MULTICAST - stochastic MULTI-grid ocean foreCASTing

Multigrid nested ocean ensembles using stochastic modelling

Session 3: Seamless integration between Coastal/Regional/Large scale systems

Vassilios Vervatis[1], Pierre De Mey-Frémaux[2], Nadia Ayoub[2], Malek Ghantous[3], Sarantis Sofianos[1]

[1]Dept. of Physics, NKUA | [2]LEGOS/CNRS | [3]CLS

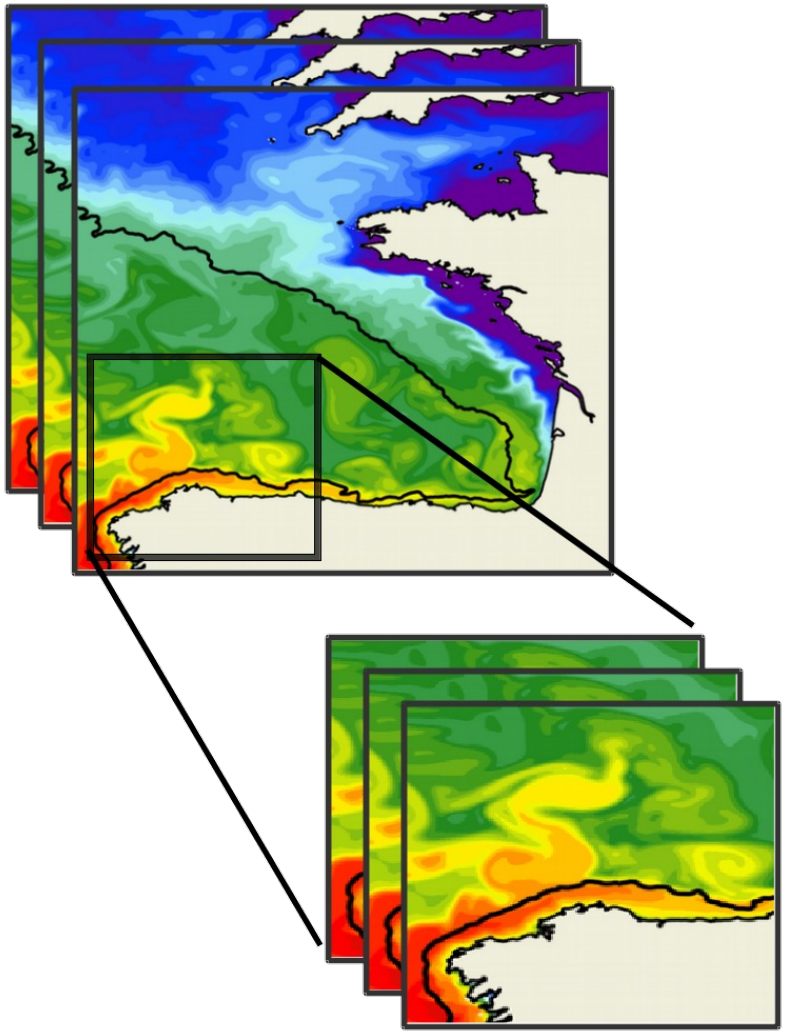
COSS-TT International Coordination Meeting (9)

Task Team meeting | 2 May 2023 – 4 May 2023, Montréal, Canada

MULTICAST - stochastic MULTI-grid ocean foreCASTing

MULTICAST is an ongoing Service Evolution project for the Copernicus Marine Service -- Objectives :

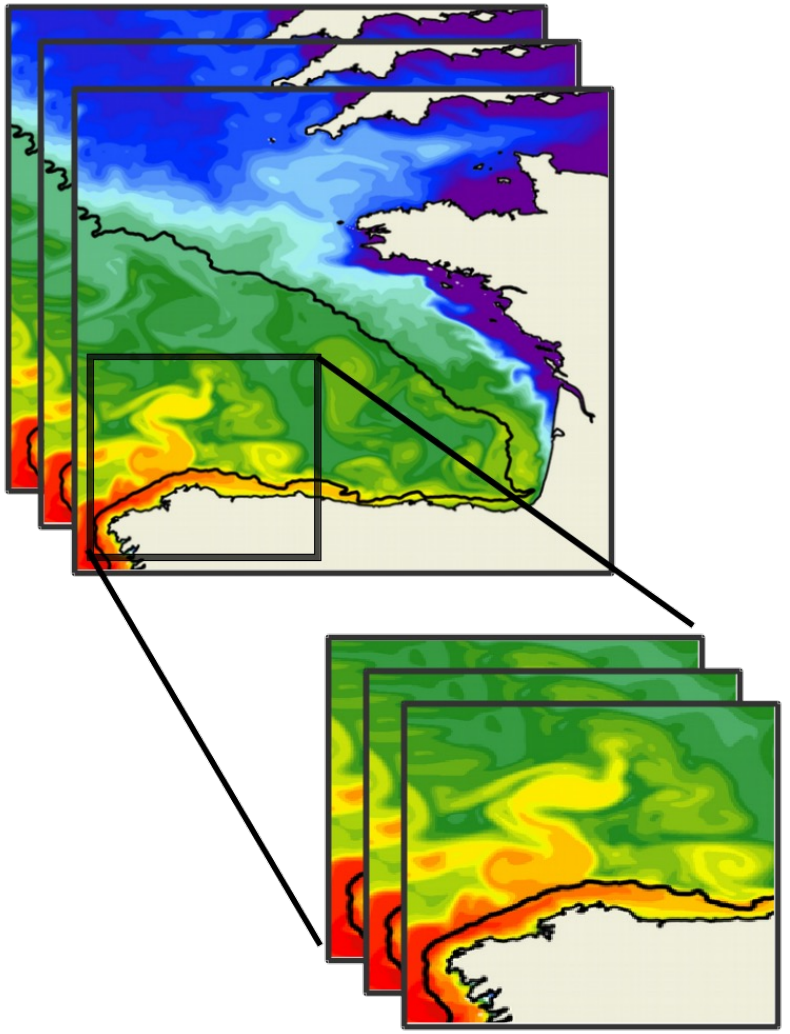
1. Development of nested stochastic model configurations: 1-way vs. 2-way nesting, uncertainties in parent only vs. uncertainties in parent & child = **This presentation**.



MULTICAST - stochastic MULTI-grid ocean foreCASTing

MULTICAST is an ongoing Service Evolution project for the Copernicus Marine Service -- Objectives :

