

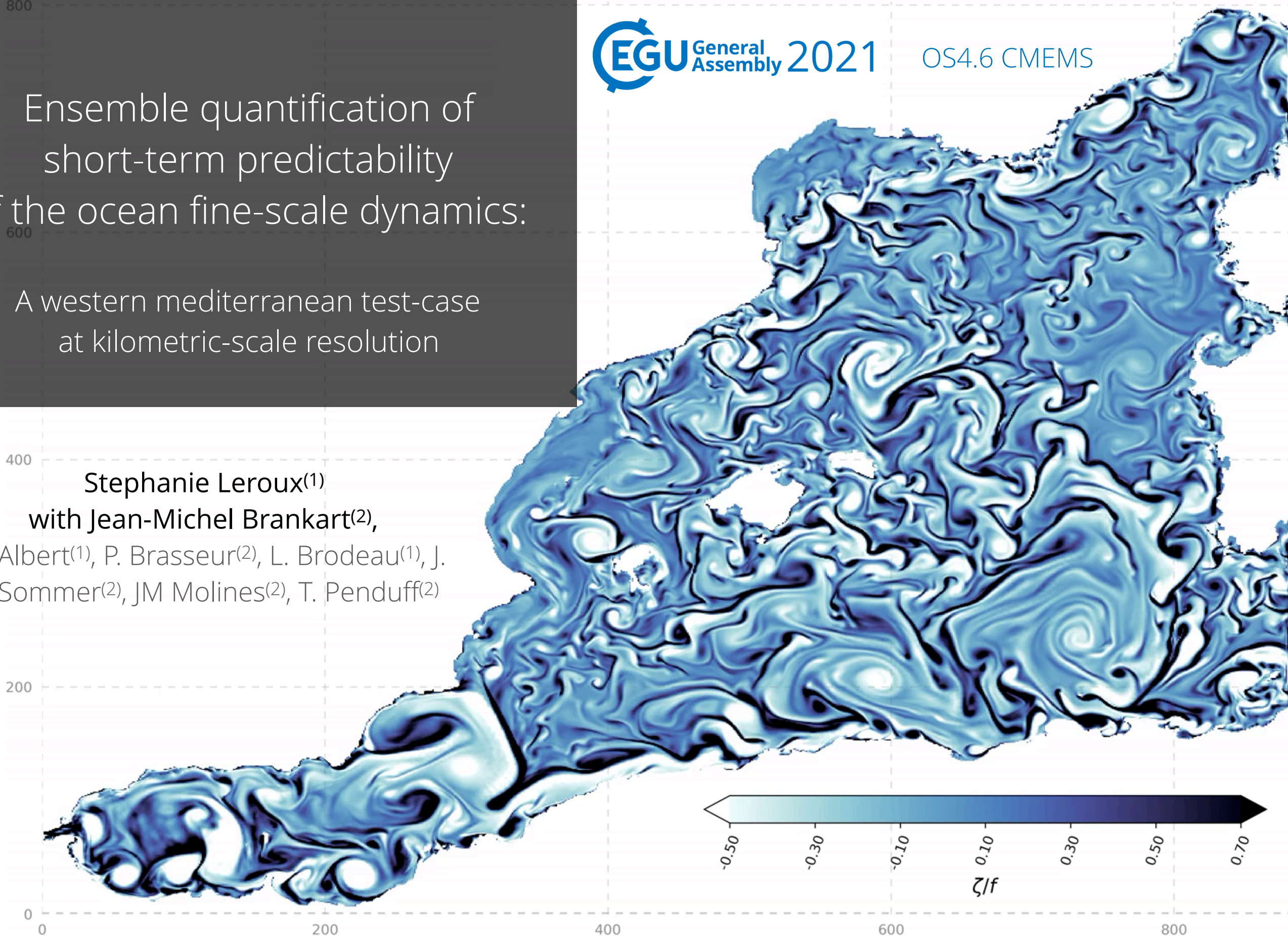
Ensemble quantification of short-term predictability of the ocean fine-scale dynamics:

A western mediterranean test-case at kilometric-scale resolution

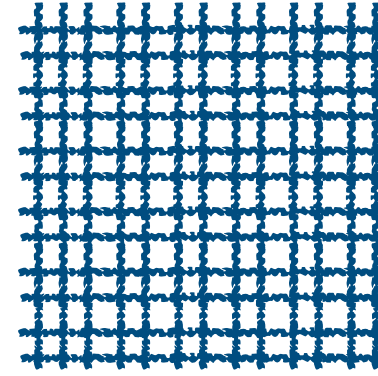
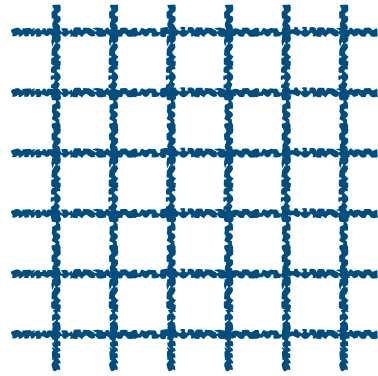
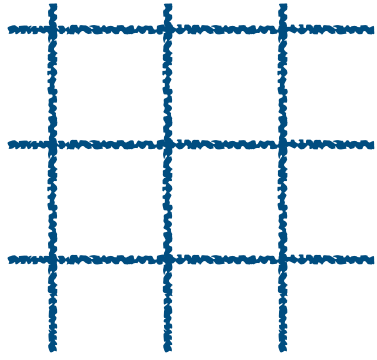
Stephanie Leroux⁽¹⁾

with Jean-Michel Brankart⁽²⁾,

A. Albert⁽¹⁾, P. Brasseur⁽²⁾, L. Brodeau⁽¹⁾, J. LeSommer⁽²⁾, JM Molines⁽²⁾, T. Penduff⁽²⁾

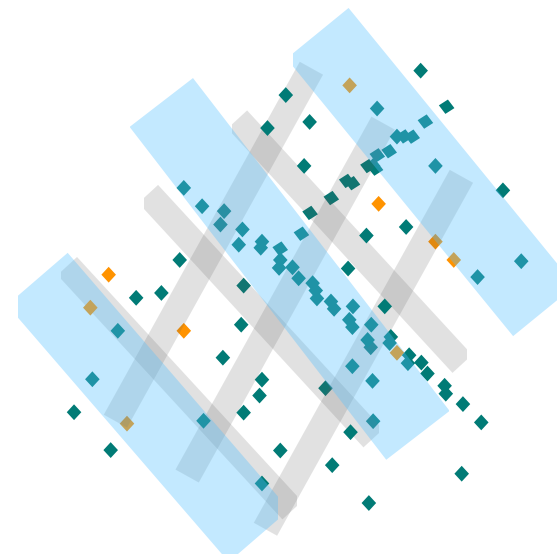
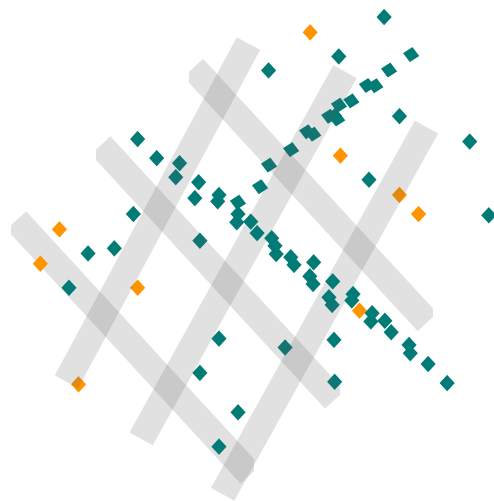
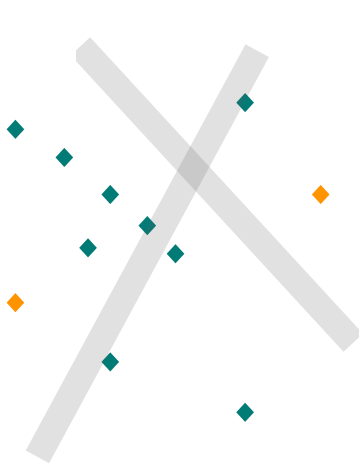


Towards higher-resolution ocean operational forecasting systems



and nevertheless:

- **Imperfect numerical models**
(unresolved processes, numerical schemes, etc)
- **Imperfect initial states of the forecast**
(i.e. imperfect control of the ocean state by the assimilated observations, due to imperfect obs coverage, measurement errors, model errors, etc).



Towards higher-resolution ocean observation

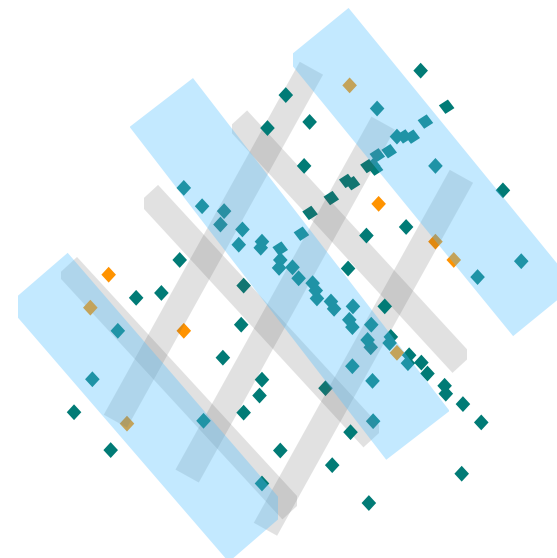
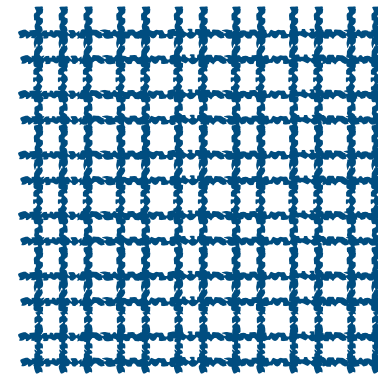
PREDICTABILITY,
in an operational context

