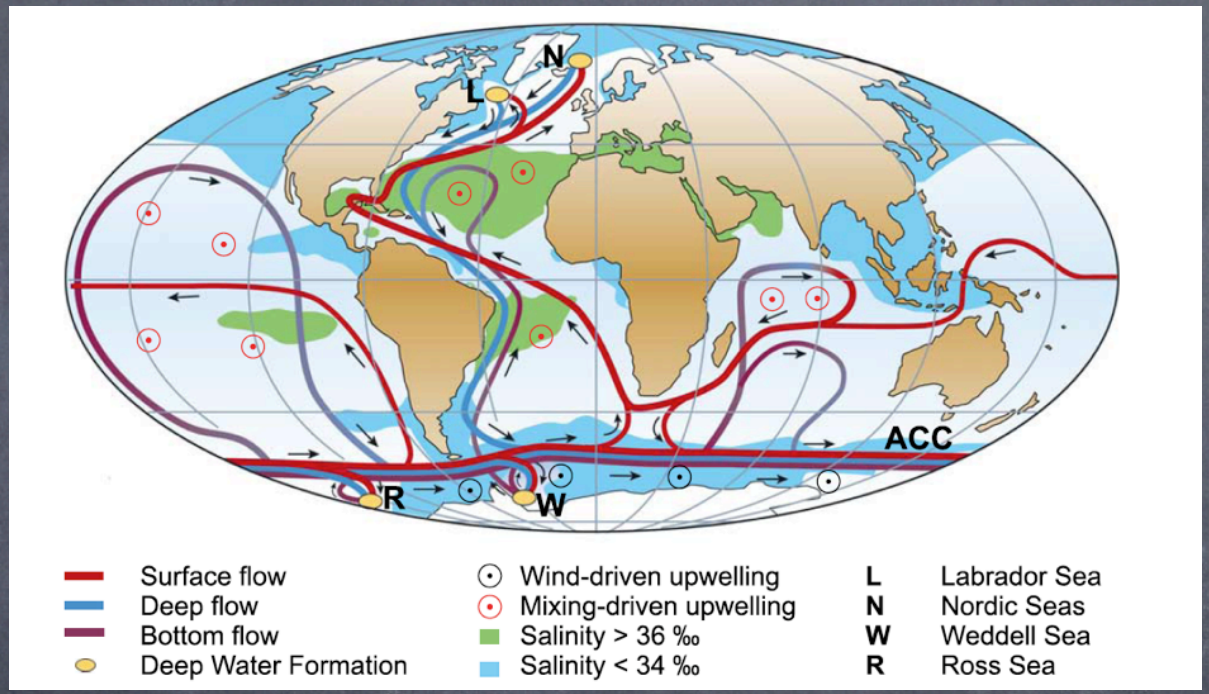
# A scalar indicator of the stability of the MOC

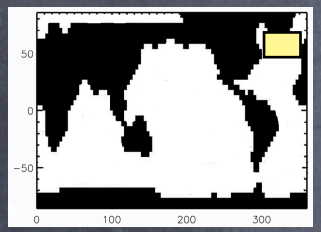



Kuhlbrodt et al., RoG, (2007)