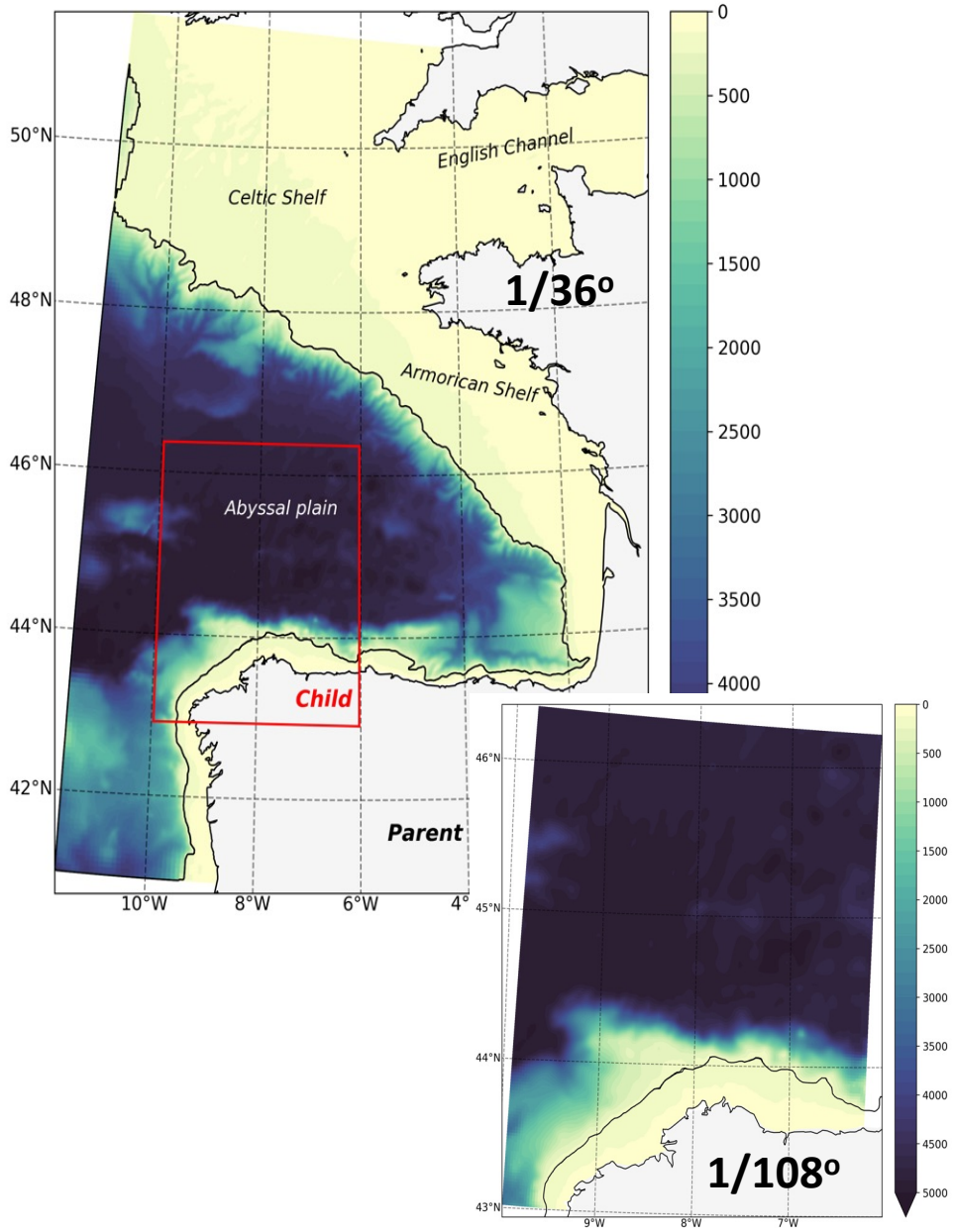
1. Development of nested stochastic model configurations: 1-way vs. 2-way nesting, uncertainties in parent only vs. uncertainties in parent & child = **This presentation**.
2. Short/medium-term skill assessment (O(1d) to O(1wk)) of 1-way and 2-way nested forecasting systems
   - Development of multiscale/multiresolution forecast skill assessment metrics
3. Formulation of a multigrid control vector for ensemble-based Data Assimilation.



Development of a MG/MR configuration for Ensemble-based fcst

Ocean modelling configuration

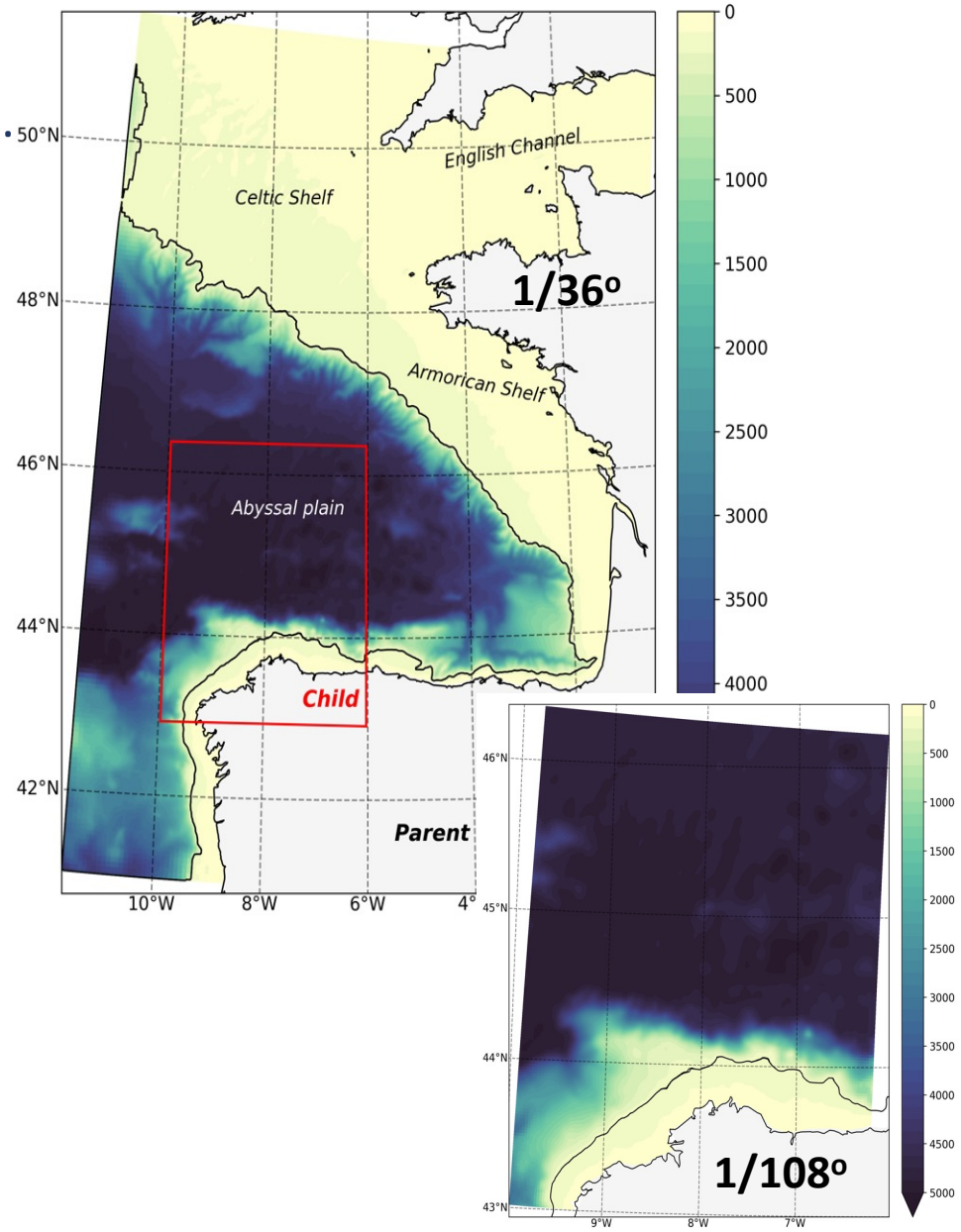
- Deterministic runs: NEMO4.2/AGRIF parent-child 1-way vs. 2-way nested configurations for the year 2017:
  - BISCAY36 parent grid res. at 1/36° (~2.5 km)
  - Zoom area a 1:3 refinement of BISCAY36 i.e., 1/108° (~750 m)
  - Same physics for the parent and child (physical parameterizations may depend on resolution; cf. IMMERSE project eNEATL36 config.; pers. comm. Jérome Chanut, Théo Brivoal -- MOi)
- Stochastic (Ensemble) runs: to model and downscale/upscale model uncertainties.



Development of a MG/MR configuration for Ensemble-based fcst

Stochastic modelling

- SPPT-AR1 u,v-wind perturbations; same parent-child stoch. param. (2^o, 3-day, 30%)
- Ens. members 20+1; use parent-child stochastic restarts to ensure reproducibility and differentiation of members
- Two periods winter/spring-2017, 30-day medium-range ens. fcst



