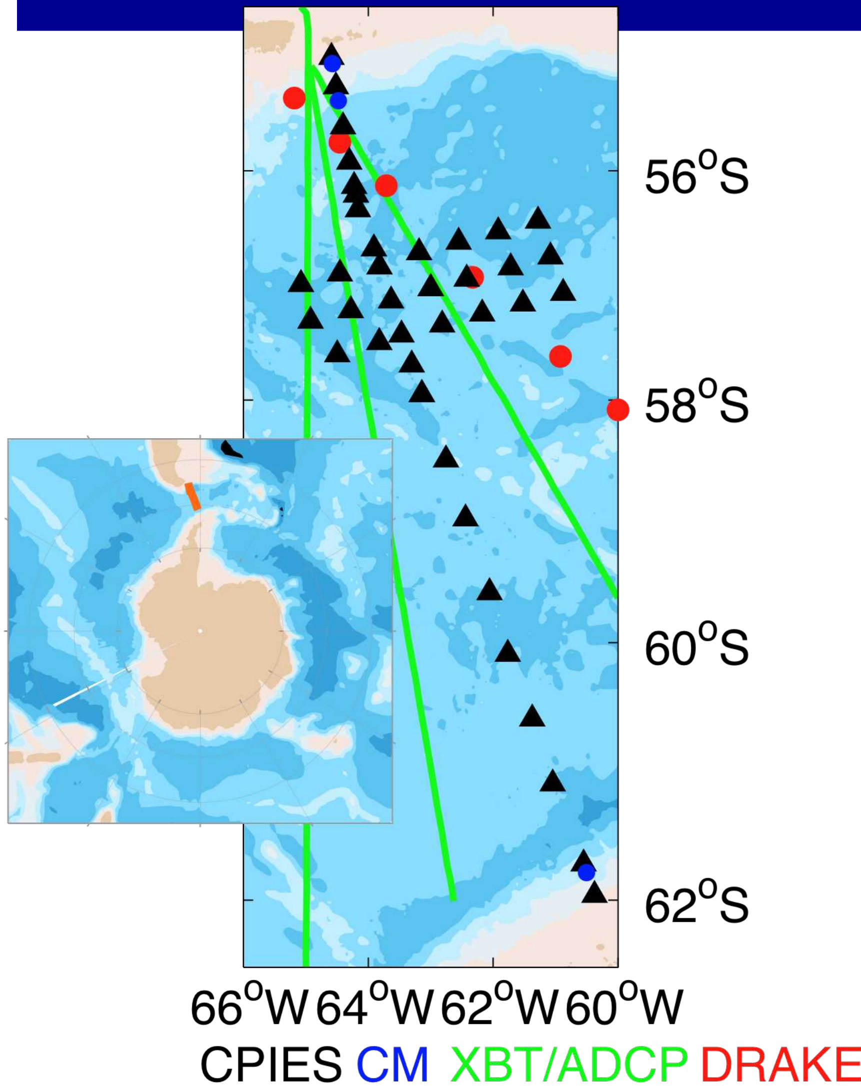
Barotropic Transport Variability in Drake Passage from the cDrake Experiment



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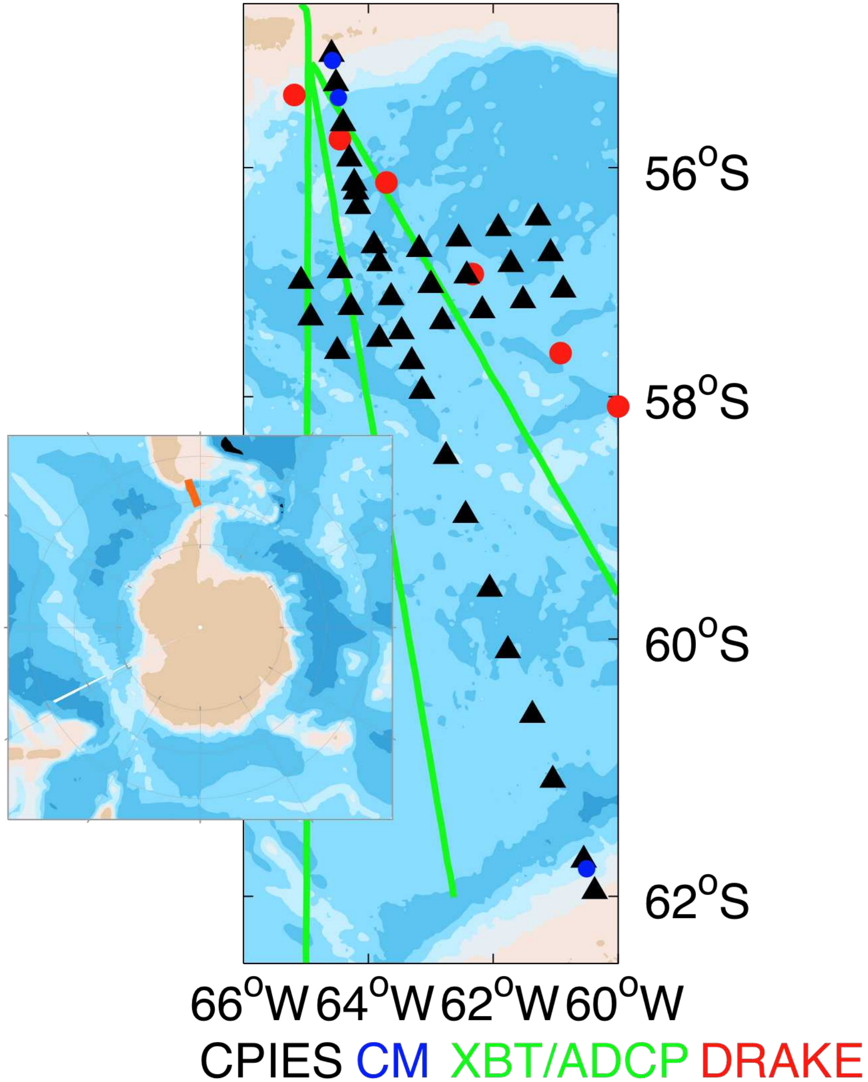
cDrake Objectives



Quantify ACC transport and dynamics for 4 years.

- Use a transport line to determine horizontal and vertical structure of the time-varying transport.
- Use a local dynamics array to describe the mesoscale eddy field.
- Provide guidance for future monitoring arrays.
- Assess the skill of model simulations.

CPIES:
current and pressure recording inverted echo sounder

Measures bottom current.
(50 m off bottom)

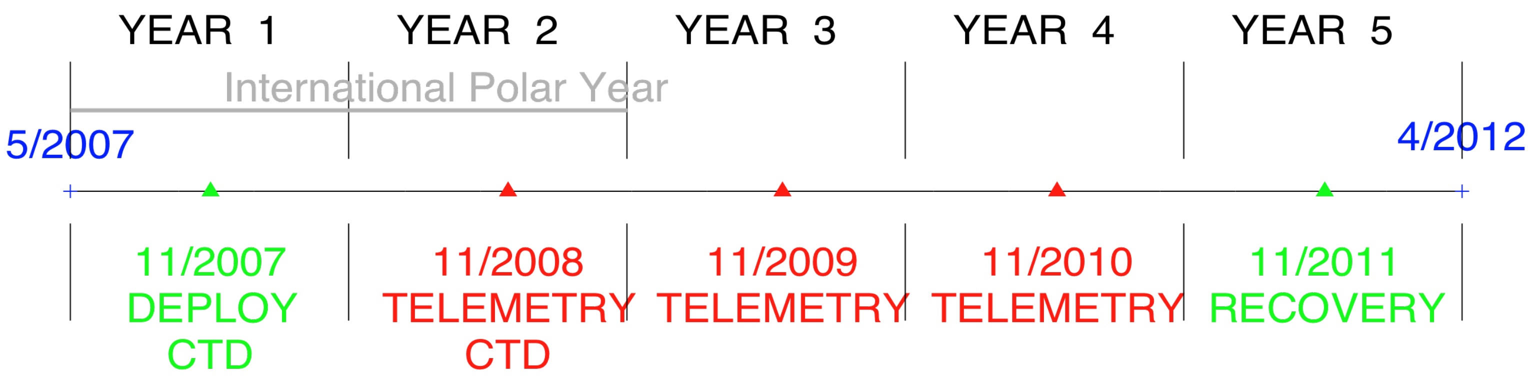
Measures bottom pressure.

Emits 12kHz sound pulses.
Measures round trip travel times of acoustic pulses to sea surface and back.

Behind the scenes:
Erran Sousa and Gerry Chaplin

Photo courtesy of Sharon Escher

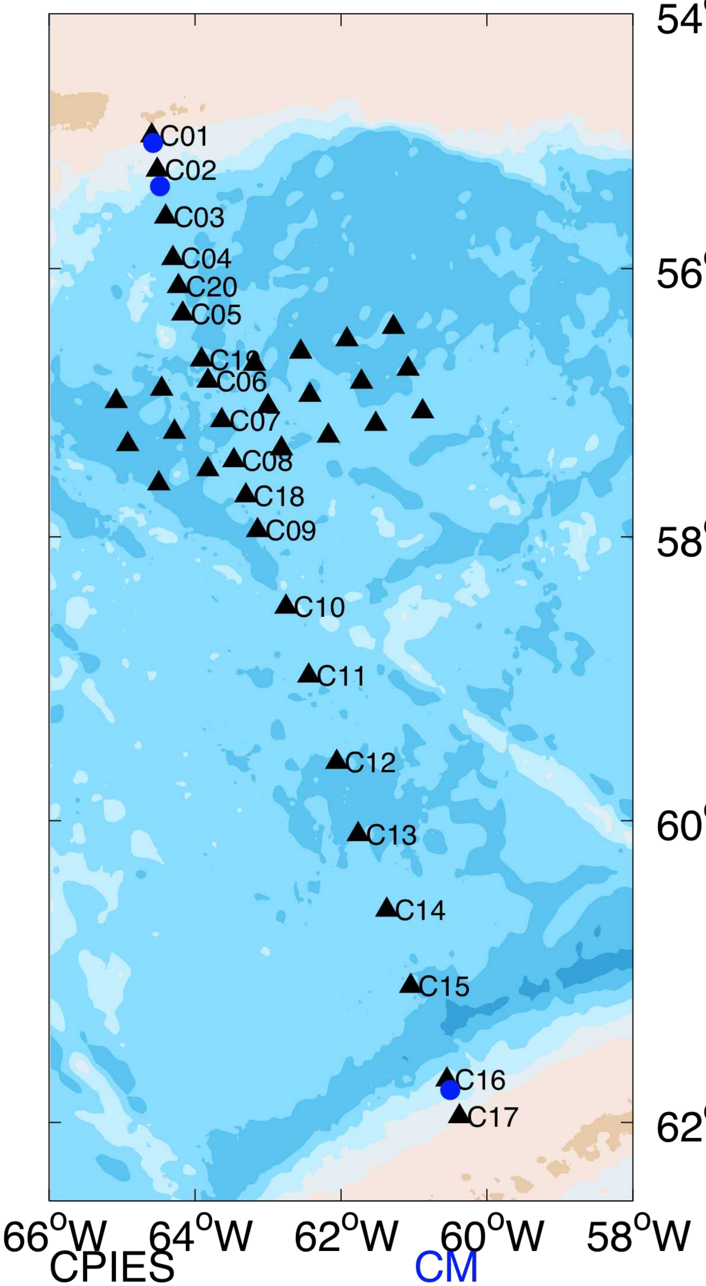
cDrake Timeline

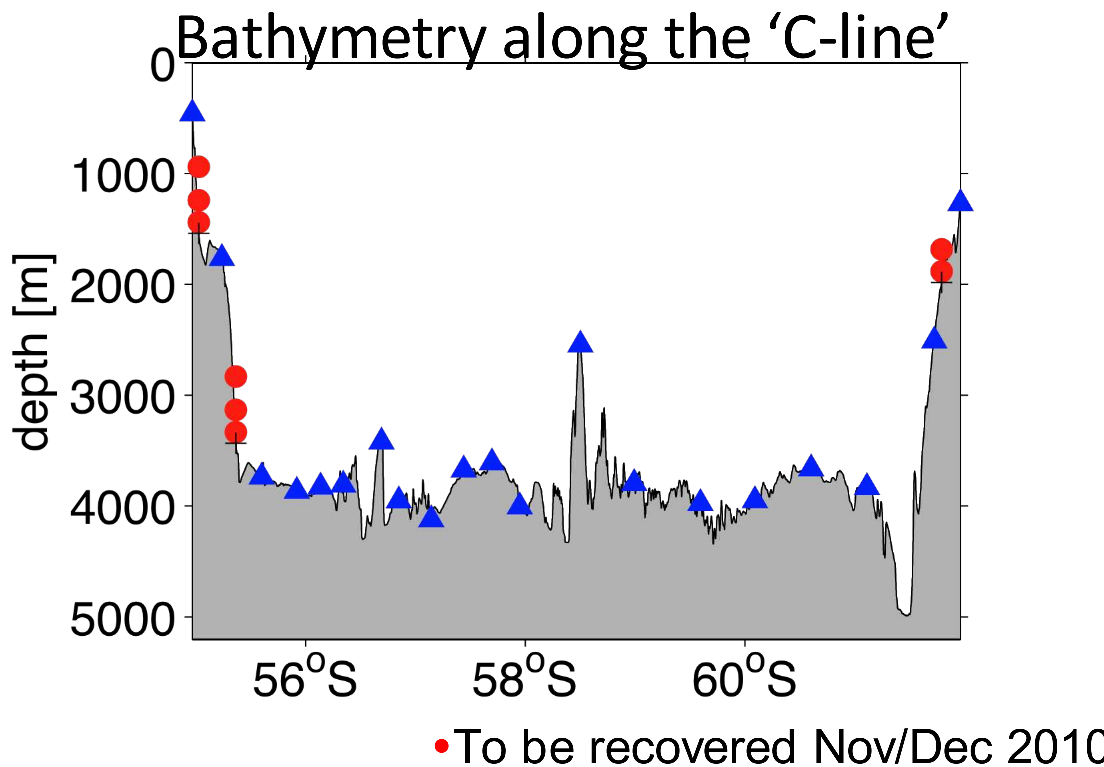


- 2007 Nov/Dec Deployment
- 2010 Nov/Dec Recovery
- Annual Telemetry cruises (2008,2009,2010)

Noteworthy for this workshop

- cDrake offers unprecedented horizontal resolution and coverage of Drake Passage bottom-pressure variability.
- IES+pressure gauge = sea level





Motivation

- ISOS results showed that ACC transport variability is mainly barotropic and can be monitored using across passage pressure differences.

