# The OCCIPUT Project : An ensemble of 1/4° ocean/sea-ice hindcasts to characterize the ocean intrinsic variability.

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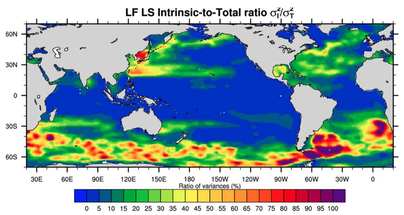
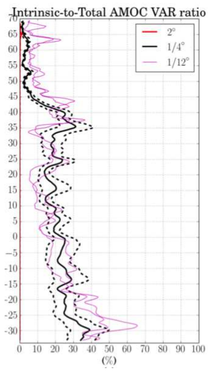
## Context:

- The variability of the climate system has a chaotic nature, involving ocean-atmosphere interactions.
- IPCC climate modeling systems are based on :
  - laminar oceans (1-2° resolution) currently (IPCC-AR5),
  - **eddying oceans (<1/4°) in the next (IPCC-AR6).**
- The origin of the low-frequency variability (period >1 year) in forced ocean hindcasts is:
  - in the laminar regime: 100% forced (→*deterministic* nature),
  - **in the eddying regime: 10 to 90% intrinsically generated by the forced ocean (→forced stochastic nature)**




**Figs:** Ratio of intrinsic-to-total interannual variance of the Atlantic Meridional Overturning Circulation (AMOC) from **Gregorio et al, 2015** (right) , and of the Sea Level Anomaly (SLA) low-pass filtered for scales larger than 1.5 yr and 1300 km from **Serrazin et al, 2015** (below). The ratio is deduced from comparing pairs of ocean simulations: (1) forced at the surface with a repeated climatological seasonal cycle, (2) forced with the full (interannual) forcing.

## The OCCIPUT project :

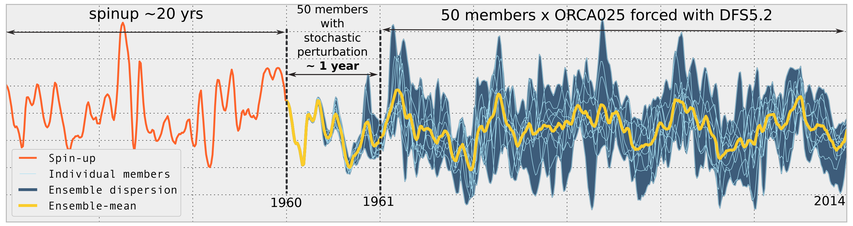
- **Perform a 50-member global 1/4° ensemble ocean hindcast of 55 years (1960-2014)** with perturbed initial conditions and same atmospheric forcing, to sample 50 of the possible ocean trajectories.
- **Extract and study the intrinsic and forced components of the 1-10 year variability of the fully-forced ocean:**
  - 3D modes of the forced component (→ Ensemble-mean) and of the intrinsic component (→ Ensemble-deviation),
  - Ensemble-PDFs of integrated quantities relevant for the climate system (MOC, Thermal Heat Content in 0-700m, etc),
  - Ensemble-PDFs of synthetic altimeter and in-situ T/S records.

### References

-**Bessière et al** (to be submitted in 2015) Development of a probabilistic ocean modelling system with NEMO at eddying resolution,Geoscientific Model Development.
-**Brankart (2013)** Impact of uncertainties in the horizontal density gradient upon low resolution global ocean modelling, Ocean Modelling, 66, pp 64-76.
-**Gregorio et al. (2015)** Intrinsic variability of the Atlantic meridional overturning circulation at interannual-to- multidecadal timescales, Journal of Physical Oceanography (EOR).
-**Leroux et al** (to be submitted in 2015), An ensemble of 10×20-yr ocean-sea-ice hindcasts at 1/4° to characterize interannual intrinsic variability in the North-Atlantic ocean, GRL.
-**Penduff et al. (2014)** Ensembles of eddying ocean simulations for climate, Clivar Exchanges.
-**Sérazin et al. (2015)** Intrinsic variability of sea-level from global 1/12° ocean simulations: spatio-temporal scales, Journal of Climate, EOR.

