Sources and Sinks of Ocean Mesoscale Eddy Energy, Tallahassee, FL 2019

The Nature and Variability of Eddy Kinetic Energy in the Labrador Sea

Different Types of Mesoscale Eddies, their Temporal Variability and Impact on Deep Convection

Jan Klaus Rieck*

with C. W. Böning*, and K. Getzlaff*

* GEOMAR Helmholtz Centre for Ocean Research Kiel

GEOMAR

The Labrador Sea

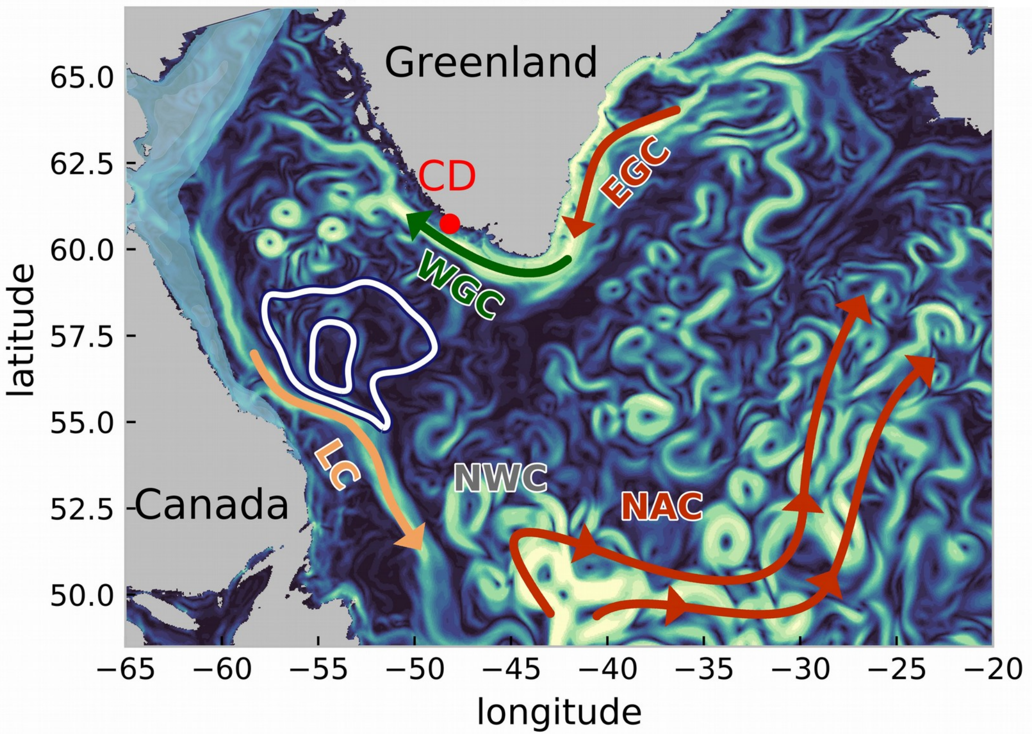
Labrador Sea is an important site of **deep convection**.

Influence on deep water formation and **meridional overturning**.

Mesoscale **eddies** play important role in **preconditioning** and **restratification**.

(e.g. Chanut et al., 2008; Gelderloos et al., 2011; Zhang and Yan, 2014)

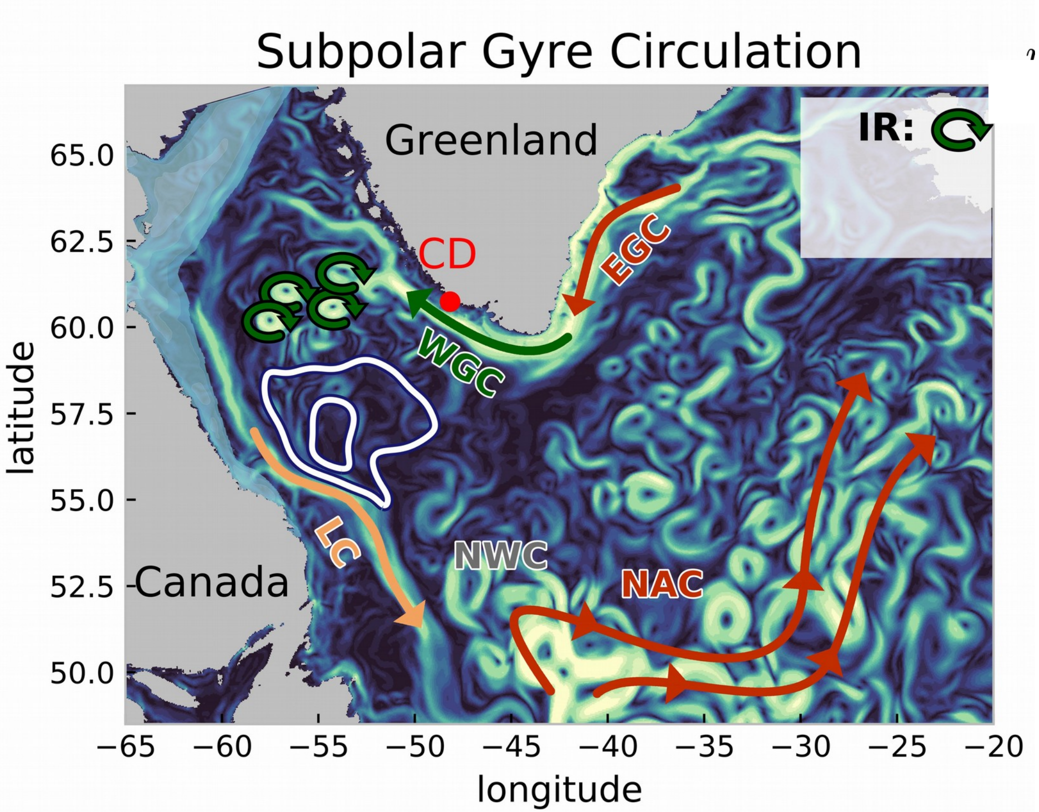
Subpolar Gyre Circulation



The Labrador Sea Eddies

Three major types of **mesoscale eddies** in the Labrador Sea:

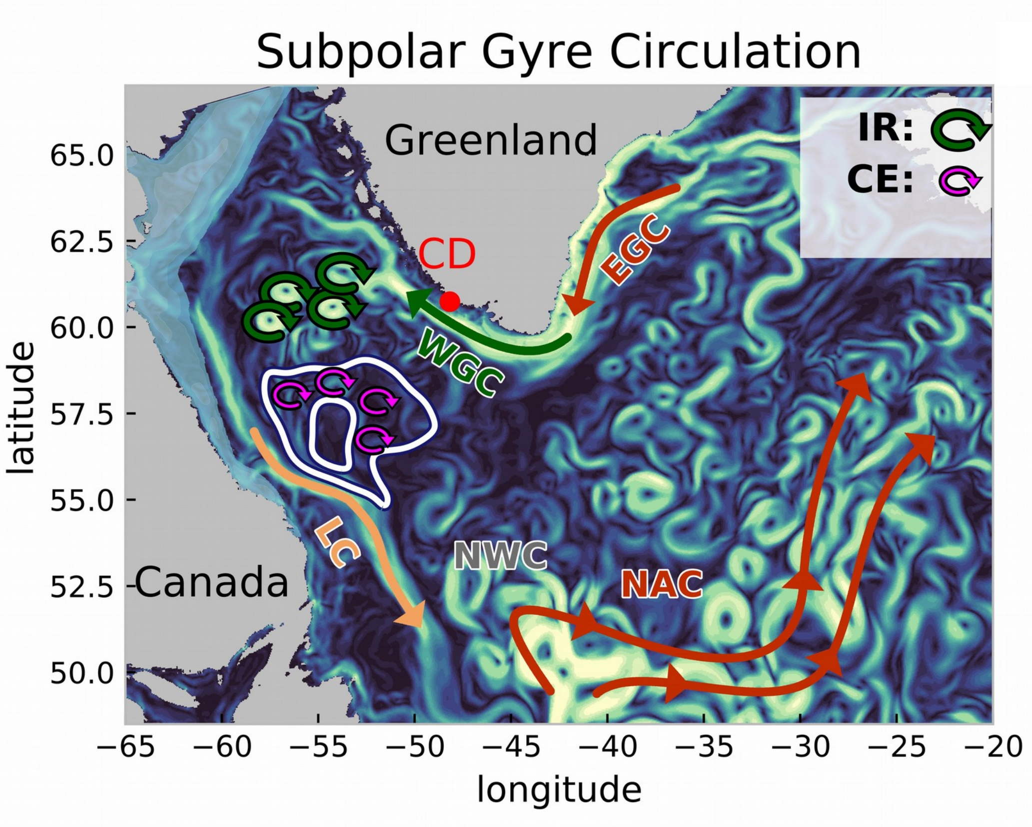
- **Irminger Rings** (IR)



