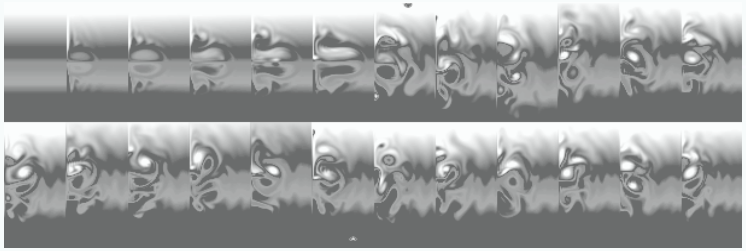
Intrinsic interannual variability in the ocean : global simulations and altimeter observations

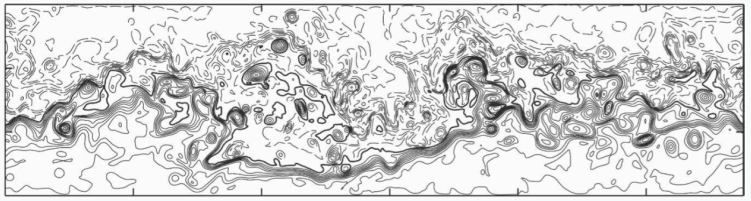
Thierry Penduff
CNRS-LEGI, Grenoble, France
and Florida State University, USA

with B. Barnier, M. Juza,
J. Le Sommer, A.-M. Treguier

Background

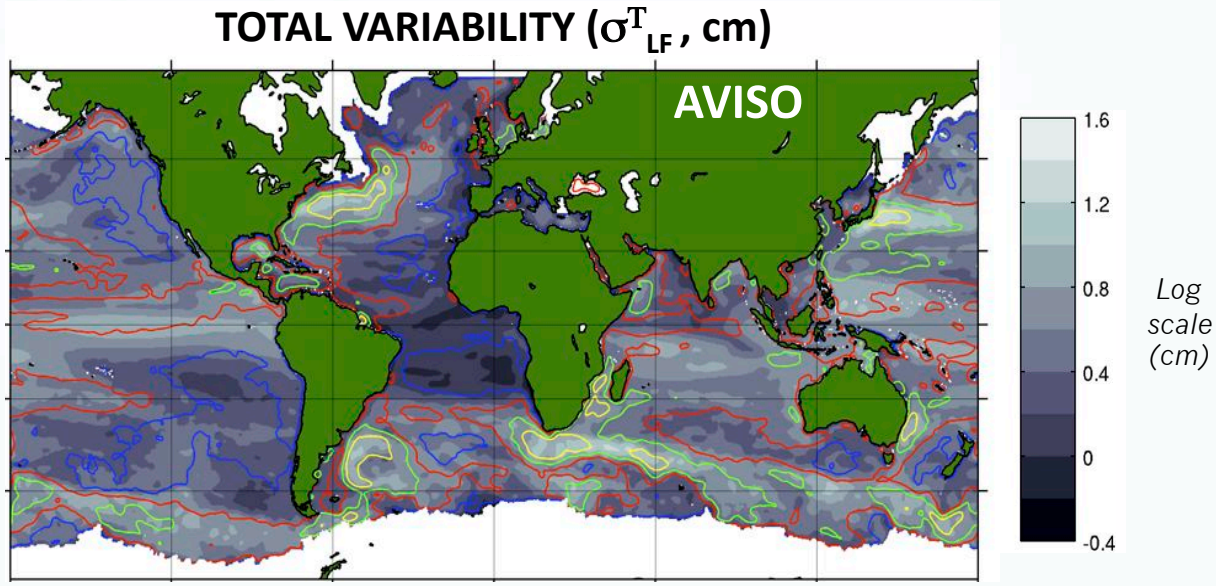
- « Noise » superimposed on ocean's response to atmosphere
- Idealized studies: mesoscale eddies can drive *intrinsic*, chaotic interannual variability (e.g. Jiang et al. 1995, Spall 1996, Dewar 2003, Cessi & Loizel 2001, Berloff & McWilliams 1999, etc)





- Regional evidences of this in seasonally-forced, eddying OGCMs (e.g. Penduff et al. 2004, Hall et al. 2004, Cabanes et al. 2006, Biastoch et al. 2008)
- No global description yet

This study



- **Realistic** context — Link with AVISO SLA (1993-2004)
- Timescales **T>18 months** — Surface horizontal circulation

➔ Magnitudes of **intrinsic** and forced interannual variabilities ?

➔ Global **distribution** of these contributions ?

Approach

	full forcing	clim. annual cycle	
2° OGCM	Total = Intrinsic + Forced	Intrinsic	Forced ?
1/4° OGCM			
AVISO	(coupled)		

