

# A PARAMETERIZATION FOR GRAVITY CURRENT OVERFLOWS IN THE COMMUNITY EARTH SYSTEM MODEL (CESM) OCEAN COMPONENT

Gokhan Danabasoglu  
Bill Large and Bruce Briegleb

National Center for Atmospheric Research (NCAR)  
Boulder, Colorado, USA

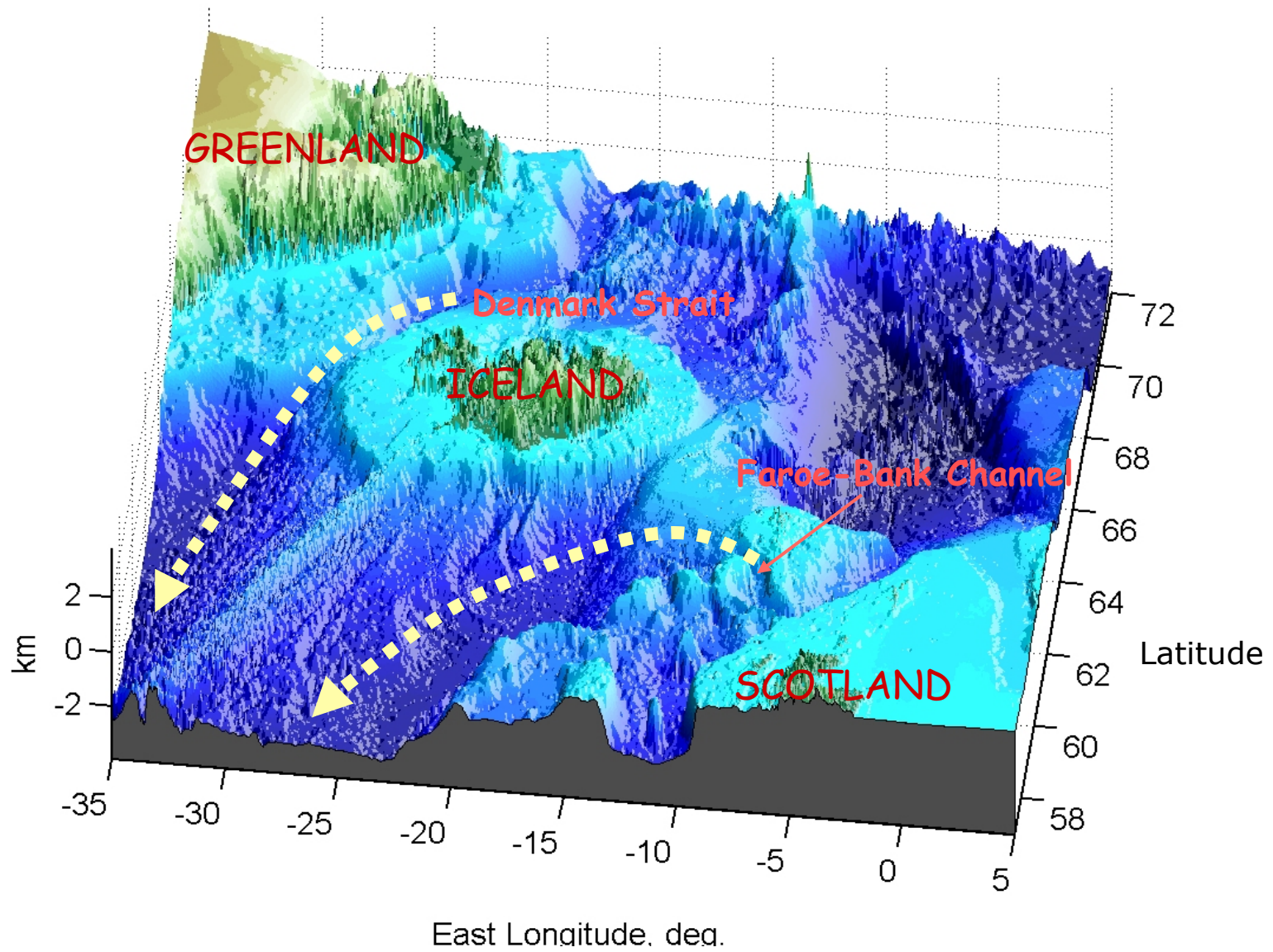
Climate Process Team (CPT) on Gravity Current Entrainment

## OUTLINE:

- Nordic Sea focus
- Motivation
- Brief description
- Impacts (prediction)
- Summary