The Labrador Sea Eddies

Three major types of **mesoscale eddies** in the Labrador Sea:

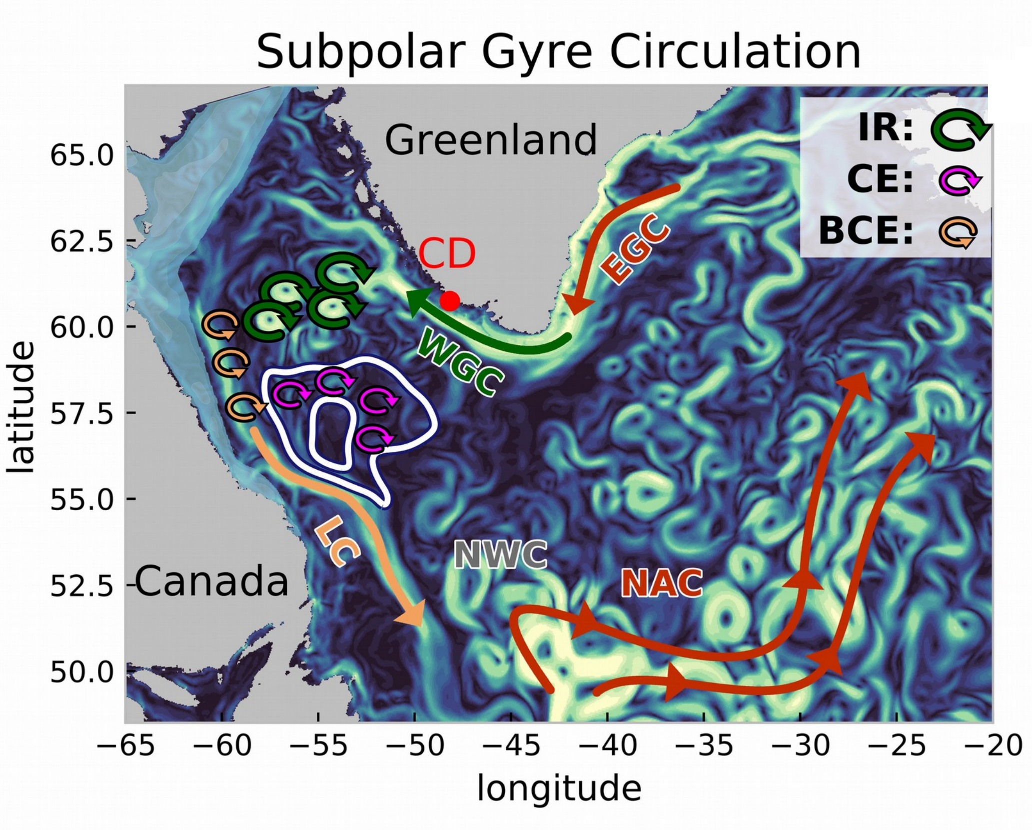
- **Irminger Rings** (IR)
- **Convective Eddies** (CE)



The Labrador Sea Eddies

Three major types of **mesoscale eddies** in the Labrador Sea:

- **Irminger Rings** (IR)
- **Convective Eddies** (CE)
- Boundary Current Eddies (BCE)



Modeling the Labrador Sea

High resolution

VIKING20X

NEMO3.6 1/4° model with **1/20°** nest embedded in the **North Atlantic** (33°S-70°N)
→ to resolve mesoscale at subpolar latitudes

Long hindcast

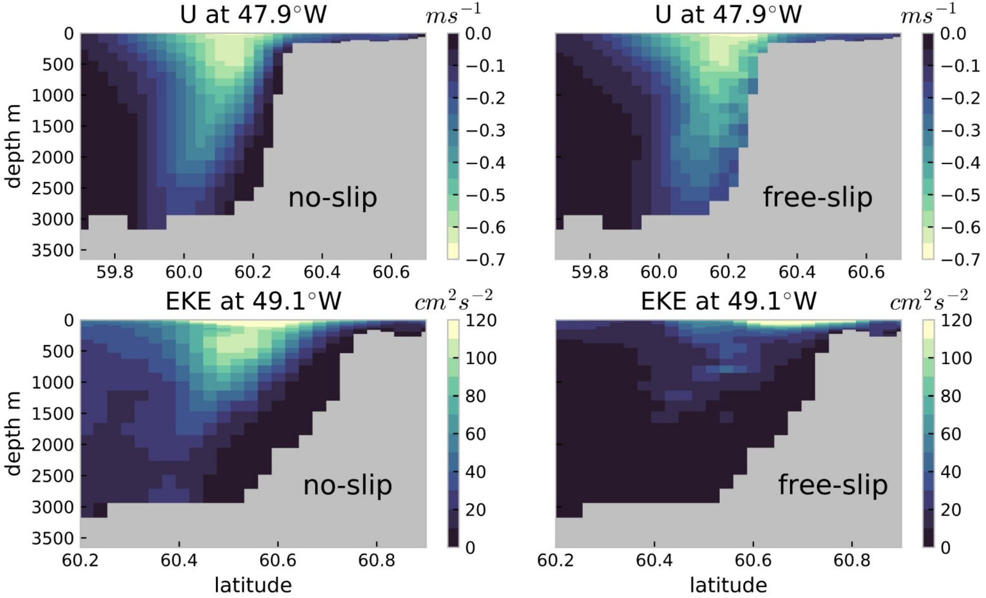
CORE.v2

1958-2009 atmospheric forcing, supported by the new JRA55-do (1980-2017)
→ to investigate the atmospherically forced signal

Lateral boundary condition

No-slip condition in the WGC (43-51°W, 59-62°N) around Cape Desolation
→ formation of IR

Modeling the Labrador Sea



Lateral boundary condition

No-slip condition in the WGC (43-51°W, 59-62°N) around Cape Desolation

→ formation of IR

Mesoscale Eddies the Labrador Sea

- What are the generation mechanisms?

  The processes leading to IR formation are highly debated (*e.g. Chanut et al., 2008, Bracco et al., 2008, Zhu et al., 2014*).

- What causes the temporal variability?

  Can it be traced back to the circulation of the Subpolar Gyre and/or the atmospheric circulation (*Zhang and Yan, 2018*)?

- What is the impact on deep convection?

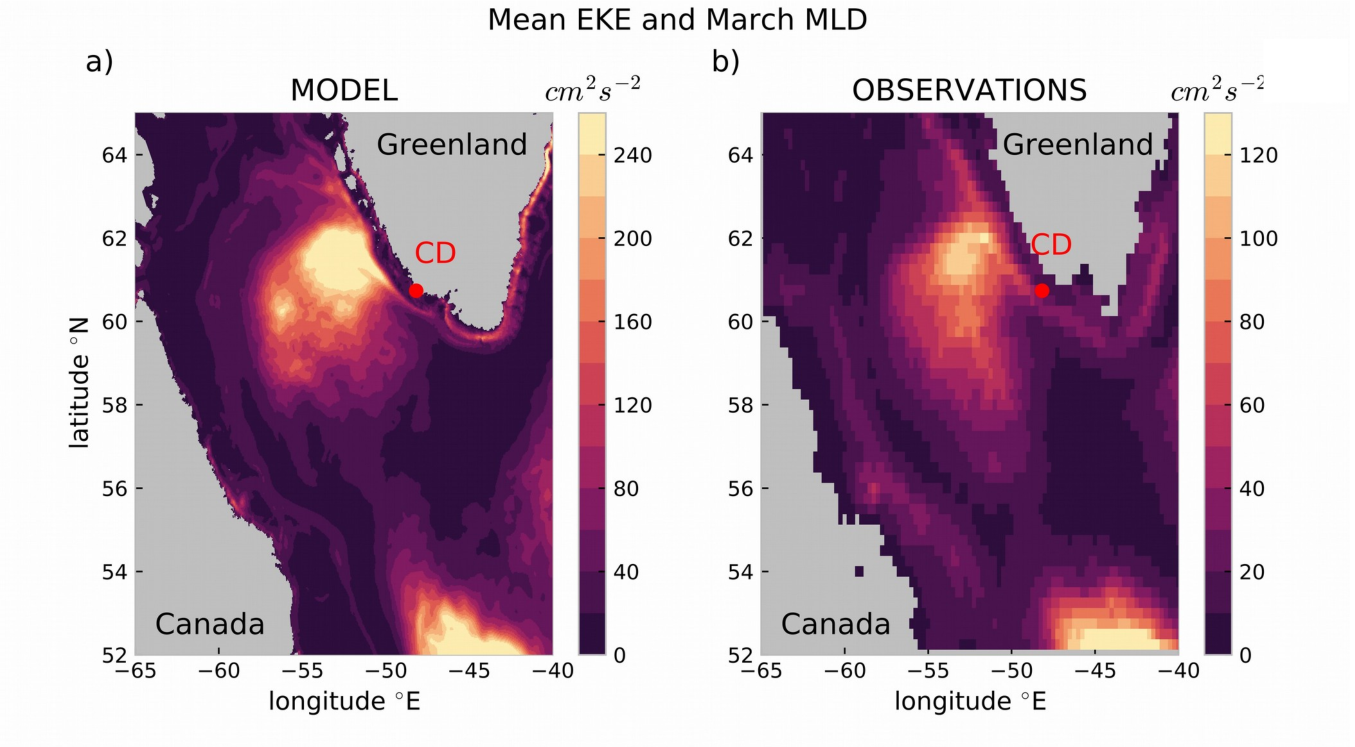
  The importance of the different types of eddies for restratification of the convection area is unclear.

