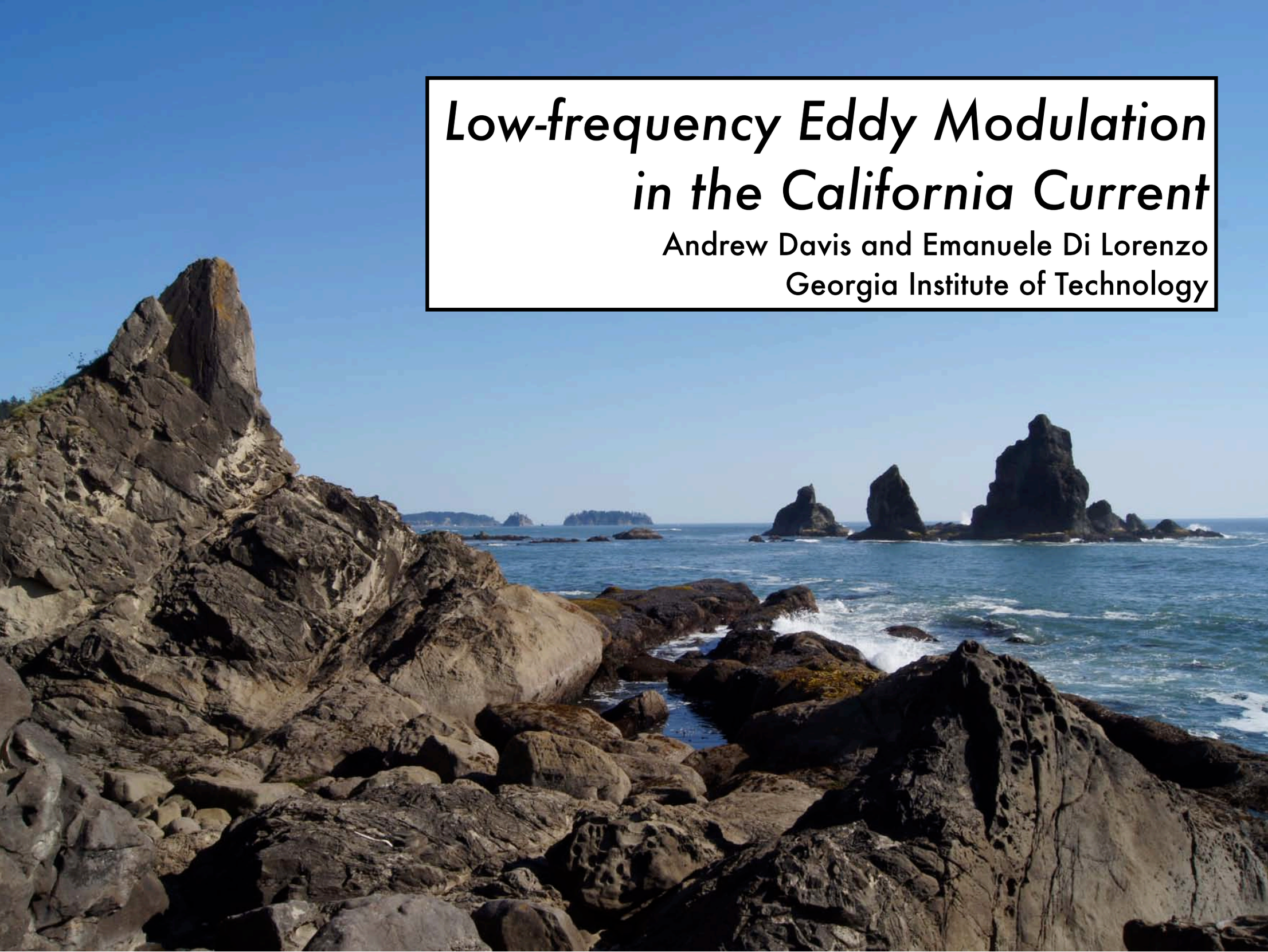
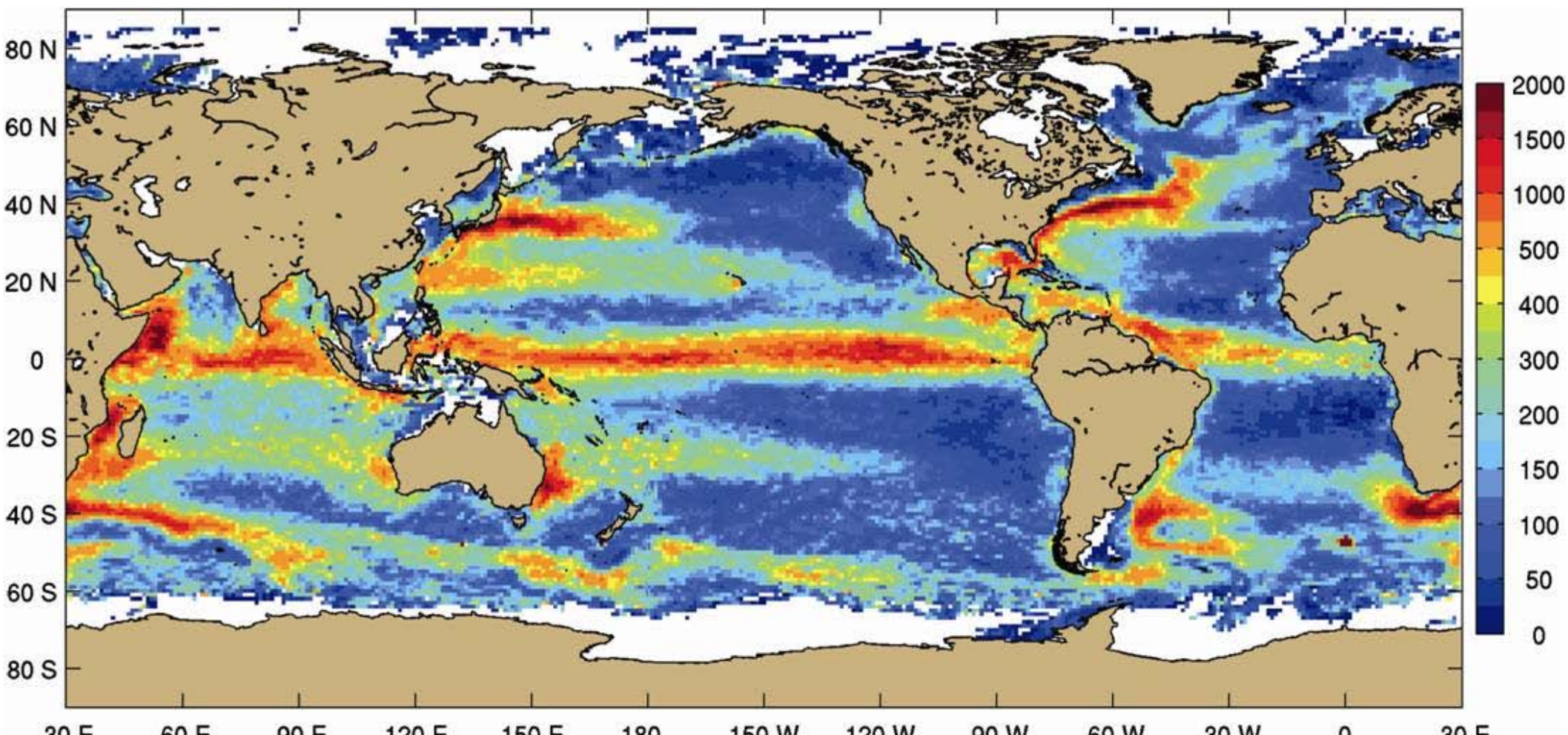


# *Low-frequency Eddy Modulation in the California Current*

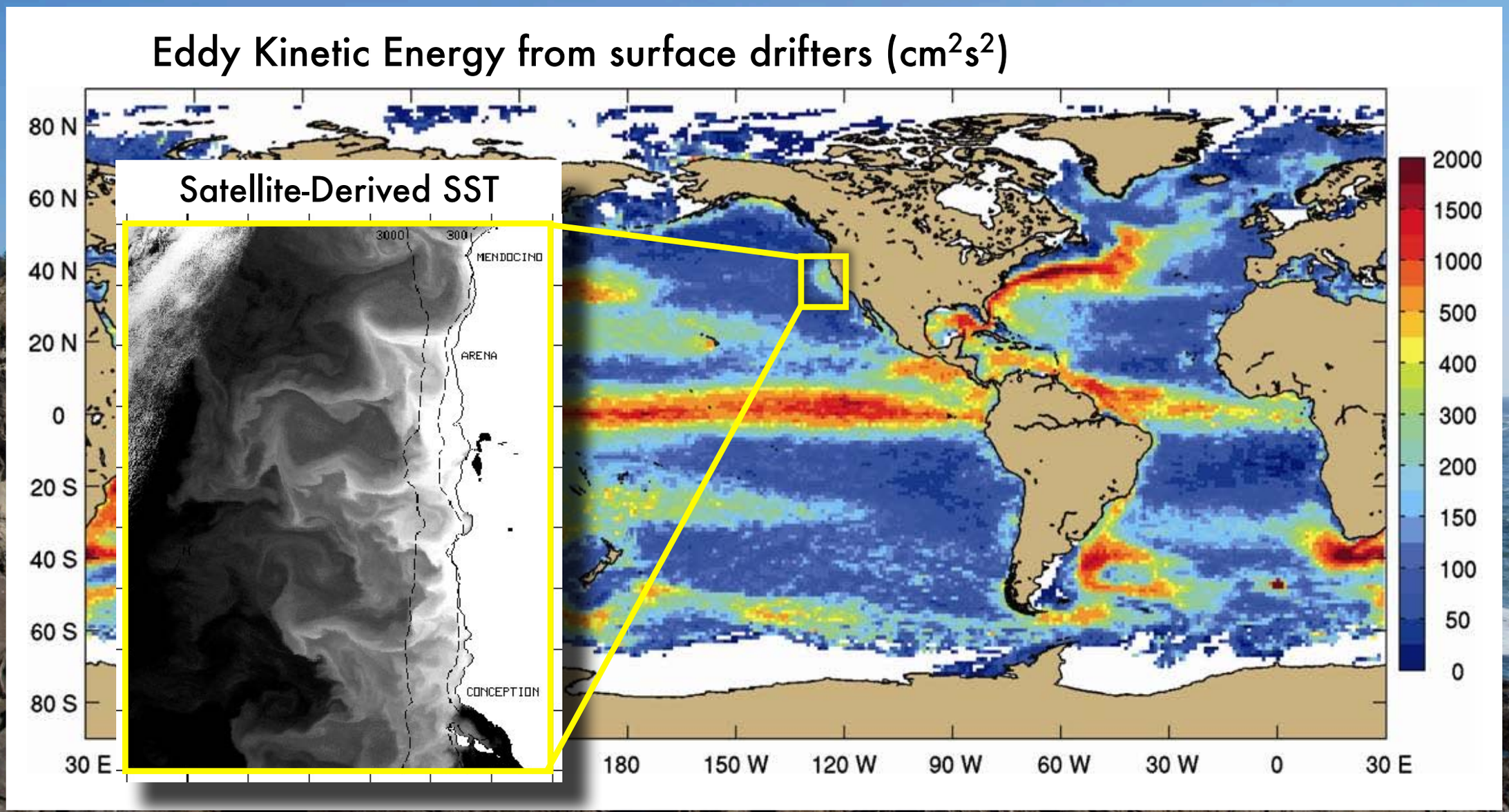
Andrew Davis and Emanuele Di Lorenzo
Georgia Institute of Technology

# *What dynamics control interannual and decadal variability in mesoscale eddies in the California Current?*

Eddy Kinetic Energy from surface drifters ($cm^2s^2$)

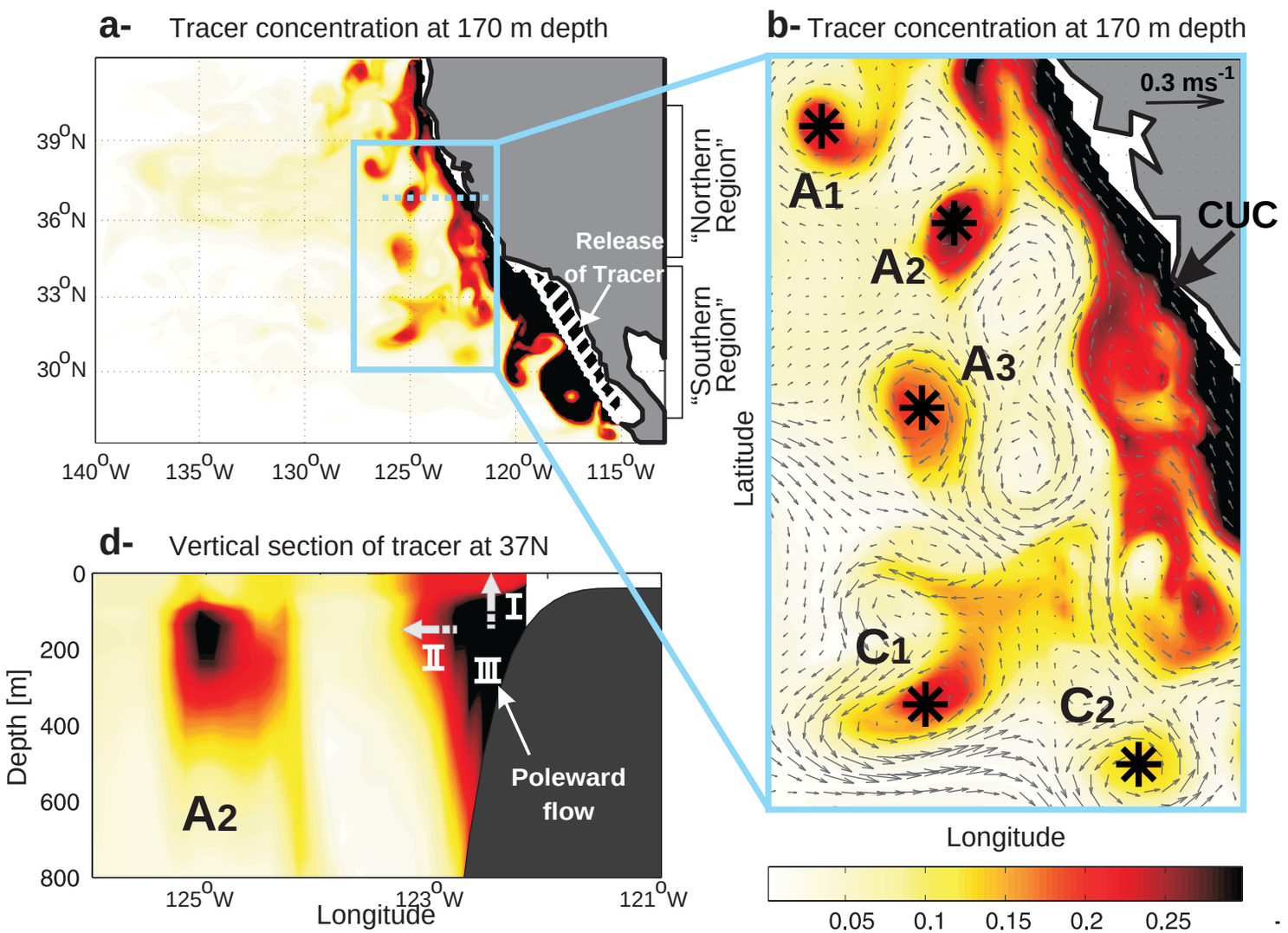


# *What dynamics control interannual and decadal variability in mesoscale eddies in the California Current?*



# ROMS passive tracer study of Eddy transport

**March 2007**



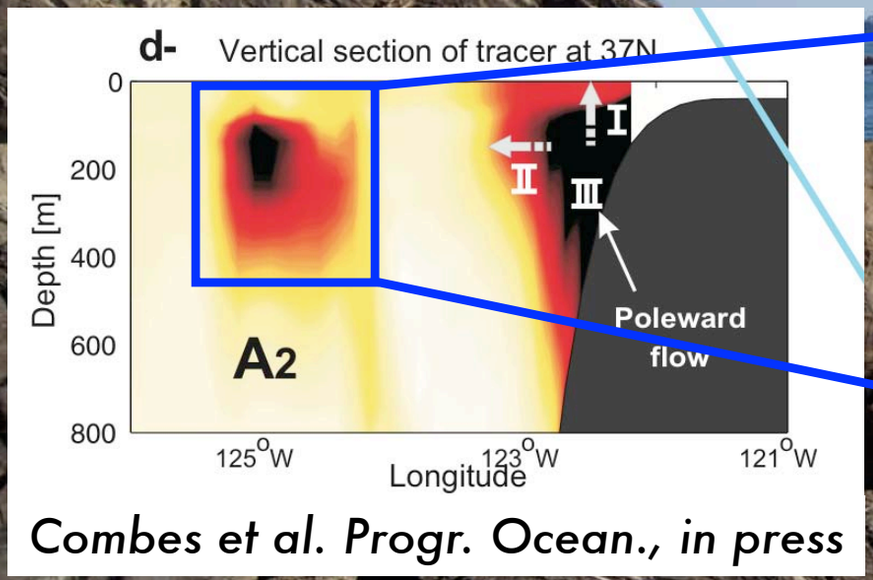

*Combes et al. Progr. Ocean., in press*

This passive tracer experiment (using our ROMS model data), shows the importance of eddy variance to offshore mixing.


*Combes et al. Progr. Ocean., in press*

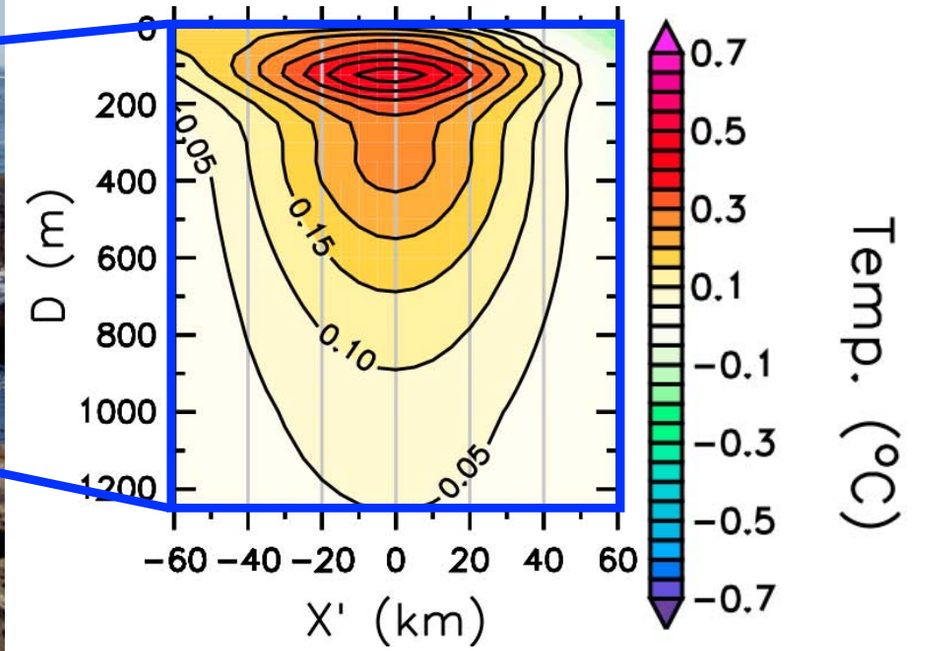
## Deep-core Anticyclones (DA)

- vorticity maximum around 400m depth
- formed in the central CC
- arise from baroclinic instabilities between the CC and counter-current
- deflect equatorward
- associated with <u>lateral</u> mixing




*Combes et al. Progr. Ocean., in press*

Composite Temperature Anomaly (DA)




Kurian et al. 2011

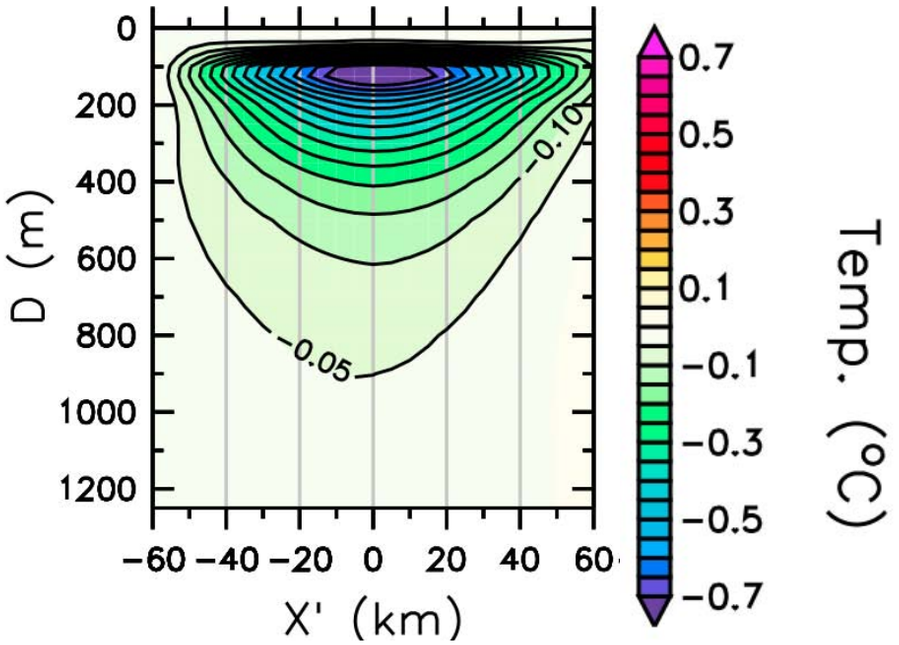
## Surface-core Cyclones (SC)

- vorticity maximum near surface
- formed at the CC/return flow interface
- arise from meridional current shear
- deflect poleward
- associated with lateral and vertical mixing

## Deep-core Anticyclones (DA)

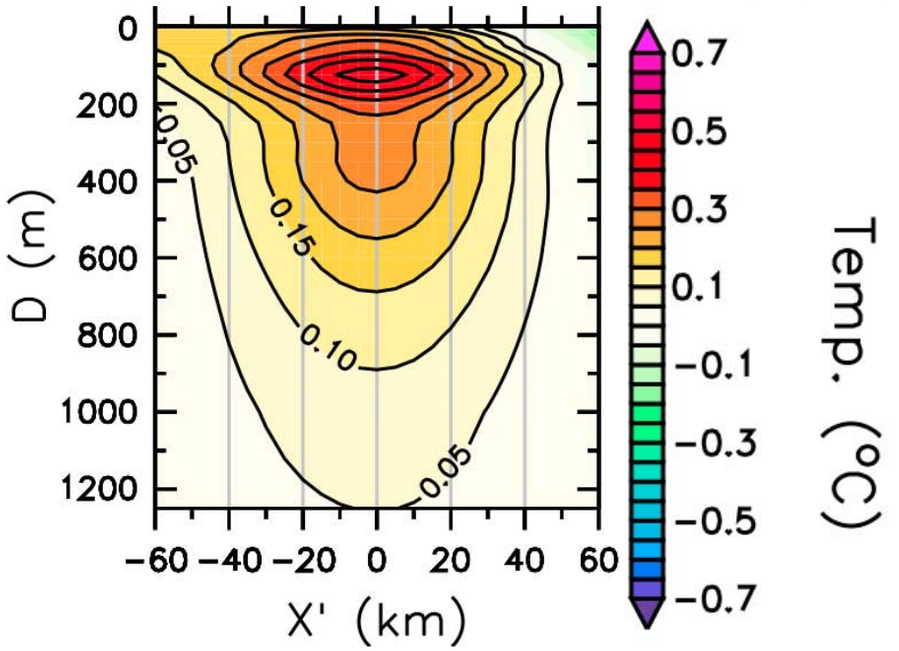
- vorticity maximum around 400m depth
- formed in the central CC
- arise from baroclinic instabilities between the CC and counter-current
- deflect equatorward
- associated with lateral mixing

Composite Temperature Anomaly (SC)