- Hughes et al. 1999 provide a theoretical case for a southern circumpolar ACC transport mode.

  - This transport is dominated by a barotropic mode that follows f/H contours and is highly correlated to bottom pressure on the southern side of the ACC.

  - Observationally, this mode is difficult to observe, local baroclinic processes swamp the lager-scale barotropic variability in measurements.

Conclusions

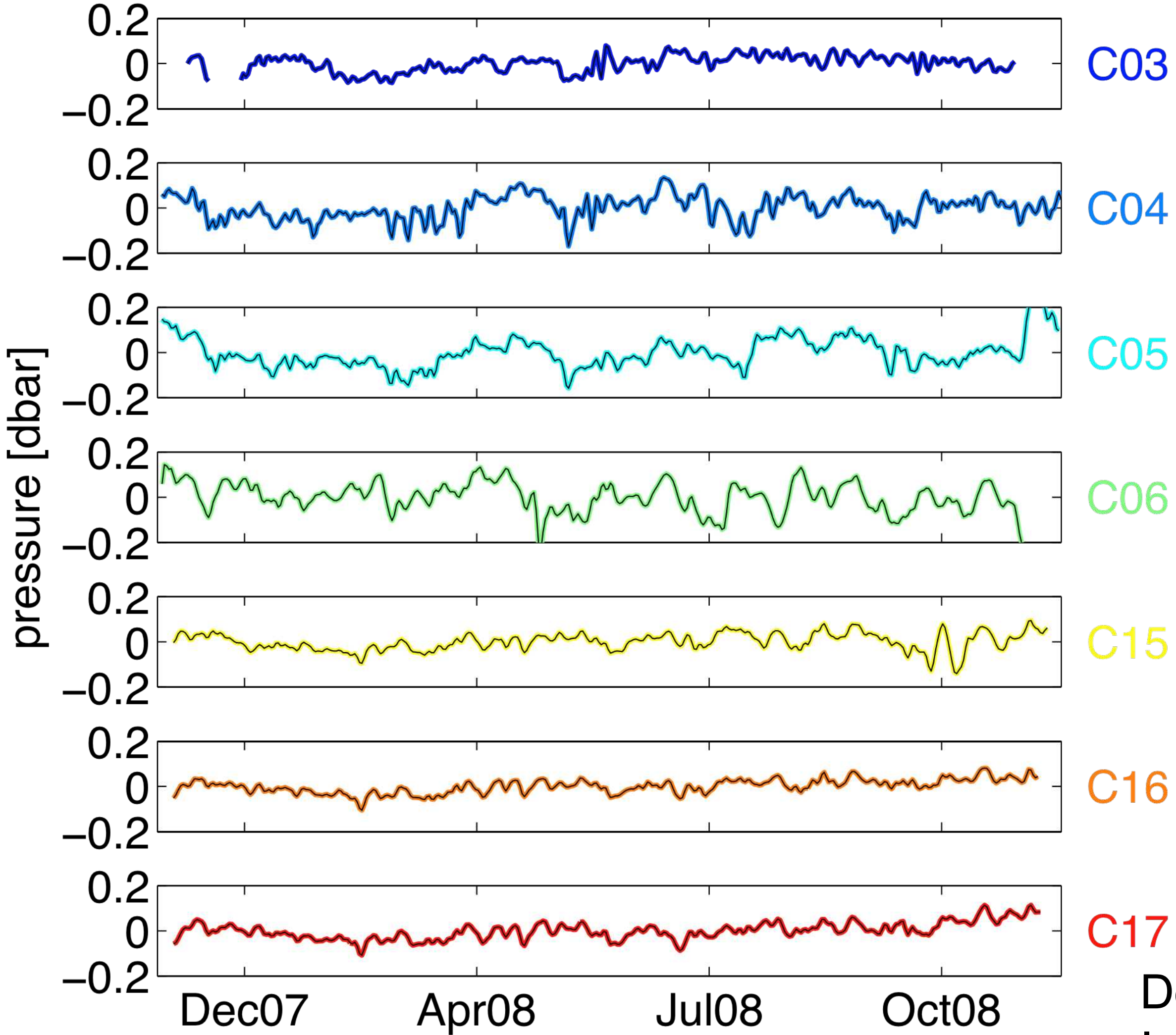
EOF along the transport line

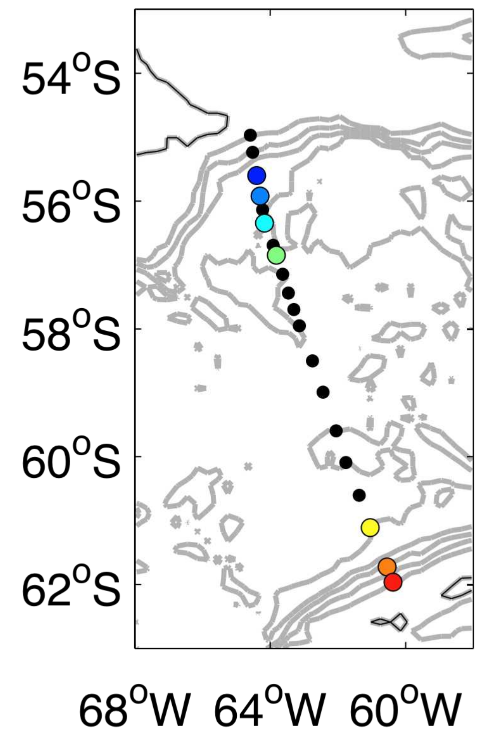
- The leading mode is a passage-wide uniform-amplitude signal.
- The second mode represents a transport mode: northern sites are out of phase with southern sites.
- Both modes are coherent with SAM but at different frequencies.

Decomposition of SSH into mass-loading and steric contributions

- The mass-loading and steric SSHA components are mainly uncorrelated.
- Relative contributions vary along the transport line.
- South of 59°S, the mass-loading variance > 40% of the total variance.