The Labrador Sea: Overview

EKE maximum and **convection region** (MLD):

Locations are well-represented and clearly separated

→ no convection in the IR path



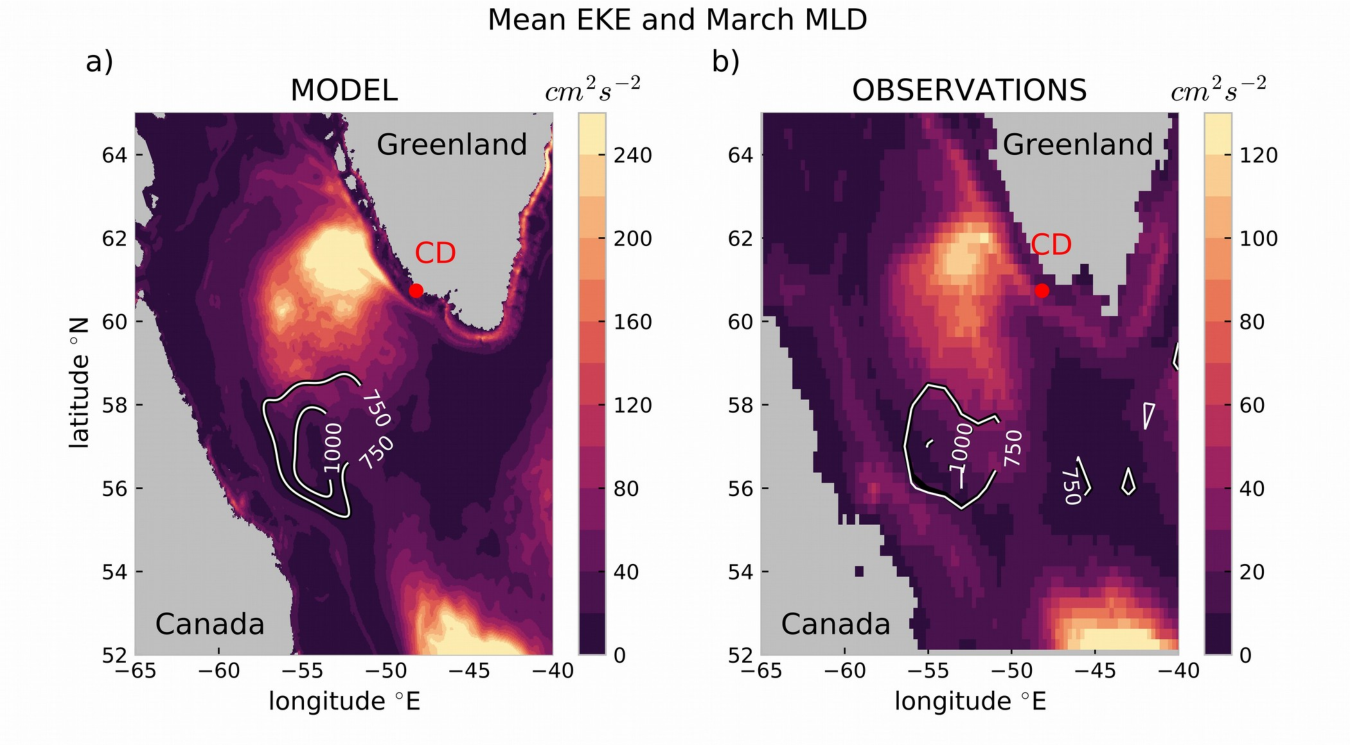
Colors: Mean EKE

The Labrador Sea: Overview

EKE maximum and **convection region** (MLD):

Locations are well-represented and clearly separated

→ no convection in the IR path



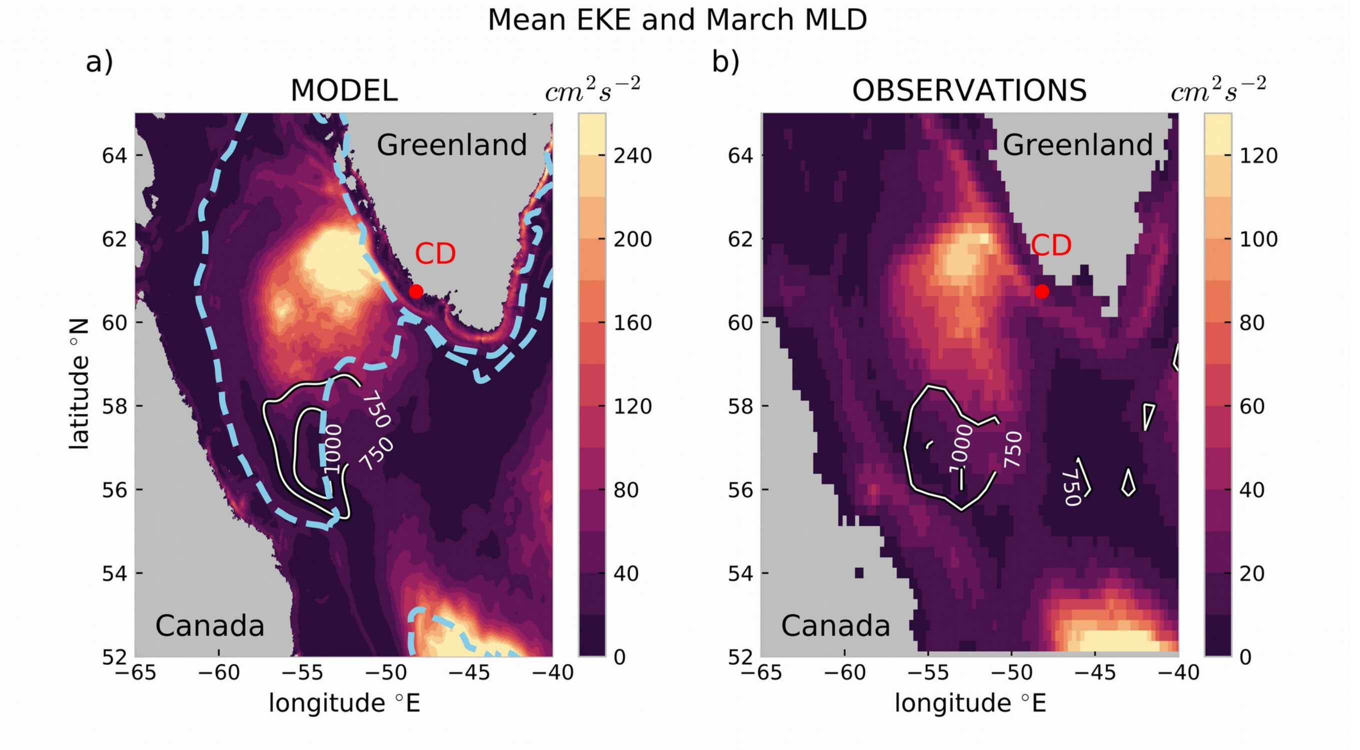
Colors: Mean EKE White contour: March MLD

The Labrador Sea: Overview

EKE maximum and **convection region** (MLD):

