Do Sub-Mesoscales Control Vertical Iron Transport in the Southern Ocean?

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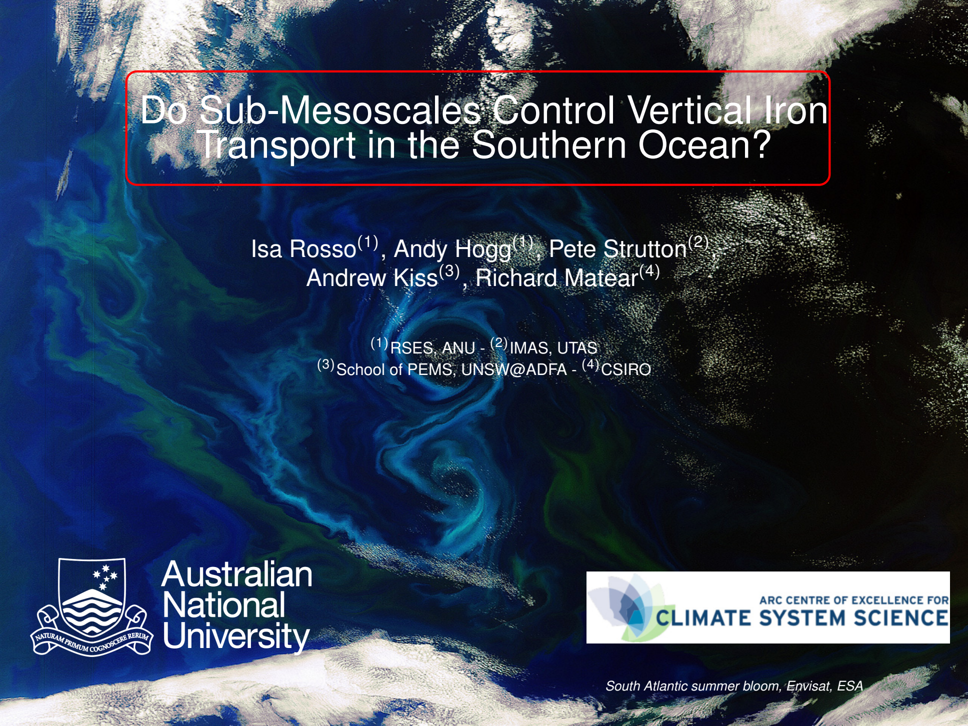
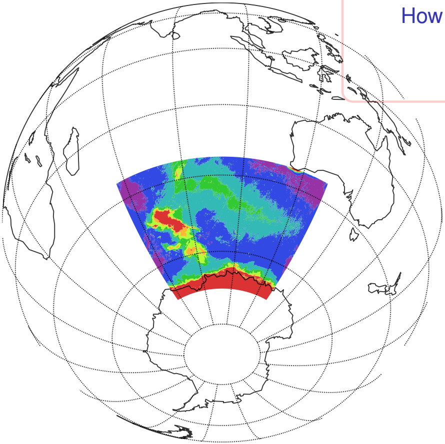
ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE



South Atlantic summer bloom, Envisat, ESA

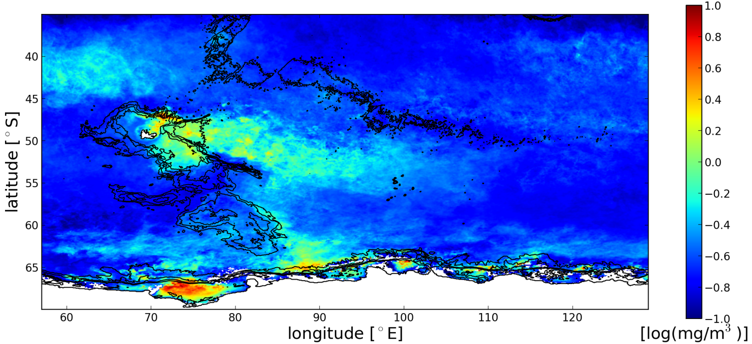
Topic

What	Ocean model
Where	Indian Ocean sector of the Southern Ocean (fundamental role in climate system)
How	Numerical simulations of ocean circulation at very high horizontal resolutions (1/20° and 1/80°)



