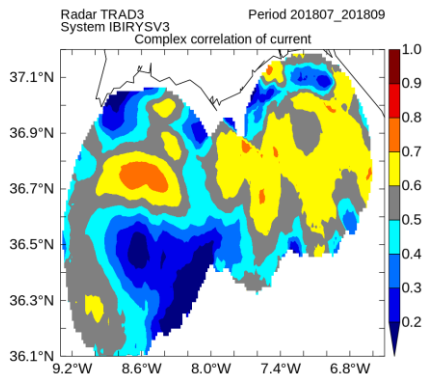
in the following, a summary of verification results, per variable

Metrics

“eulerian” comparison to drifters, moorings, **HF radars**, altimetry currents

Vector correlation
HF radars (total) and
IBIRYS currents in
summer 2018

Drifters vs PSY4 in
2019 (from Aijaz et
al, Oceanpredict
collaboration)



NB : “lagrangian” behaviour vs drifters is also assessed

Main issues identified

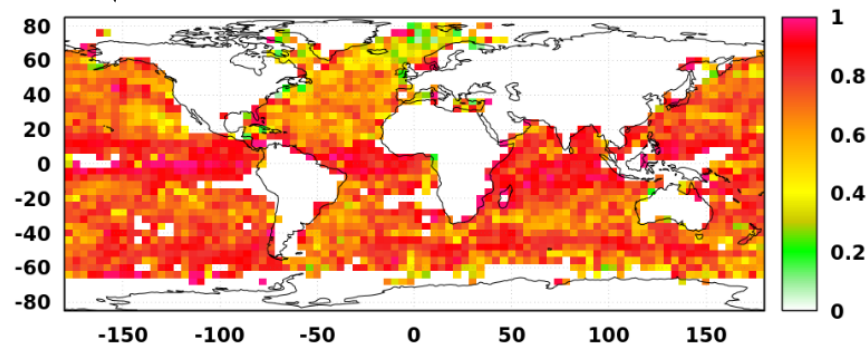
- Boundary and coastal currents, part of mesoscale not (well) constrained
- Overestimation in the tropics
- Underestimation in the mid latitudes
- Stokes drift important in subtropical gyres
- Small scales and gravity waves noise

Development of models

- Development of ORCA36
- including waves and tides
- Coupling with atmospheric boundary layer
- Implement HF forcing

Development of data assimilation

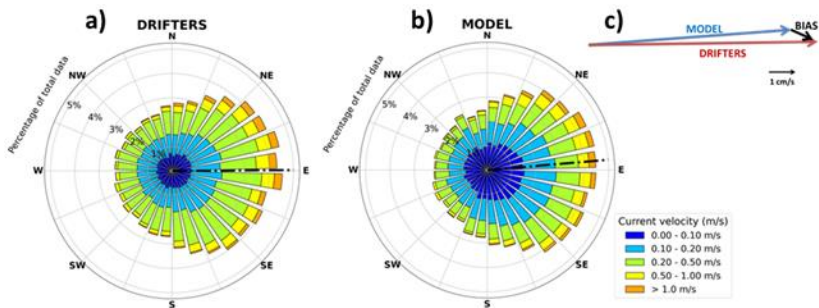
- filtering out or assimilating HF signal
- assimilation of wide swath altimeters, and future missions dedicated to surface currents
- observation operator and errors characterization



Metrics

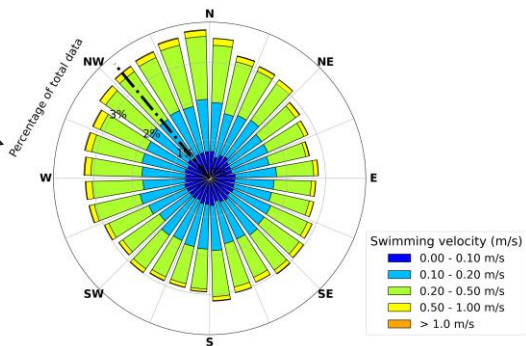
comparisons to **drifting buoys**, “lagrangian” behaviour vs drifters, argo floats, **turtles**

