# Mesoscale Eddies Modulate Mixed Layer

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Overview

1. Background on the problem

2. Observations of mesoscale modulations of MLD

3. Discussion differences between cyclones and anticyclones

Suomi-NPP/VIIRS 14 May 2015 Georges Bank and Gulf Stream North Wall

# *In situ* Observations of Eddy-Mediated MLD Variability





Waite *et al.* (2007b) figure 5, b and c

#### Argo Float Profiles In Eddies



In total there were 222,879 Argo float profiles in eddies during the period 1-Jan-2000 through 23-Apr-2015, representing **23%** of all profiles.

#### **Profiles in Cyclones and Anticyclones**



114,224 profles in anticyclones 12% of all profiles

108,655 profiles in cyclones 11% of all profiles

### Combing Altimetry and Argo to Observe Eddy-Impacts on MLD Variability



Argo float profiles collocated to South Indian Ocean eddies tracked in maps of sea level anomaly

#### Seasonal Cycle of MLD in South Indian Ocean Eddies

MLD from Argo float profiles (Holte and Talley, 2009, http://mixedlayer.ucsd.edu/)



#### Net Effect of Eddies on MLD in the Southern Ocean



- Observed that over much of the SO, eddies generate deeper mixed layer depths
- Concluded that eddies have result in a small, yet significant, deepening of MLD.

# Global Observations of Eddy-Mediated MLD Variability



# Global Observations of Eddy-Mediated MLD Variability



# Seasonal Variability of Eddy Impacts on MLD Harmonic fit of seasonal cycle to MLD estimated from Argo profiles collocated to eddies



#### **Eddy-Centric Analysis**





- The largest eddy-induced MLD anomalies occur in the inner-core
- Anomalies become indistinguishable from zero at a distance of about 1 L<sub>s</sub>.
- The magnitude of MLD anomalies is larger in anticyclones.

#### Anticyclones Generate Larger MLD Anomalies



#### Winter MLD Anomalies



# Winter MLD Anomalies Overlaid with Eddy Amplitude



# Magnitude of MLD Anomalies Scale with Eddy Amplitude



- In anticyclones, MLD anomalies scale linearly with eddy amplitude, slope of 100/1.
- Cyclones scale with a slope of ~90/1.
  - This relationship can be used as a basis from which to examine eddyimpacts on MLD and subsequent effects on biogeochemical cycling and air-sea interaction.

# Summary and Conclusions

- Eddies modulate mixed layer depth globally with anticyclones generating deeper MLD and cyclones shoal MLD.
- The largest eddy-induced MLD anomalies occur in the inner core of eddies.
- The magnitude of MLD anomalies is larger in anticyclones compared to cyclones
- Magnitude of MLD anomaly scales with eddy amplitude.

### **Future Direction**

- Identify mechanisms generating asymmetry in magnitude of MLD anomalies in cyclones and anticyclones.
- Determine the role that eddy-induced MLD variability plays in modulating phytoplankton growth and mortality rates:
  - 1) Enhanced nutrient supply in anticyclones due to deeper mixing [Song et al., (in review), Dawson et al., (submitted)]
  - 2) Decoupling of grazers from phytoplankton in anticyclones during deep mixing (central focus of NASA NAAMES project).

#### Deeper MLD in South Indian Ocean Anticyclones Results in Enhanced Nitrate Flux



#### Deeper MLD in Southern Ocean Anticyclones Results in Enhanced Iron Flux -or -Light Limitation Song et al., (2017; in review



### Eddy-Mediated Export Observed by Bio-Argo Float