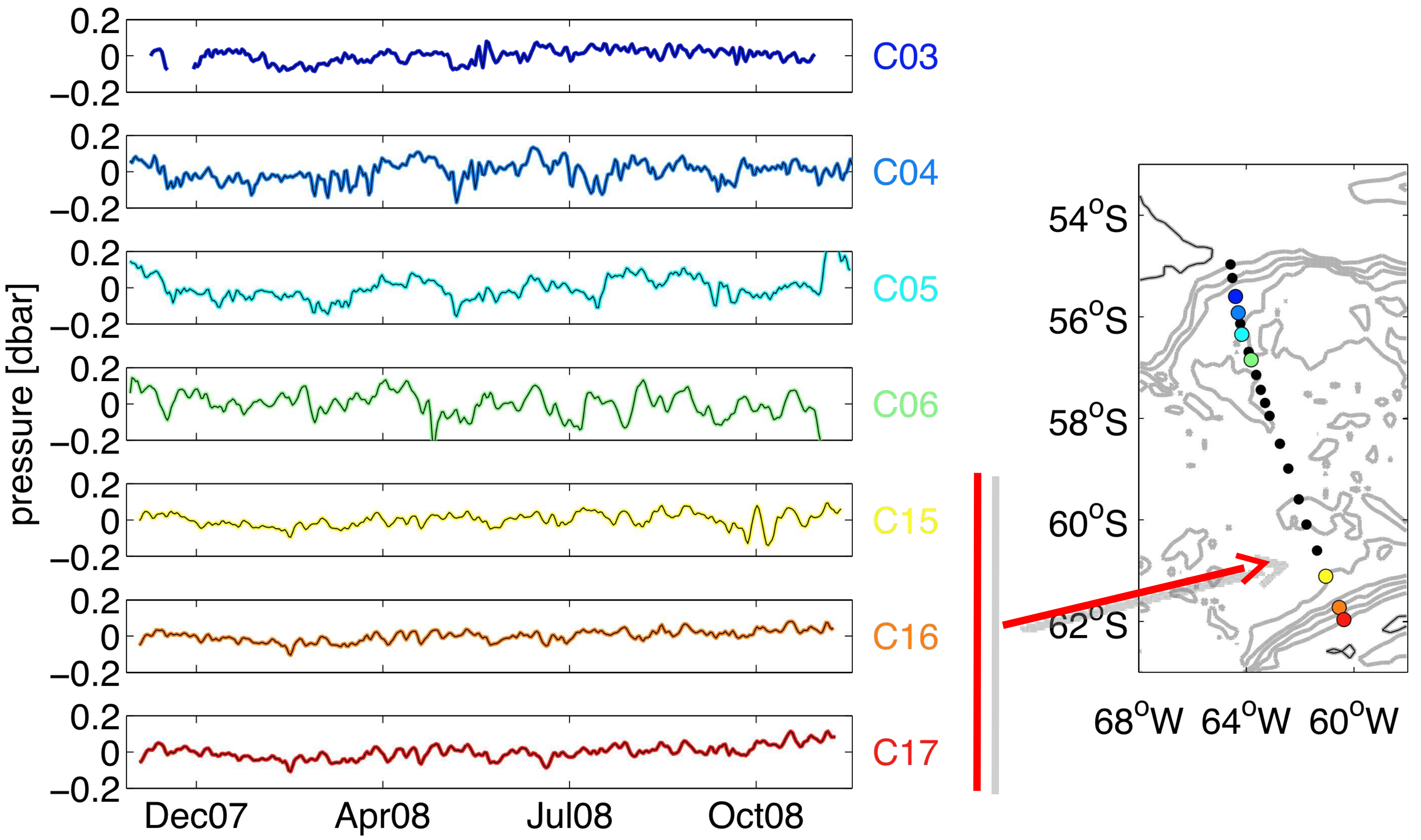
Bottom pressure

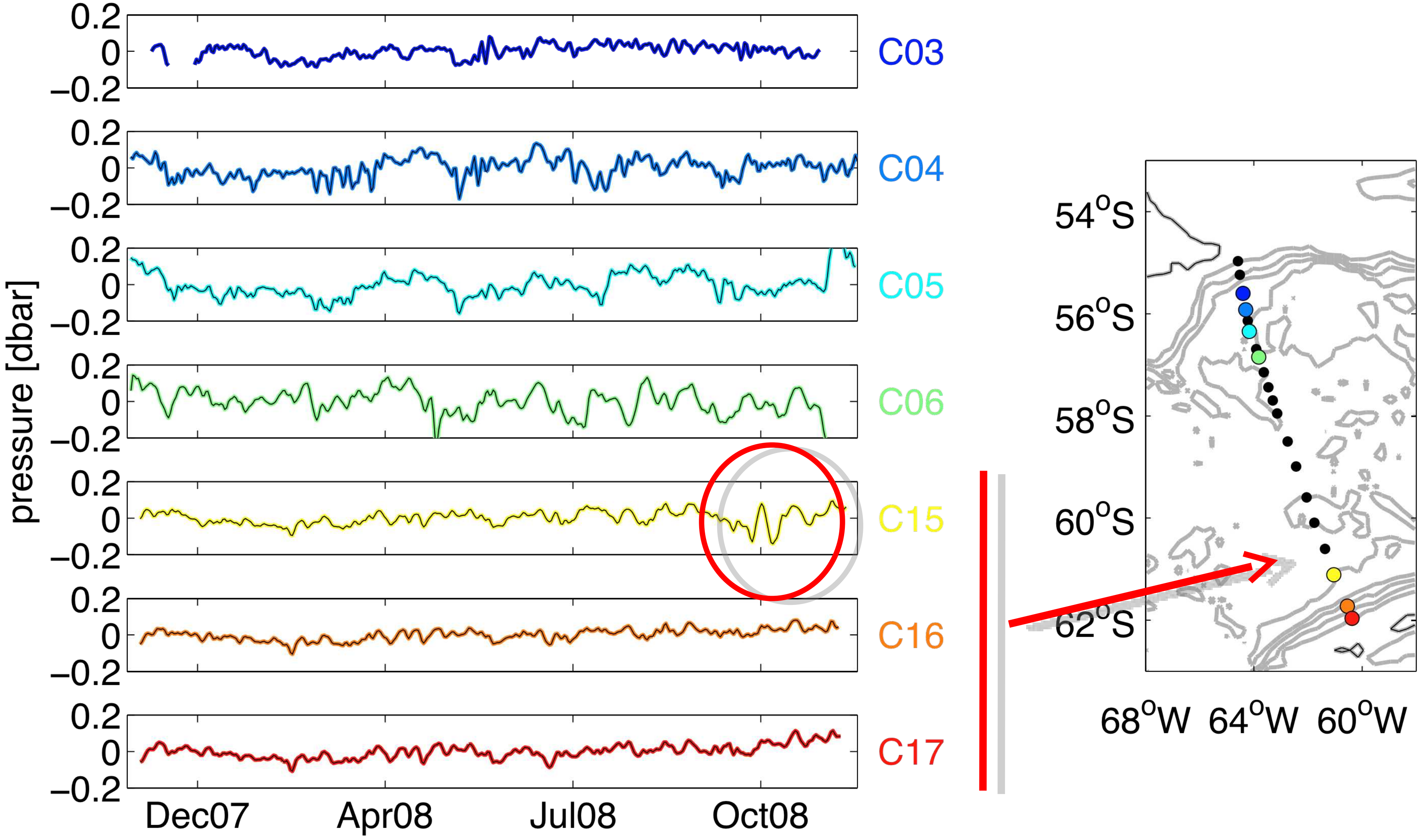




Detided Mf Mm w/ OSU Global Inverse Tide Model TPXO 7.1

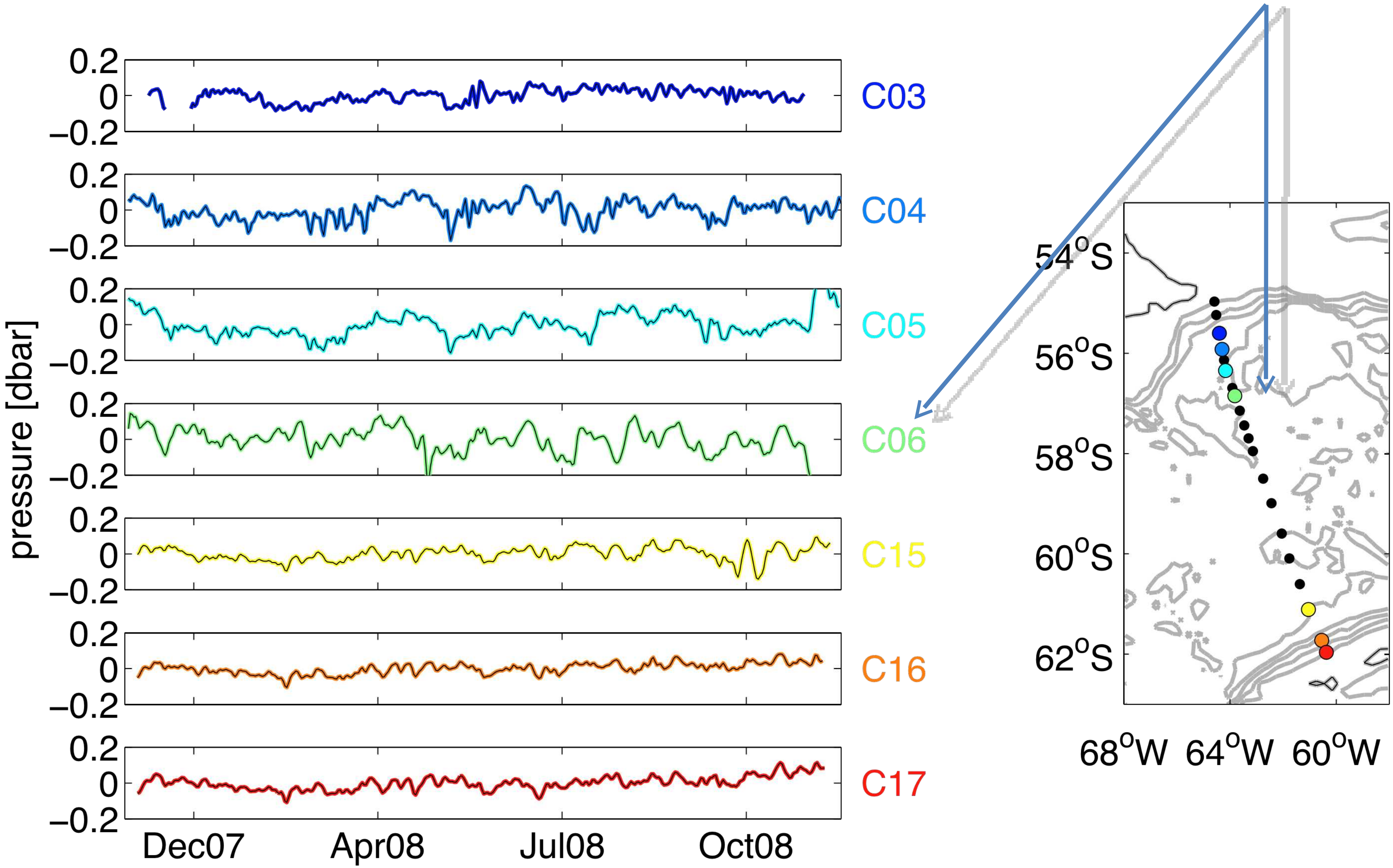
Southern sites are highly correlated.



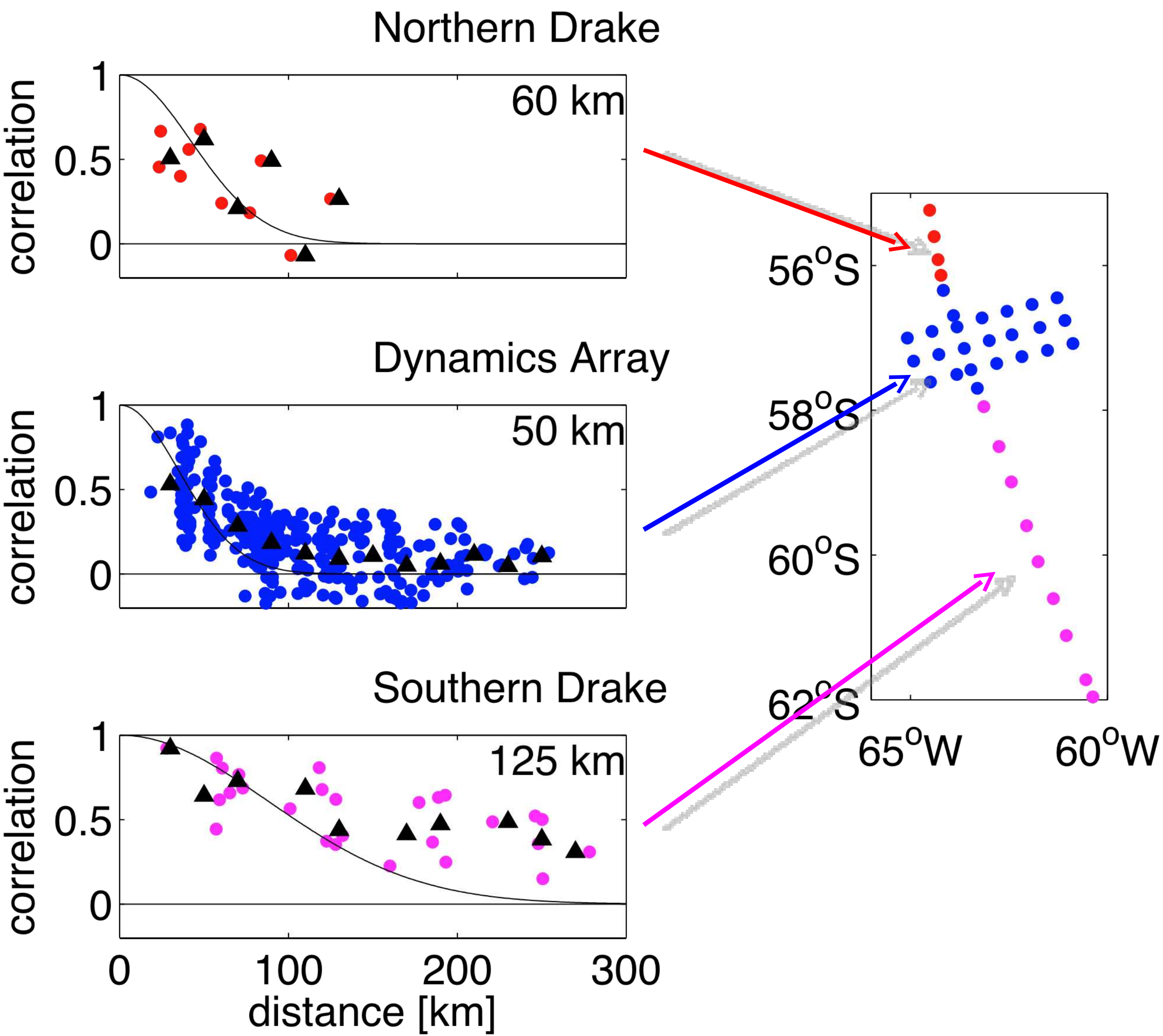


pressure [dbar]
0.2
0
−0.2
C03
C04
C05
C06
C15
C16
C17
Dec07
Apr08
Jul08
Oct08
54°S
56°S
58°S
60°S
62°S
68°W
64°W
60°W

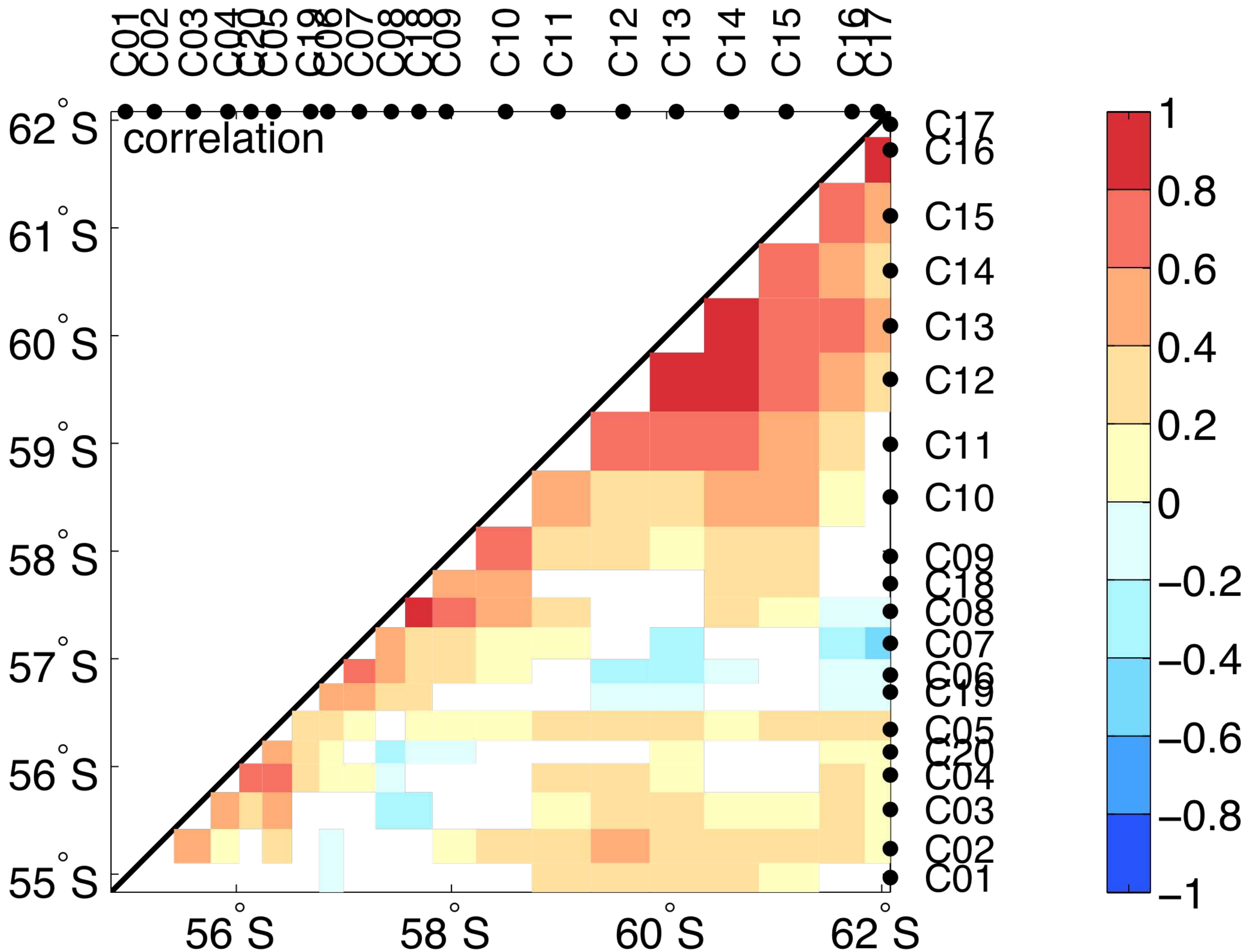
Highest bottom pressure variance exists within the dynamics array.



