National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

UNIVERSITY OF LIVERPOOL

Complementary Data from Bottom Pressure Recorders

Chris W. Hughes

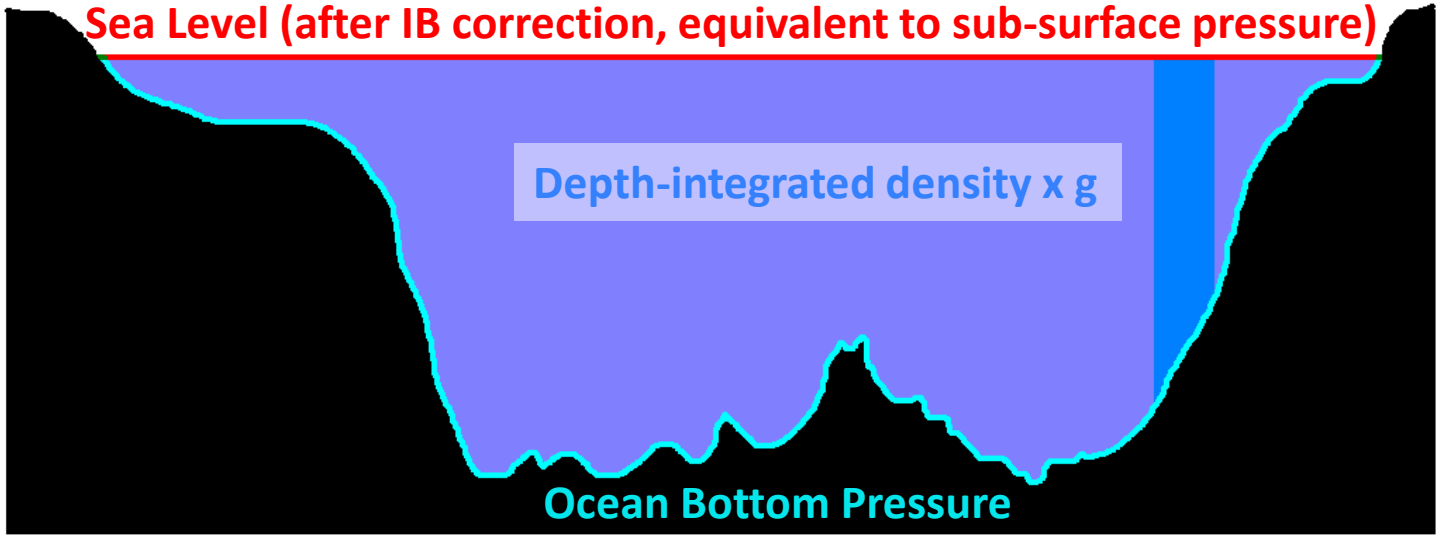
University of Liverpool /NOC

With Mark Tamisiea, Joanne Williams, Rory Bingham, Miguel Angel Morales Maqueda, Shane Elipot, John Loder, Angela Hibbert, Philip Woodworth, Richard Ray …

PSMSL 80th anniversary sea level workshop, October 2013

Global Sea Level related to total ocean volume

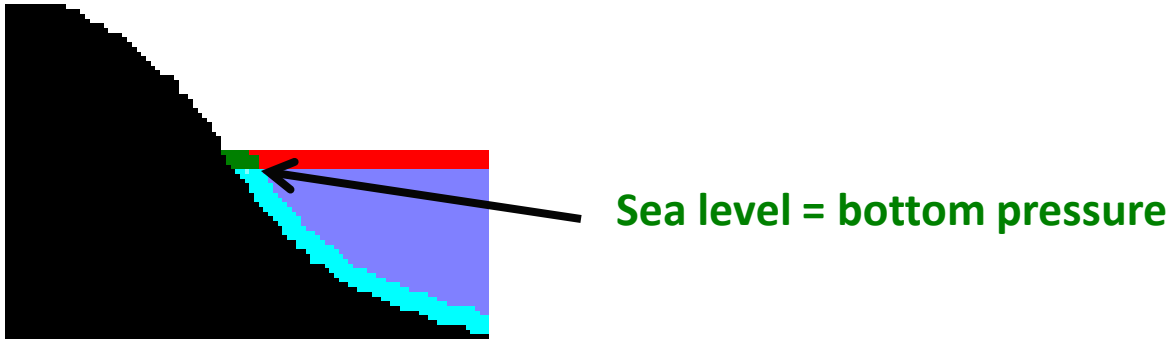
Altimetry
Tide Gauges



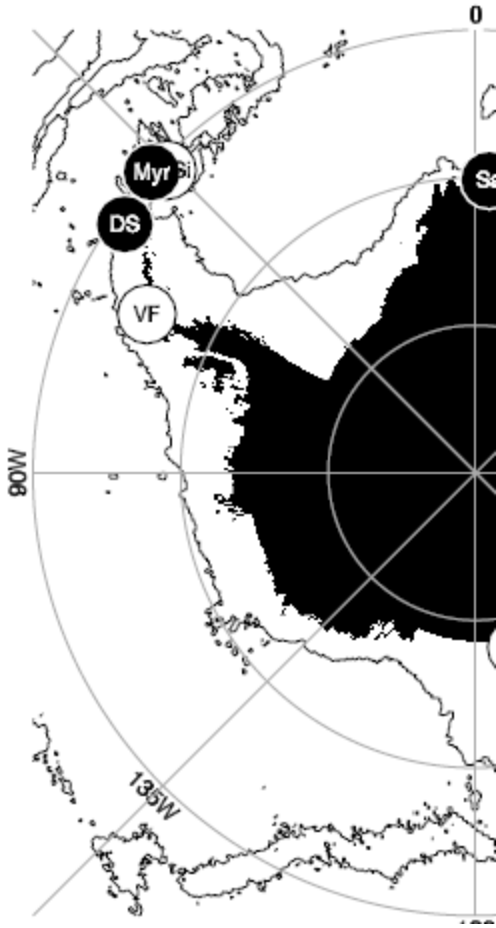
ARGO

Global Ocean Bottom Pressure related to total ocean mass

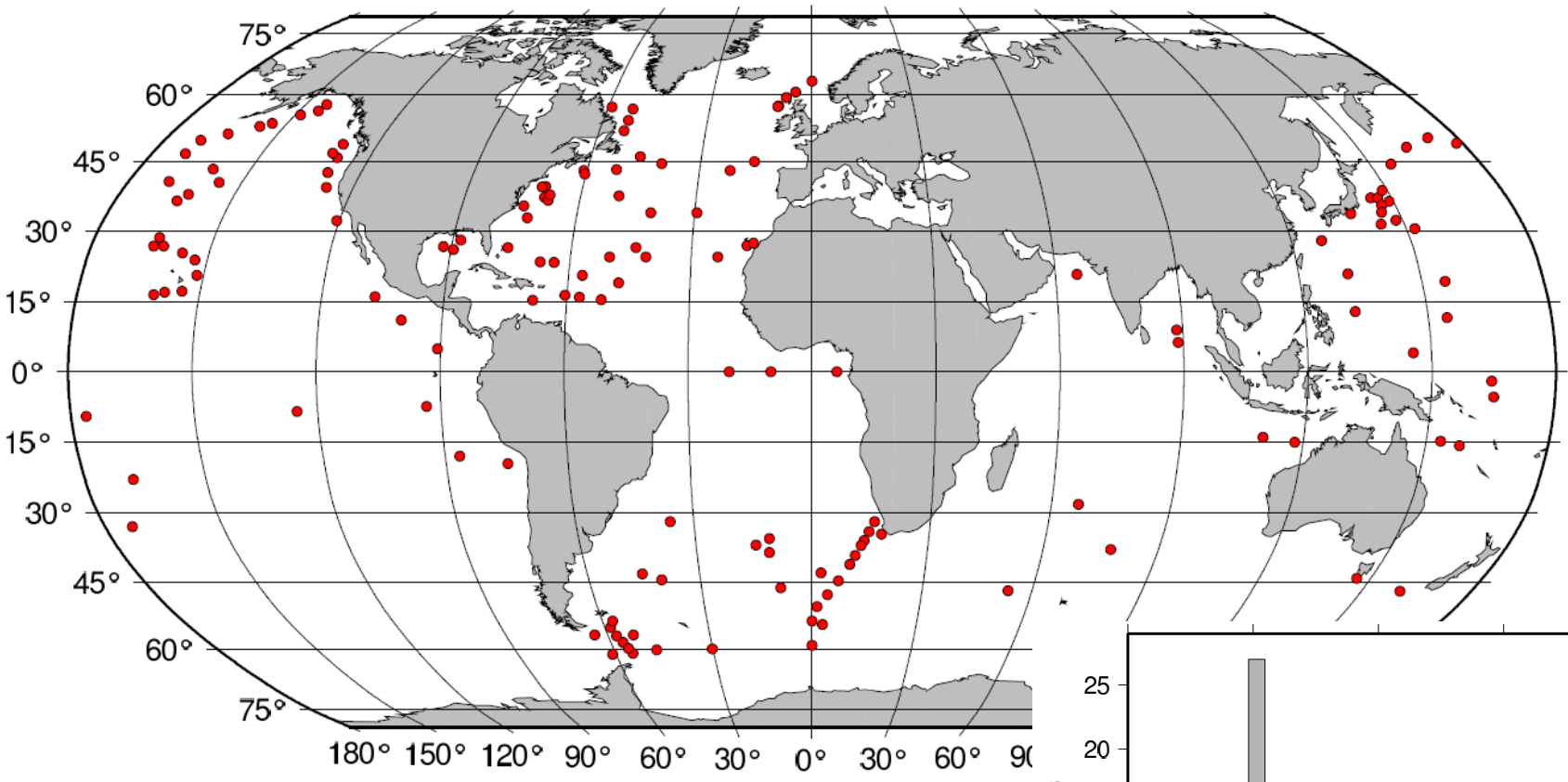
GRACE
BPRs

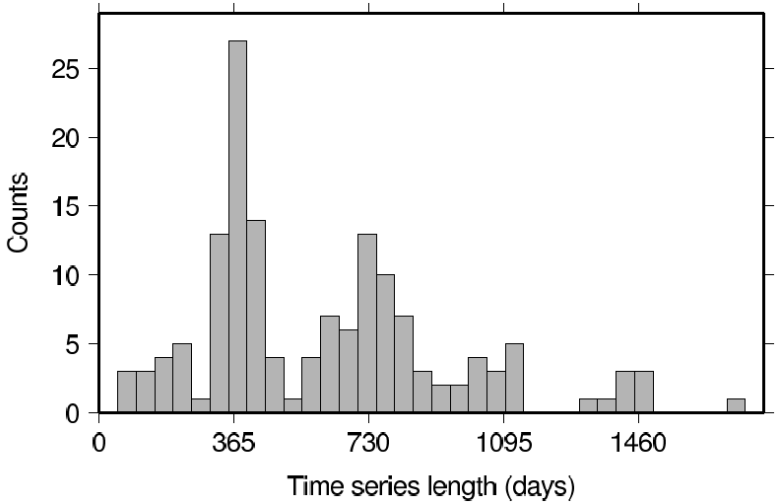


A typical Bottom Pressure Recorder (BPR)



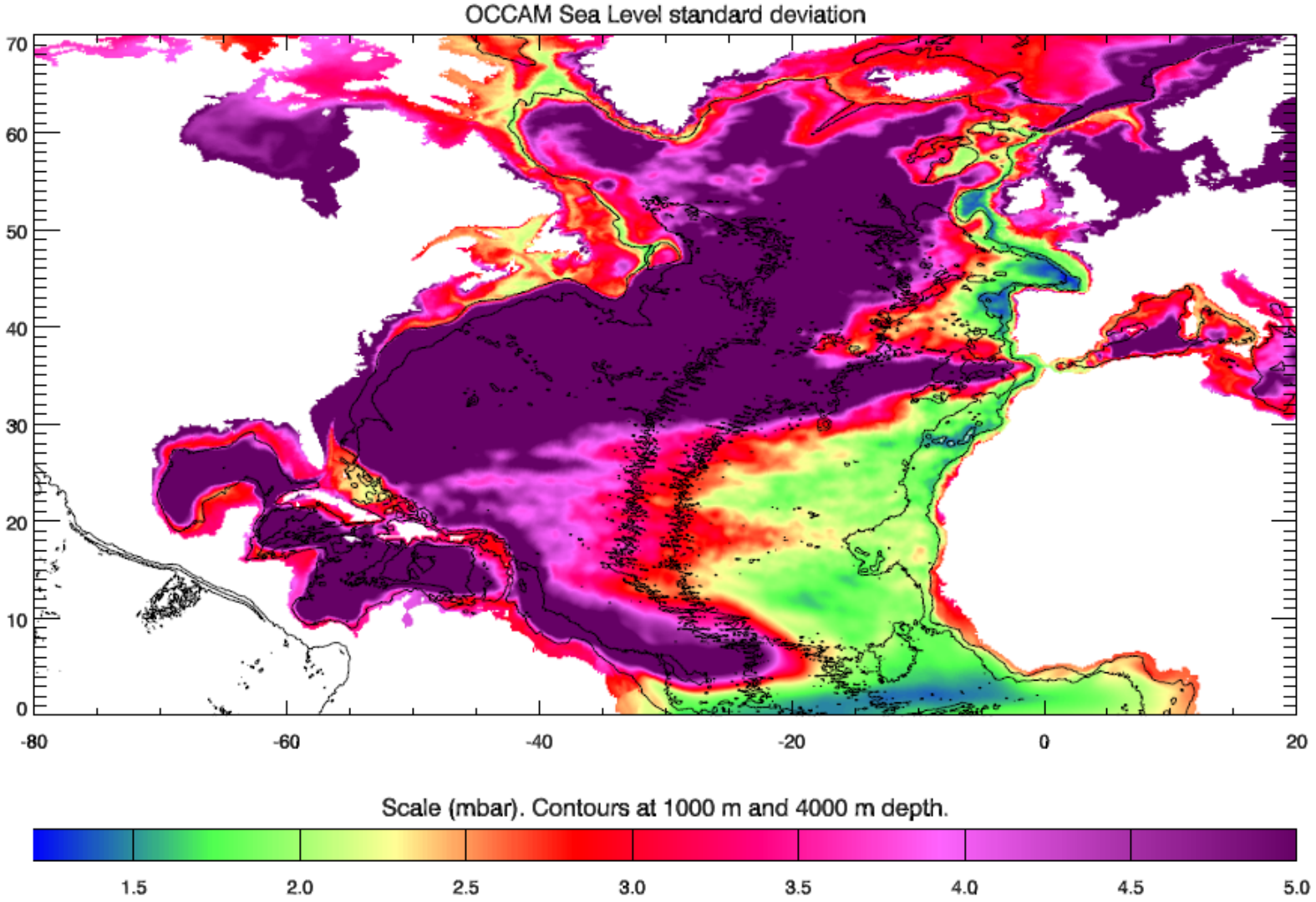
Long BPR records are becoming quite common