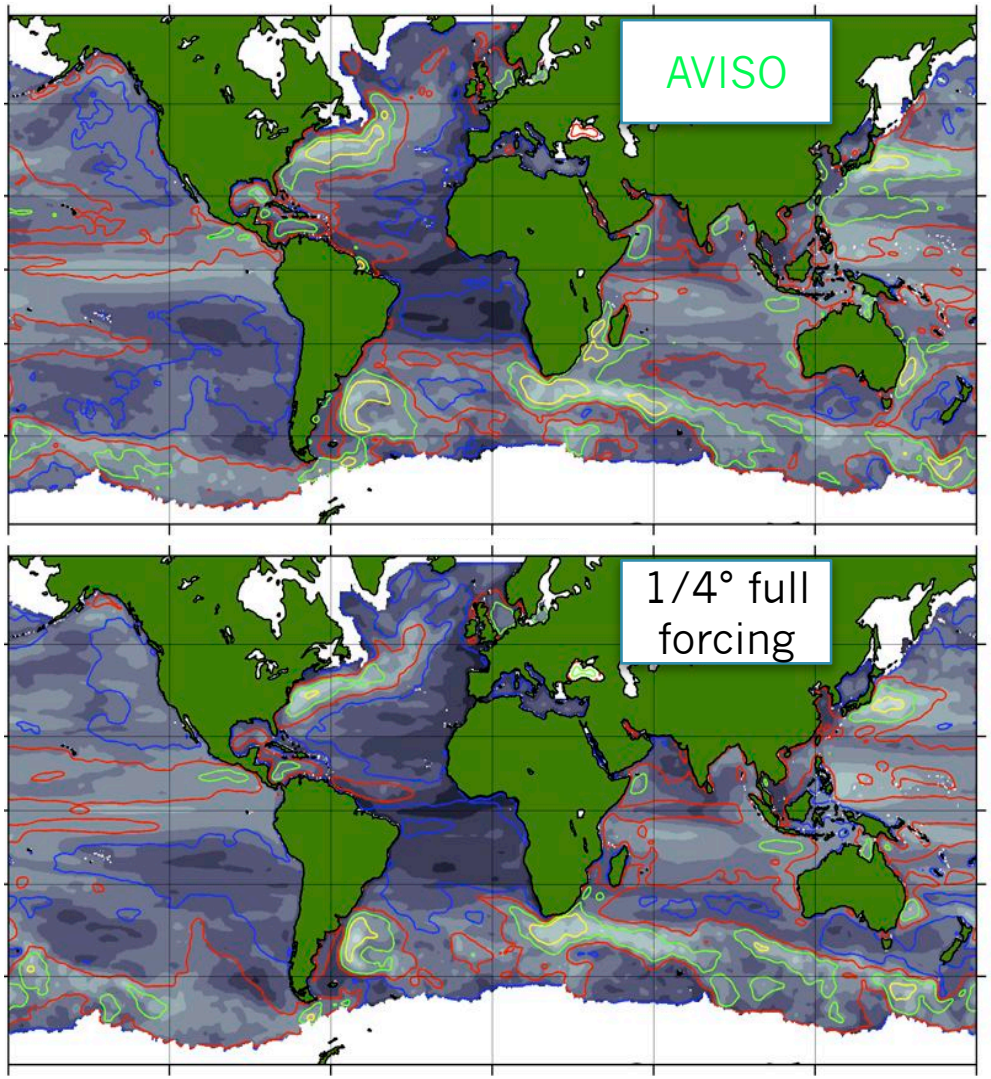
- Collocate **model** SLA's onto **AVISO** observations
- Extract **low-freq** (T>18months) and hi-freq (T<5months) SLAs
- Statistics : **standard deviations** σ, temporal & spatial correlations

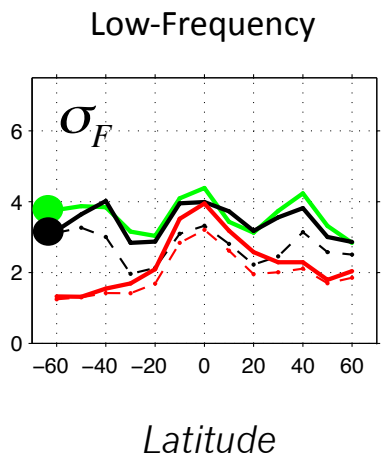
Total STD's: **AVISO** vs **1/4° run**

- Realistic magnitudes
- Realistic $\sigma^T(x,y)$ patterns

➔ Realistic interannual variability in the « pivot » experiment

Further assessed in
Barnier et al., 2006;
DRAKKAR Group, 2007;
Treguier et al., 2007;
Penduff et al., 2007;
Lique et al., 2009;
Lombard et al., 2009;
Penduff et al., 2010

