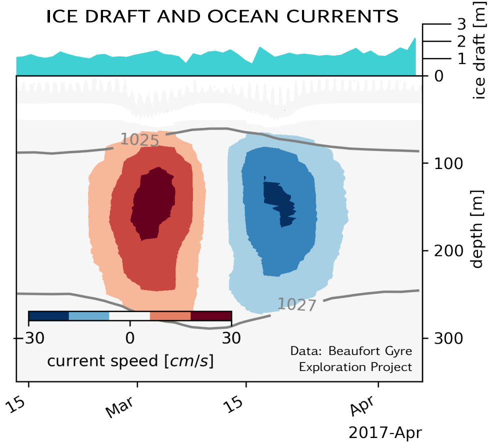
What controls mesoscale eddies and eddy fluxes in the Arctic Ocean?

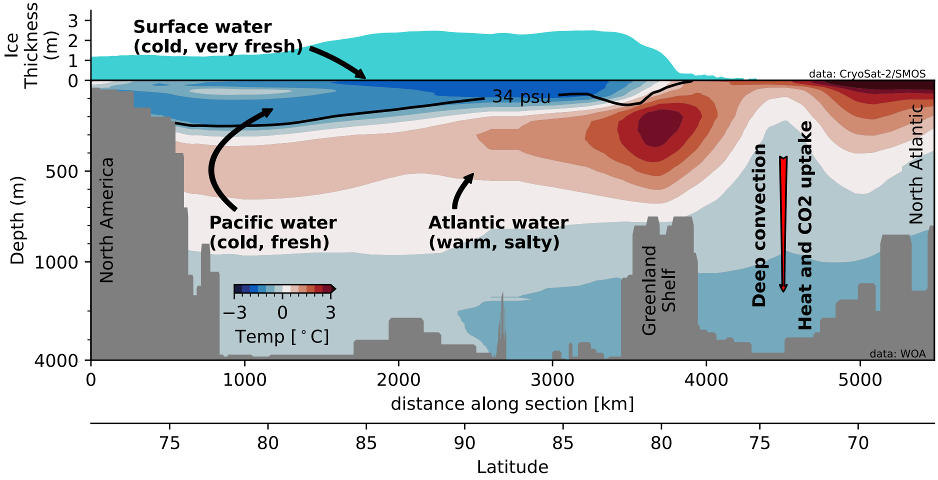
Gianluca Meneghello

ENS | PSL



To each water mass their own eddy system

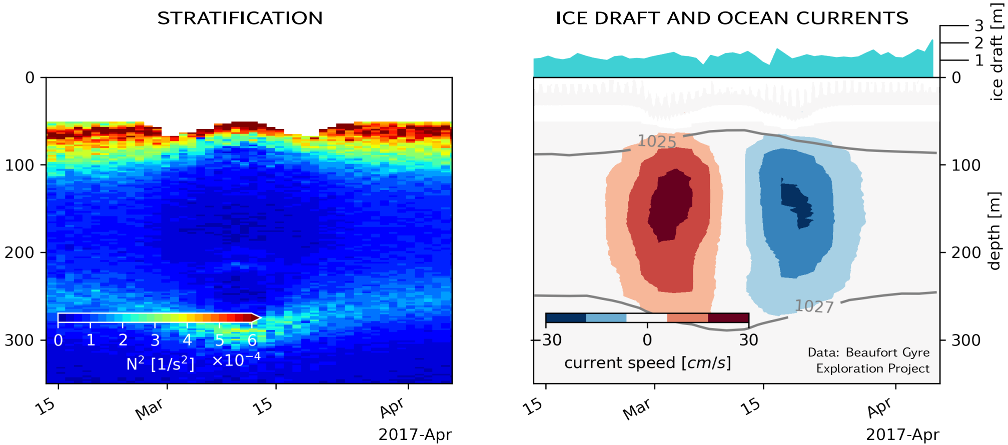
Independent, very different mesoscale eddies develop in each water mass.