Drifters vs GLORYS12, validation for STAMM application (turtles)



Turtles swimming velocity can be deduced

Here Luth turtles in the North Pacific



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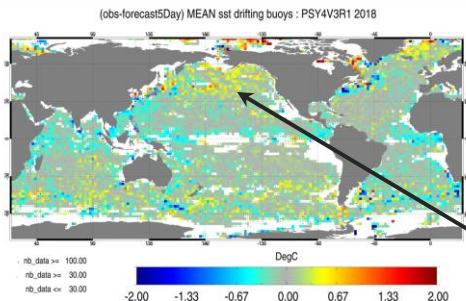


Development of data assimilation

- filtering out or assimilating HF signal
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Metrics

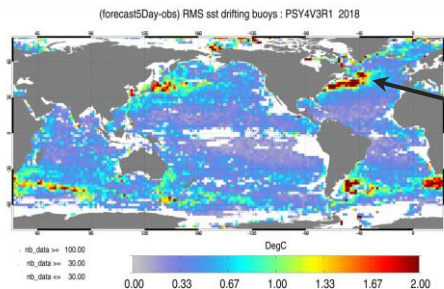
comparison to **satellite and buoys SST**



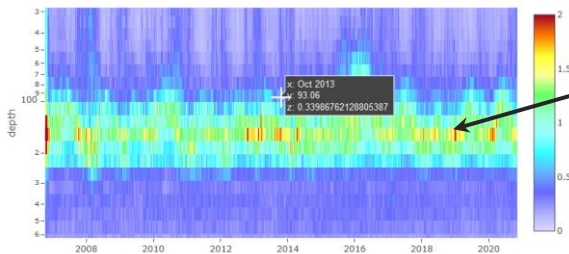
5-day forecast error is very similar to analysis error (not shown) except:

Large scale biases increase (warm tropics, cold mid-latitudes)

The uncertainty grows in high variability areas (western boundary currents...)



comparison to
ARGO/XBT/CTD
and HF
moorings,
Here RMS forecast –
obs in nino 4 box



Main issues identified

- SST biases
- SST forecast skill score < other global systems
- Key areas for SST: upwelling, subpolar gyres, ...?
- T(z) biases and drift under 700m
- T signature of undercurrents misplaced, overflows
- No HF signature of internal waves in the forecast

Development of models

- Work on surface layer mixing
- Work on internal tide modelling
- Coupling with waves and atmospheric boundary layer

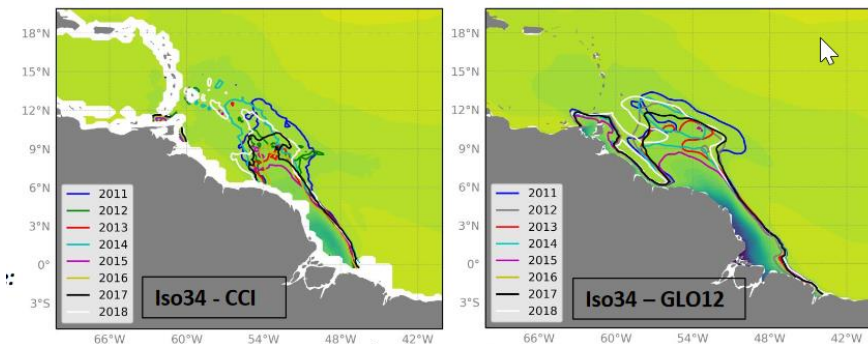


Development of data assimilation

- Assimilation of L3S SST, work on observation operator
- 4D cycles // daily analyses
- Regular improvement of MDT to reduce systematic biases
- Introduce deep argo to reduce biases at depth
- Work on initialization

