FINGERPRINTS OF OCEANIC CHAOS AND ATMOSPHERIC FORCING ON ALTIMETER/IN-SITU DATA: OBSERVATIONAL CONSEQUENCES

Thierry Penduff[1],

S. Leroux[1],
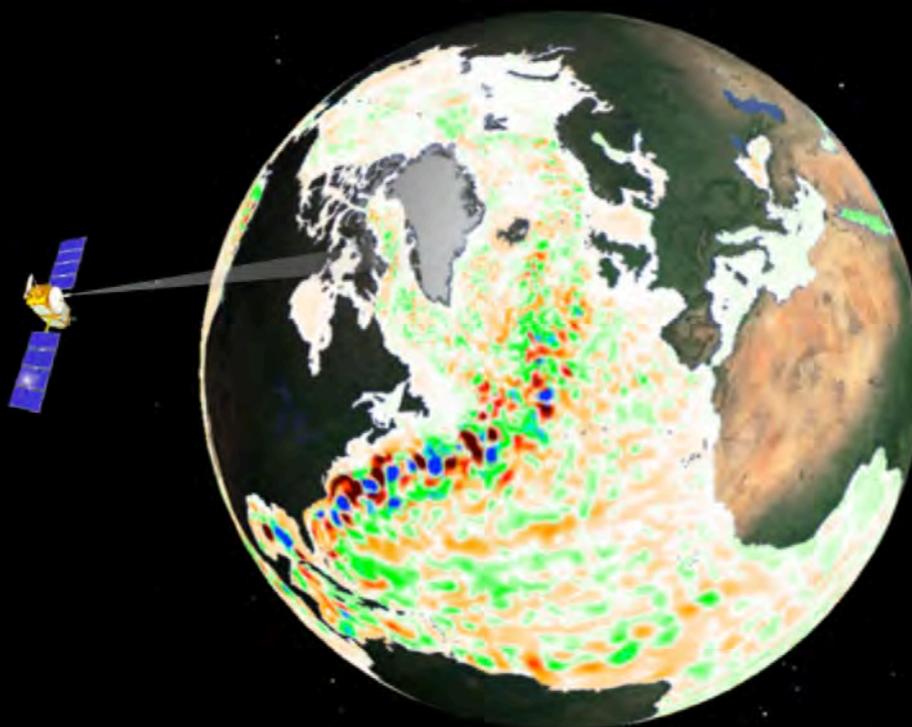L. Bessières[2],
G. Sérazin[1, 2],
P.V. Huot[1],
A. Jaymond[1],
S. Grégorio[1],
J.M. Molines[1],
B. Barnier[1],
L. Terray[2],

[1]CNRS – LGGE, Grenoble
[2]CERFACS, Toulouse

sea-level intrinsic/chaotic variability (-20/+20cm)
(seasonally-forced NEMO ¼°simulation)

What is the actual influence of the atmosphere on observed oceanic states ?