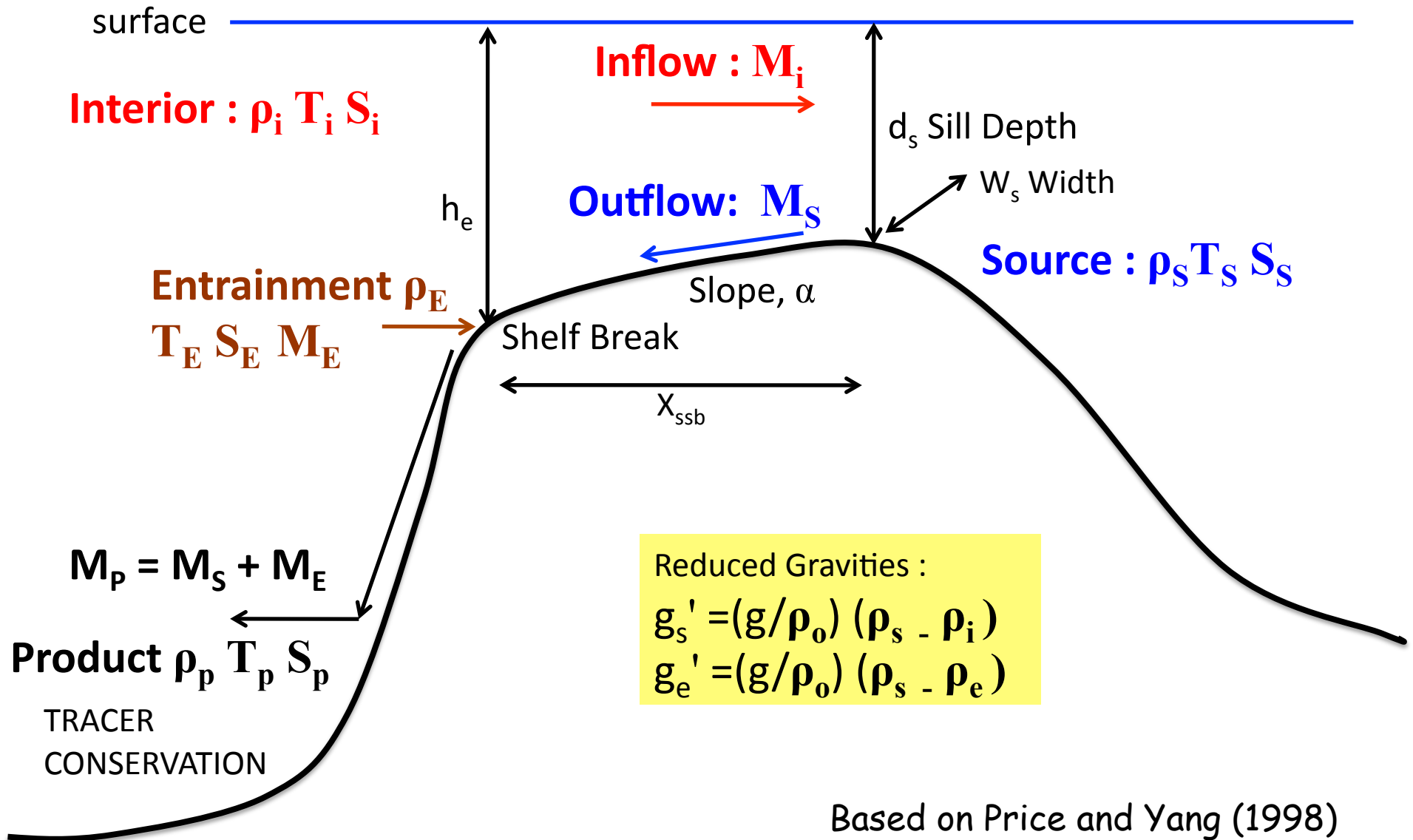
# GRAVITY CURRENT OVERFLOWS



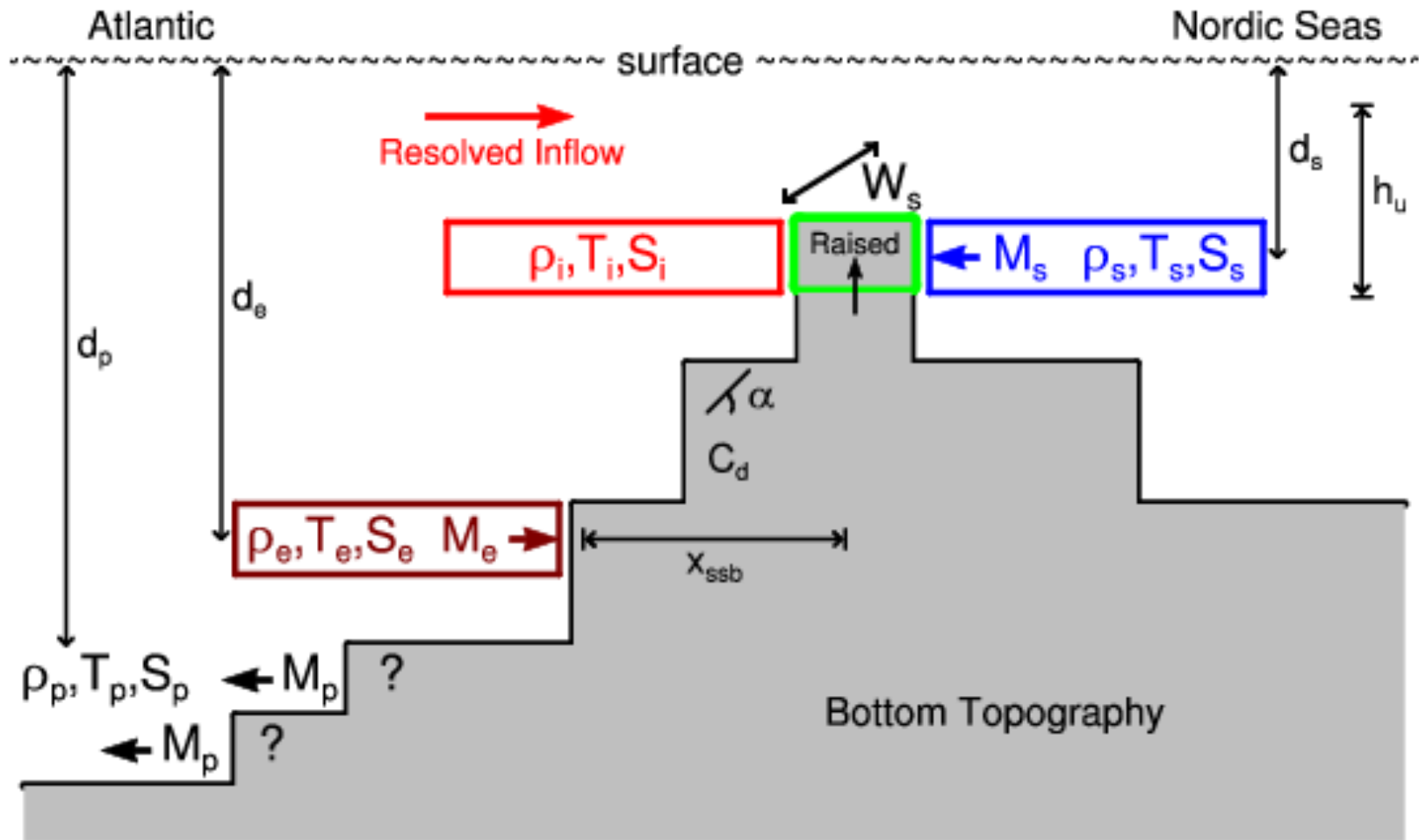
from J.Price

- FBC and DS overflow waters combine with the Labrador Sea deep convection to supply the lower branch of the Atlantic Meridional Overturning Circulation (AMOC).
- Associated horizontal and vertical length scales (order 1 km and 10 m, respectively) are small - sub-grid scale.
- Level coordinate models have the additional problem of excessive convective entrainment due to stair-case topography, resulting in deep waters that are too light and that remain too shallow.
  
- Artificial modification of bottom topography (ad-hoc),
- High resolution nested modeling (technical challenges),
- Shaved or partial bottom cells (steep-sloped regions?),
- Bottom boundary layer schemes,
- Streamtube approaches.