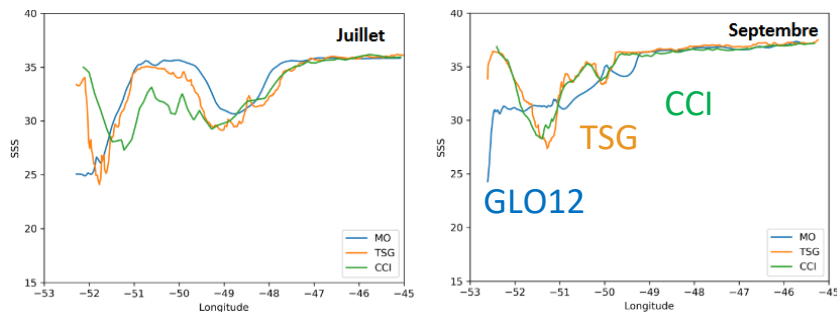
Metrics

comparison to **satellite ESA CCI SSS** and **TSG SSS**



*Amazon river **plume interannual variability** is captured but **freshwater extension** is too strong*

*comparison to **TSG** and **ESA CCI SSS***



Main issues identified

- SSS large scale biases linked with atmospheric biases
- S(Z) biases under 700 m
- Biases at river mouths and in coastal areas
- Too strong export freshwater along the coast compared to observations
- Large salinity errors at global scale mostly found in river plume extension due to missing tide effect and erroneous runoffs.

Development of models

- Test of interannual river outputs from GLOFAS
- Work on surface layer mixing
- Coupling with waves and atmospheric boundary layer
- Impact of tides at river mouths

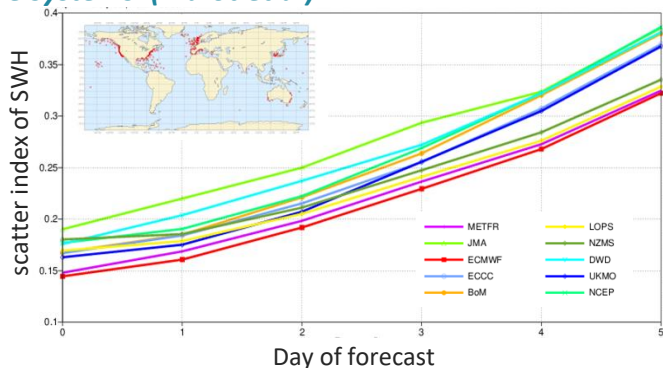


Development of data assimilation

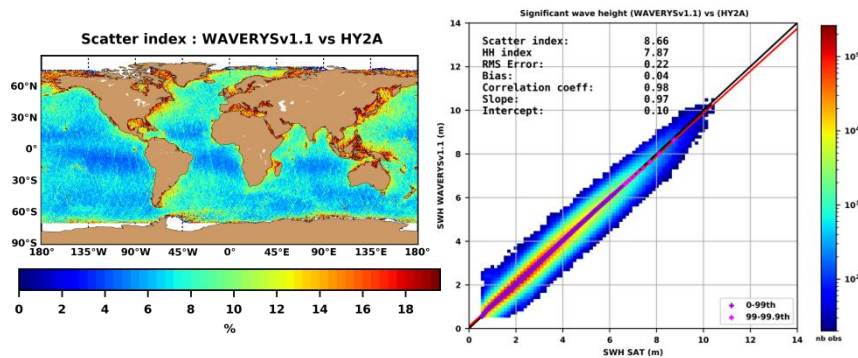
- assimilation of satellite SSS (SMOS/ESA CCI SS) in reanalyses

Metrics

Comparison to **wave buoys** : *GOOS intercomparison of wave systems (Bidlot et al)*



Statistics to **independent altimeters** : *ex WAVERYS*



Main issues identified

- Assimilation benefit vanishes quickly for waves (+30% of error in 2 days)
- Main errors in coastal situation
- Inject, dissipate and flow energy in adequate spectral bands
- Wave response to high frequency variability

Development of models

- Increase spectral resolution
- Better bathymetry
- Non-linear interactions source term
- Interaction with upper ocean dynamics (currents/tide) + atm forcing