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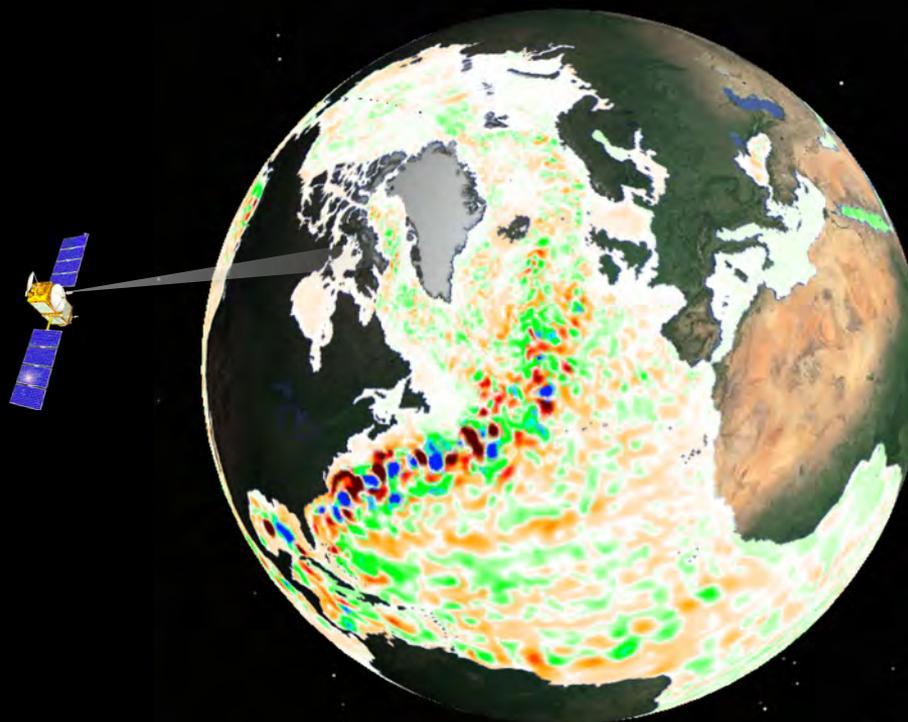S. Leroux[1],
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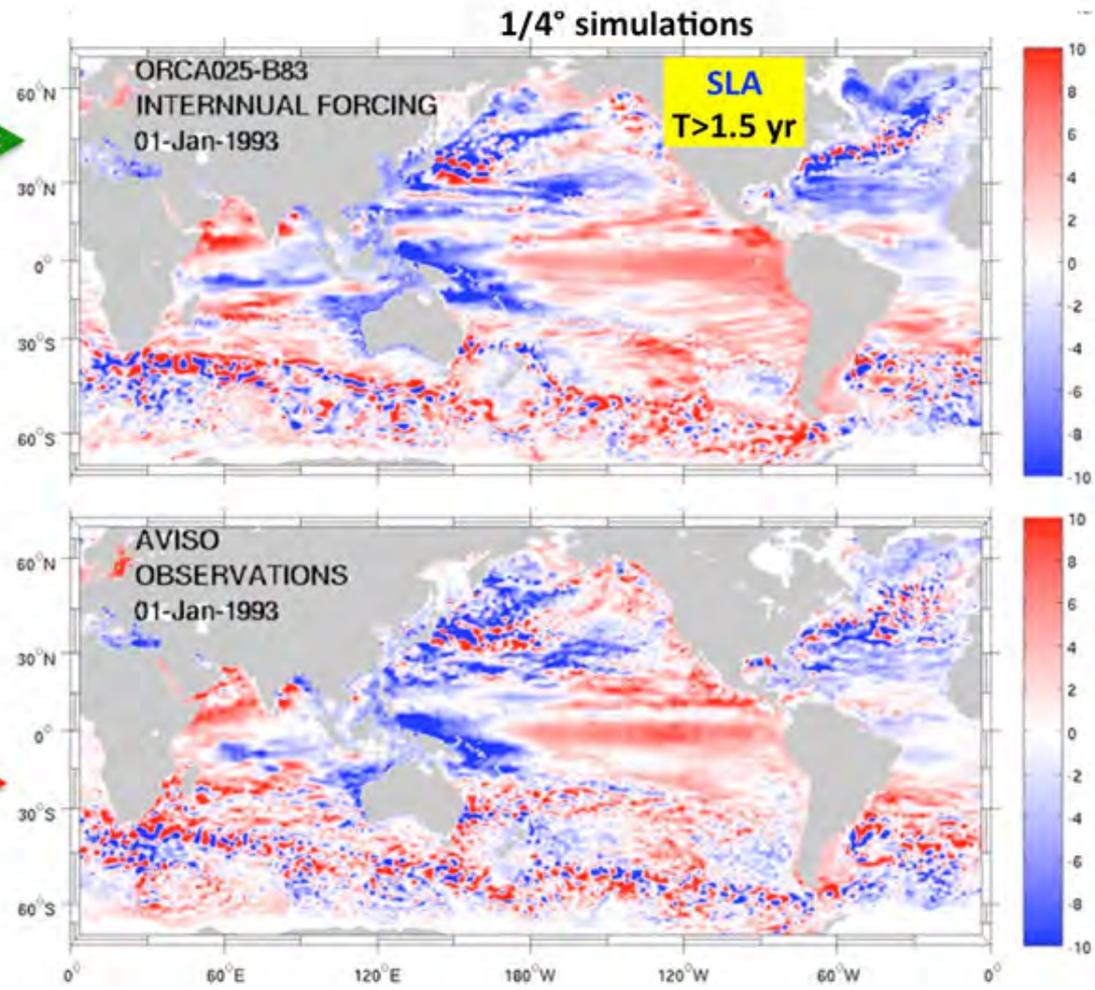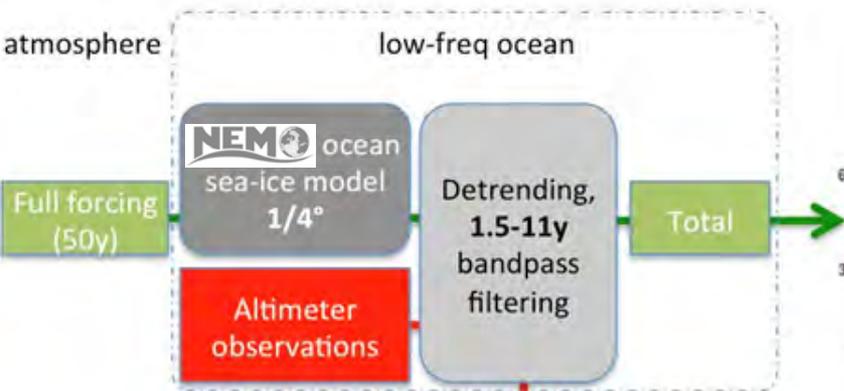
Outline

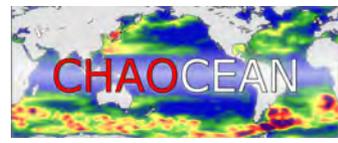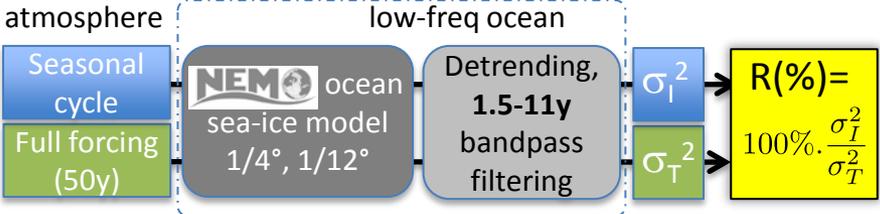Chaotic Intrinsic Variability in the global ocean

1. CIV isolated under seasonal forcing
   - Imprints on observed fields
   - Open questions

2. CIV modulated by full (reanalyzed) forcing
   - Global ensemble simulation
   - Imprints on observed fields → D/A questions

3. Observational issues

4. Conclusions and perspectives

Low-frequency SLA variab.
Experimental strategy

Approach

atmosphere | low-freq ocean

Full forcing (50y) → NEMO ocean sea-ice model 1/4° → Detrending, 1.5-11y bandpass filtering → Total

Altimeter observations

1/4° simulations

ORCA025-B83 INTERNNUAL FORCING 01-Jan-1993

SLA T>1.5 yr

AVISO OBSERVATIONS 01-Jan-1993

Penduff et al (Jclim 2011),
Brodeau et al (Ocean Mod. 2010)

Chaotic part (%) of the large-scale low-frequency variance

atmosphere — low-freq ocean

| Seasonal cycle | NEMO ocean sea-ice model 1/4°, 1/12° | Detrending, **1.5-11y** bandpass filtering | σ_I^2 | $R(\%)=$ |
| Full forcing (50y) | | | σ_T^2 | $100\%\cdot\dfrac{\sigma_I^2}{\sigma_T^2}$ |

CHAOCEAN

2013-2016 OST-ST Project

Atlantic MOC

OVIDE **5%**

RAPID **25%**

SAMO C **40%**

Legend: 2° , 1/4° , 1/12°

R(%)

Atlantic MHT

5%

15%

25%

R(%)

SLA (T>1.5 year, L>12°)

80%

100%

R(%)