=

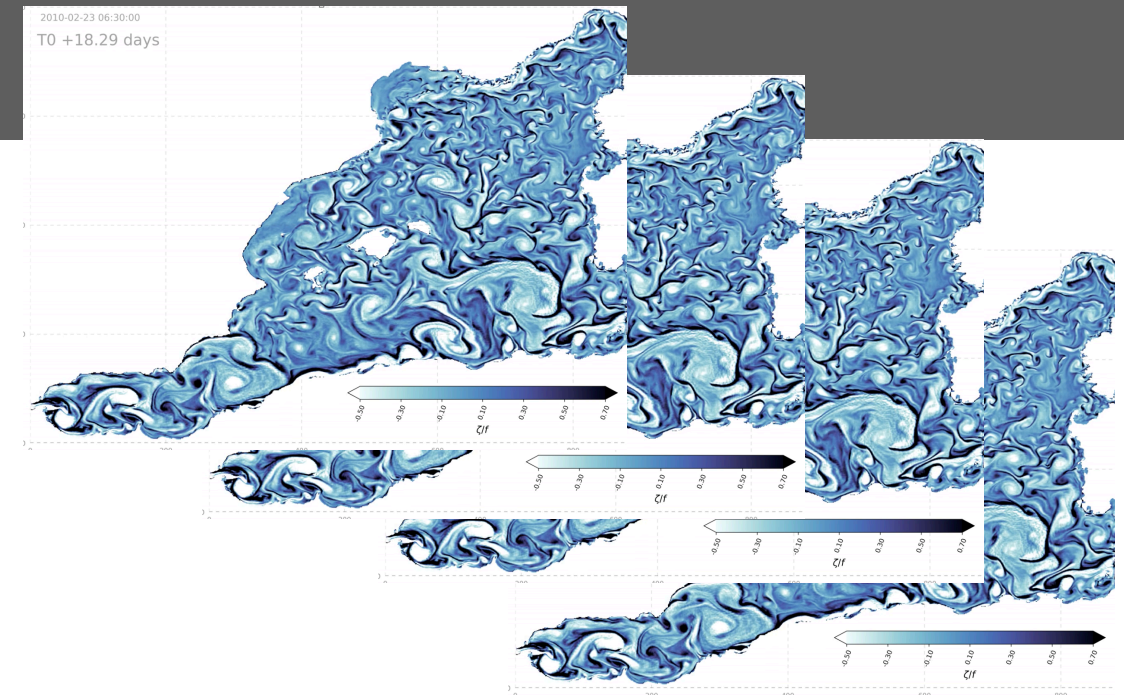
Effective skill of the forecast,
required for a given CMEMS
application.

in practice,
limited
by both:

- Imperfect numerical models
(unresolved processes, numerical schemes, etc)
- Imperfect initial states of the forecast
(i.e. imperfect control of the ocean state by the assimilated observations, due to imperfect obs coverage, measurement errors, model errors, etc).



Goal of the study



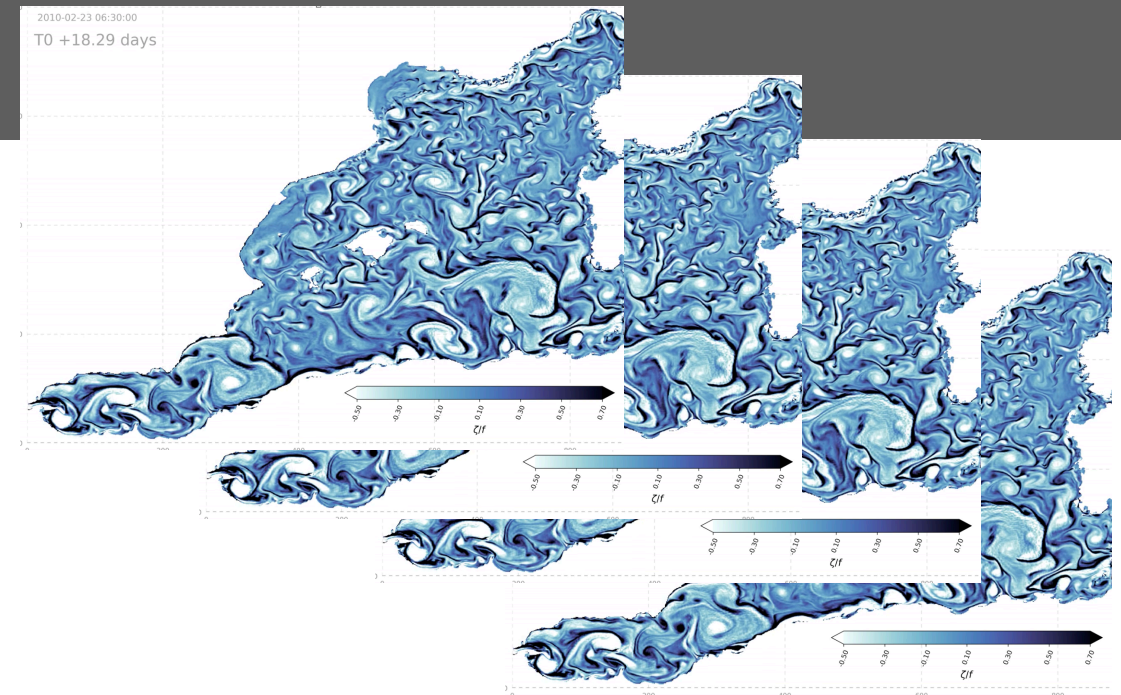
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Effective skill of the forecast,
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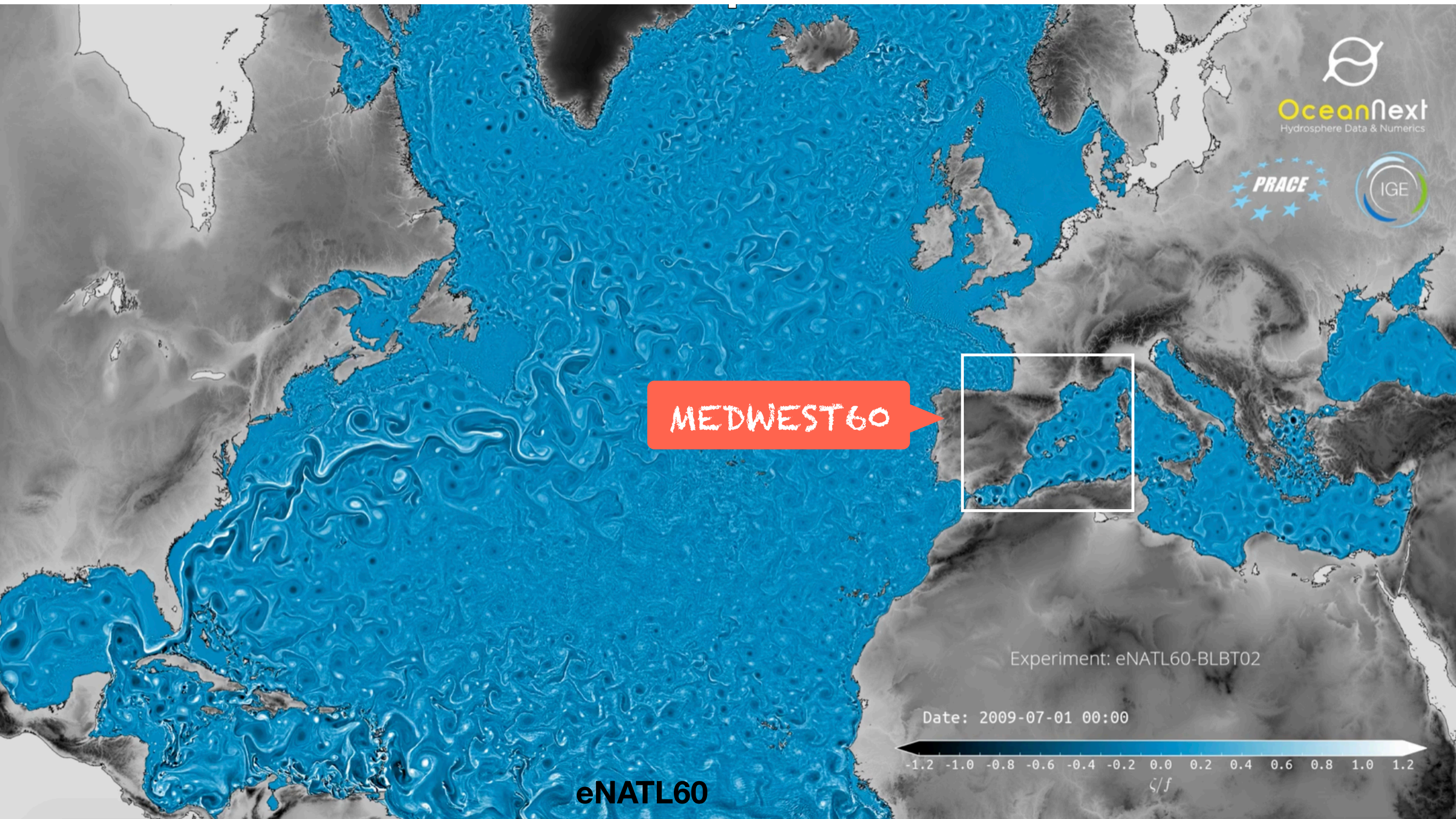
- Propose a probabilistic approach based on ensemble simulations,
- to quantify predictability as a function of both initial and model errors,
- and reciprocally, to inform on necessary requirements to meet in terms of precision of the initial state and model in order to achieve a given required skill of the forecast.

Ingredients



1. A new $1/60^\circ$ regional configuration: MEDWEST60.
2. A set of 3 ensemble simulations representing :
 - uncertain initial conditions,
 - the effect of model errors on the fine scales.
3. A methodology to:
 - study the growth of the ensemble spread,
 - and deduce predictability.