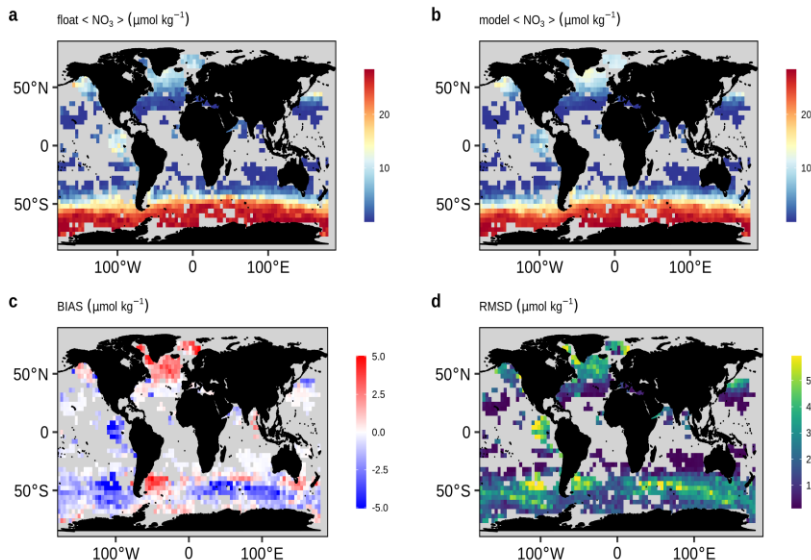


Development of data assimilation

- Persistence in DA
- Ensemble techniques for background errors
- Assimilation of new data:
 - 1/ High frequency SWH from swath altimetry (SWOT)
 - 2/ Directional wave spectra: S1 for now, CFOSAT in the future

Metrics

comparison to **satellite ocean colour maps**, **BGC argo**, and other in situ obs



Depth-averaged nitrate in the productive layer (max of MLD and euphotic depth) from Mignot et al. (in prep)

- Focus on process-oriented metrics rather than on specific variables
- Global, in 3D
- Direct obs. datasets but also reconstructions

Main issues identified

- Large scale structures and interannual variability are well captured
- Large amplitude of errors vs observations and poor forecast skill
- Models with physical DA are too productive in the Tropical band
- The bloom is taking place too early
- With physical DA, oligotrophic gyres tend to disappear in time

Development of models

- Understand and mitigate spurious enrichment due to physical data assimilation
- Sensitivity studies with a 1D version of the PISCES model

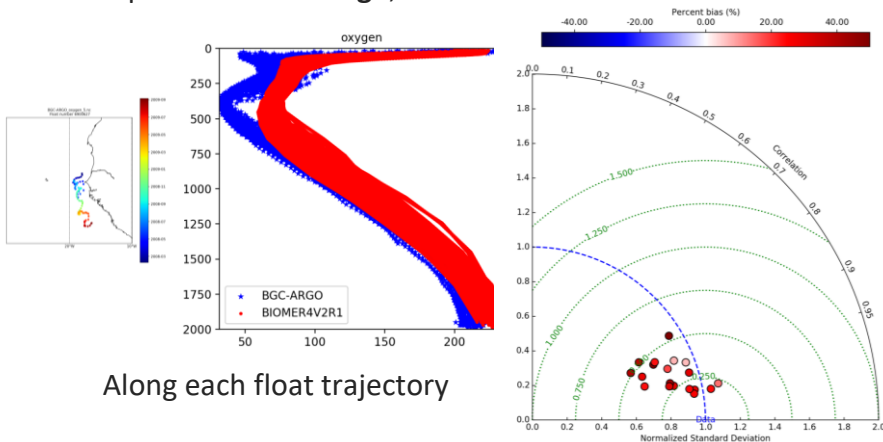


Development of data assimilation

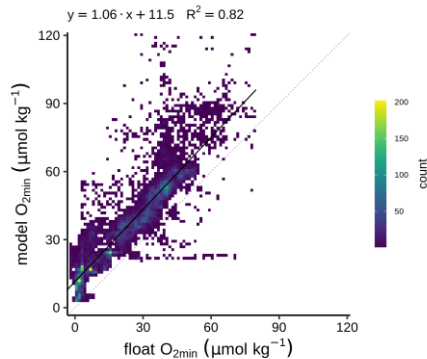
- Assimilation of satellite chlorophyll and relaxation to nutrient/chemical climatologies
- Work on assimilation of BGC argo

Metrics

comparison to **BGC argo**, and other in situ obs (PIRATA...)