Ratio of variances (%)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
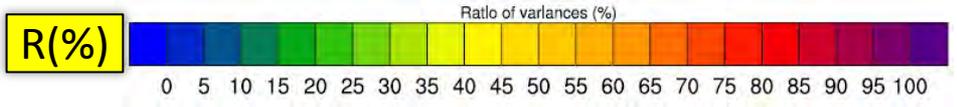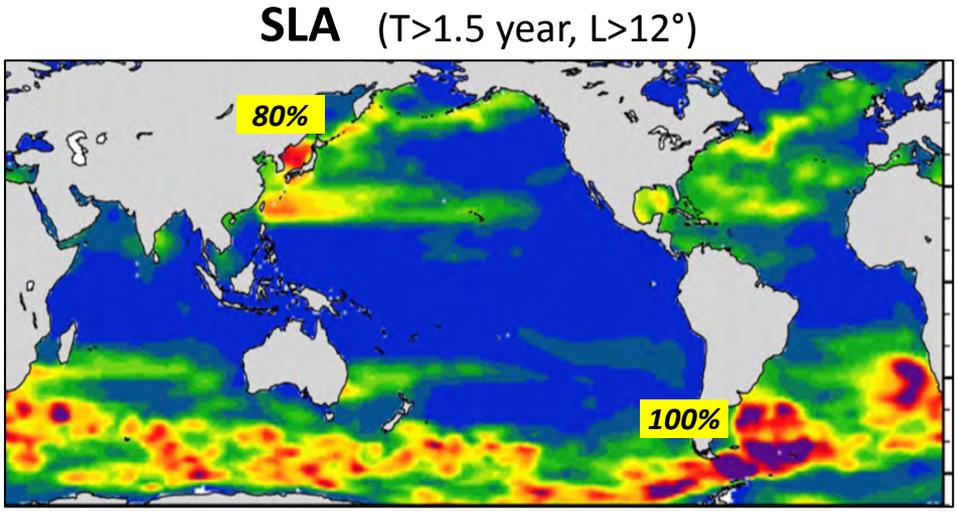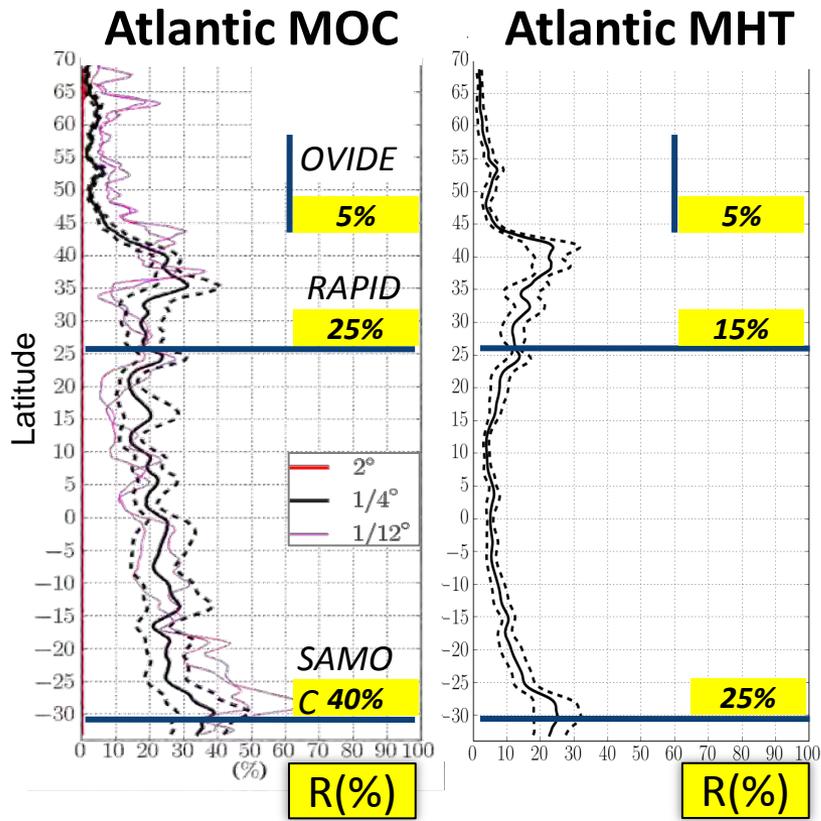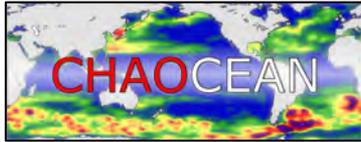
Laminar simulations : R ~ 0%

Penduff et al (Jclim 2011), Sérazin et al (Jclim 2015), Grégorio et al (JPO 2015)
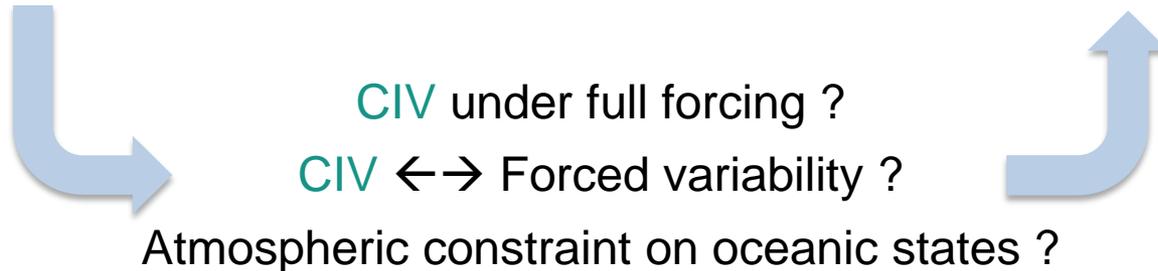
Chaotic Intrinsic variability

CIV isolated under seasonal forcing

- Strong

- Broad range of scales

- Multiple observable imprints

CIV under full (reanalyzed) forcing

- Ensemble run

- Perturbed initial conditions

- Same forcing on all members

CIV under full forcing ?

CIV ← → Forced variability ?