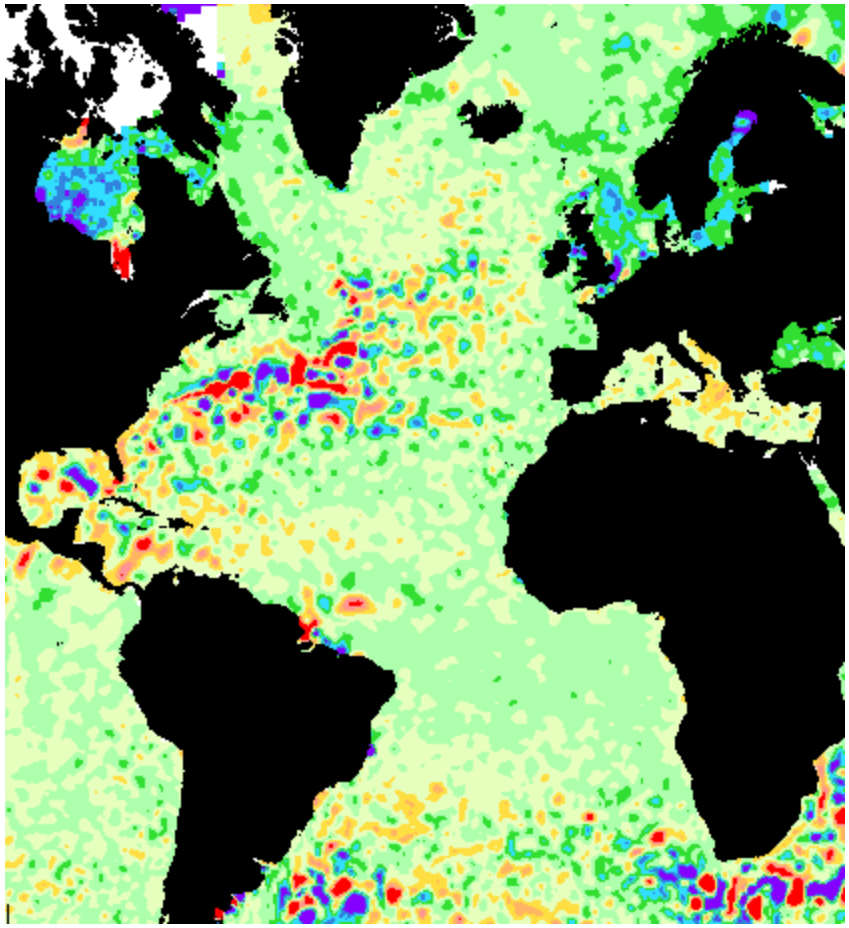


Pictures from Ray, JGR(2013), tidal analysis paper
BPRs from DART, ACCLAIM, RAPID, HOME, MOVE, KESS, FOCAL, SEQUAL, … many other experiments

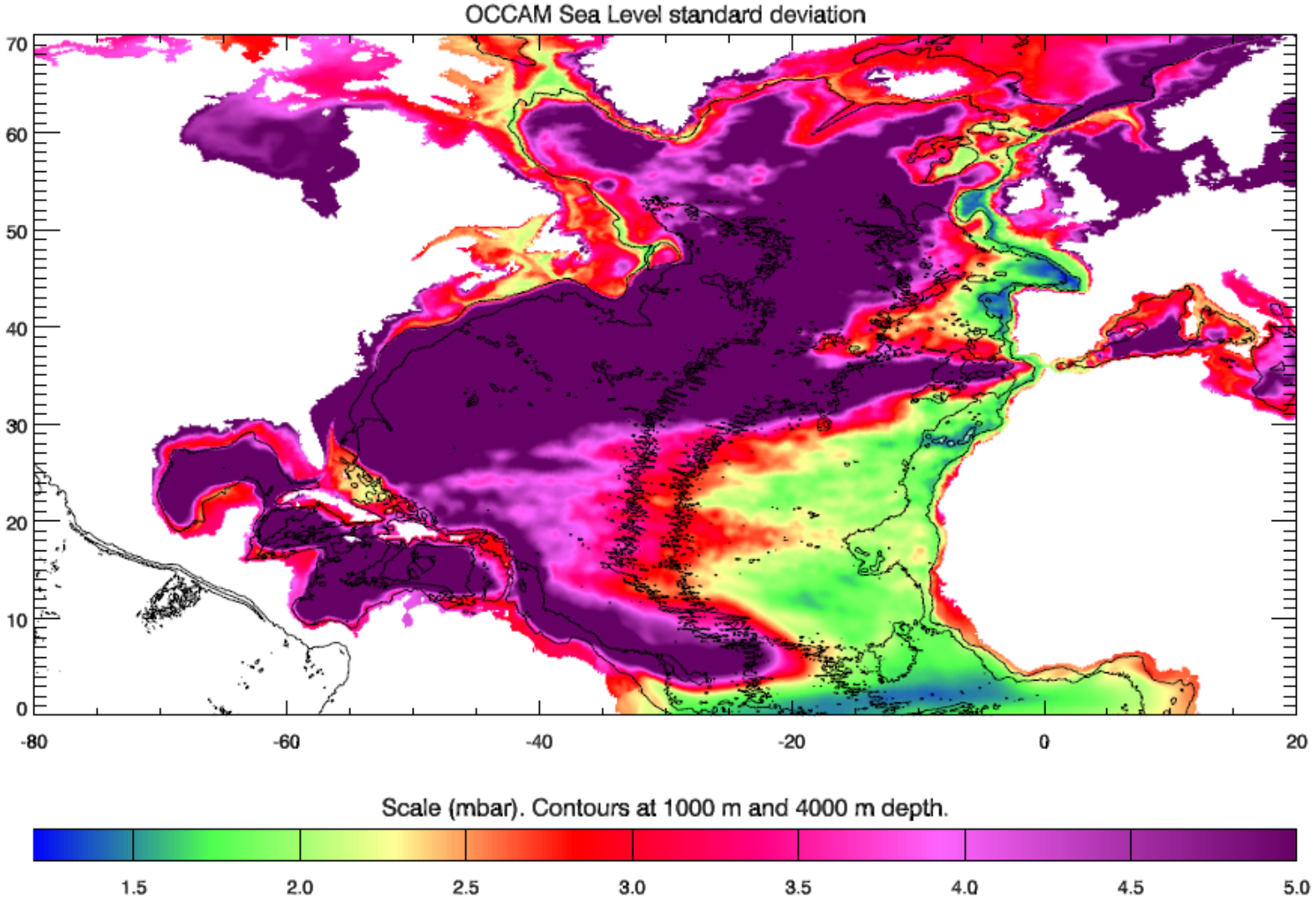
OCCAM 1/12 degree model– standard deviation of sea level (17 years of 5-day means, annual, semiannual and trend removed)



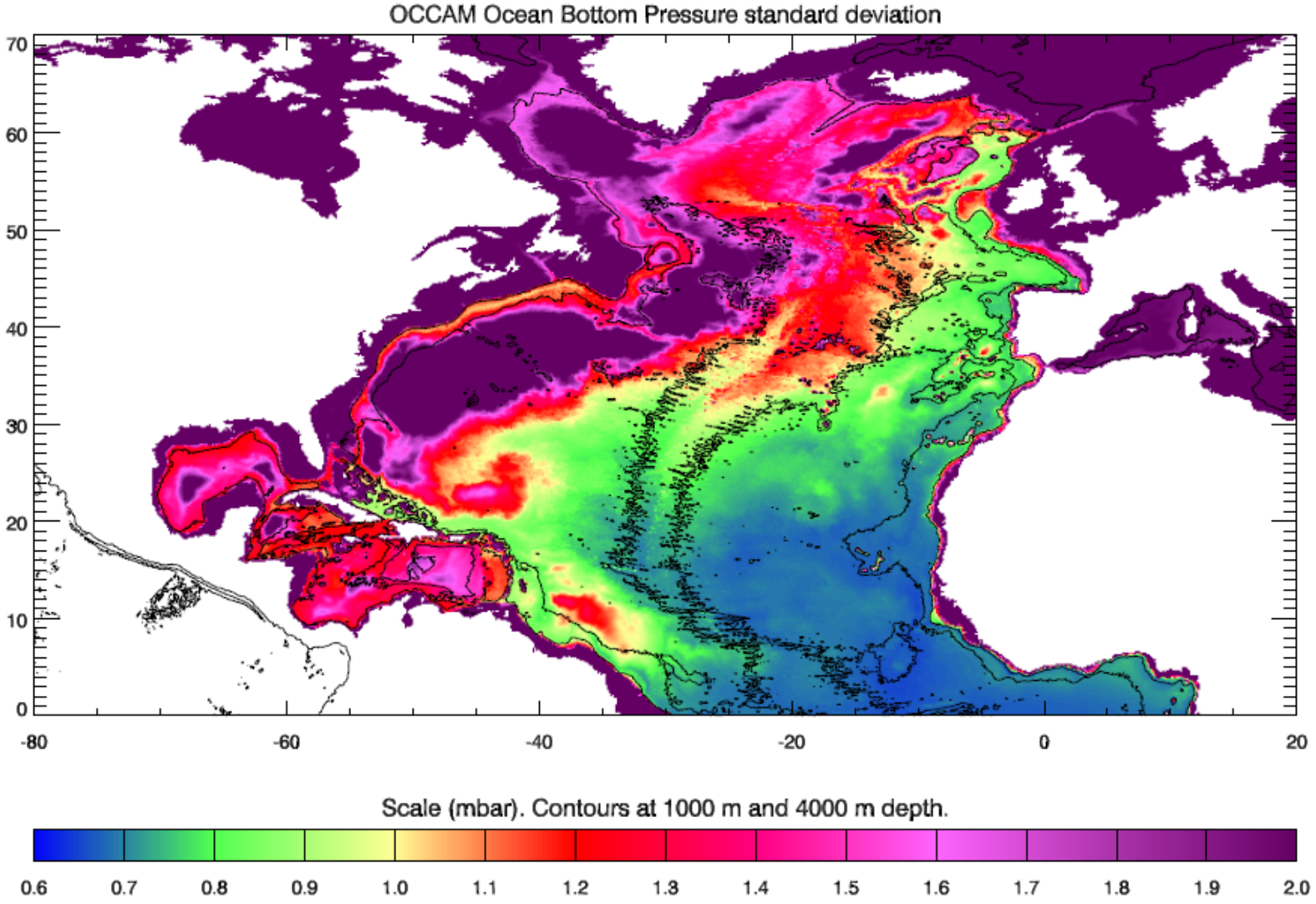
Most of that is eddies



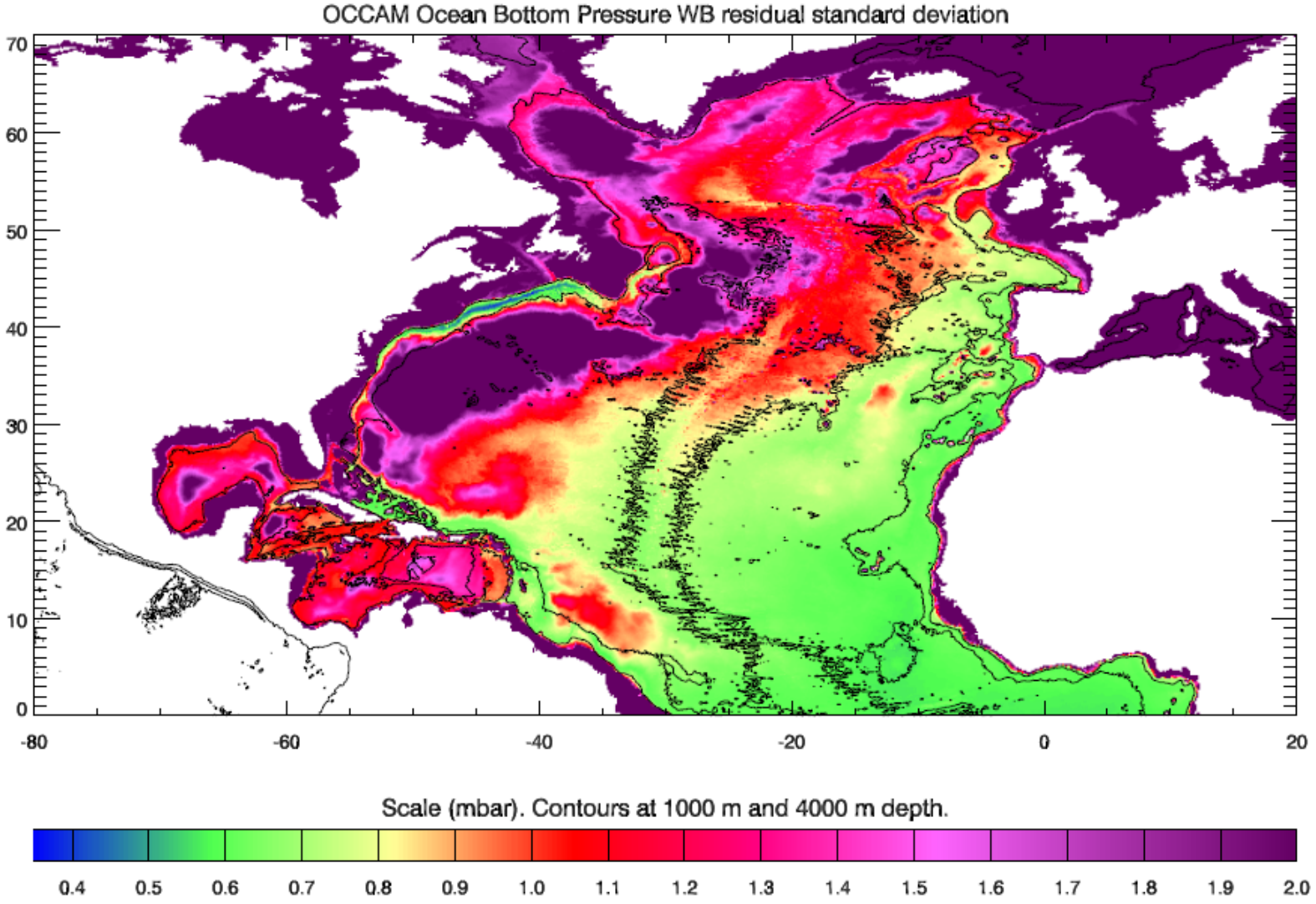
OCCAM 1/12 degree model– standard deviation of sea level (17 years of 5-day means, annual, semiannual and trend removed)