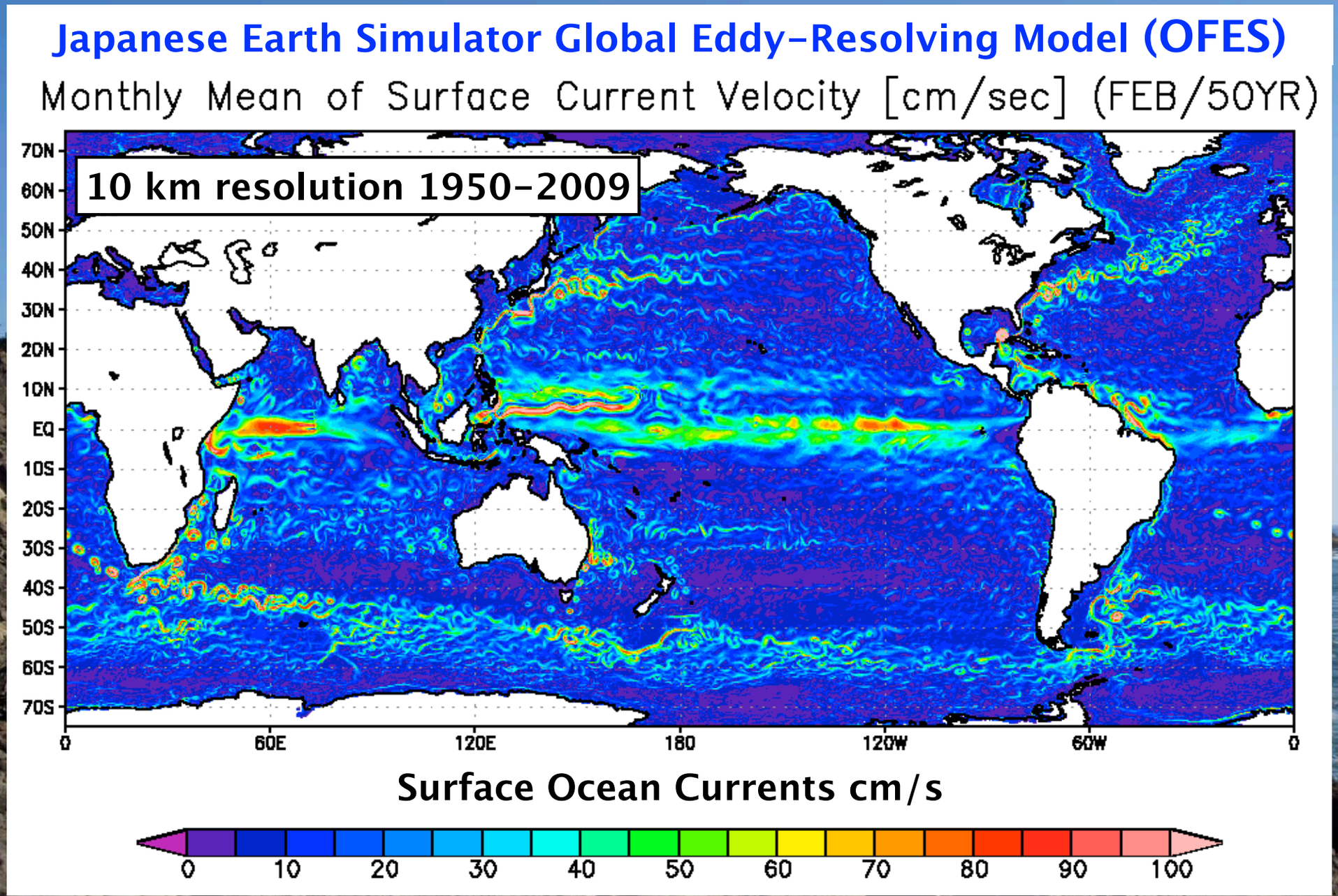

Kurian et al. 2011

Composite Temperature Anomaly (DA)

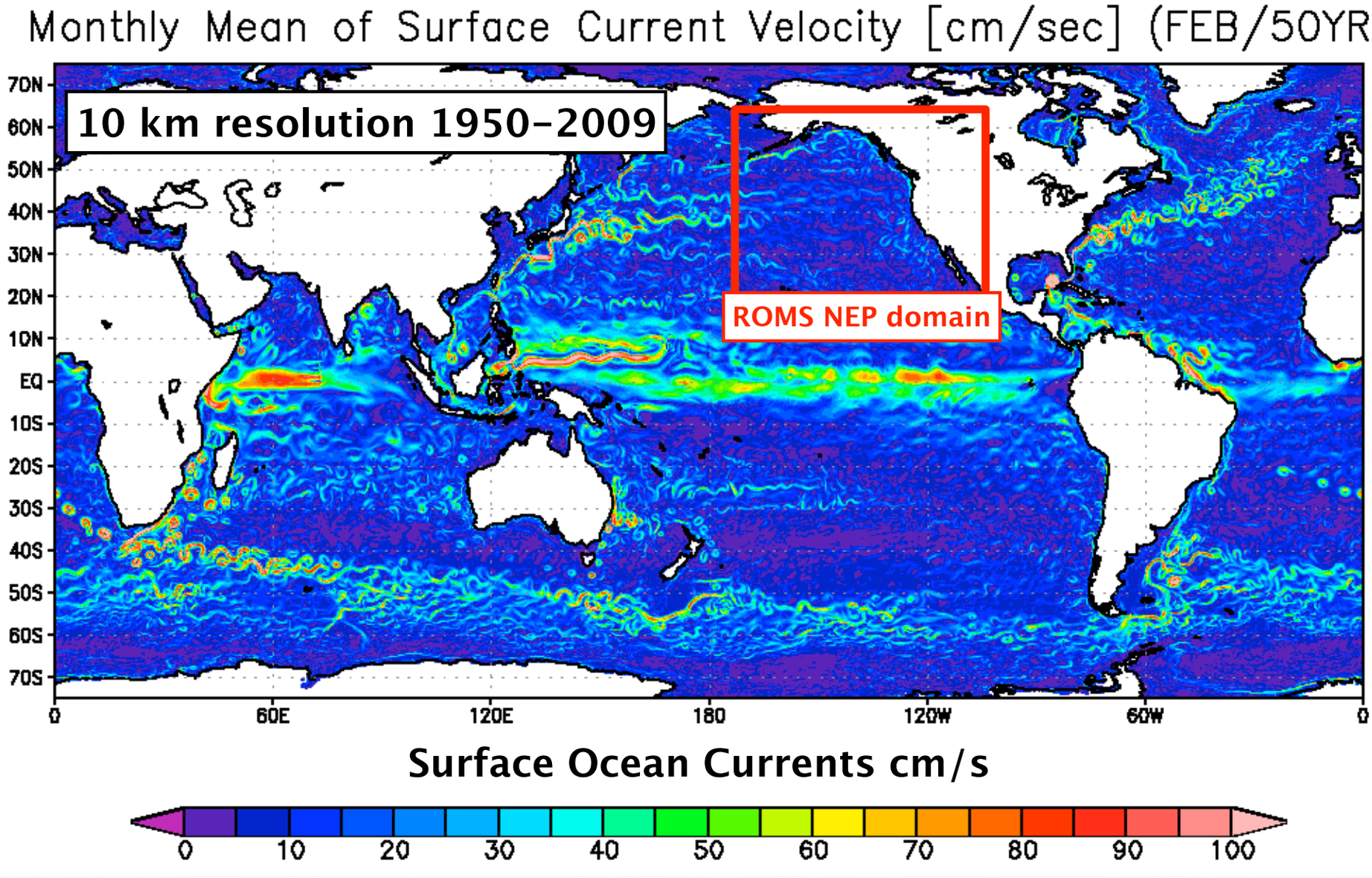



Kurian et al. 2011

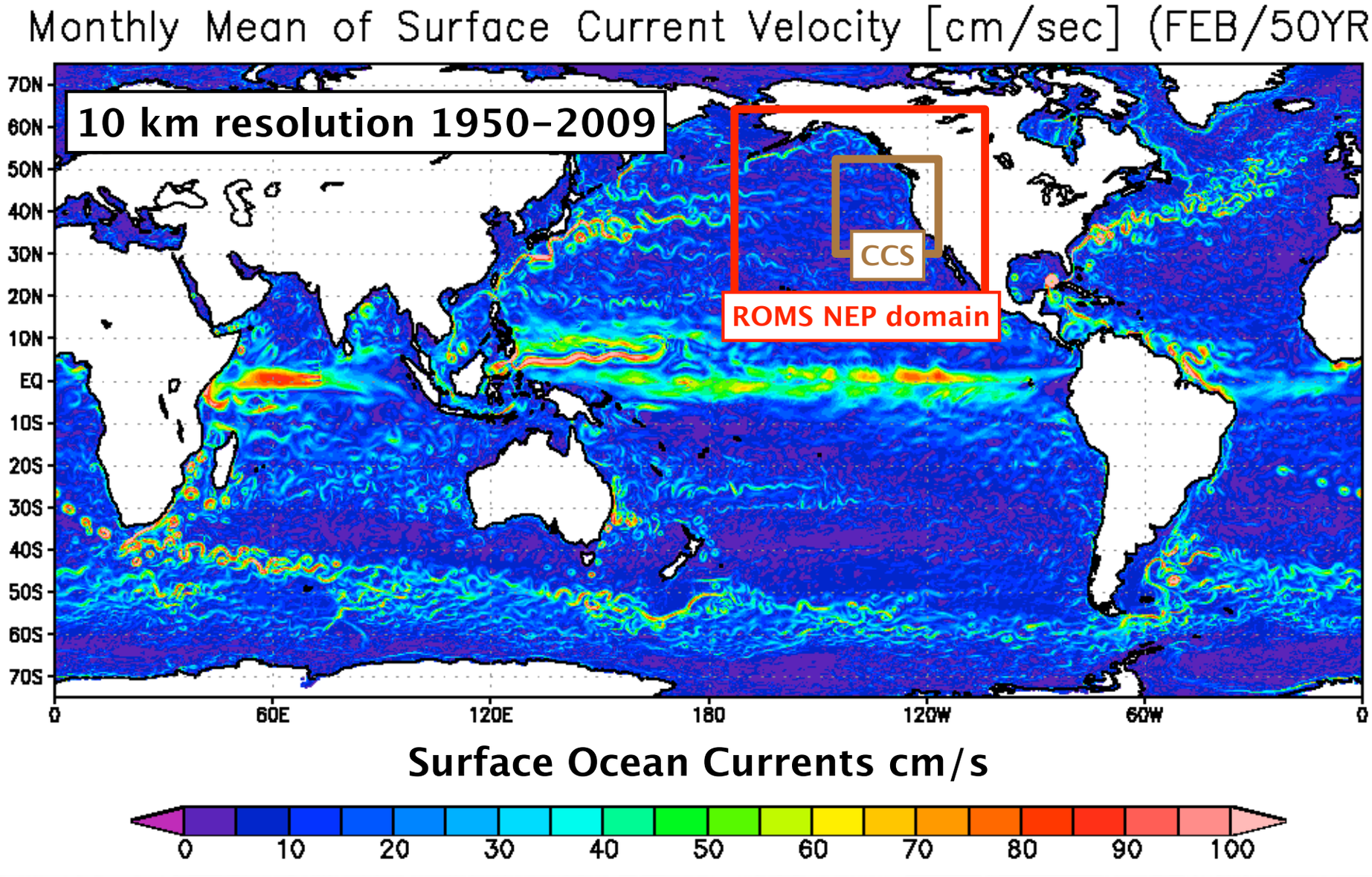
# Japanese Earth Simulator Global Eddy-Resolving Model (OFES)



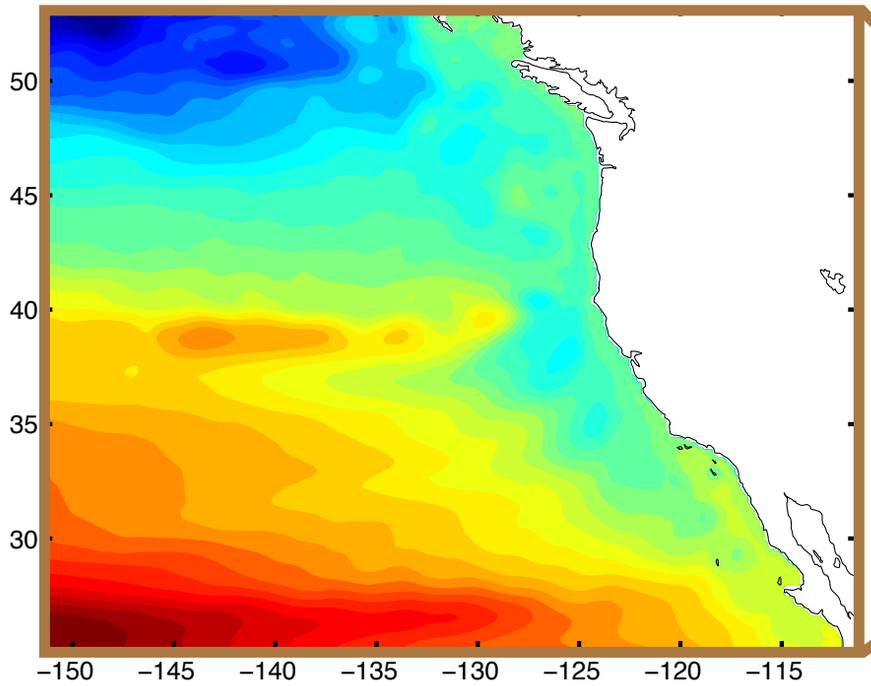
# Japanese Earth Simulator Global Eddy-Resolving Model (OFES)



# Japanese Earth Simulator Global Eddy-Resolving Model (OFES)



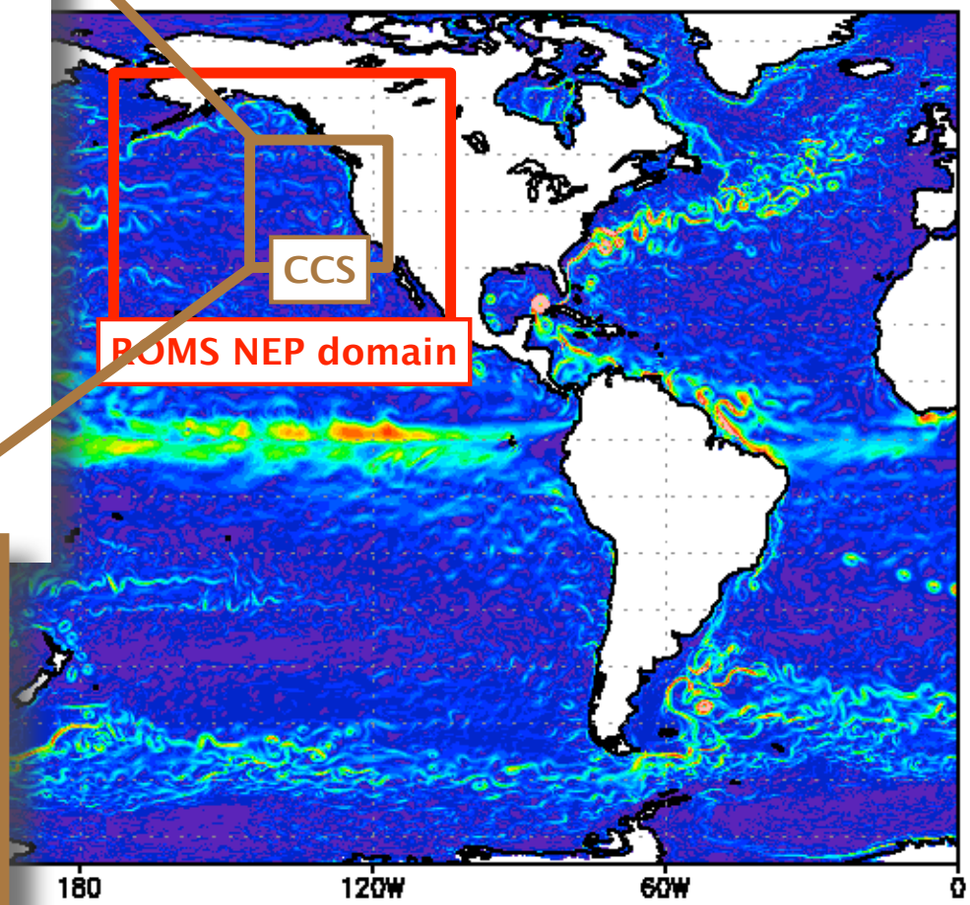
# ROMS Mean SSH




- 3 hindcasts from 1950-2008
- 10km resolution
- forced by NCEP reanalysis
- 2 use OFES boundary condition to include effect of equatorial CTW variance

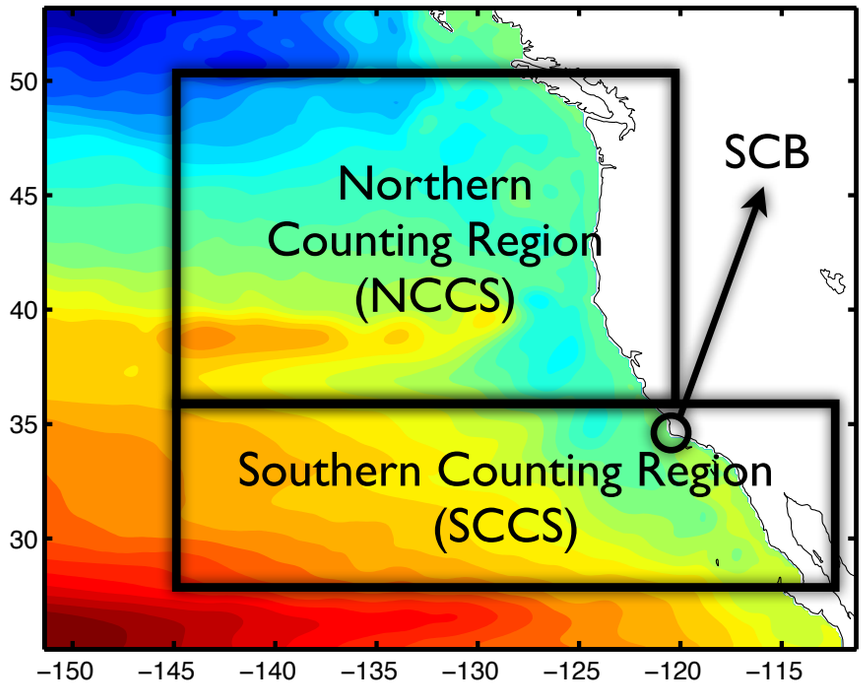
## l Eddy-Resolving Model (OFES)

nt Velocity [cm/sec] (FEB/50YR)




an Currents cm/s

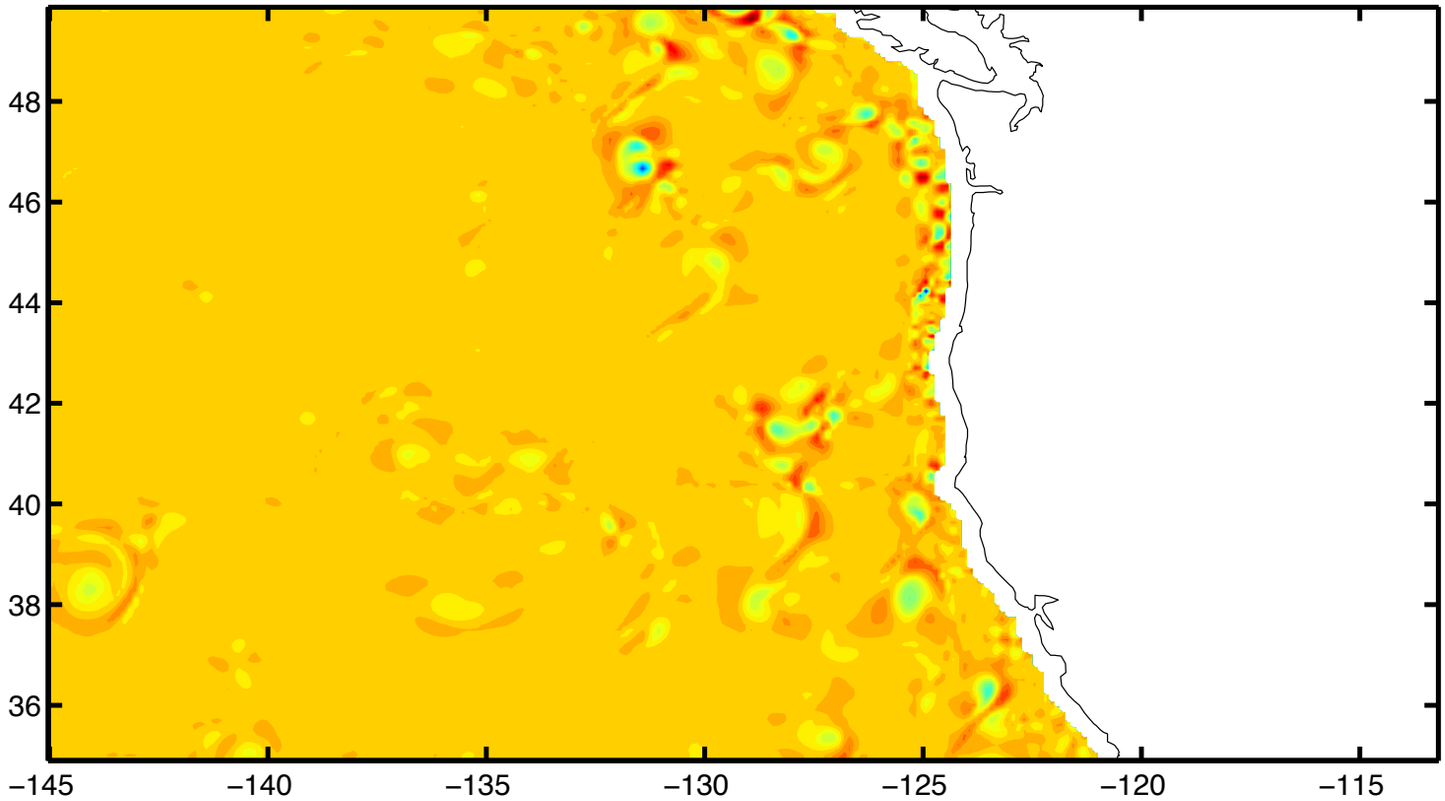
# ROMS Mean SSH




We expect equatorial wave energy (ENSO) to dissipate at the SCB. (Davis & Di Lorenzo, in prep.)

This leads us to separate two forcing regions within the CCS.

# Okubo-Weiss Parameter (W)

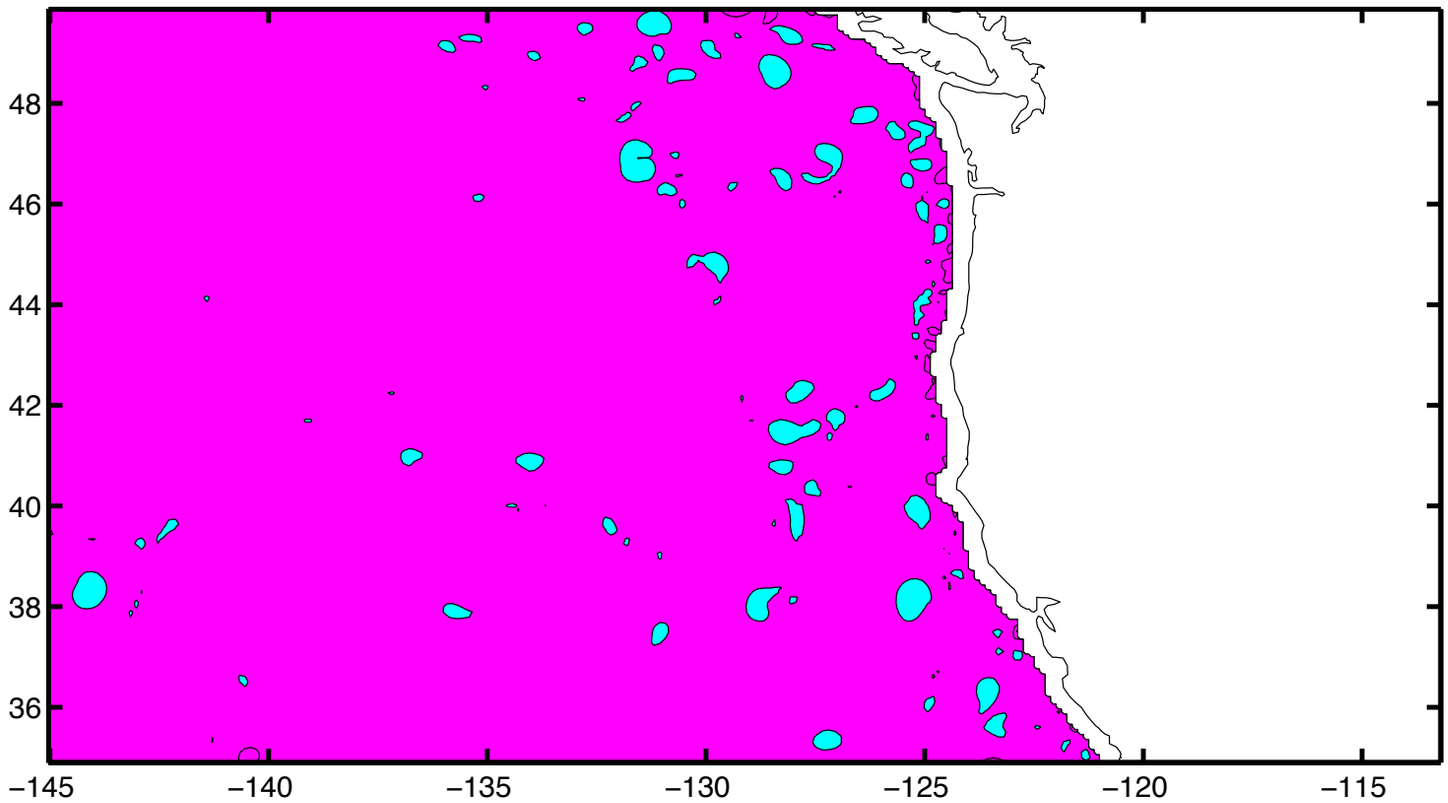



Our eddy-counting method (one of many) uses the Okubo-Weiss parameter *W*:

$$W = 4((\partial u/\partial x)^2 + (\partial v/\partial x)(\partial u/\partial y))$$

This is a measure of the dominance of rotation over deformation.