Atmospheric constraint on oceanic states ?
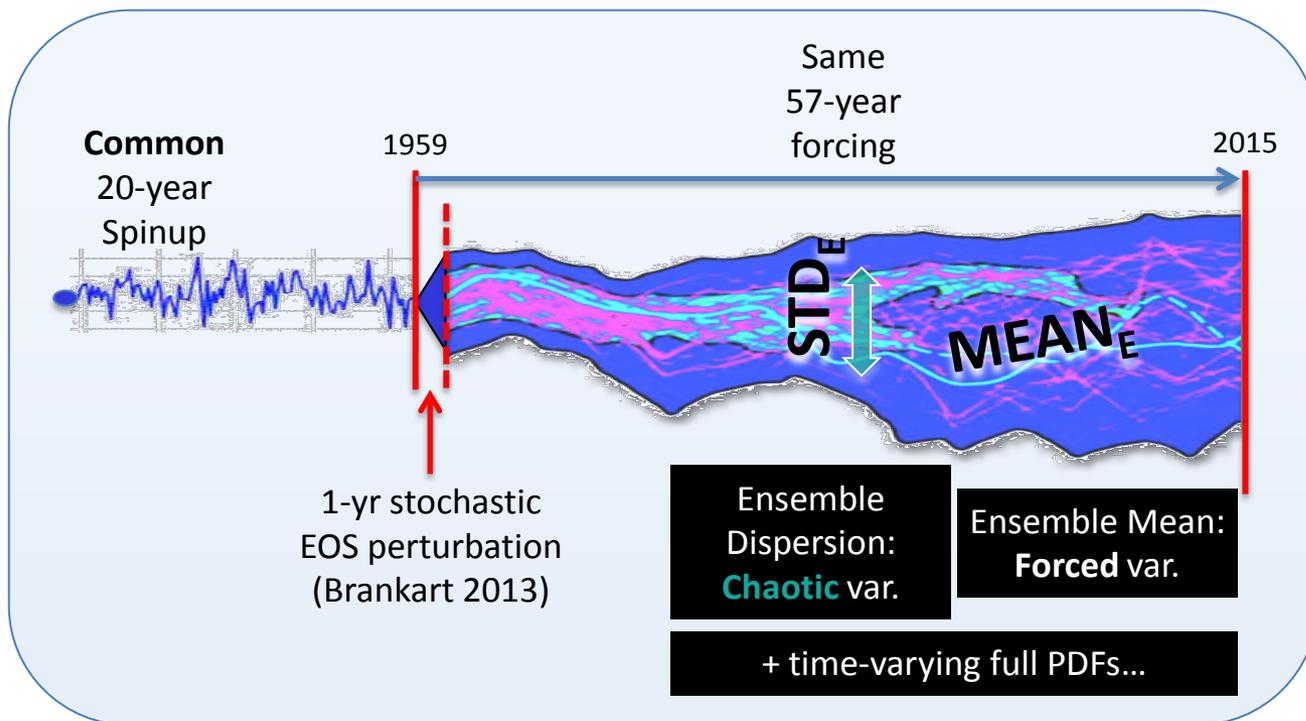
Penduff et al (2014)

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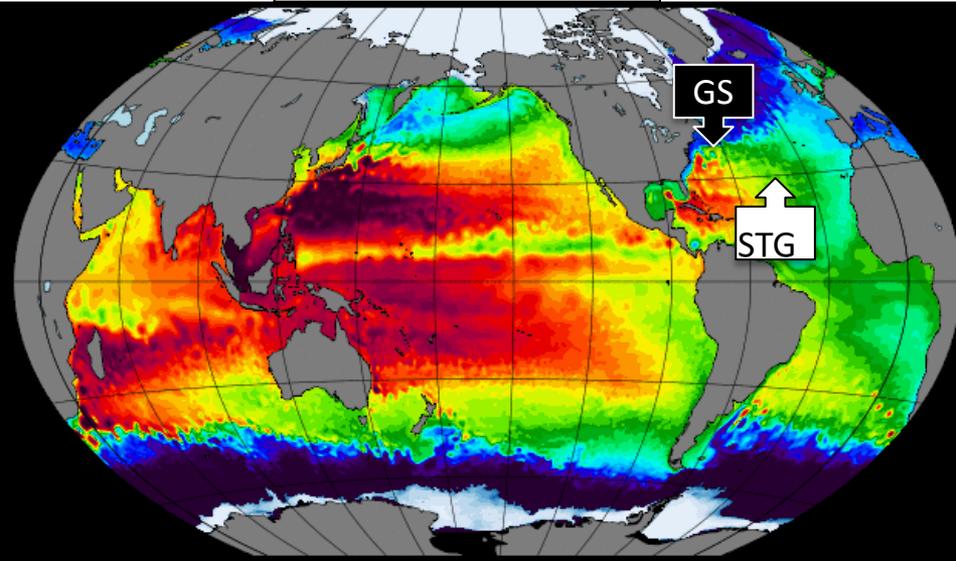
From CHAOCEAN to the OCCIPUT Project

50-member ensemble of
57-year Global Ocean/sea-ice ¼° hindcasts

Common 20-year Spinup

1959

Same 57-year forcing

2015

STD_E

$MEAN_E$

1-yr stochastic EOS perturbation (Brankart 2013)

Ensemble Dispersion: **Chaotic** var.

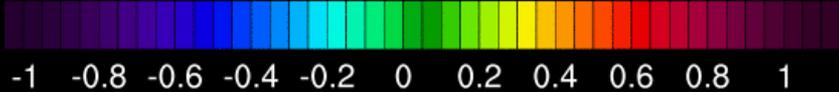Ensemble Mean: **Forced** var.

+ time-varying full PDFs...

Penduff et al (2014)

5-day SSH: Forced and Chaotic variability (1960-1965)

Ensemble Mean FORCED variability

Ensemble STD CHAOTIC variability

GS

STG

GS

STG

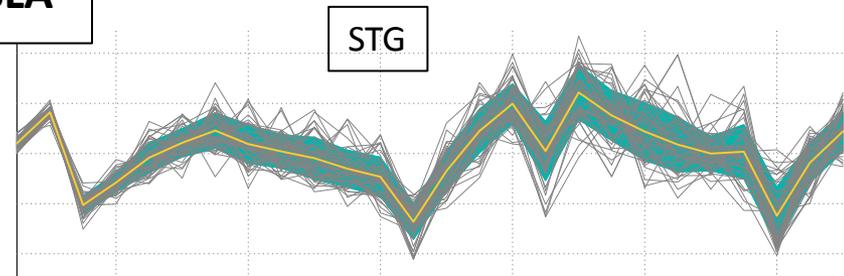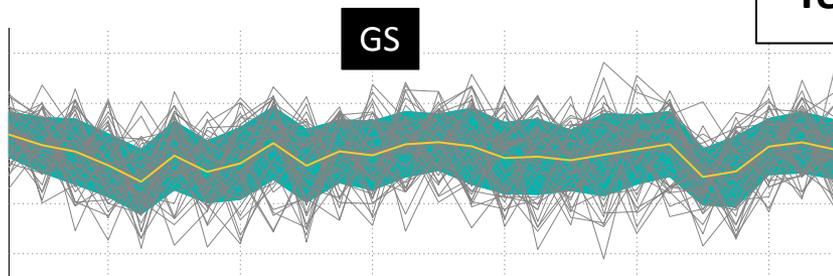03 Jan 1960   Unit: m