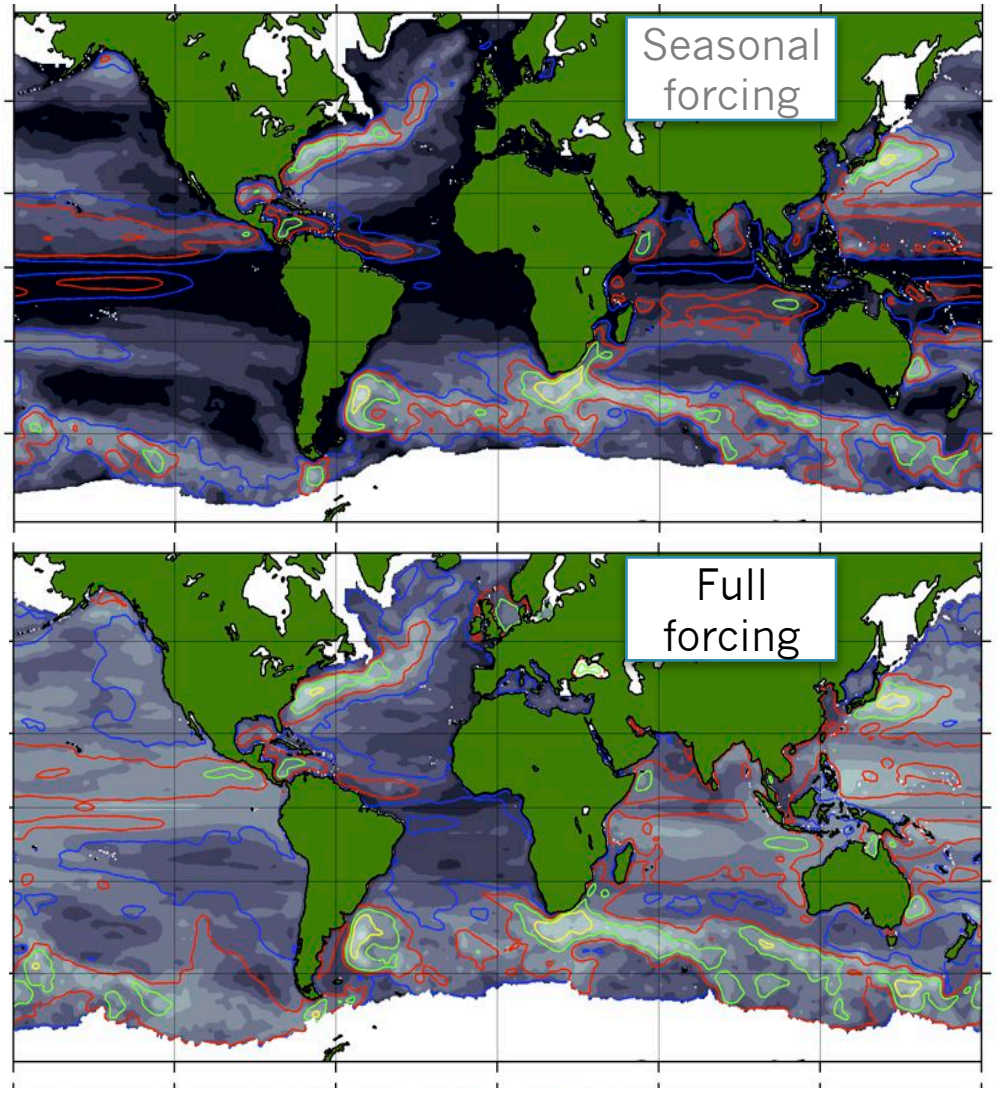


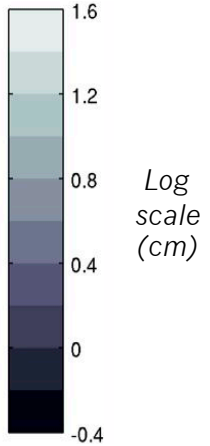


1/4° runs = **Total** **vs** **Intrinsic** STD's

- Southern Ocean and mid-latitudes: 50-80% interann. variance without direct forcing

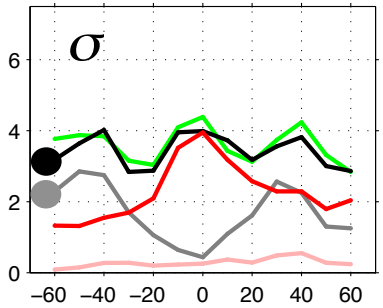
➔ **Substantial intrinsic variability in eddying regions**





Log scale (cm)

Low-Frequency

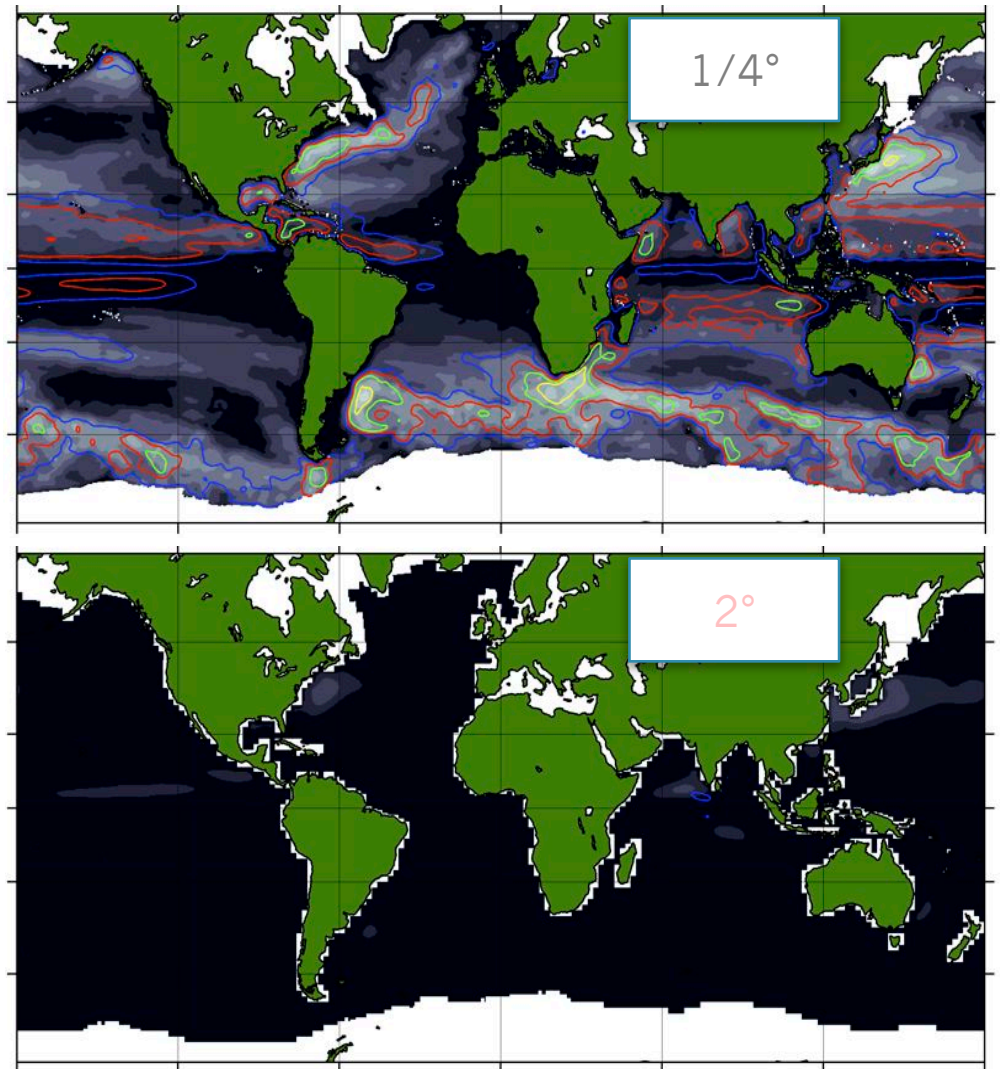


Latitude

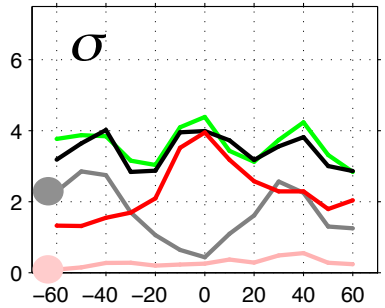
Intrinsic STD's: 1/4° vs 2°

- No eddies ➔ Huge decrease in intrinsic variab.