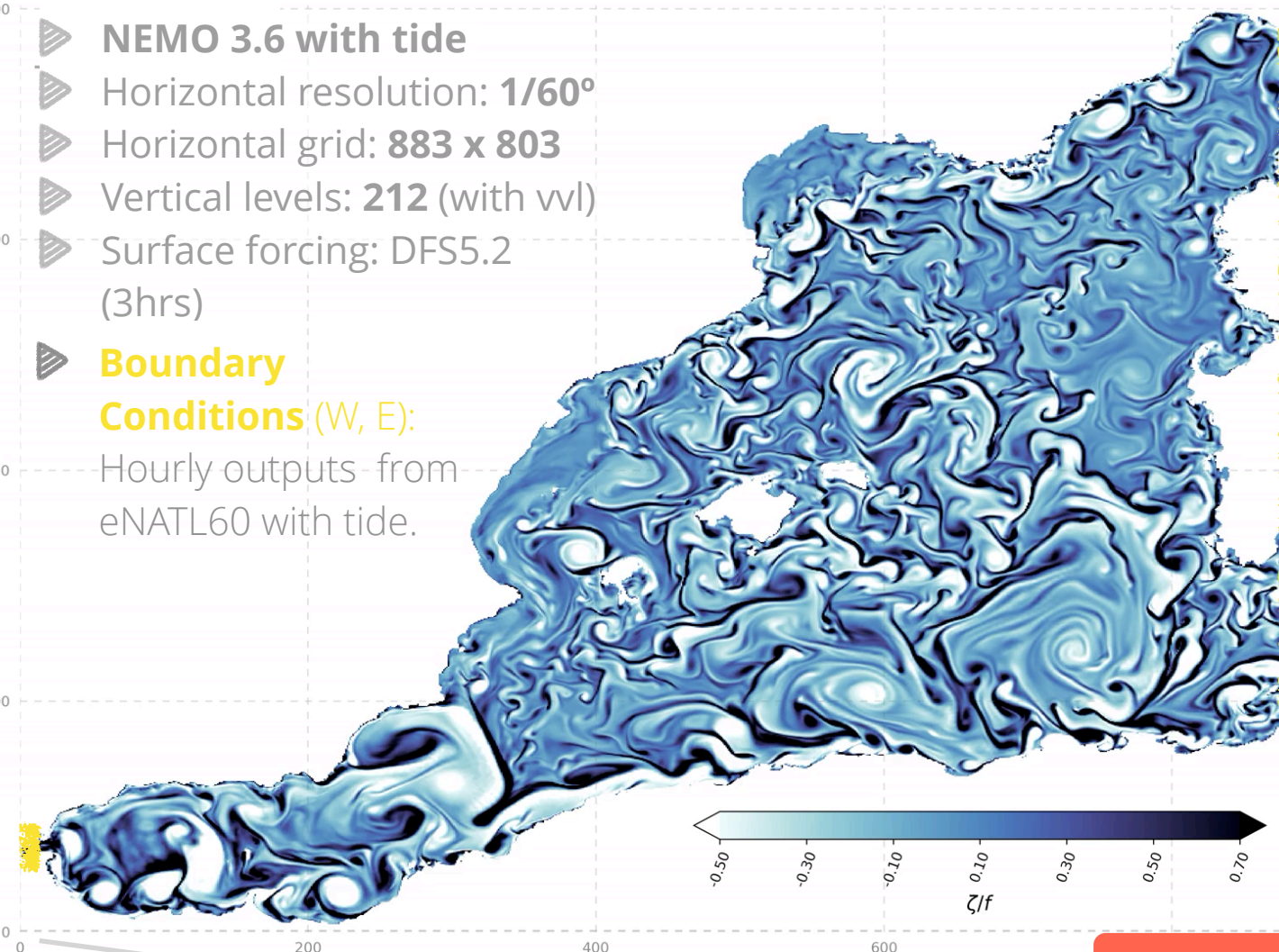
MEDWEST60: a new regional configuration at kilometric-scale horizontal resolution



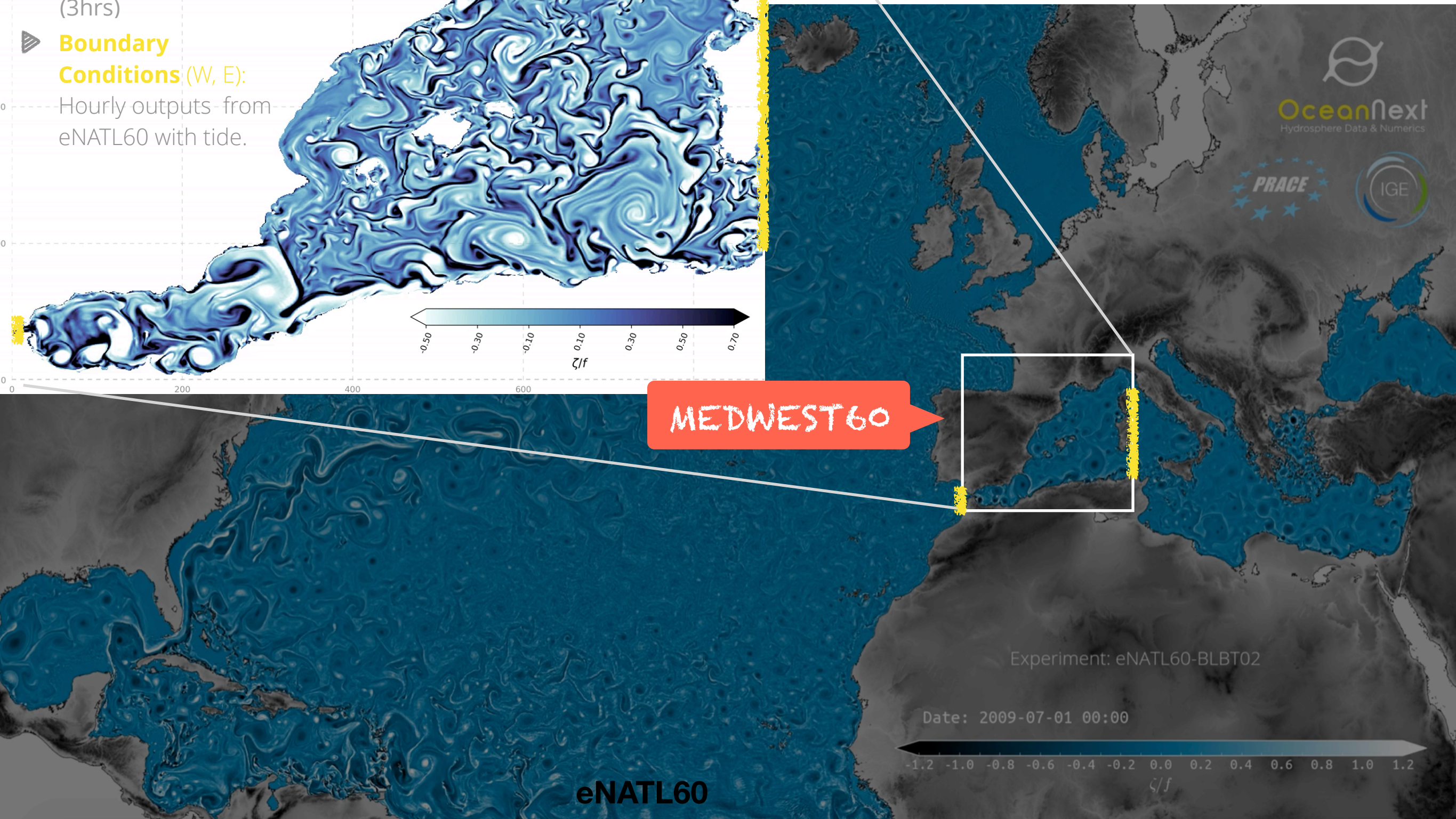
MEDWEST60: a new regional configuration at kilometric-scale horizontal resolution

- ▶ **NEMO 3.6 with tide**
- ▶ Horizontal resolution: **1/60°**
- ▶ Horizontal grid: **883 x 803**
- ▶ Vertical levels: **212** (with vvl)
- ▶ Surface forcing: DFS5.2 (3hrs)
- ▶ **Boundary Conditions** (W, E):
Hourly outputs from eNATL60 with tide.

- ▶ +Routines to run parallelized ensemble simulations with stochastic parameterisations (Brankart 2015, Bessieres 2017).