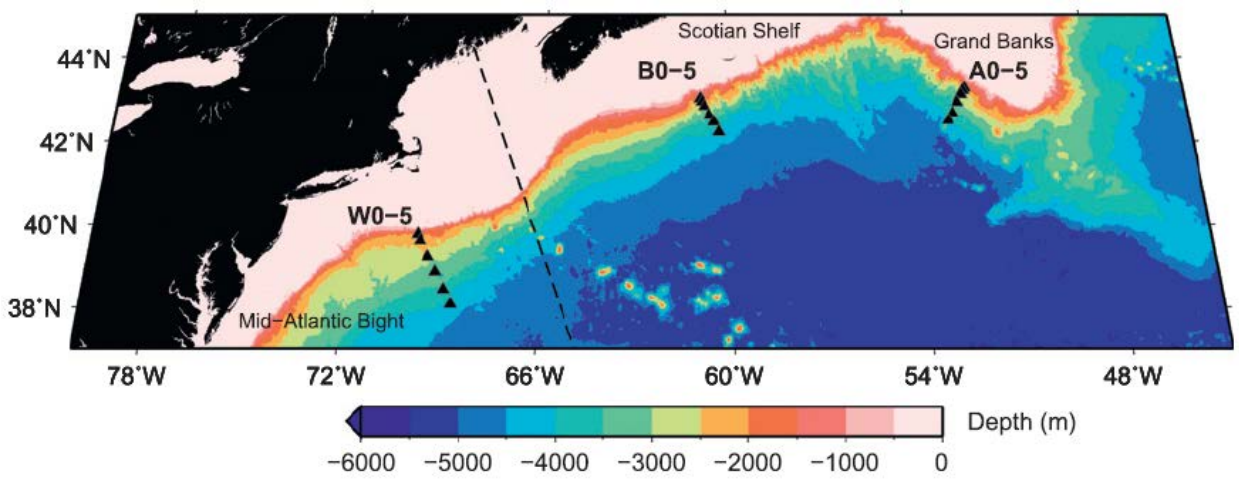


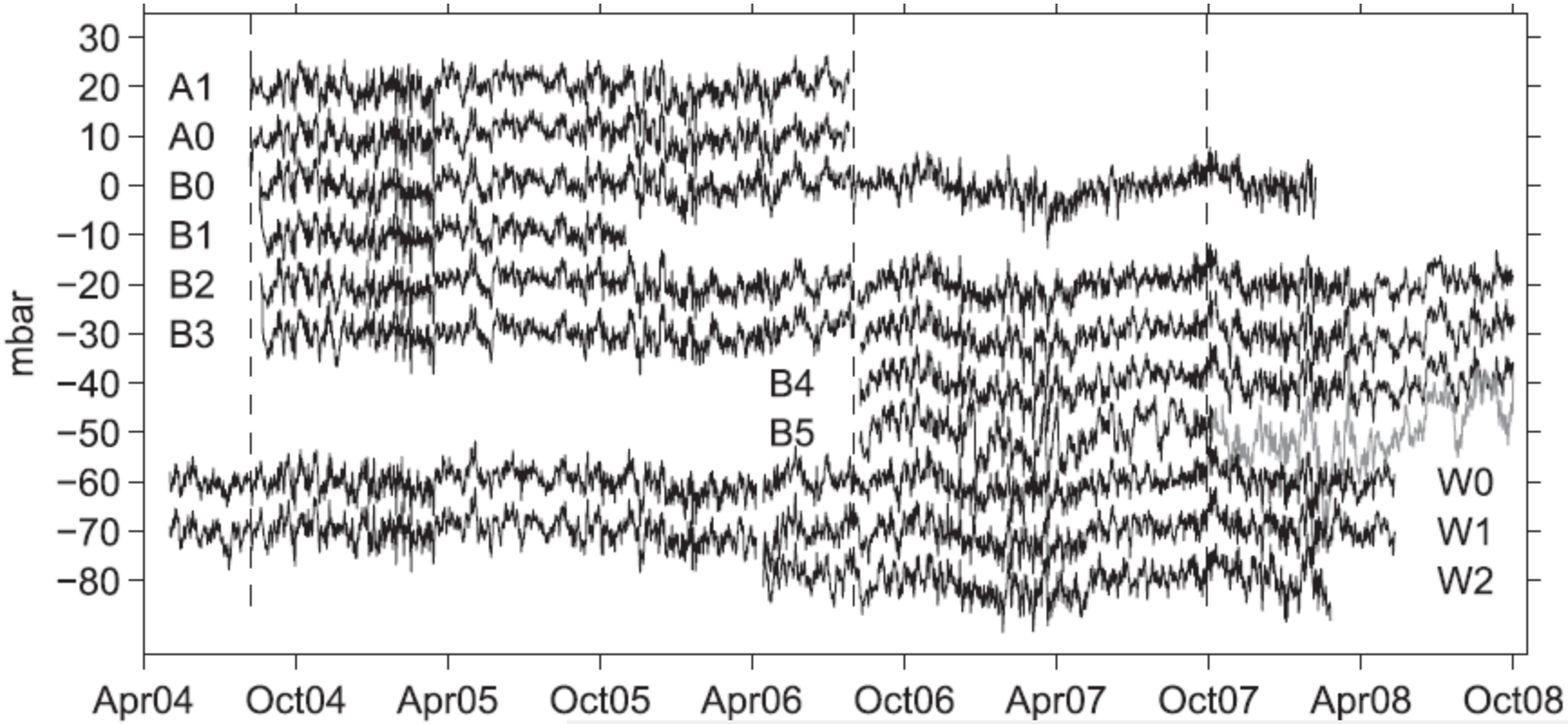
OCCAM 1/12 degree model– bottom pressure



OCCAM 1/12 degree model– bottom pressure minus western boundary average







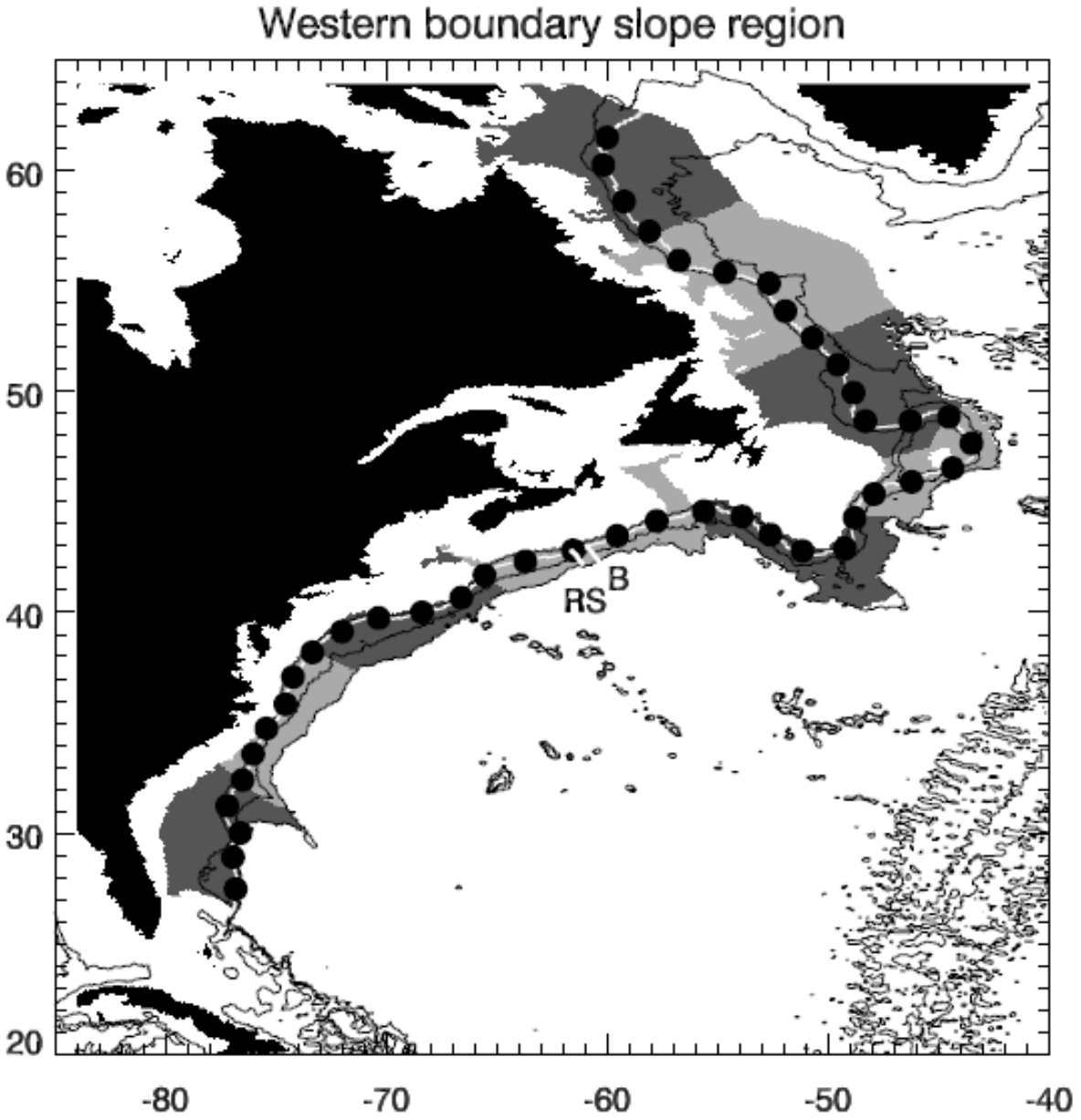
Correlations between records between 0.61 and 0.96.
Lags corresponding to wave speeds of about 200 m/s

Elipot et al., JPO 2013

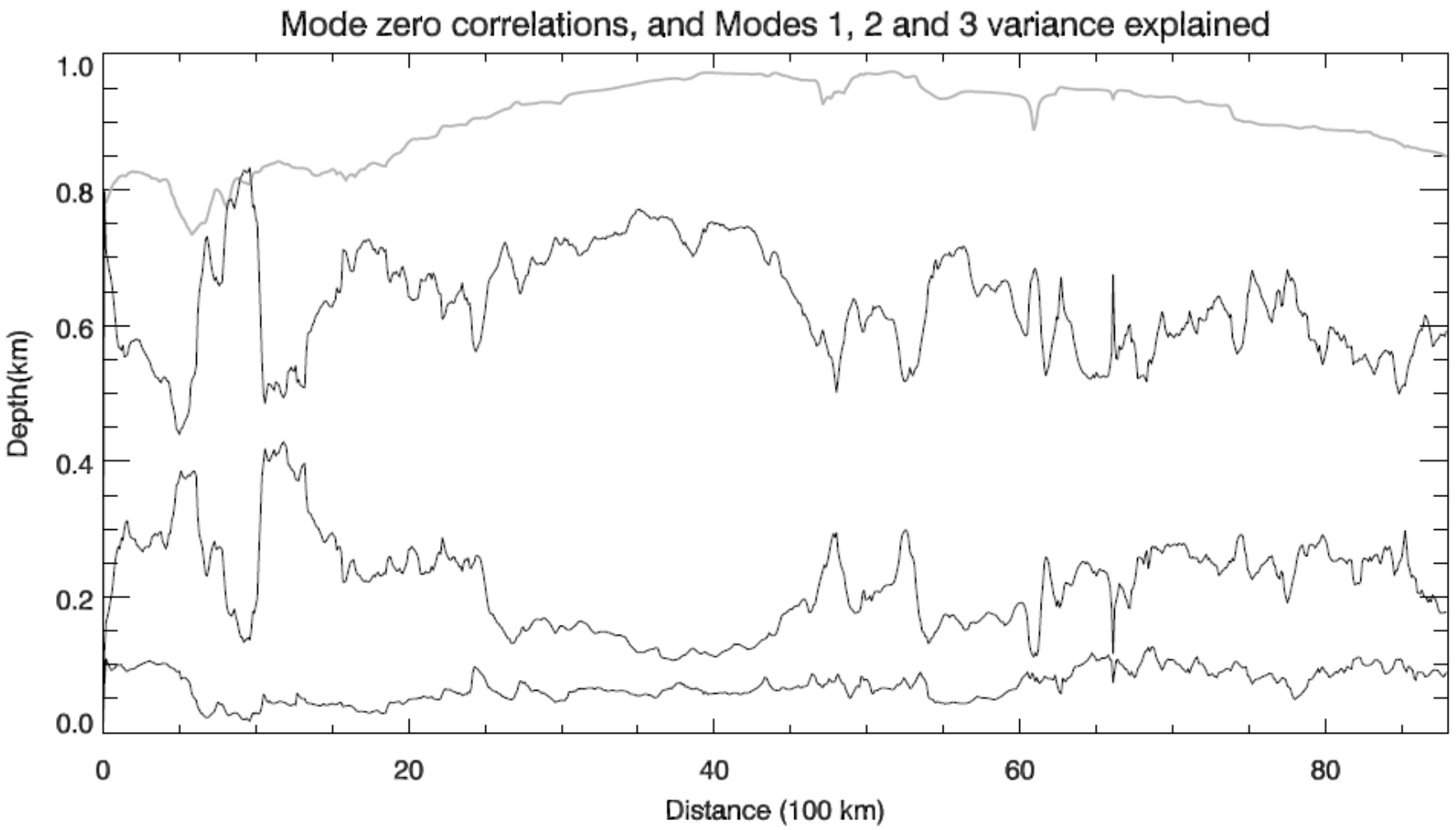
Extracted data from 200-4000m depth range along western continental slope, from 1/12 degree OCCAM.