Locations are well-represented and clearly separated

→ no convection in the IR path



Colors: Mean EKE White contour: March MLD Blue contour: March heat loss

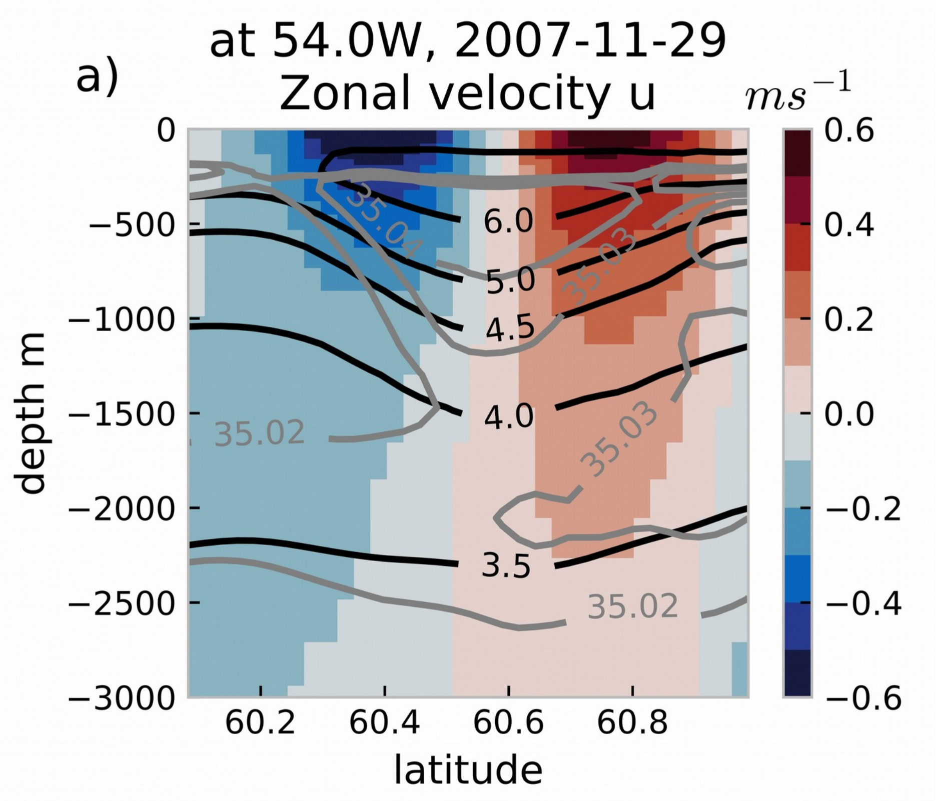
Irminger Rings

warm, **saline**,

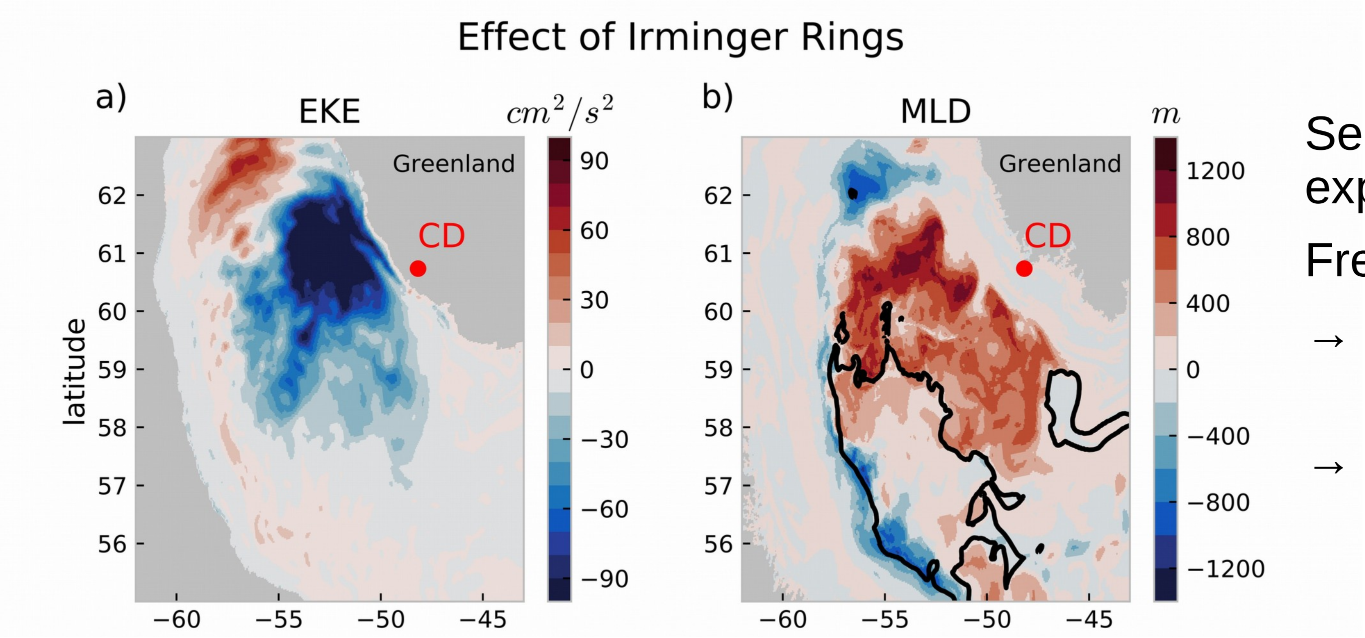
stratified core, fresh cap

→ propagate westward
and **suppress**
deep **convection**
north of 58-59°N

Do IR restratify
the convected water in the central LS?



Irminger Rings: Impact on Deep Convection



Sensitivity experiment:

Free-slip everywhere

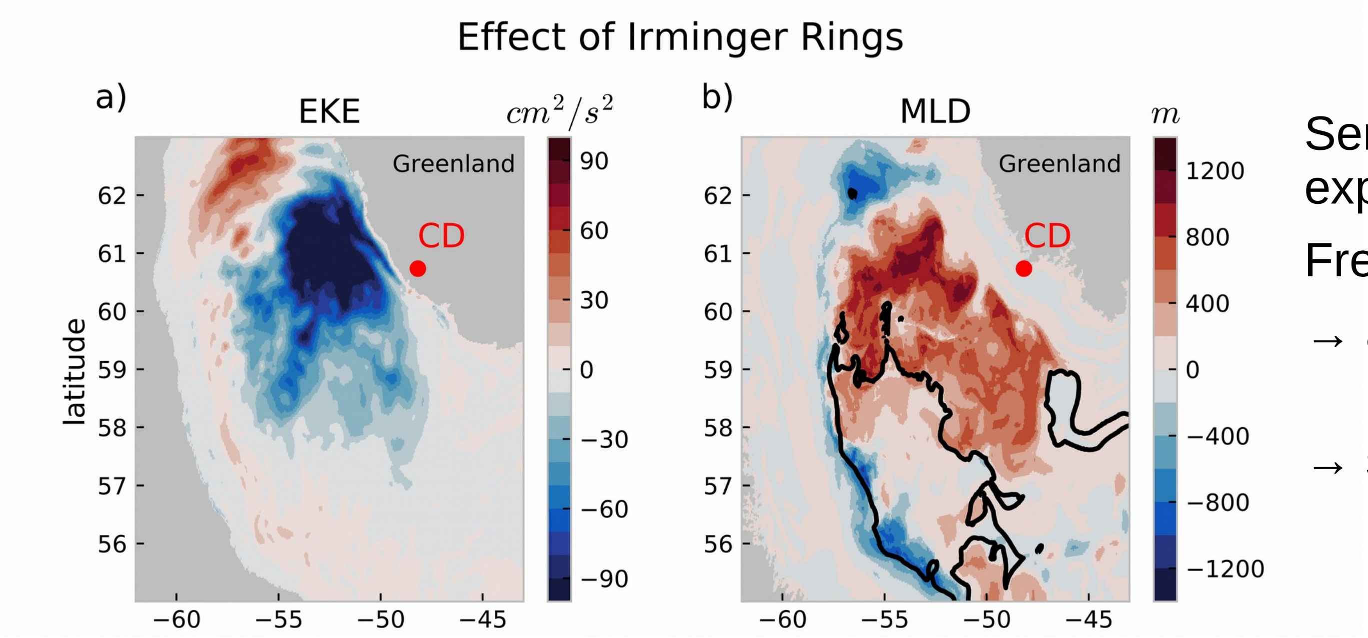
→ almost no IR in WGC

→ slightly more eddies in boundary current

MLD in **convection** region is **not impacted** by the reduced number of **IR.**

→ IR do **not restratify** convected water significantly.