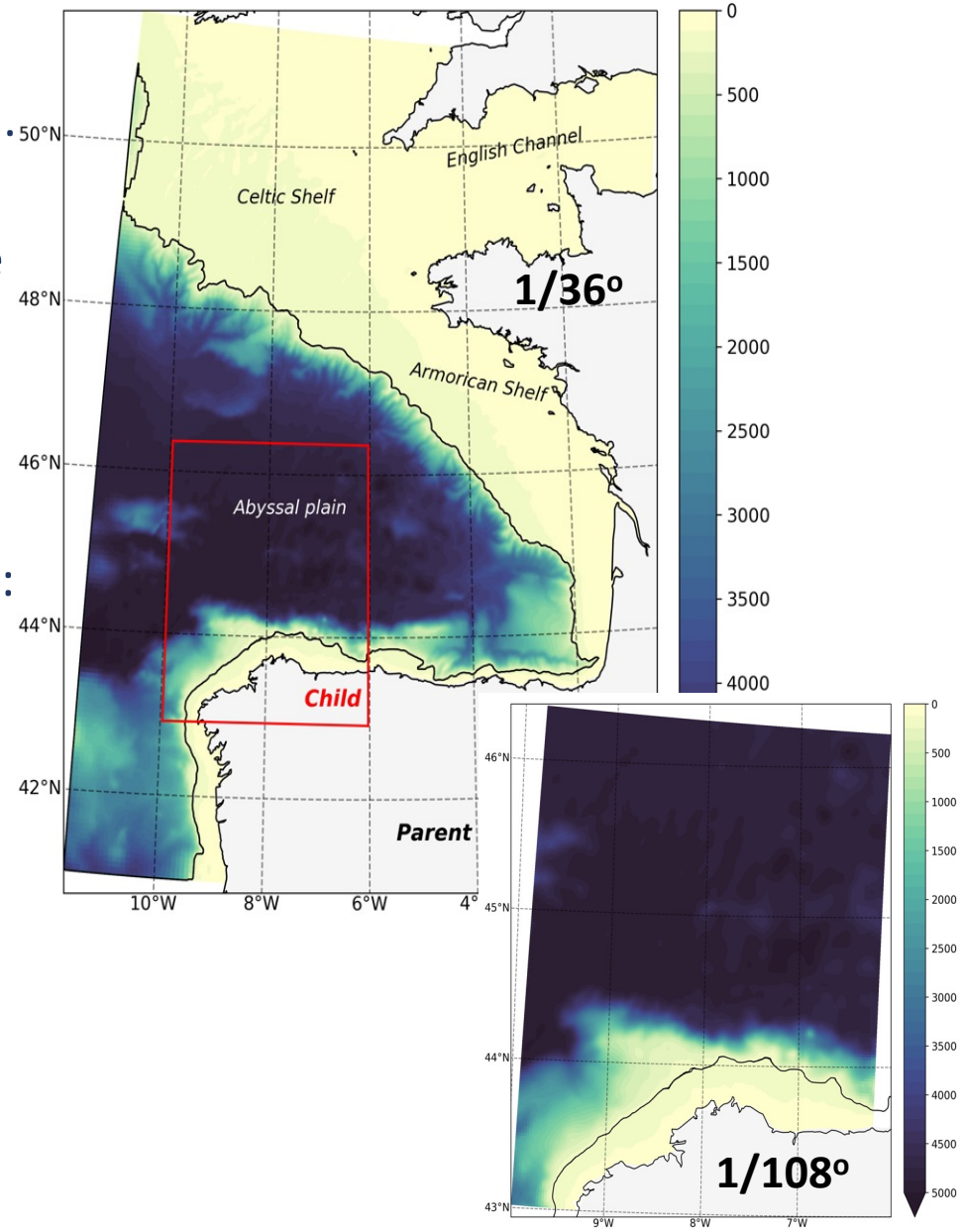
Development of a MG/MR configuration for Ensemble-based fcst

Stochastic modelling

- SPPT-AR1 u,v-wind perturbations; same parent-child stoch. param. (2^o, 3-day, 30%)
- Ens. members 20+1; use parent-child stochastic restarts to ensure reproducibility and differentiation of members
- Two periods winter/spring-2017, 30-day medium-range ens. fcst

Target Operational Protocols (TOPs)

- **TOP-0: 1-way nesting, no child wind errors** -- stochastic approach:
  - Perturbing the wind only for the parent
  - Downscaled child model errors via OBC (no upscale)



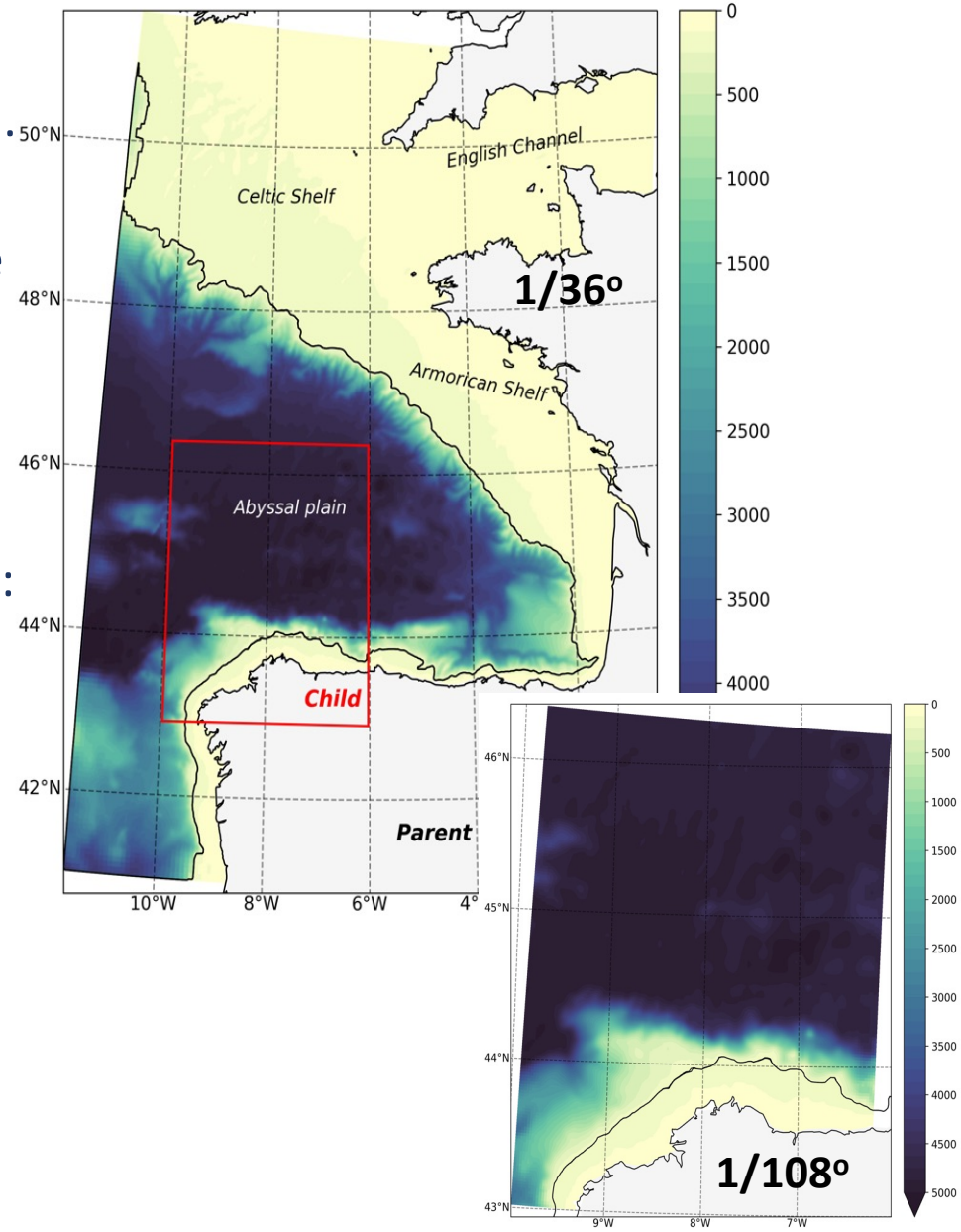
Development of a MG/MR configuration for Ensemble-based fcst

Stochastic modelling

- SPPT-AR1 u,v-wind perturbations; same parent-child stoch. param. (2^o, 3-day, 30%)
- Ens. members 20+1; use parent-child stochastic restarts to ensure reproducibility and differentiation of members
- Two periods winter/spring-2017, 30-day medium-range ens. fcst

Target Operational Protocols (TOPs)

- **TOP-0: 1-way nesting, no child wind errors** -- stochastic approach:
  - Perturbing the wind only for the parent
  - Downscaled child model errors via OBC (no upscale)
- **TOP-1: 1-way nesting, parent & child wind errors** -- stoch. appr.:
  - Perturbing the wind for the parent & the child
  - Downscaled child model errors via OBC (no upscale)