OMZ metrics: Oxygen concentration at the O₂ minimum (Mignot et al. In prep)



Main issues identified

- The OMZs are reasonably well represented in the model
- The OMZ is too oxygenated due to physical DA
- Oxygen levels at 0 and 300 m depth are particularly well represented

Development of models

- Understand and mitigate spurious enrichment due to physical data assimilation
- Test the diurnal vertical migration of mesozooplankton in PISCES

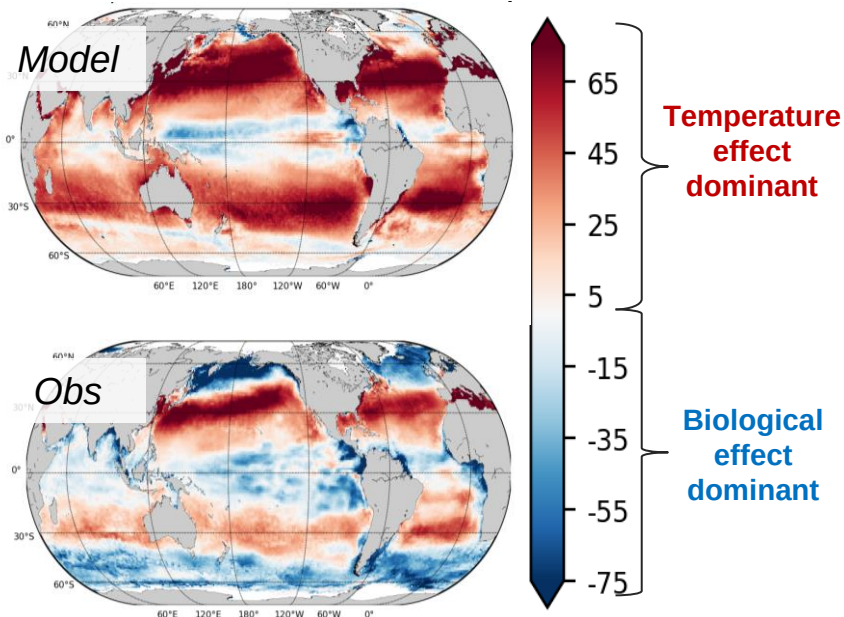


Development of data assimilation

- Assimilation of satellite chlorophyll and relaxation to nutrient/chemical climatologies
- Work on assimilation of BGC argo

Metrics

comparison to **BGC argo**, and other obs-based products



Main issues identified

- Large-scale features of the air-sea CO₂ flux is reasonably well represented by the model
- Biological-effect too low in the surface pCO₂ (too low inputs of DIC during ML deepening, too low PP during summer)

Development of models

- Understand and mitigate spurious enrichment due to physical data assimilation
- Sensitivity studies with a 1D version of the PISCES model

Development of data assimilation

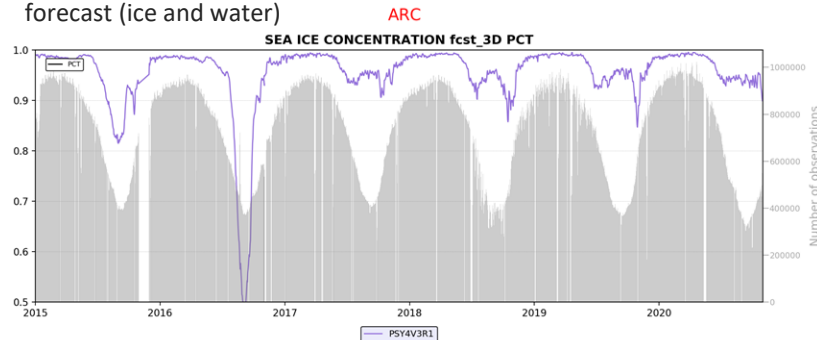
- Assimilation of satellite chlorophyll and relaxation to nutrient/chemical climatologies
- Work on assimilation of BGC argo and spco₂ maps