- Meneghello et al. JPO (2021)

Observations of mesoscale eddies in the Canadian Arctic

Peaks in stratification limit vertical extent of mesoscale eddies

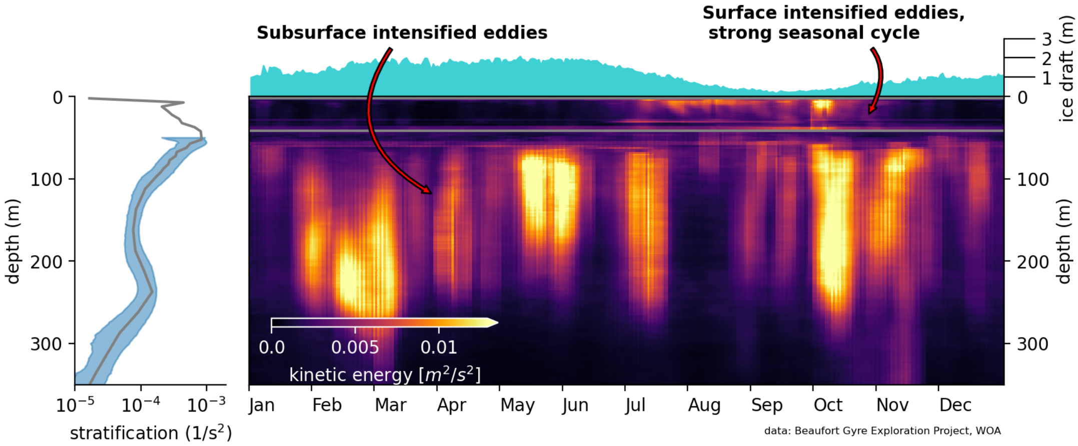


- Meneghello et al. JPO (2021)

Observations of mesoscale eddies in the Canadian Arctic

Sea ice controls the level of kinetic energy at the surface

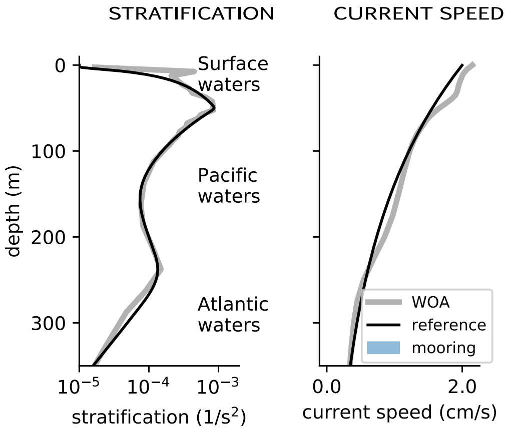
A 15 year climatology of eddy kinetic energy



- Meneghello et al. JPO (2021)

The origin of mesoscale eddies

Can baroclinic instability explain the vertical structure of the Arctic's eddy field?



Quasi-geostrophic balance

$$\frac{d\rho}{dt} = -\mathbf{u}\cdot\nabla\bar{\rho} \pm w_{Ek}\frac{\partial\bar{\rho}}{\partial z}$$

Density conservation (boundary)

$$\frac{dq}{dt} = -\mathbf{u}\cdot\nabla Q$$

PV conservation (interior)

Ekman pumping w_{Ek} has a stabilizing effect on baroclinic instability.

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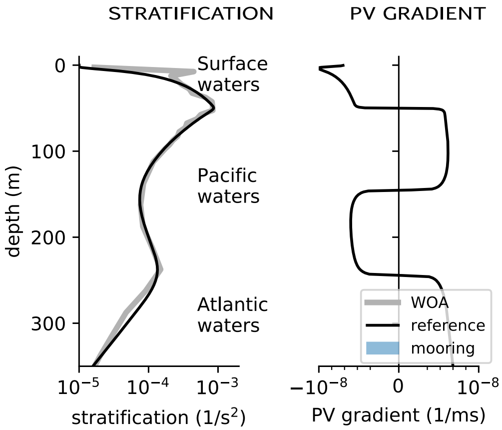

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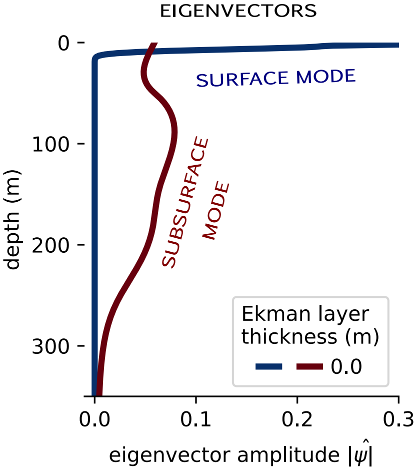
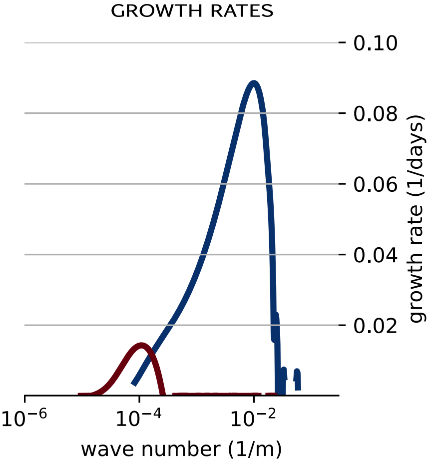
The origin of mesoscale eddies