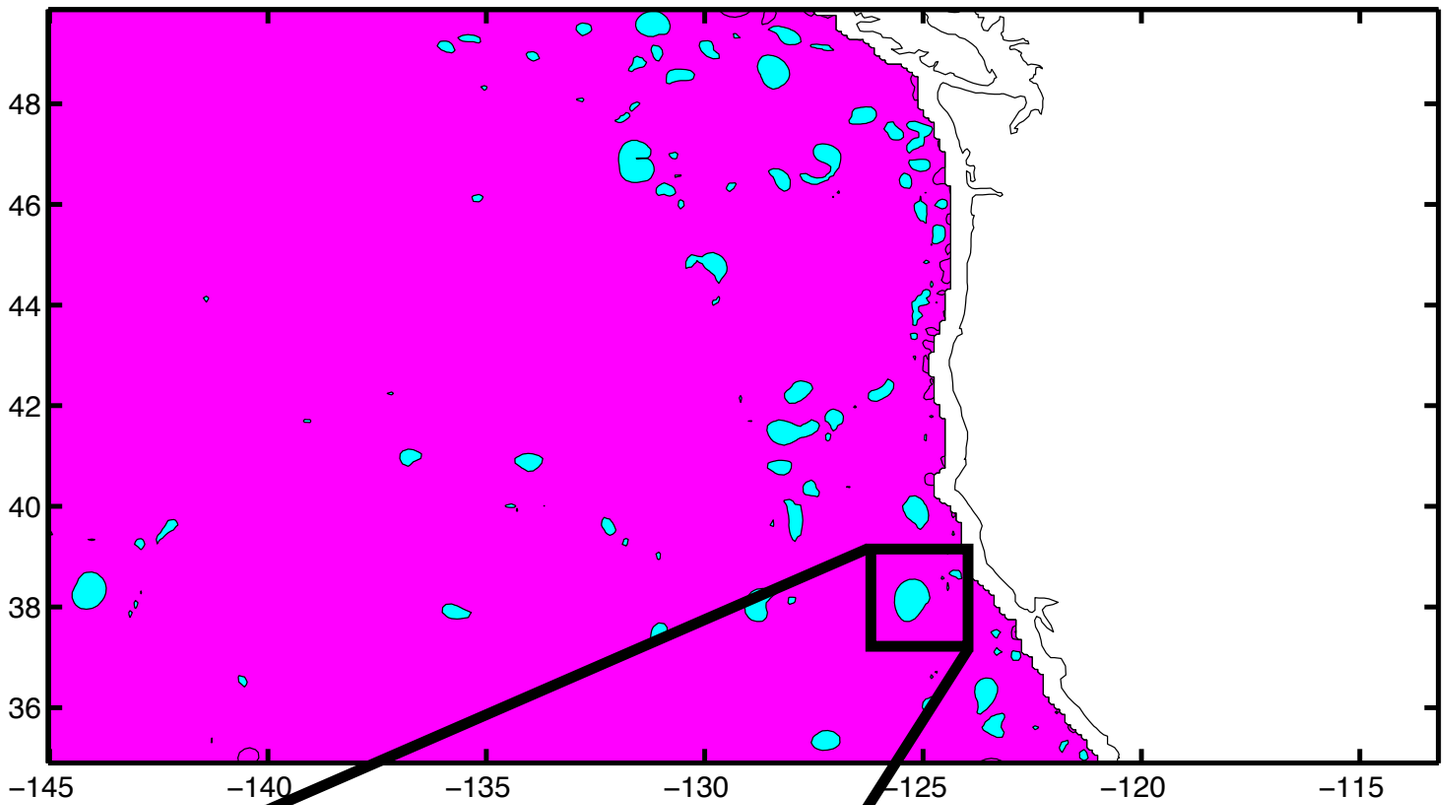
# Okubo-Weiss Parameter (W)

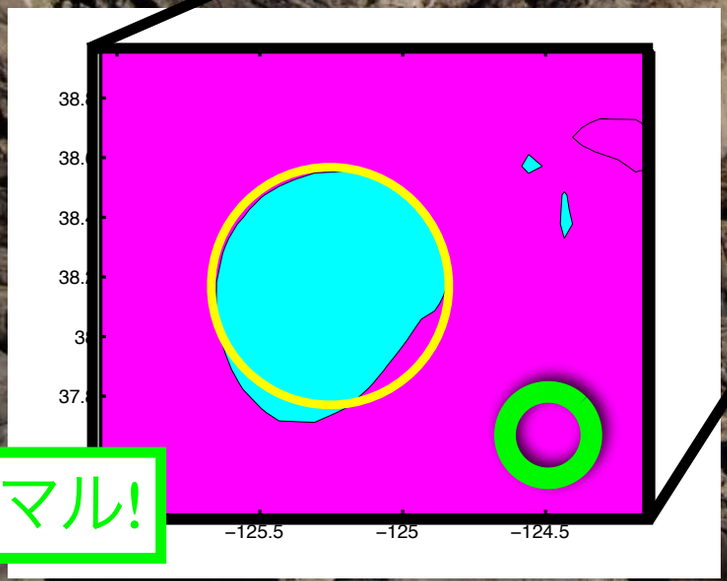



We count closed contours of W to develop eddy count time series.

We also filter by size and shape.

# Okubo-Weiss Parameter (W)



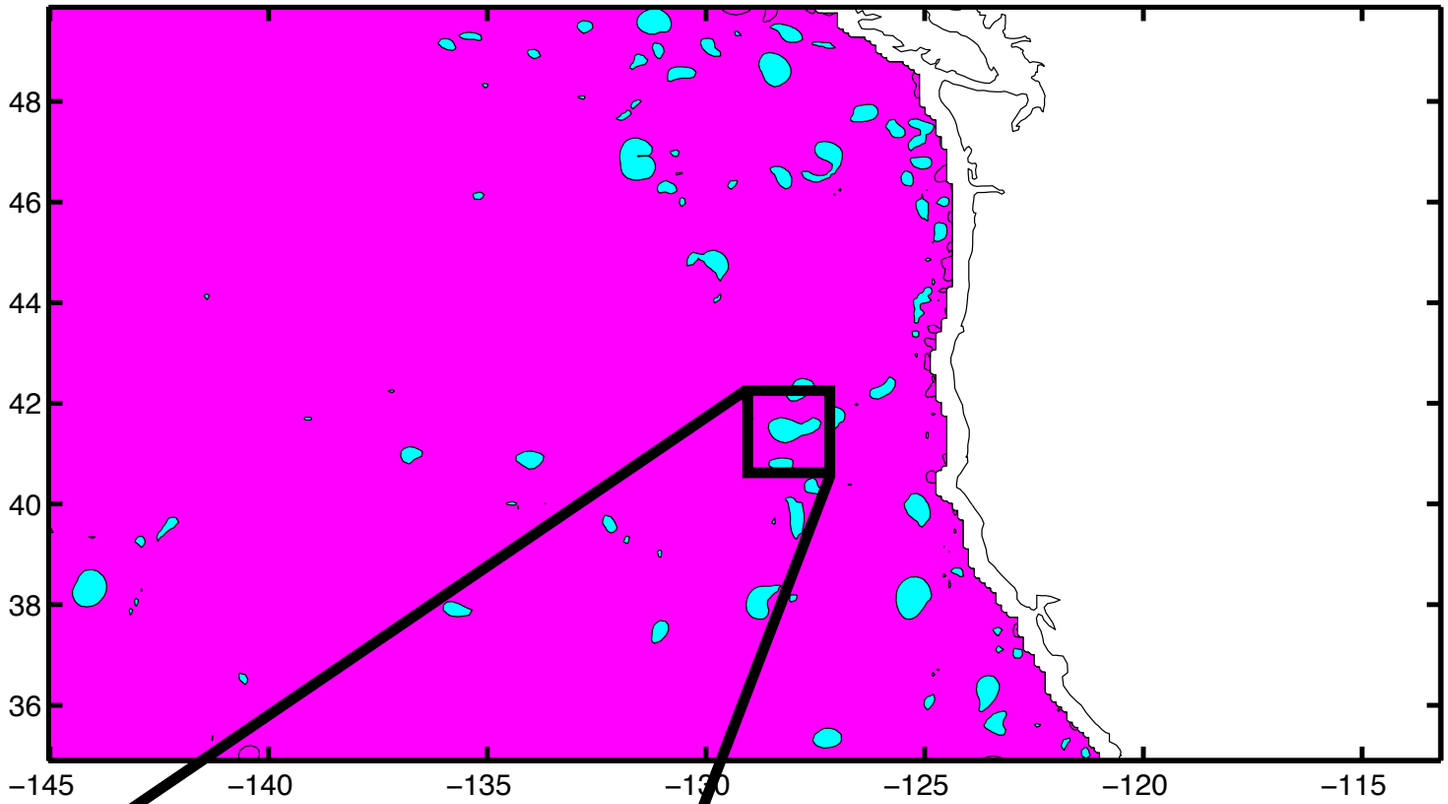



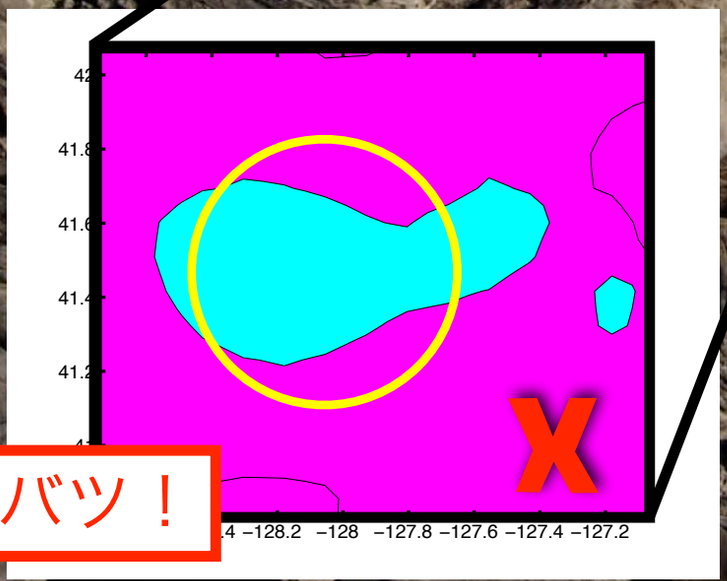

マル!

This eddy has a very small "shape error." Its area conforms to a circle of the same radius.

We consider it well-formed and it is included in the count.

# Okubo-Weiss Parameter (W)

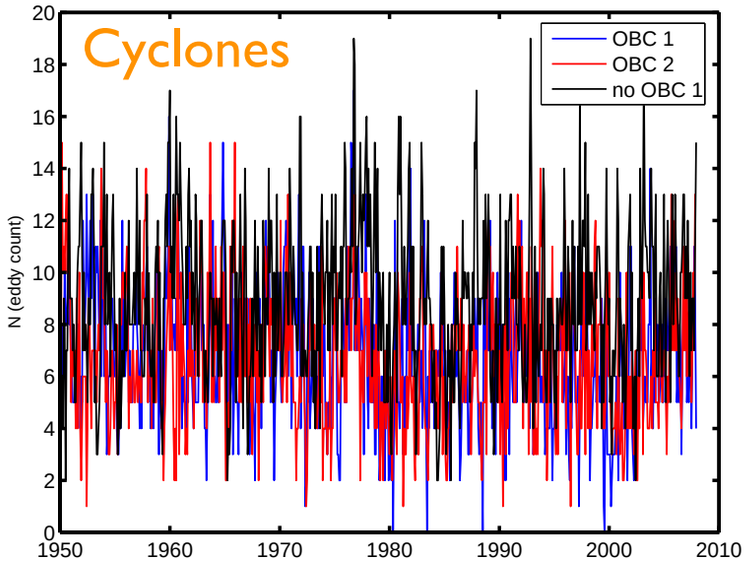


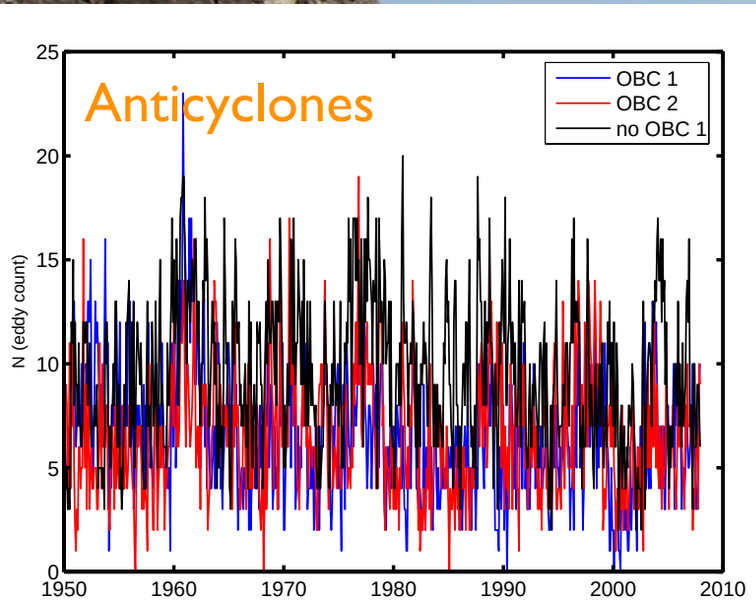




バツ！

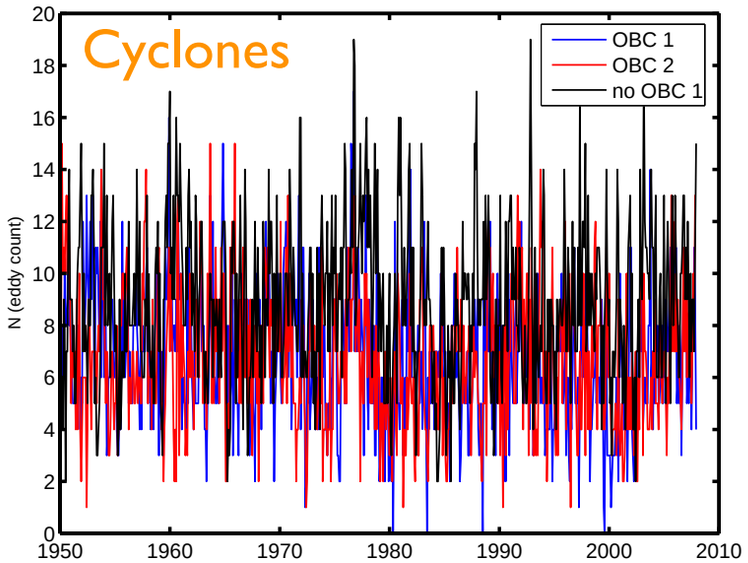
This eddy has a much larger “shape error” and is excluded from the count.

# Eddy Time Series (North)

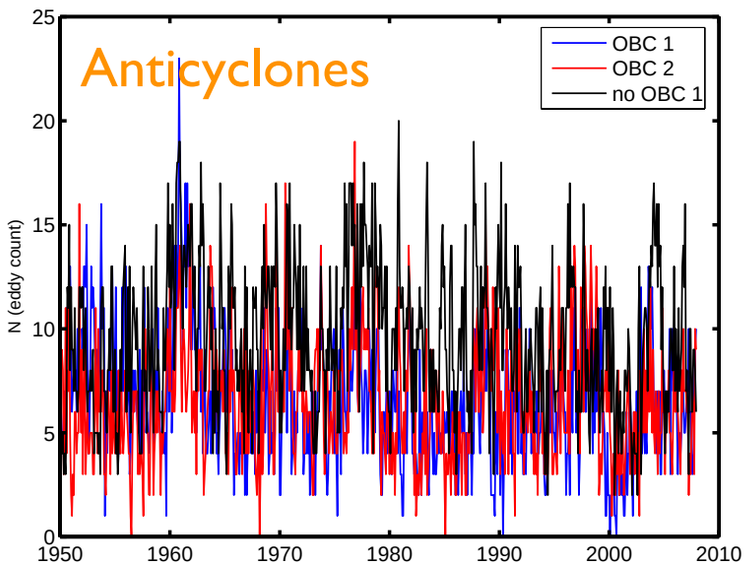


# Eddy Time Series (North)

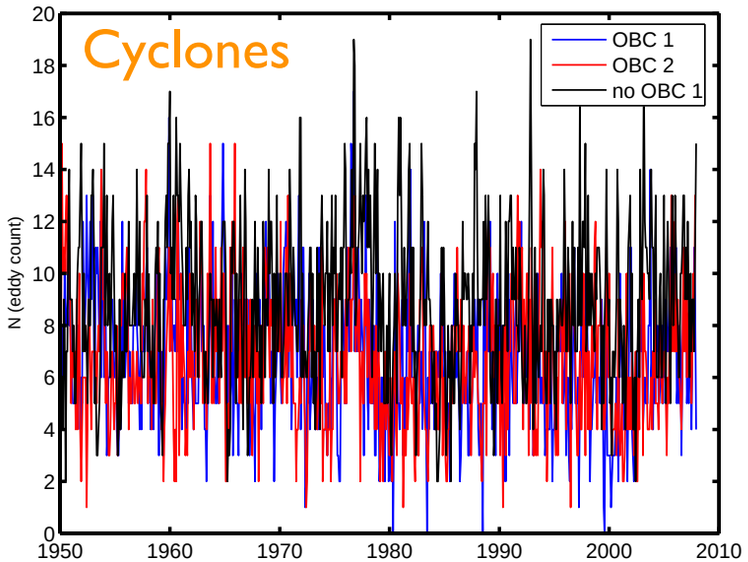



mean: 6.7 6.7 8.9
std: 2.7 2.7 3.0

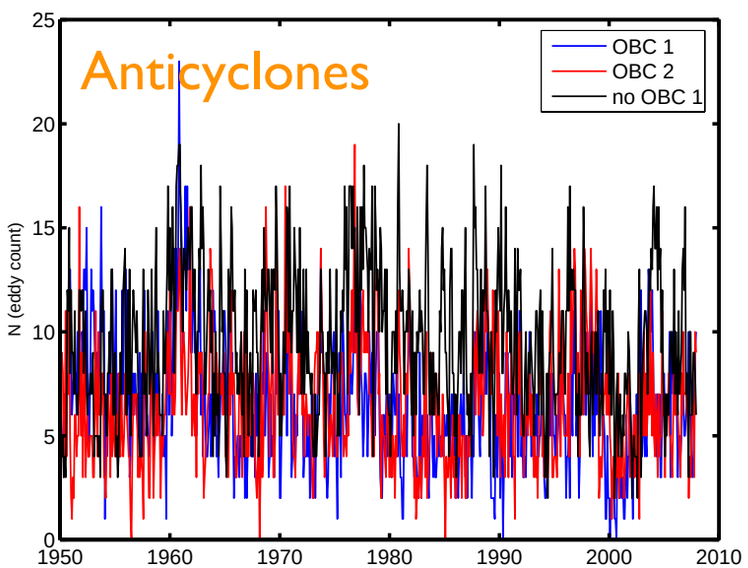



mean: 6.6 6.5 9.6
std: 3.1 3.0 3.5

# Eddy Time Series (North)



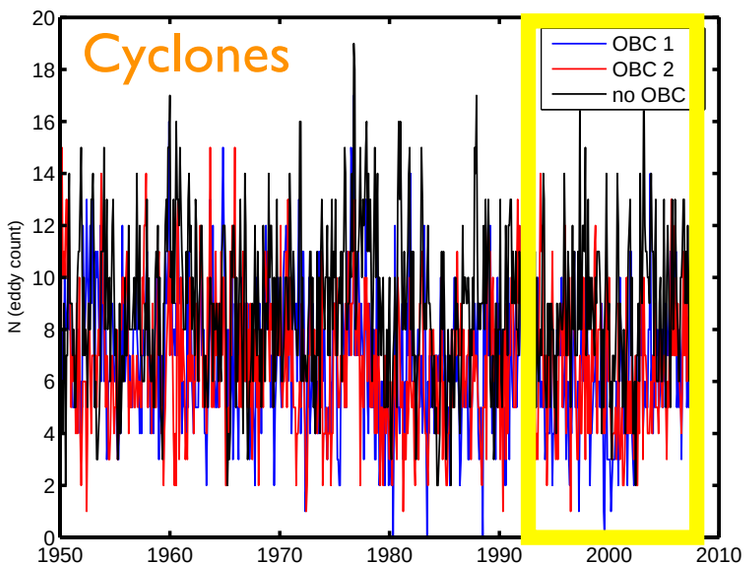

mean: 6.7 6.7 8.9
std: 2.7 2.7 3.0

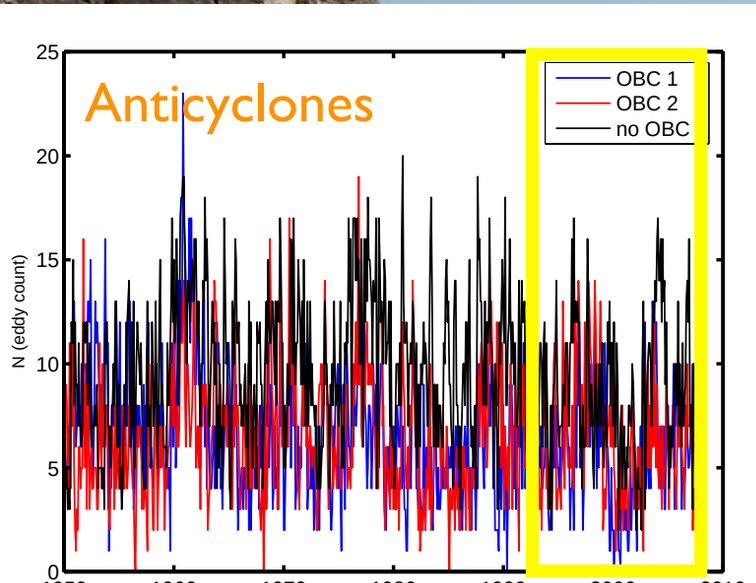



mean: 6.6 6.5 9.6
std: 3.1 3.0 3.5

*How do modeled eddy counts compare with satellite SSHa observations?*

# Eddy Time Series (North)

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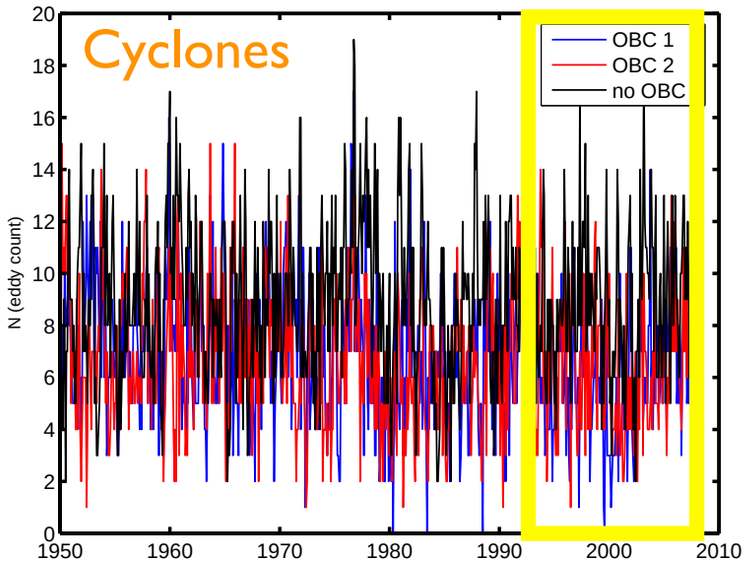