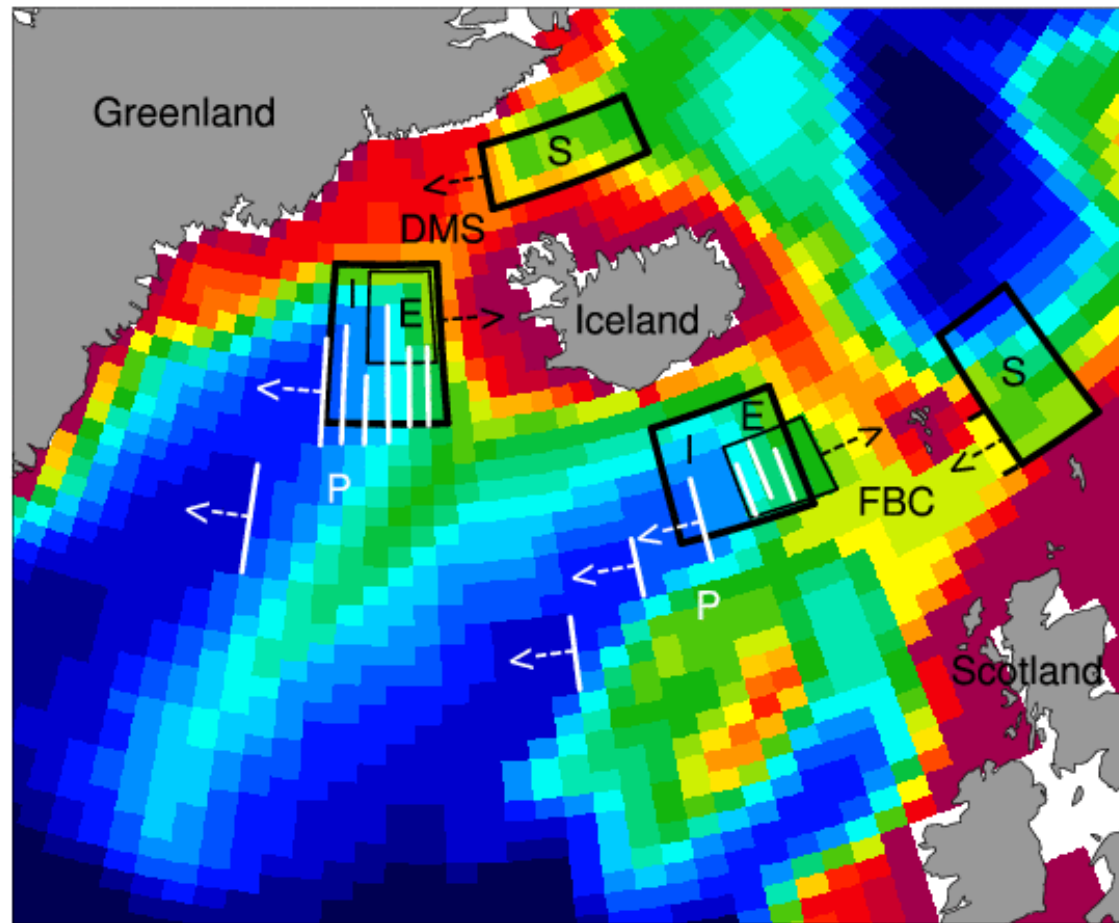
# GRAVITY CURRENT OVERFLOW PARAMETERIZATION



# OVERFLOW PARAMETERIZATION MODEL SCHEMATIC



# BOTTOM TOPOGRAPHY OF THE 1° RESOLUTION CESM OCEAN MODEL



Depth in Meters

200 300 400 450 500 550 600 700 800 900 1000 1300 1600 2000 2500 2750 3000 3500



20 25 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

Vertical Level

- Although the parameterization is based on the Marginal Sea Boundary Condition (MSBC) scheme of Price and Yang (1998), there are significant differences from it.
- Overflows are driven by reduced gravities.
- The Whitehead et al. (1974) formula for rotating, hydraulically controlled maximum geostrophic flow through a strait is used to calculate the source transport.
- The entrainment transport is computed using an end-point model of an entraining, rotating density current based on Price and Baringer (1994).

Our development, formulation, implementation, and results are given in Briegleb, Danabasoglu, and Large (2010; NCAR Tech. Note) and Danabasoglu, Large, and Briegleb (2010; JGR-Oceans).

# VERIFICATION AND IMPACTS OF THE OVERFLOW PARAMETERIZATION IN CESM

	UNCOUPLED	COUPLED
Control (no overflows)	OCN	CCSM
With overflows	OCN*	CCSM*

- Ocean model uses nominal 1° horizontal resolution with 60 vertical levels.
- OCN is forced with the CORE NYF data sets.
- Atmospheric model uses a finite volume dynamical core with 2° horizontal resolution with 26 vertical levels.
- Each experiment is run for 170 years.

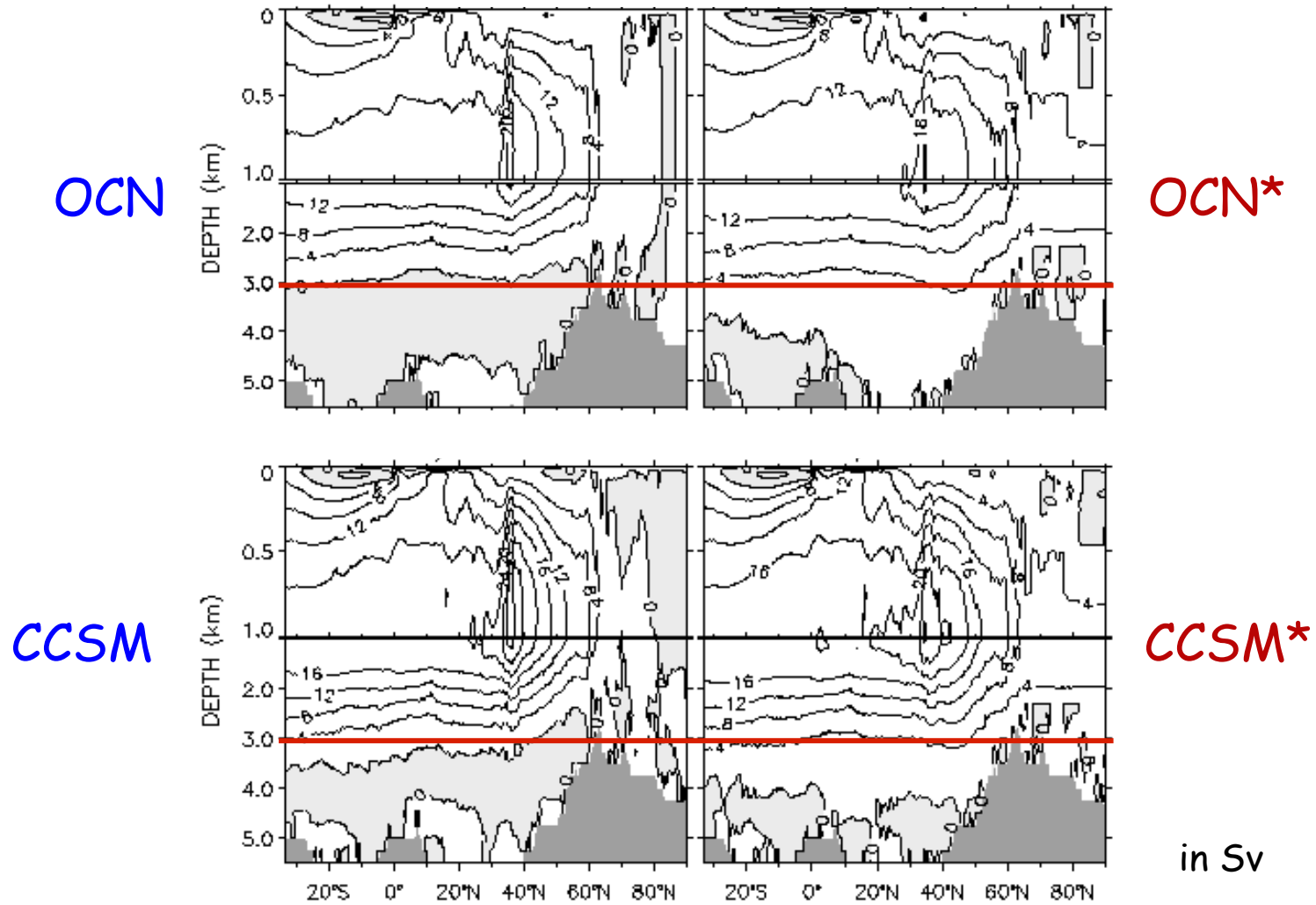
# NORDIC SEA OVERFLOW TRANSPORTS

	Observed <sup>+</sup>	Diagnostic model (offline)	OCN*	CCSM*
M <sub>I</sub>				
M <sub>S</sub>	4.1 - 7.5	5.2	4.7	4.4
M <sub>E</sub>	1.5 - 3.7	1.2	0.9	1.1
M <sub>P</sub>	6.4 - 9.4	6.4	5.6	5.5