Study of which process constrains the spco₂ variations, according to the method of Takahashi et al. (2002)

Metrics

comparison to **satellite sea ice observations**

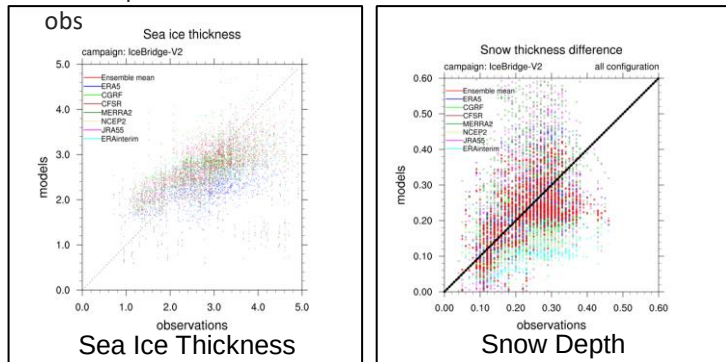
PCT: % of successful
forecast (ice and water)



comparison to **in situ observations**

scatter plots model vs

obs



Main issues identified

- Disagreement at HF vs AMSRE for sea ice concentration
- Seasonal cycle of the errors (sea ice concentration)
- Sea ice is too thick in the Beaufort Gyre (Arctic)
- High sensitivity of Antarctic sea ice with atmospheric forcing
- Underestimation of snow depth (Arctic) with ECMWF atmospheric reanalysis
- Ice Surface temperature is too warm (Arctic)

Development of models

- Use of NEMO4 capacities: test of different rheology, use of Landfast parameterisation
- Multi category model
- Sensitivity to atmospheric forcing (albedo)