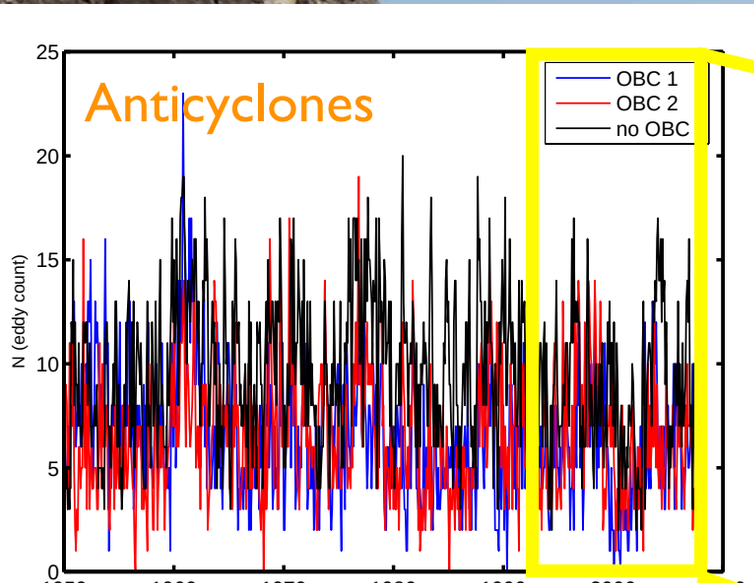


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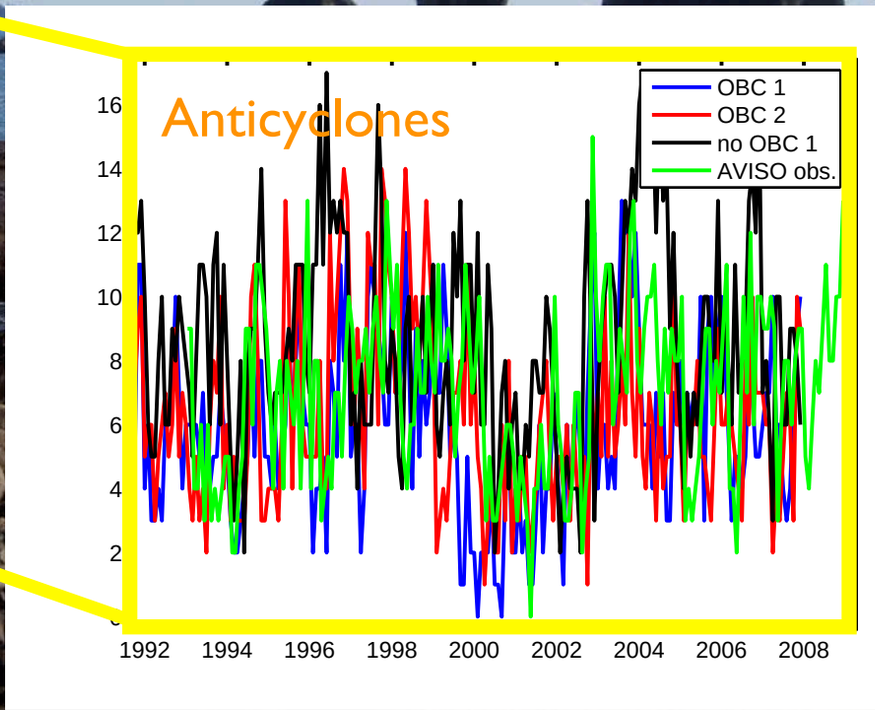

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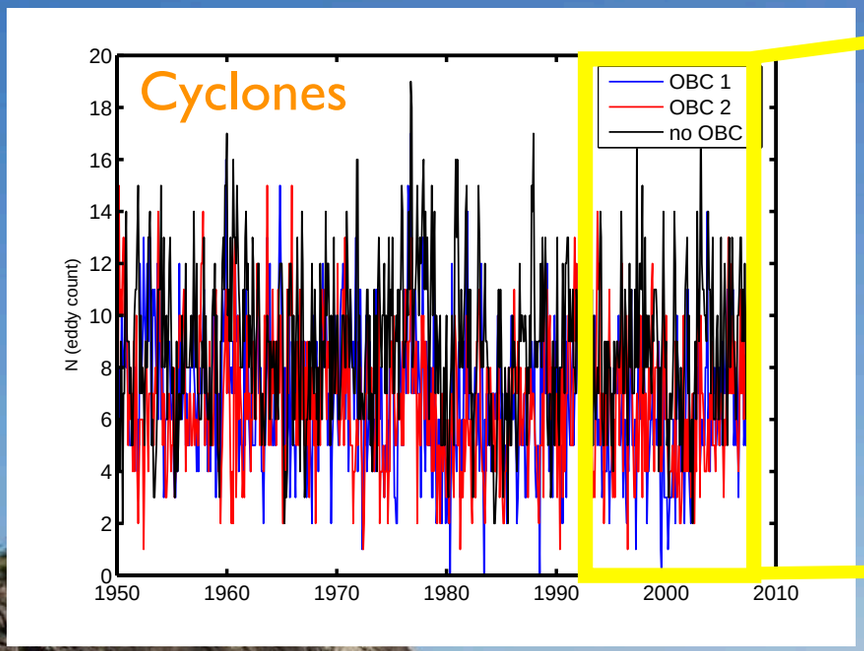
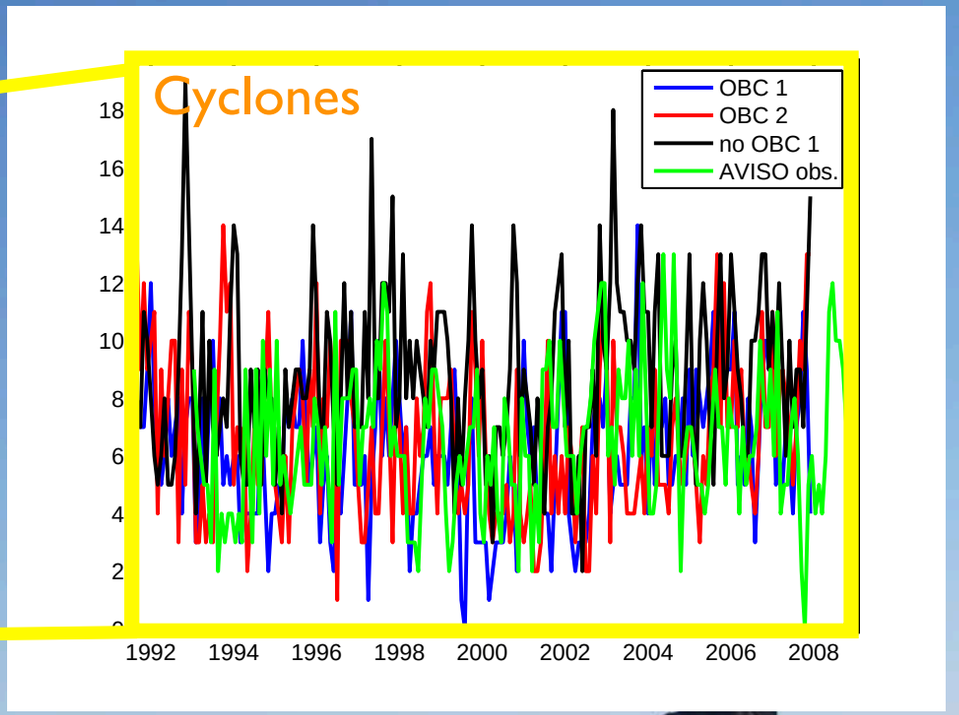
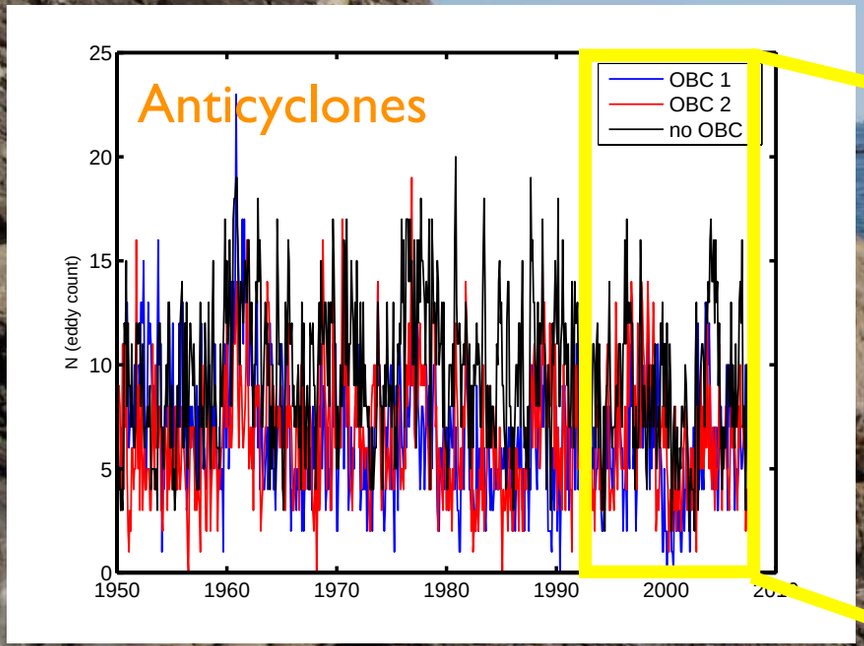
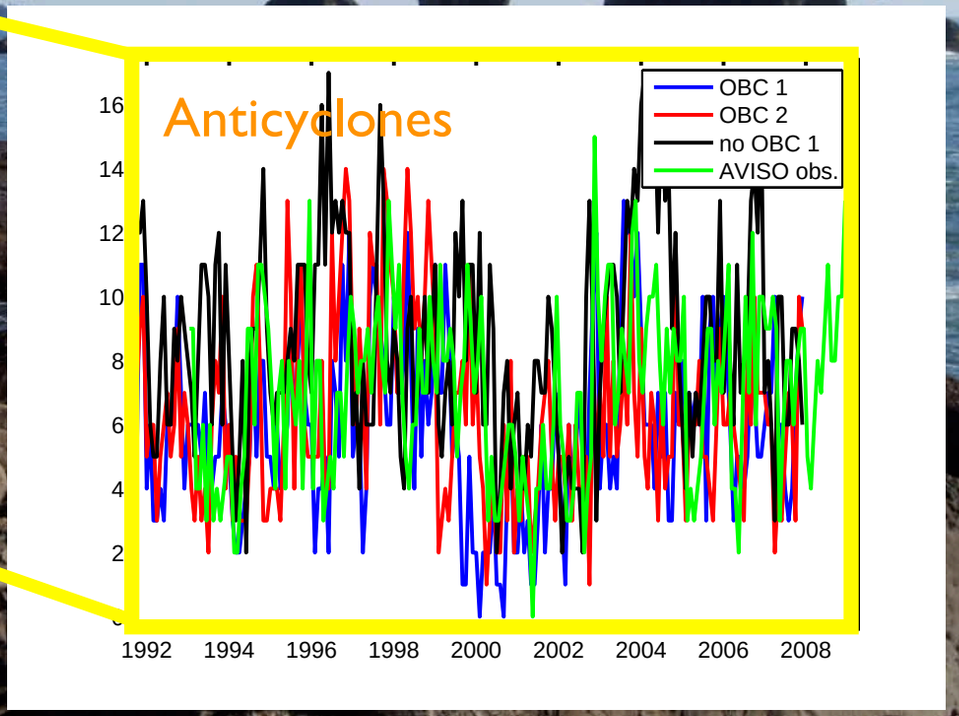


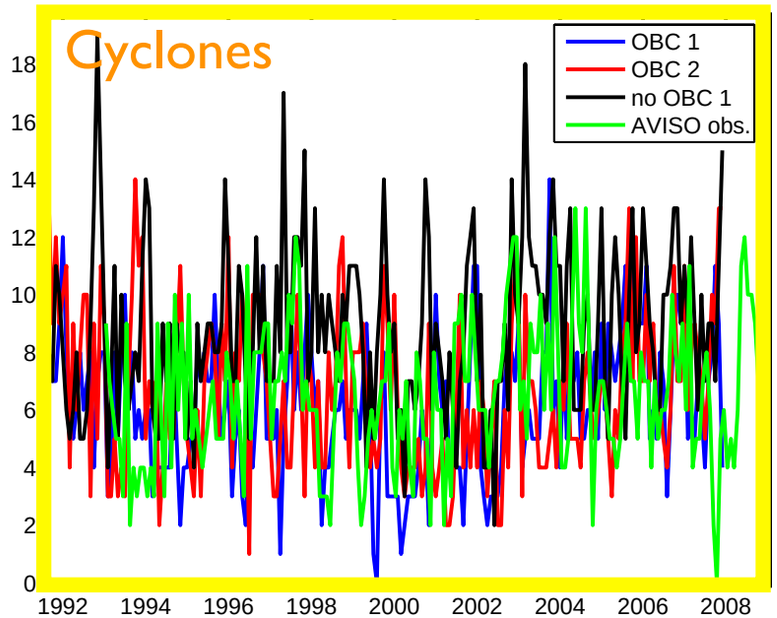



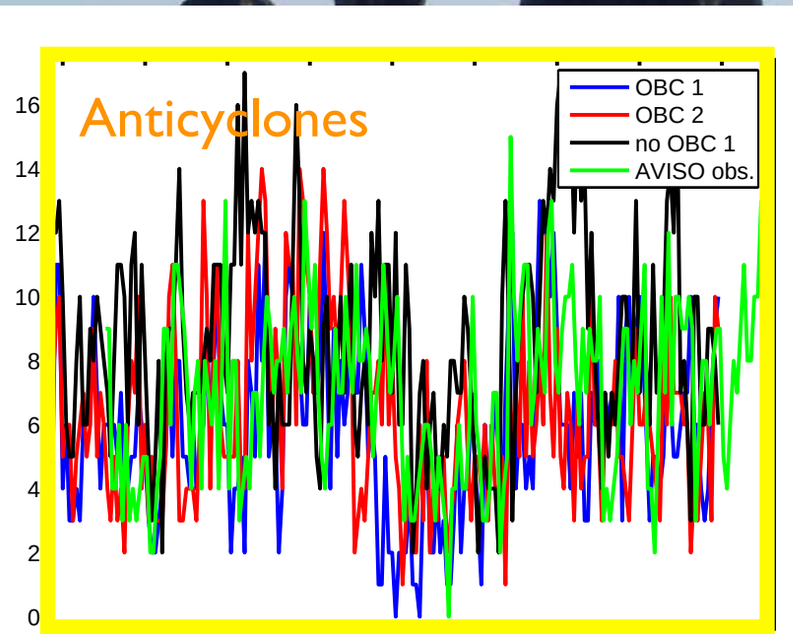



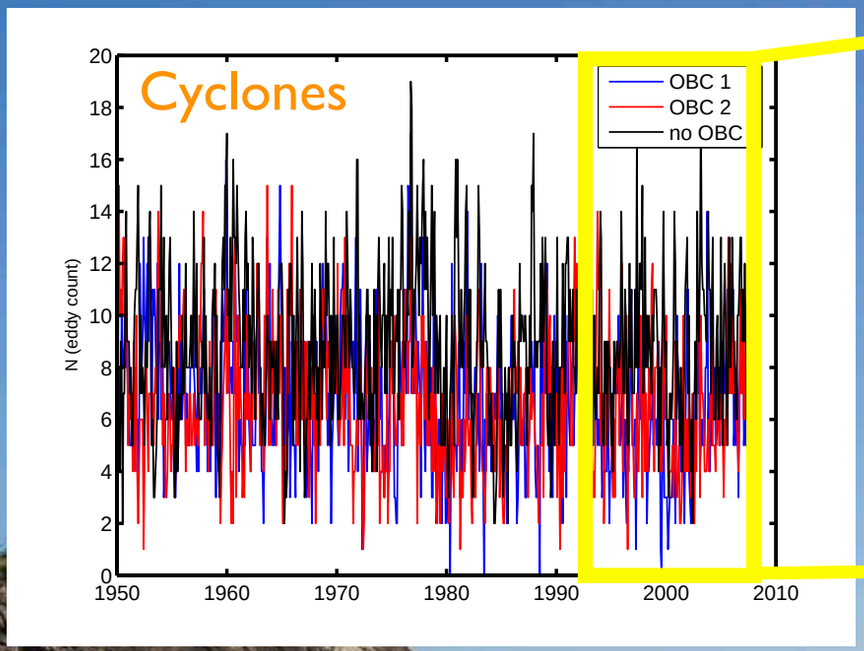
# Correlation Table

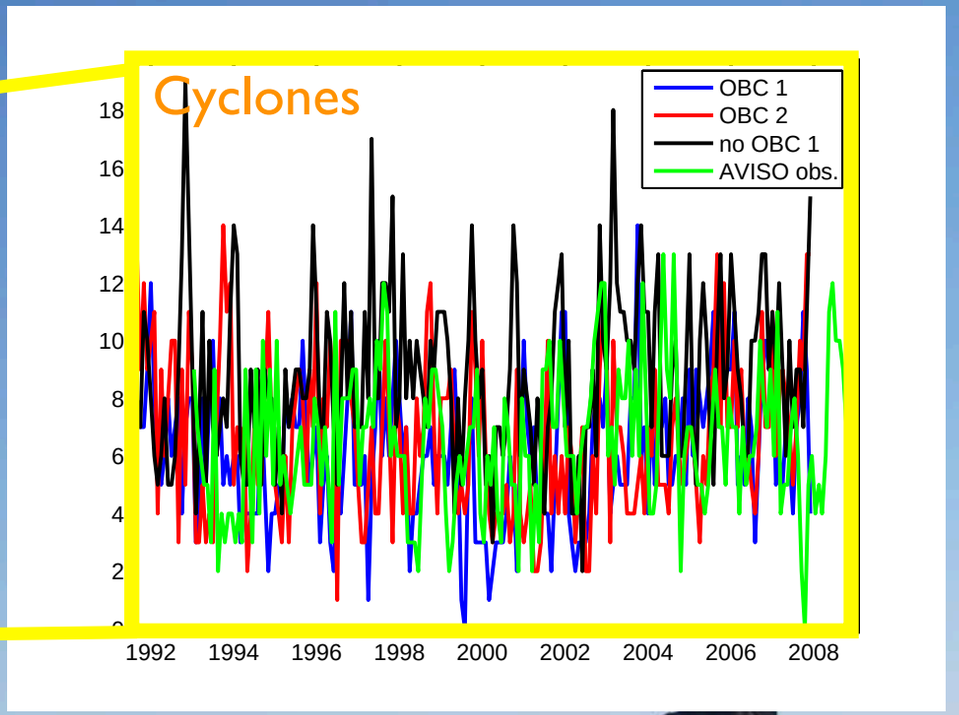
| | OBC 2 | no OBC | AVISO |
|---|---|---|---|
| OBC 1 | 0.336 | 0.241 | 0.382 |
| OBC 2 | | 0.295 | 0.256 |
| no OBC | | | 0.283 |