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

03 Jan 1960   Unit: m

0 0.03 0.06 0.09 0.12 0.15 0.18 0.21 0.24 0.27 0.3

Yearly SLA

GS

STG

Bessières et al, 2016
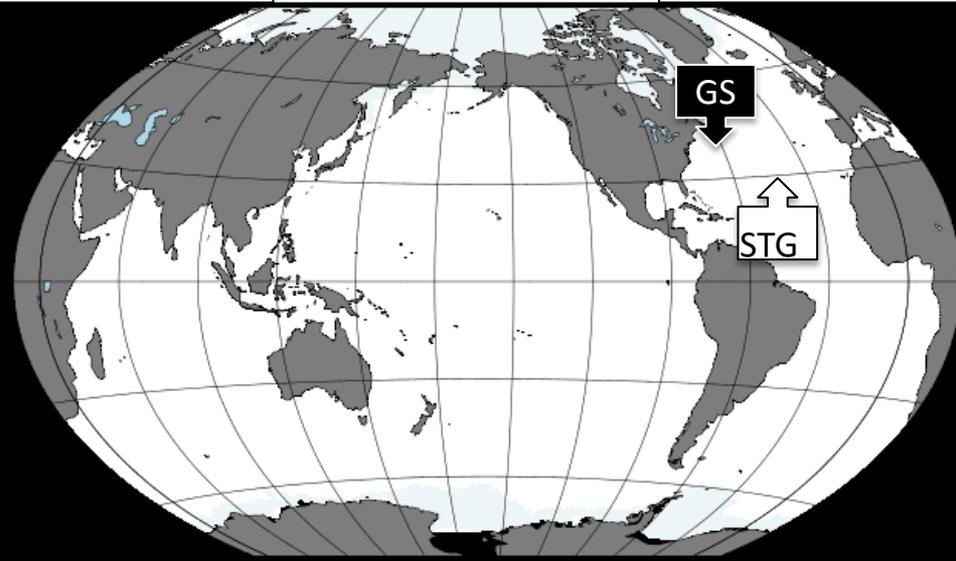
Daily SSH: atmospherically-modulated Chaotic var.

AVISO

Huot, 2016
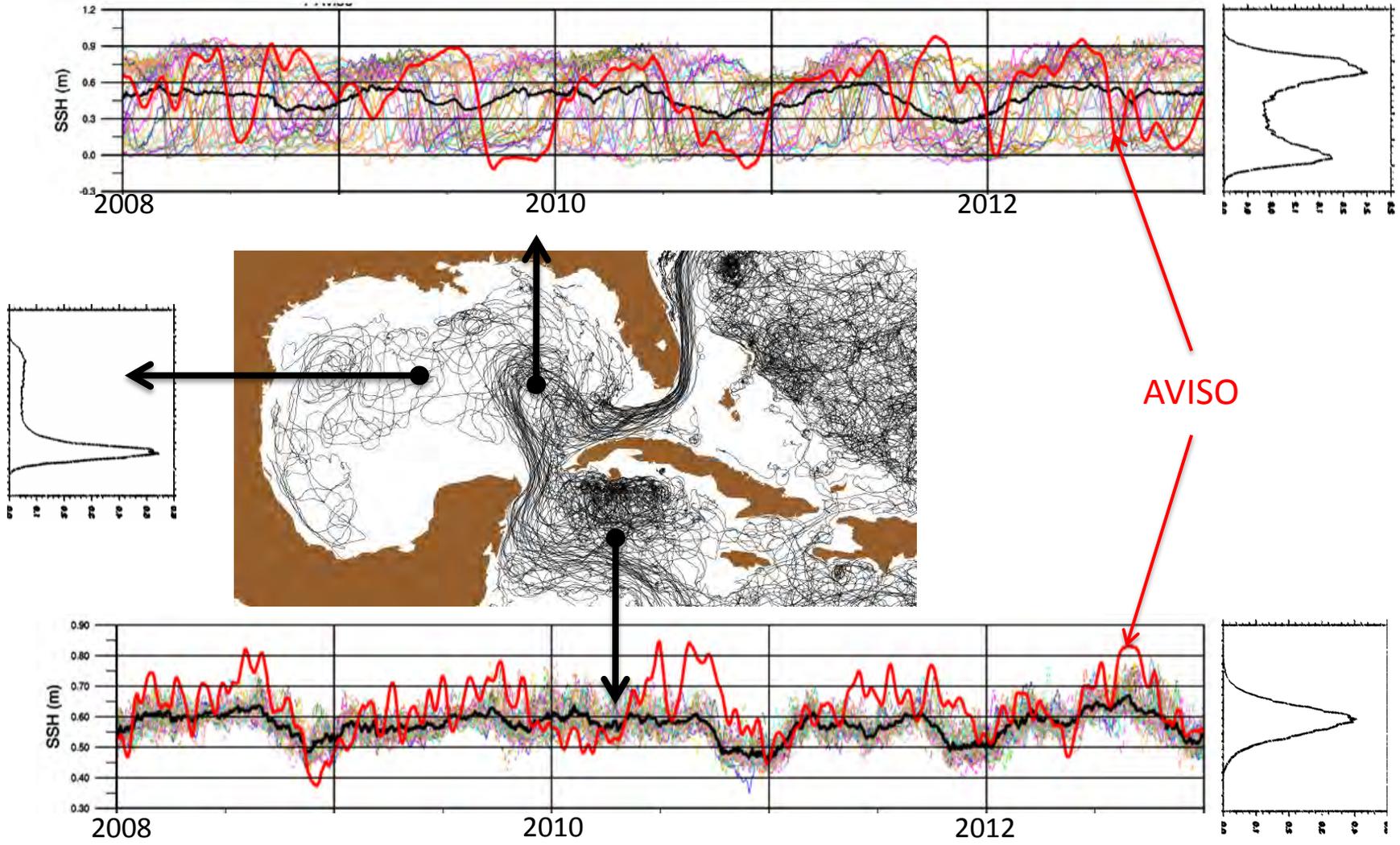
2-15 yr OHC : Forced vs Chaotic variability (1980-2010)