MEDWEST60



Experiment: eNATL60-BLBT02

Date: 2009-07-01 00:00

eNATL60

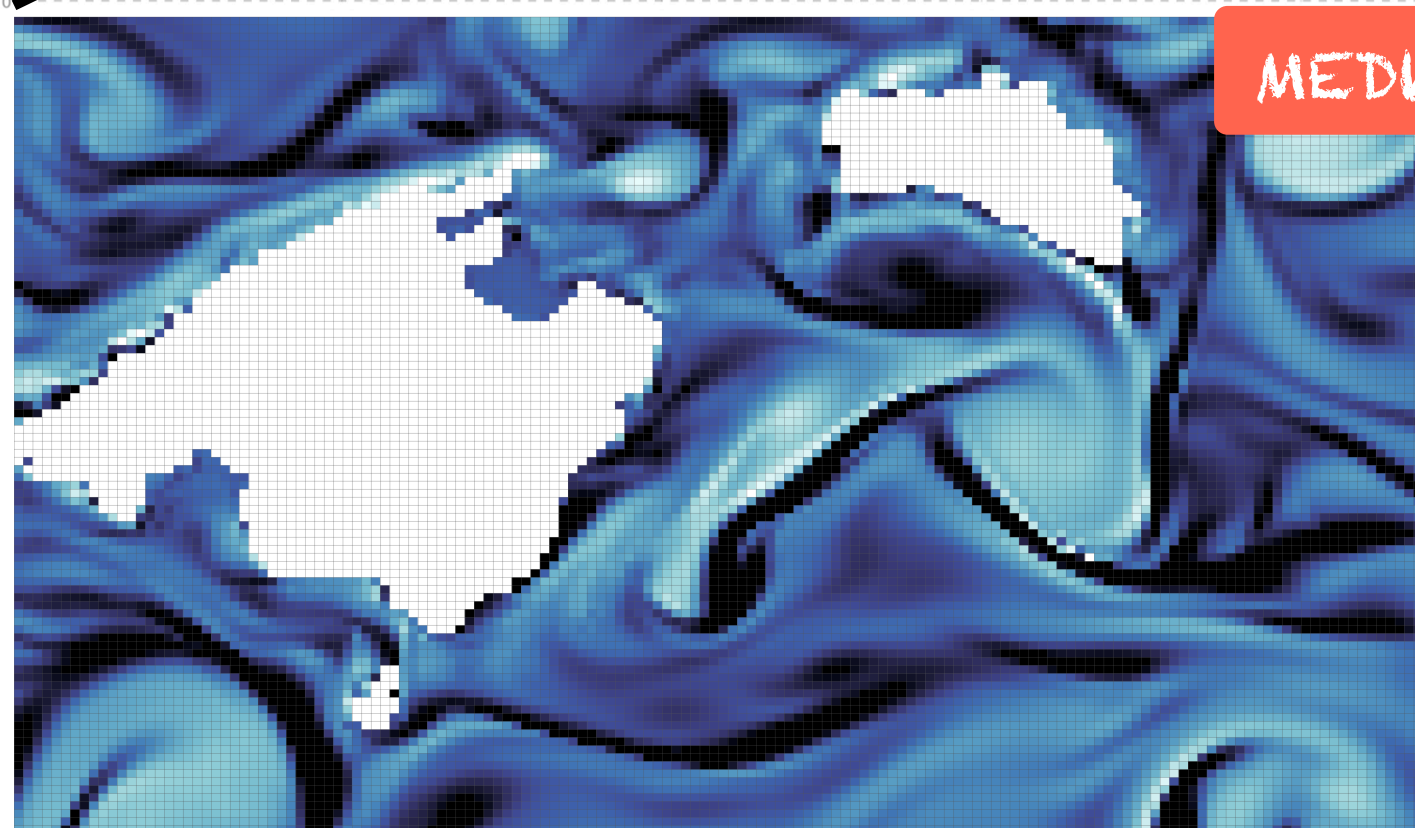
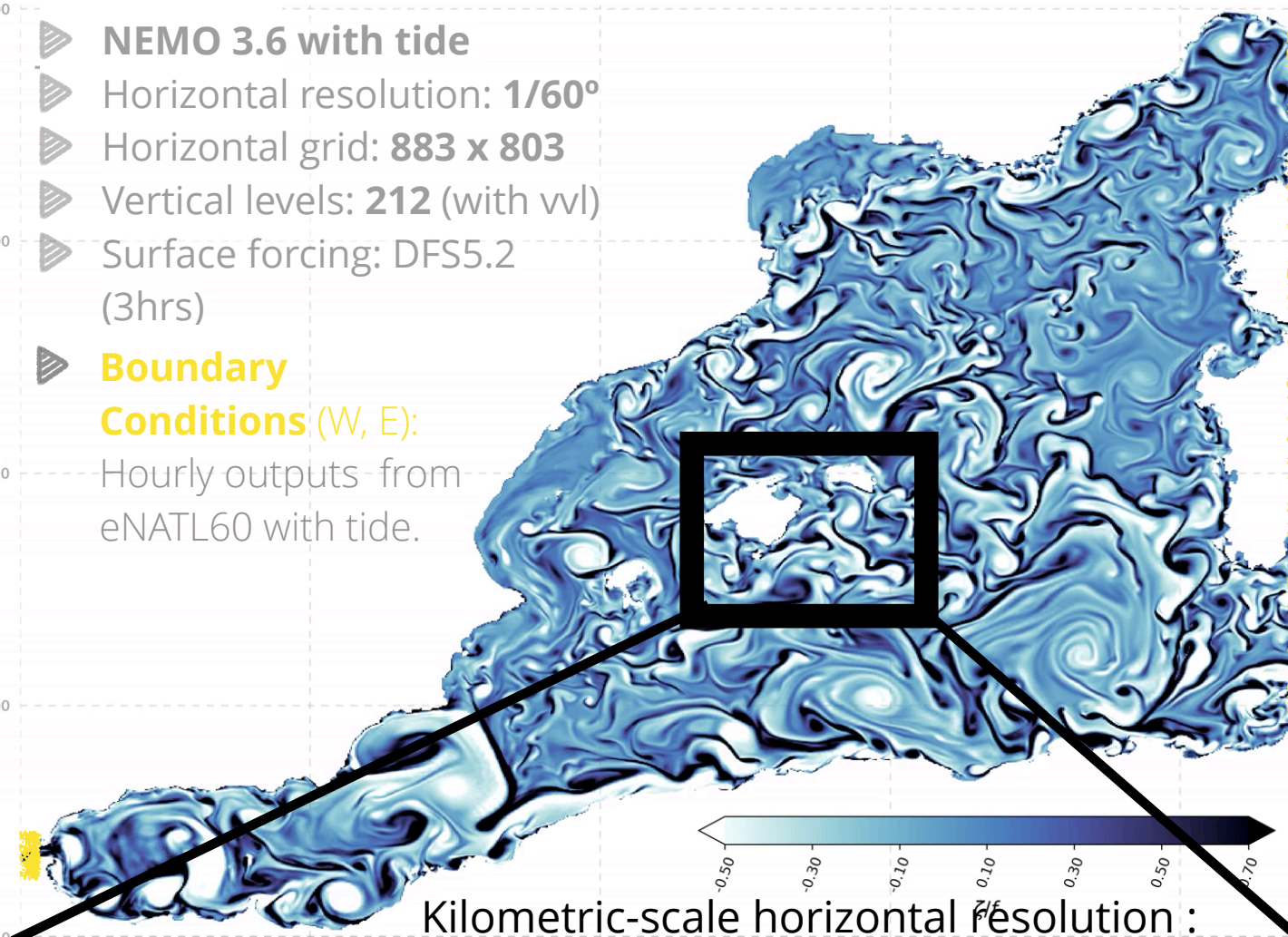

OceanNext
Hydrosphere Data & Numerics


PRACE


IGE

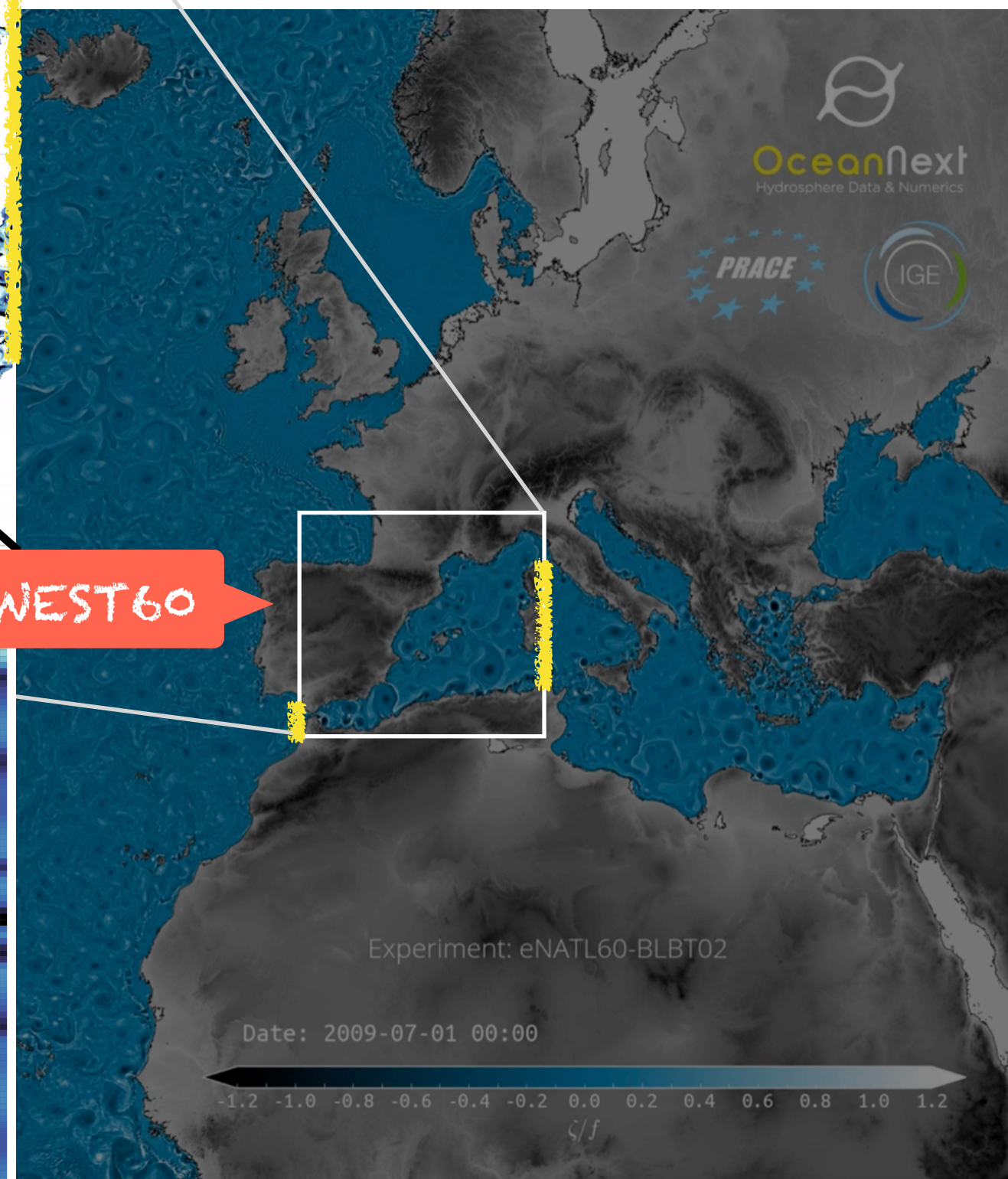
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MEDWEST60

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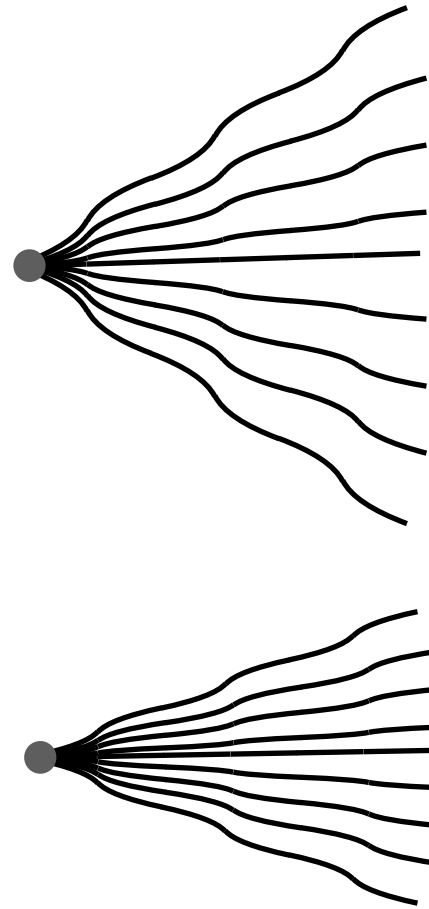


2. A set of 3 ensemble simulations of 20 members x 2-months

to represent uncertain initial conditions and the effect of model errors on the fine scales

Probabilistic model

With a stochastic parameterisation* representing the effect of model errors on the fine scales.