Irminger Rings: Impact on Deep Convection



Sensitivity experiment:

Free-slip everywhere

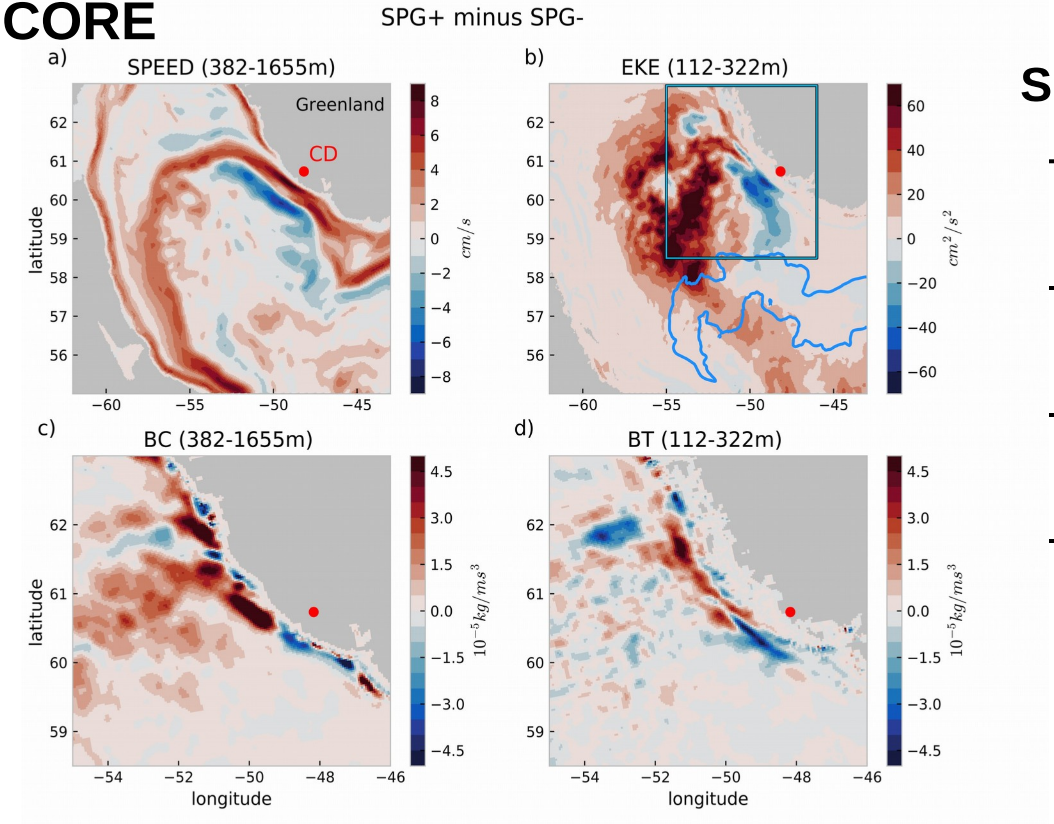
- → almost no IR in WGC
- → slightly more eddies in boundary current

Can results the results be transferred to realistic scenarios?

Hypothesis: **strong SPG** → **more IR** → **higher EKE**

Irminger Rings: Decadal Variability

CORE

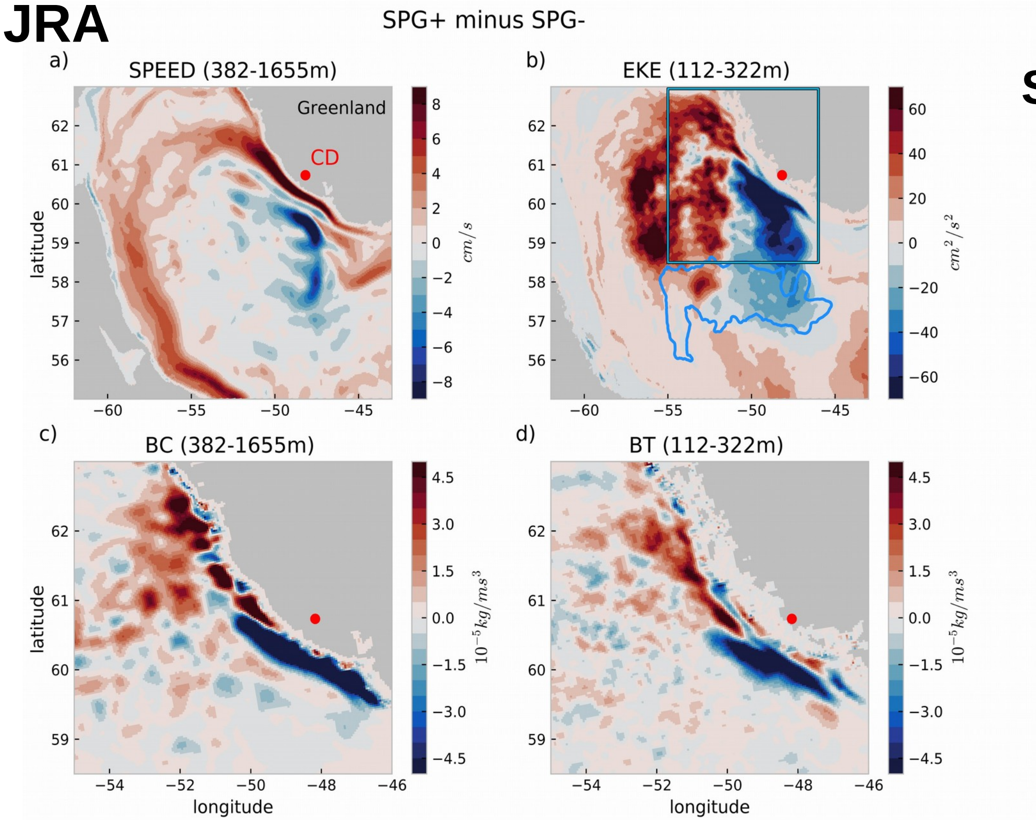


SPG+:

- **strong WGC** closer to shelf
- **instabilities** and **EKE** shifted **downstream**
- **EKE increase** north of convection region
- **MLD** and **convection** are controlled by **local heat loss**, IR play minor role

Irminger Rings: Decadal Variability

JRA

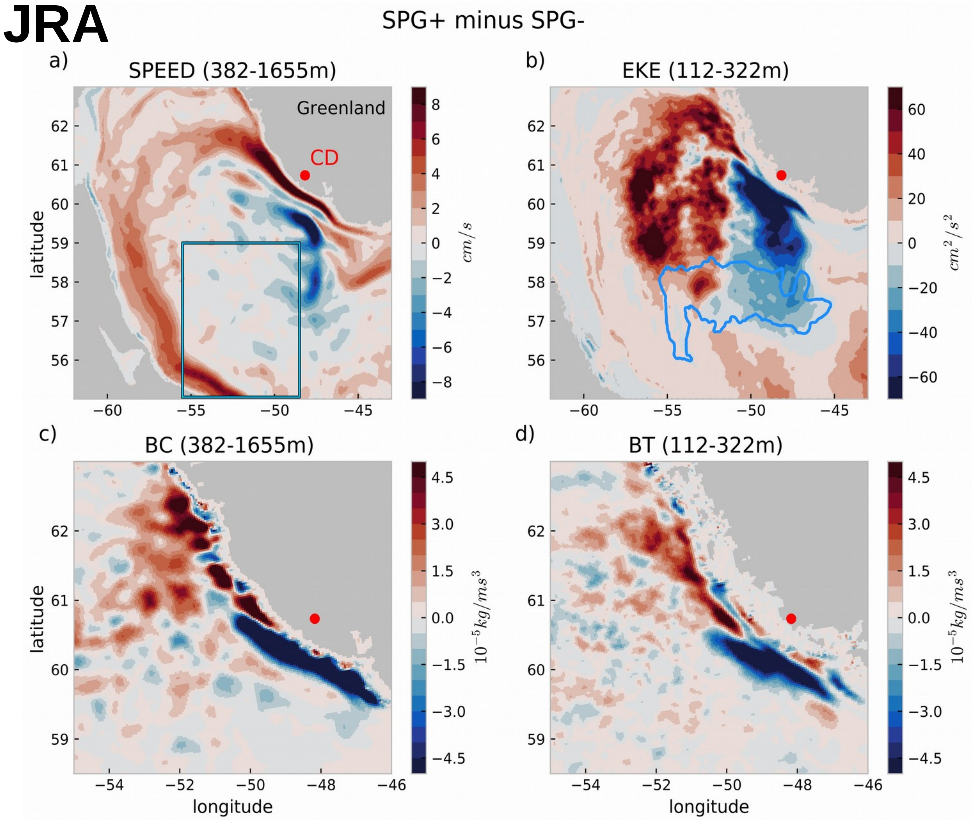


SPG+:

- **strong WGC** closer to shelf
- **instabilities** and **EKE** shifted **downstream**
- **EKE increase** north of convection region
- **MLD** and **convection** are controlled by **local heat loss**, IR play minor role

Irminger Rings: Decadal Variability

JRA



SPG+:

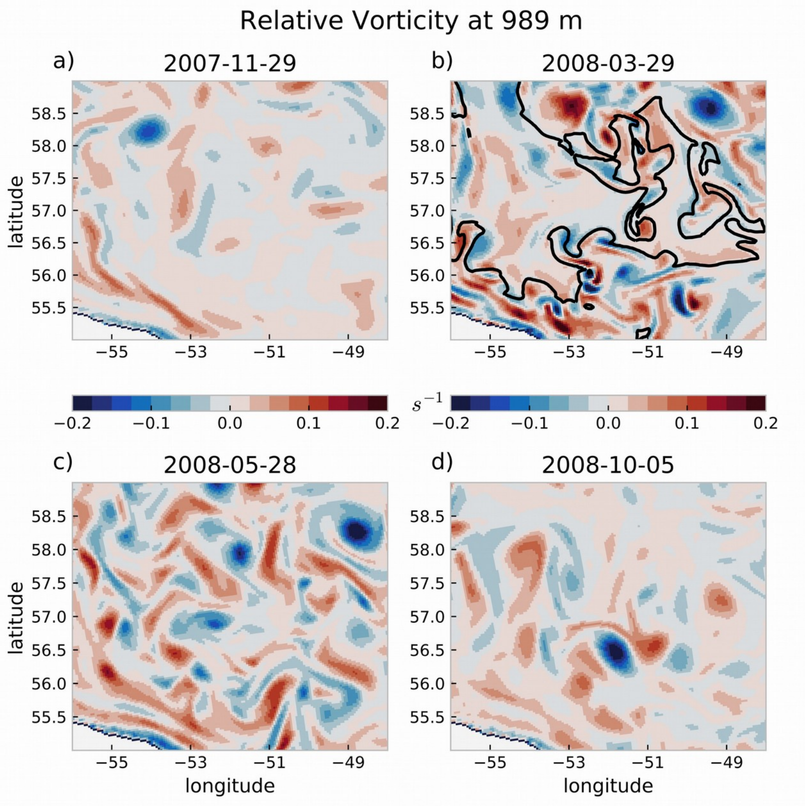
- **strong WGC** closer to shelf
- **instabilities** and **EKE** shifted **downstream**
- **EKE increase** north of convection region
- **MLD** and **convection** are controlled by **local heat loss**, IR play minor role

Instabilities associated with convection

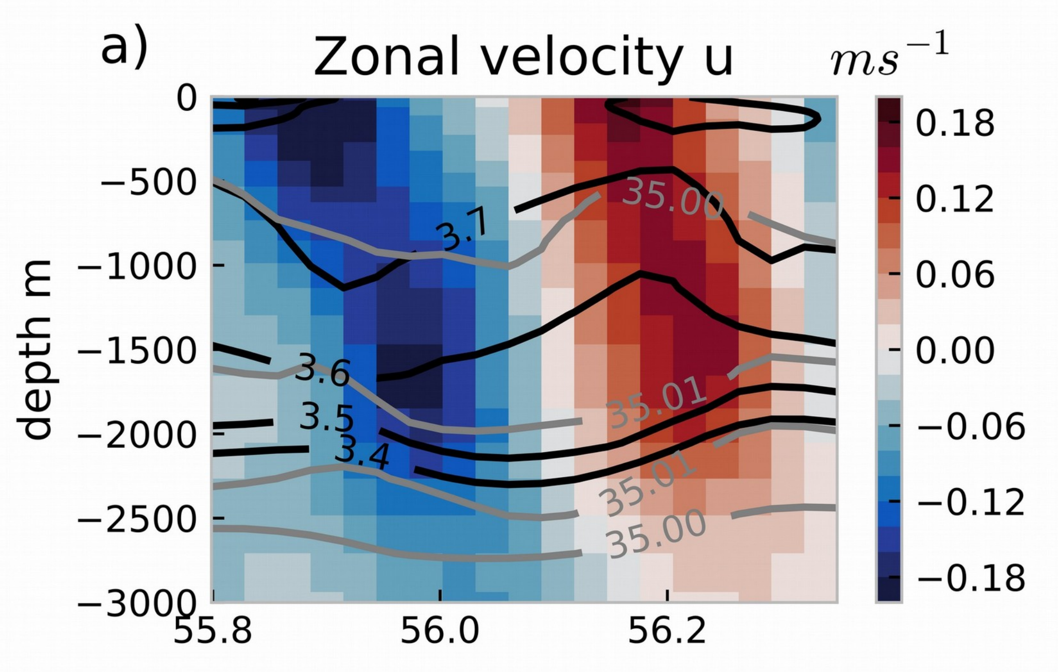
“**Rim-current**” along the convective patch is established due to **density difference** to the waters outside the convection area
(*e.g. Marshall and Schott, 1999*).

Small-scale instabilities emerge

- Largest at the **base** of the **Mixed Layer**
- **Grow** in size over time
- **Populate** the whole **convection area** after a few weeks

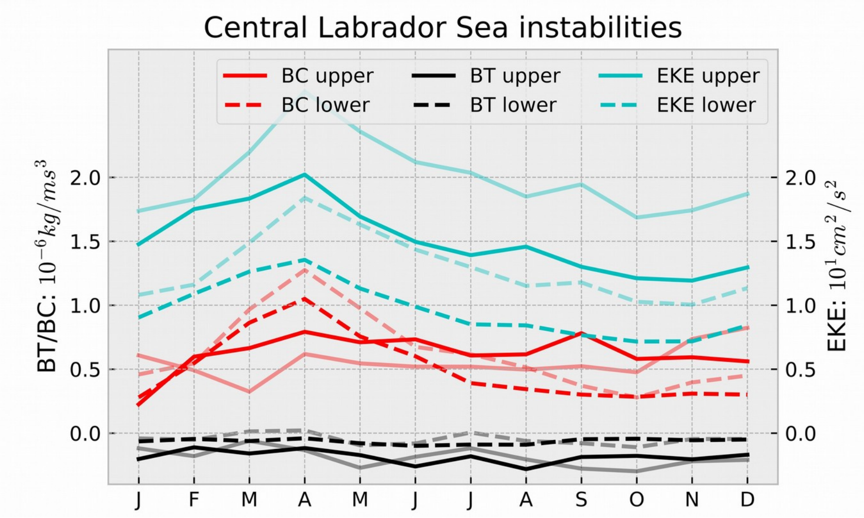


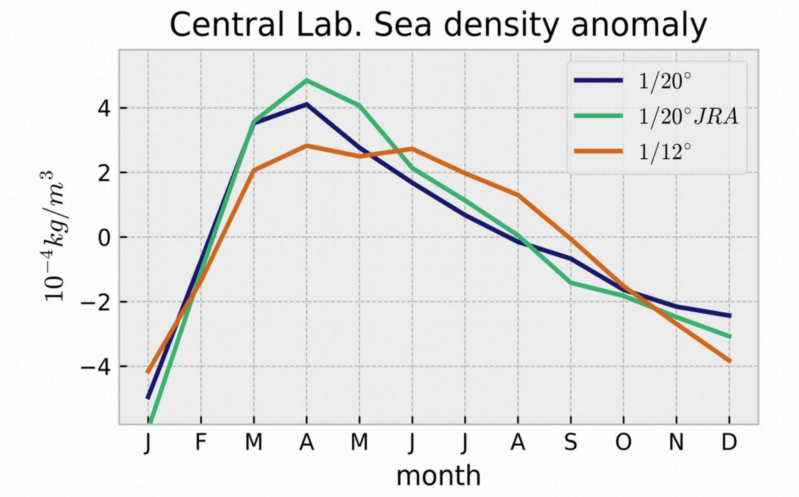
Convective Eddies



- **mid-depth** core
- usually **cold** and **fresh** (like convected water)
- **weakly stratified**
- compare well to observations by Lilly et al., 2003