GOAL *study physical processes that may influence biological activity in the Southern Ocean*

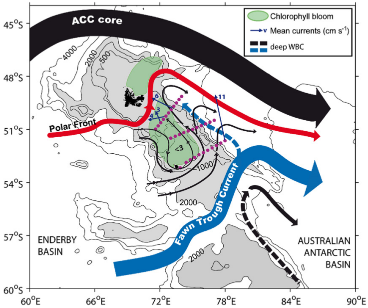
The Kerguelen Plateau: why here?



Monthly climatology (December 2002-2012) of chl a concentration in the South Indian basin (Aqua MODIS 9 km)

- ⋆ Southern Ocean → rich in nutrients, but chlorophyll concentration not high
- ⋆ Iron is limiting phytoplankton activity
- ⋆ Several locations of elevated chl concentration (e.g. bloom in the Kerguelen Plateau Region)

Natural fertilisation fuel biogeochemical cycles in the Kerguelen Plateau region



Park et al. (2008)

Blain et al. (2001) and Bucciarelli et al. (2001)

Elevated chl due to natural fertilisation

↓

What drives iron here?

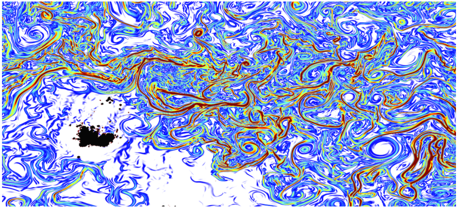
1. *Park et al. (2008), VanBeek et al. (2008)*
   Enhanced vertical mixing due to high-energetic tidal wave activity over the plateau
2. *Mongin et al. (2008)*
   Horizontal advection of iron from the shelf
3. *Maraldi et al. (2008)*
   Lateral mixing
4. *Gille et al. (2014)*
   Wind-induced upwelling

Blooms show small structures..

Small-scale fronts as filaments and eddies

Chatham Island, NASA image by Jeff Schmaltz, MODIS

1. Horizontal length scale of O(10 km), vertical scale of O(MLD), timescale of O(days)



2. Emerging from:
   - ⋆ frontogenesis
   - ⋆ ageostrophic baroclinic instabilities

   Mahadevan and Tandon (2006), Capet et al. (2008), Thomas and Ferrari (2008)

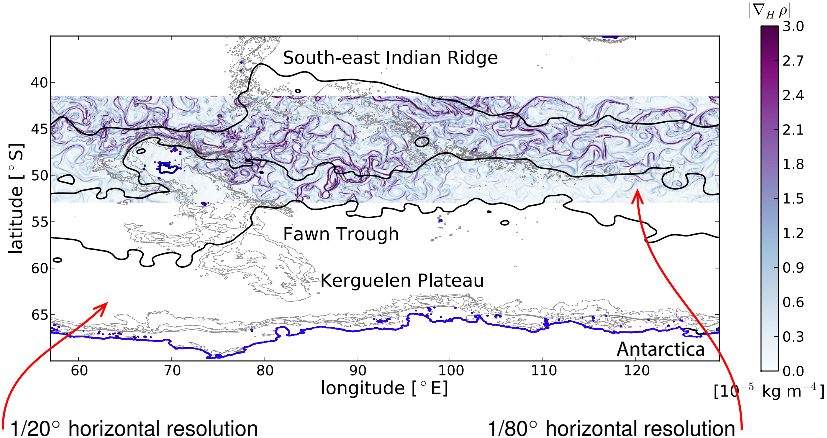
3. Fronts have large vertical velocities
   Levy et al. (2001), Capet et al. (2008), Rosso et al. (2014)