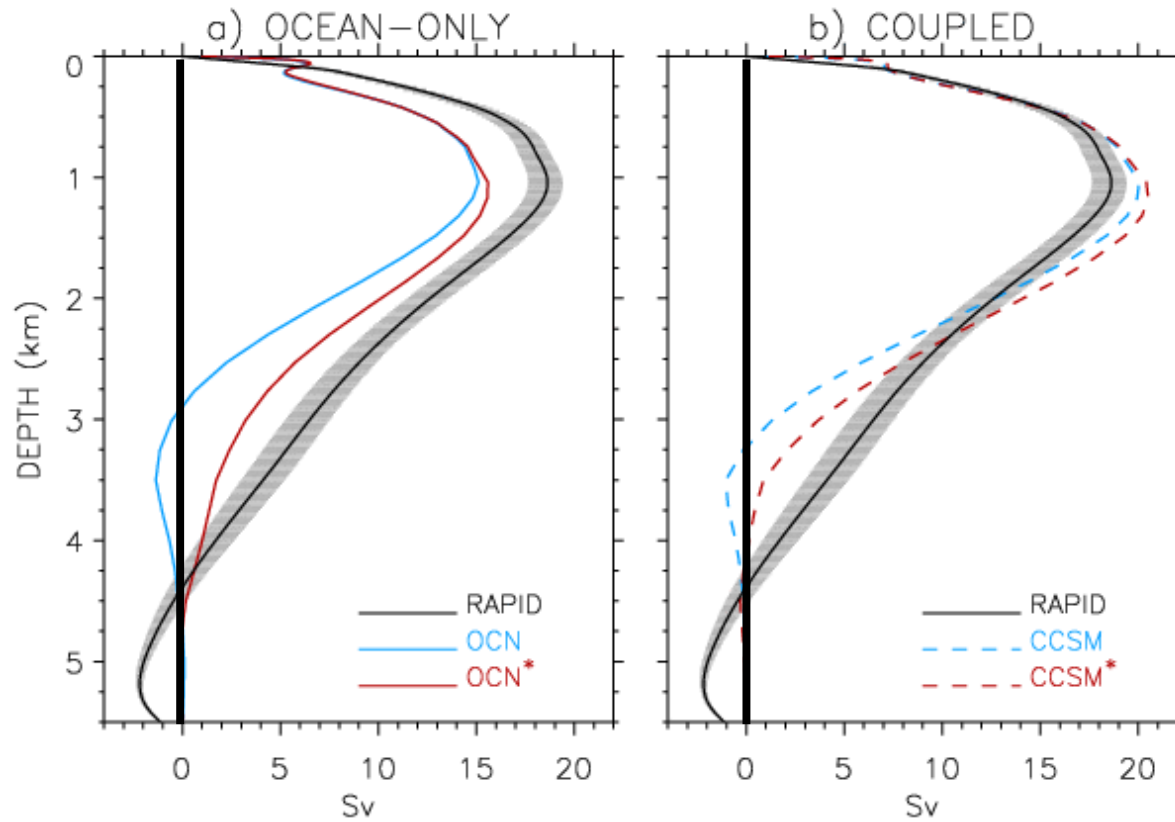
All in Sv

<sup>+</sup> from Legg et al. (2009)

# ATLANTIC MERIDIONAL OVERTURNING CIRCULATION (AMOC)



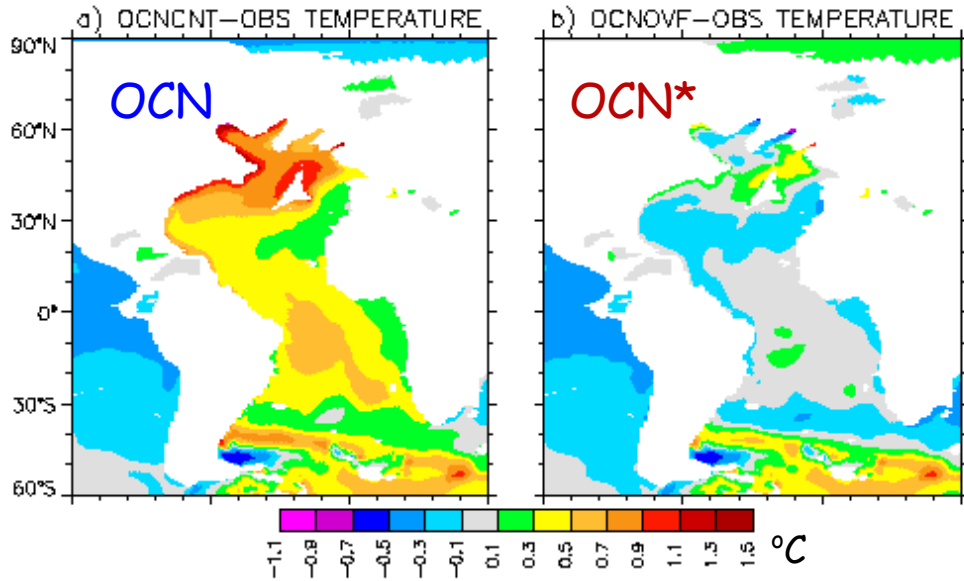
## AMOC TRANSPORT AT 26.5°N



RAPID is observational data from Cunningham et al. (2007).