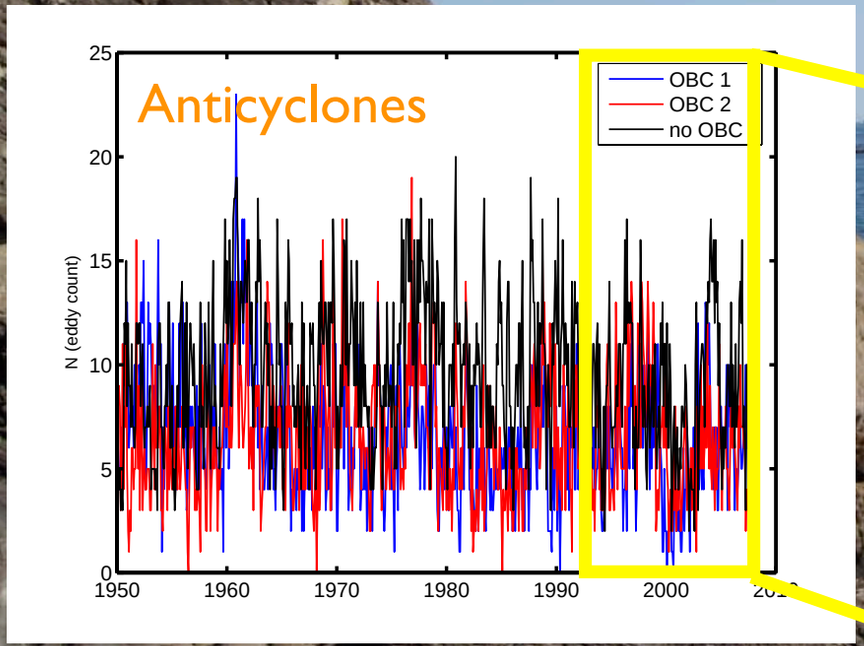


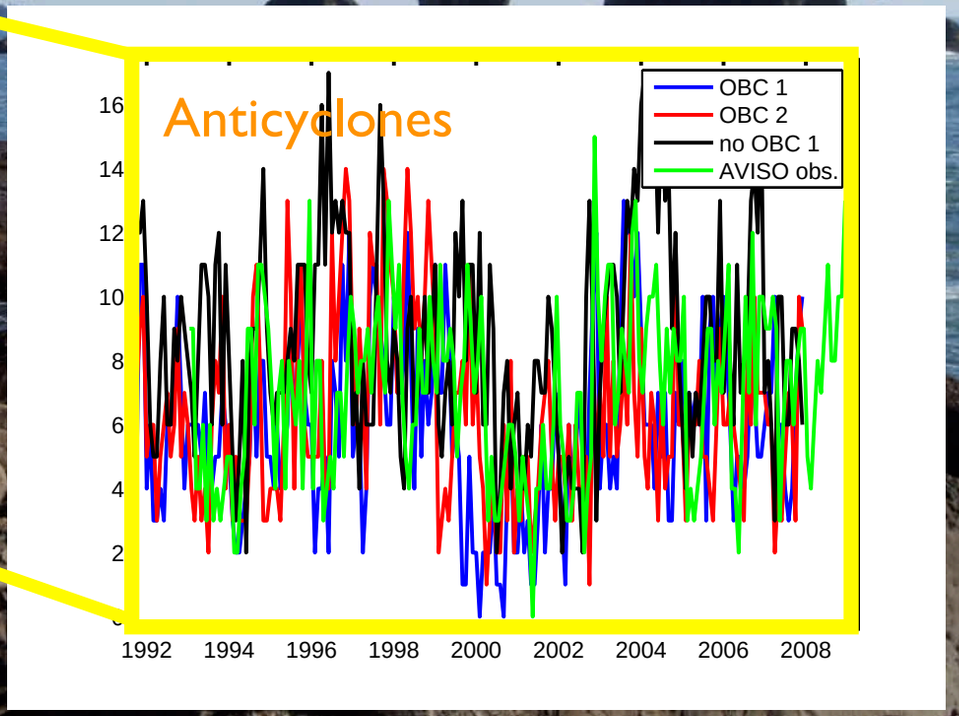



# Eddy Time Series (North)

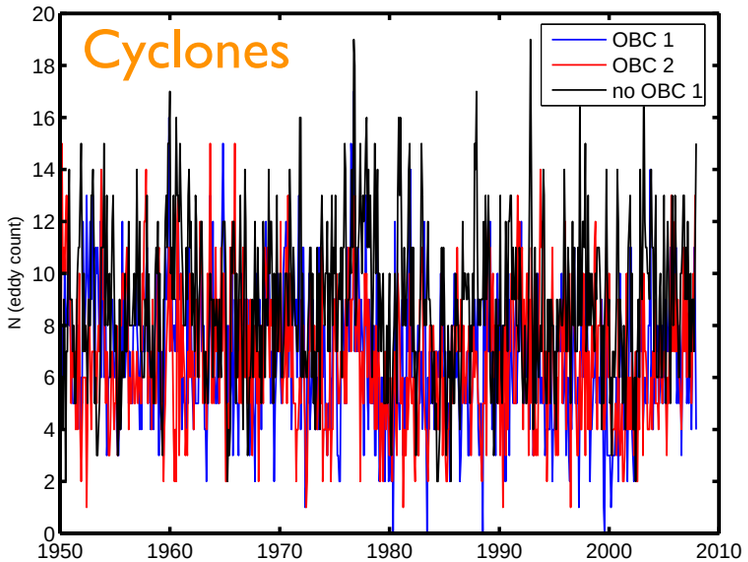


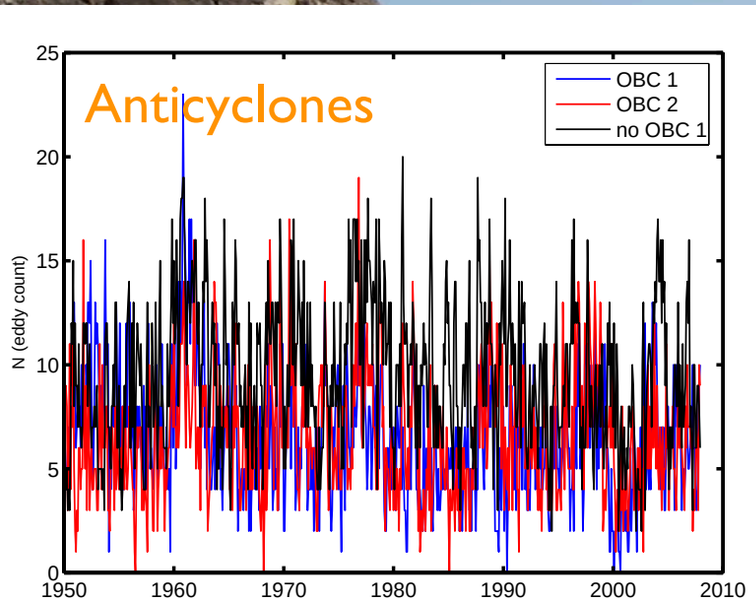



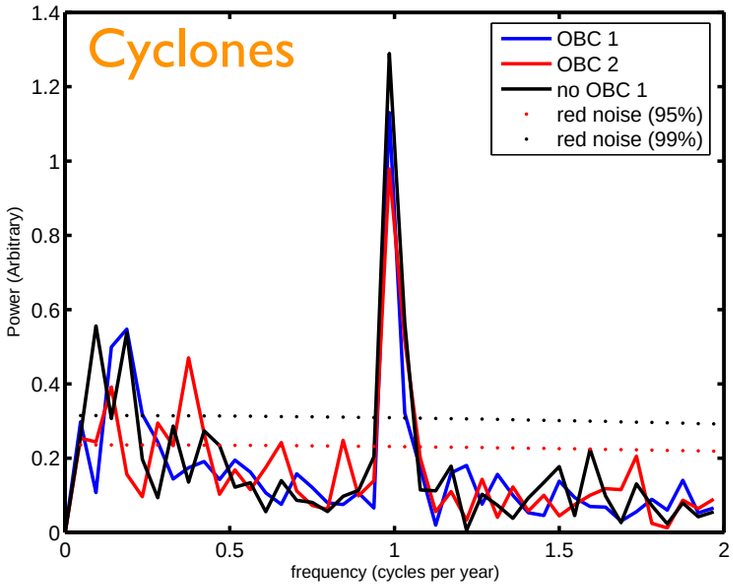
# Eddy Time Series (North)




*What frequencies contain the most eddy variance?*

# Eddy Spectra (North)

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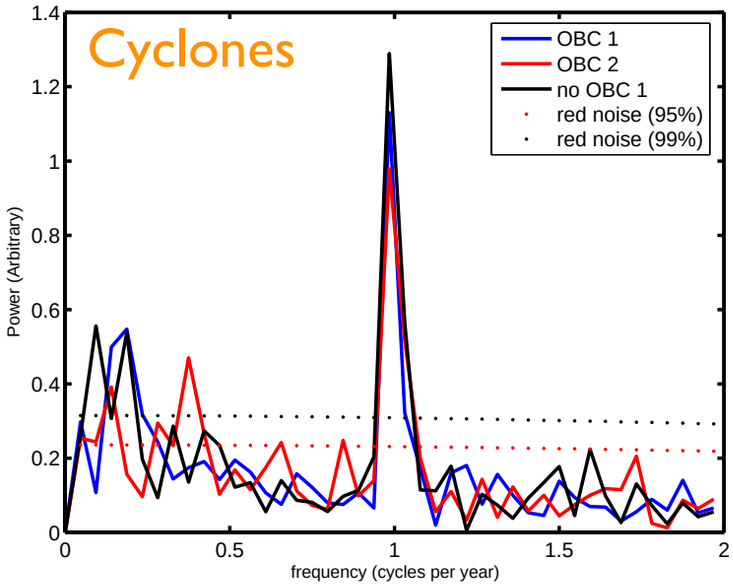


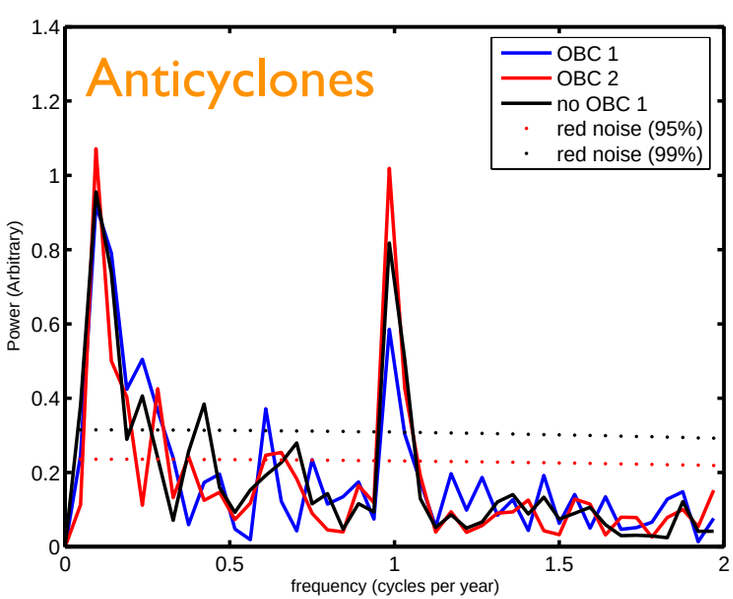


*What frequencies contain the most eddy variance?*

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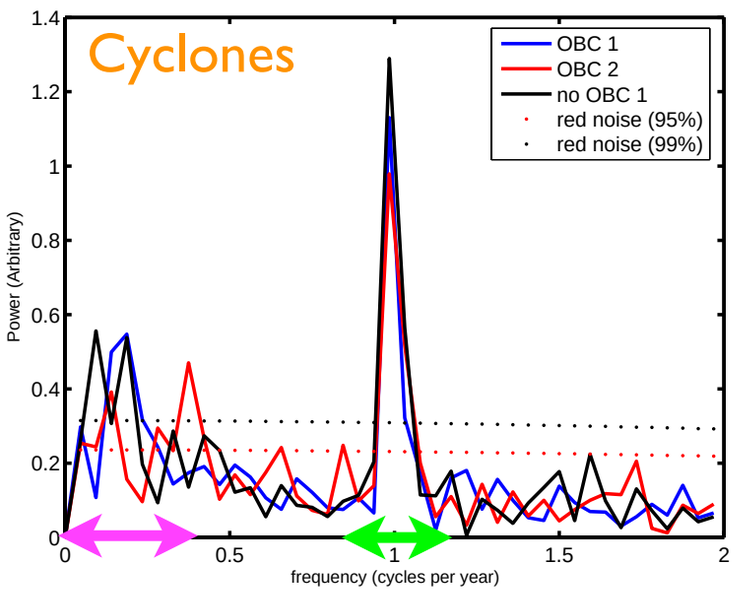
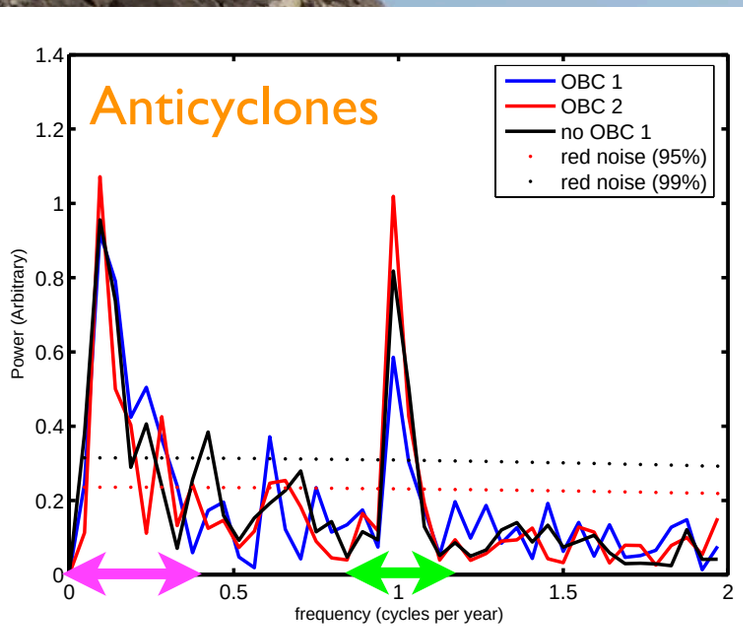



*What frequencies contain the most eddy variance?*

Low Frequency: 18% 14% 19%

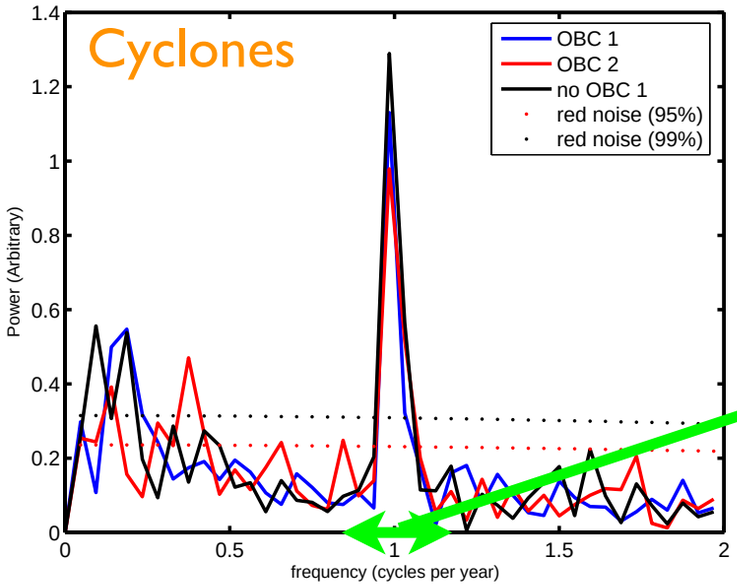
Seasonal: 14% 16% 19%

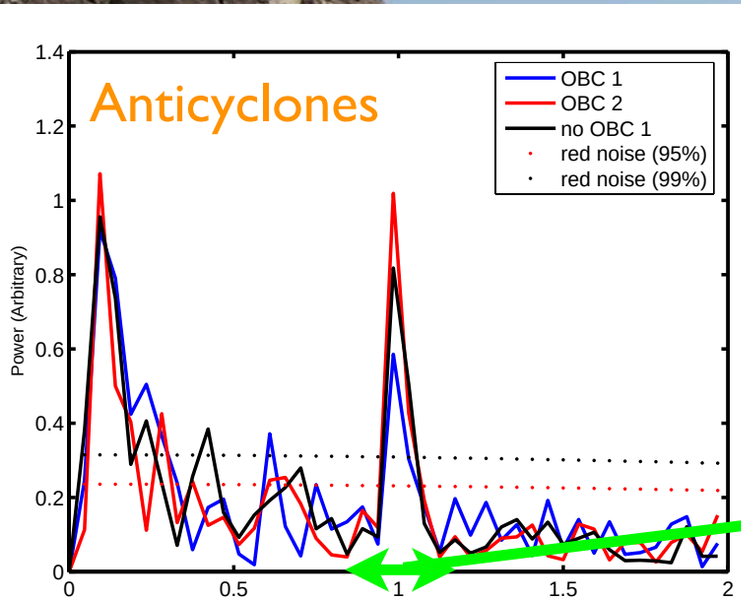



Low Frequency: 29% 23% 26%

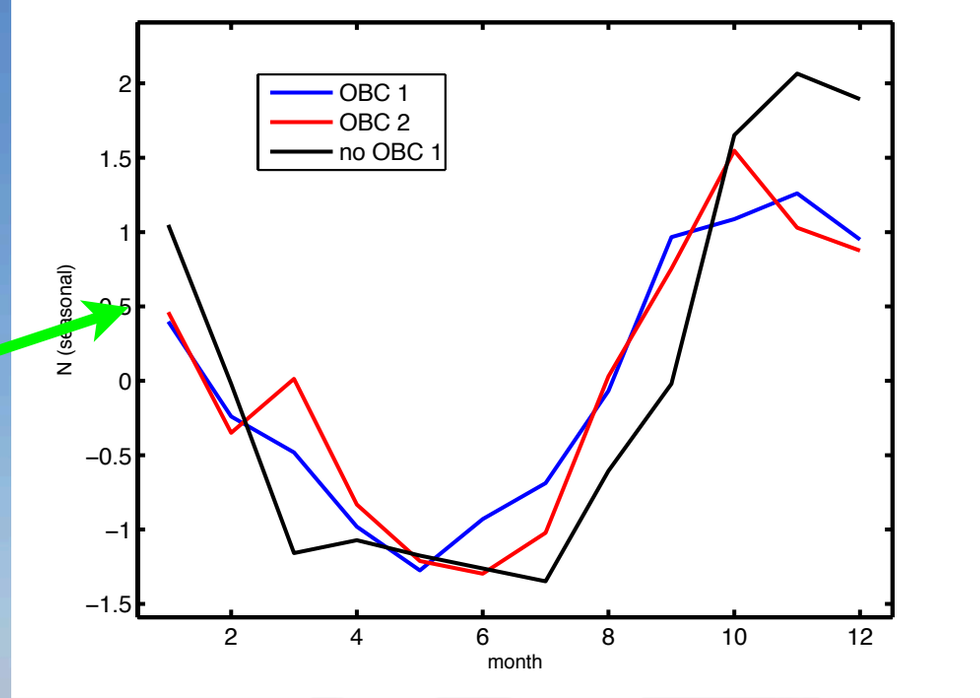
Seasonal: 9% 15% 13%

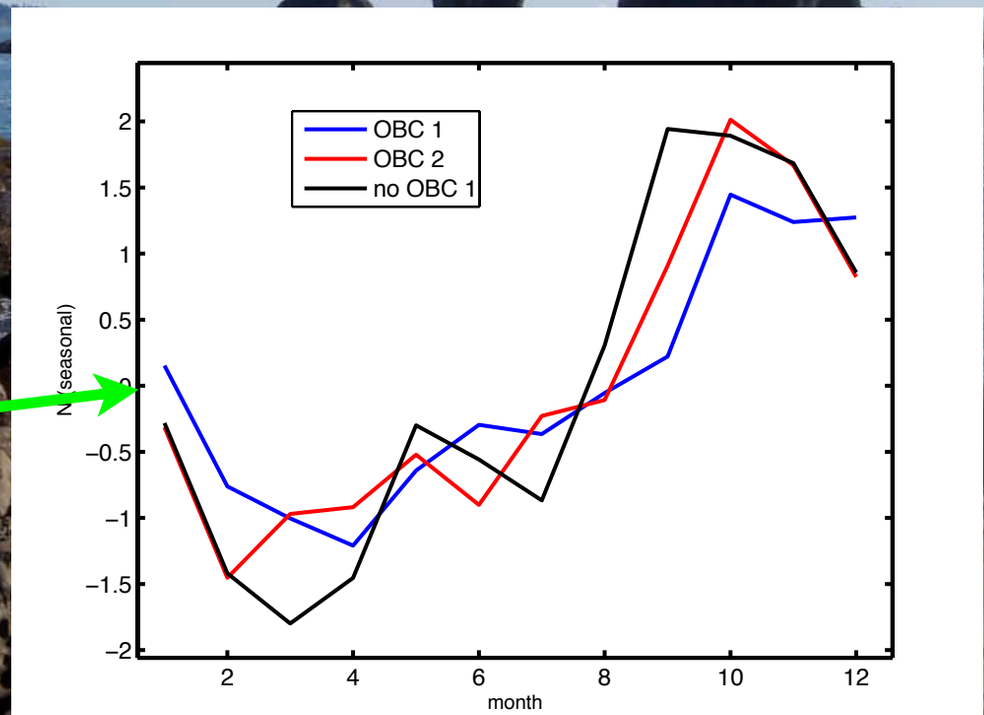
# Eddy Spectra



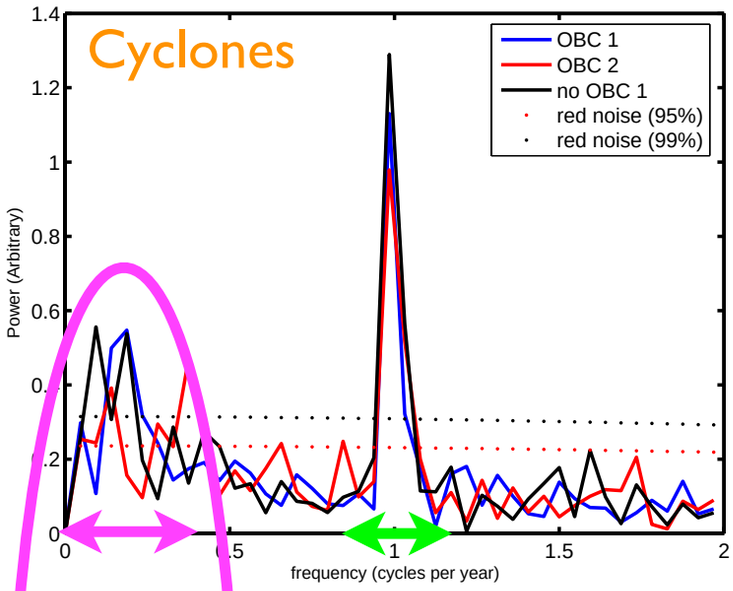



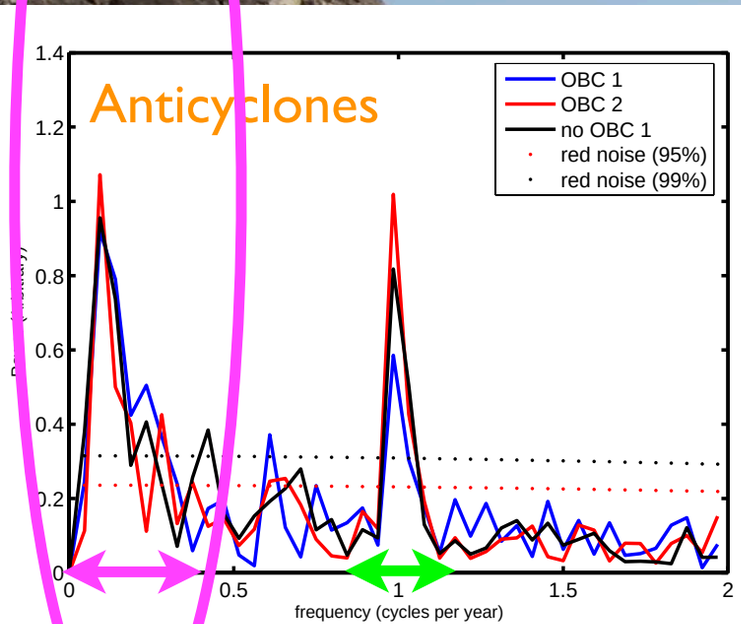

# Seasonal Cycle



# Eddy Spectra (North)



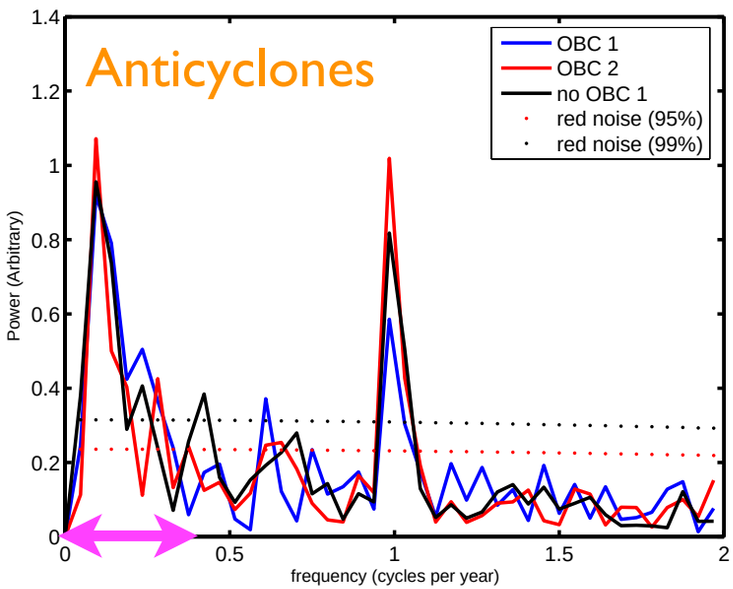

(Periods > 40 months)

*What dynamics control interannual changes in mesoscale eddies in the California Current?*

*What dynamics control interannual changes in mesoscale eddies in the California Current?*

*How much of this variance is forced (deterministic) vs. internal (instrinsic)?*

## Eddy Spectra (North)

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*What dynamics control interannual changes in mesoscale eddies in the California Current?*

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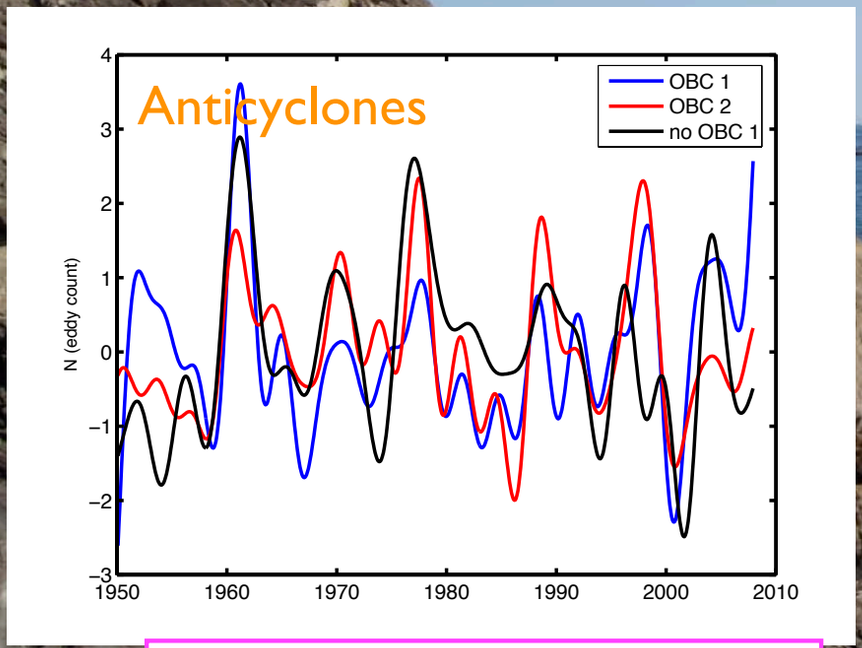
Eddy Time Series (North)