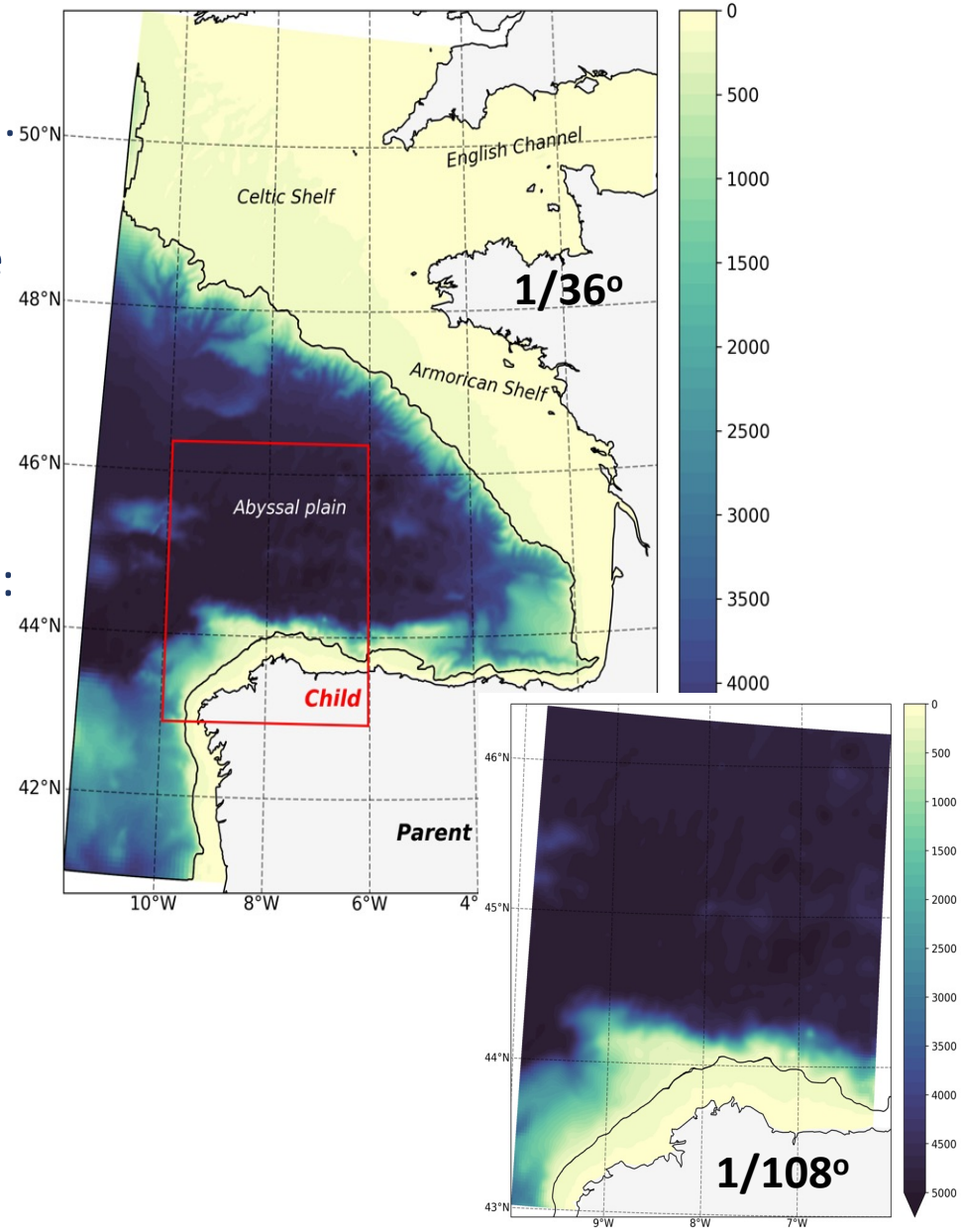
Development of a MG/MR configuration for Ensemble-based fcst

Stochastic modelling

- SPPT-AR1 u,v-wind perturbations; same parent-child stoch. param. (2^o, 3-day, 30%)
- Ens. members 20+1; use parent-child stochastic restarts to ensure reproducibility and differentiation of members
- Two periods winter/spring-2017, 30-day medium-range ens. fcst

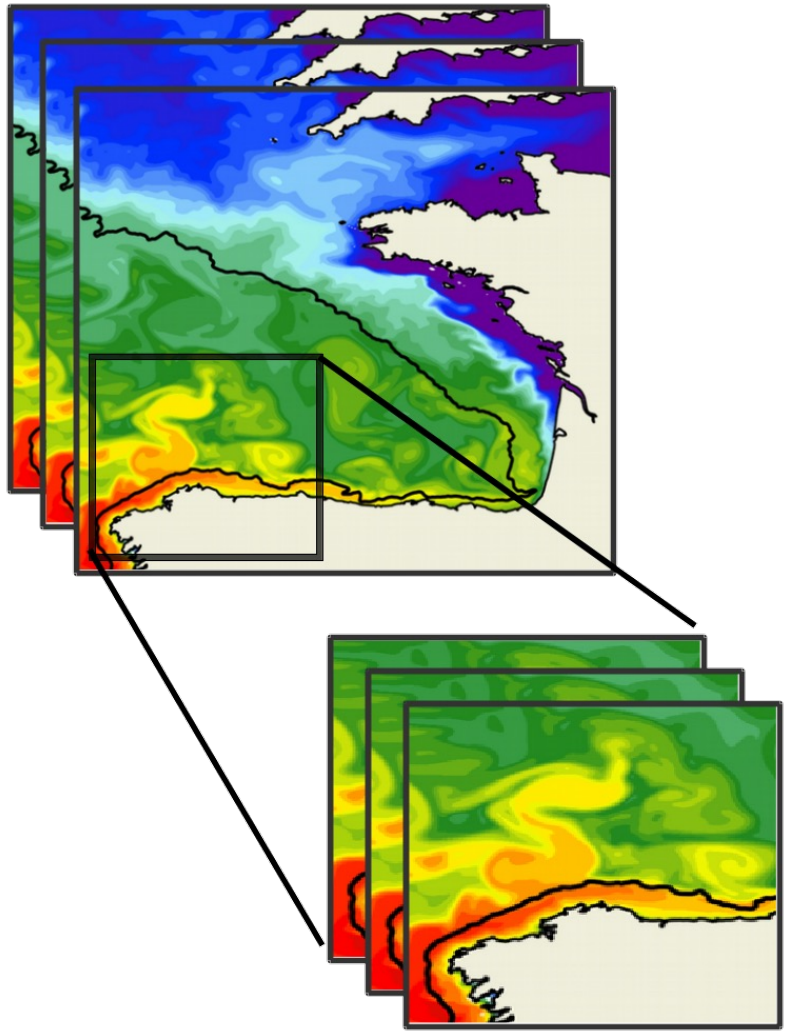
Target Operational Protocols (TOPs)

- **TOP-0: 1-way nesting, no child wind errors** -- stochastic approach:
  - Perturbing the wind only for the parent
  - Downscaled child model errors via OBC (no upscale)
- **TOP-1: 1-way nesting, parent & child wind errors** -- stoch. appr.:
  - Perturbing the wind for the parent & the child
  - Downscaled child model errors via OBC (no upscale)
- **TOP-2: 2-way nesting, parent & child wind errors** -- stoch. appr.:
  - Perturbing the wind for the parent & the child
  - Upscaled/downscaled parent/child OBC model errors



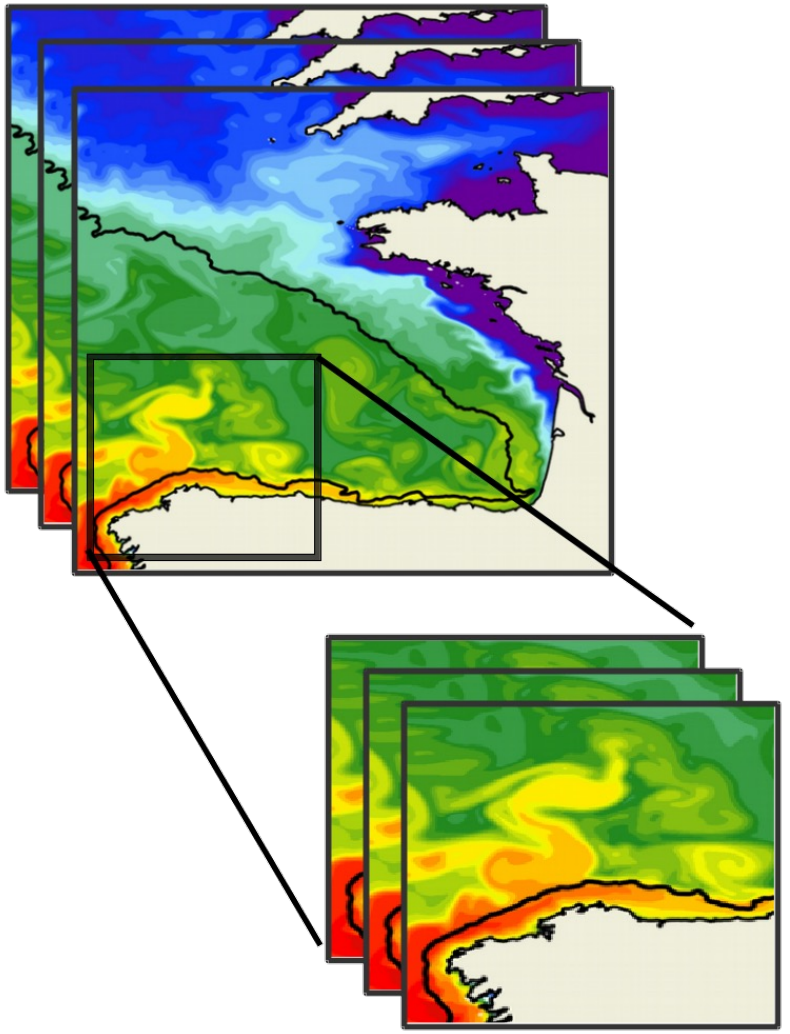
Focus on ocean physical processes and their model errors