4. Iron concentration is greater at depth

1. *Can the sub-mesoscales contribute to iron supply in the Kerguelen Plateau region?*

2. *What is their contribution respect to mesoscales?*

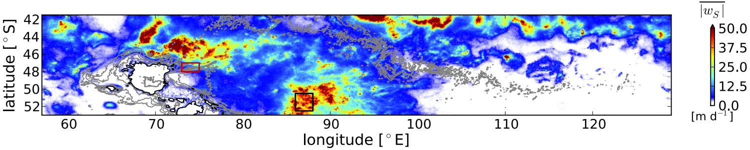
From large-scales to sub-mesoscales



1/20° horizontal resolution (mesoscale-resolving)

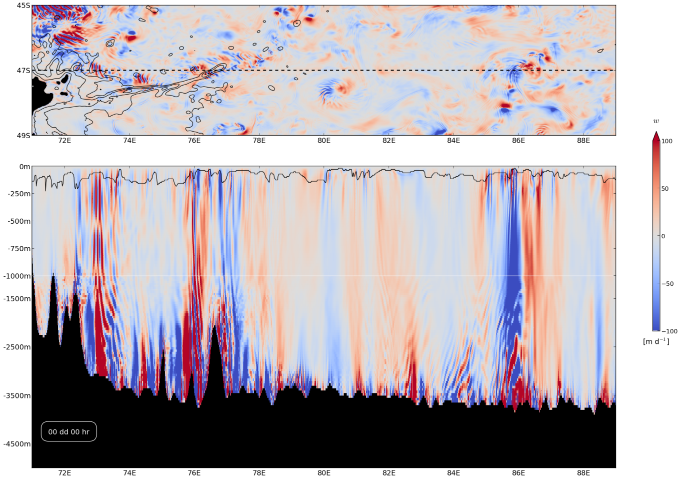
1/80° horizontal resolution (sub-mesoscale-resolving)

Patchiness in the sub-mesoscales



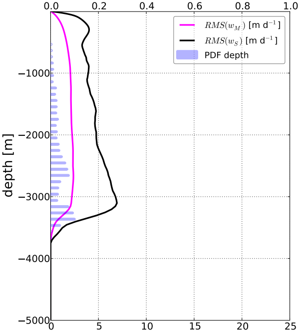
What generates this patchiness?

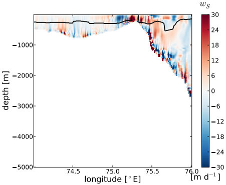
Observing vertical velocities..

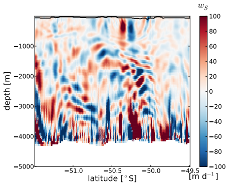


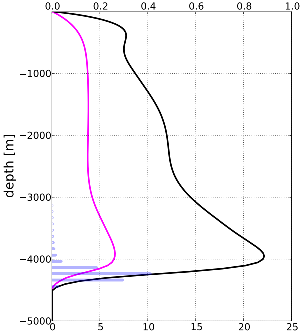
Upper-ocean *w* due to several mechanisms..