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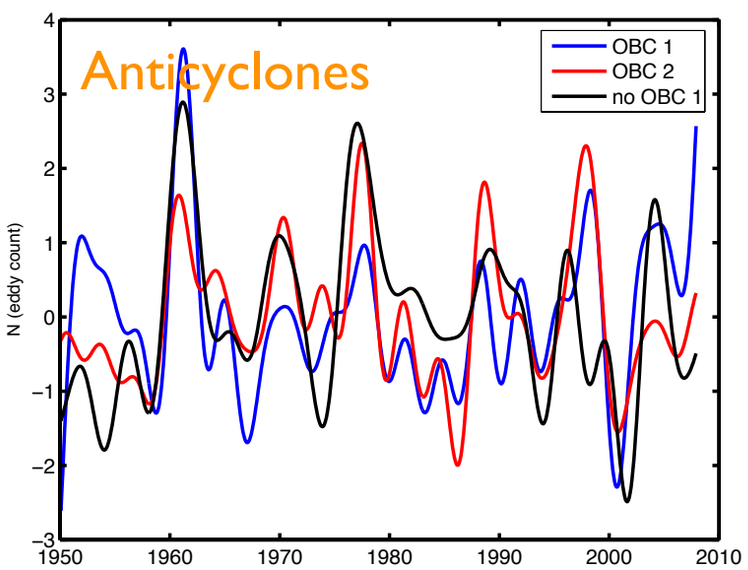


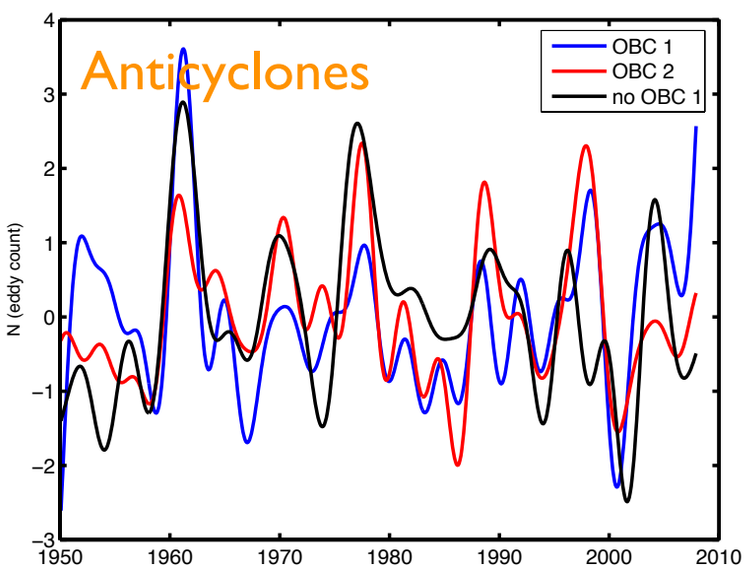

## Correlation Tables (lowpassed)

| | OBC 2 | no OBC |
|---|---|---|
| OBC 1 | 0.594 | 0.473 |
| OBC 2 | | 0.587 |

*What dynamics control interannual changes in mesoscale eddies in the California Current?*

*How much of this variance is forced (deterministic) vs. internal (instrinsic)?*

Eddy Time Series (North)



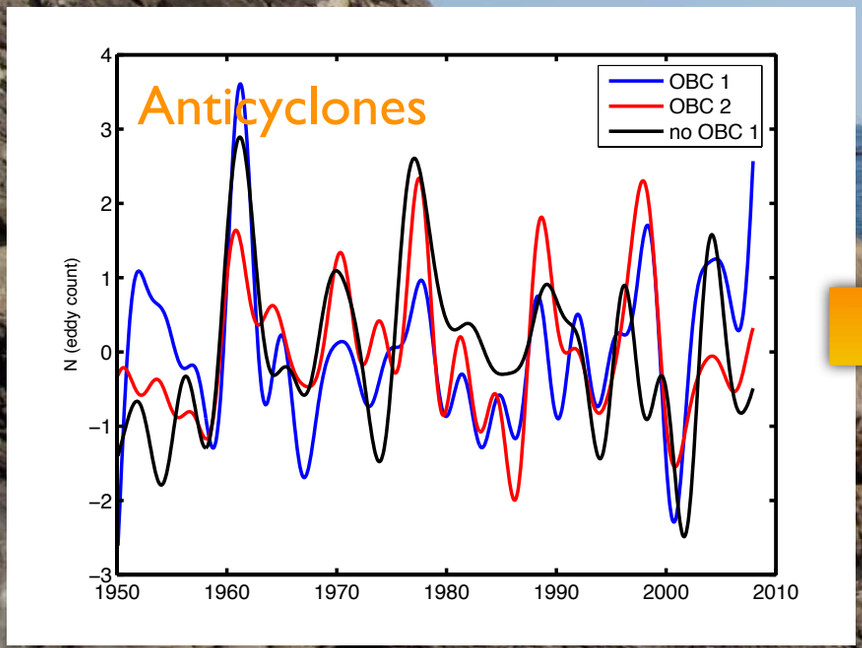

**25-35%** deterministic

Correlation Tables (lowpassed)

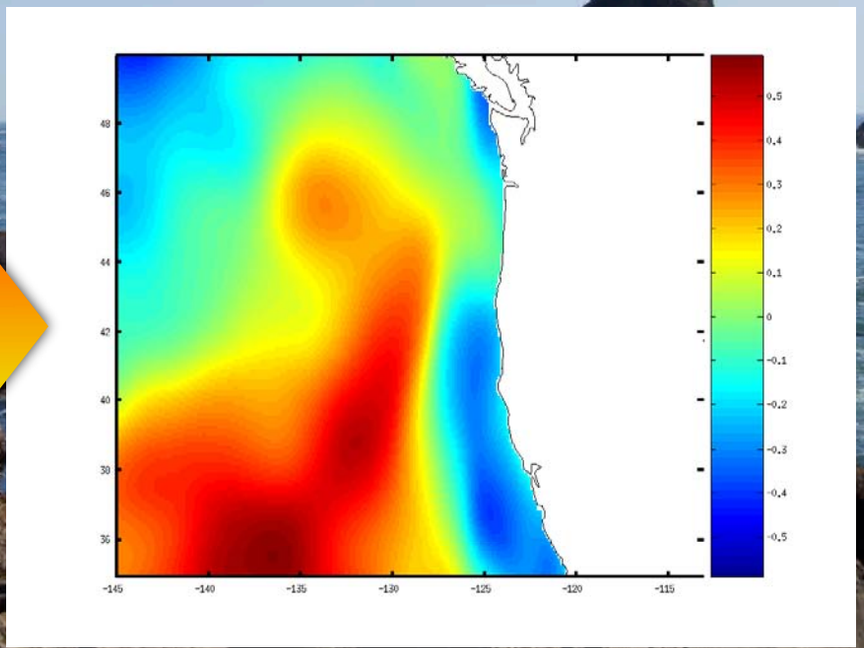
| | **OBC 2** | **no OBC** |
|---|---|---|
| **OBC 1** | 0.594 | 0.473 |
| **OBC 2** | | 0.587 |

*What dynamics control interannual changes in mesoscale eddies in the California Current?*

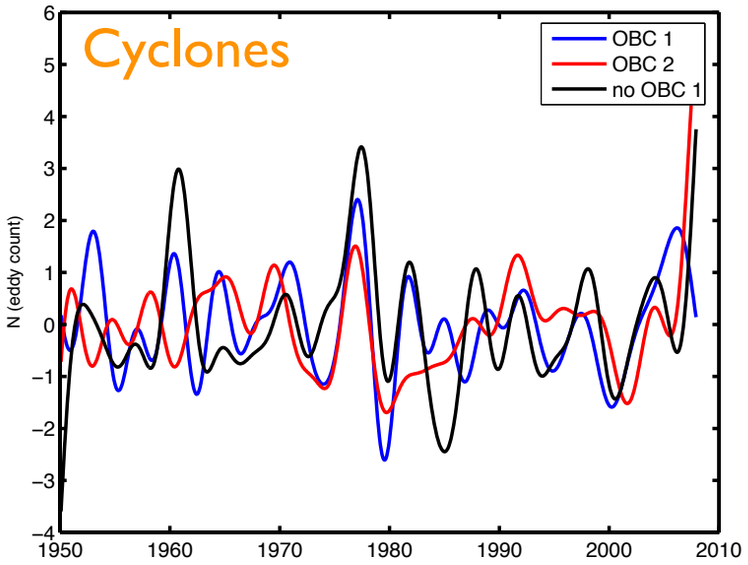
Eddy Time Series (North)