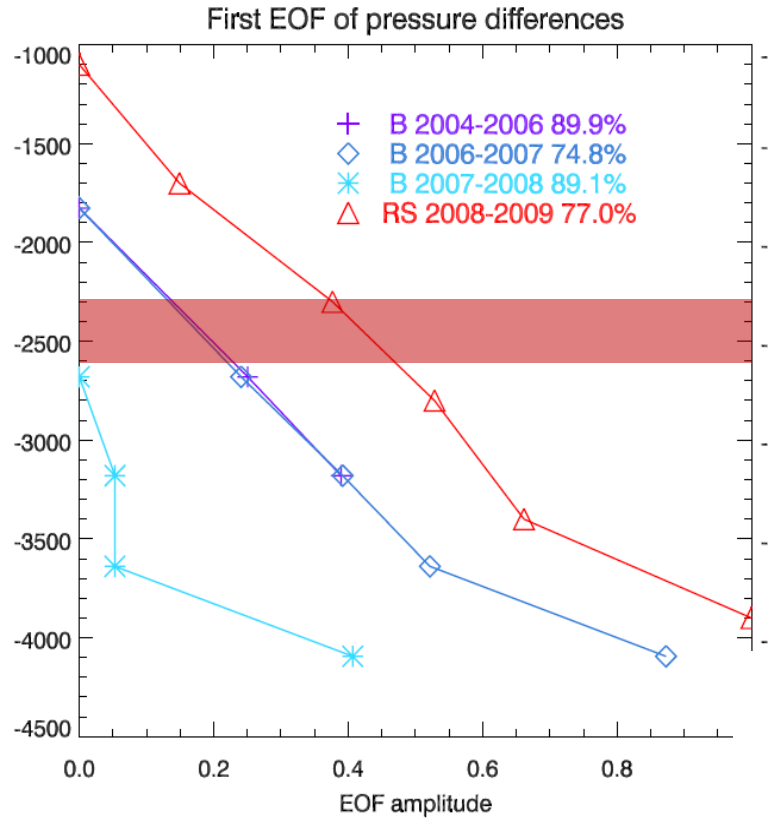
Plotted as a function of distance from the southern end, and depth.

Dots are every 200 km, colour changes every 1000 km



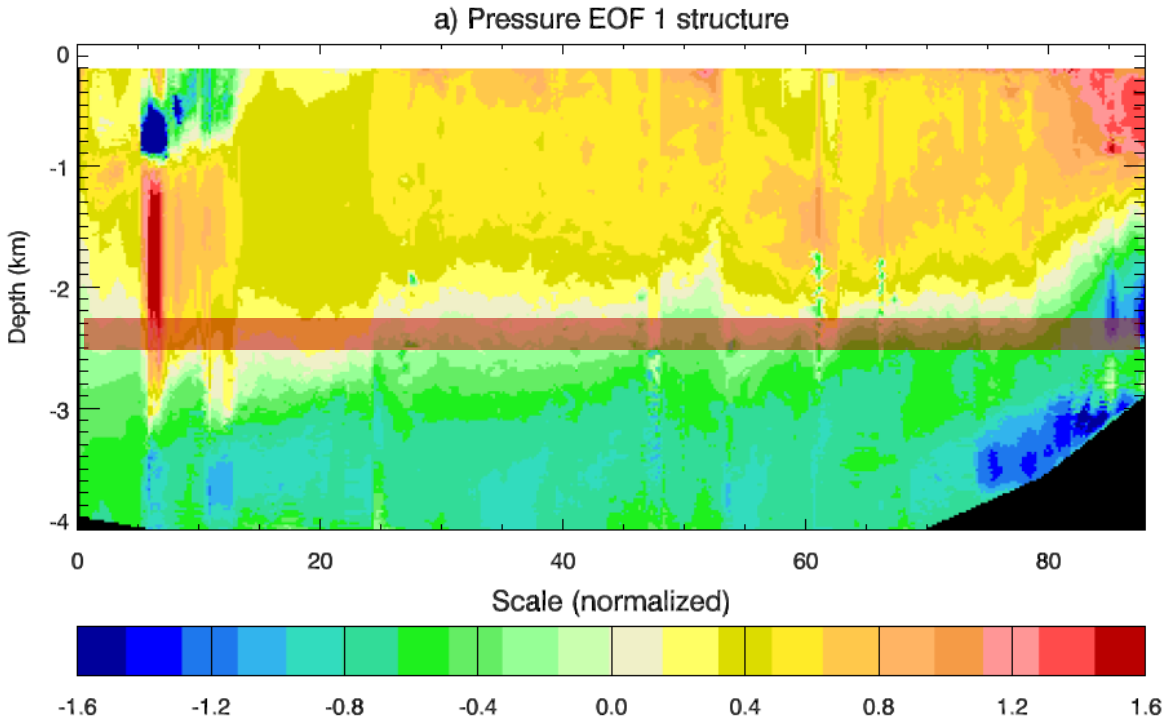
Black contours: 1, 3, 4 km. White contour: 2 km

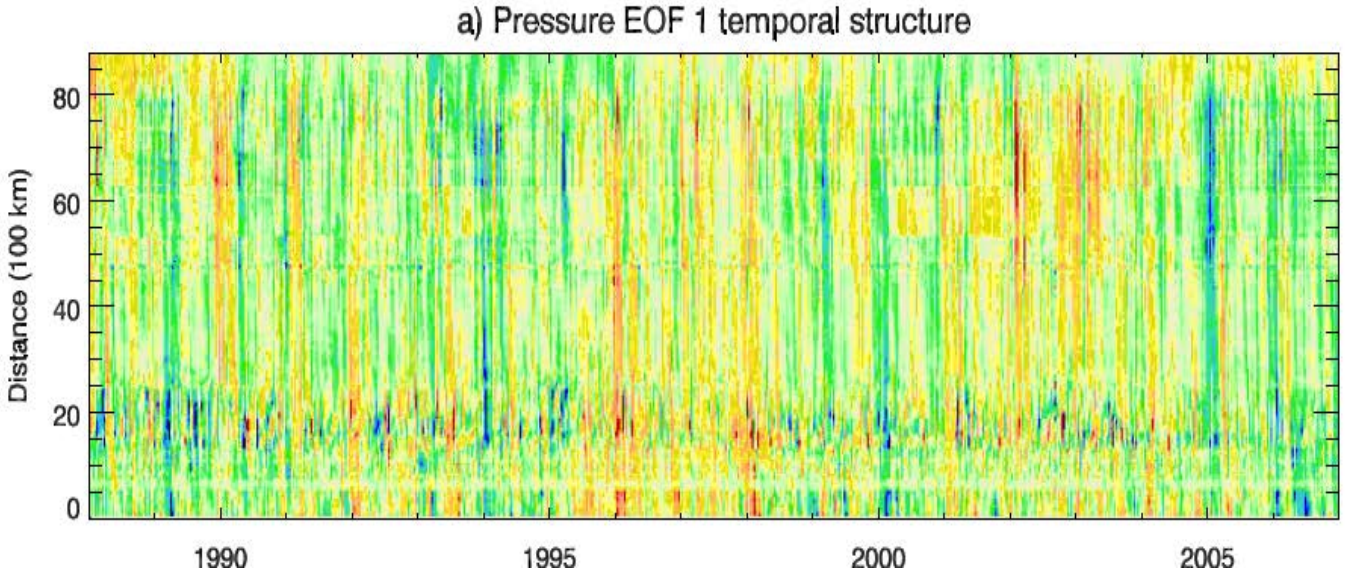

Mode zero correlations, and Modes 1, 2 and 3 variance explained
1.0
0.8
0.6
0.4
0.2
0.0
Depth(km)
0
20
40
60
80
Distance (100 km)