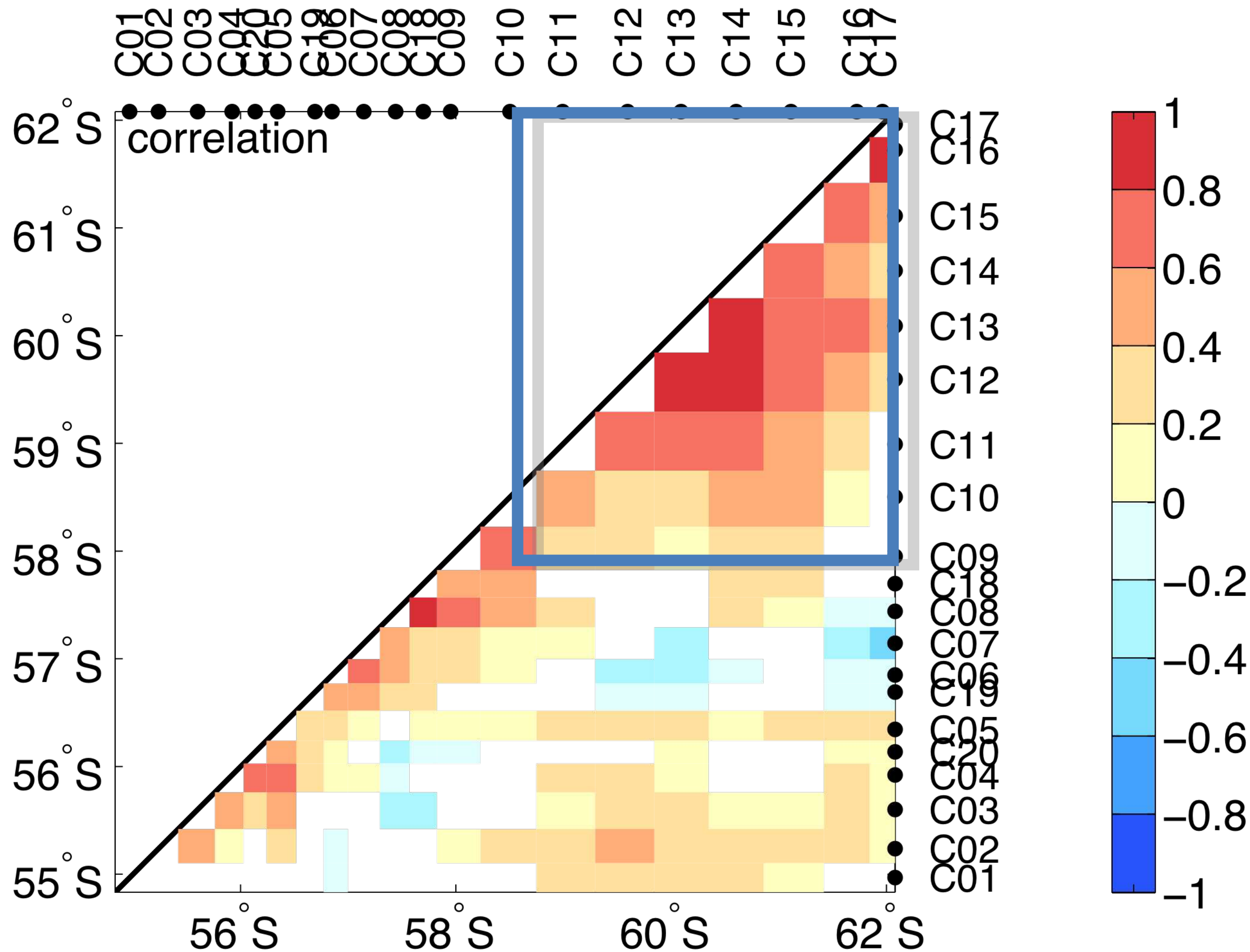
Horizontal scales vary across the passage.



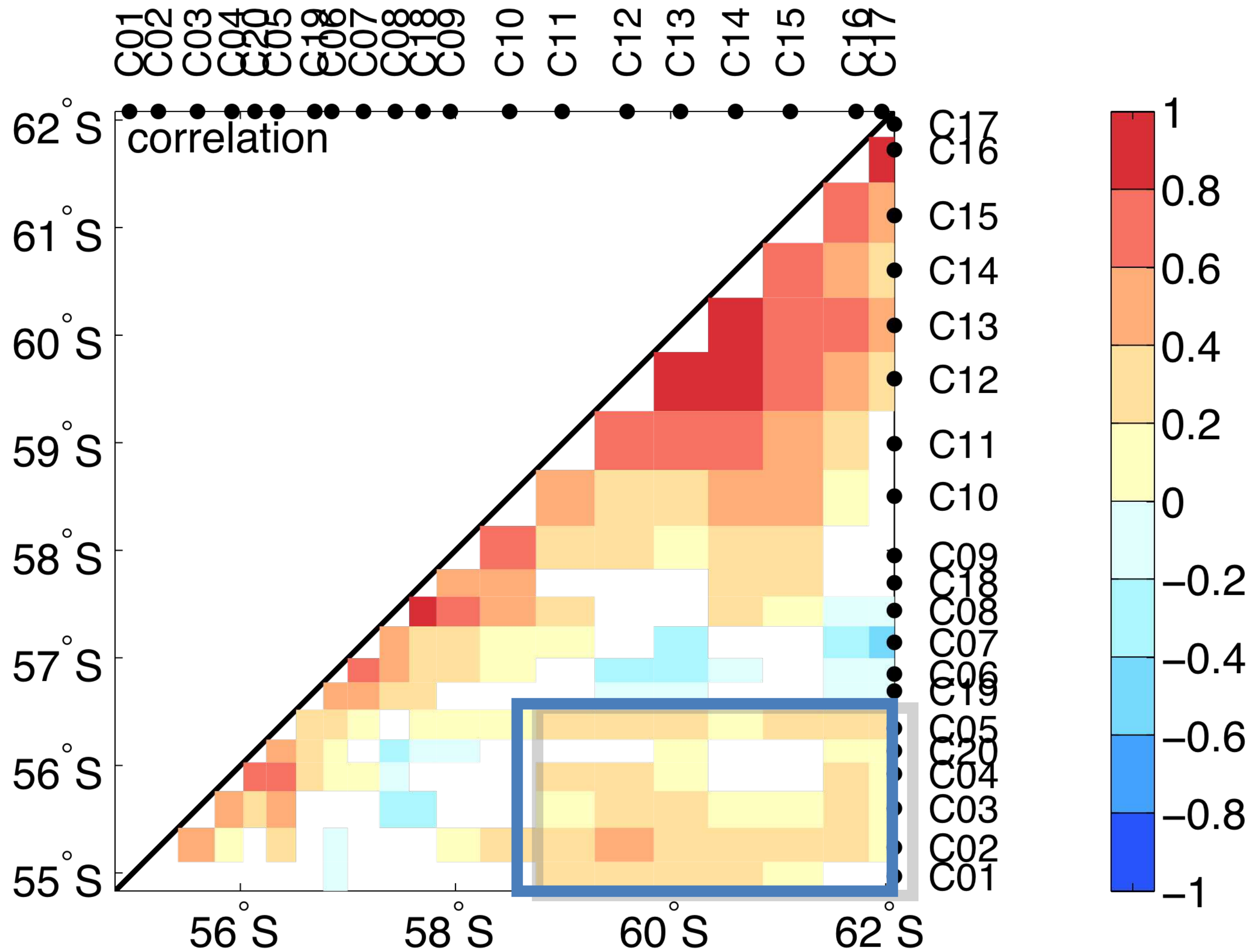
Correlations between all pair of bottom pressure.



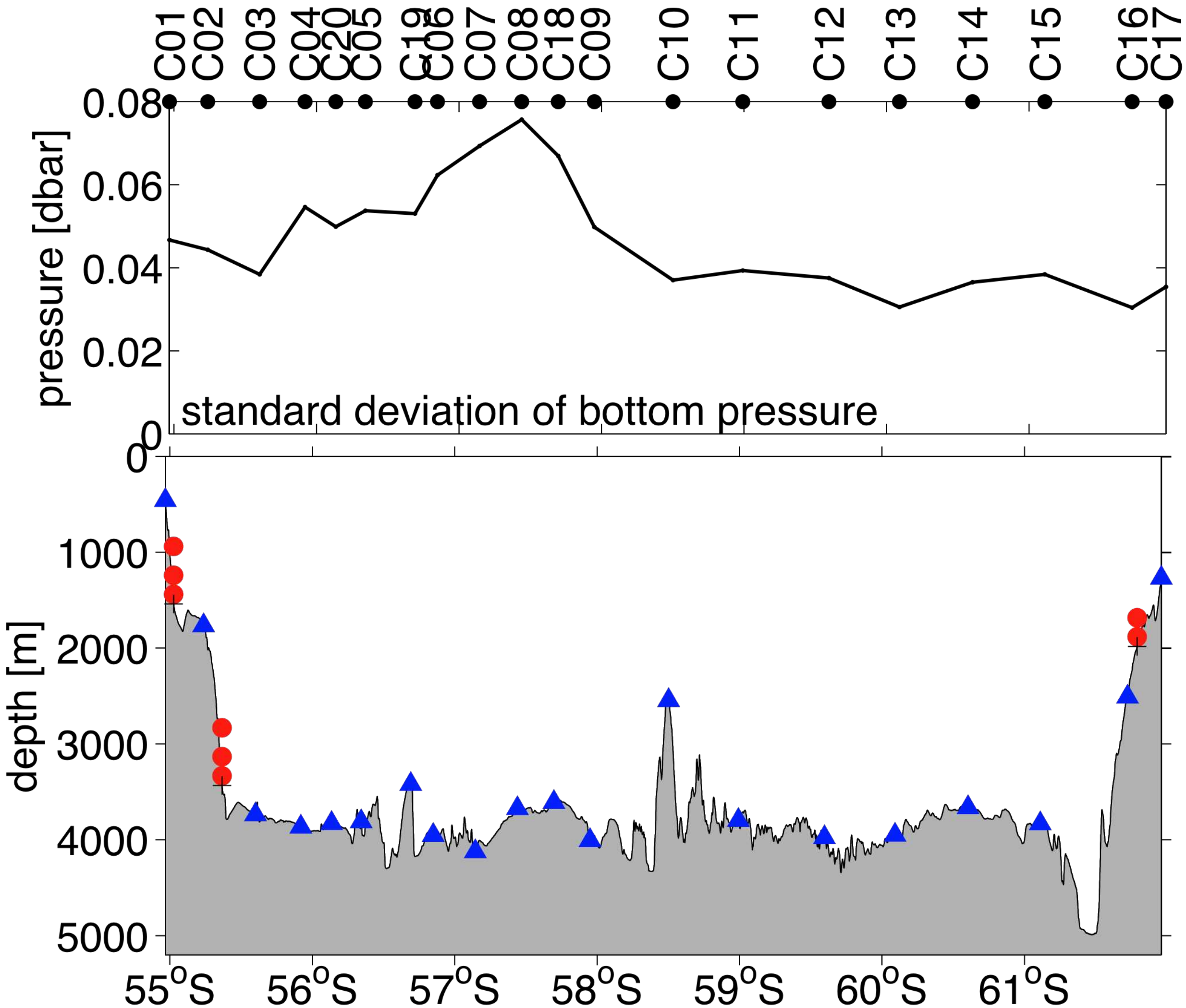
Long horizontal scales in southern line.



North-South correlations appear.