Temporal Variability and Impact on Convection



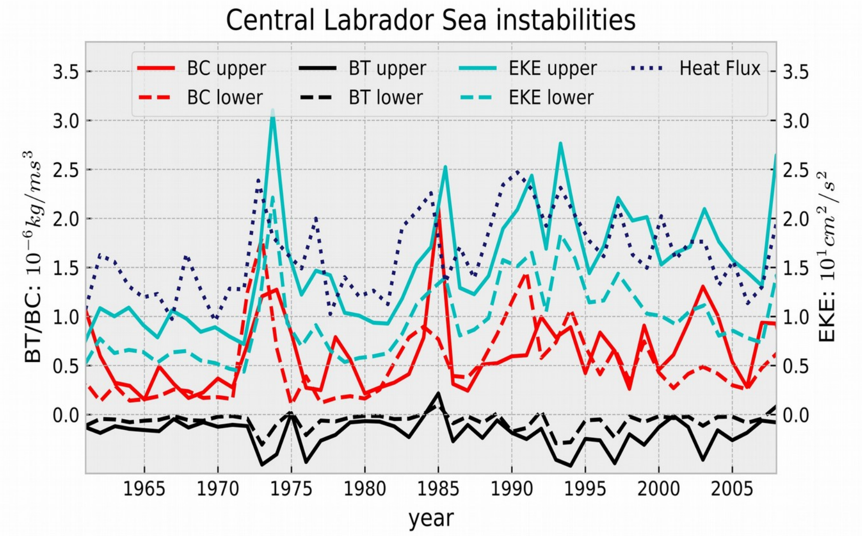


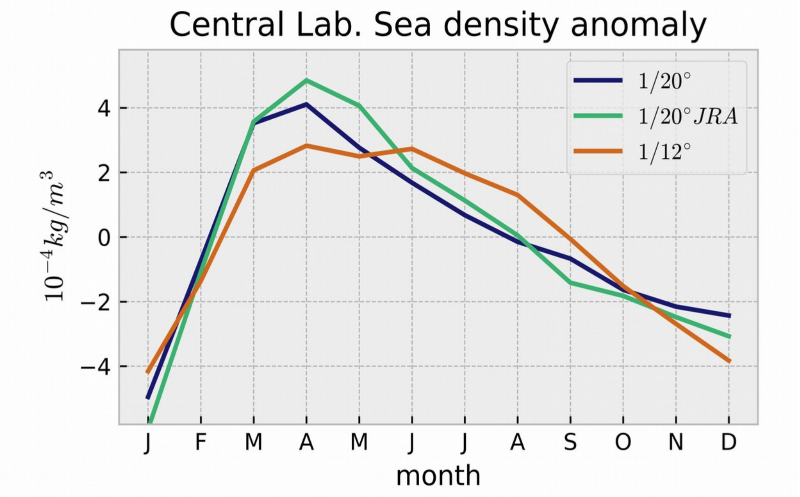
CE are generated by **baroclinic instability** of the “rim-current”.

Related to **local atmospheric forcing** through deep convection (on seasonal to decadal time scales).

When **less CE** are present (coarser resolution), **restratification** of convective patch takes significantly **longer**.

Temporal Variability and Impact on Convection





CE are generated by **baroclinic instability** of the “rim-current”.

Related to **local atmospheric forcing** through deep convection (on seasonal to decadal time scales).

When **less CE** are present (coarser resolution), **restratification** of convective patch takes significantly **longer**.

Summary

- What are the generation mechanisms?

  The processes leading to IR formation are highly debated (*e.g. Chanut et al., 2008, Bracco et al., 2008, Zhu et al., 2014*).

- What causes the temporal variability?

  Can it be traced back to the circulation of the Subpolar Gyre and/or the atmospheric circulation (*Zhang and Yan, 2018*)?

- What is the impact on deep convection?

  The importance of the different types of eddies for restratification of the convection area is unclear.

Summary

	Irminger Rings	**Convective Eddies**	**Boundary Current Eddies**
Generation mechanisms	Baroclinic and barotropic WGC, CD	Baroclinic Rim-current	Baroclinic Boundary Currents
Causes for temporal variability	Subpolar Gyre Large scale atmospheric	Deep convection Local atmospheric	Boundary Current strength
Impact on deep convection	Preconditioning Limit extent of convection area	Restratifiy convection area	(limit extent of convection area)

References

Bracco et al. (2008), Eddy Formation near the West Coast of Greenland, *J. Phys. Oceanogr.*, **38**, 1992–2002, doi:10.1175/2008JPO3669.1.

Chanut et al. (2008), Mesoscale Eddies in the Labrador Sea and Their Contribution to Convection and Restratification, *J. Phys. Oceanogr.*, **38**, 1617–1643, doi:10.1175/2008JPO3485.1.

Gelderloos et al. (2011), Assessing the Roles of Three Eddy Types in Restratifying the Labrador Sea after Deep Convection, *J. Phys. Oceanogr.*, **41**, 2102–2119, doi:10.1175/JPO-D-11-054.1.

Lilly et al. (2003), Observations of the Labrador Sea eddy field, *Prog. Oceanogr.*, **59**, 75–176, doi:10.1016/j.pocean.2003.08.013.

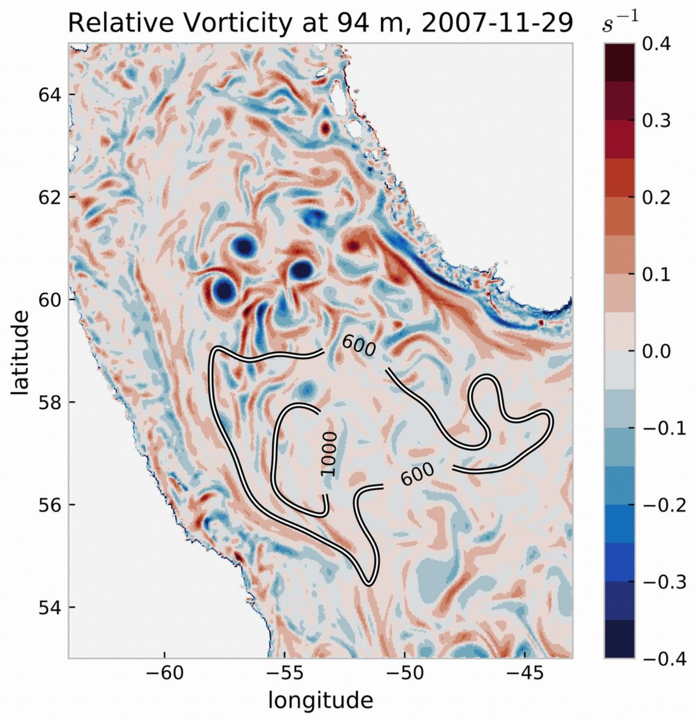
Zhang and Yan (2014), Lateral Heat Exchange after the Labrador Sea Deep Convection in 2008, *J. Phys. Oceanogr.*, **44**, 2991–3007, doi:10.1175/JPO-D-13-0198.1.

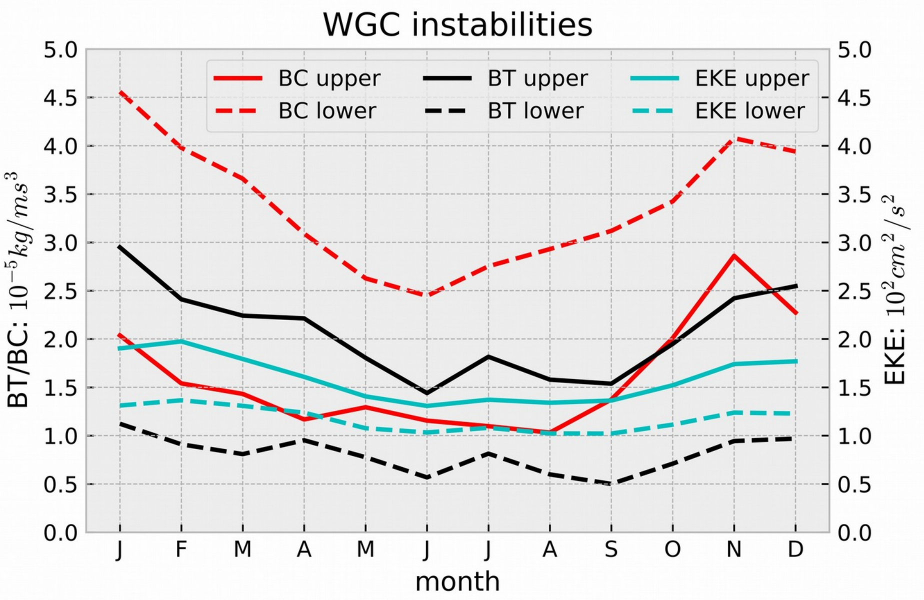
Zhang and Yan (2018), Variability of the Labrador Sea Surface Eddy Kinetic Energy Observed by Altimeter From 1993 to 2012, *J. Geophys. Res. Oceans*, **123**, 601–612, doi:10.1002/2017JC013508.