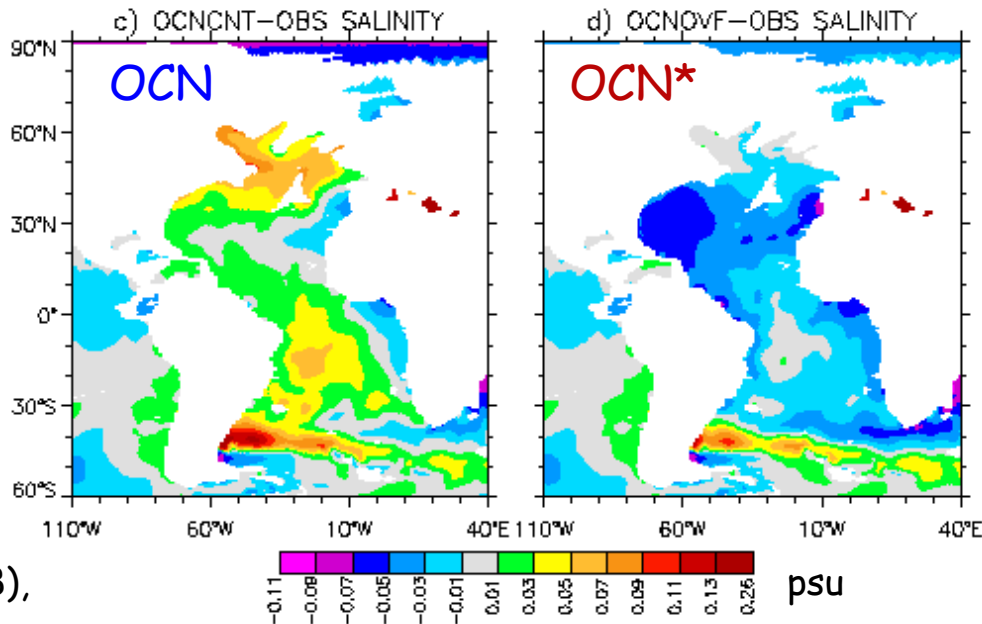
# TEMPERATURE AND SALINITY DIFFERENCES FROM OBSERVATIONS AT 2649-m DEPTH

mean= 0.45°C  
rms= 0.50°C



mean= -0.04°C  
rms= 0.13°C

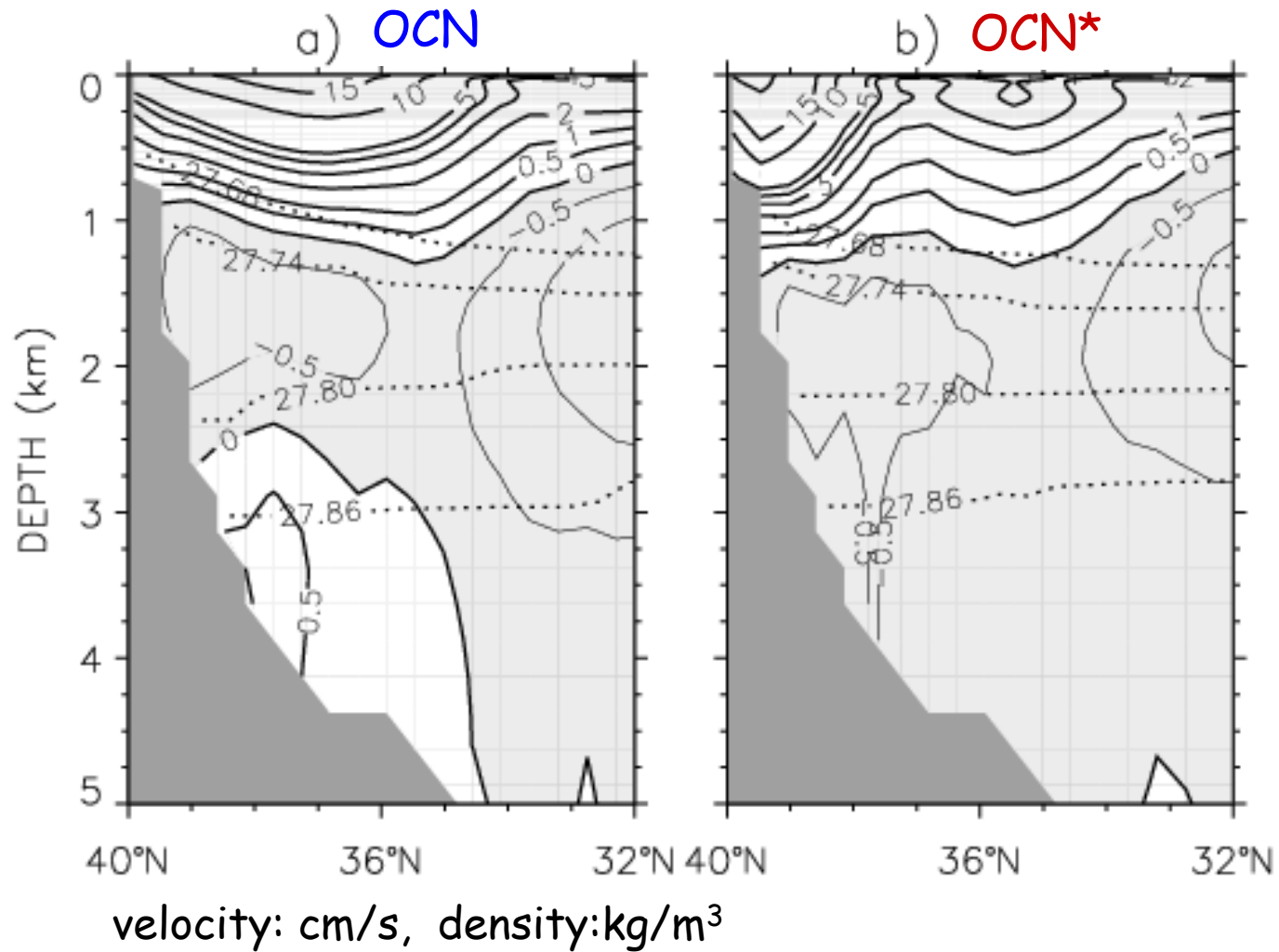
mean= 0.02 psu  
rms= 0.03 psu



mean= -0.03 psu  
rms= 0.03 psu

Obs: Levitus et al. (1998),  
Steele et al. (2001)

# ZONAL VELOCITY ACROSS 69°W IN THE NORTH ATLANTIC



## EQUATORWARD VOLUME TRANSPORTS

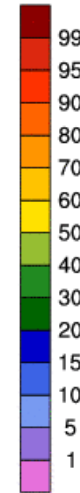
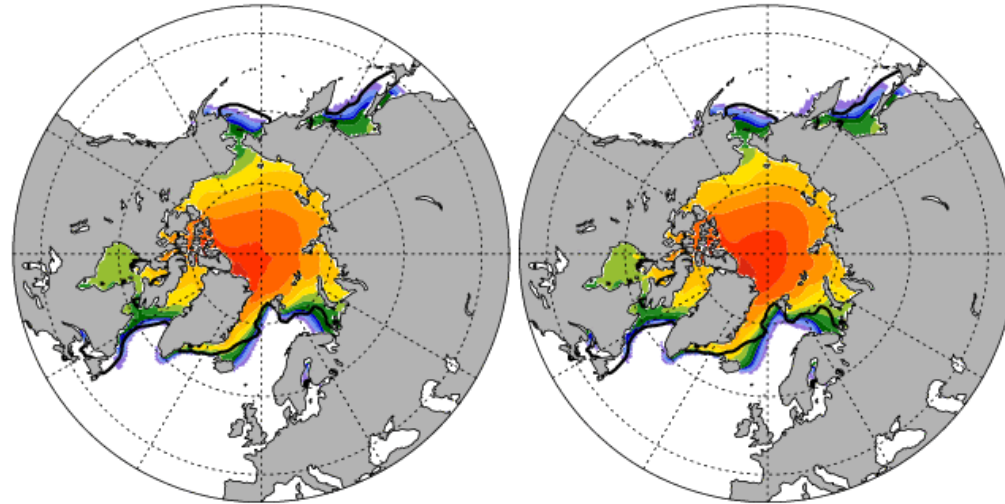
$\sigma_{\theta} \geq$	44°W 27.80	49.3°W 27.80	49.3°W 27.74	69°W 27.80
OCN	5.3	3.5	17.3	0.2
OCN*	10.7	9.3	26.7	2.0
OBS	13.3 Dickson and Brown(1994)	14.7 Fischer et al. (2004)	26 ± 5 Fischer et al. (2004)	12.5 Joyce et al. (2005)