Oceanic Heat Content
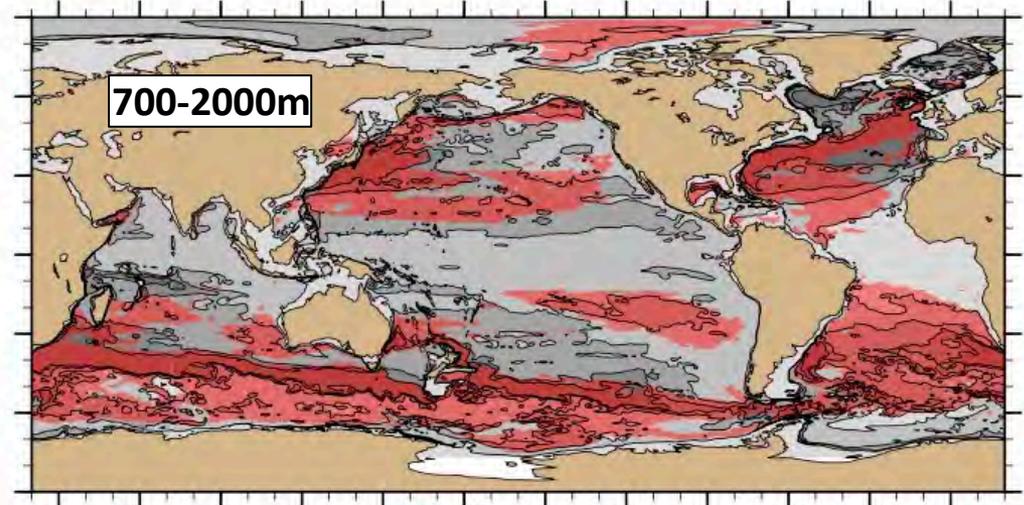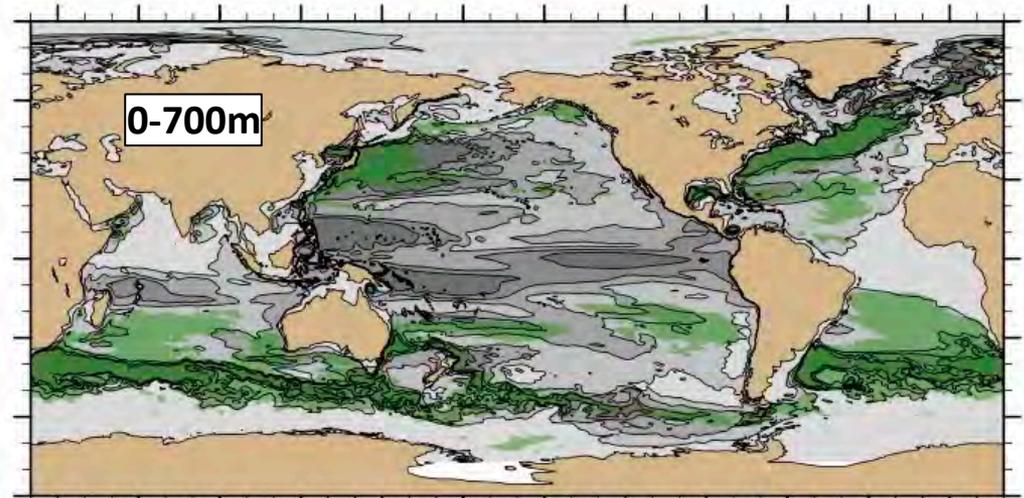
y = 1980,2010   m = 1,50

Emean (Tstd) → Total var.

Tstd (Emean) → Forced var.

Tmean (Estd) → Chaotic var.

Colors :
Chaotic
exceeds
Forced

Sérazin et al (to be submitted to GRL.)

30-year OHC$_{0-700m}$: Forced vs Chaotic trends (1980-2010)