Independent surface- and subsurface-intensified instabilities are identified

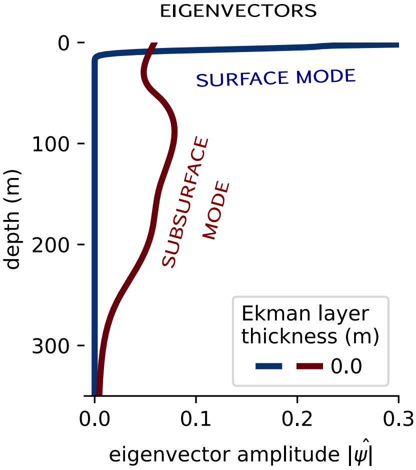


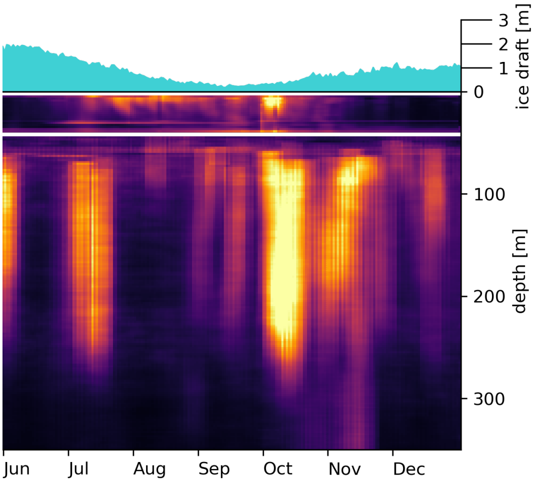


- Meneghello et al. JPO (2021)

THE ORIGIN OF MESOSCALE EDDIES

A very close match with observations

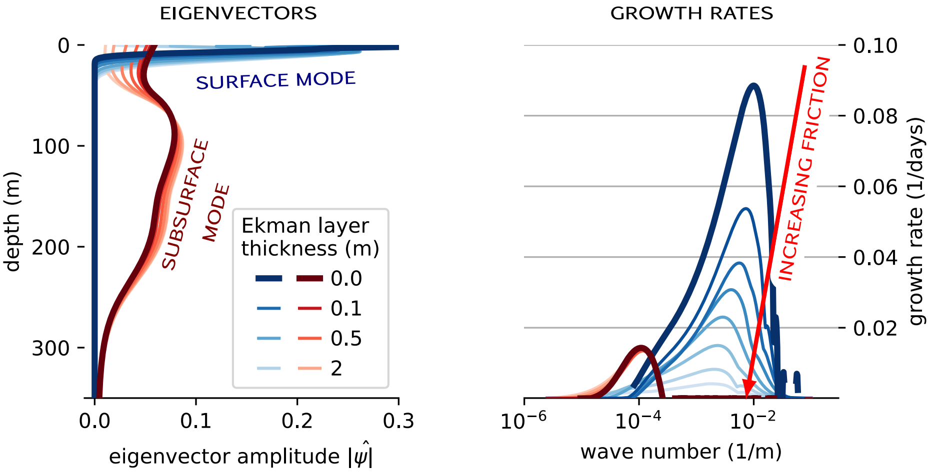




- MENEGHELLO ET AL. JPO (2021)