All in Sv

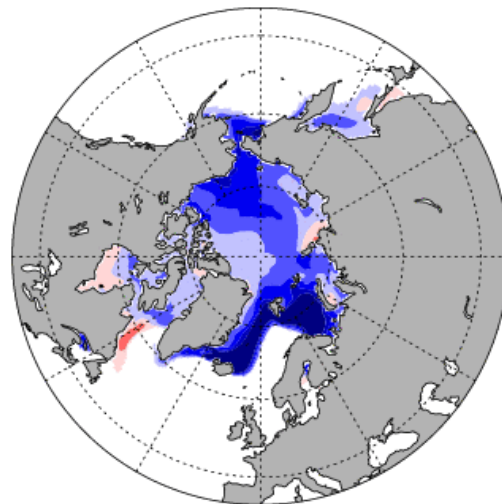
# IMPACTS ON SEA-ICE CONCENTRATION

CCSM\*

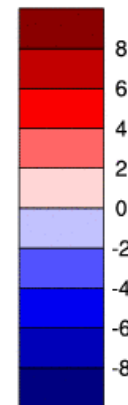
CCSM



CCSM\* - CCSM

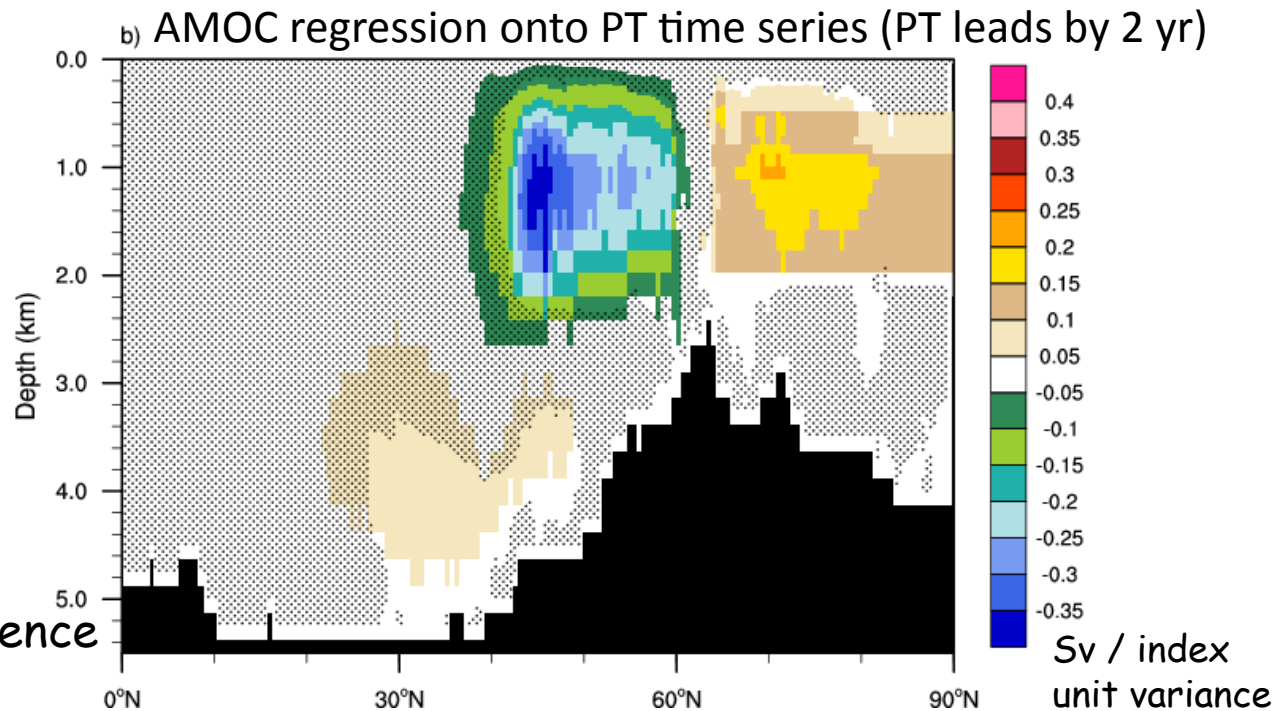
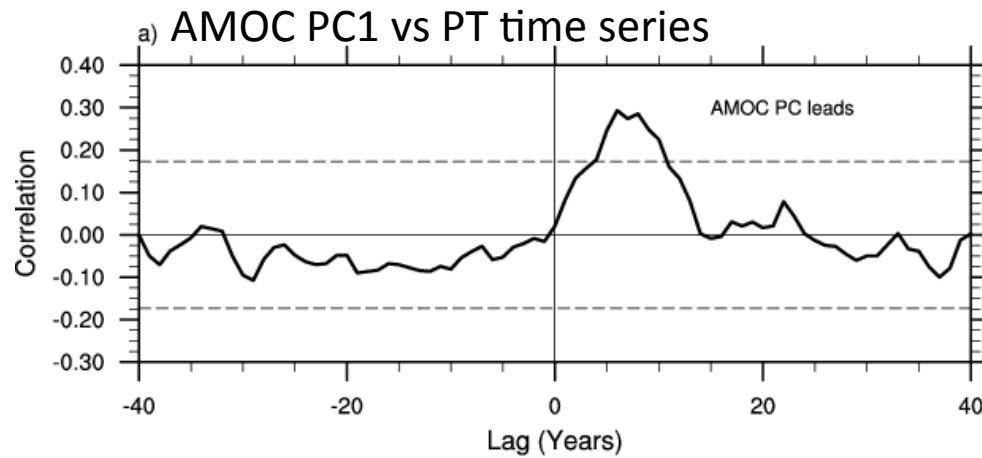