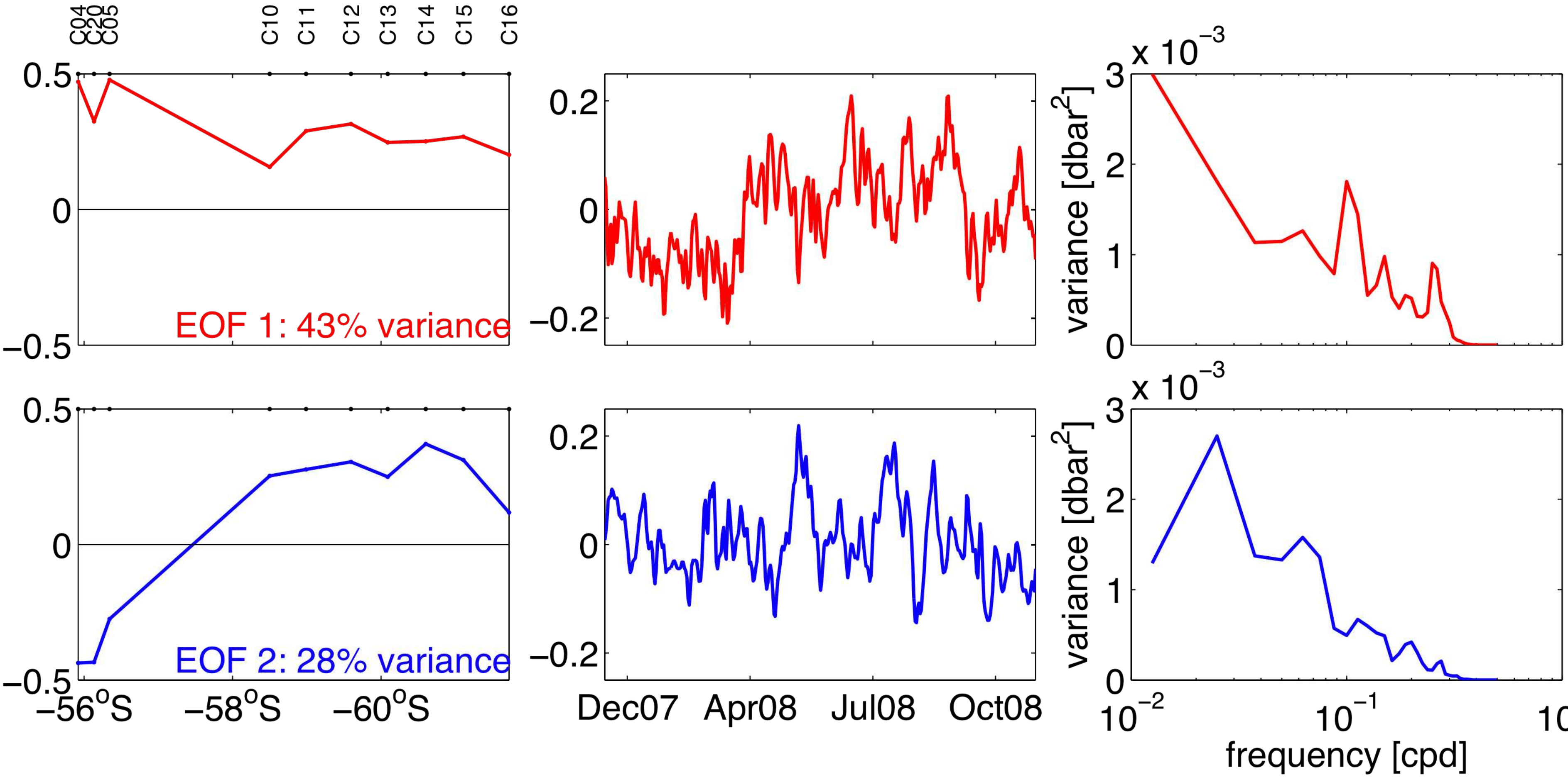


- Variance within the array is two times higher than to the north and three times higher than variance to the south.
- Bottom pressure in the dynamics array was strongly influenced by the meandering of the two northern ACC fronts.



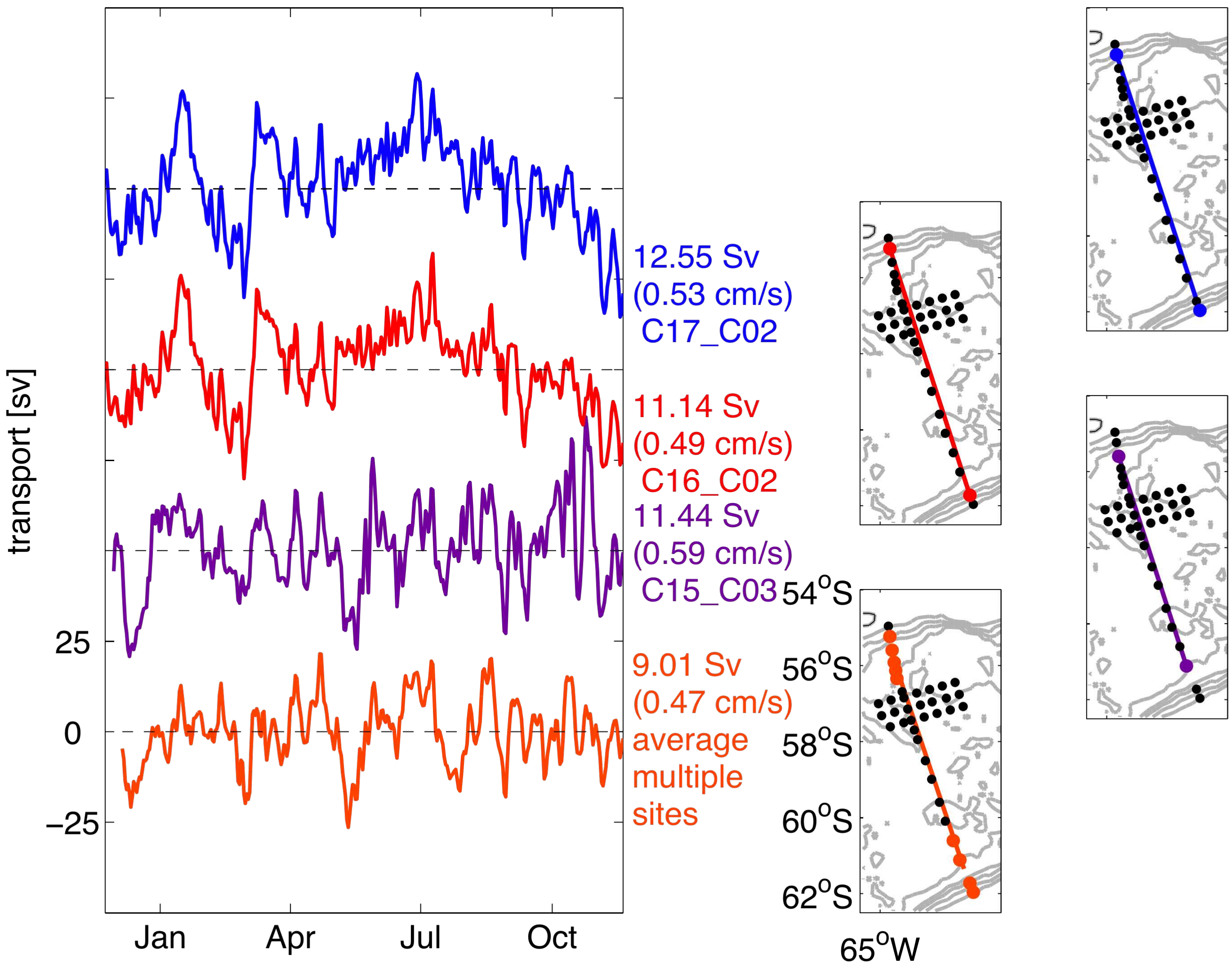
To focus on large-scale variability, EOFs are calculated along the transport line but outside the dynamics array.

- The leading mode is a passage-wide uniform-amplitude signal.
- The second mode represents a transport mode: northern sites are out of phase with southern sites.
- Both modes are coherent with SAM but at different frequencies.

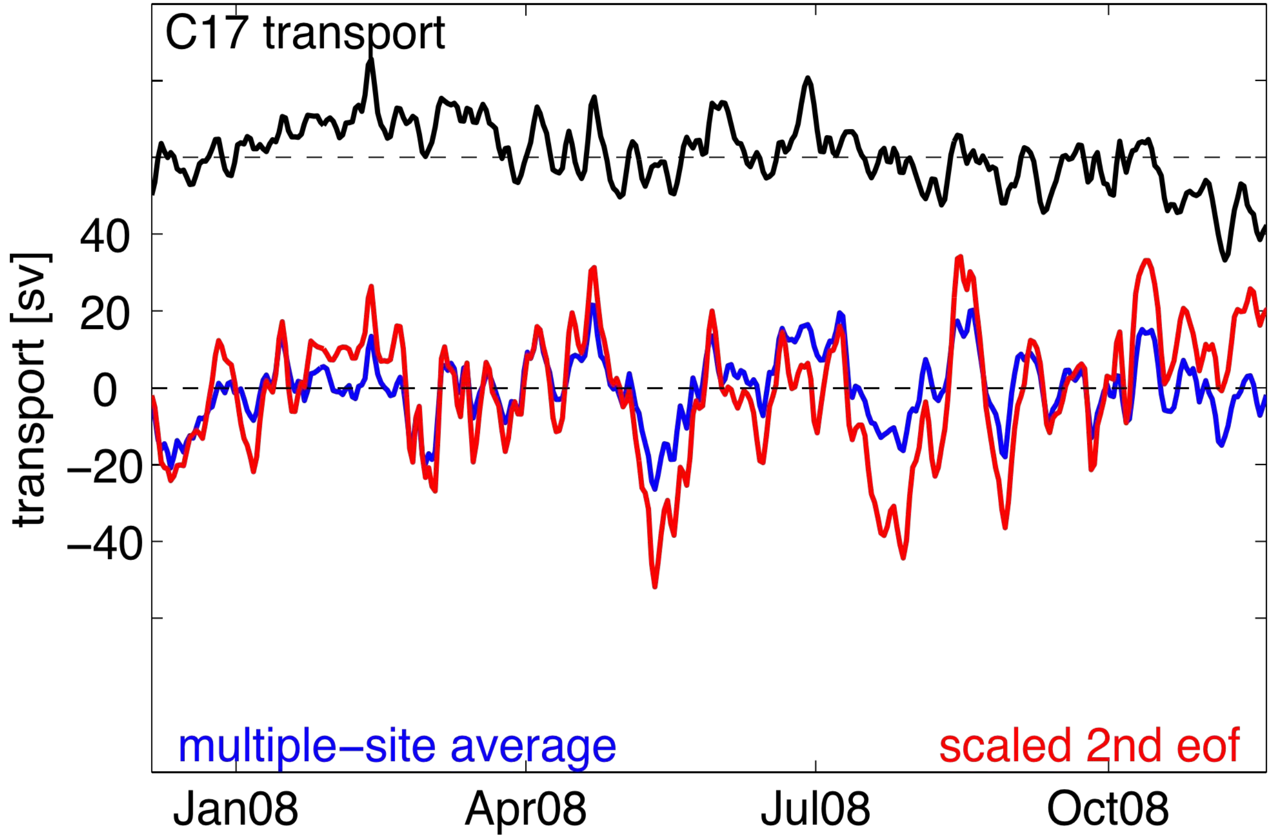


Barotropic transports are estimated by pressure differences across the passage.

- Transports are sensitive to the choice of endpoints, particularly the northern endpoint.
- Large fluctuations, as high as 30 Sv, occur over time scales of weeks to days.



The presence of a large common pressure signal across Drake Passage indicates that barotropic transports cannot be monitored by a single southern pressure gauge.



CPIES measurements can help interpret the contribution of bottom pressure to sea surface height.