➔ **Eddy-driven intrinsic variability**



Low-Frequency



Latitude

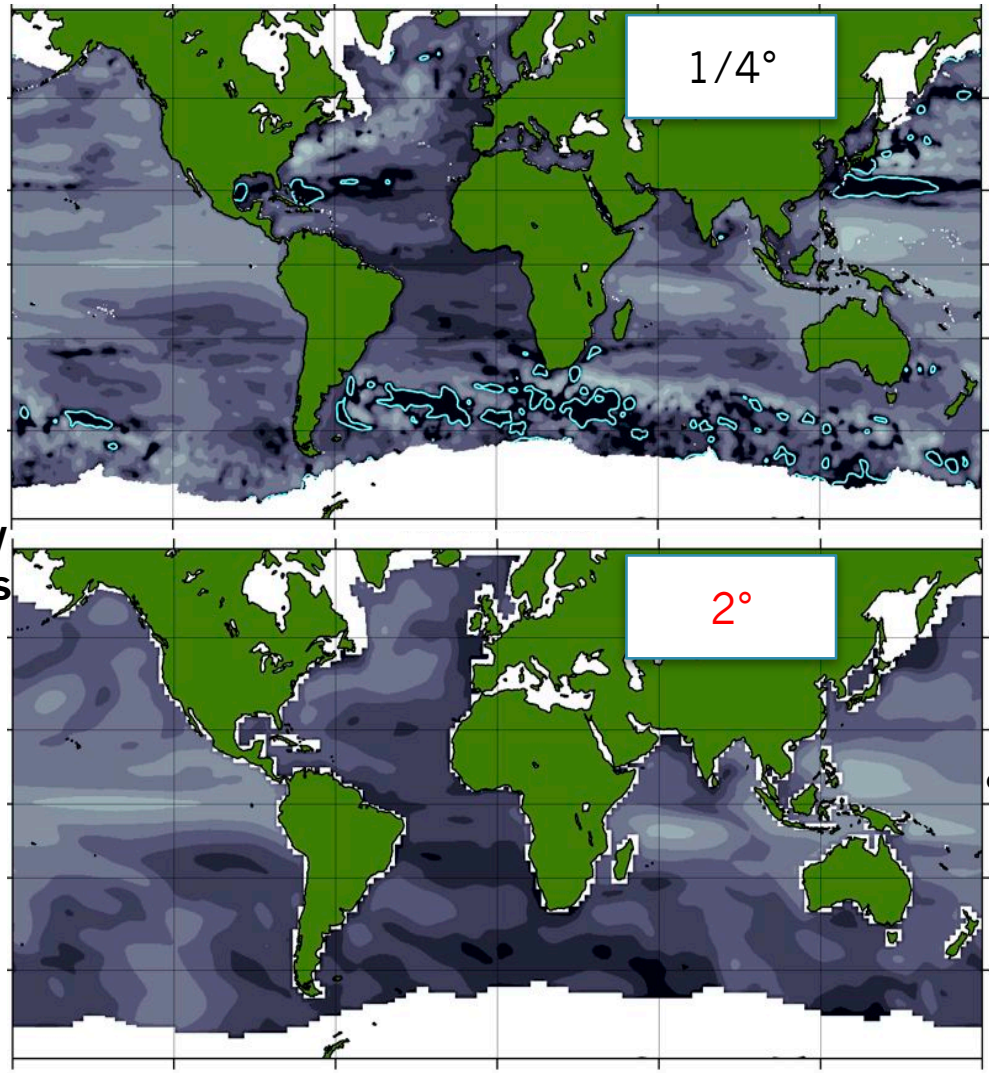
Forced STD's: 1/4° vs 2°

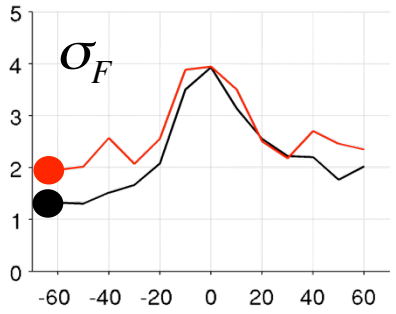
- Assuming :