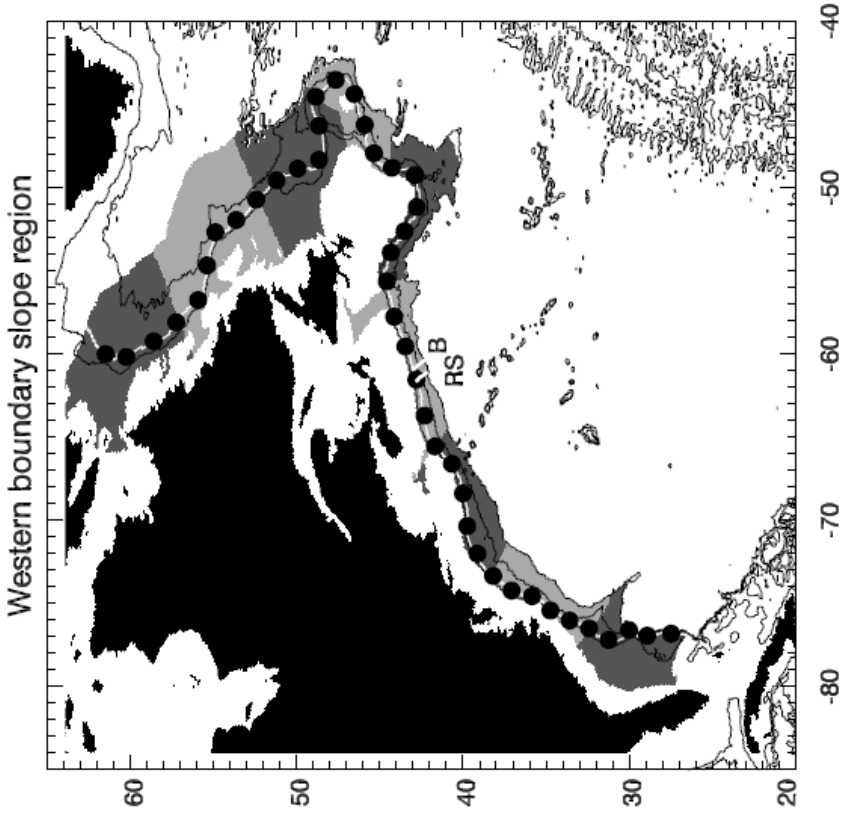


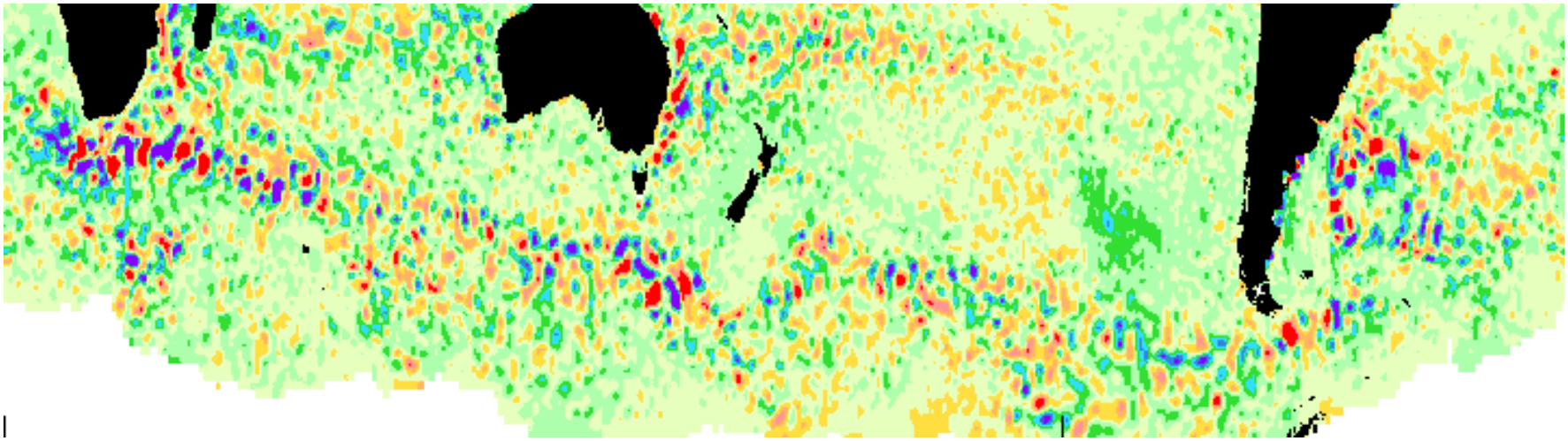
measured

modelled

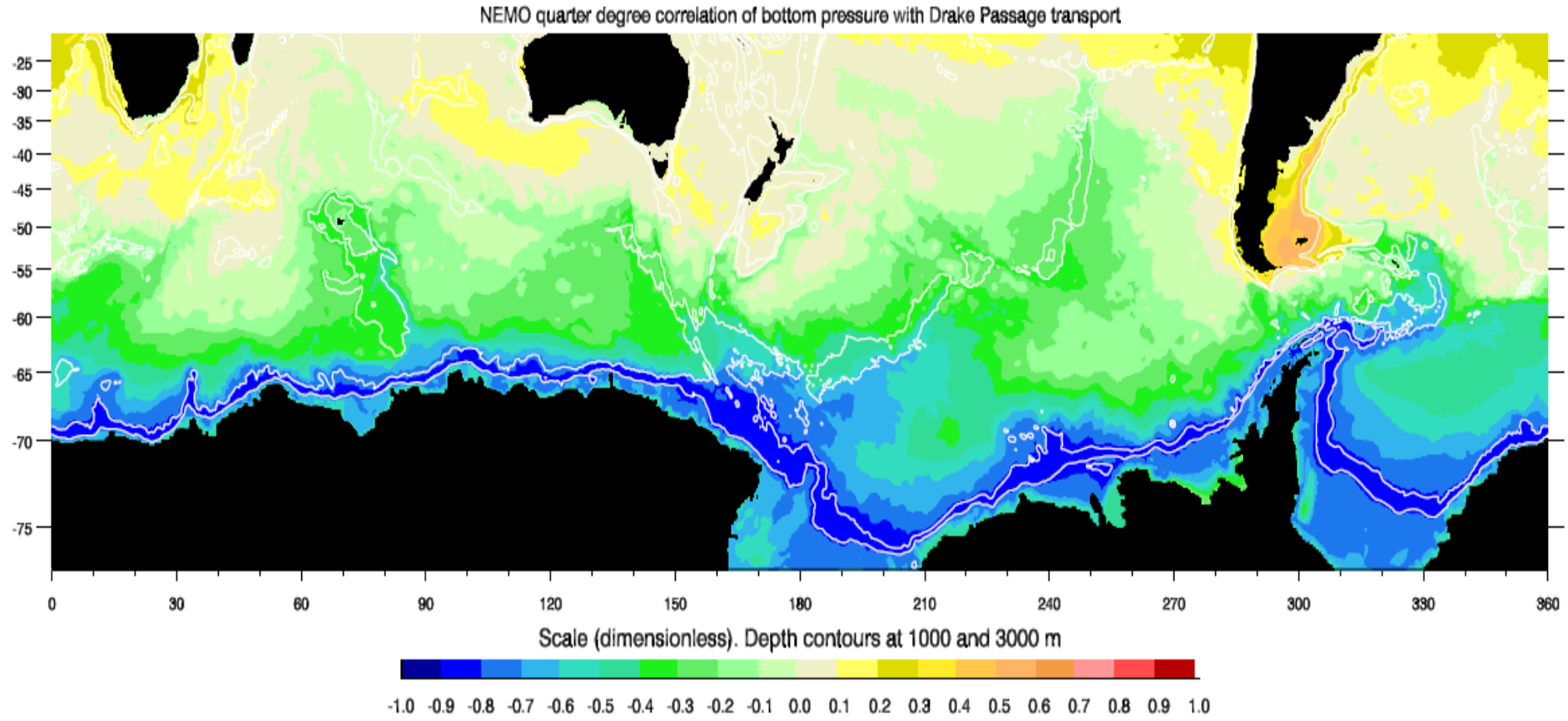


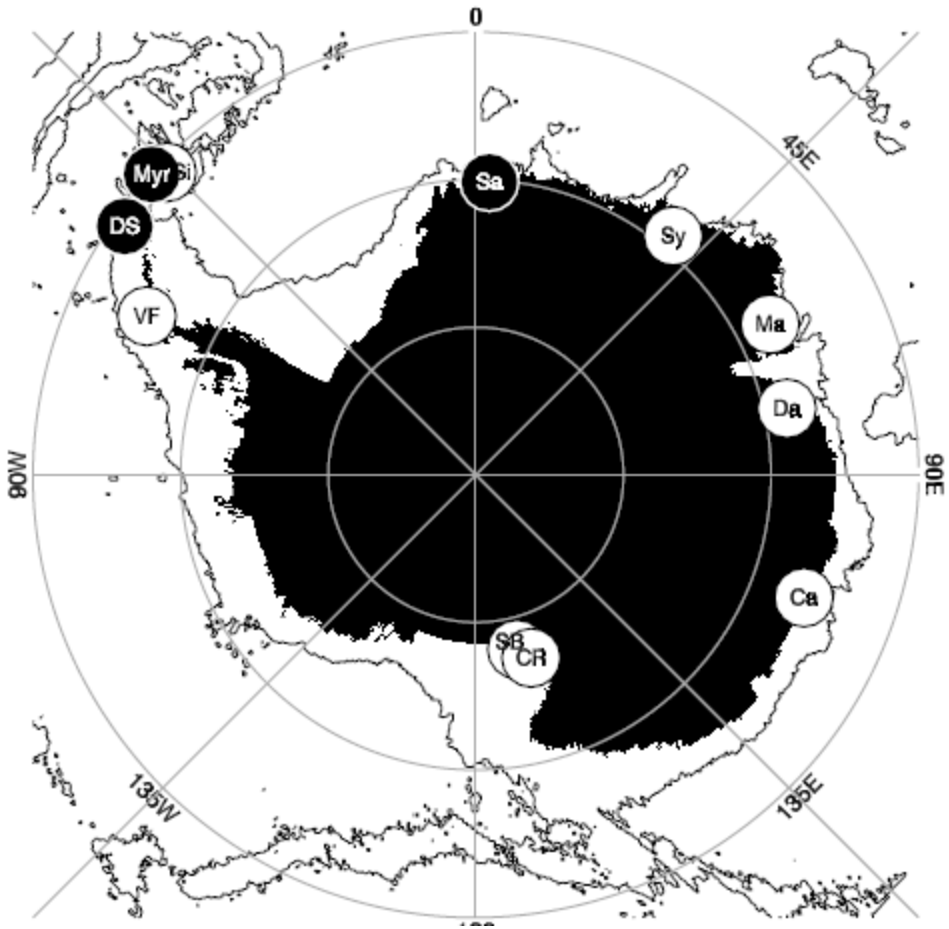

a) Pressure EOF 1 temporal structure
Distance (100 km)
0
20
40
60
80
1990
1995
2000
2005


Western boundary slope region
RS
B
60
50
40
30
20
-40
-50
-60
-70
-80



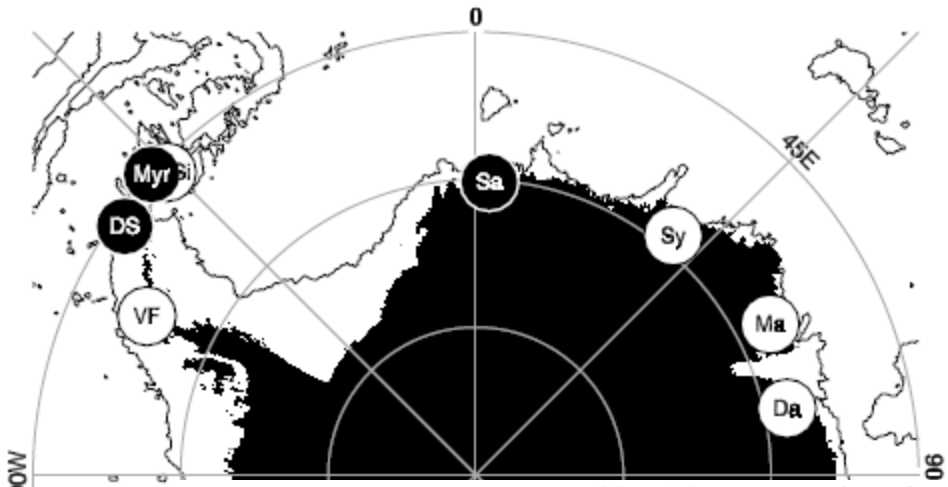
The Southern Mode





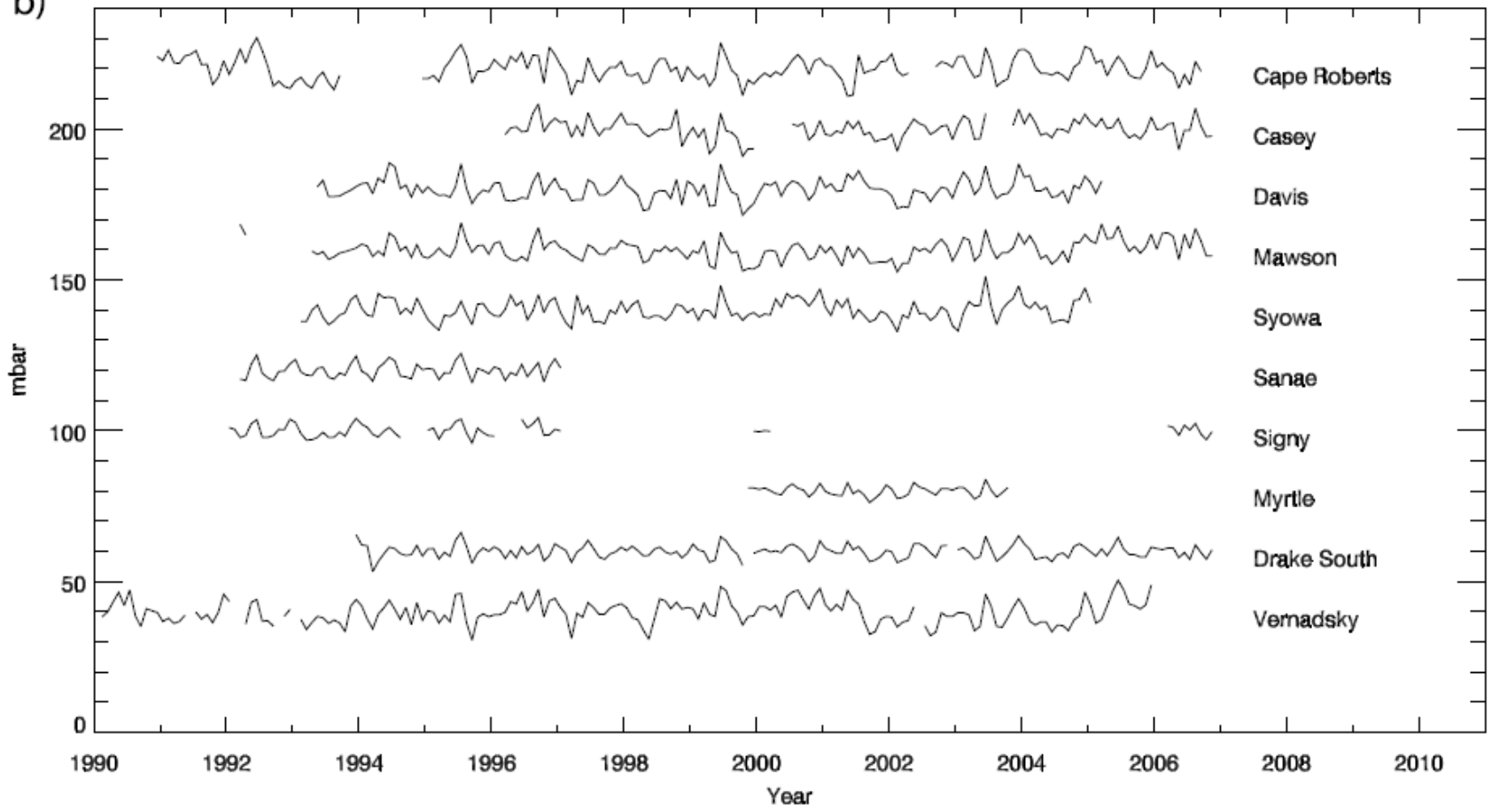
Meredith et al., Rev. Geophys., 2011
contribution from Angela Hibbert

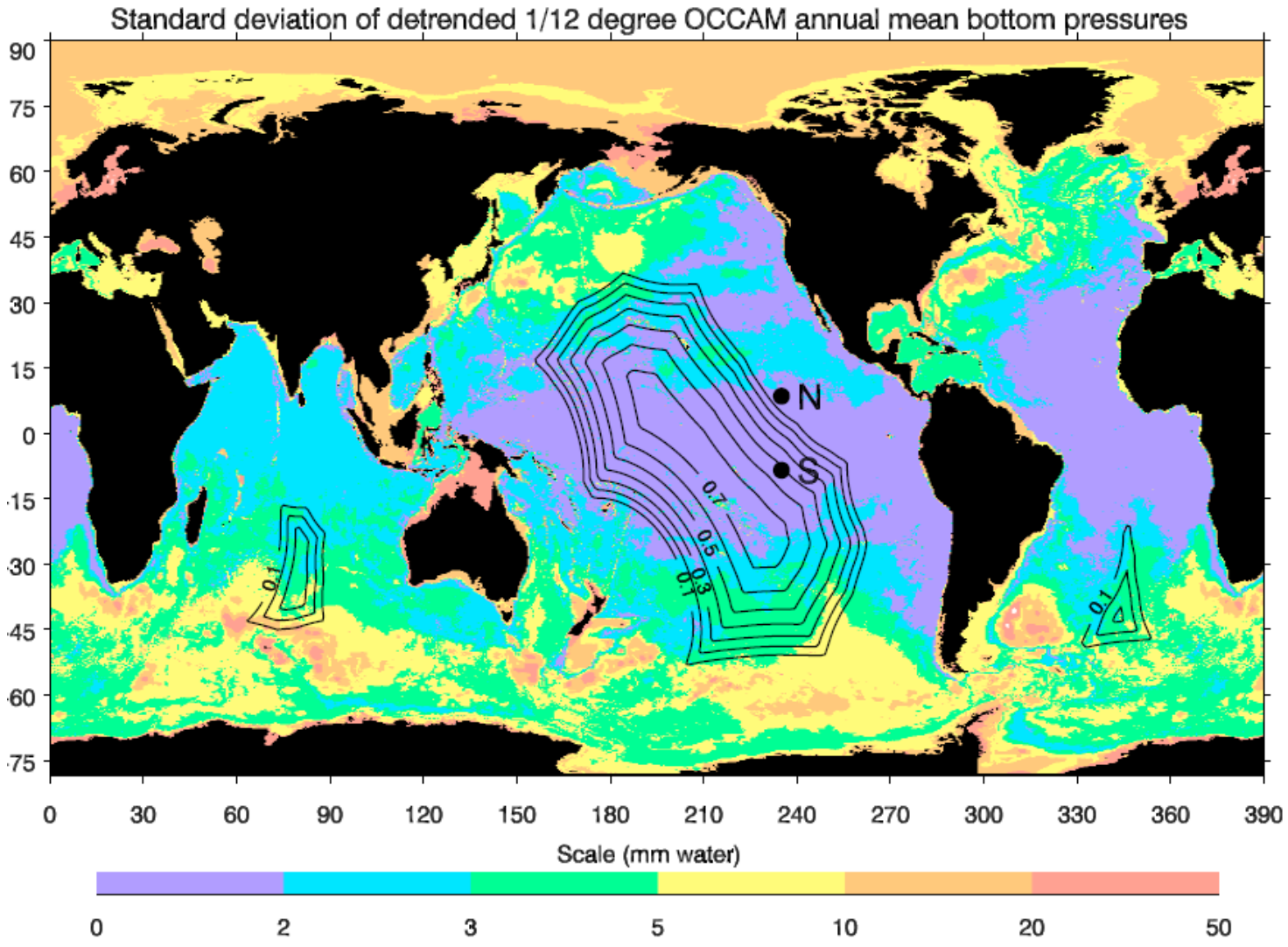
Meredith et al., Rev. Geophys., 2011
contribution from Angela Hibbert