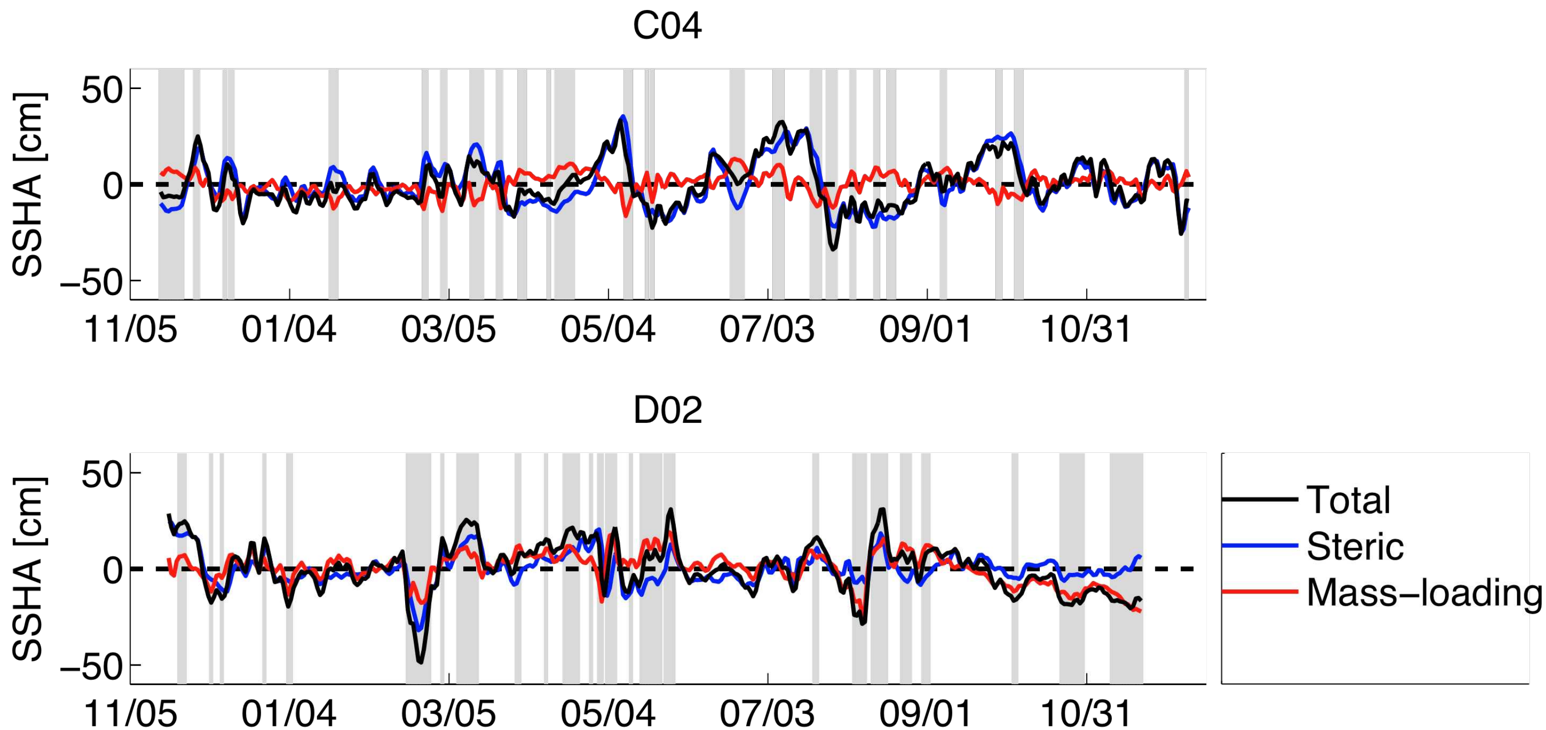
Sea Surface Height Anomaly =

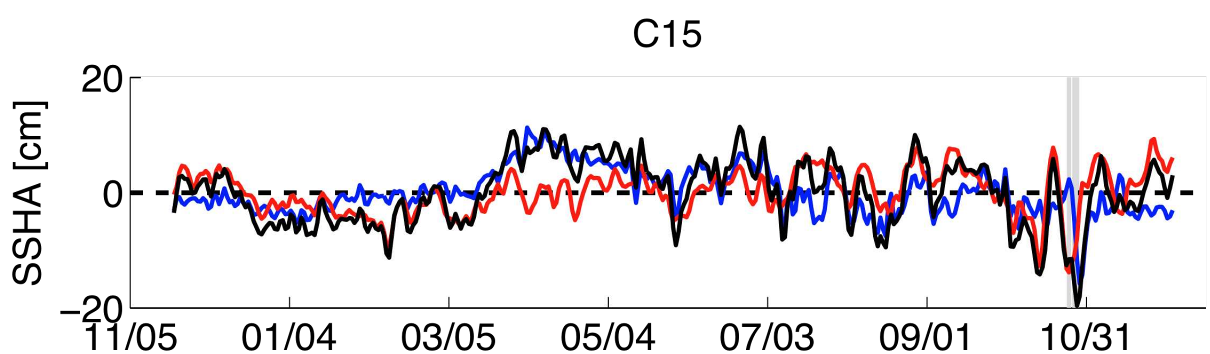
Pressure'(t)/(ρg) + Geopotential'(t)/(g)

Mass Loading Steric

*Round-trip travel time measurements are converted to geopotential using historical hydrography.

The mass-loading and steric SSHA components are uncorrelated, except in the eastern local dynamics array where strong deep cyclone formation associated with the meandering Polar Front occurs.

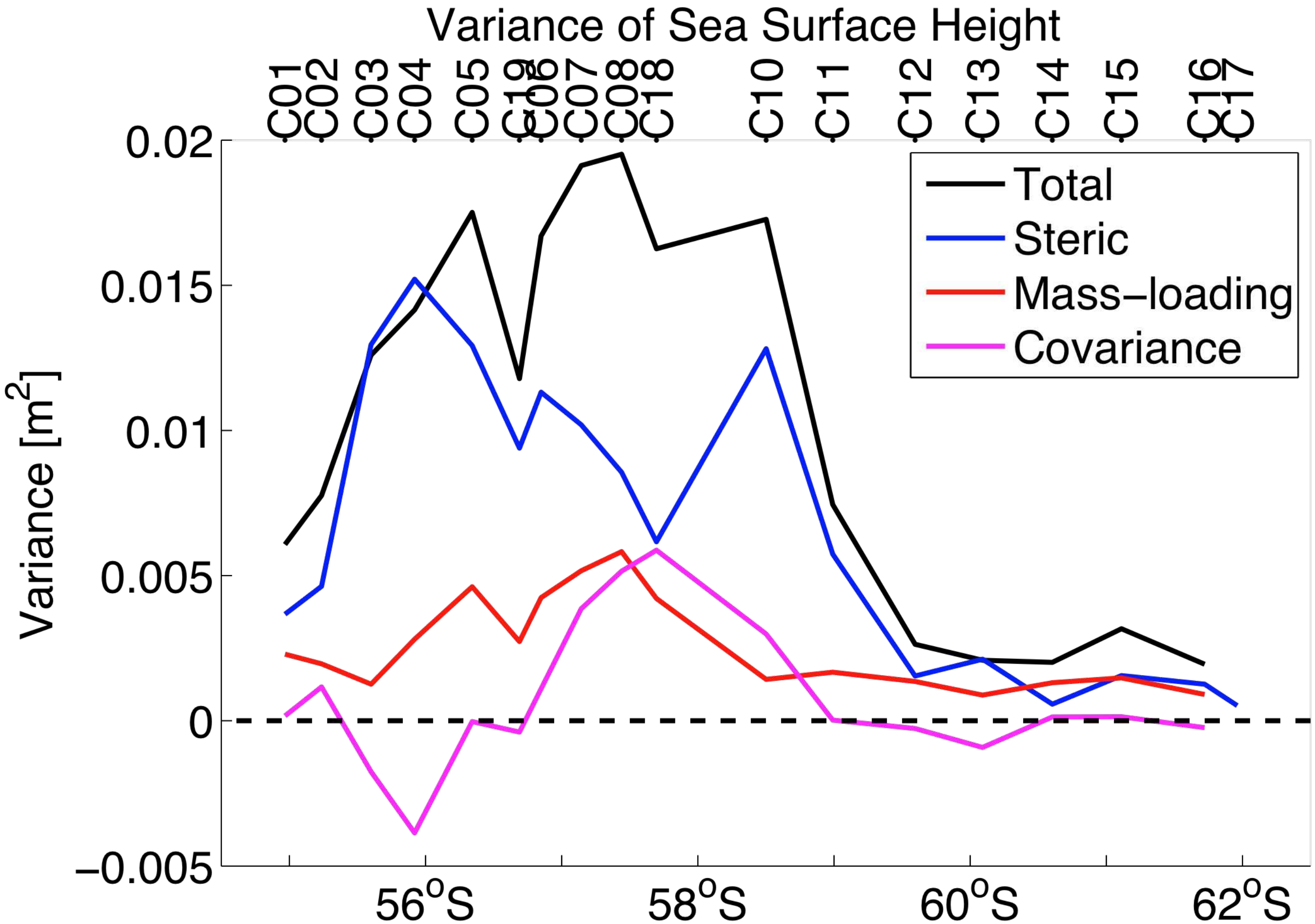




Note different scale is used here.

Relative contributions vary along the transport line.

North of 57°S, steric variance > 60% of the total variance.
South of 59°S, the mass-loading variance > 40% of the total variance.



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What's next?

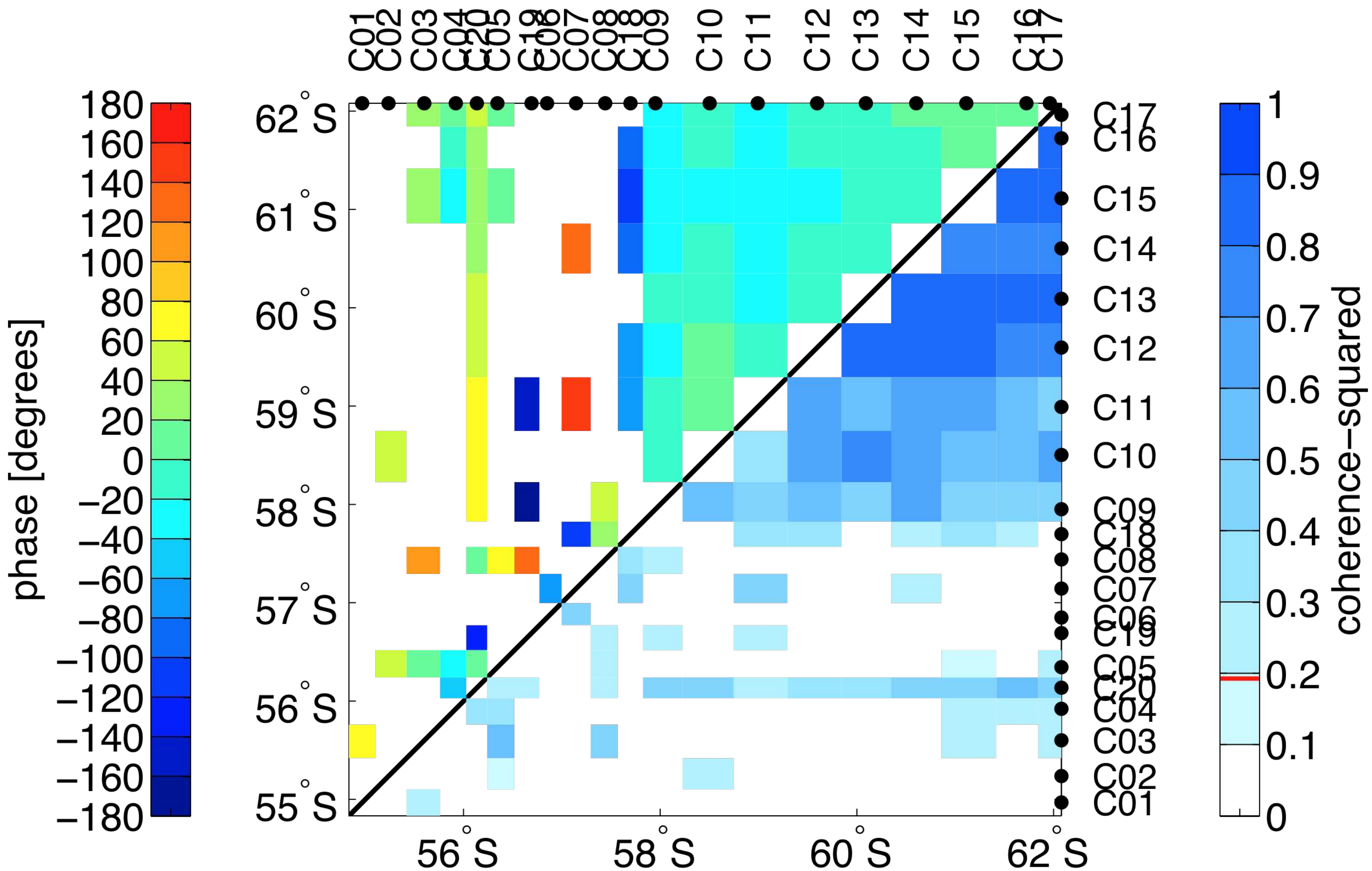
- cDrake 2009 telemetry and mooring recovery cruise
- cDrake 2009 current-meter cook-off
    - VMCM/RCM-11/SeaGuard/Aquadopp intercomparison
- Ocean Science 22-26 February 2010, Portland, Oregon, USA
    - IT61: Towards Comprehensive Observing Systems in Polar Regions 2: Southern Ocean
    - IT41: Southern Ocean Dynamics, Biogeochemistry and Air-Sea Exchange
    - IT37: Predicting climate change and its impacts on the Pacific Sector of Antarctica