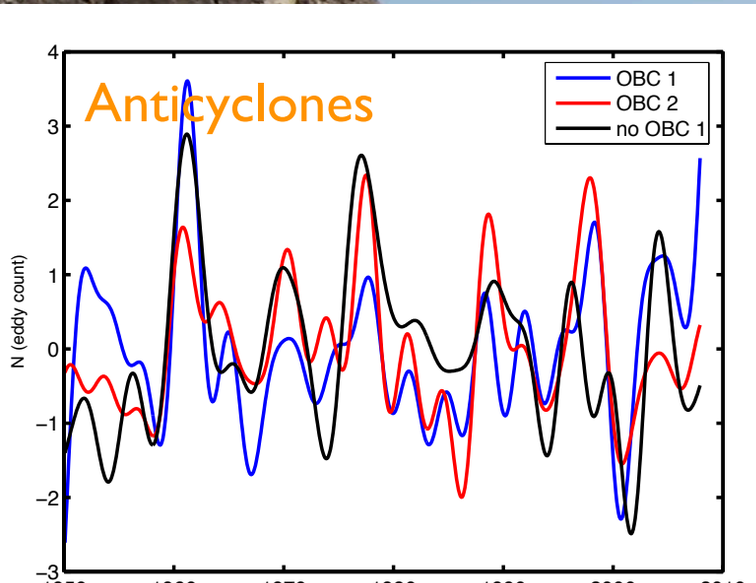



*Wind Stress Curl Forcing Pattern (AR-1)*

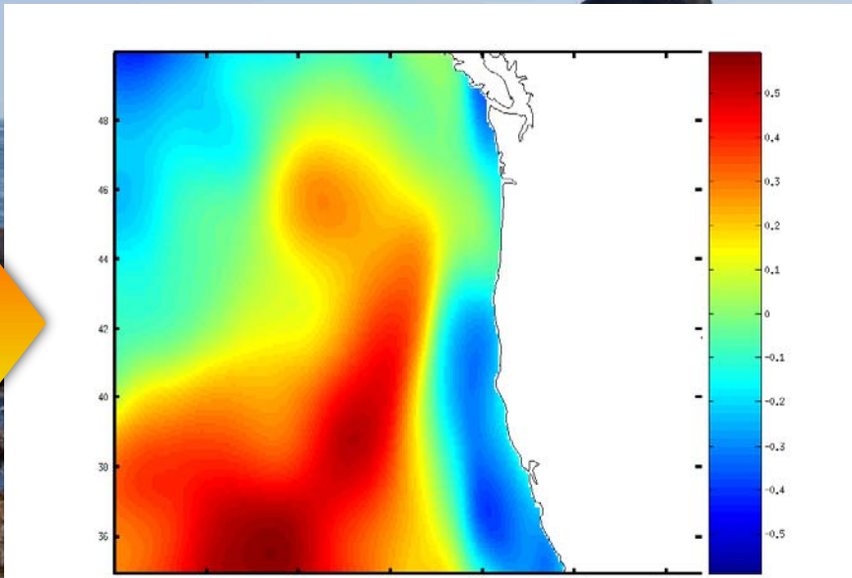


# Eddy Time Series (North)

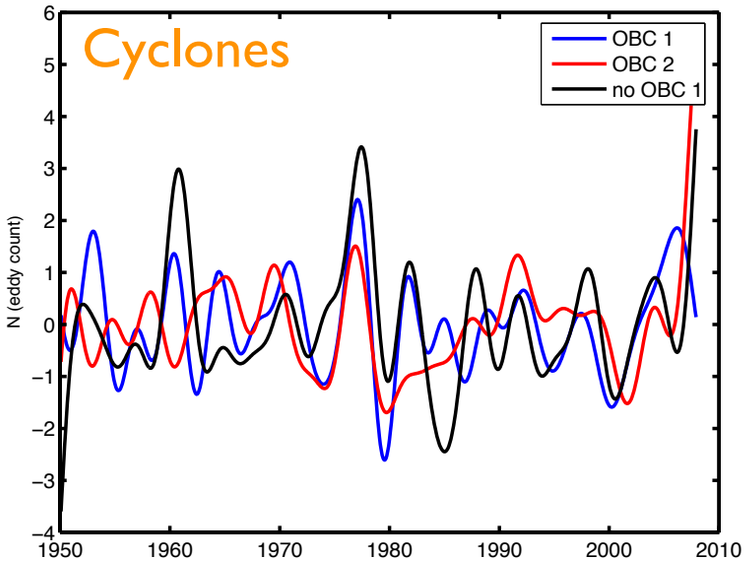


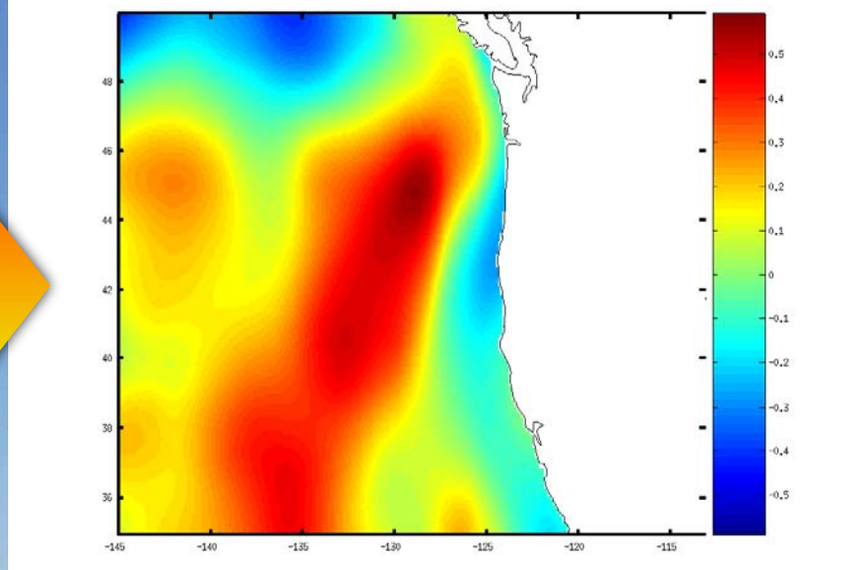



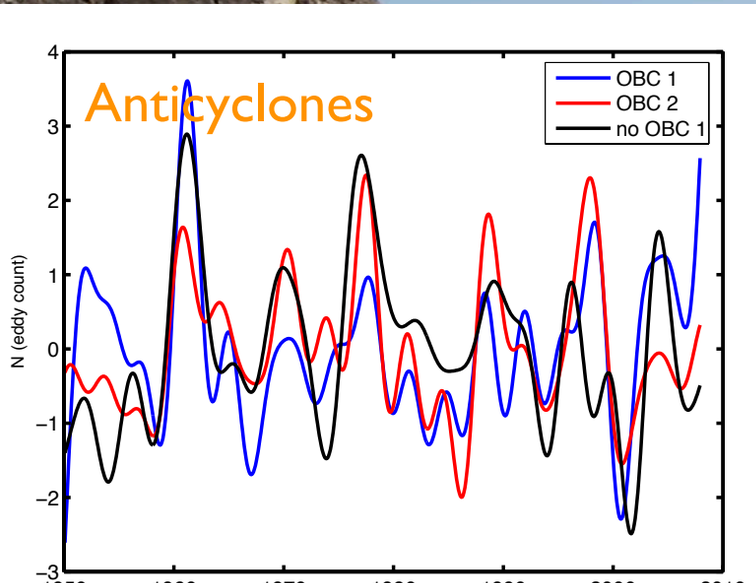

## *Wind Stress Curl Forcing Pattern (AR-1)*

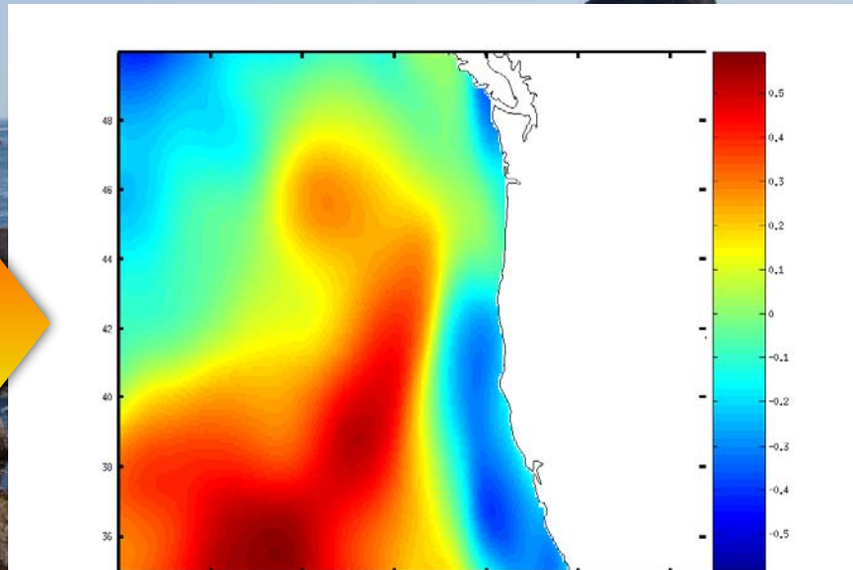


# Eddy Time Series (North)

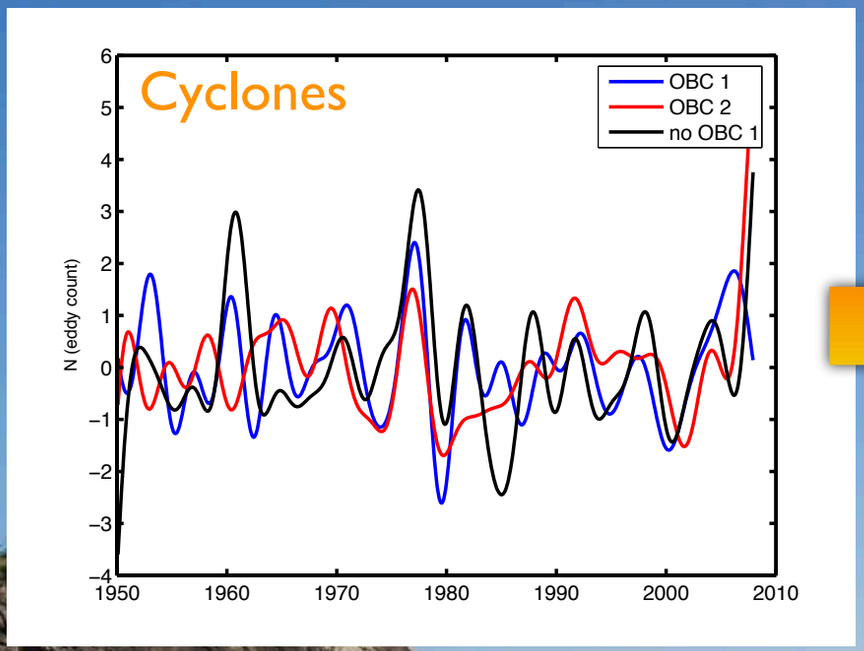


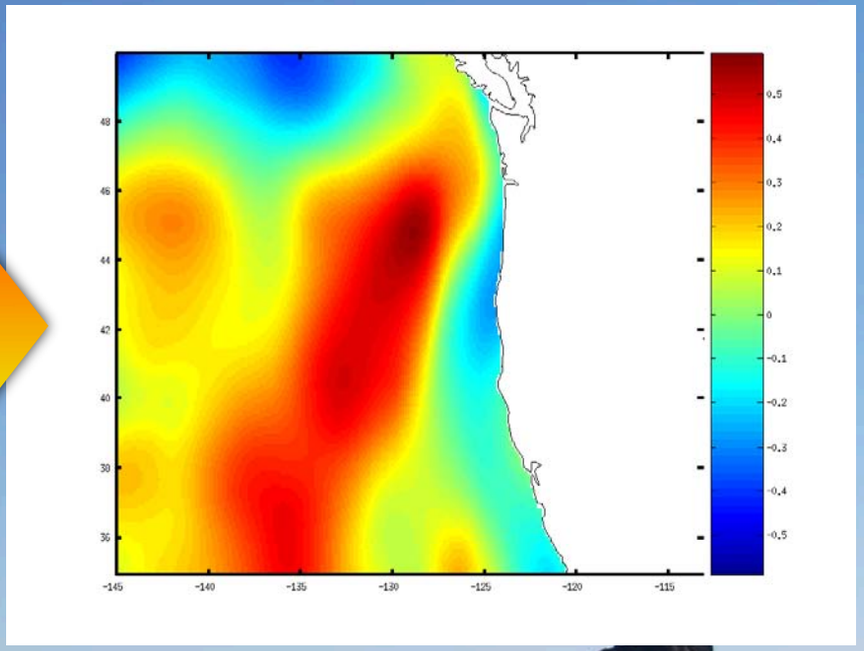



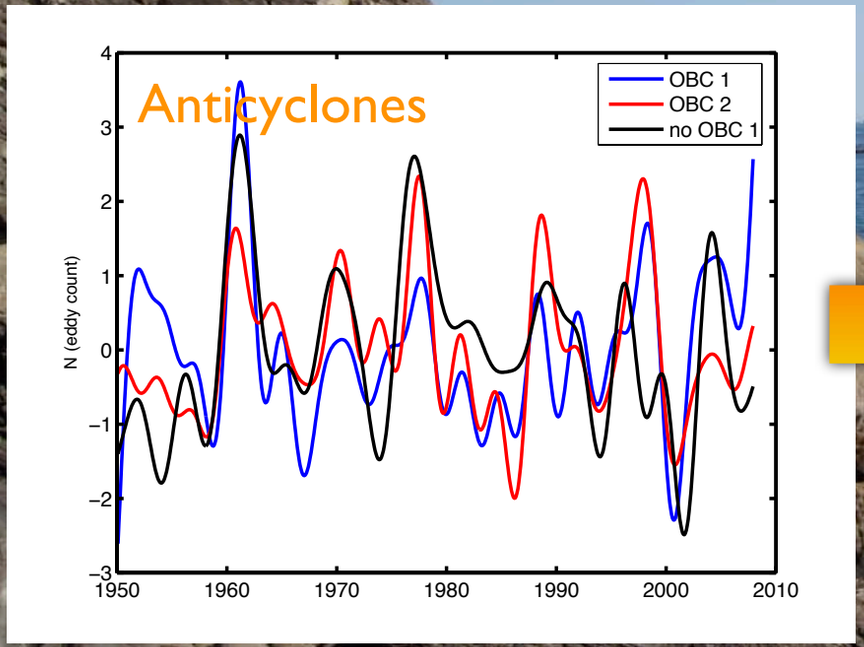



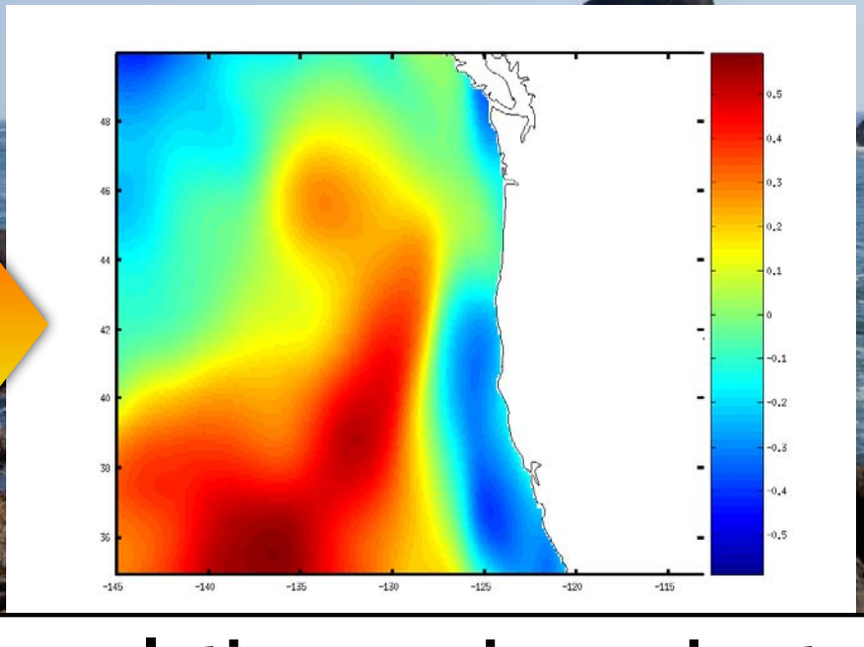



# Eddy Time Series (North)



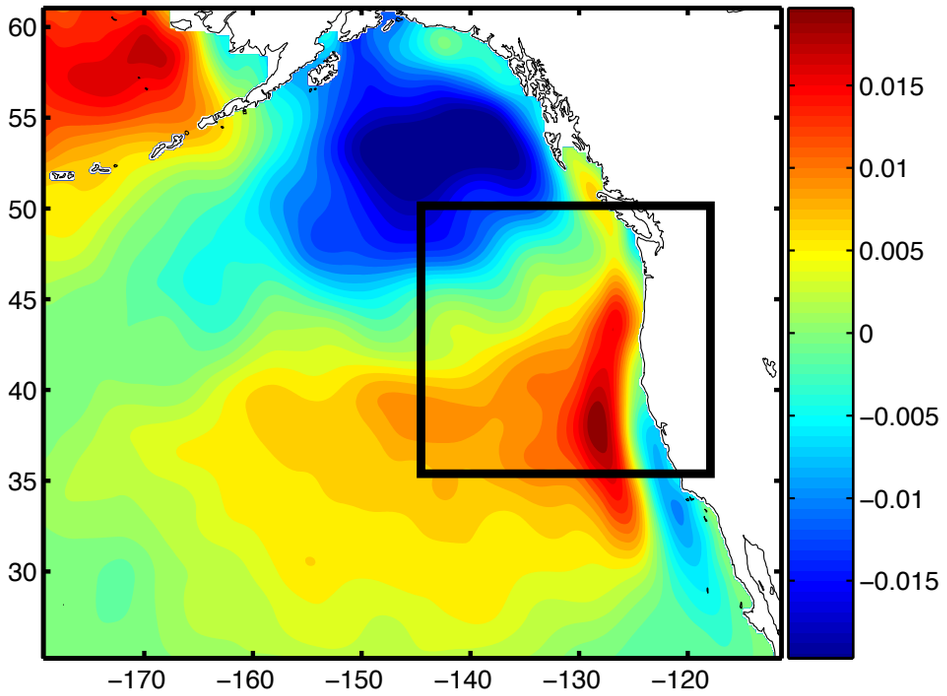



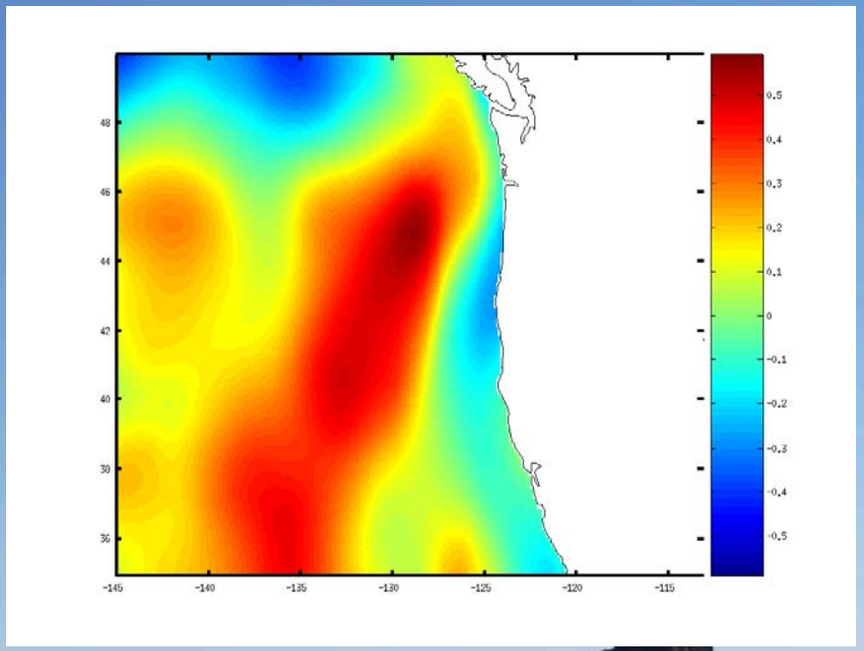


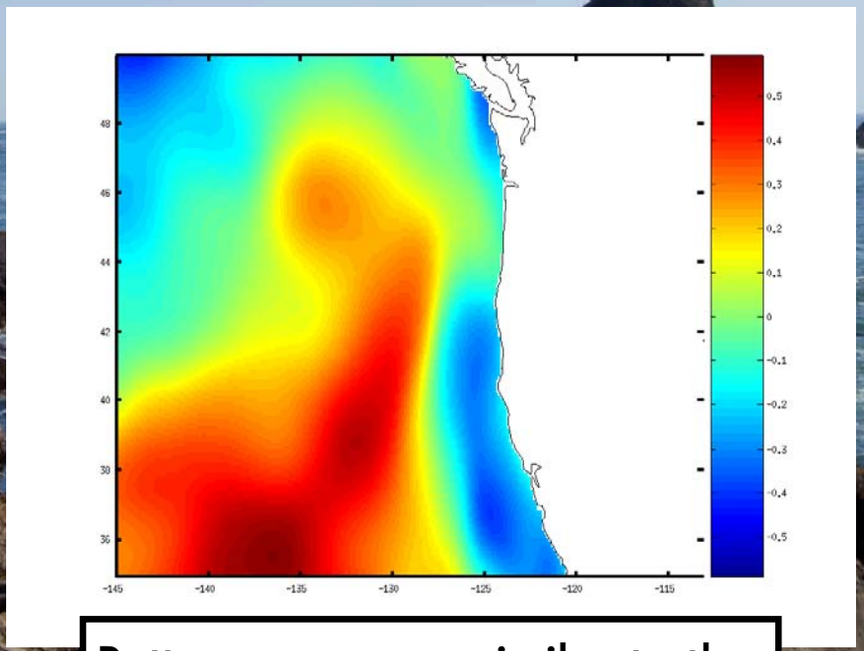



**correlation maximum is at .6**

# NEP WSC EOF3 (7% of variance)

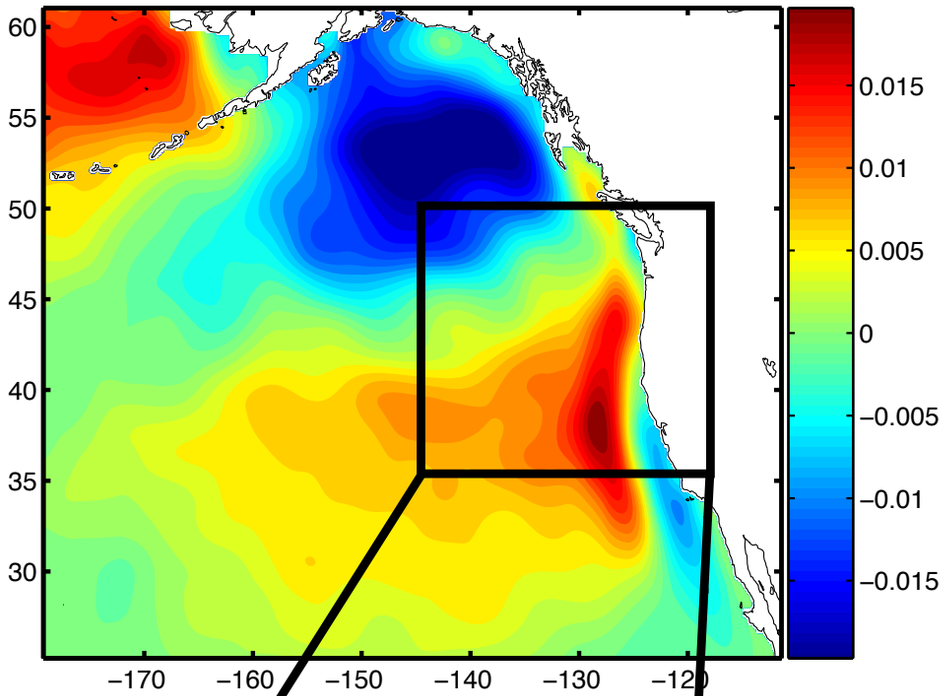


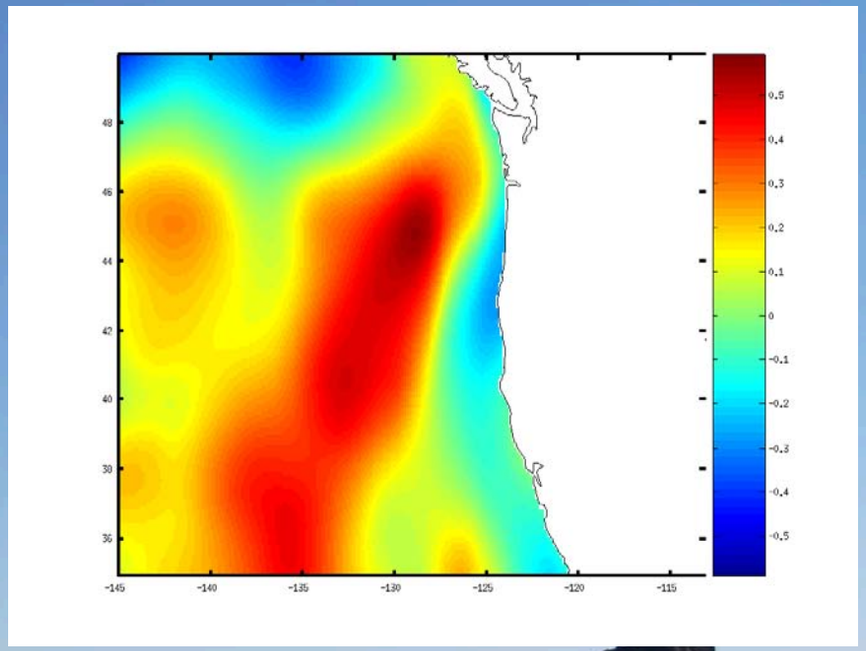



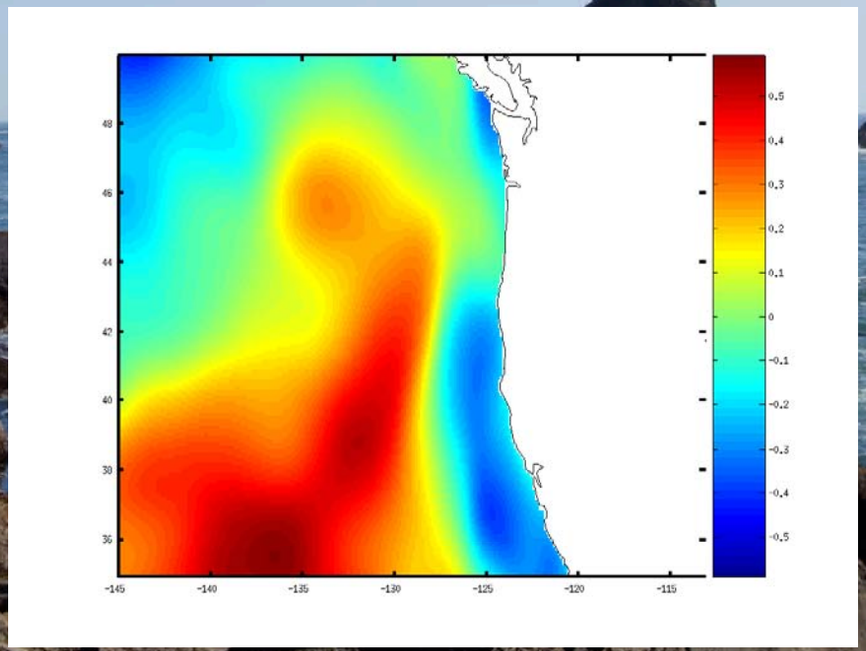


Patterns are very similar to the third EOF of Northeastern Pacific wind stress curl.

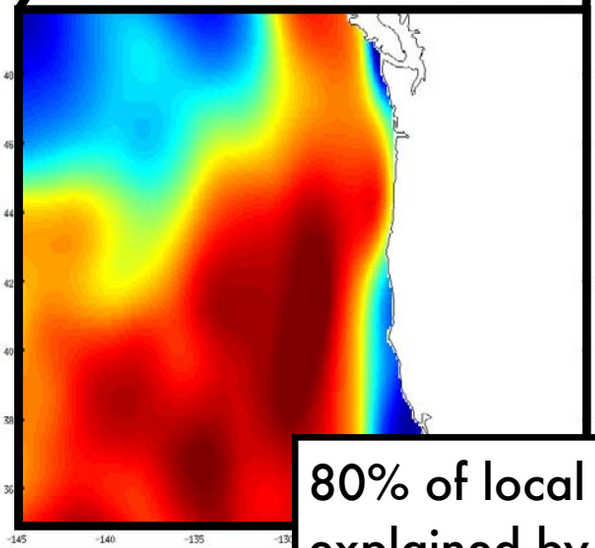
# NEP WSC EOF3



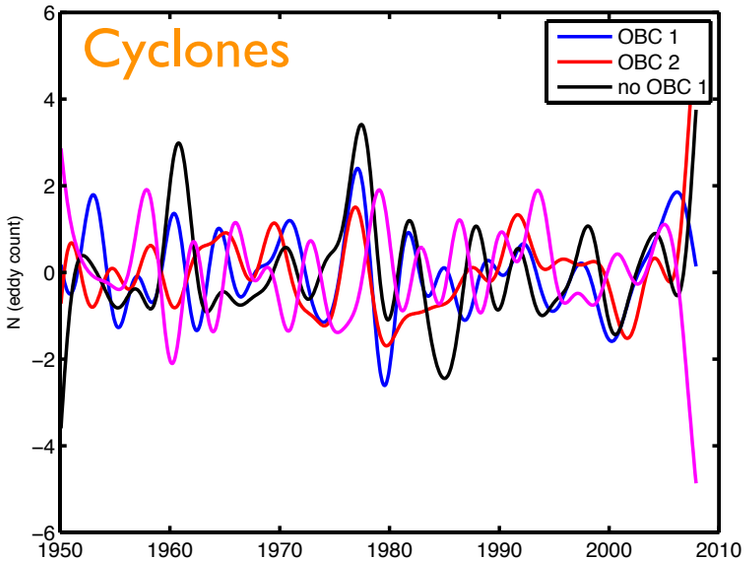


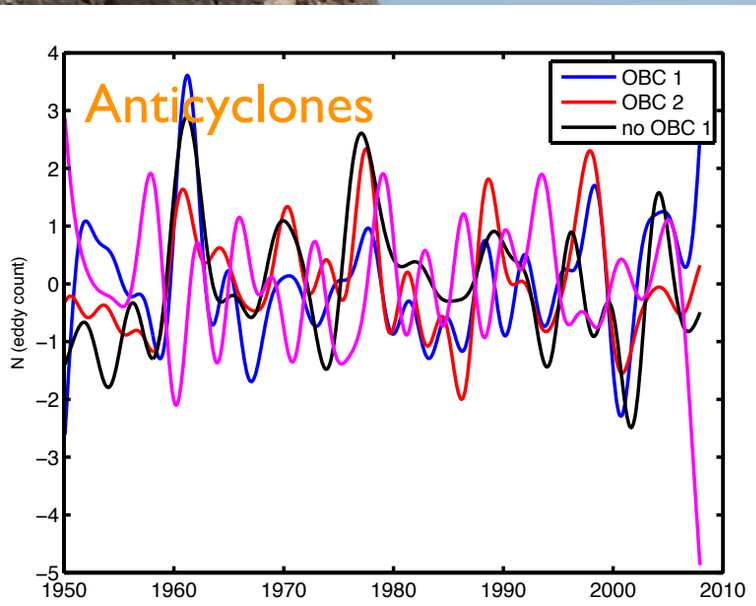
Variance explained by PC3



80% of local variance is explained by PC3

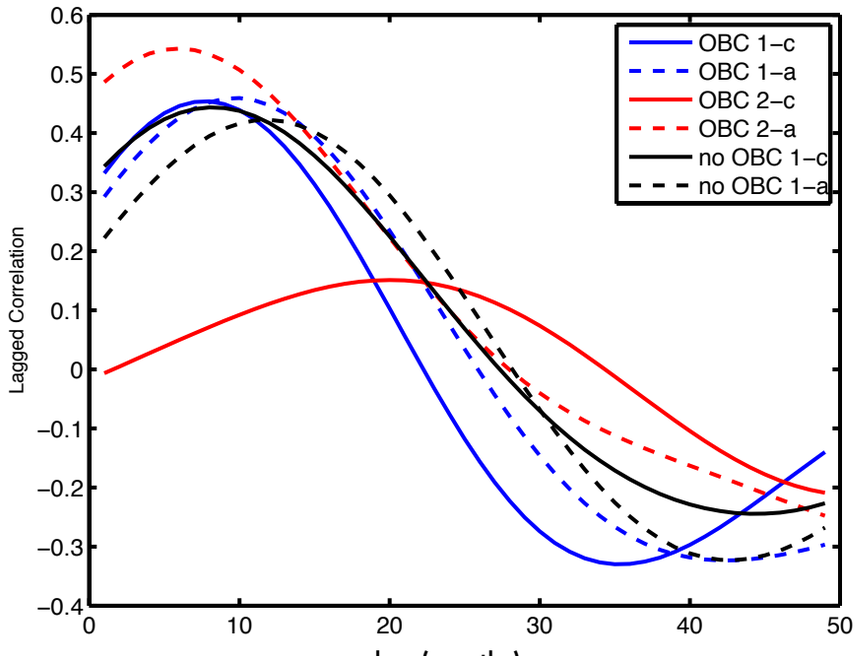
# Eddy Time Series (North)



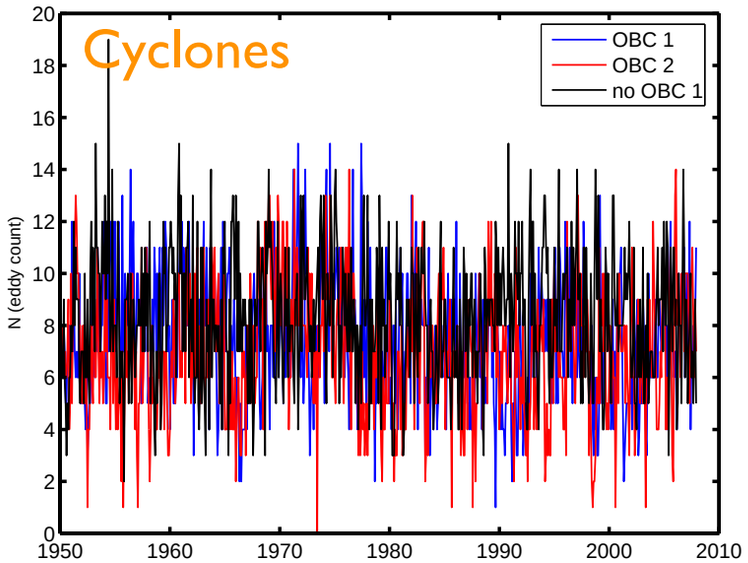




Both anticyclonic and cyclonic eddy counts show a strong correlation with PC3 at a lag of 5-8 months.