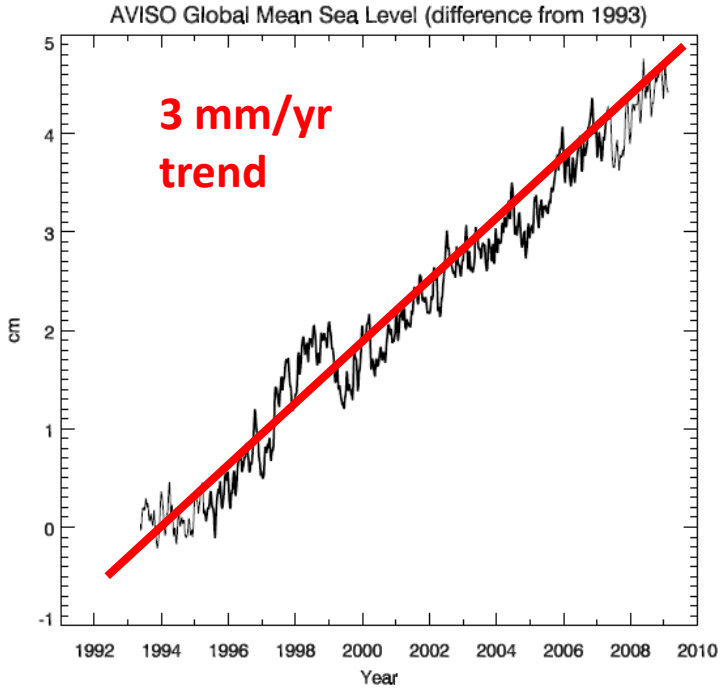


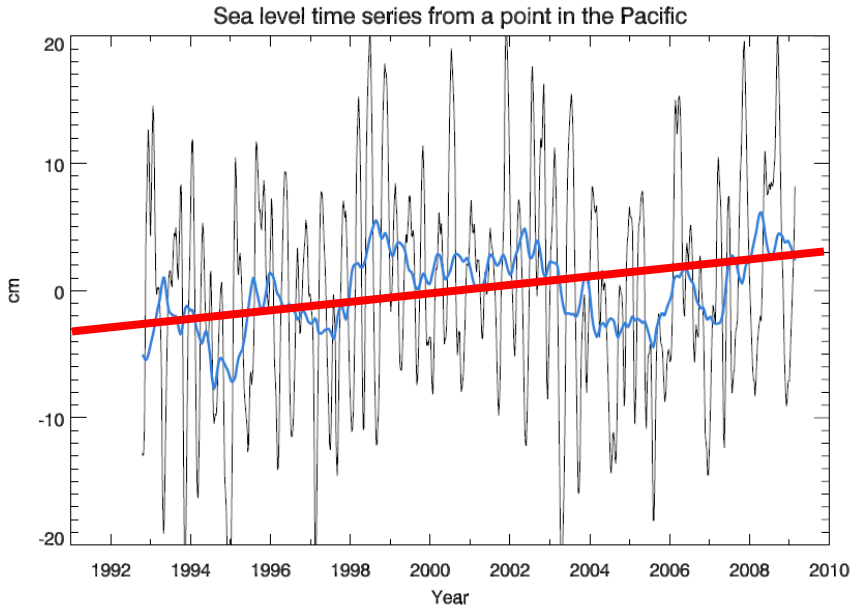
b)

Monthly mean subsurface or bottom pressure, annual cycle removed

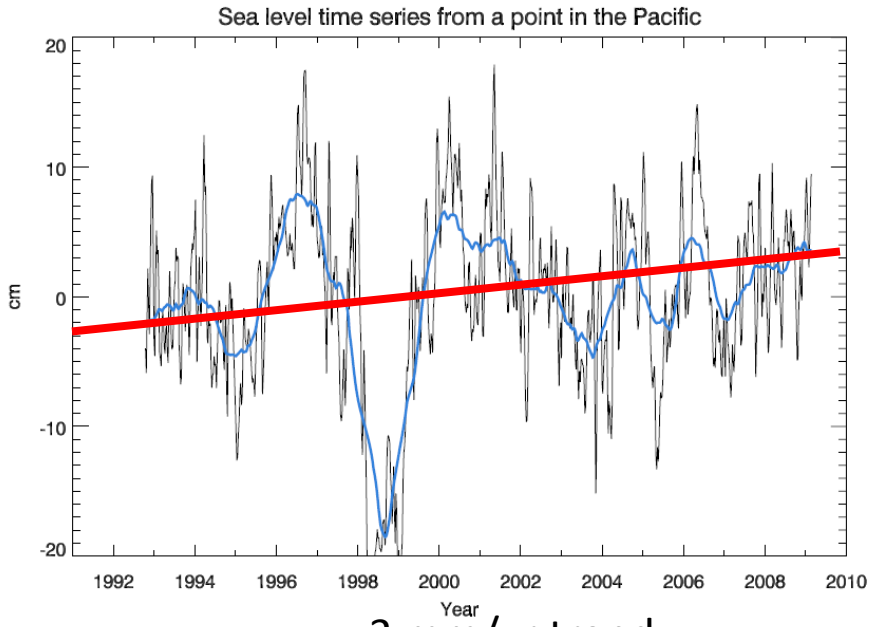



Standard deviation of detrended 1/12 degree OCCAM annual mean bottom pressures
90
75
60
45
30
15
0
-15
-30
-45
-60
-75
0
30
60
90
120
150
180
210
240
270
300
330
360
390
N
S
0.7
0.5
0.3
0.1
0.1
Scale (mm water)
0
2
3
5
10
20
50