- The stochastic approaches for Ensemble generation permit the representation of physical uncertainty processes related to:
  - OBCs model errors
  - Wind forcing model errors



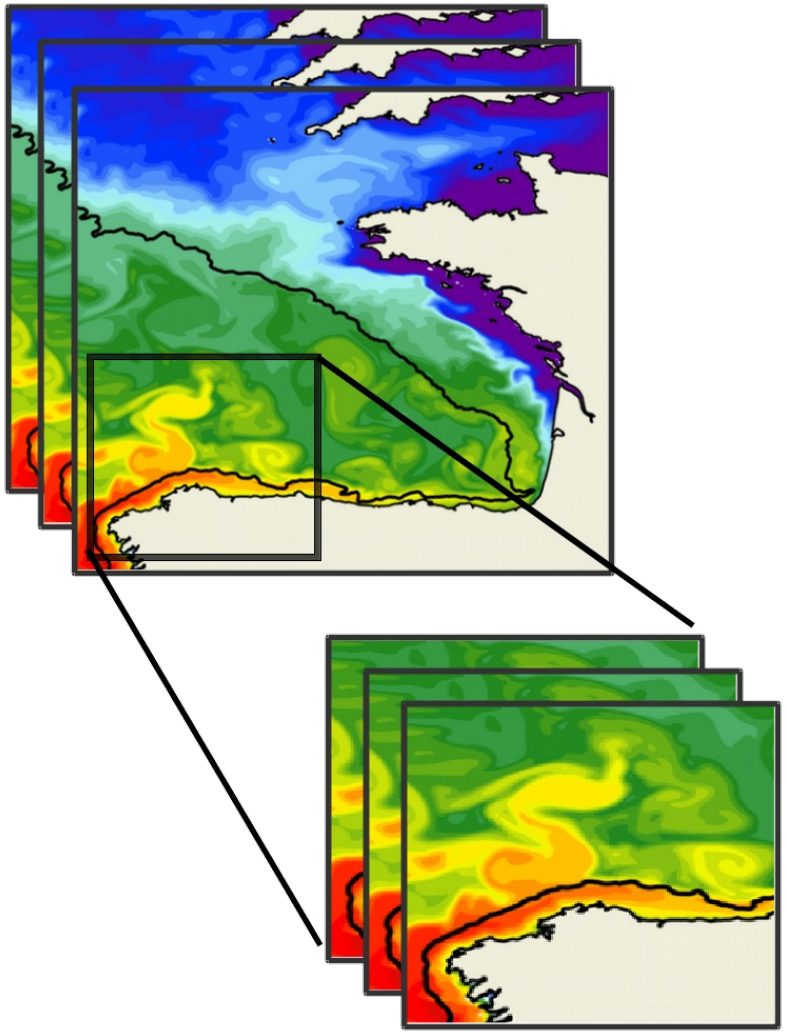
Focus on ocean physical processes and their model errors

- The stochastic approaches for Ensemble generation permit the representation of physical uncertainty processes related to:
  - OBCs model errors
  - Wind forcing model errors
- Special focus on some processes in error subspace:
  - Intrusion of the warm Iberian Poleward Current - IPC during winter, an ocean process forced outside the parent-child areas and controlling the mesoscale eddy activity in the open ocean.



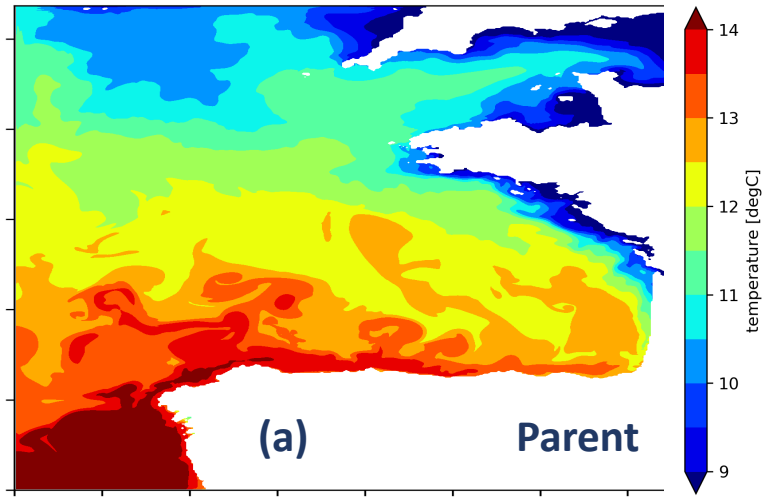
Focus on ocean physical processes and their model errors

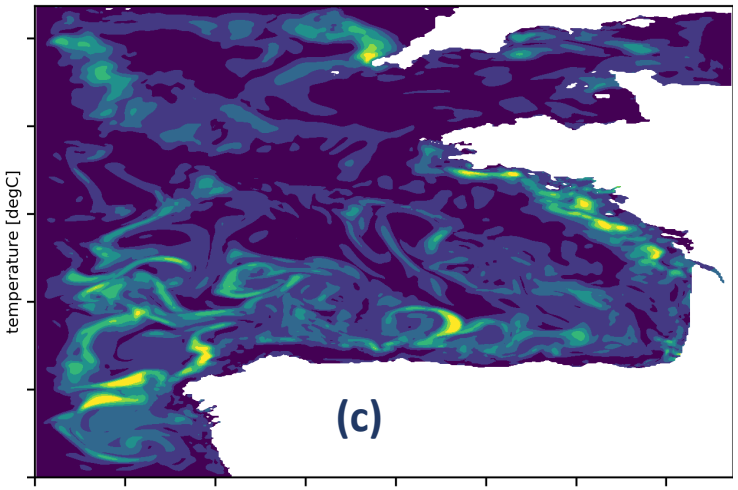
- The stochastic approaches for Ensemble generation permit the representation of physical uncertainty processes related to:
  - OBCs model errors
  - Wind forcing model errors
- Special focus on some processes in error subspace:
  - Intrusion of the warm Iberian Poleward Current - IPC during winter, an ocean process forced outside the parent-child areas and controlling the mesoscale eddy activity in the open ocean.
  - Upper-ocean properties regulated by atmospheric fluxes and re-stratification processes during spring. When the stratification is strong, wind forcing uncertainties can impact also upwelling.