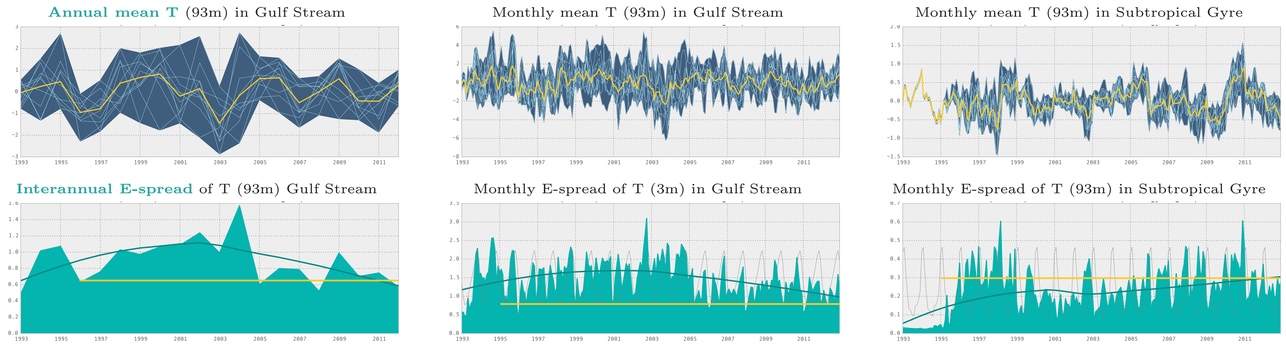
## OCCIPUT modeling set-up and outputs:

- MODEL: NEMO 3.5 BETA + XIOS
- INITIAL PERTURBATION STRATEGY: Stochastic parametrization on density (Brankart et al, 2013) applied to each member of the ensemble for the first year of the ensemble (each member has a stochastic equation of state).
- ON-LINE ENSEMBLE STATISTICS: computed across the ensemble as all members are run in parallel in one executable (E-mean, E-std, PDFs at gridpoints).
- OUTPUTS: 50 members × monthly 3D fields, 5-day 2D fields (e.g. SST. U-V-T-S at RAPID & OVIDE), 1-day transport terms (MHT).
- SYNTHETIC OBS GENERATOR: 50 members × (altimeter and in-situ T/S records) (50 realisations of ENACT-like and JASON-like databases).



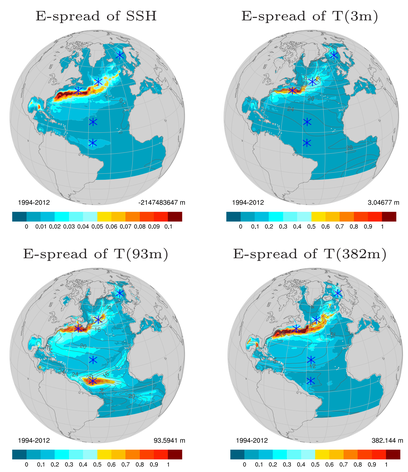

| | Regional Prototype | OCCIPUT ensemble |
|---|---|---|
| Domain | North Atlantic | Global |
| Resolution | NATL025-L46 | ORCA025-L75 |
| Ens. size | 10 mbs × 20 yrs | 50 mbs × 55 yrs |
| Periode | (1993-2012) | (1960-2014) |
| Forcing | DFS5.2 (ERA40) | DFS5.2 (ERA40) |
| Schedule | March 2015 (done) | Summer 2015 |

## Preliminary results from the North-Atlantic prototype (NATL025: 10 members × 20 years)




**Upper panels:** Monthly and Annual temperature timeseries at depth 93 and 3 m at two grid points in the Gulf Stream and Subtropical Gyre from the NATL025 ensemble. The timeseries have first been detrended (loess function removed from each member separatly) and the monthly timeseries has been also deseasonalized (ensemble-mean seasonal cycle removed from all the members). The yellow curve shows the ensemble mean (E-mean).

**Lower panels:** **Interannual and monthly E-spread (E-Std-deviation → intrinsic variability)** of the detrended-deseasonalized ensemble. The yellow line shows the amplitude of the time-standard-deviation of E-mean (→ forced variability) for comparaison. The grey line shows the phase of the removed seasonal cycle.




**Figs:** **Interannual E-spread** (→ E-Std-deviation) of annual mean SSH and T at depths 3, 93 and 382 m, in average over 1994-2012.

- The stochastic perturbation strategy applied for 1 year fulfills its aimed purpose to seed a spread between the members ("E-spread"), that keeps growing after the stochastic parametrization has been switched off.
- As expected, some E-spread arises and grows faster in areas of intense meso-scale activity (e.g. Gulf Stream), but it also arises in less turbulent areas (slowlier).
- The spread first arises at small scales but **cascades toward larger spatio-temporal scales (~1000km, interannual and slower)**.
- The amplitude of the **intrinsic interannual variability (E-spread)** is in some cases higher -or of same order- as the time-variations of the forced interannual variability (E-mean).
- The imprint of the intrinsic low frequency variability is a function of the variables, location, depth, etc.
- Still on-going work: more analyses of the North-Atlantic prototype to come (Leroux et al., in prep, Bessiere et al, in prep) + Preparation of the global OCCIPUT ensemble: run-time scheduled for summer/fall 2015.

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