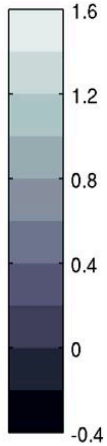
Total=Forced+Intr.,
C(Forced,Intr.)=0 ➔

$$\sigma^F = \sqrt{(\sigma^T)^2 - (\sigma^I)^2}$$

➔ **Forced variability moderately depends on resolution**



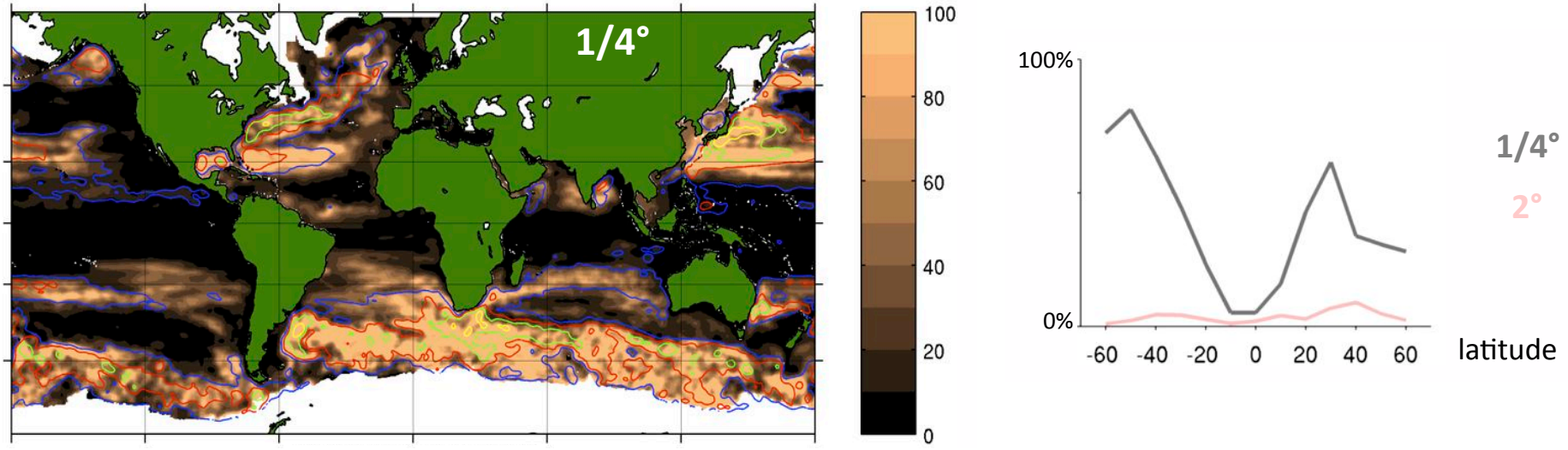




Log scale (cm)

SLA interannual variability: **Conclusions**

Percentage of total SLA variance due to intrinsic



- **Total variability (1/4°)** : comparable to **AVISO** (magnitude, distribution)

Intrinsic variability:

- ✓ Eddy-driven
- ✓ Up to **50-70%** of total var.
- ✓ where mesoscale activity

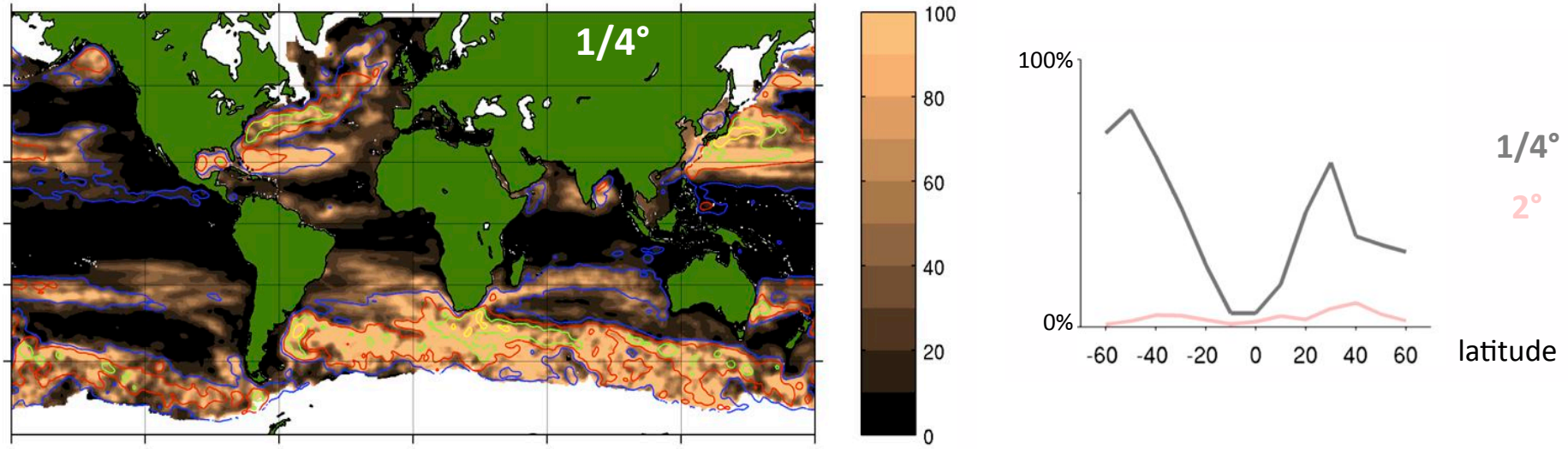
Forced variability:

- ✓ Comparable at 1/4° and 2°
- ✓ Partly linear ?

- **Total variability (2°)** : 2-3 times too small because no intrinsic component

SLA interannual variability: **Conclusions**

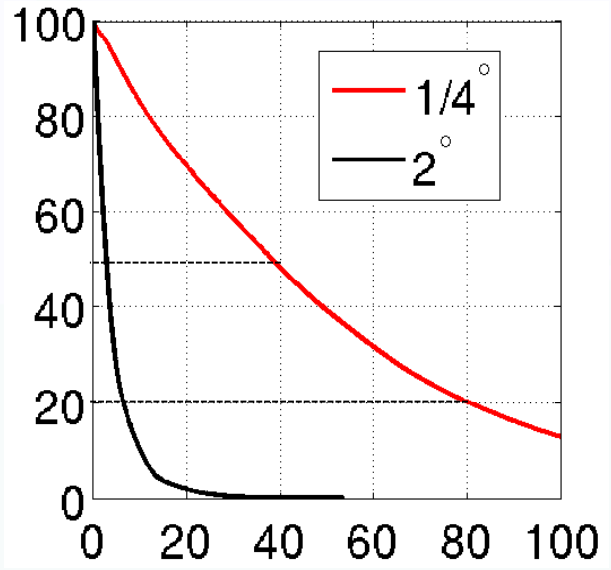
Percentage of total SLA variance due to intrinsic



- **Total variability (1/4°)** : comparable to **AVISO** (magnitude, distribution)
- **Intrinsic variability** : Eddy-driven — Up to **50-70% at 1/4°**

  : Found where mesoscale eddies are present
- **Forced variability** : comparable at 1/4° and 2° → partly linear
- **Total variability (2°)** : 2-3 times too small because no intrinsic component