"Large" model error
and perfect initial conditions (●).

ENS-5%

"Small" model error
and perfect initial conditions (●).

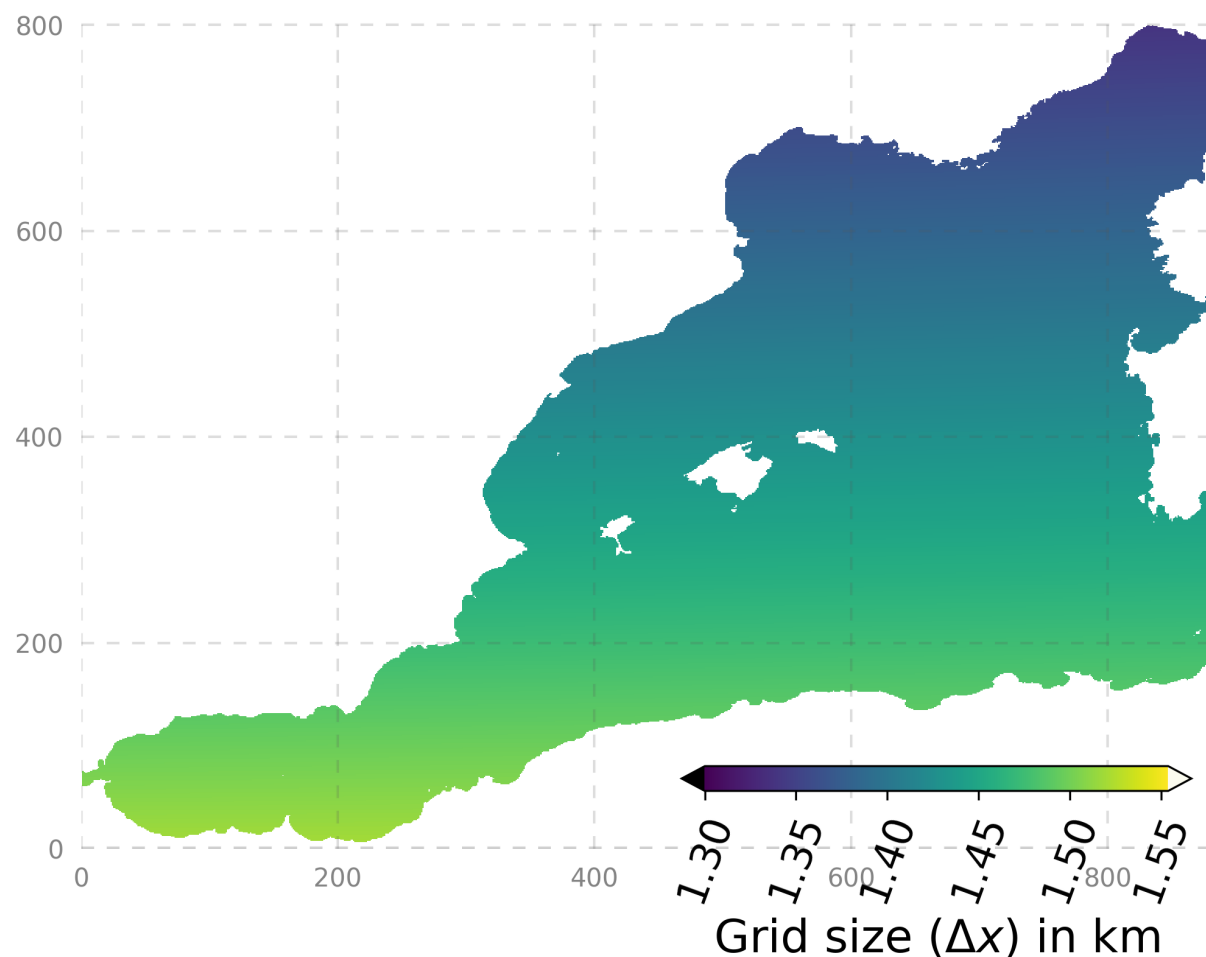
ENS-1%

(*) a stochastic parameterisation representing the effect of model errors on the fine scales:

- Stochastic perturbation of the horizontal grid metrics of the model (Δx and Δy) to represent location uncertainties in the horizontal displacements of the fluid parcels (in line with Memin 2014, Chapron et al 2018).
- Affects primarily the small scales (through derivative computations in the model code) and then cascade to larger scales following the model dynamics.