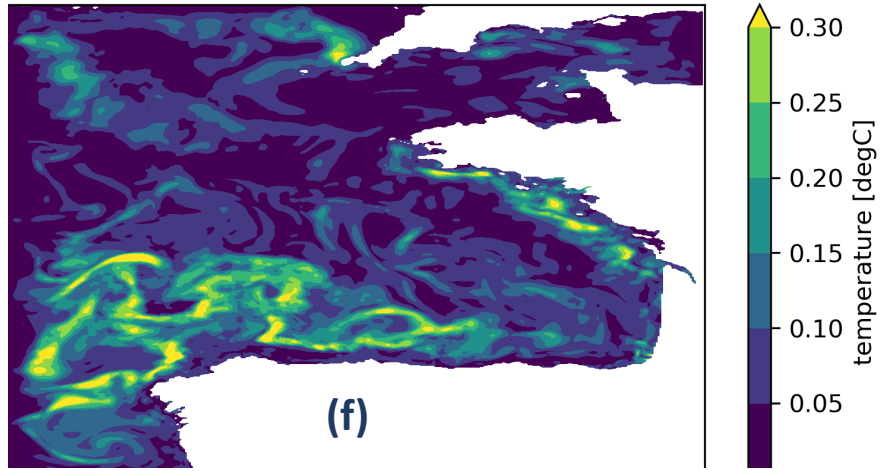
Parent-child ensemble spread

Deterministic run, SST (oC), 20170210





TOP ensemble runs, spread SST (°C), 20170210, ens. fcst. lead day 30



Warm IPC intrusion & mesoscale activity

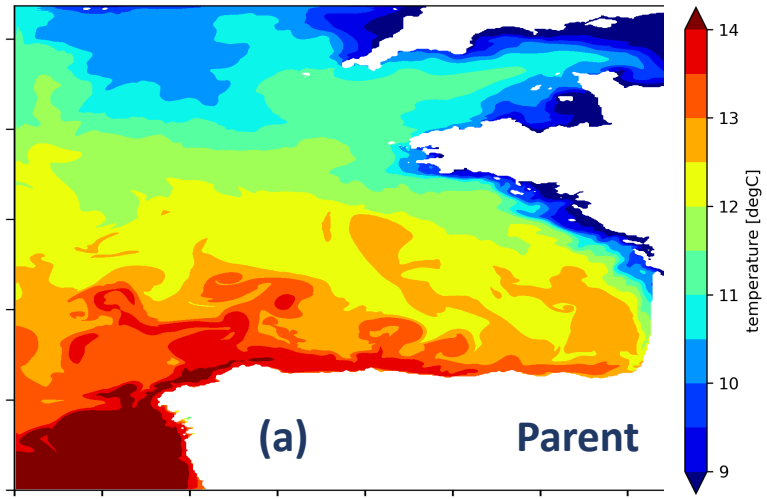
1-way (TOP-0)

1-way (TOP-1)

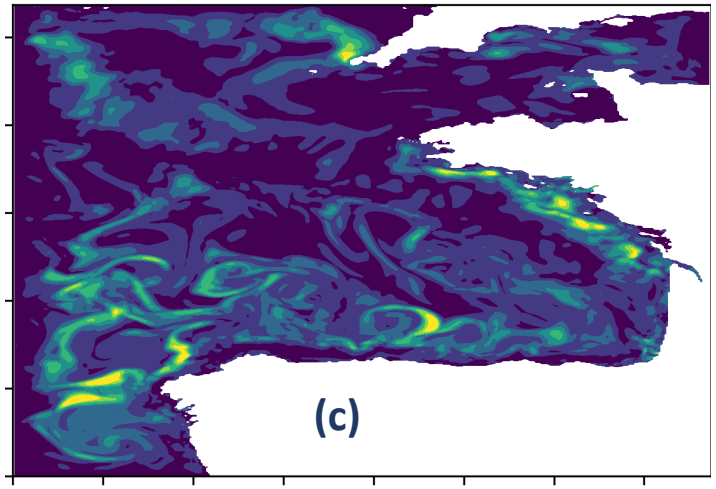
2-way (TOP-2)

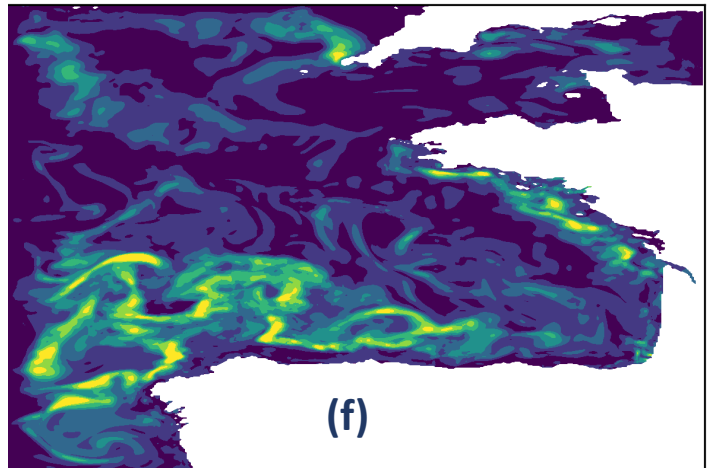
Parent-child ensemble spread

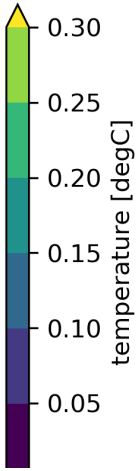
Deterministic run, SST (oC), 20170210



TOP ensemble runs, spread SST (°C), 20170210, ens. fcst. lead day 30





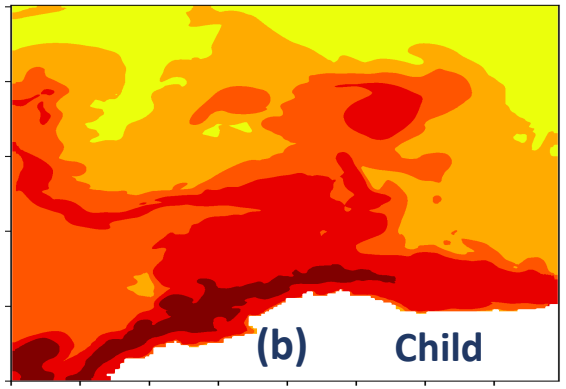


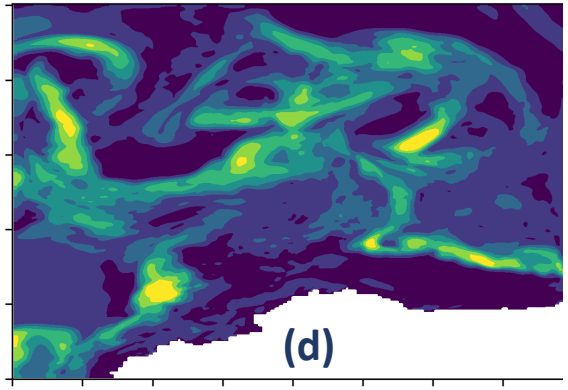
Warm IPC intrusion & mesoscale activity

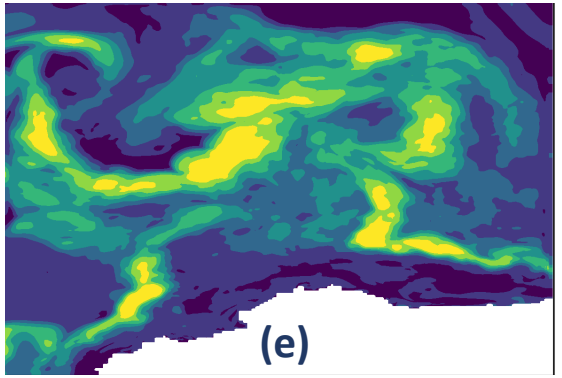
1-way (TOP-0)

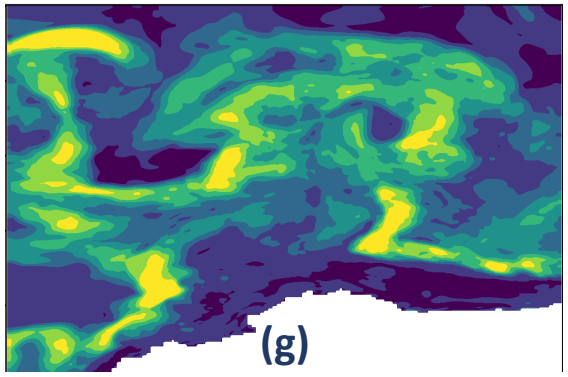
1-way (TOP-1)

2-way (TOP-2)