Relative contributions of Intrinsic & Forced



$$1 = \frac{\sigma_F^2}{\sigma_T^2} + \frac{\sigma_I^2}{\sigma_T^2}$$

%forced %intrinsic

At **1/4°** resolution:
intrinsic contribution exceeds **40%** over **50%** of the global ocean
80% **20%**

At **2°** resolution:
intrinsic contribution exceeds **3%** over **50%** of the global ocean
7% **20%**

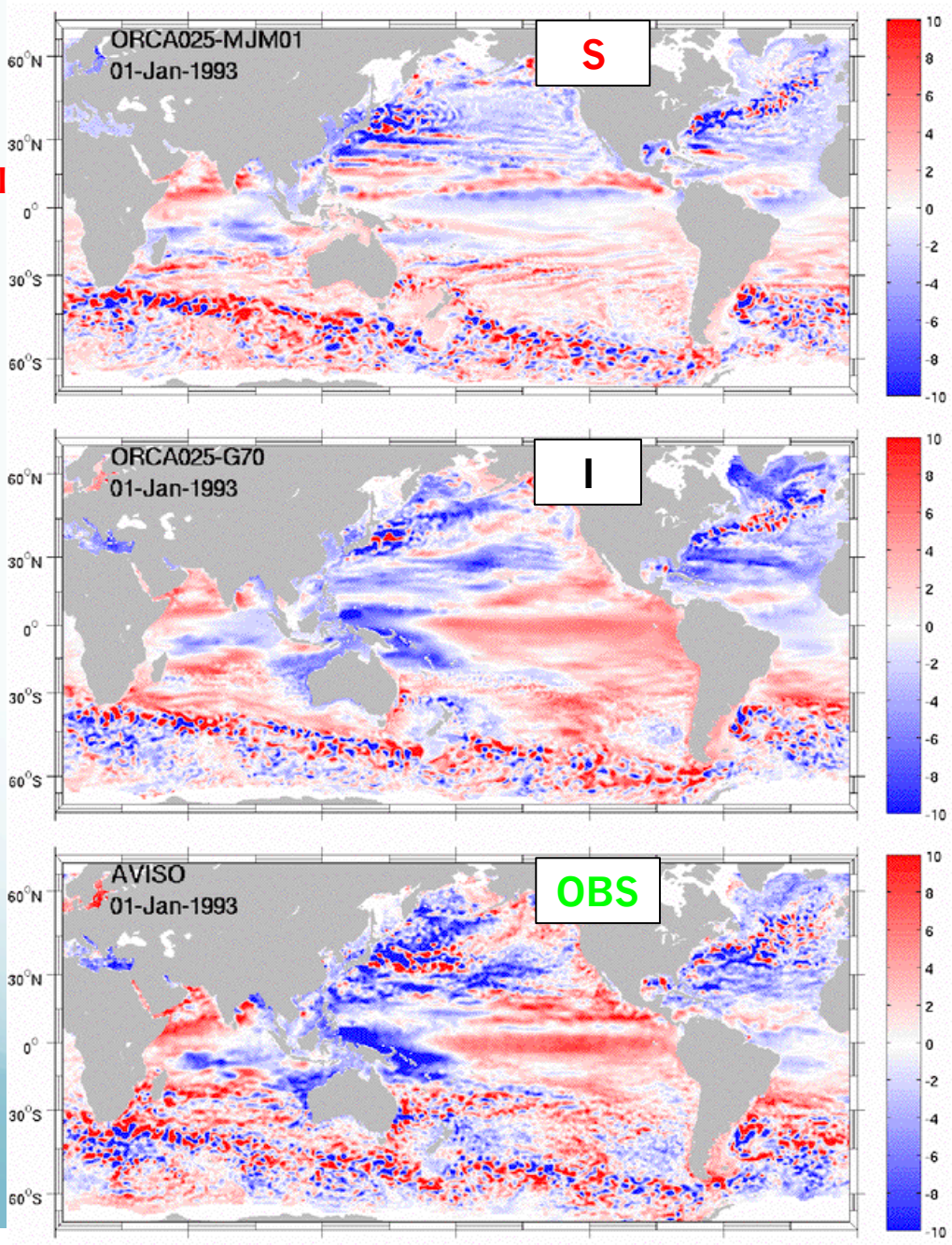
Interannual variability : η with & without interannual forcing (global 1/4°)