MIN = -27.27 MAX = 3.31



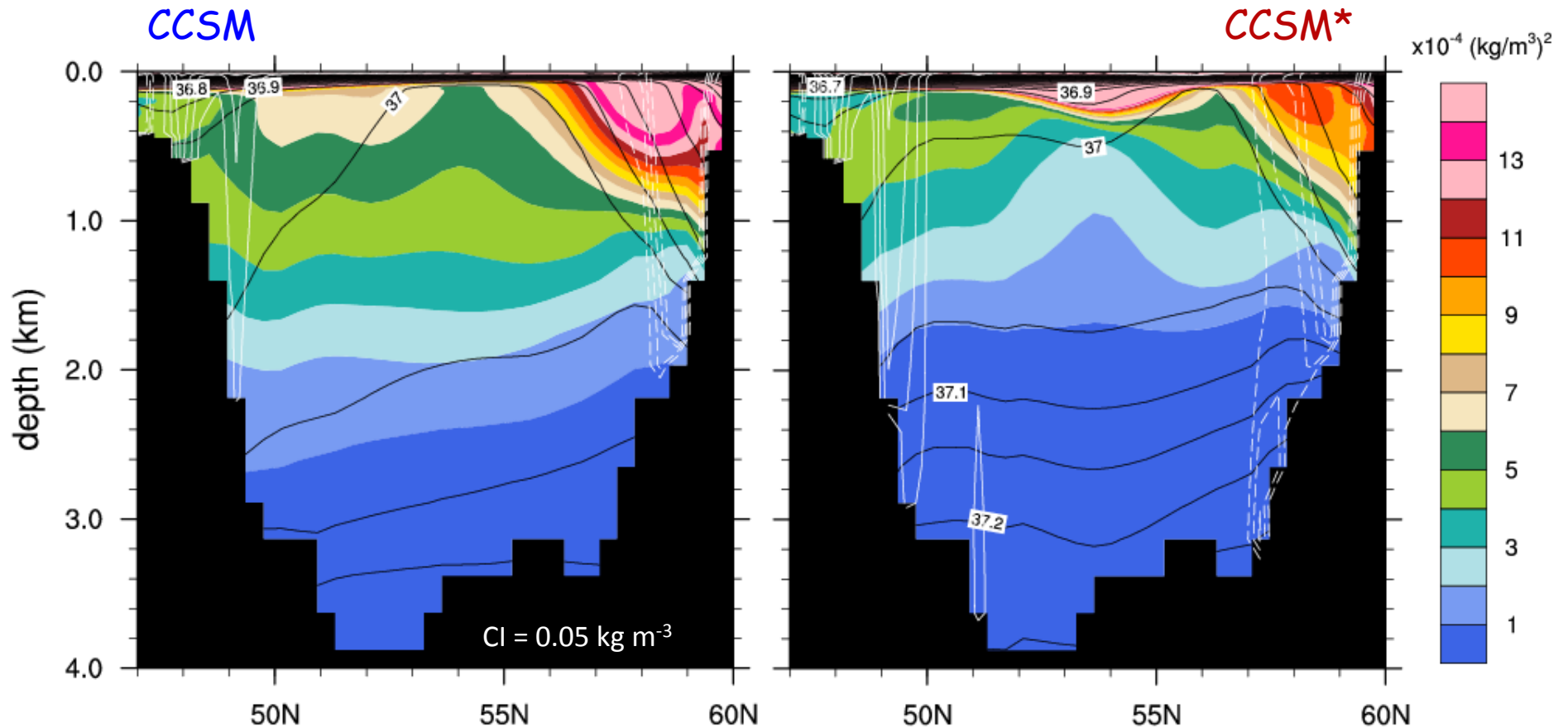
% of grid area

# DENMARK STRAIT & FAROE BANK CHANNEL OVERFLOW PRODUCT WATER TRANSPORTS (PT) and AMOC

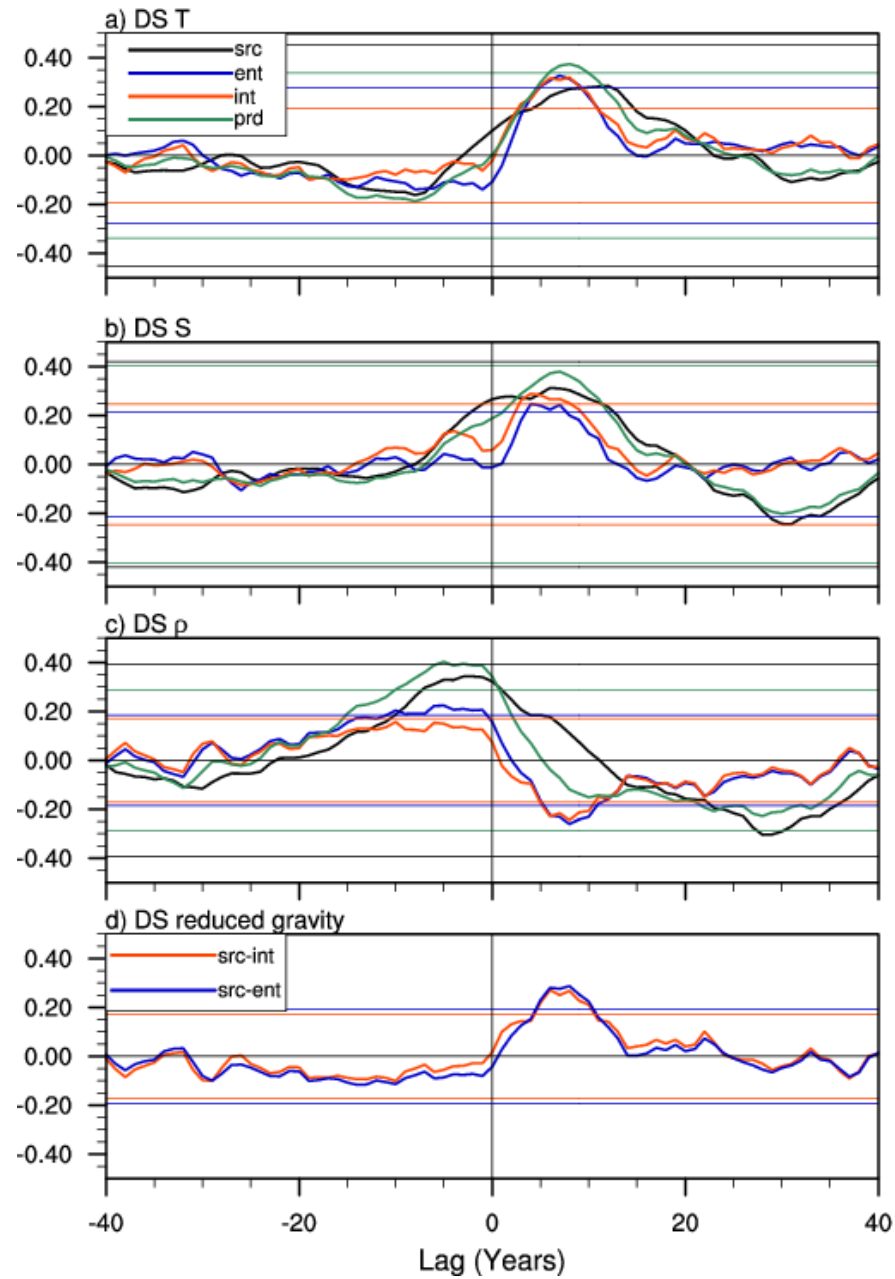


stippling: confidence  
level < 95%

Density variance (color) and mean (black lines)  
Zonal velocity (white lines)



# OVERFLOW PROPERTY CORRELATIONS WITH AMOC PC1



AMOC PC1 leads  
for positive lags

## SUMMARY

- Substantial improvement in the penetration depth of the North Atlantic Deep Water,
  - Reductions in the temperature and salinity biases in the deep and abyssal North Atlantic,
  - There are modest climate impacts,
  - Increased overflow transports do not lead to higher *AMOC* - with important implications for decadal prediction studies.
- 
- Low entrainment needs further attention.



ATLANTIC

ARCTIC

Surface

-z

$\rho_0$   
(Ent. density based on 12 grid points)

$\rho_s$   
(Source density based on 12 grid points)