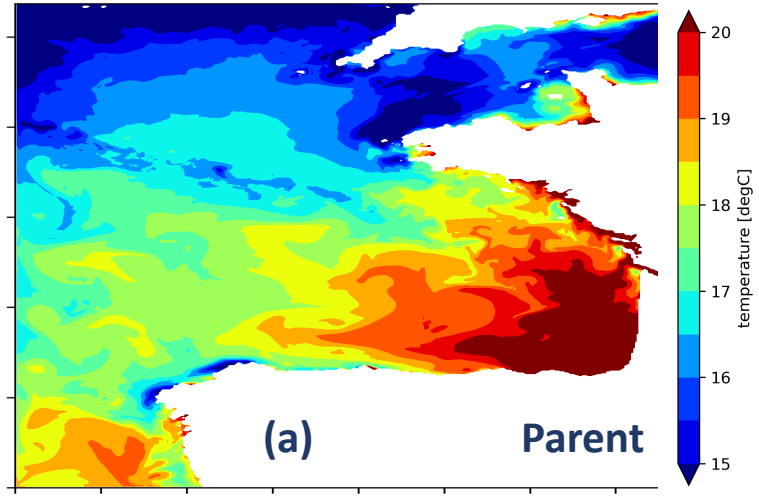




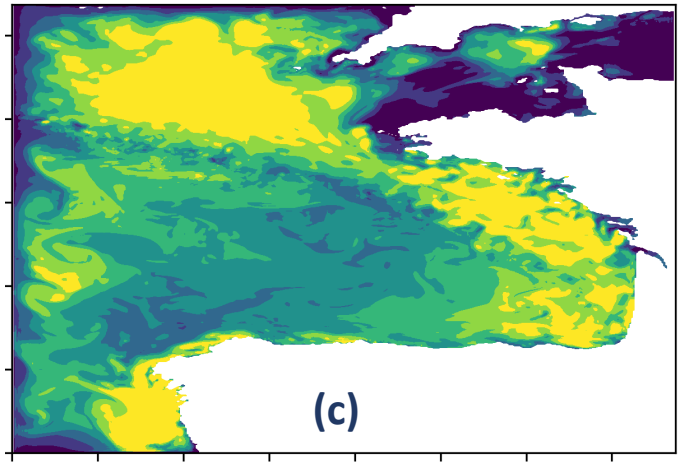


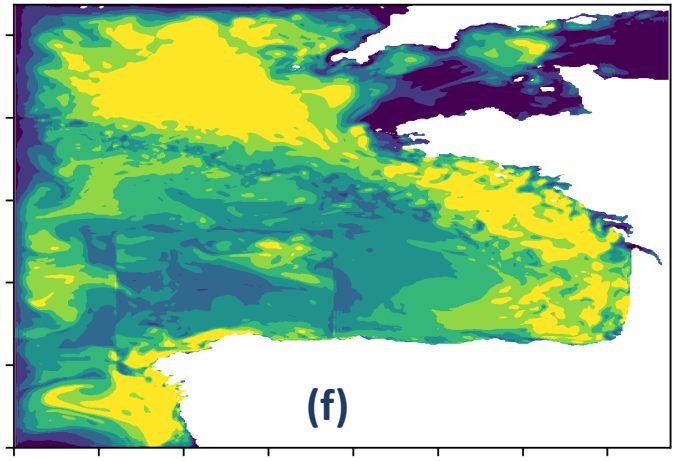
Parent-child ensemble spread

Deterministic run, SST (oC), 20170617



TOP ensemble runs, spread SST (°C), 20170617, ens. fcst. lead day 17



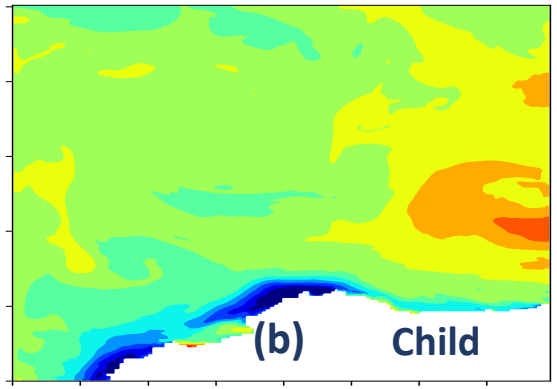


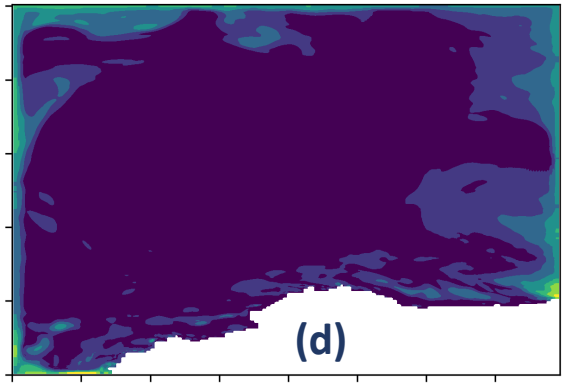
1-way (TOP-0)

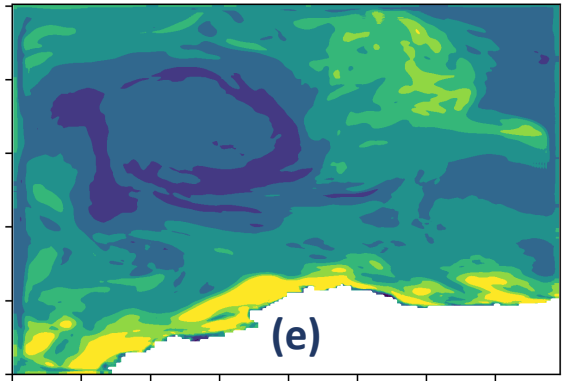
1-way (TOP-1)

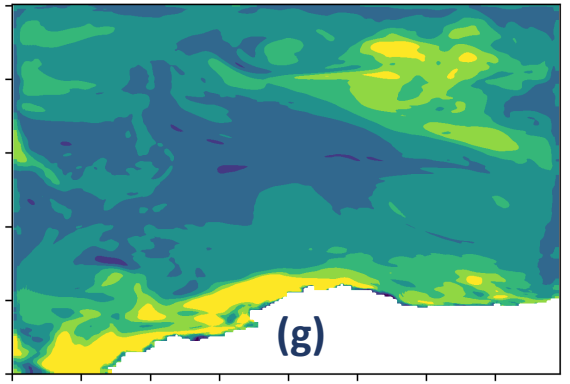
2-way (TOP-2)

Upwelling event









Comparative assessment of the fcst skill on parent-child grids

Challenges for the intercomparison between various TOPs:

- Different state vectors => two set of metrics in a MG context: one for the child and one for the parent, comparing the common zoomed area
- Ensembles drawn from different IC for each TOP => develop fcst skill metrics considering trends between LT and IC

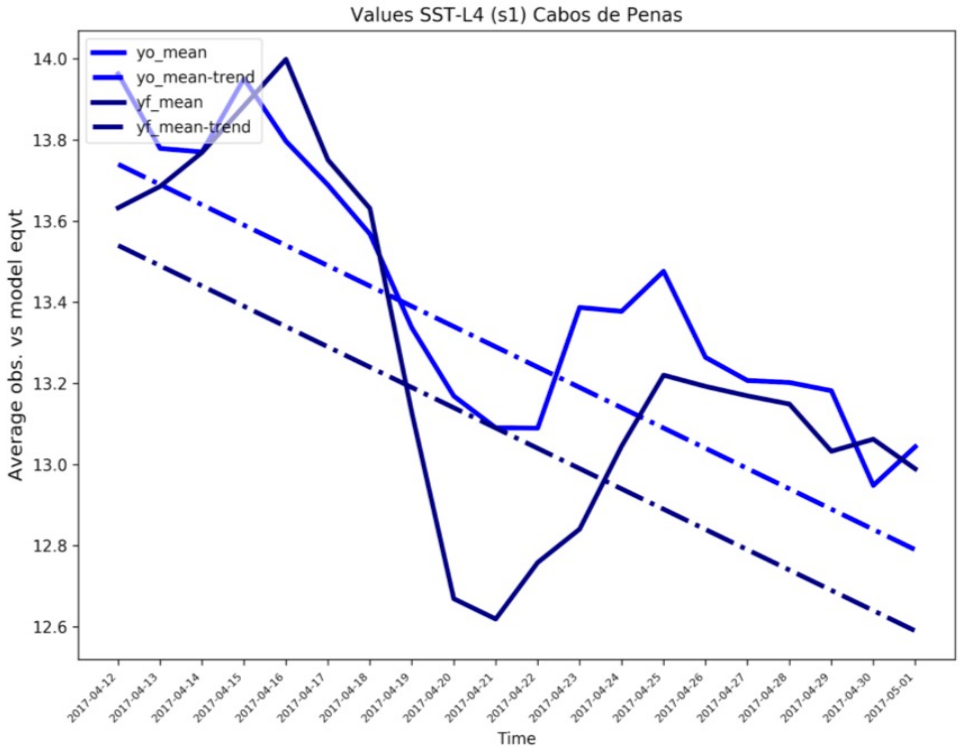
Comparative assessment of the fcst skill on parent-child grids