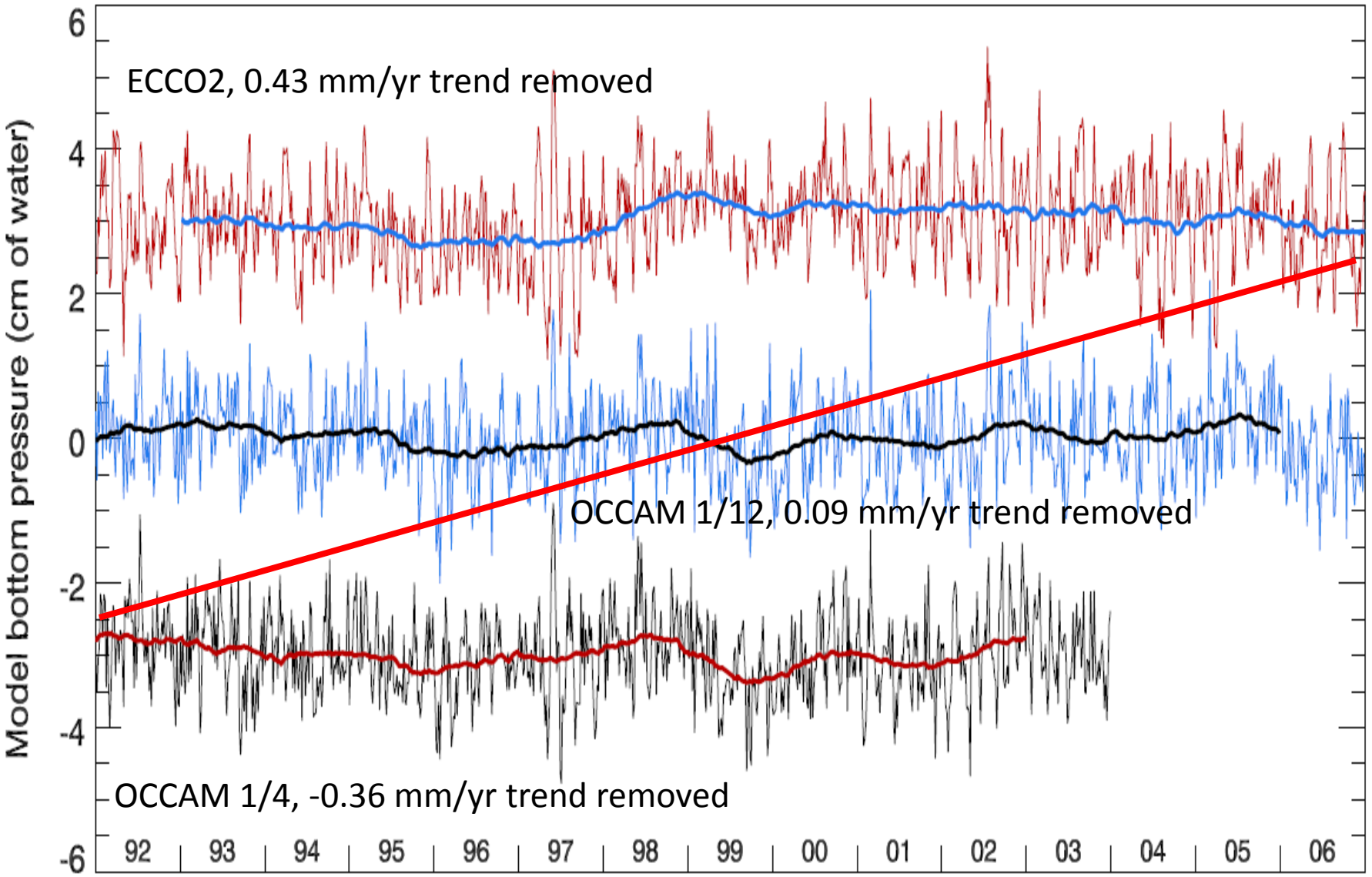


Running annual mean



3 mm/yr trend

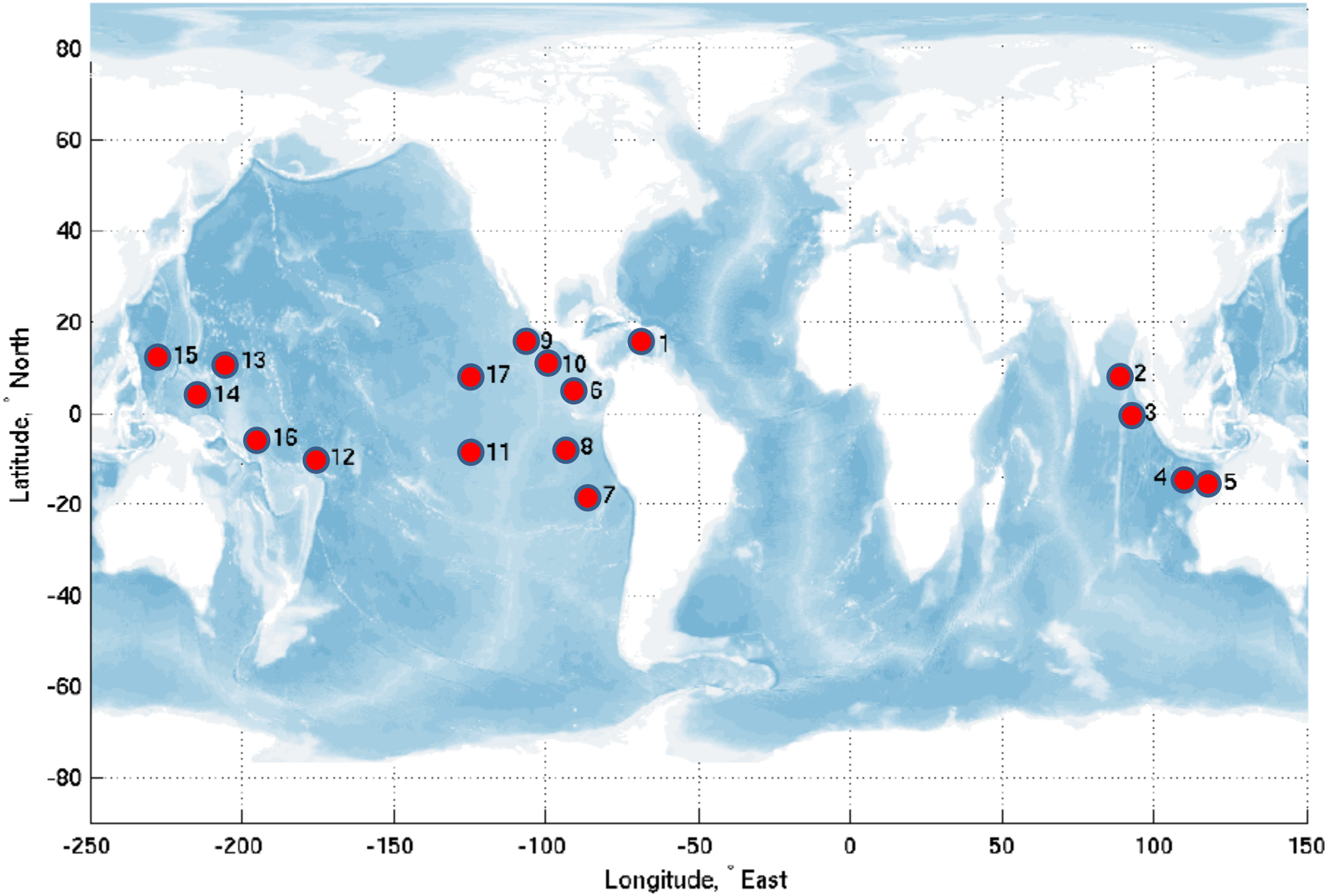
Model OBP at site S

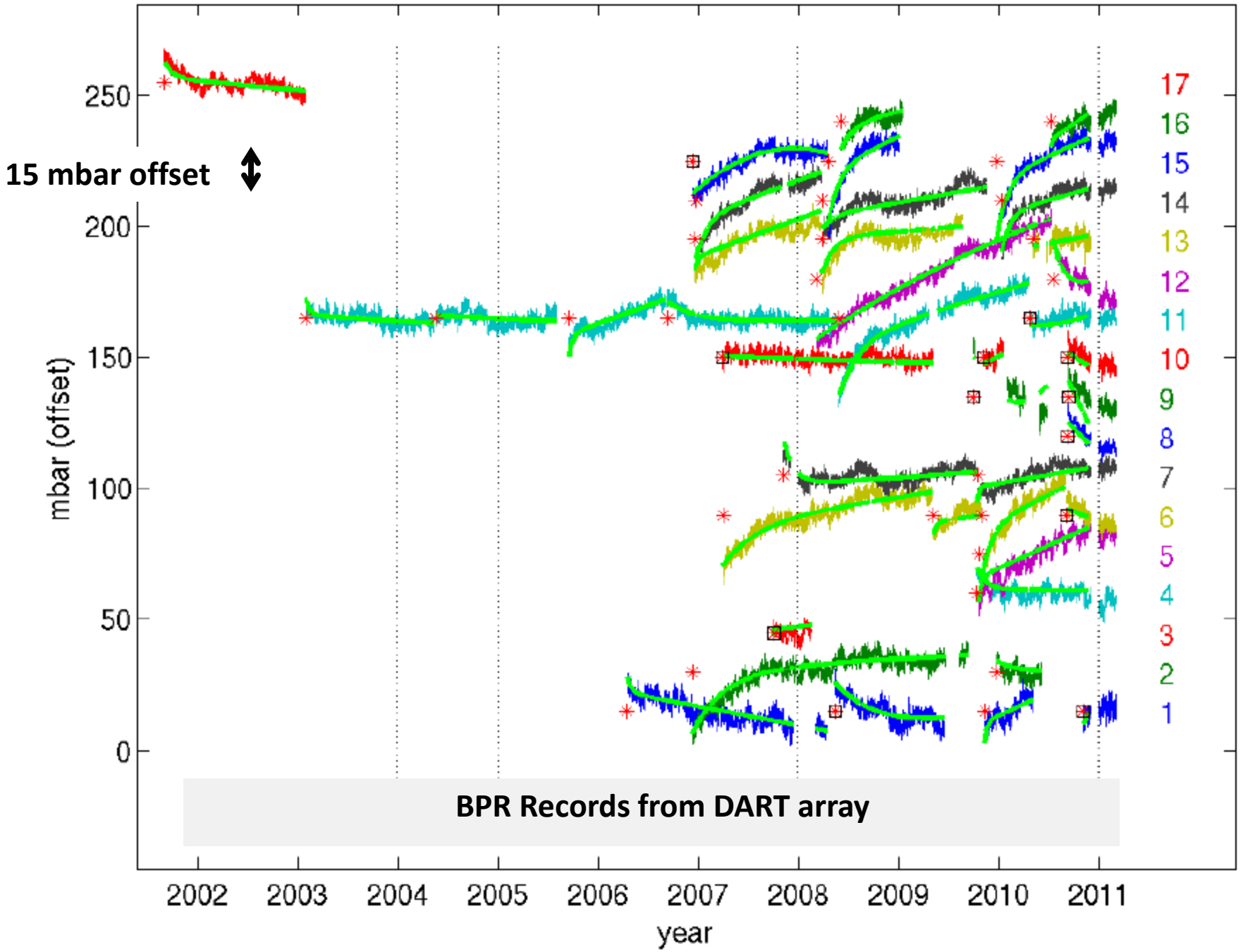


BPRs can do everything

- Filter out eddies
- Measure Antarctic Circumpolar Transport
- Measure the Meridional Overturning Circulation
- Measure changes in total ocean mass (barystatic sea level)

BUT…


80
60
40
20
0
-20
-40
-60
-80
Latitude, ° North
-250
-200
-150
-100
-50
0
50
100
150
Longitude, ° East
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17



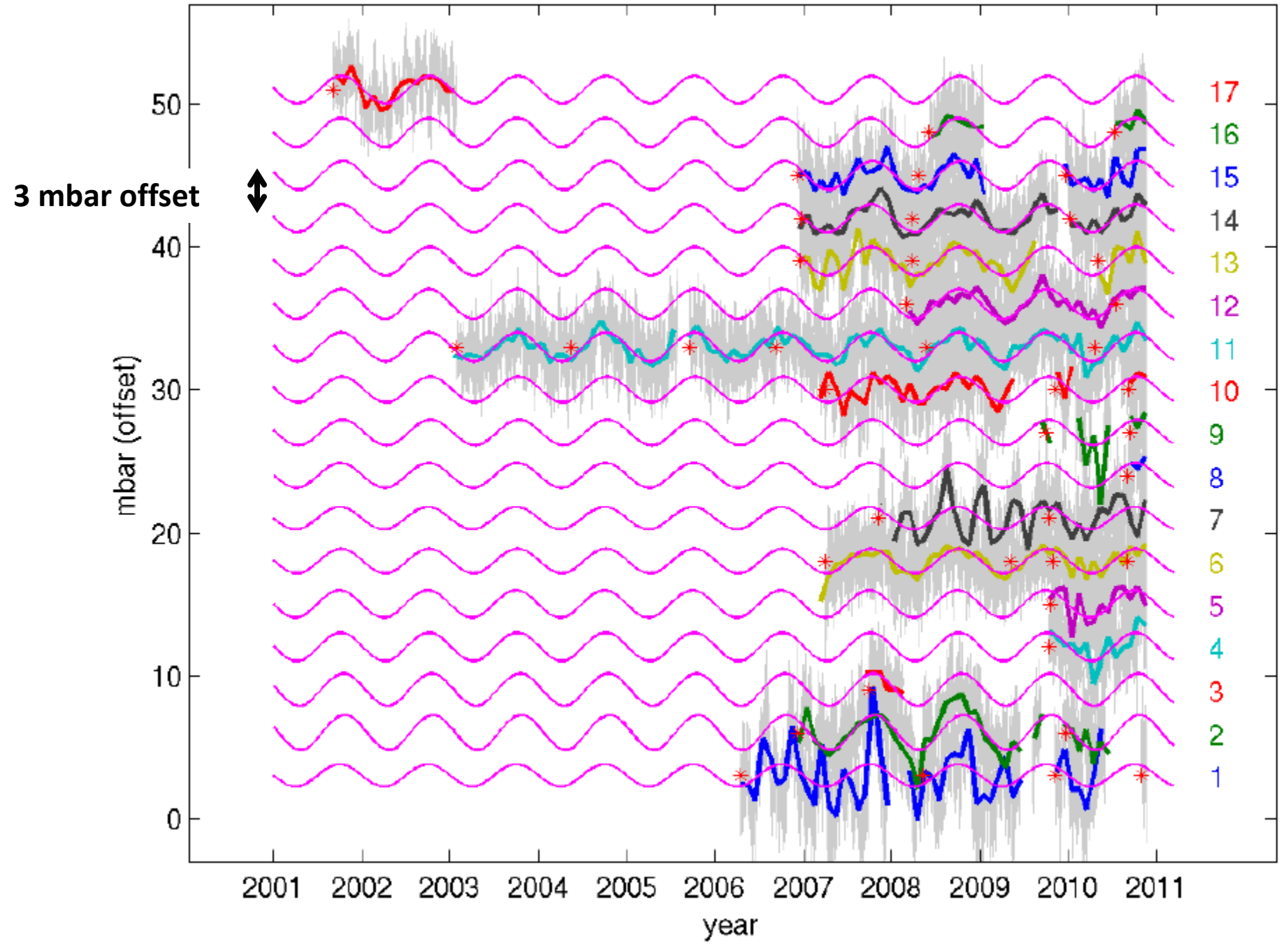
Williams et al., Ocean Science Discussions, 2013

See Joanne Williams' poster

Subtract:

- Ocean dynamics (from model)
- Global ocean atmospheric pressure (from analysis)
- Long period tides and pole tide (self-consistent equilibrium solution)
- Exponential + linear fitted trend (fit together with annual cycle)

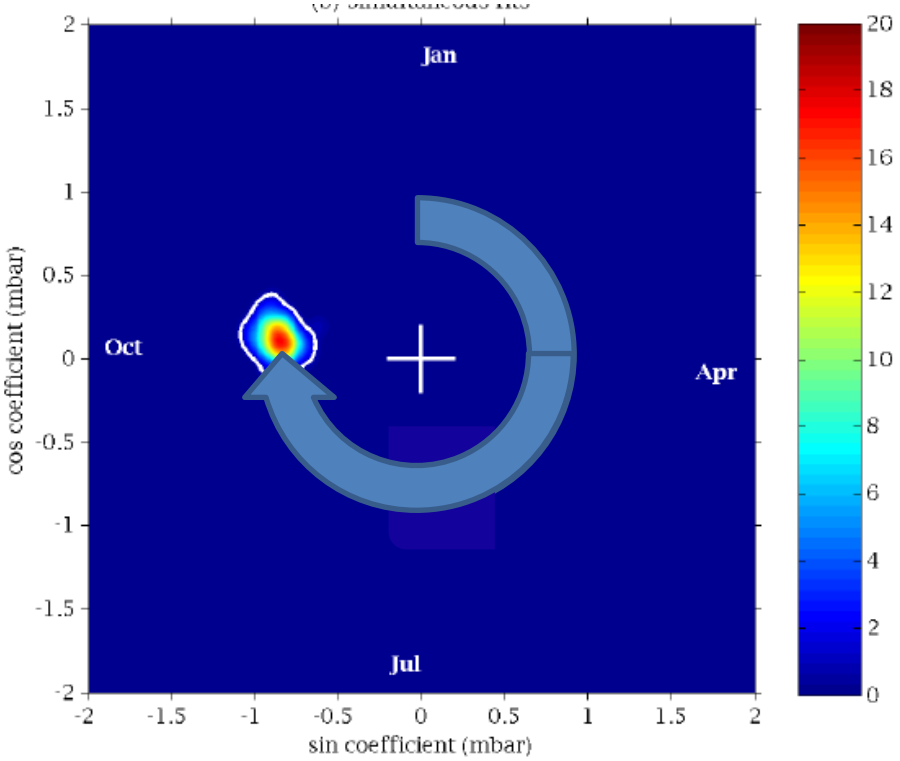
What is left should result from total ocean mass changes and planetary mass redistribution…



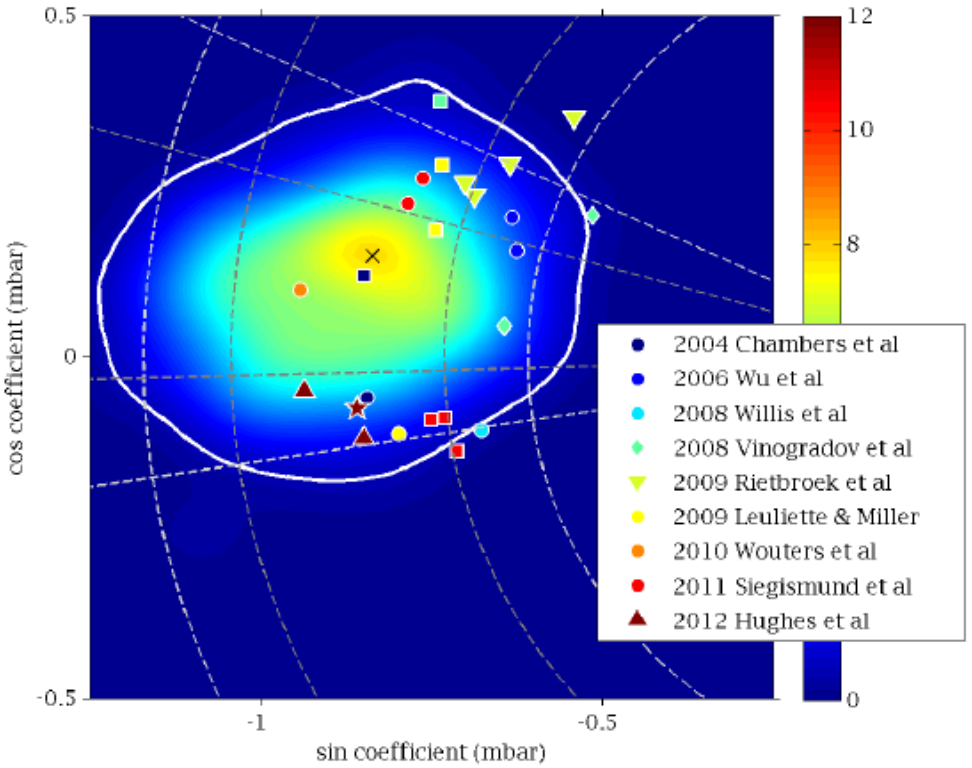
Williams et al., Ocean Science Discussions, 2013