The origin of mesoscale eddies

Only surface perturbations are affected by friction



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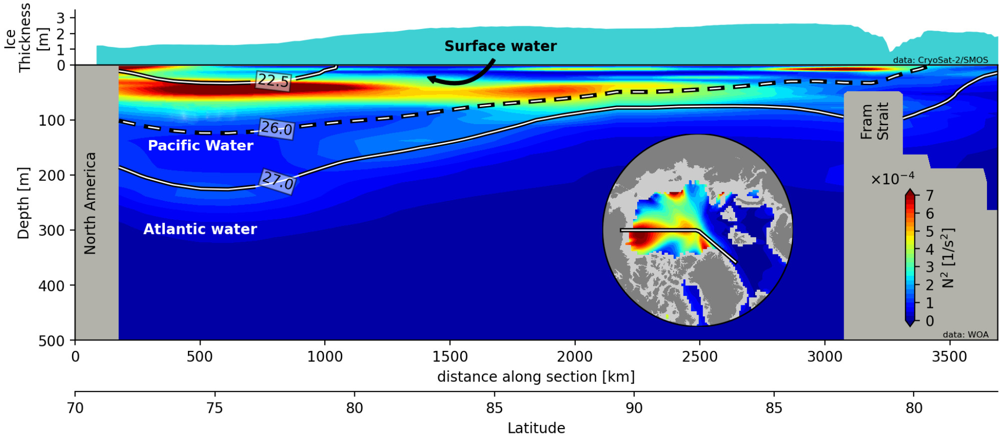
From a mooring to the entire Arctic

Peaks in stratification extend all across the Arctic



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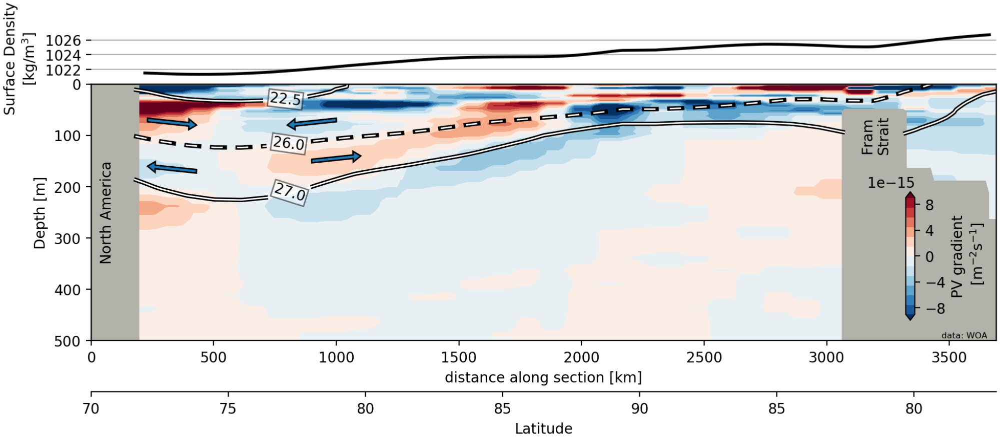
From a mooring to the entire Arctic

Interior PV gradients enable the development of subsurface-intensified turbulence.



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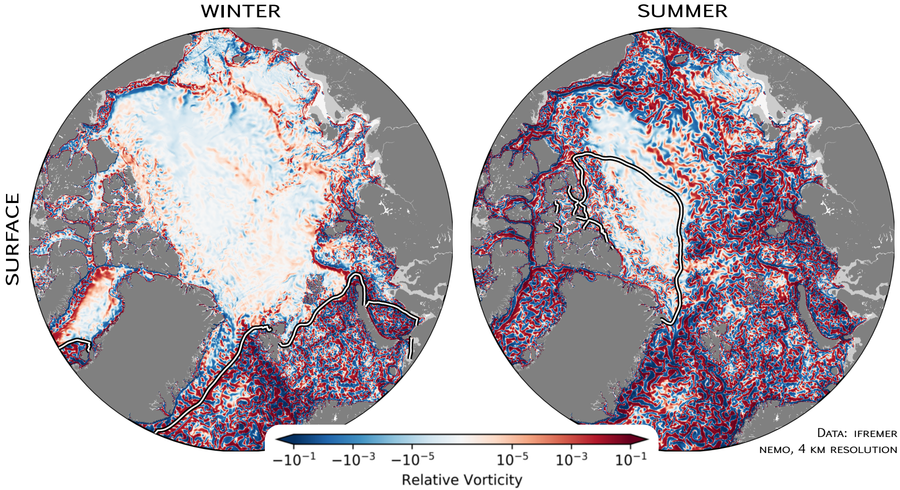
From a mooring to the entire Arctic