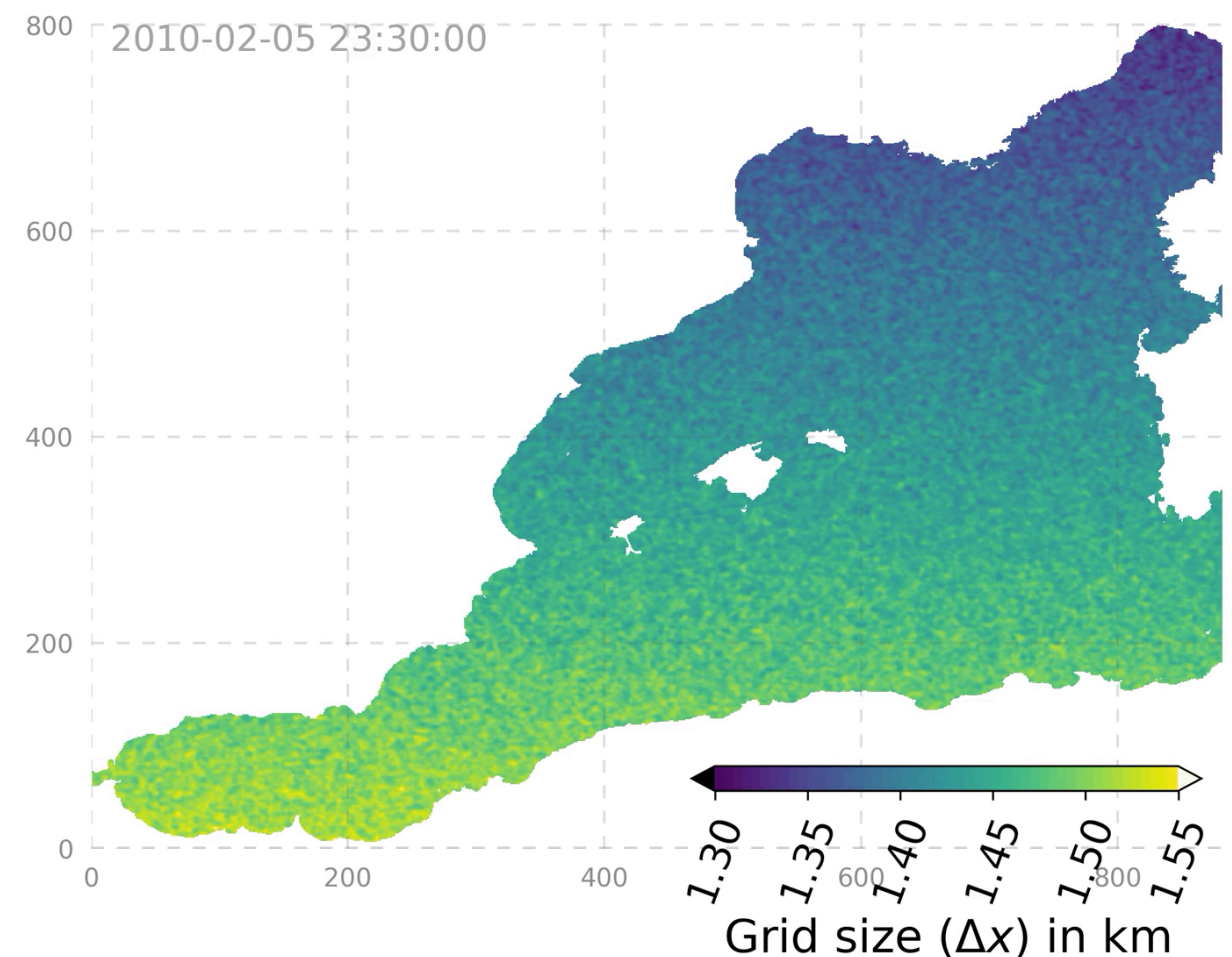
Deterministic model

(a) Standard NEMO grid size (Δx) in km



Probabilistic model

(b) 1%-perturbed gridsize (Δx) in km

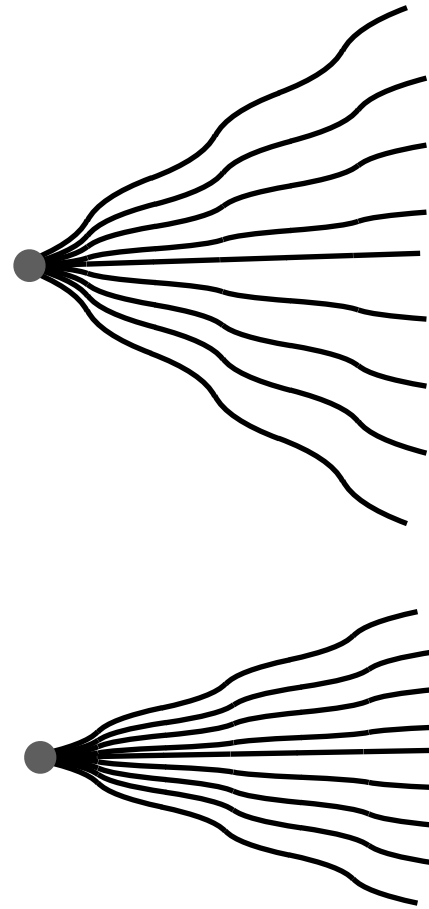


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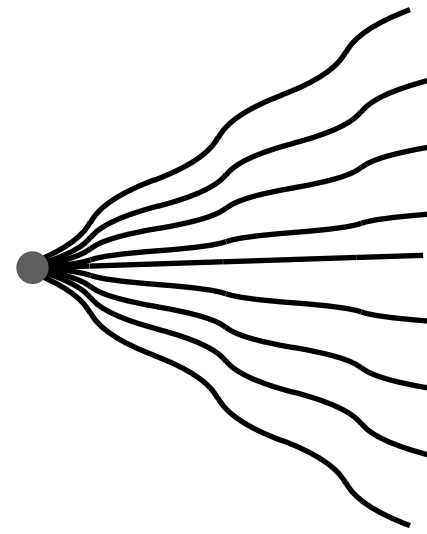
ENS-1%

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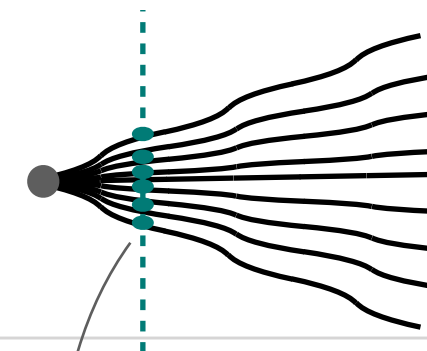
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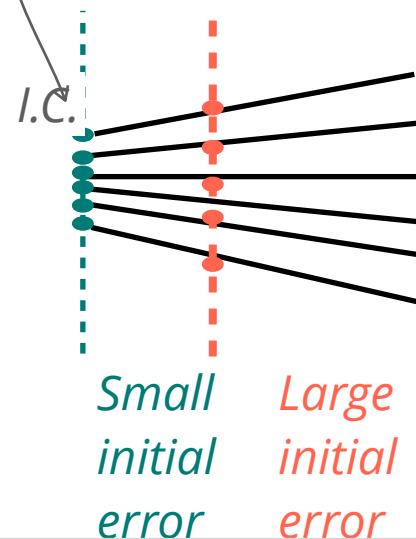
ENS-5%



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Deterministic model

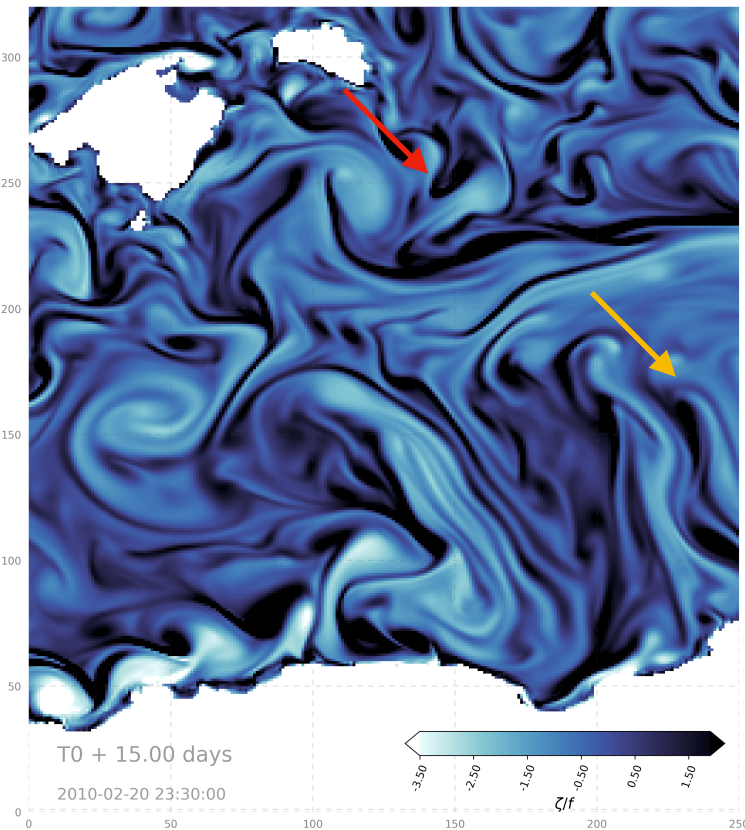


No model error
but unperfected initial conditions
(small, large).

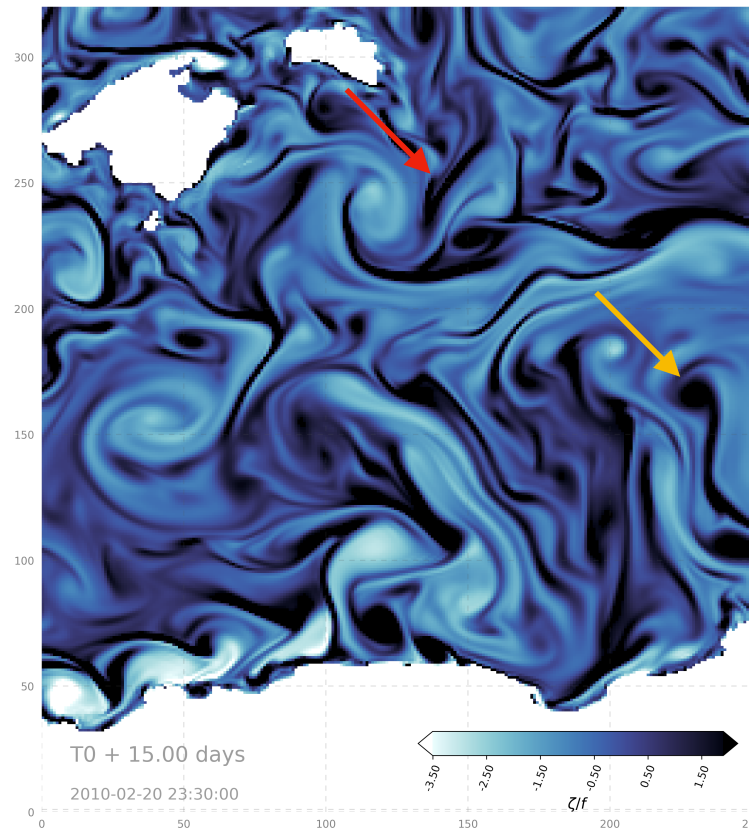
ENS-CI

3. Illustration of the proposed approach

Membre 1



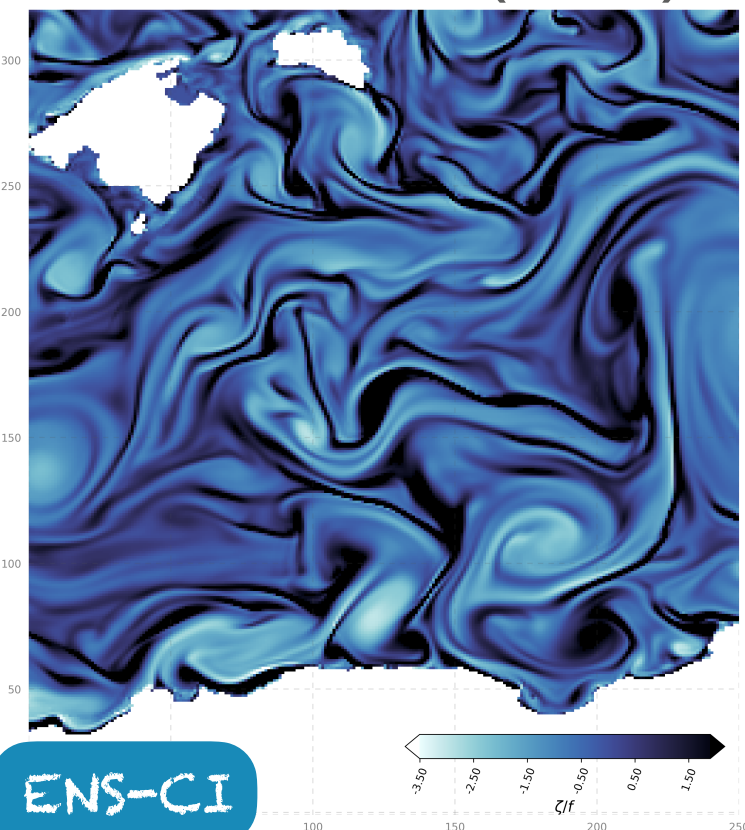
Membre 2



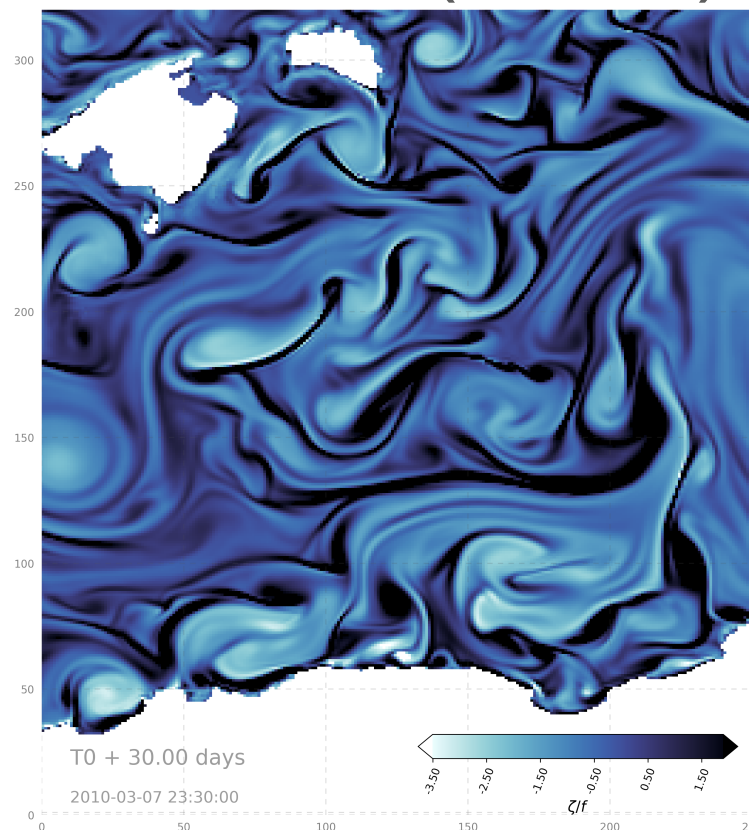
t0 (example of initial conditions)

- The vorticity fields are still very similar in the two members, but small differences exist (-> uncertain initial conditions).