Direct generation



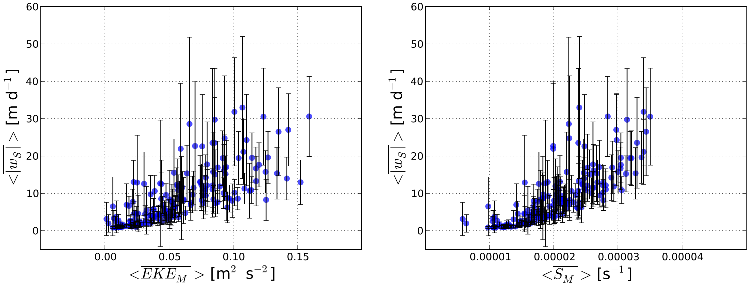






Internal wave activity and sub-mesoscale processes

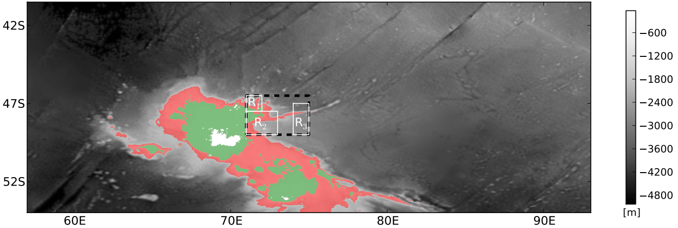
Proxy for sub-mesoscales



Strong correlation ($r = 0.79$ for $< \overline{EKE_M} >$ and $r = 0.82$ for $< \overline{S_M} >$)

Rosso et al. (2015)

Transport from tracking particles..



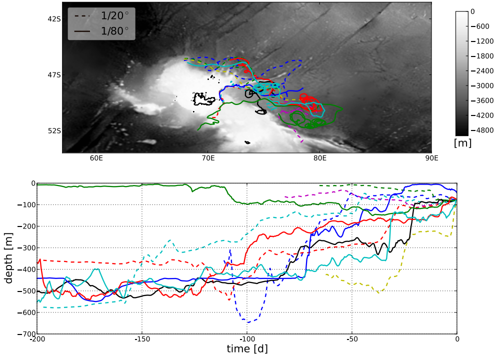
- ⋆ Off-line Lagrangian particle-tracking experiments to investigate transport at the 2 resolutions

Connectivity Modelling System of Paris et al. (2013)

- ⋆ 11500 particles released in the area of phytoplankton activity and run backward in time (max 200 days)

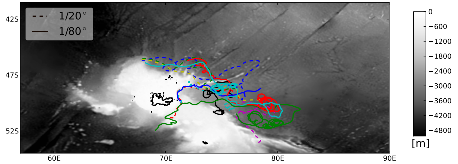
- ⋆ *AIM:* investigate sources of waters and vertical transport of waters

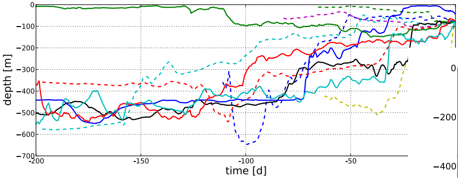
Transport from tracking particles..

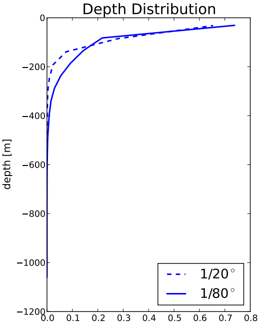


⋆ More frequent vertical excursions of the particles in the 1/80°

Transport from tracking particles..







- ⋆ More frequent vertical excursions of the particles in the
- ⋆ Vertical transport is sensitive to resolution
- ⋆ More particles at depth in the 1/80°

Quantifying dissolved iron concentration

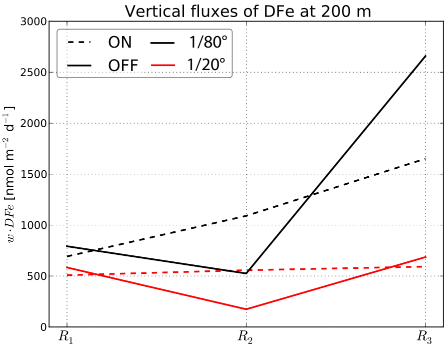
Off-line estimate of [DFe]

$$\frac{d[DFe]}{dt} = -\lambda(z)[DFe] - \phi(z)([DFe] - < [DFe] >)$$

$\lambda(z)$ decay rate of iron (parameterise biological activity)

$\phi(z)$ replenishment rate of iron at depth

$< [DFe] >$ mean concentration the particle relaxes to at depth



Conclusions

Sub-mesoscales

- ⋆ *are affected by topography*
- ⋆ *impact vertical transport*
- ⋆ *supply more iron into the upper-ocean*