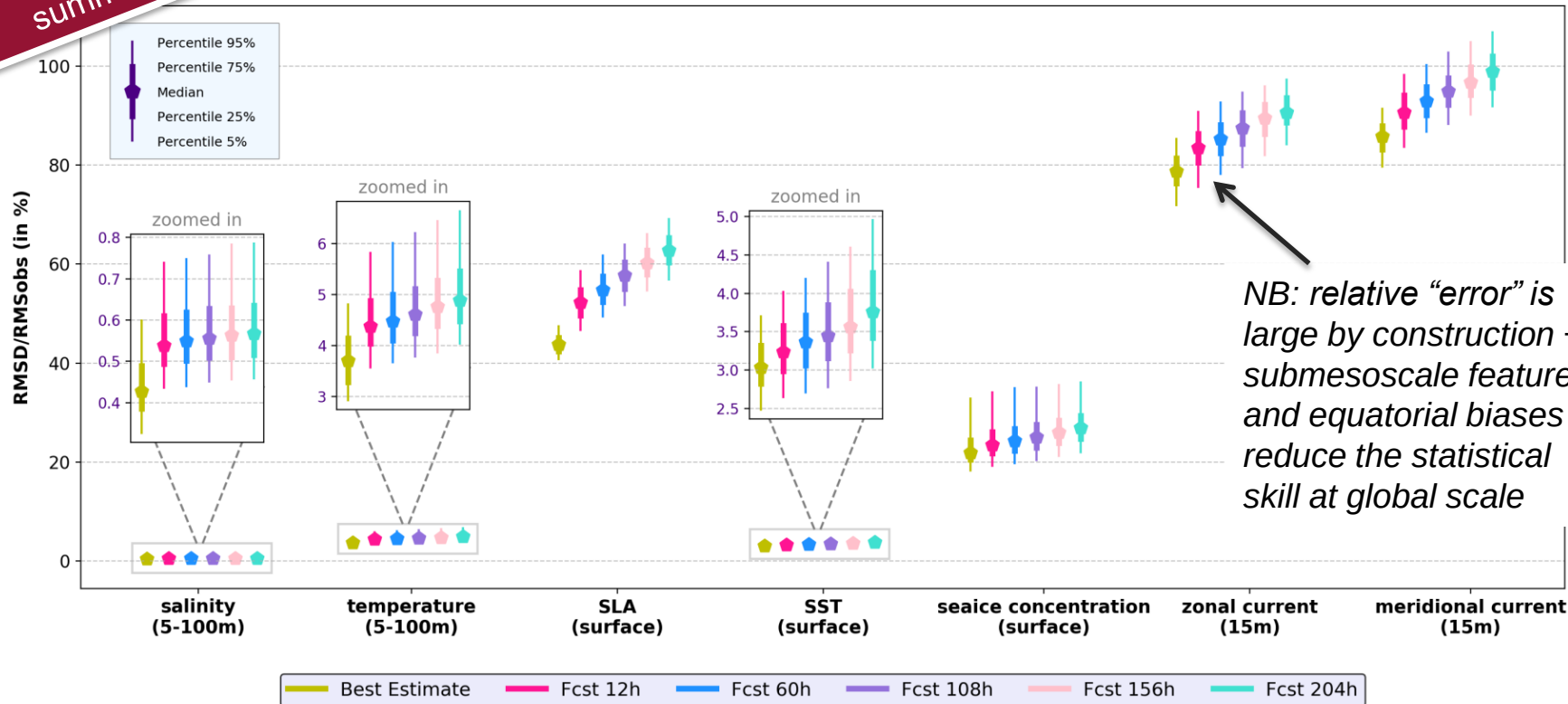
Development of data assimilation

- Sea ice also is tested within the ensemble assimilation approach
- Assimilation of sea ice concentration in a multi category context
- Work on assimilation of sea ice thickness (control of sea ice volume)

CLASS4
metrics
summary

Global average forecast uncertainty (%)

Date: year 2019



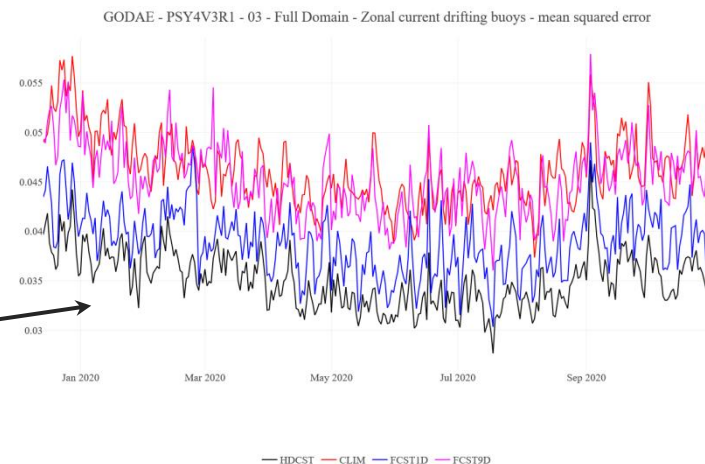
Summary of forecast verification, by variable

For all variables, uncertainty vs obs grows with forecast lead times

All forecast lead times do better than a climatology except BGC variables

The variability is well captured (anomaly correlations) while the accuracy is not high

Global behaviour	1-day	3-day	5-day	9-day
SST	Forecast slightly better than persistence Anomaly correlation > 0.6			
S(z)	Equivalent forecast and persistence Anomaly correlation > 0.6			
SLA	Persistence slightly better than forecast Anomaly correlation > 0.8			
U,V	In construction 😊 forecast better than Lumpkin climatology			
BGC	Forecasts do not do better than climatology Anomaly correlation > 0.4			
Sea Ice	Persistence slightly better than forecast		Forecast slightly better than persistence	



Conclusions

Related to the verification procedure and metrics

- Need for alternative methods to quantify uncertainties and model skill, in variables which relative error is large (currents, SLA, biogeochemistry)
- Need to develop uncertainty information that can actually be used together with the product: “user oriented”
- Main developments planned in 2021 :
 - *Implementation of ensemble scores, including lagrangian.*
 - *Implementation of BGC Argo metrics*
 - *Exploration of feature based verification methods (Mittermaier et al, 2020) for biogeochemistry*
- Implementation of a new routine verification website and procedure (new python plots and interactive navigation)