Membre 1 (truth)



Membre 2 (forecast)



t0+15 days (example of forecast)

- The vorticity fields have become clearly distinct between the two members.

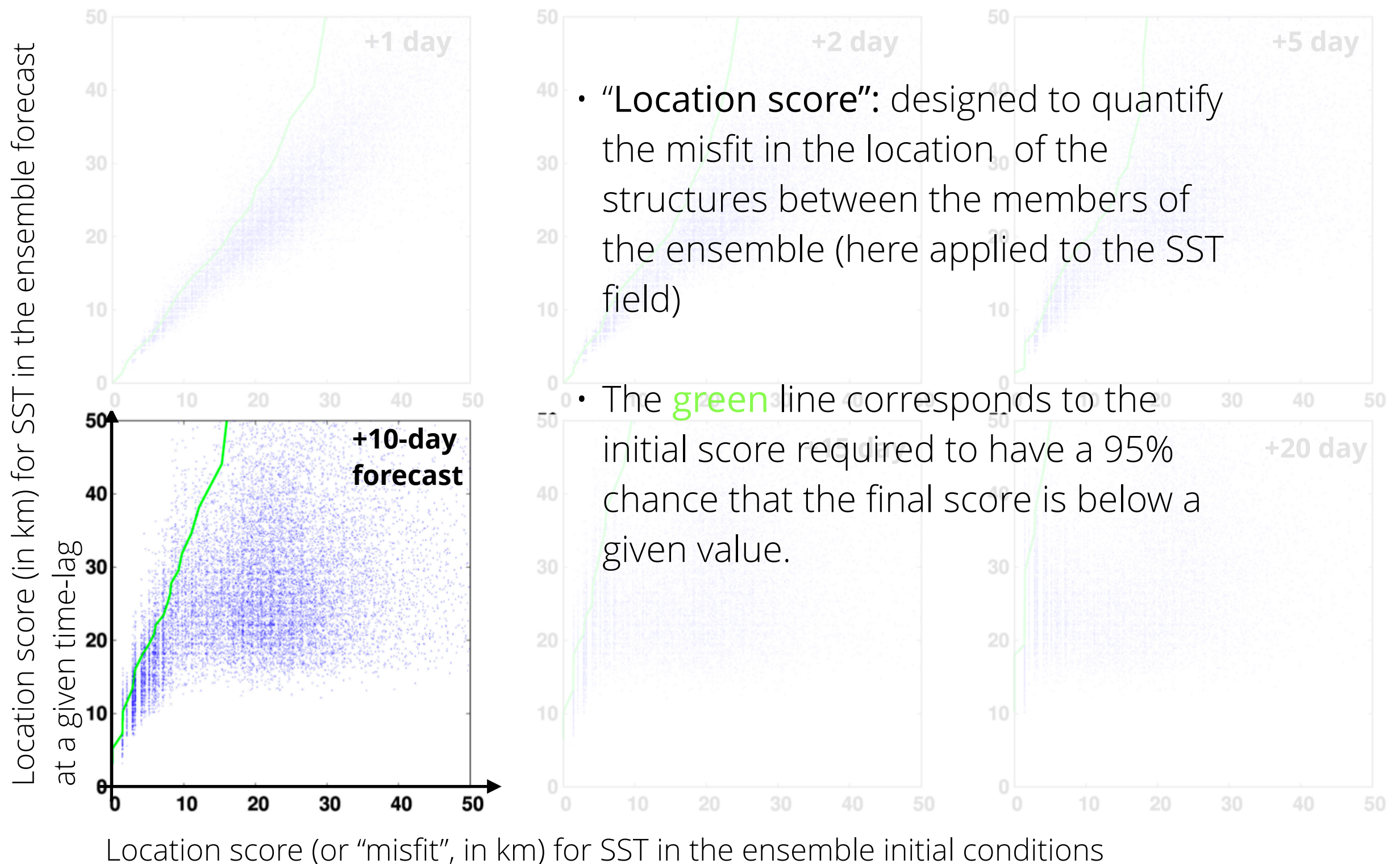
Quantify the "misfit" between one member taken as the pseudo truth and the other 19 members taken as the ensemble forecast, as a function of the initial "misfit".

3. Methodology

- Each ensemble member is alternatively taken as a reference truth and the remaining 19 members as ensemble forecast.
- A given “score” is used to assess the accuracy of both the forecast (at a given time-lag), and the initial conditions. For ex:
 - CRPS score,
 - location score,
 - etc.
- From the joint distribution of initial score and final scores, you can then assess the probability distribution of the forecast score given the initial score: **predictability**.

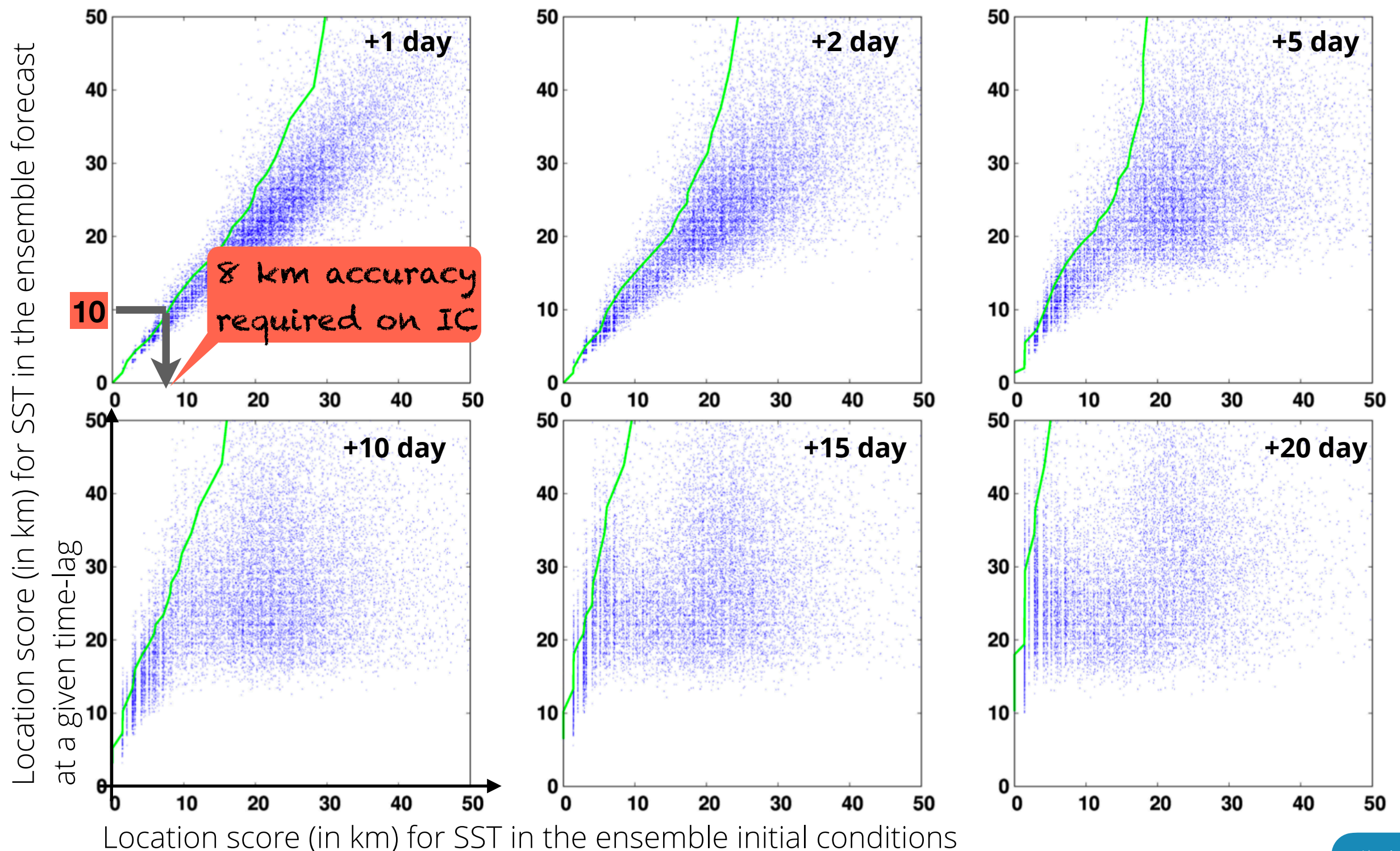
3. Predictability: an example of result

What is the accuracy required on the initial conditions in order to achieve a forecast accuracy of 10 km with a 95% confidence?