High-resolution models support theoretical results



Data: ifremer
nemo, 4 km resolution

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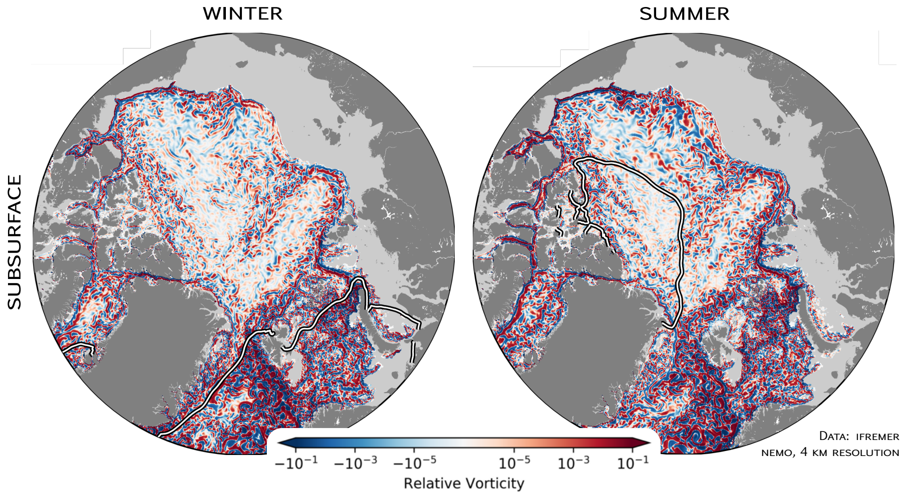

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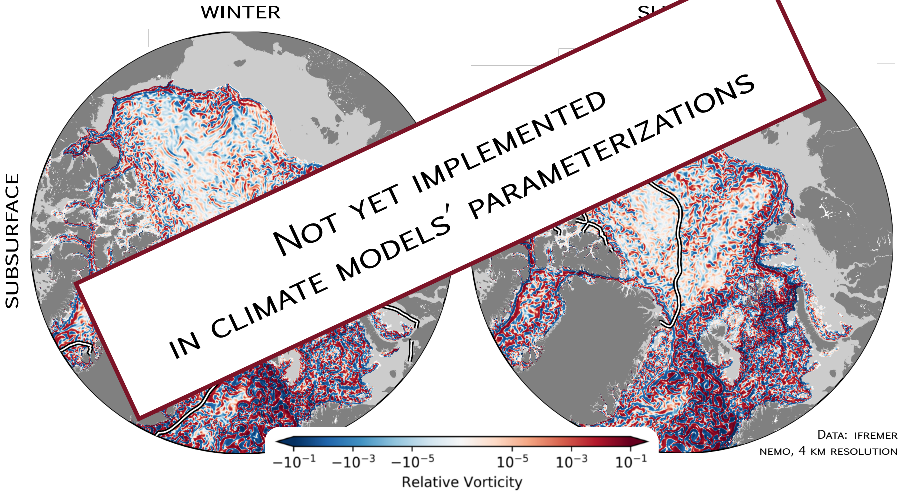

Not yet implemented in climate models' parameterizations

Data: ifremer
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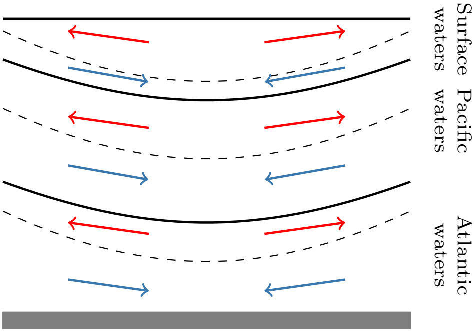
The origin of mesoscale eddies — the simplest model



Quasi-geostrophic balance

$$\frac{dq}{dt} = -\mathbf{u} \cdot \nabla Q$$

PV conservation (interior)

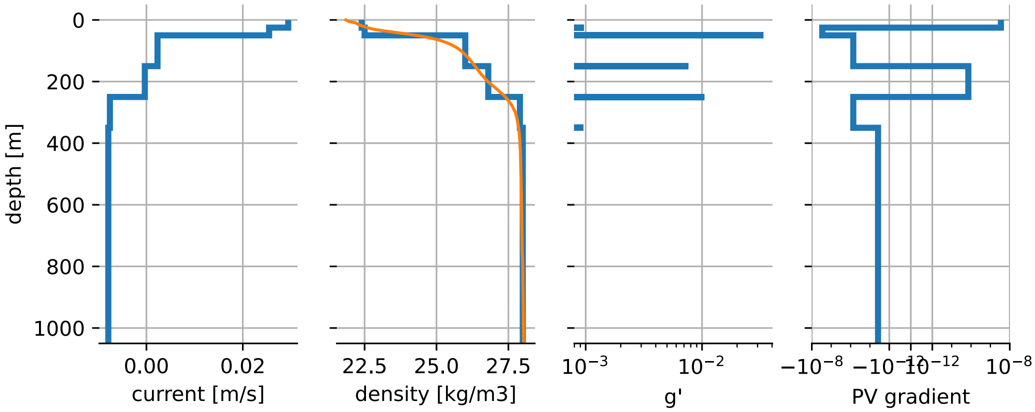
$$\nabla Q = f_0 \frac{\nabla h}{H} = f_0 \frac{d\mathbf{S}}{dz}$$