Zhu et al. (2014), Model simulations of mesoscale eddies and deep convection in the Labrador Sea, *Adv. Atmos. Sci*., **31**, 743–754, doi:10.1007/s00376-013-3107-y.

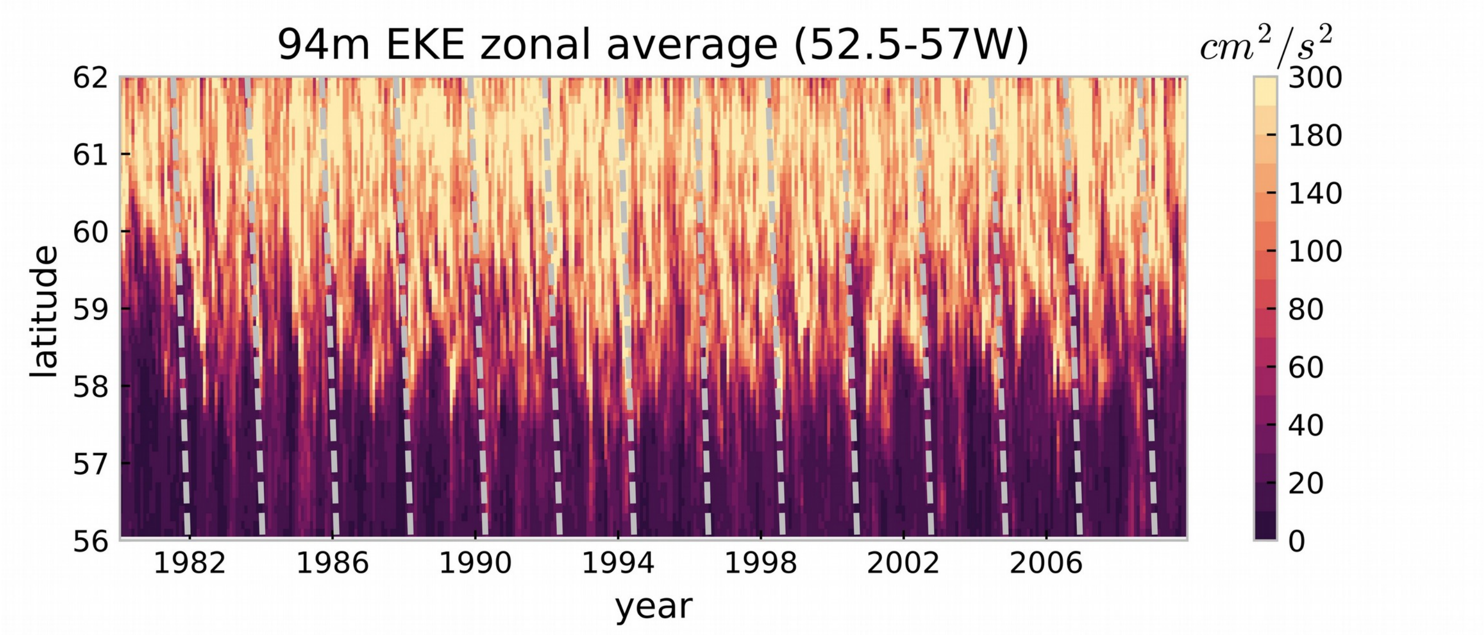
Additional Figures

Additional Figures

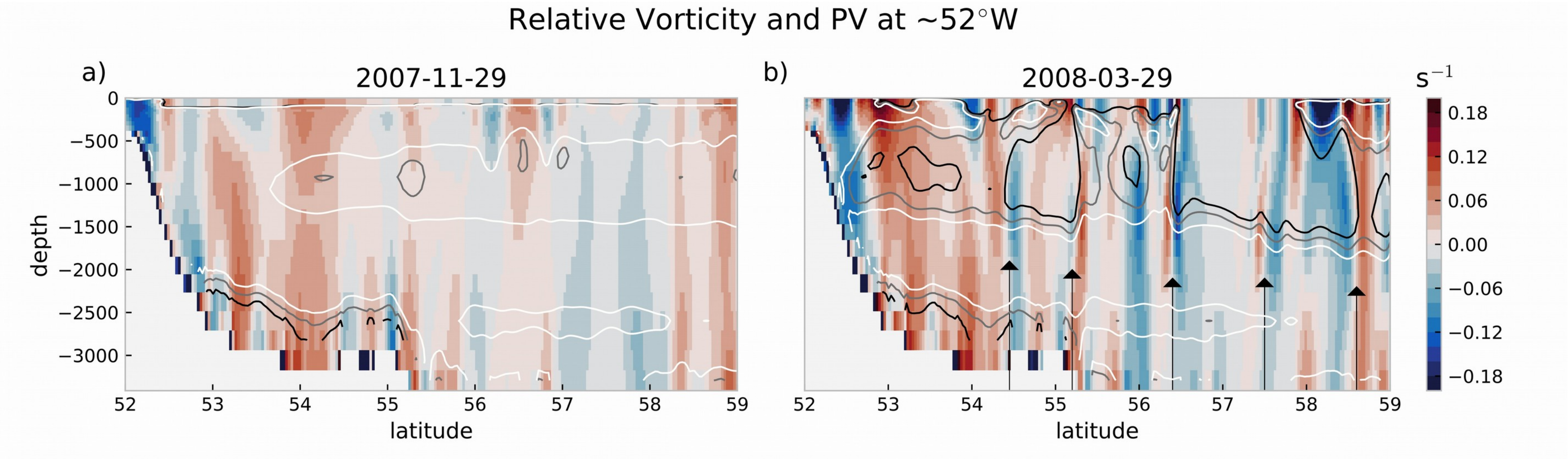




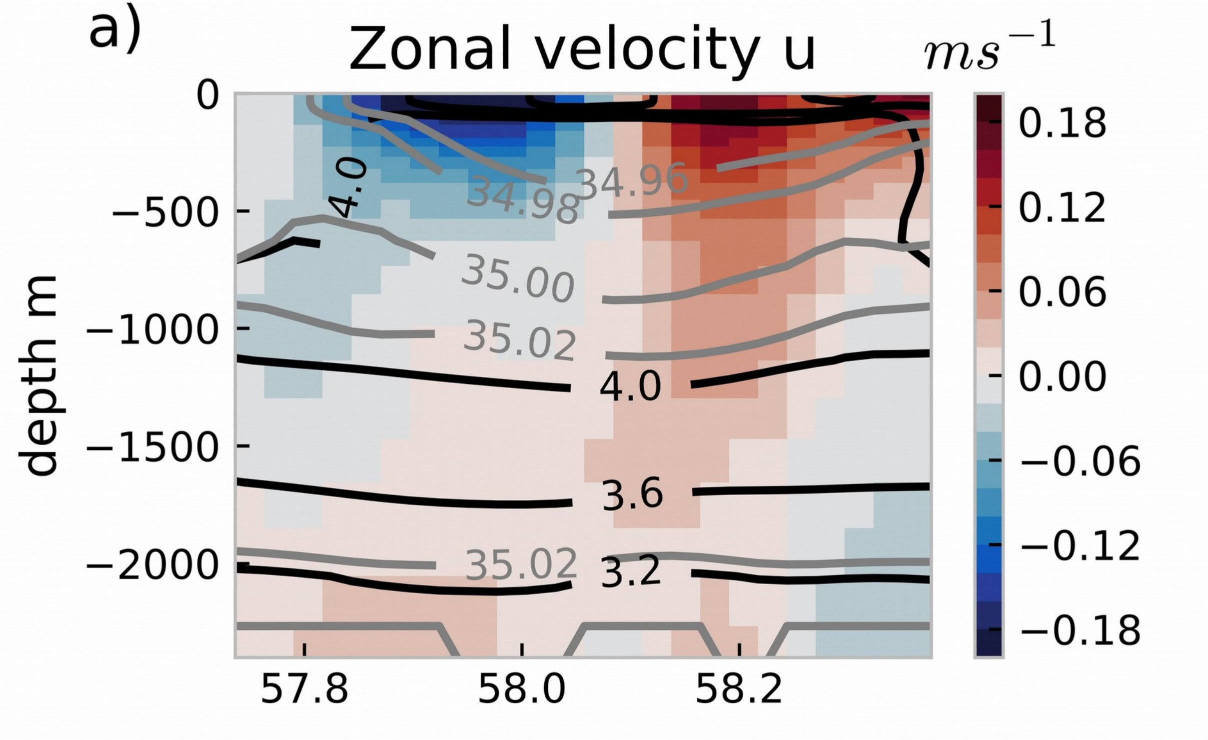
Additional Figures



Additional Figures



Additional Figures



Additional Figures