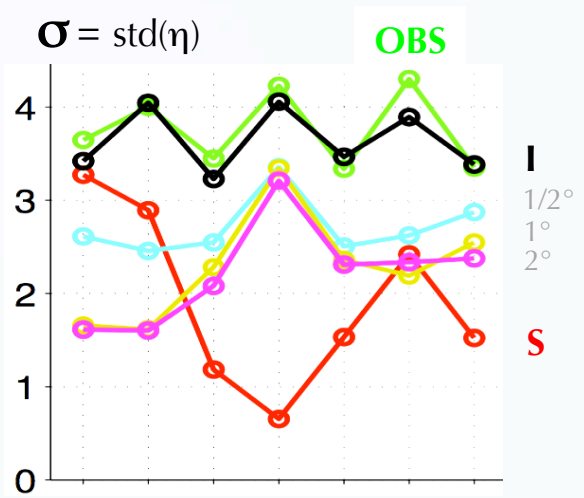
work in progress

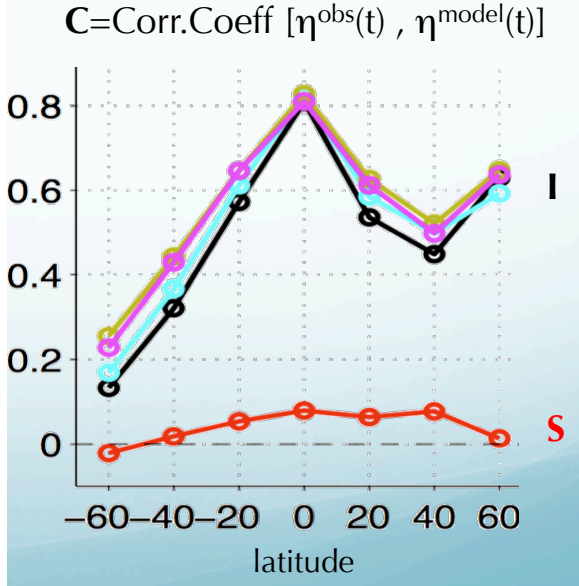
Seasonal Forcing

Full Forcing

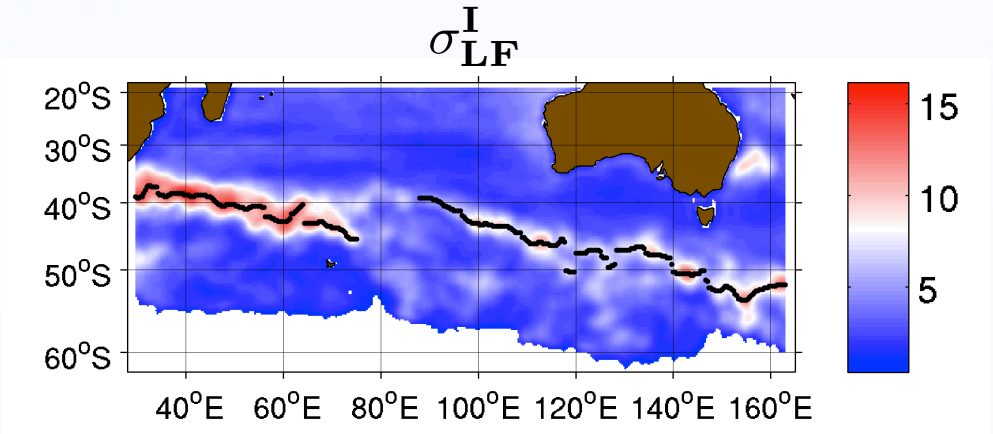
AVISO

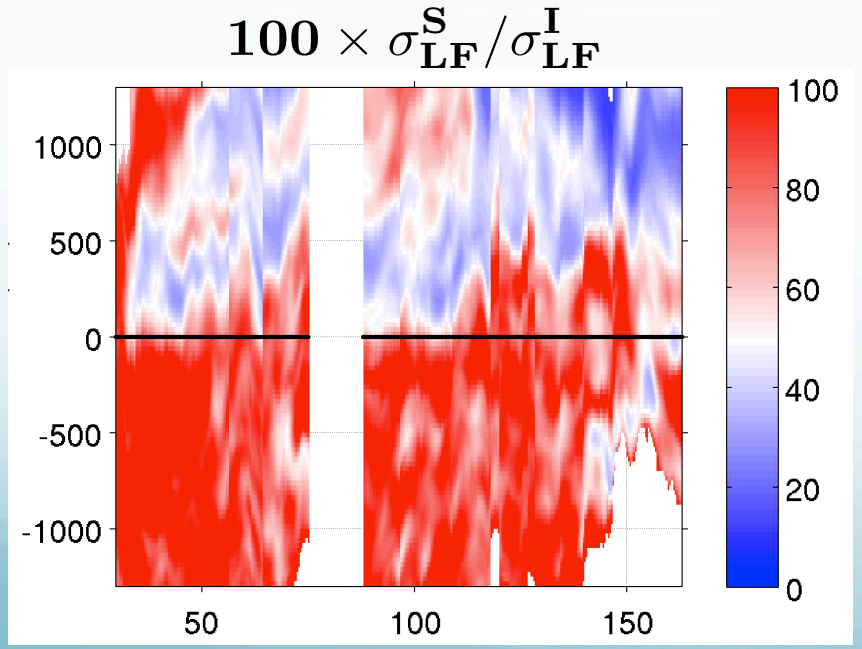


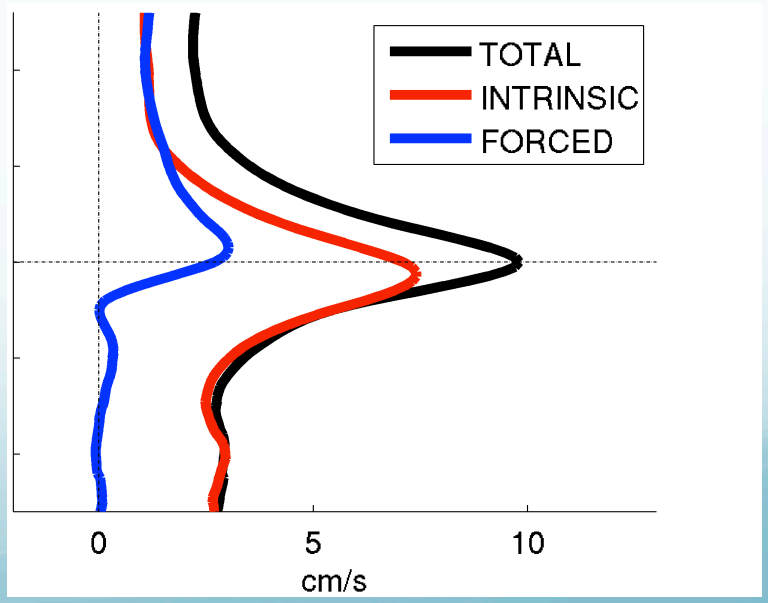




Relative contributions of Intrinsic & Forced (ACC)