(L>12°)
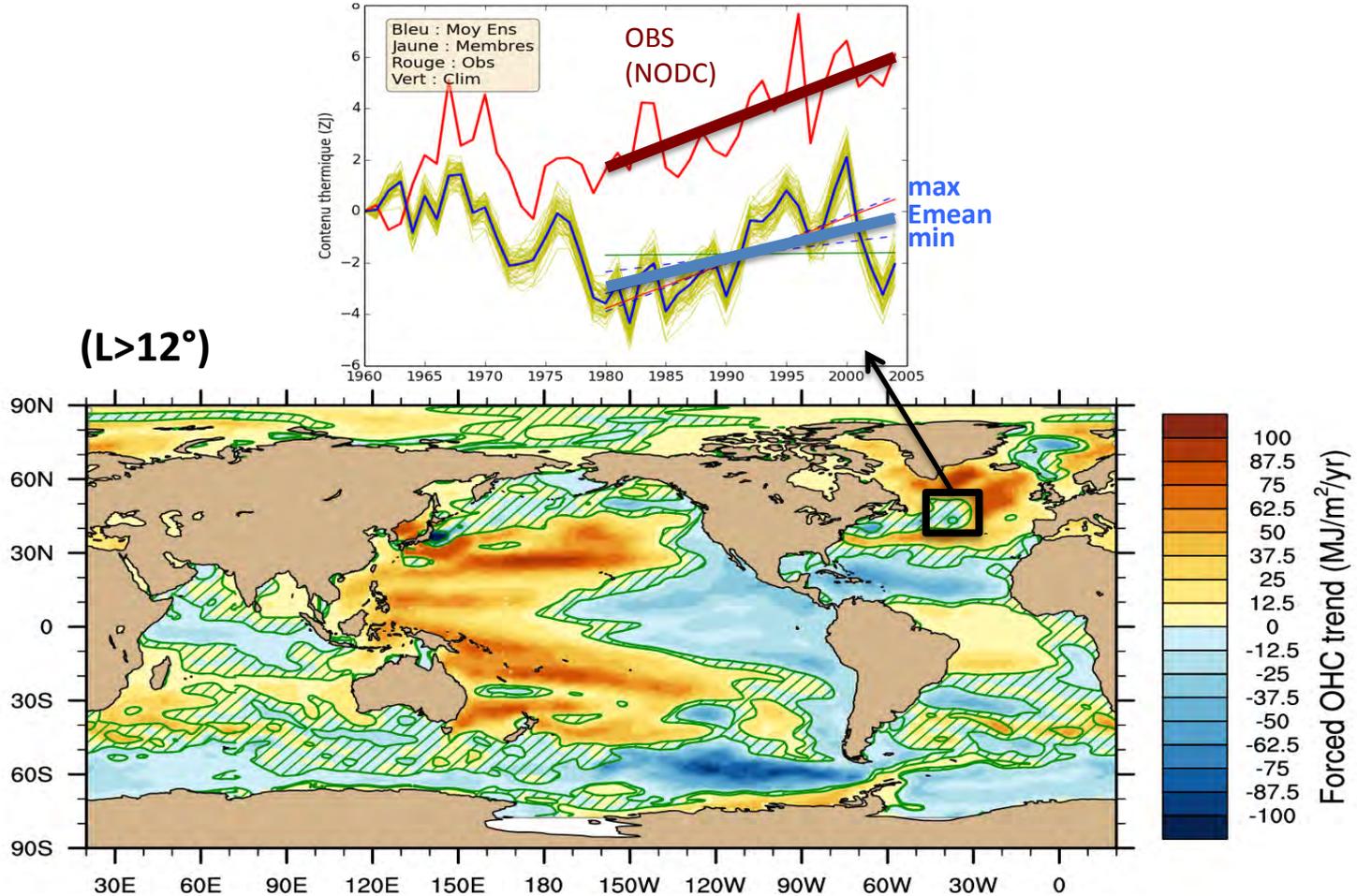
30-year OHC trends exhibit a large ensemble spread. Trends cannot be unambiguously attributed to the atmospheric forcing

Sérazin et al (to be submitted to GRL.)

Yearly **AMOC$_z$** : **Forced** **& Chaotic** var. (2004-2013)
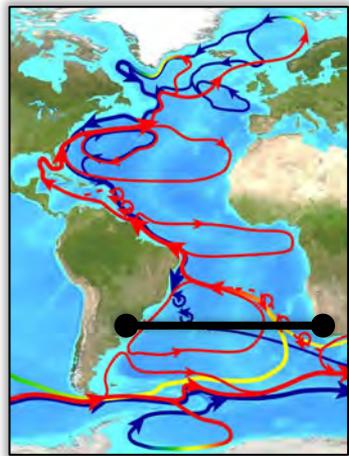
SAMOC
34.5°S
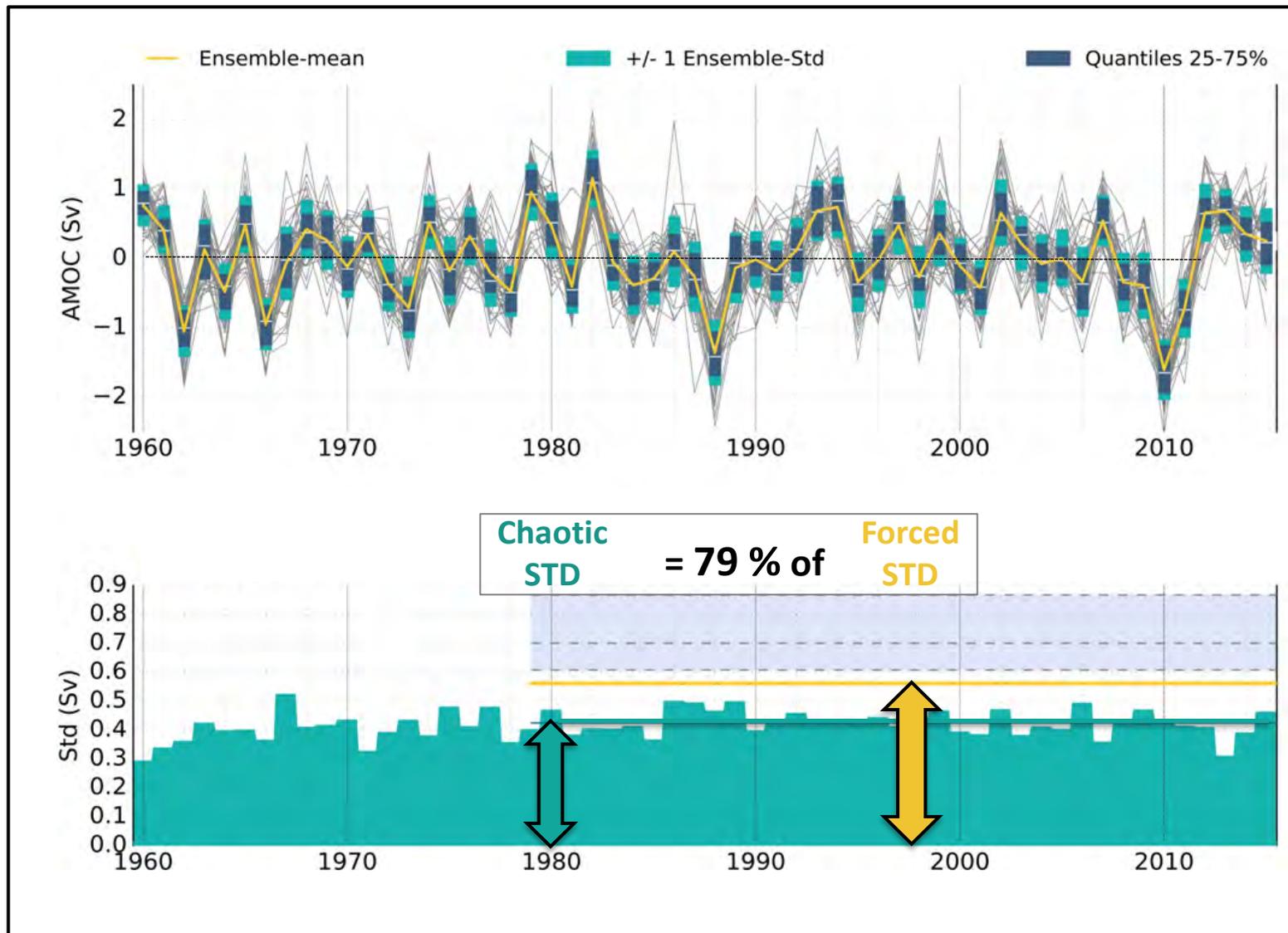
Yearly AMOC$_z$: Forced & Chaotic var. (2004-2013)