$$g' = g (\rho_s - \rho_0) / \rho_{ref}$$

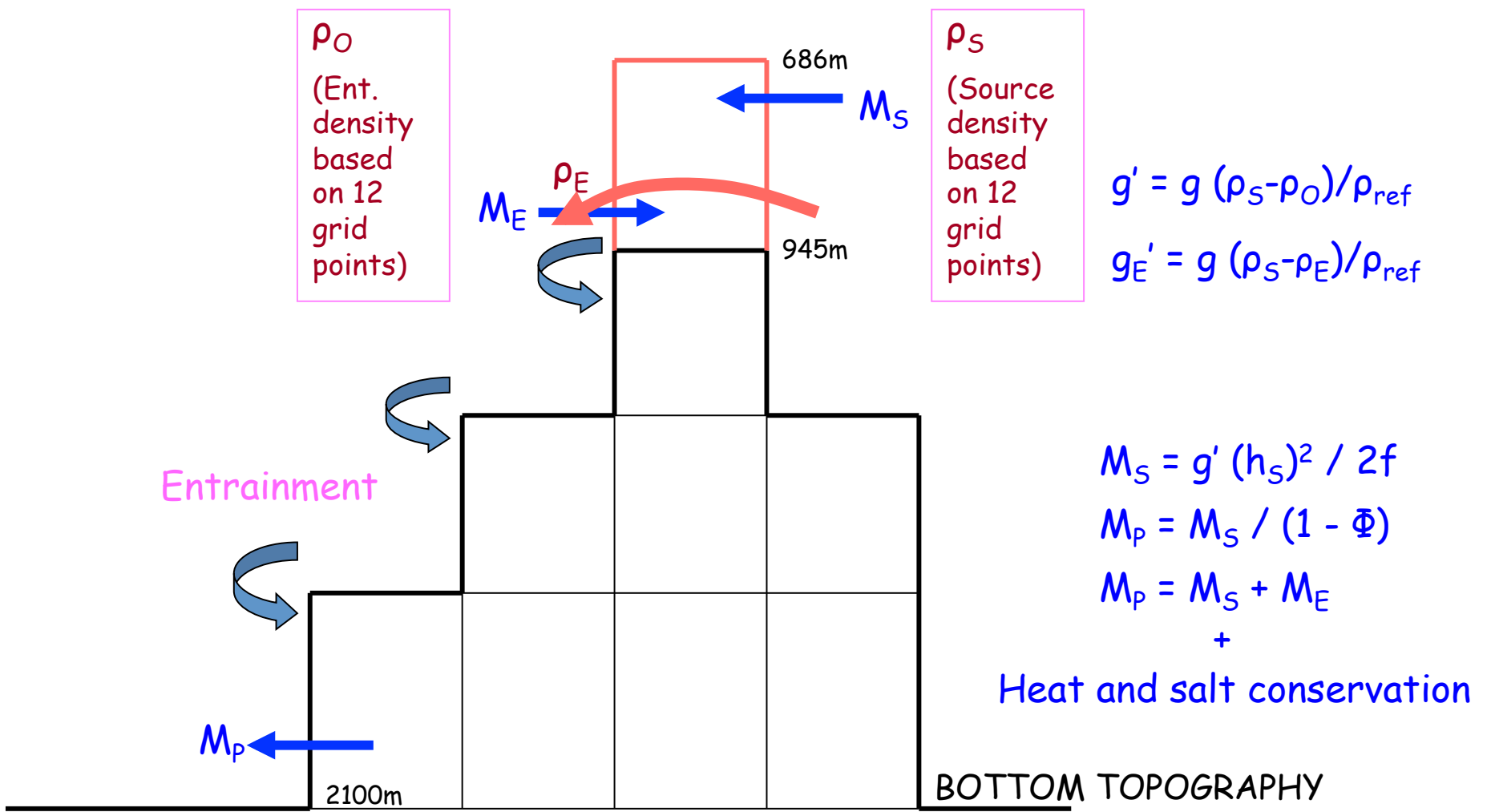
$$g'_E = g (\rho_s - \rho_E) / \rho_{ref}$$

$$M_s = g' (h_s)^2 / 2f$$

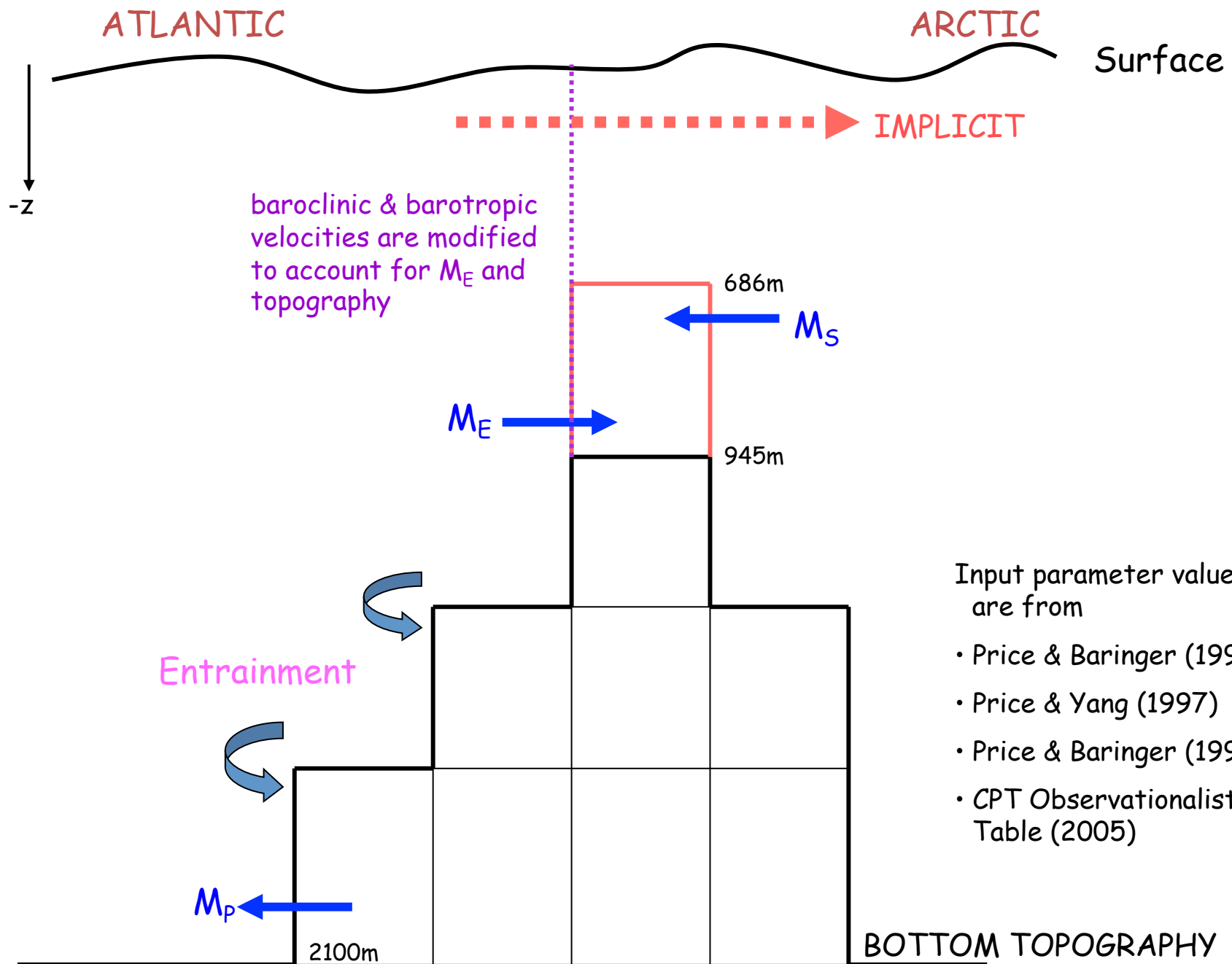
$$M_p = M_s / (1 - \Phi)$$

$$M_p = M_s + M_E$$

Heat and salt conservation



BOTTOM TOPOGRAPHY



Our first implementation of the MSBC scheme was for the Mediterranean Outflow. The results were shown at the Providence Meeting (2004). They are also discussed, including the climate impacts, in the renewal proposal.

In the present work, extending the implementation of the "MSBC" scheme to FBC and DS overflows.

Our approach/implementation differ from the MSBC scheme in some important aspects:

- Applied to open ocean at depth (therefore no MSBC!).
- No explicit inflow into the source water regions (this is done by the large scale flow).
- Entrained and product water transports can occur at different (horizontal) locations.
- As in our Mediterranean implementation, the reduced gravity depends on evolving model T and S, i.e., it is time dependent!

It is not an MSBC anymore..... more like an overflow parameterization!