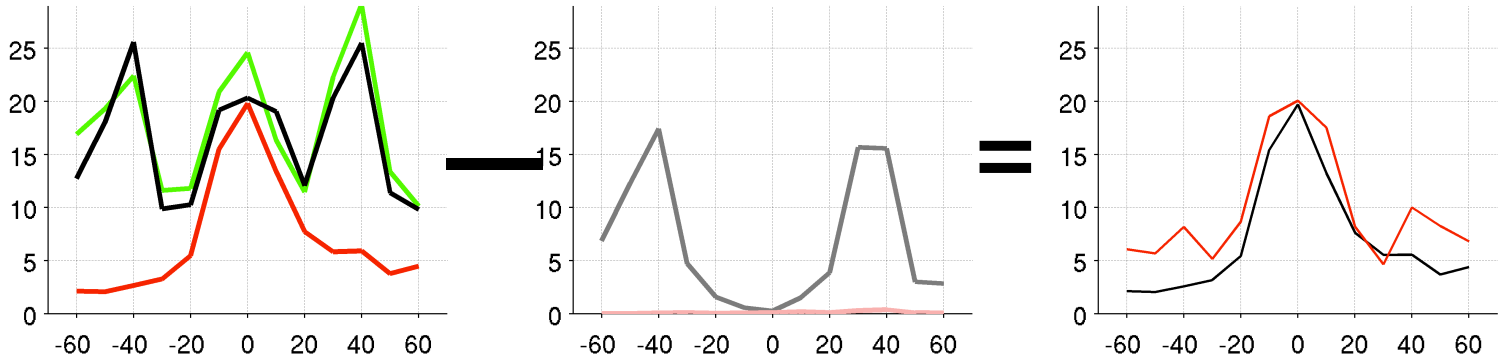


Summary : all variances in zonal average

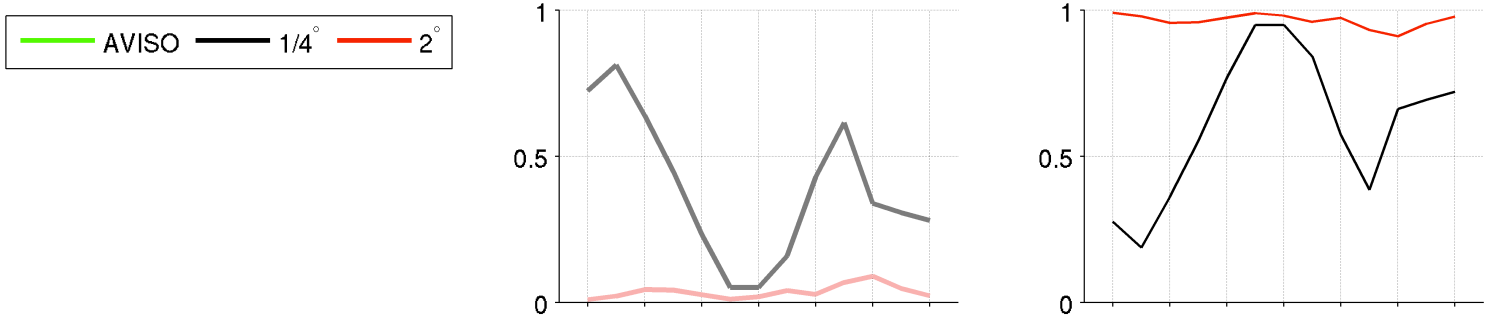
TOTAL FORCED

INTRINSIC

ABSOLUTE (cm^2/s^2)



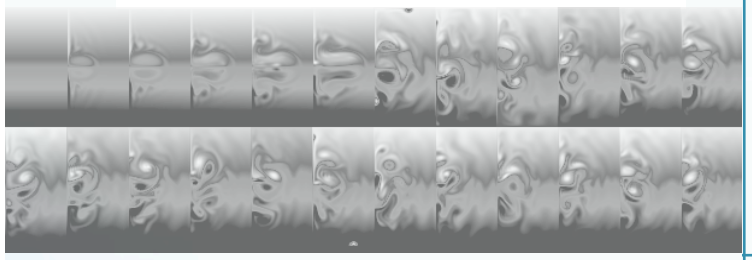
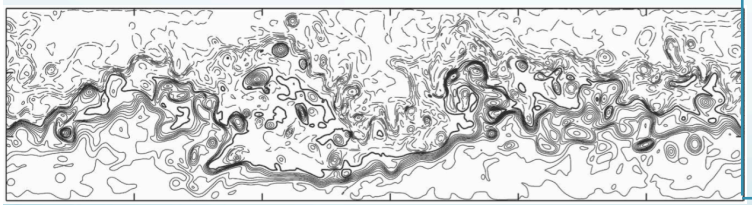
RELATIVE TO TOTAL



- 1/4° Full forcing : Total variability matches AVISO obs.
- Intrinsic variab. : up to 50-70% at 1/4° — Almost 0% at 2°
- Forced variab. : comparable at 1/4° and 2°
- I-2° total variab. too small because no intrinsic

Context

Eddying ocean models ➔ non-linearity, inverse cascade, scale interactions

	idealized QG or PE models	'realistic' PE models
Closed basin (WBC) 	Jiang et al. 1995, Spall 1996 Dewar 2003, Cessi & Loizel 2001 Berloff & McWilliams 1999, etc **forcing without interann.** **➔ intrinsic variability** **➔ isolated processes** **eddy redistribute PV**	Penduff et al. 2004, Hall et al. 2004 Cabanes et al. 2006, Biastoch et al. 2008 **forcing with and without interann.** **➔ forced+intrinsic variab.** **➔ Location, relative magnitude** **Processes difficult to isolate**
Channel (Southern Ocean) 	Hogg & Blundell, 2006 **eddy–mean flow momentum feedback hypothesis**	?
Forced and intrinsic interannual ocean variabilities	- quasi-equilibrium, many runs - can be excited separately	- still adjusting, a few runs - more difficult to separate

Approach

- Force global 2° and 1/4° global OGCMs with
  - ✓ full forcing ➔ Total interann. variab
  - ✓ clim. annual cycle ➔ Intrinsic interann. variab
- Collocate **model** SLA's onto **AVISO** observations
- Extract low-freq (T>18months) and hi-freq (T<5months) SLAs

	full forcing	clim. annual cycle	
2° OGCM	T = I + F	I	F
1/4° OGCM	T = I + F	I	F
AVISO	(coupled)		