Ensemble-mean +/- 1 Ensemble-Std Quantiles 25-75%

AMOC (Sv)

Y: 40%

Y: 79%

SAMOC
34.5°S

Chaotic
STD = 79 % of Forced
STD

Std (Sv)

Leroux et al (in prep.)

AMOC$_{\sigma 2}$: Forced & Chaotic var. spectra (1960-2015)

trend & mean seasonal cycle removed

Forced variability

Chaotic variability

Latitude

Period (years)

Period (years)

Leroux et al (in prep.)

AMOC$_{\sigma 2}$: Forced & Chaotic var. spectra (1960-2015)

trend & mean seasonal cycle removed

Forced variability

Chaotic variability

$\sigma_C / \sigma_F =$

50%   70%   100%

Latitude (°)

Latitude

Period (years)   Period (years)

Leroux et al (in prep.)

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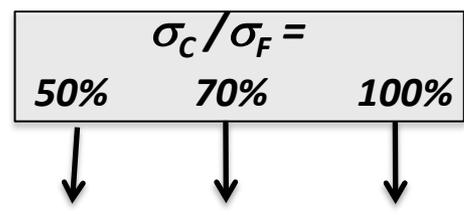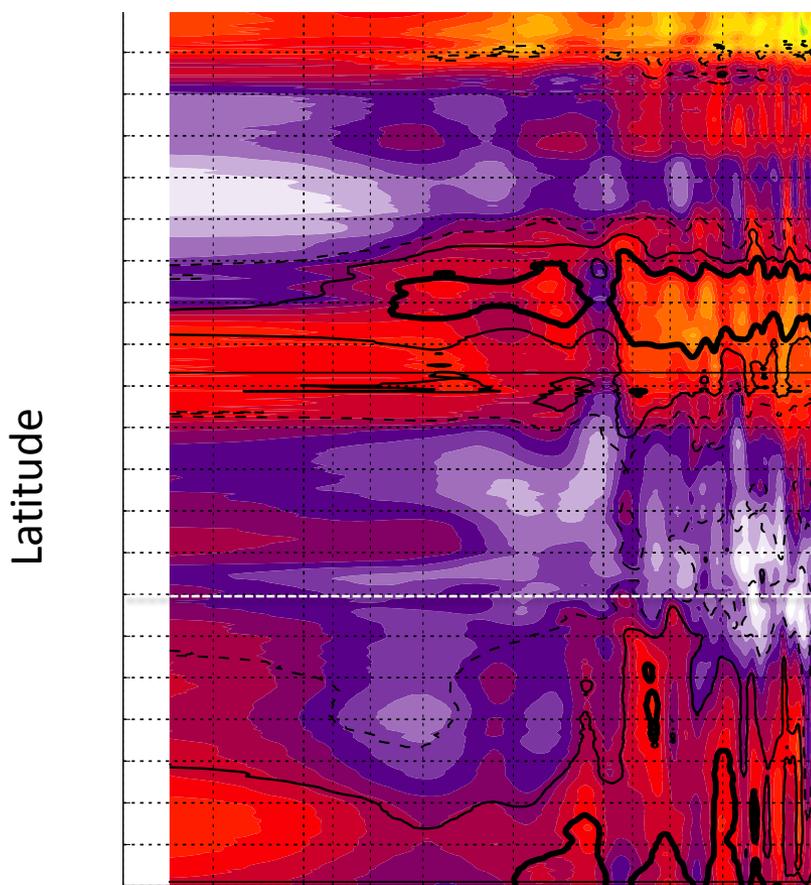
4. Conclusions and perspectives

Forced & Chaotic variability: observational issues

Most observed fields are impacted by **F** & **C**

1960-2015
Ensemble simulation

Individual Observations
(**Jason-2** tracks,
historical T/S profiles,
MOC timeseries, etc)

Atmospheric constraint
Chaos-related uncertainty

for each real observation, we produced 50 synthetic obs.

Representativeness of each observation

Detection/ attribution studies

Data assimilation

Probabilistic model assessment

Jason2

Argo, CTD, XBT, TAO, etc

OSNAP

RAPID

SAMOC

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OSNAP
RAPID
SAMOC

Which observations, locations, timescales ?

Contribution in the recent warming hiatus ?

Atmospheric constraint
Chaos-related uncertainty

Can it be attenuated in observational data ?

Conclusions & Perspectives

◆ **Multiscale variability in the eddying ocean**

➢ Simulations :   Atmospherically-modulated **chaos** (SSH, OHC, SST, MOC, …)

From mesoscale to multidecadal/basin scales

Poorly-known & strong   ➔ *Ensemble hindcasts required*

➢ Observations :   One among many possible evolutions

➔ Ensemble runs : Simulate these possible evolutions

Disentangle Forced / Chaotic observed signals

Assess representativeness of each observation   ➔ *Probabilistic oceanography*

◆ **Open questions & perspectives**

➢ Detection & Attribution implications   ➔ *Ensemble synthetic observations*

➢ Chaotic variability : atm./climate/biogeochem. impacts   ➔ *Future work*

➢ Collaborative investigations   ➔ *OCCIPUT data subsets*

OCCIPUT	:	Penduff et al (Clivar Exchanges Newsletter, 2014)
	:	Penduff et al (2nd IUGG Quadriennal Report, 2015)
	:	Bessières et al (Geoscientific Model Development disc., 2016)
SLA	:	Penduff et al (Journal of Climate, 2011)
Scales	:	Sérazin et al (Journal of Climate, 2015)
MOC, MHT	:	Grégorio et al (Journal of Physical Oceanography, 2015)