Challenges for the intercomparison between various TOPs:

- Different state vectors => two set of metrics in a MG context: one for the child and one for the parent, comparing the common zoomed area
- Ensembles drawn from different IC for each TOP => develop fcst skill metrics considering trends between LT and IC

Example of empirical assessment for a target processes:

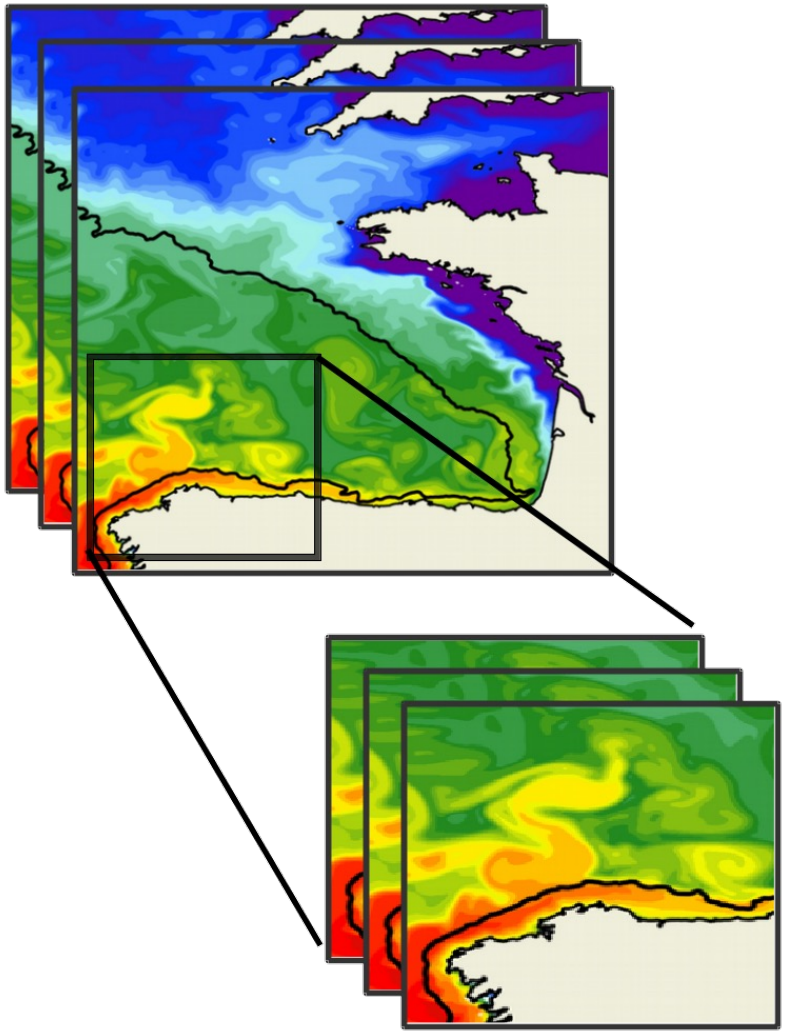
Evolution of the regional OSTIA SST data and the model Ensemble (cf. SCRUM2). We can construct the Brier Score for SST selecting a threshold value to identify upwelling, when the following are observed: i) warm observation & model bias during the upwelling, ii) differentiated cooling trends and ii) ~2-day lag in the upwelling relaxation between ensemble and data.



MULTICAST - stochastic MULTI-grid ocean foreCASTing

Outlook :

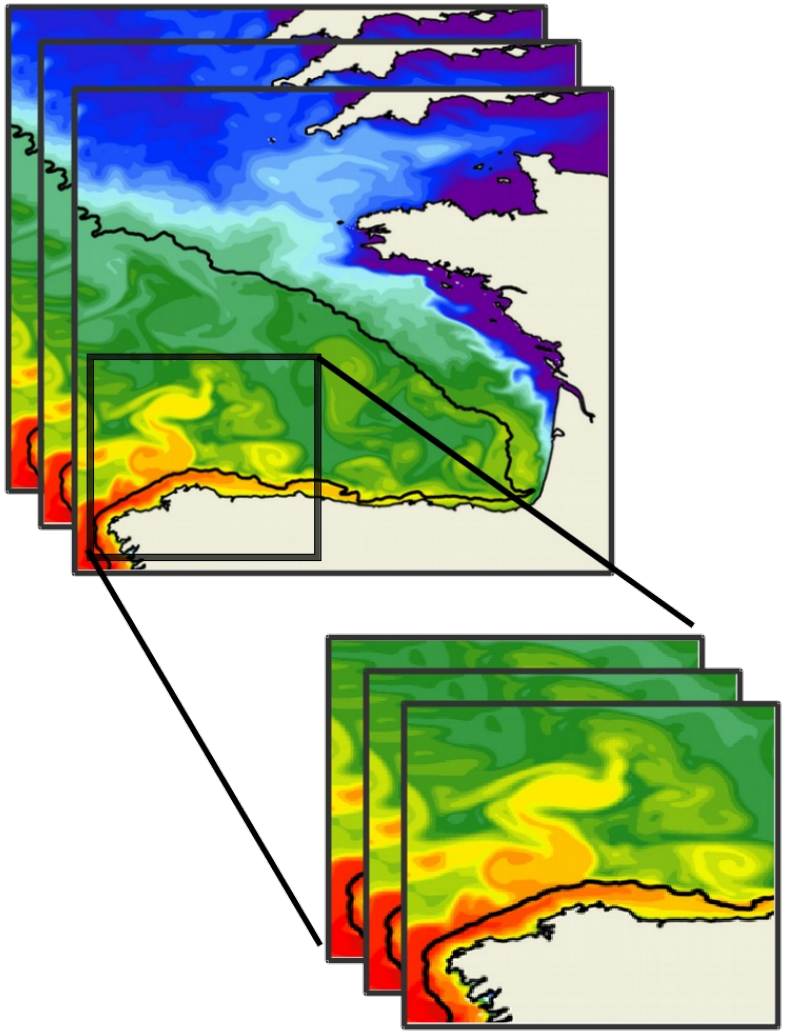
1. Development of nested stochastic model configurations: 1-way vs. 2-way nesting; TOPs of model uncertainties in parent only vs. uncertainties in parent & child.



MULTICAST - stochastic MULTI-grid ocean foreCASTing

Outlook :

1. Development of nested stochastic model configurations: 1-way vs. 2-way nesting; TOPs of model uncertainties in parent only vs. uncertainties in parent & child.
2. **Short/medium-term skill assessment (O(1d) to O(1wk)) of 1-way and 2-way nested forecasting systems**
   - **Development of multiscale/multiresolution forecast skill assessment metrics**
3. **Formulation of a multigrid control vector for ensemble-based Data Assimilation.**



Thank you!

References

- Ensemble downscaling of a regional ocean model, Ghantous, M., N. Ayoub, P. De Mey-Frémaux, V. Vervatis and P. Marsaleix (2020), Ocean Modelling, 145, 101511, https://doi.org/10.1016/j.ocemod.2019.101511.
- Assessment of a regional physical-biogeochemical stochastic ocean model. Part 1: Ensemble generation, Vervatis, D. V., P. De Mey-Frémaux, N. Ayoub, J. Karagiorgos, M. Ghantous, M. Kailas, C.-E. Testut and S. Sofianos, (2021), Ocean Modelling, 160, 101781, https://doi.org/10.1016/j.ocemod.2021.101781.
- Assessment of a regional physical-biogeochemical stochastic ocean model. Part 2: Empirical consistency, Vervatis, D. V., P. De Mey-Frémaux, N. Ayoub, J. Karagiorgos, S. Ciavatta, R.J.W. Brewin and S. Sofianos, (2021), Ocean Modelling, 160, 101770, https://doi.org/10.1016/j.ocemod.2021.101770.
- Implementing Operational Ocean Monitoring and Forecasting Systems. Chapter 5: Circulation Modeling, Ciliberti, S., N. Ayoub, J. Chanut, M. Cirano, A. Delamarche, P. De Mey-Frémaux, M. Drévillon, Y. Drillet, H. Hewitt, S. Masina, C. Tanajura, V. Vervatis and L. Wan (2022), Paris, France, IOC-UNESCO, 376pp. & Annexes, GOOS-275, https://doi.org/10.48670/ETOOFS.