See Joanne Williams' poster

Annual cycle from BPRs and from GRACE/Altimetry/Argo/…



Joint solution based on BPRs and one ocean model

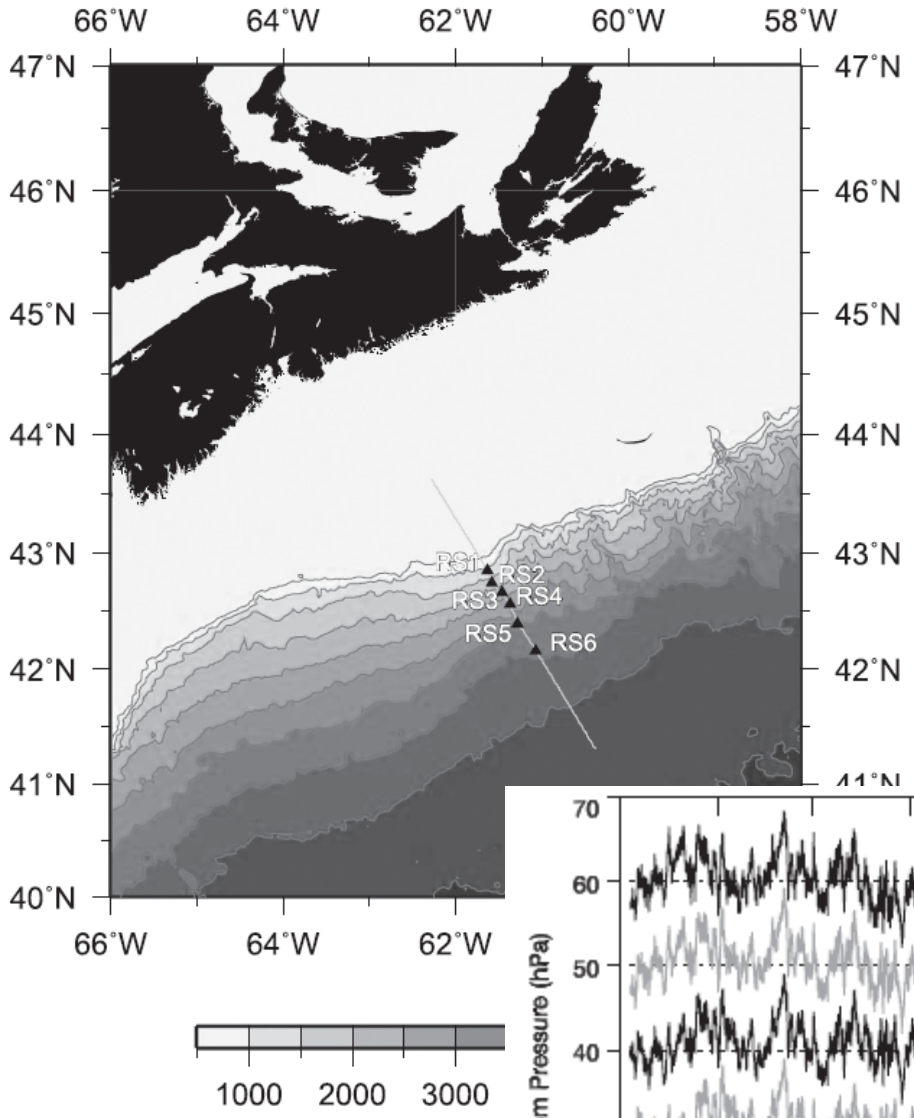


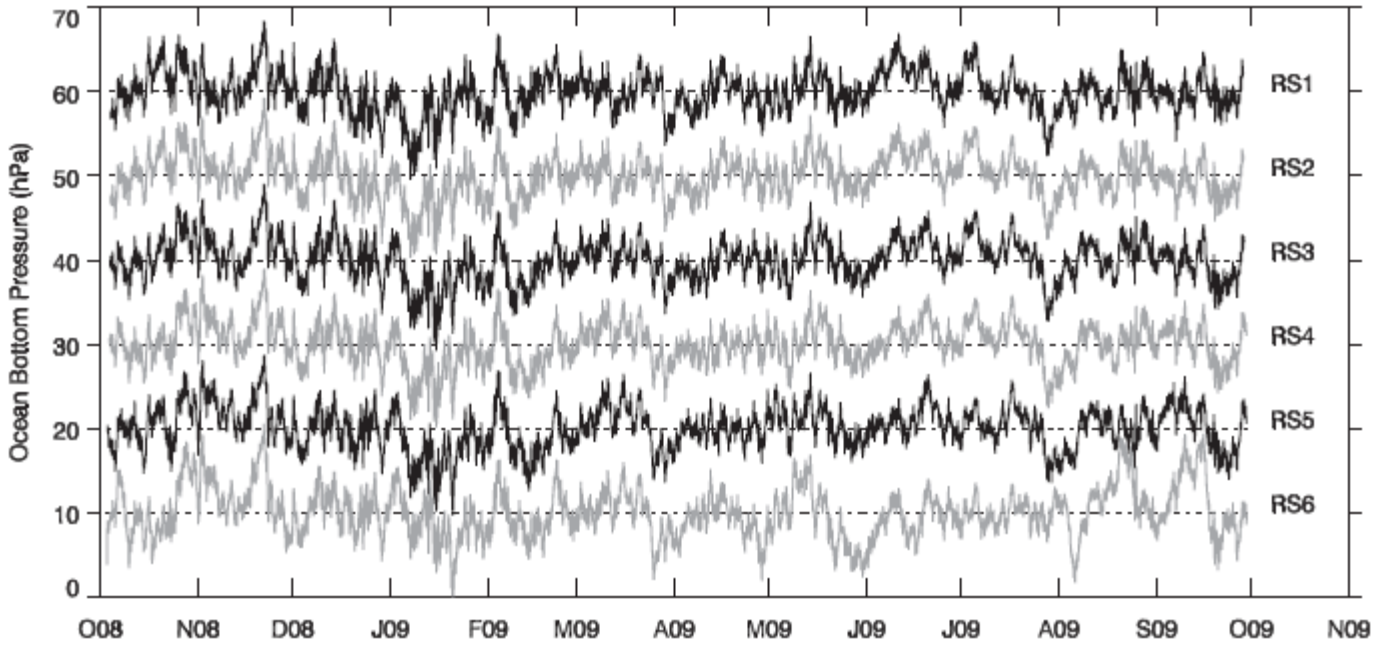
Zoomed version, with uncertainty from multiple models folded in, compared with other methods

So… BPRs are very valuable and precise at timescale of about a year or less. What about longer time scales?

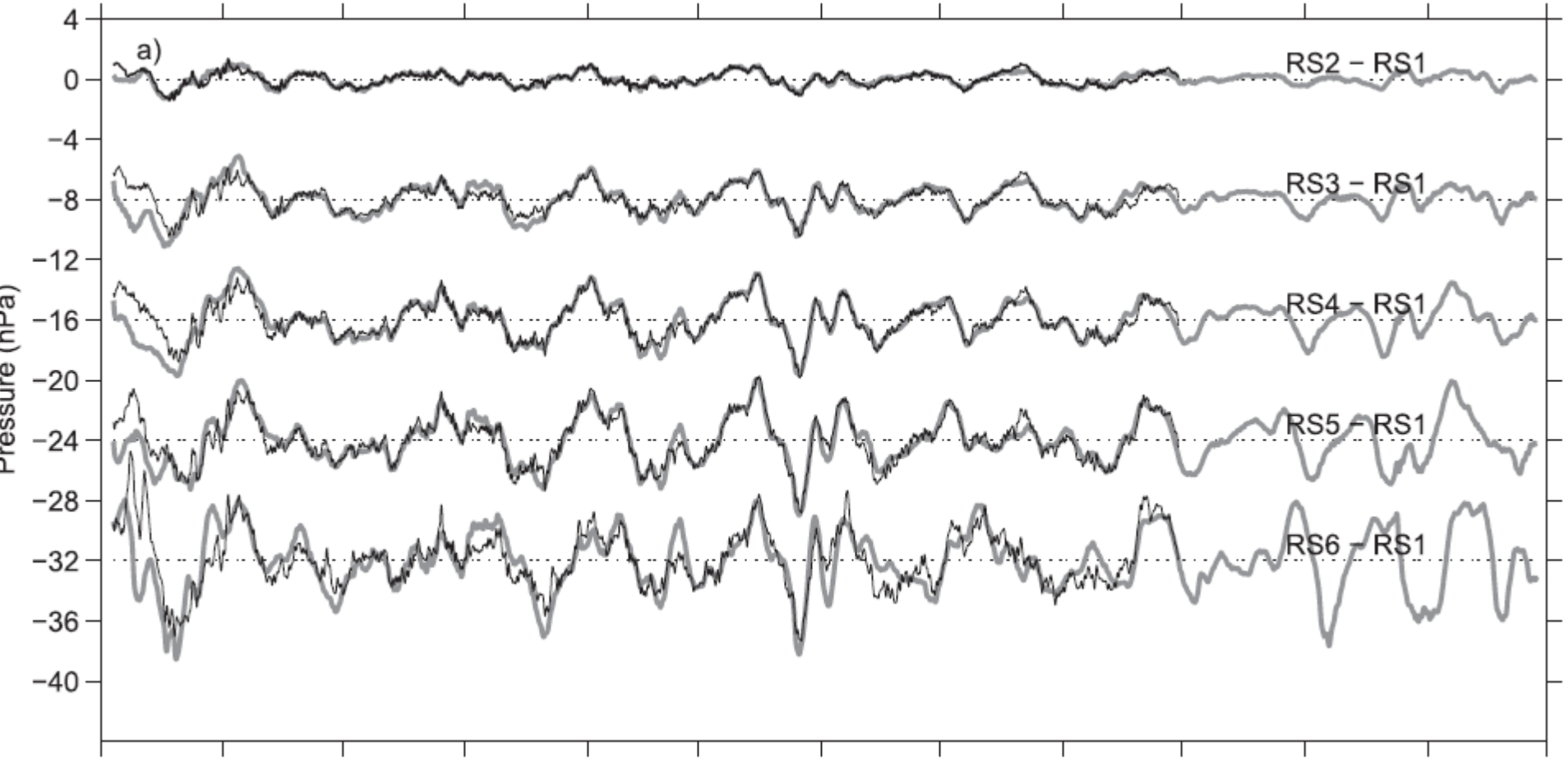
1) Can make some progress with long and overlapping deployments, but linear drift is still unknown, and nonlinear trends are still imperfectly removed.
2) Could invent a new kind of instrument to avoid the drift problem… ideas please.
3) Can measure bottom pressure indirectly, e.g. sea level + density (reference frames?)

Hughes et al., Jtech 2013 (collaboration with BIO)





Hughes et al., Jtech 2013 (collaboration with BIO)



Mooring site	Location	Measured water depth (m)
RS1	42°50.95′N, 61°37.85′W	1114 (1176)
RS2	42°44.26′N, 61°34.61′W	1701 (1771)
RS3	42°39.50′N, 61°27.70′W	2290 (2293)
RS4	42°33.35′N, 61°22.14′W	2784 (2766)
RS5	42°23.56′N, 61°16.57′W	3427 (3427)
RS6	42°09.81′N, 61°04.22′W	3882 (3916)

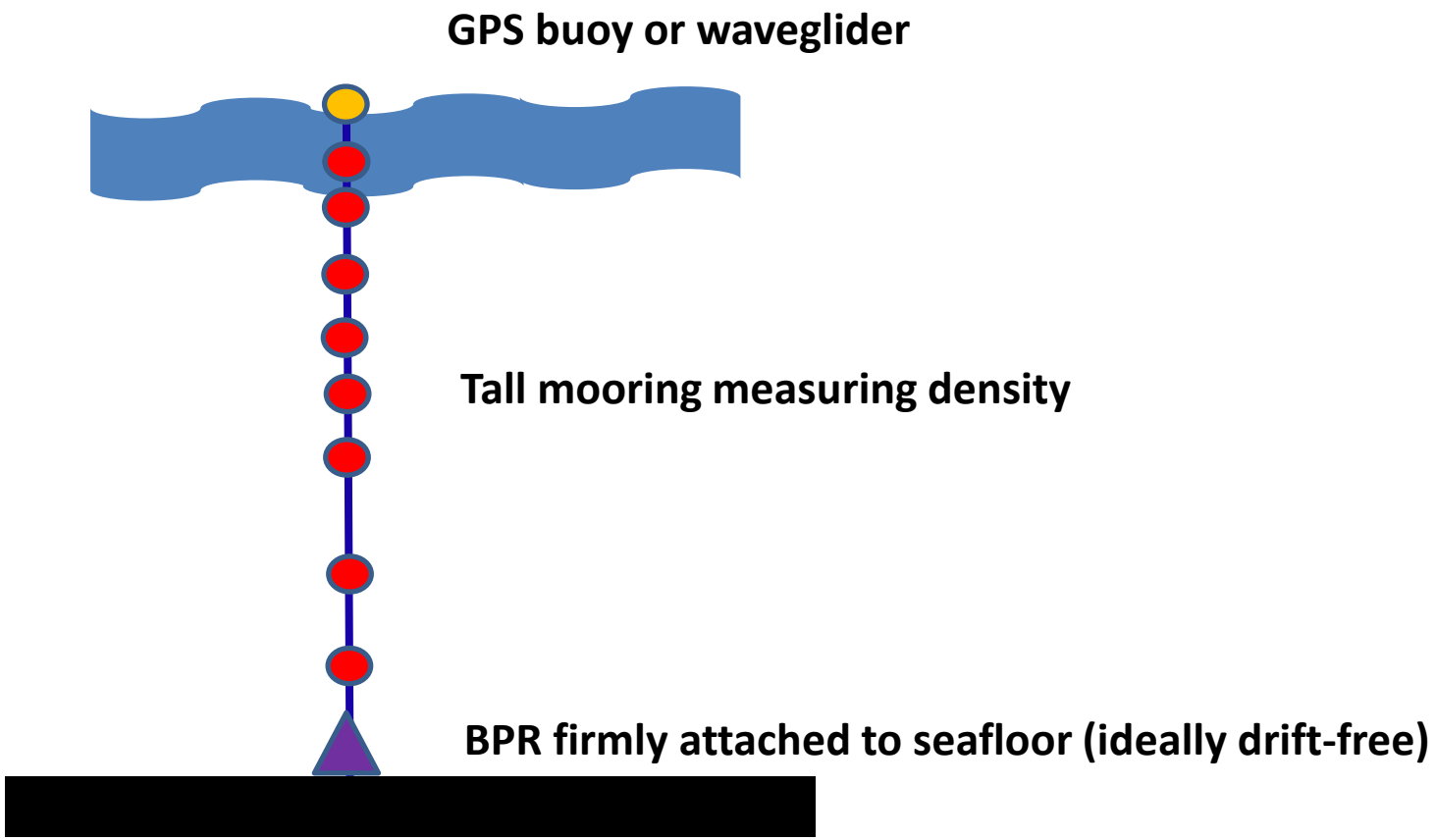
Pair	Method	Skill	Error (Pa)
RS1,2	1	0.84	16.68
	2	0.84	16.73
RS1,3	1	0.85	35.79
	2	0.85	35.27
RS1,4	1	0.92	36.77
	2	0.92	35.86
RS1,5	1	0.90	49.64
	2	0.90	49.90

Why bother, when we have GRACE?

GRACE is excellent, and has transformed what we can do, but…

- It needs extra information to define the geocentre (and probably degree 2 terms too)
- It has coarse spatial resolution… I suspect no satellite gravity mission would be able to resolve pressure changes particular to the continental slope
- To be sure of our measurements, we need an independent check
- We want to be able to bridge gaps between gravity missions.

My candidate for most valuable new observation:



The equivalent of a tide gauge for the altimeter-ARGO-GRACE system