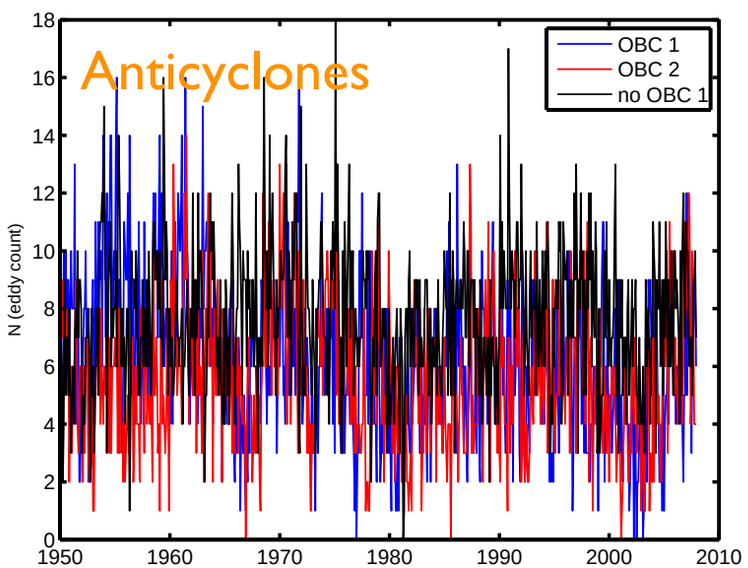
## Lagged Correlations with WSC PC3



# Eddy Time Series (South)

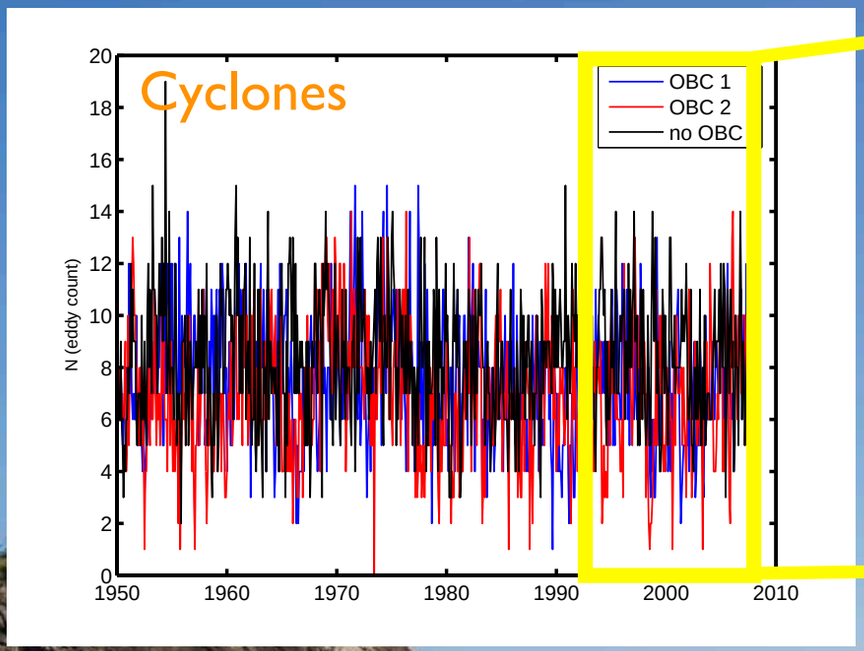


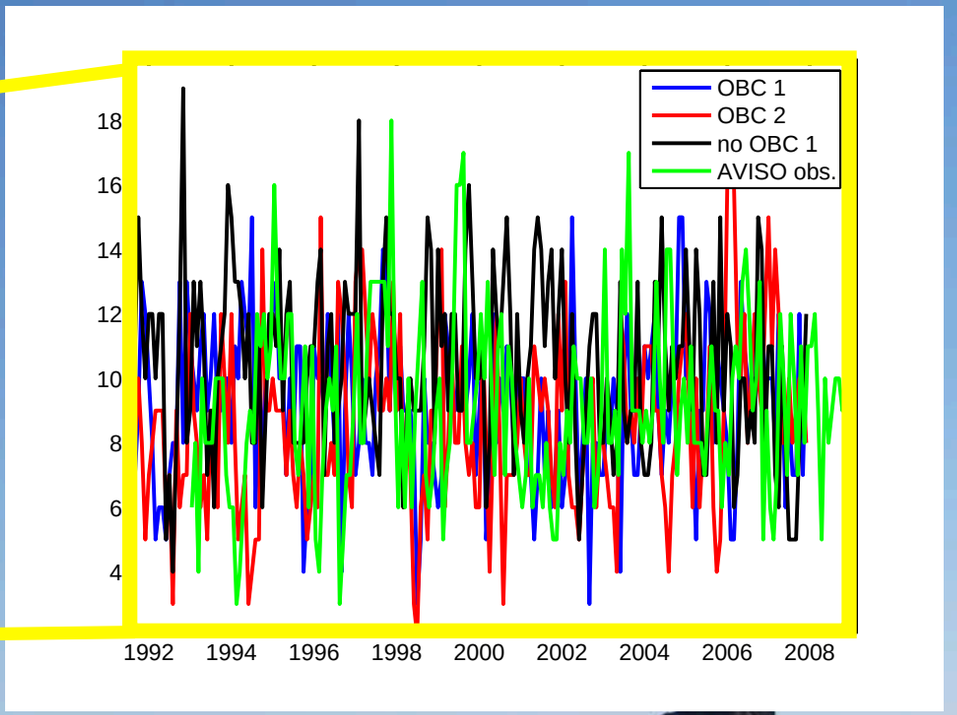

mean: 9.6 8.9 10.3
std: 2.7 2.7 2.7

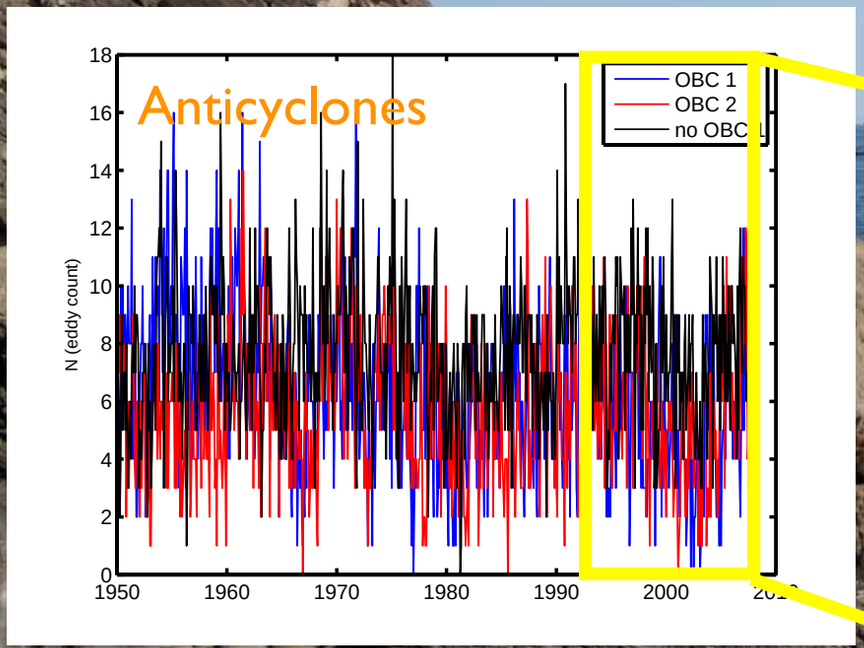


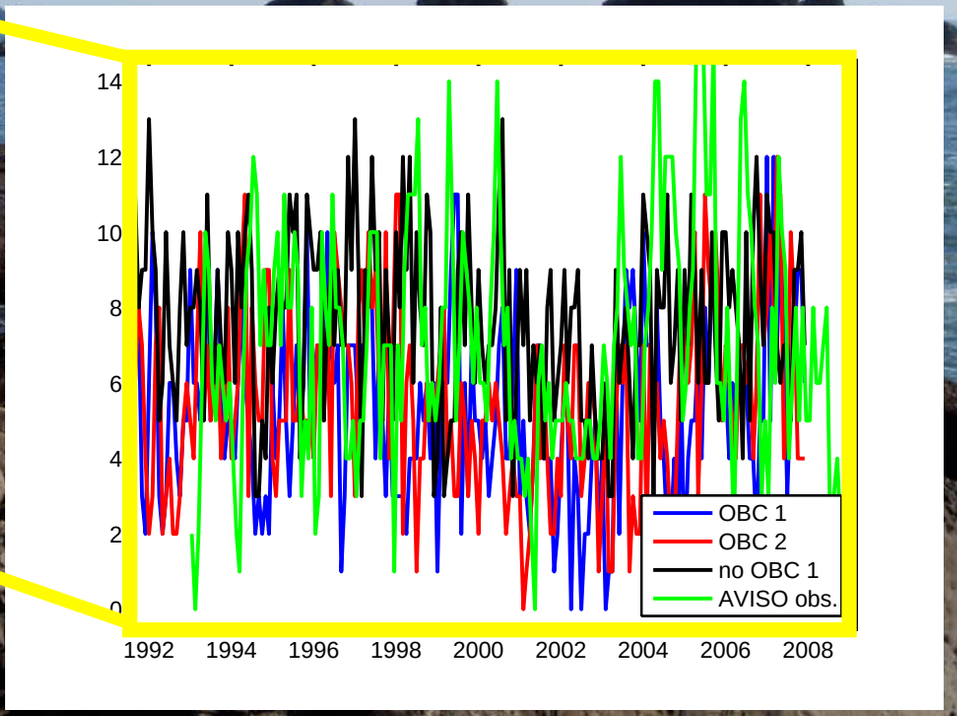

mean: 6.2 5.6 7.7
std: 2.8 2.4 2.5

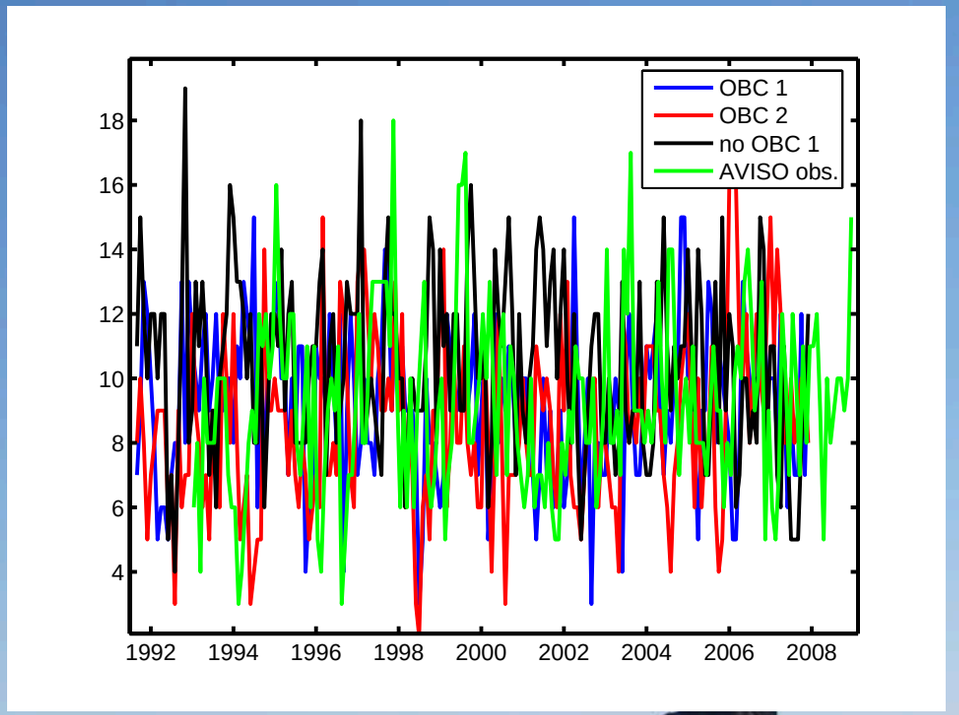
# Eddy Time Series (South)



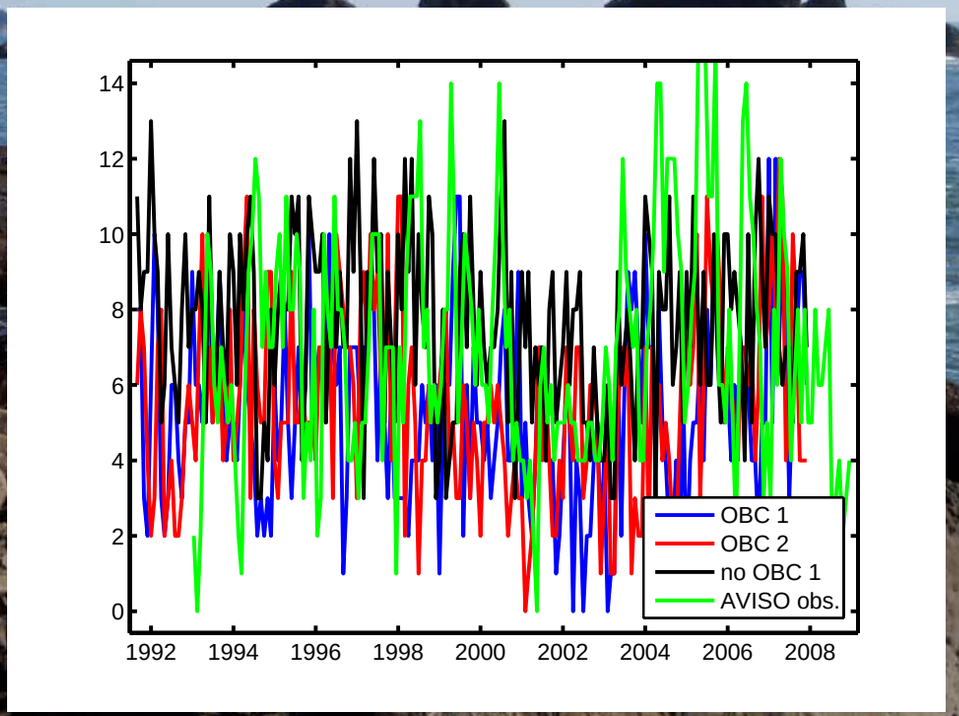



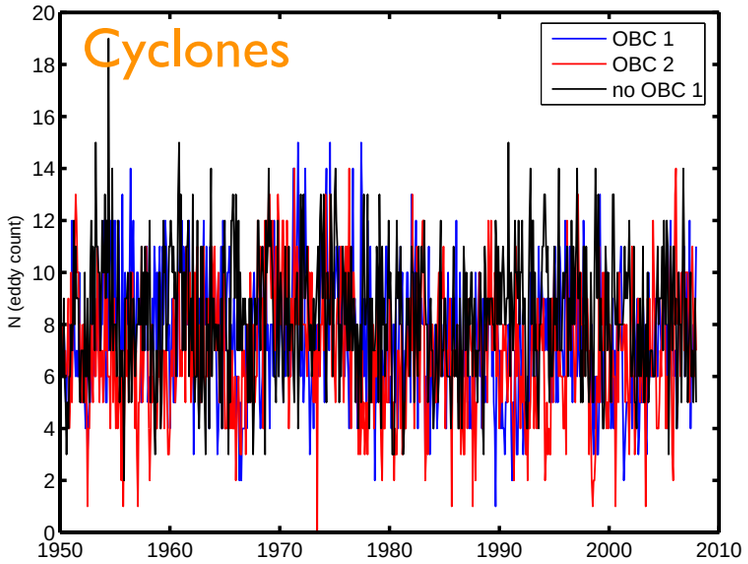


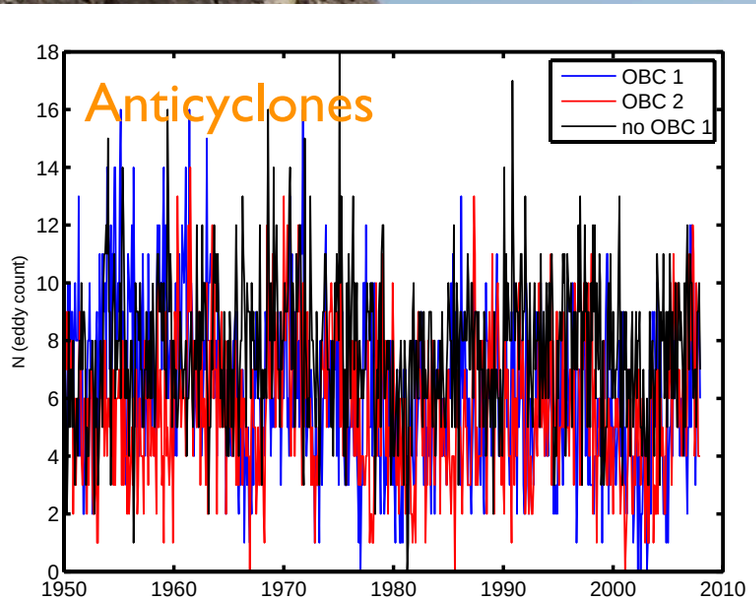

# Correlation Table

| | OBC 2 | no OBC | AVISO |
|---|---|---|---|
| OBC 1 | 0.172 | 0.110 | 0.120 |
| OBC 2 | | 0.148 | 0.204 |
| no OBC | | | 0.078 |

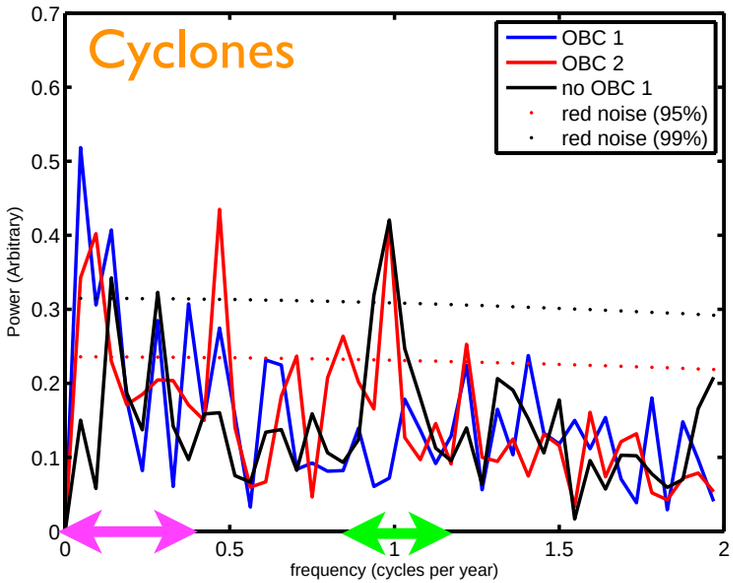


# Eddy Time Series (South)



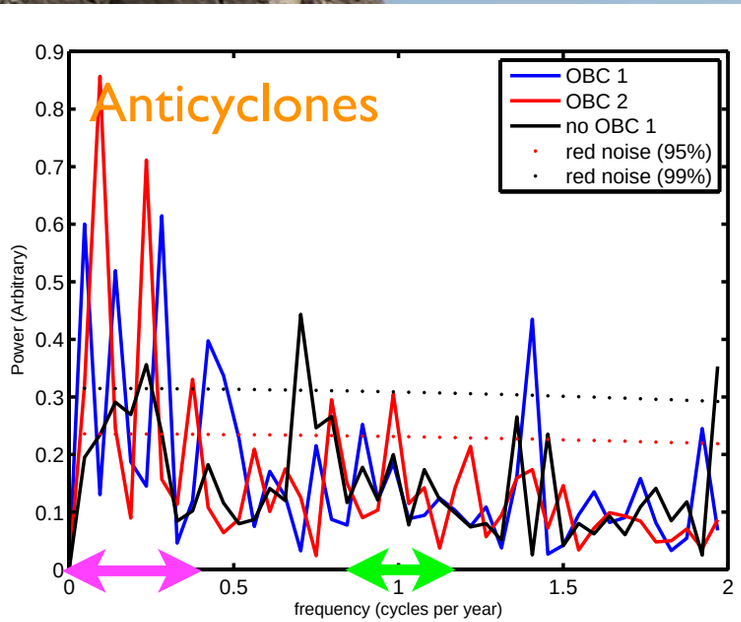



# Eddy Spectra (South)




Low Frequency: 15% 14% 11%

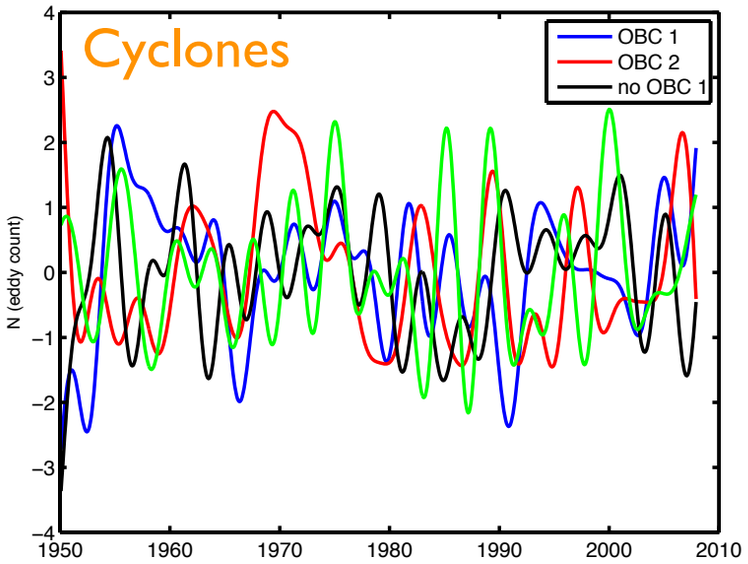
Seasonal: 5% 8% 10%

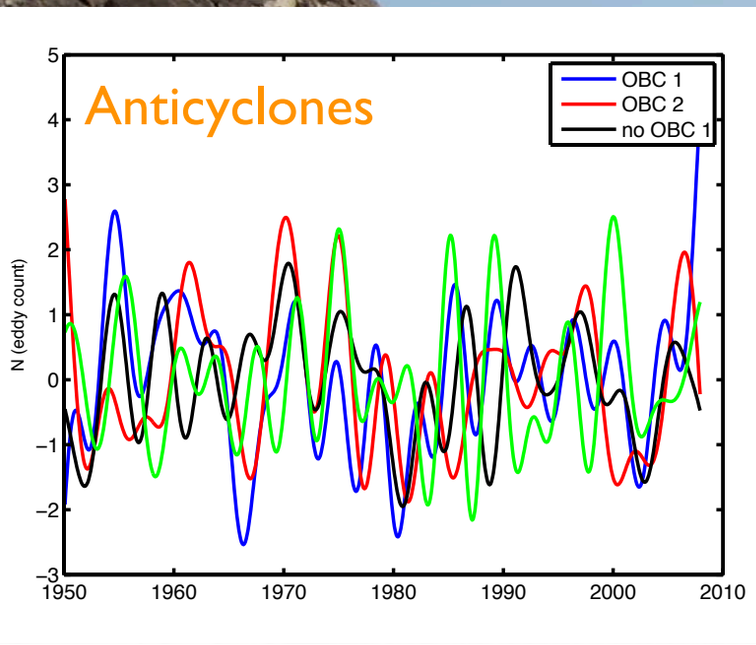



Low Frequency: 19% 20% 13%

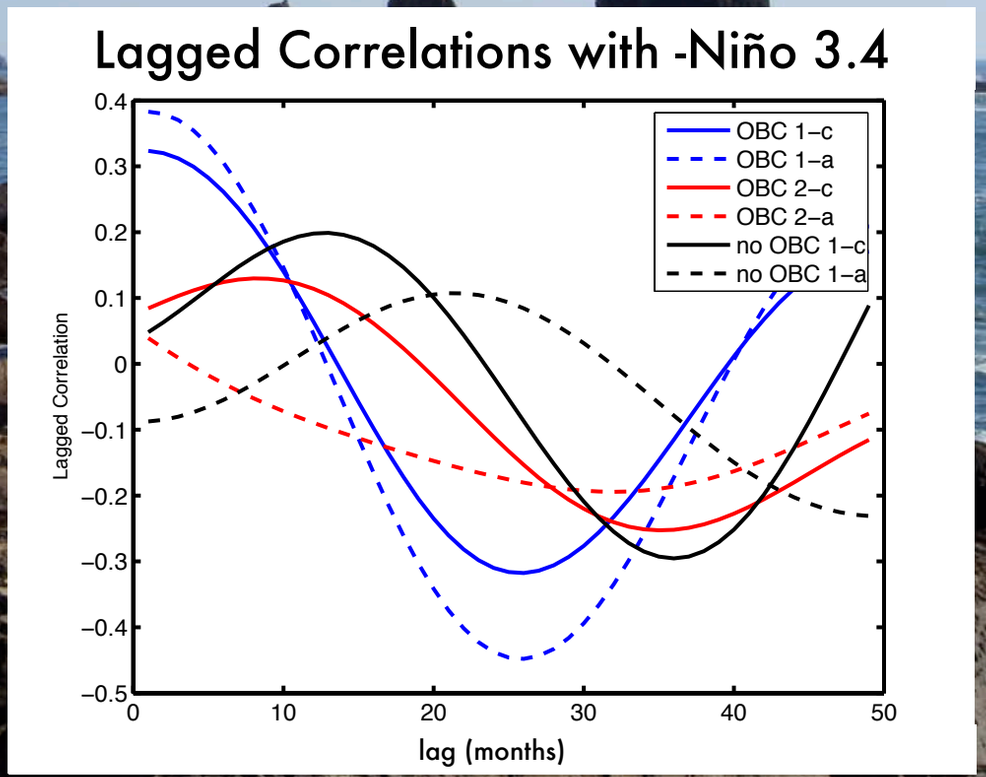
Seasonal: 5% 6% 6%

# Eddy Time Series (South)



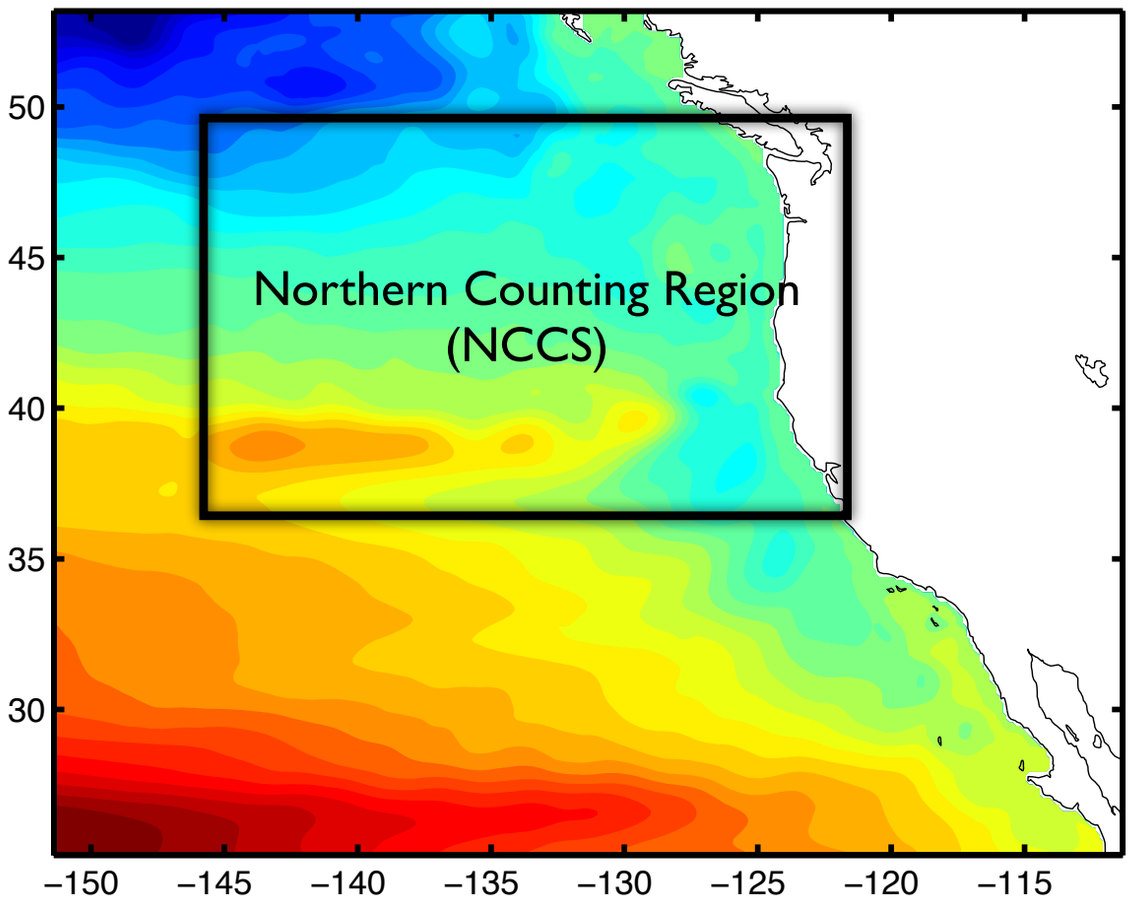

There is a weak ENSO signal in the OBC 1 eddy counts, but otherwise it resembles red noise.



## *SUMMARY*

1. North of the Southern California Bight, eddies have a large amount of driven variance associated exclusively with low-frequency variance in wind stress curl.

## ROMS Mean SSH



## *SUMMARY*

1. North of the Southern California Bight, eddies have a large amount of driven variance associated exclusively with low-frequency variance in wind stress curl.

2. South of the Southern California Bight, excluding a weakly significant ENSO signal from tropical Coastal-Trapped Waves, eddy formation is a red-noise process.

## ROMS Mean SSH