AAO/SAM

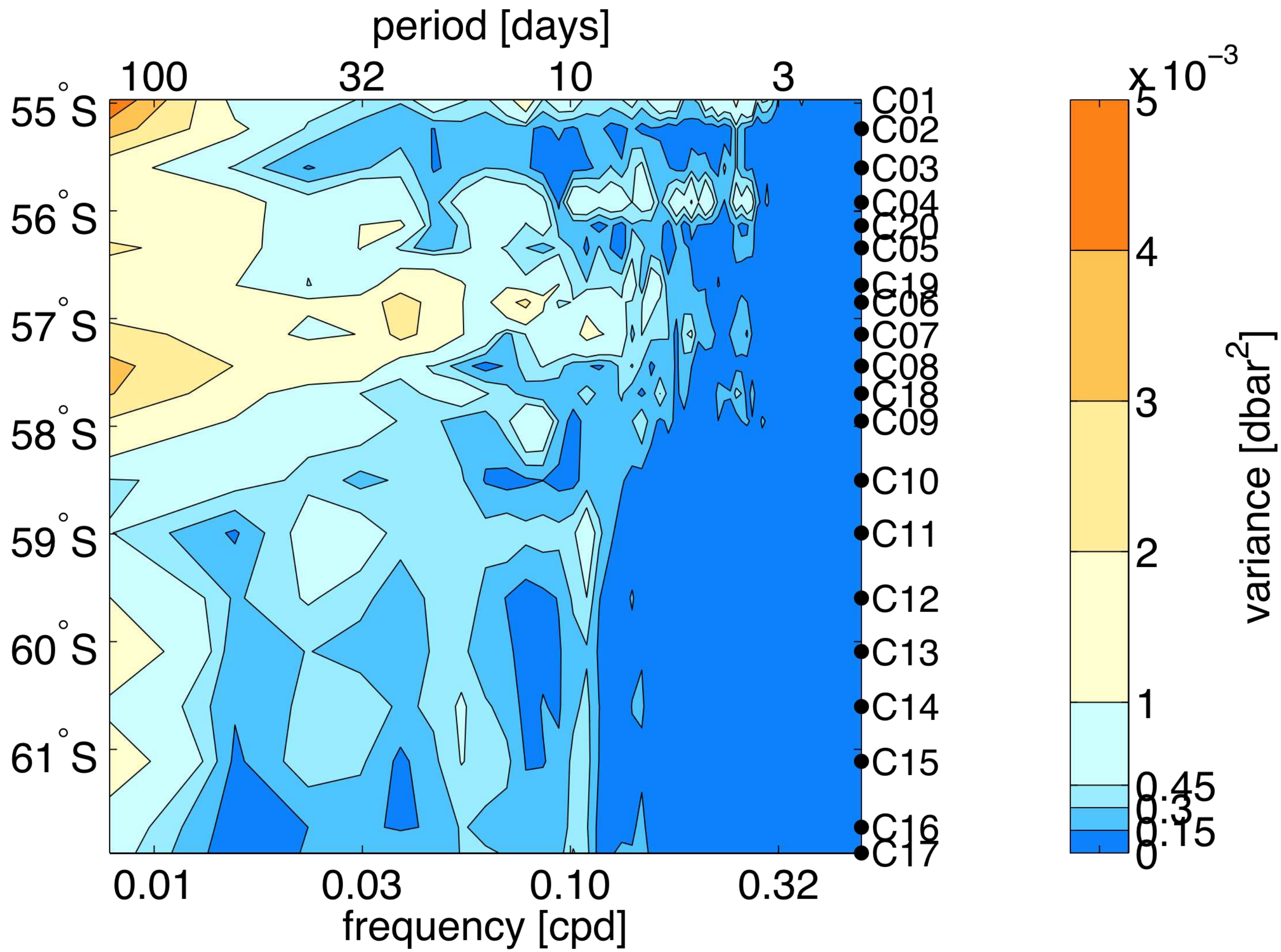
The daily AAO index is constructed by projecting the daily (00Z) 700mb height anomalies poleward of 20°S onto **the loading pattern of the AAO**.

Loading pattern of the AAO is defined as the leading mode of Empirical Orthogonal Function (EOF) analysis of monthly mean 700 hPa height during 1979-2000 period.

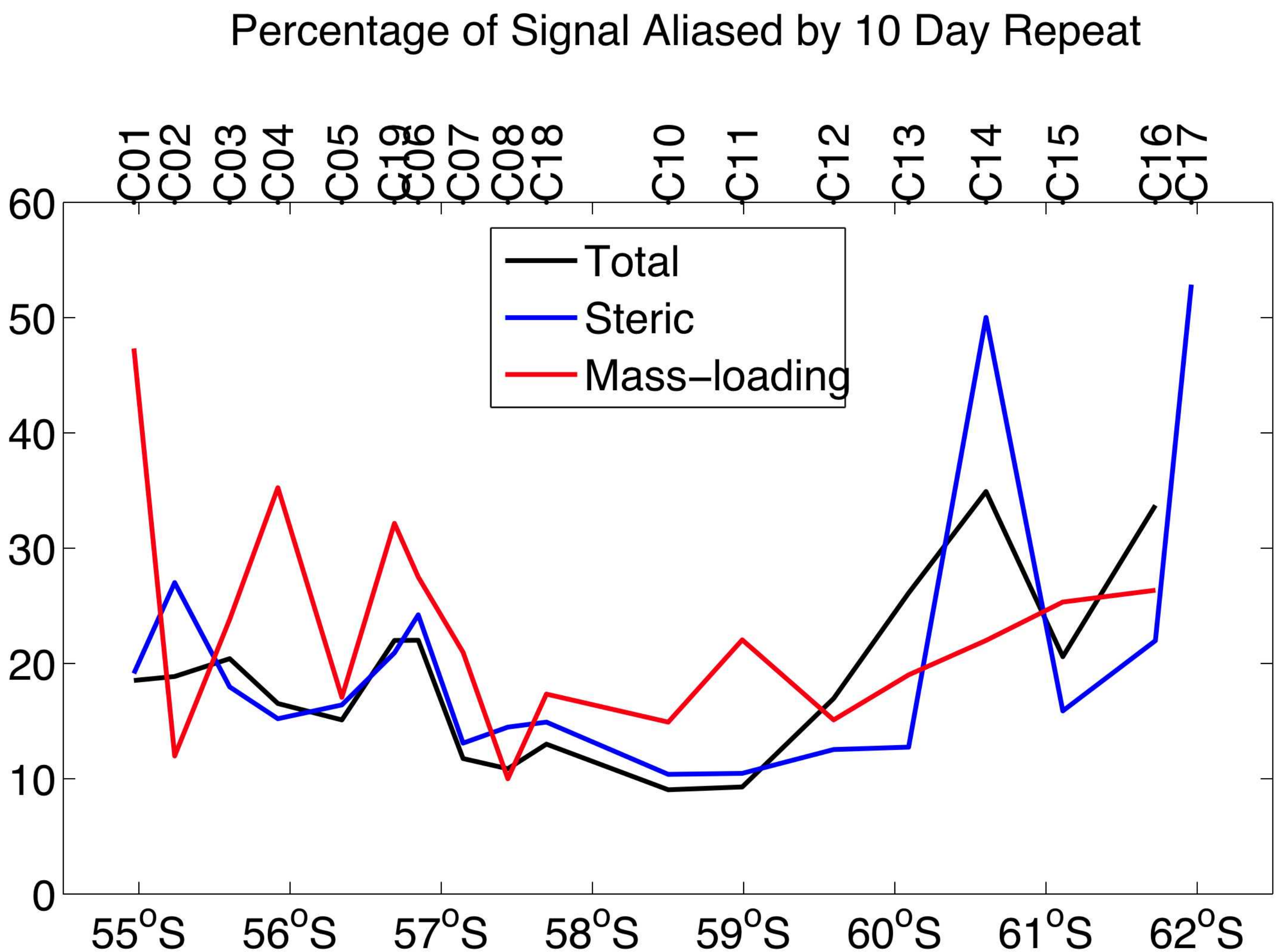
Climate Predition Center/NOAA
http://www.cpc.noaa.gov/products/precip/CWlink/daily_ao_index/aao/aao.shtml



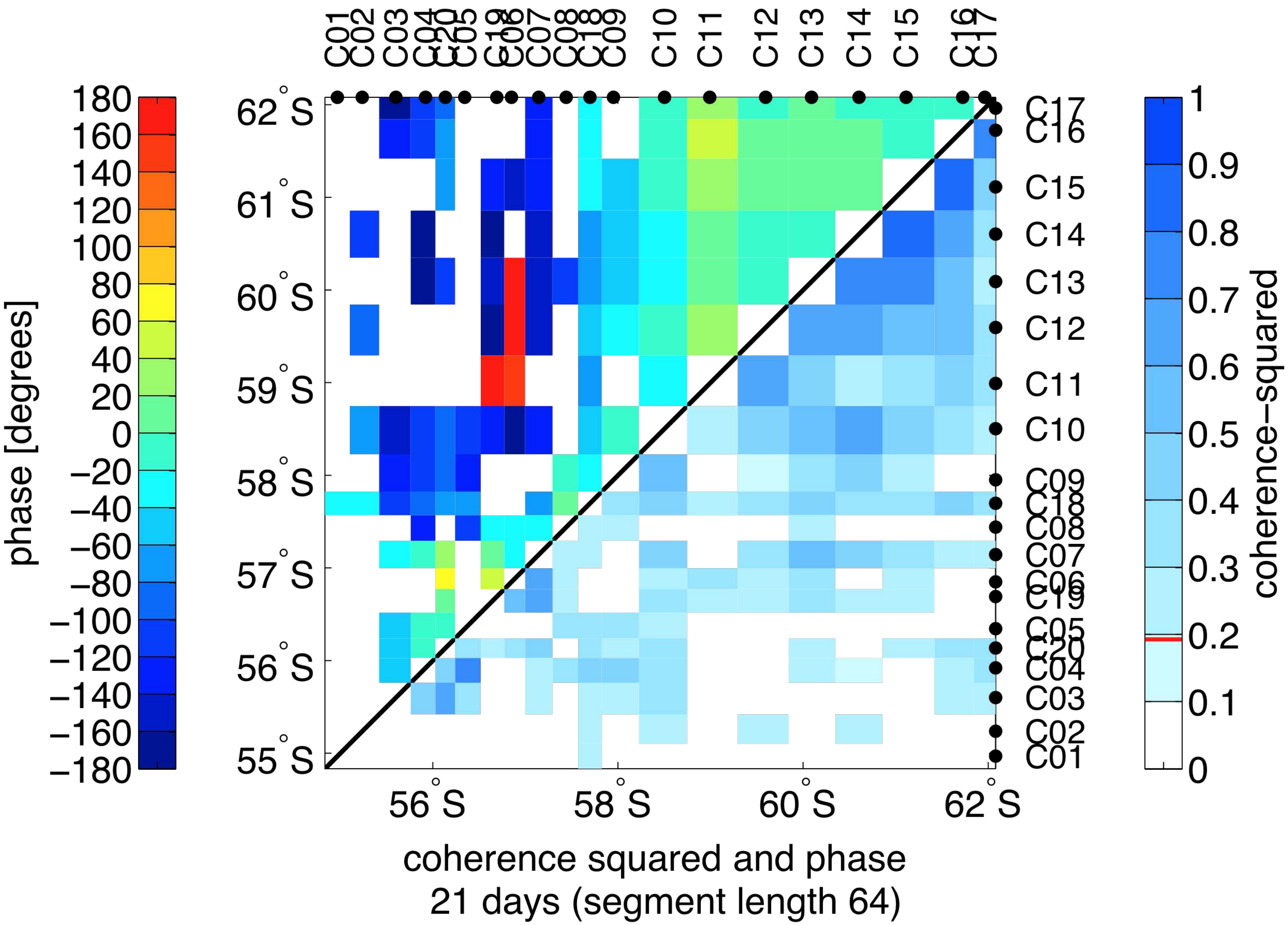
coherence squared and phase
11 days (segment length 64)