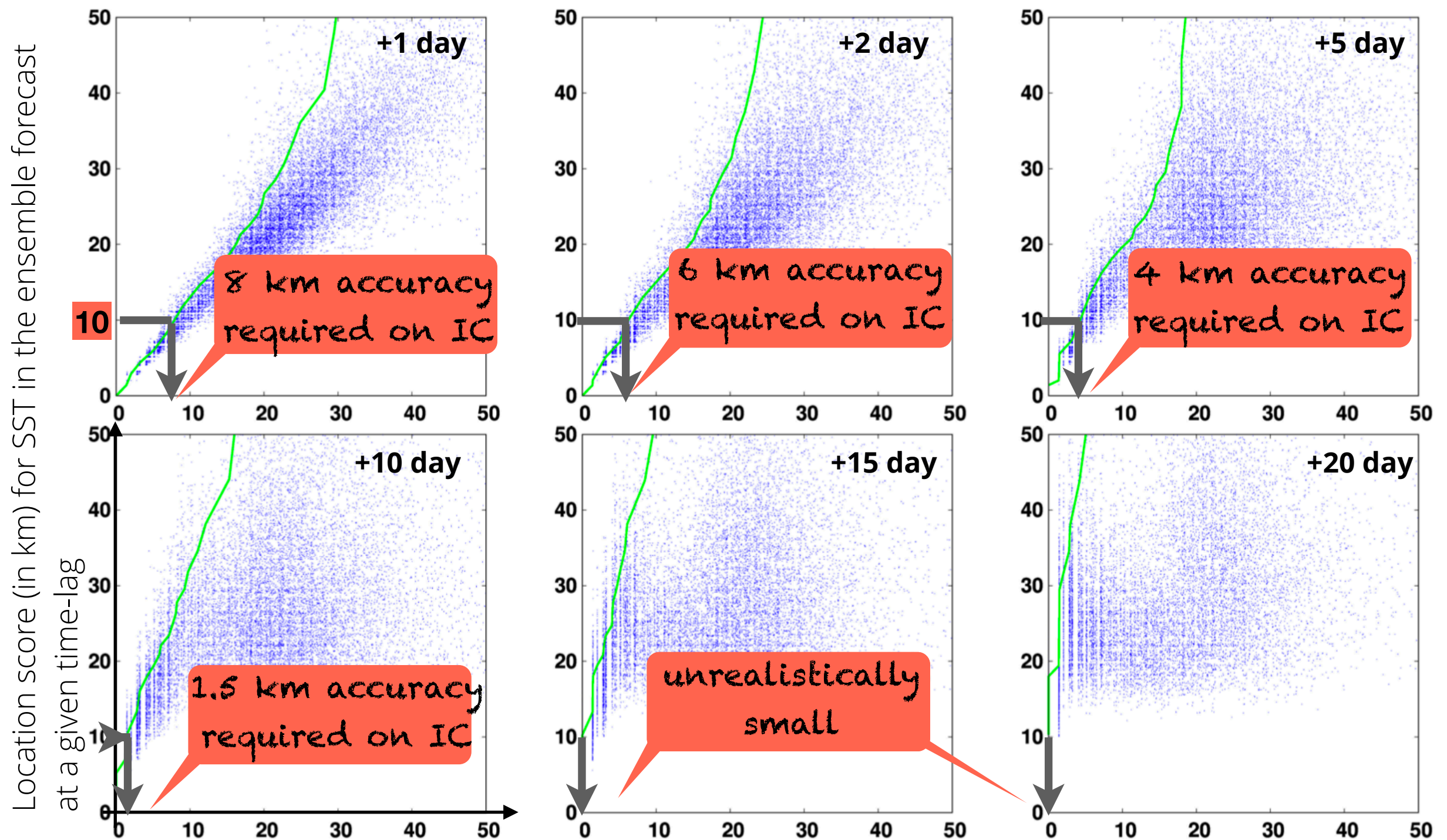
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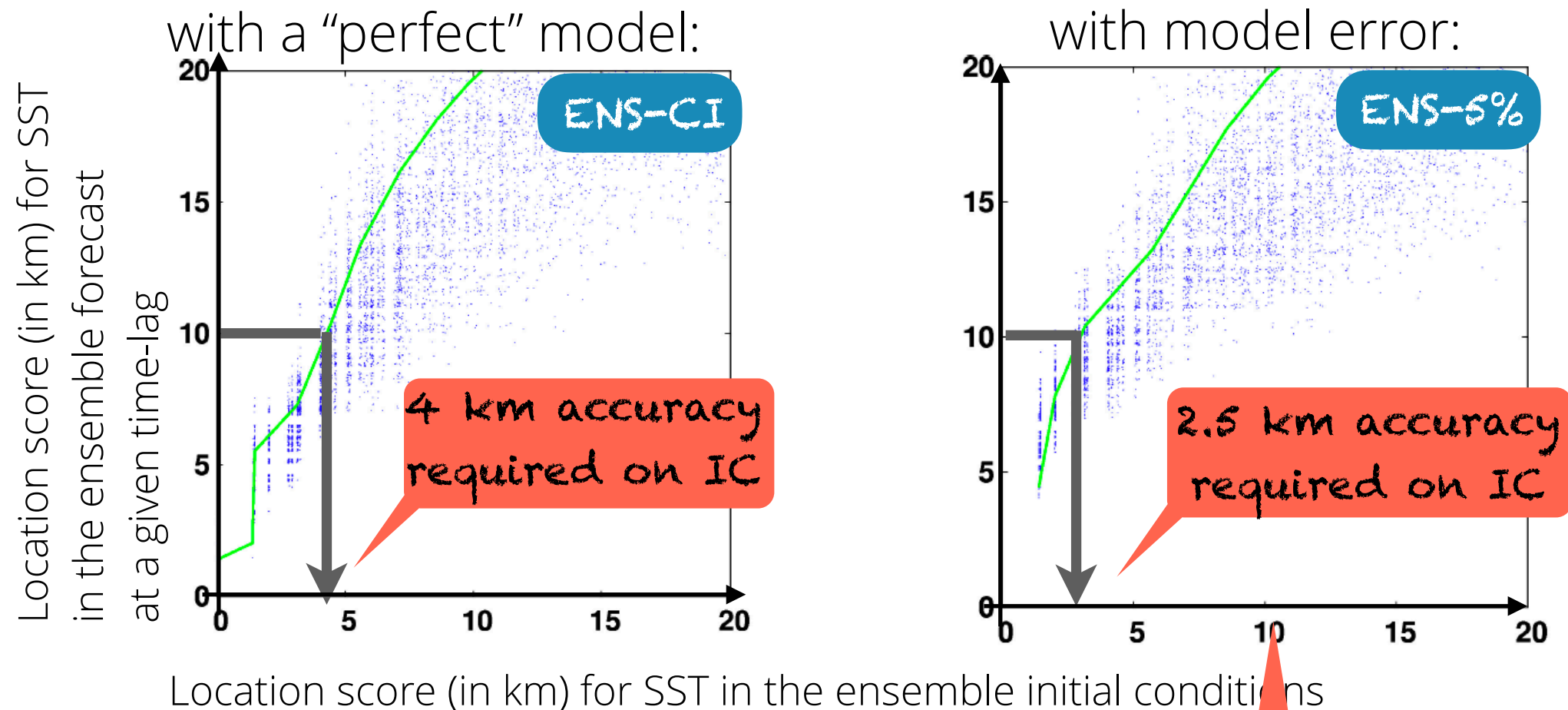


Location score (or “misfit” in km) for SST in the ensemble initial conditions

3. Predictability: an example of result

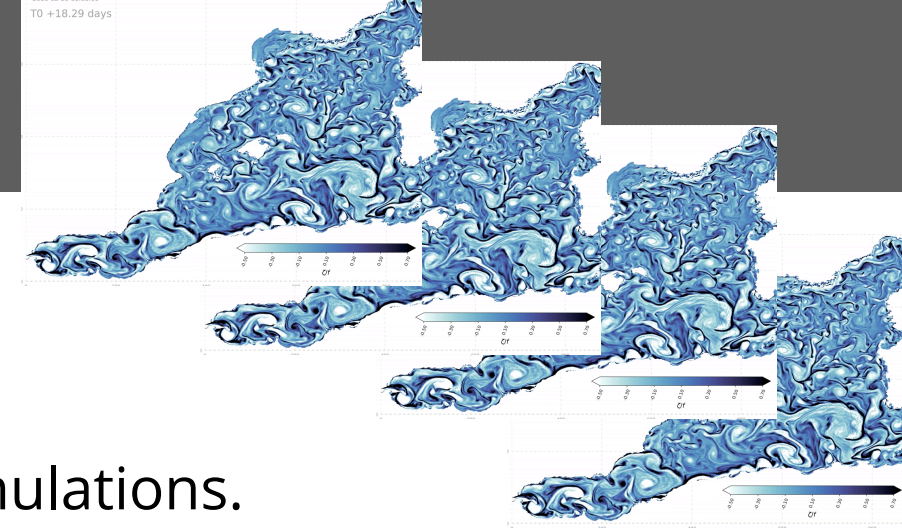
What is the accuracy required on the initial conditions in order to achieve a forecast accuracy of 10 km with a 95% confidence?

5-day forecast:



More stringent requirements if model error is taken into account (in our example, we find that it is only true for the short time-lags, after which the effect of initial conditions becomes the main factor).

To conclude



- ▶ We propose a probabilistic approach based on ensemble simulations.
- ▶ Predictability is quantified as a probability distribution of a forecast score given a score on the initial conditions.
- ▶ Model errors can be taken into account at the same time as uncertainty on the initial conditions.
- ▶ Provide necessary conditions, not sufficient conditions.
- ▶ The proposed methodology could be extended in many ways (application to different scores, and combinations of conditions on several key properties of the system, application with different sources of model error represented, etc).
- ▶ The necessary conditions on observed quantities can be translated into useful information for the design of the future ocean observing system (in terms of their accuracy and resolution). E.g., design of satellite constellations, of in-situ networks, etc.



- Contact: stephanie.leroux@ocean-next.fr
- IMMERSE deliverable (public report) available [DOI: [10.5281/zenodo.4570158](https://doi.org/10.5281/zenodo.4570158)]
- [Recording of this talk](#) at the IMMERSE GA, March 2021 .
- 1 article in prep. 2021: Leroux, Brankart et al.
- MEDWEST60 Github (codes and tools): <https://github.com/ocean-next/MEDWEST60>

Thank you for your attention !



GENCI

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