Background PV gradient

Vertical variations of isopycnal slope control subsurface eddies.

Unstable modes

Changes in the Pacific waters' PV gradient only affect the subsurface mode



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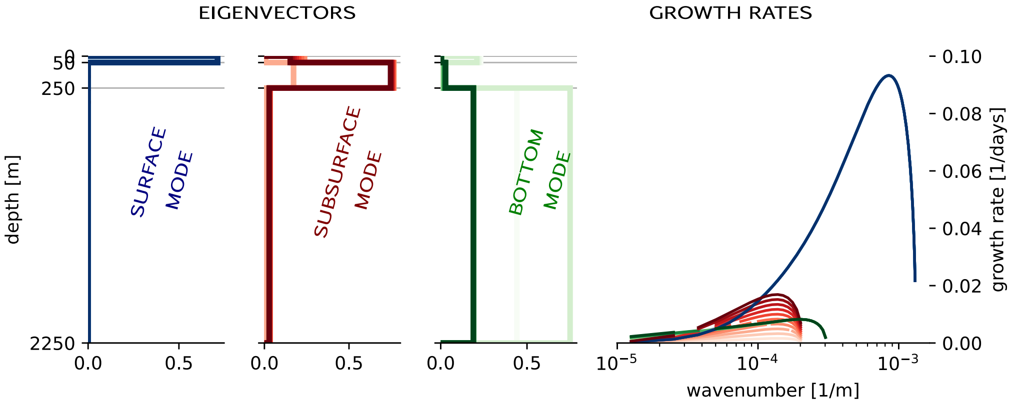

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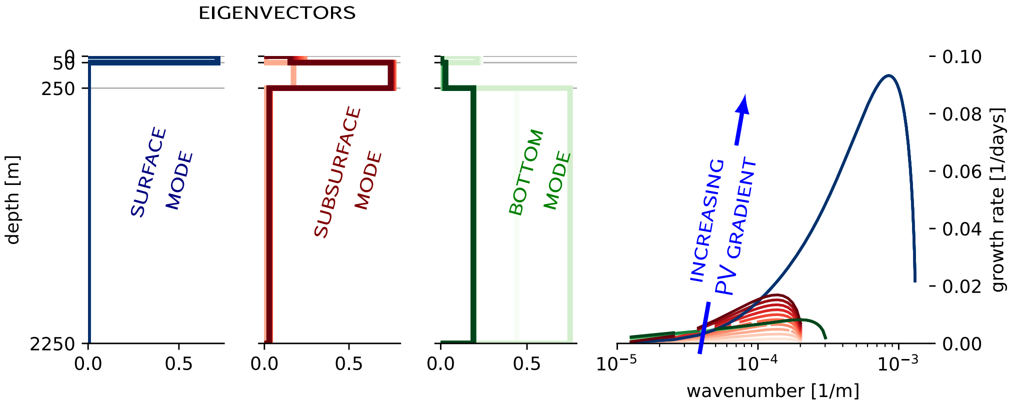
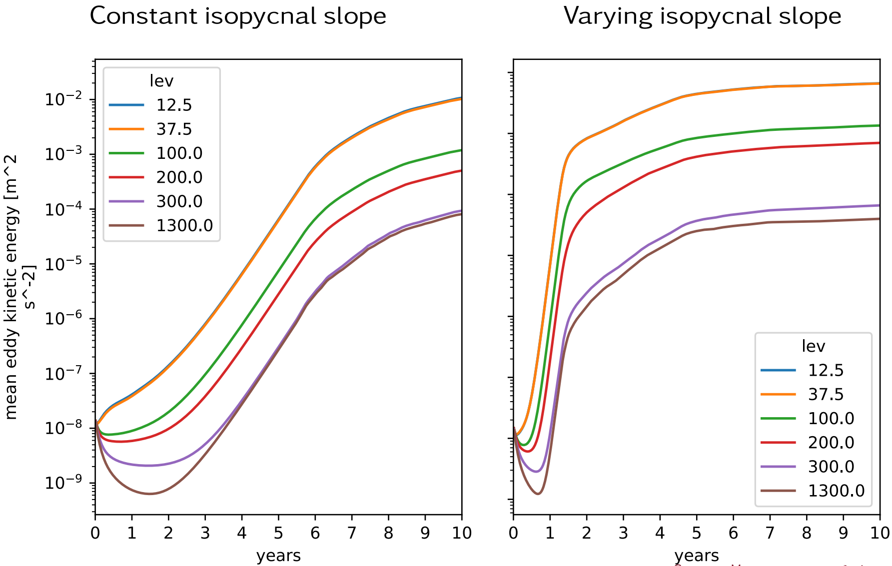