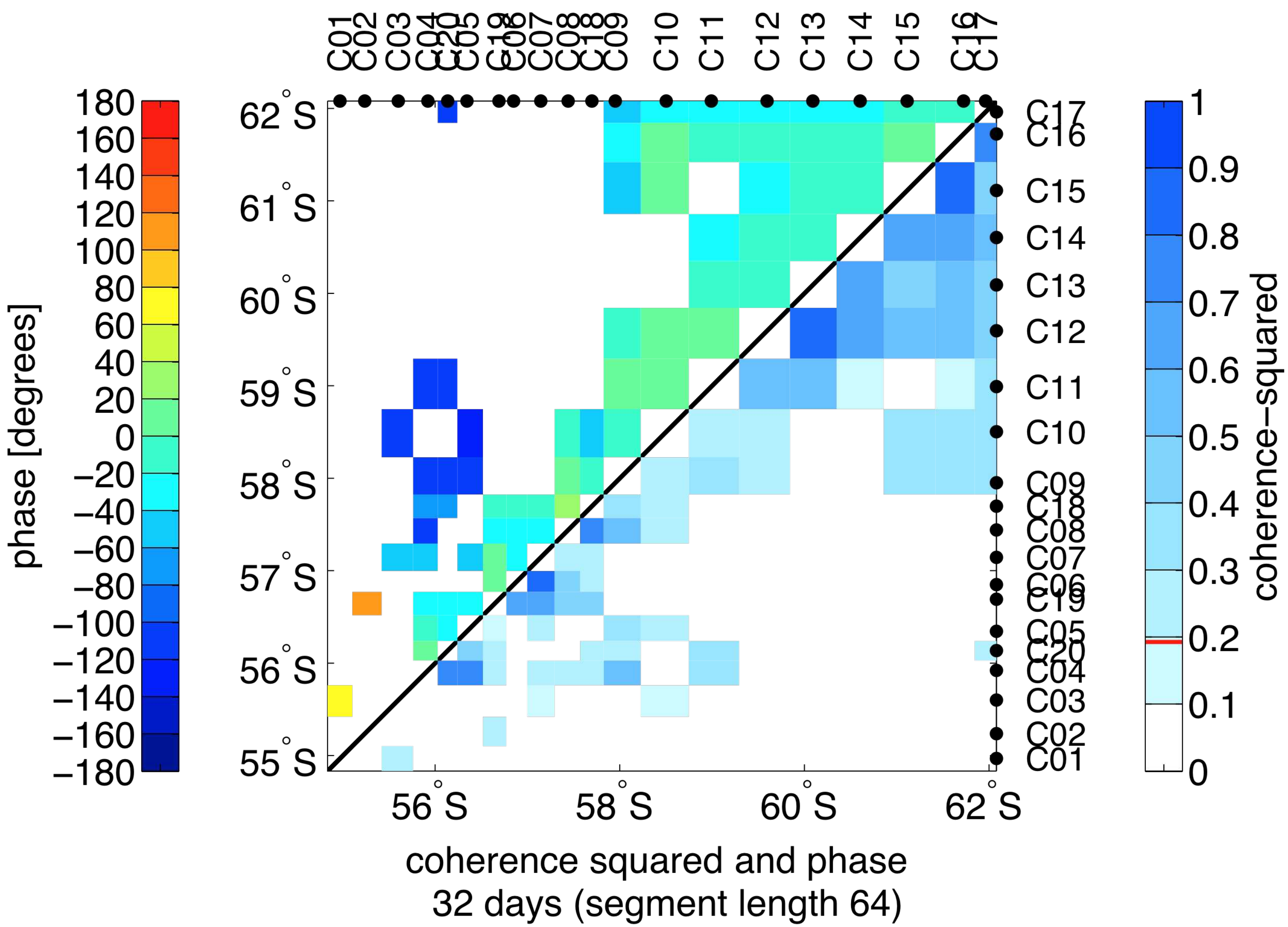


period [days]
100
32
10
3
55°S
56°S
57°S
58°S
59°S
60°S
61°S
C01
C02
C03
C04
C20
C05
C19
C06
C07
C08
C18
C09
C10
C11
C12
C13
C14
C15
C16
C17
0.01
0.03
0.10
0.32
frequency [cpd]
x 10^{-3}
5
4
3
2
1
0.45
0.3
0.15
0
variance [dbar^2]

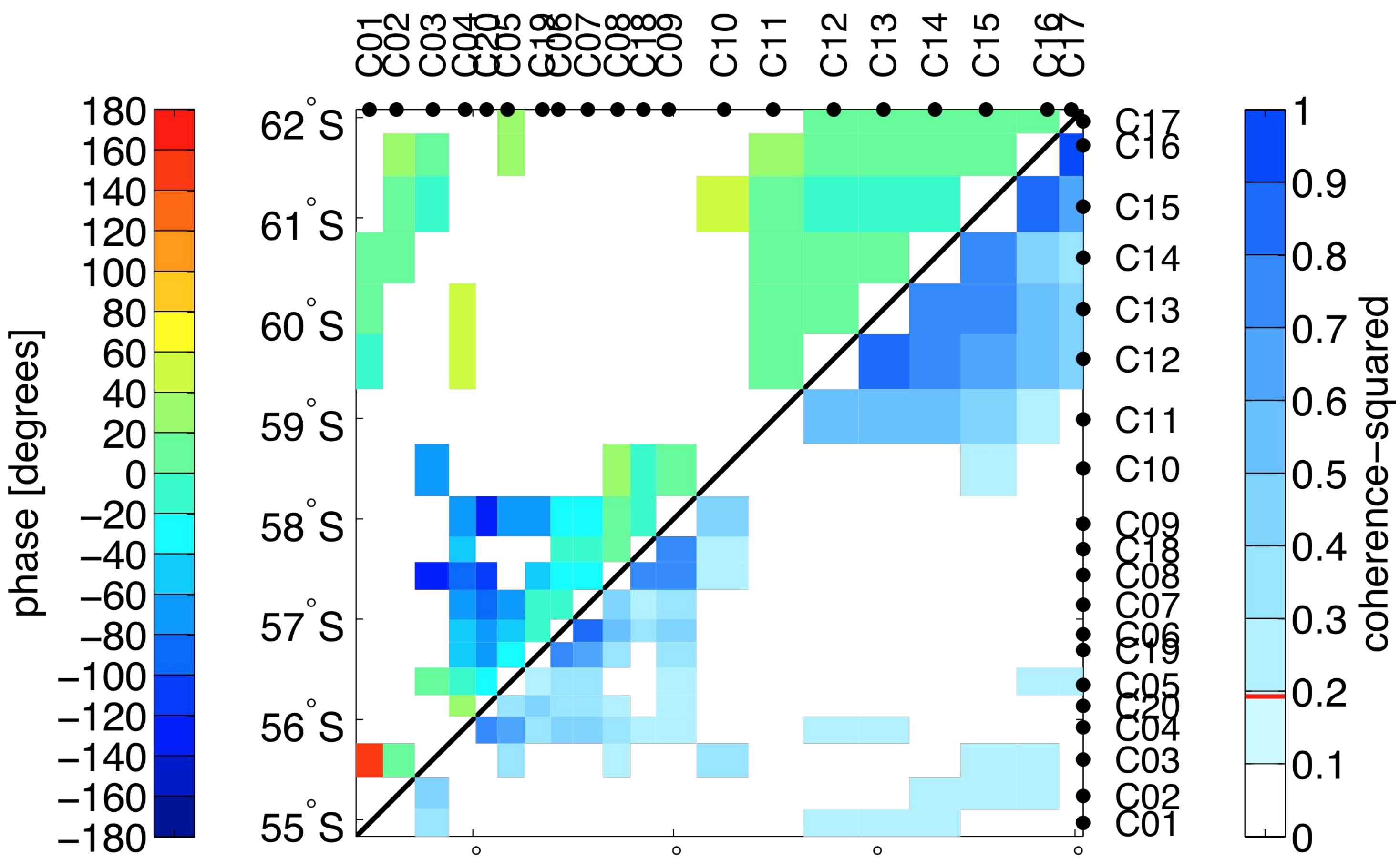


Percentage of Signal Aliased by 10 Day Repeat
C01
C02
C03
C04
C05
C19
C06
C07
C08
C18
C10
C11
C12
C13
C14
C15
C16
C17
Total
Steric
Mass−loading
0
10
20
30
40
50
60
55°S
56°S
57°S
58°S
59°S
60°S
61°S
62°S

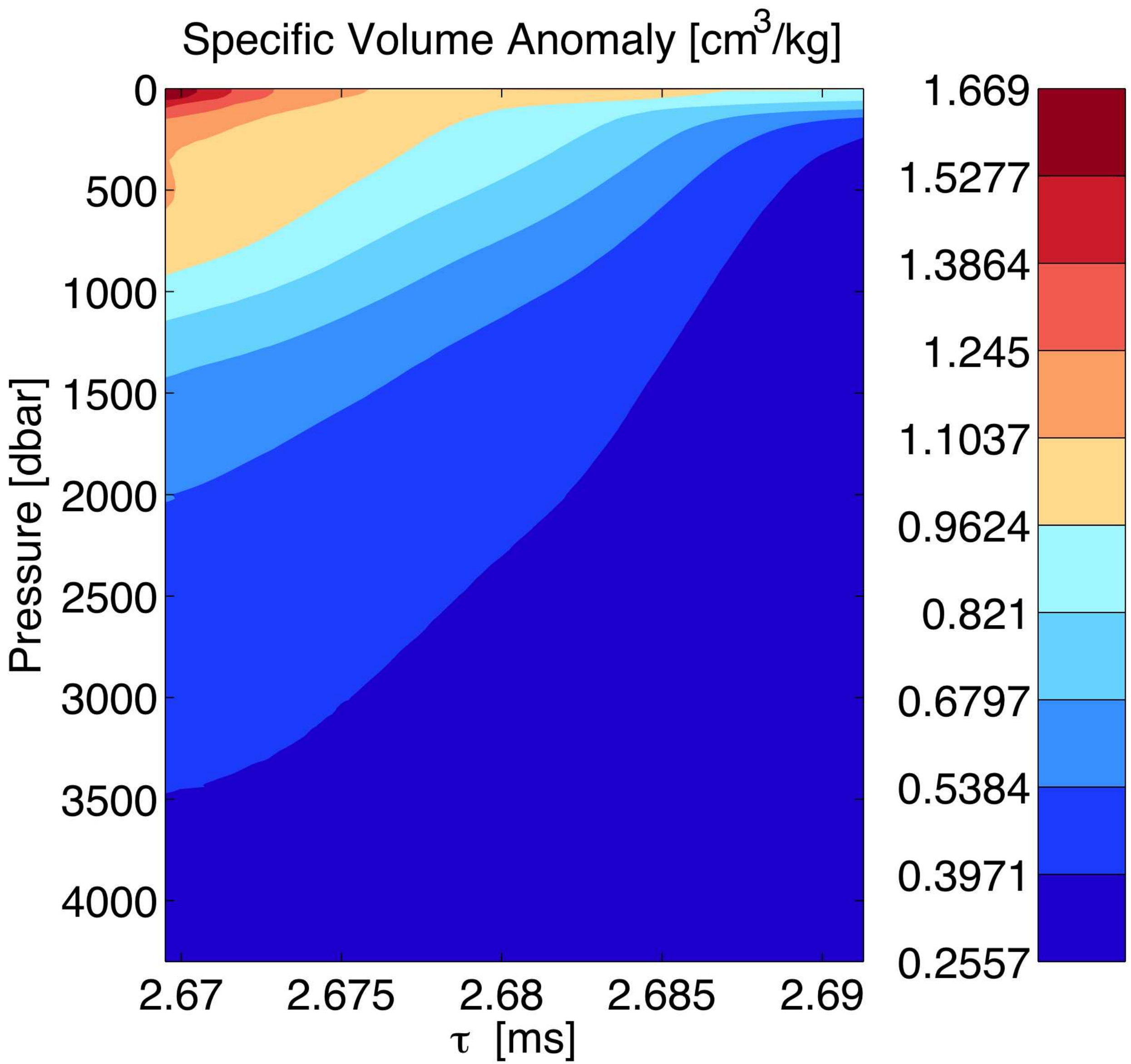

C01 C02 C03 C04 C20 C05 C19 C06 C07 C08 C18 C09 C10 C11 C12 C13 C14 C15 C16 C17
phase [degrees]
180 160 140 120 100 80 60 40 20 0 −20 −40 −60 −80 −100 −120 −140 −160 −180
62° S
61° S
60° S
59° S
58° S
57° S
56° S
55° S
56° S 58° S 60° S 62° S
coherence–squared
1 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0
coherence squared and phase
21 days (segment length 64)



phase [degrees]
180
160
140
120
100
80
60
40
20
0
−20
−40
−60
−80
−100
−120
−140
−160
−180
62° S
61° S
60° S
59° S
58° S
57° S
56° S
55° S
56° S
58° S
60° S
62° S
C01 C02 C03 C04 C20 C05 C19 C06 C07 C08 C18 C09 C10 C11 C12 C13 C14 C15 C16 C17
C17 C16 C15 C14 C13 C12 C11 C10 C09 C18 C08 C07 C06 C19 C05 C20 C04 C03 C02 C01
coherence−squared
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
coherence squared and phase
32 days (segment length 64)



coherence squared and phase
64 days (segment length 64)



Specific Volume Anomaly [cm3/kg]
0
500
1000
1500
2000
2500
3000
3500
4000
Pressure [dbar]
2.67
2.675
2.68
2.685
2.69
τ [ms]
1.669
1.5277
1.3864
1.245
1.1037
0.9624
0.821
0.6797
0.5384
0.3971
0.2557