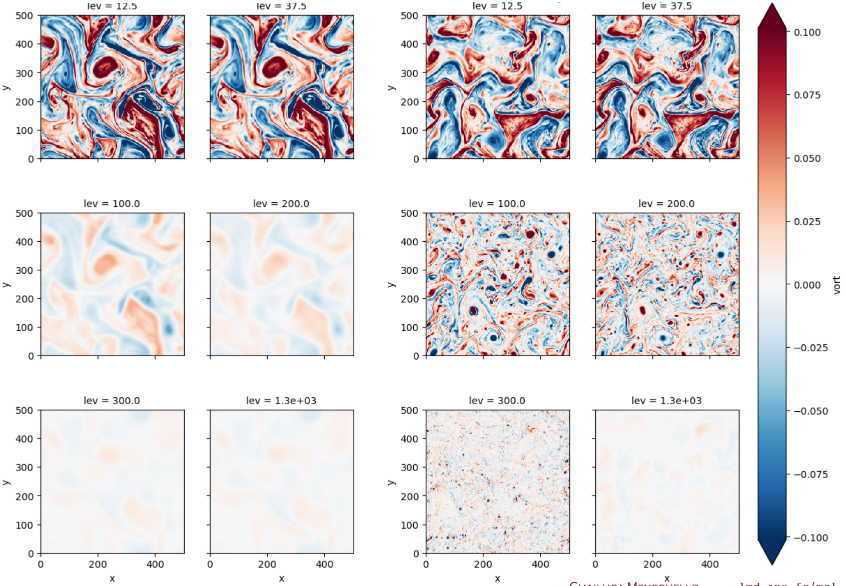
Simulation — Eddy kinetic energy



Vorticity

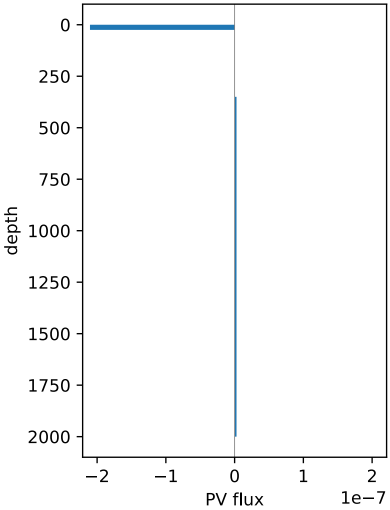
Constant isopycnal slope

Varying isopycnal slope



Eddy fluxes

Constant isopycnal slope



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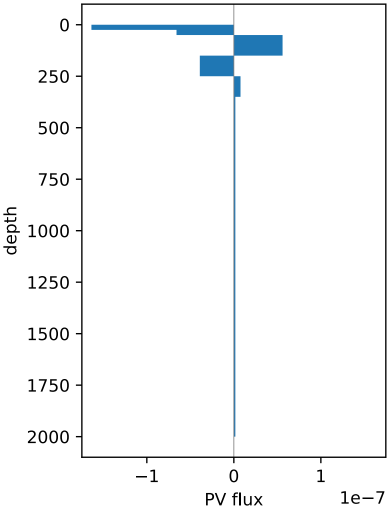

Conclusions

- To each water mass, their own eddy system
- Surface eddies are controlled by the presence of sea ice
- Subsurface eddies are controlled by internal PV gradients
  ...and cannot exist without them!
- Independent PV fluxes are generated within each water mass