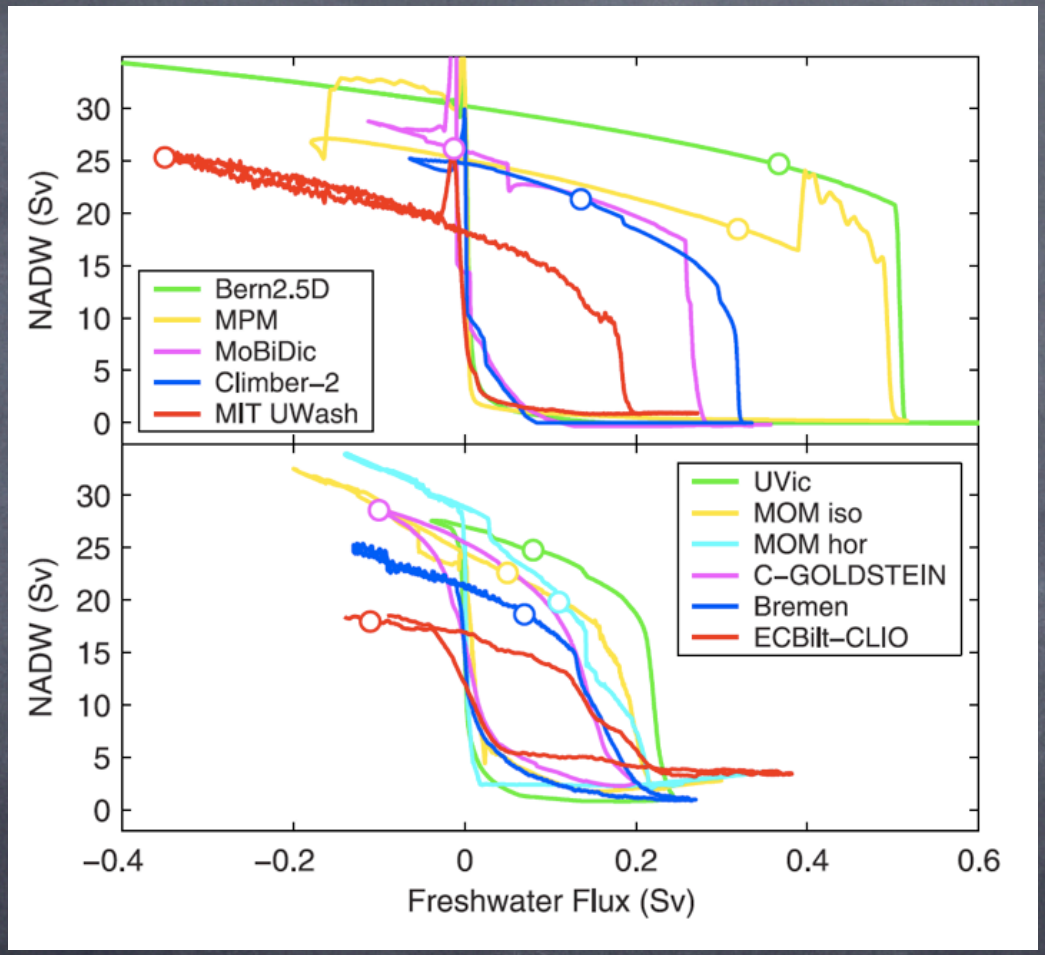
S. Huisman, M. den Toom, H.A. Dijkstra and S. Drijfhout

IMAU (UU) and KNMI, The Netherlands

# The Atlantic MOC may be sensitive to changes in the northern North Atlantic freshwater flux




$\gamma_p$

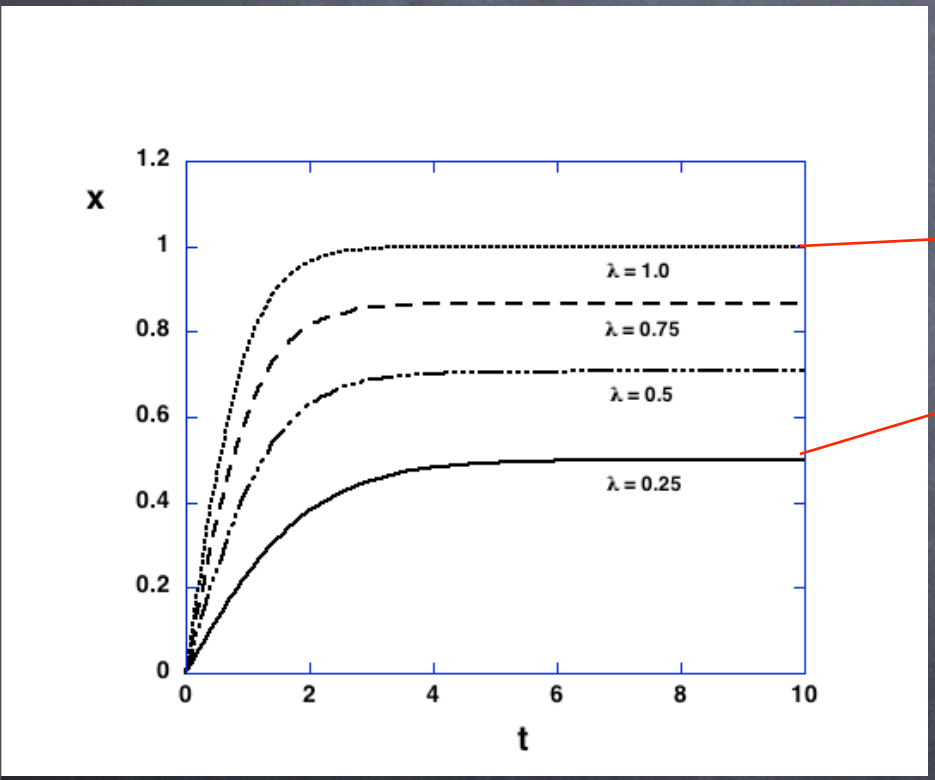


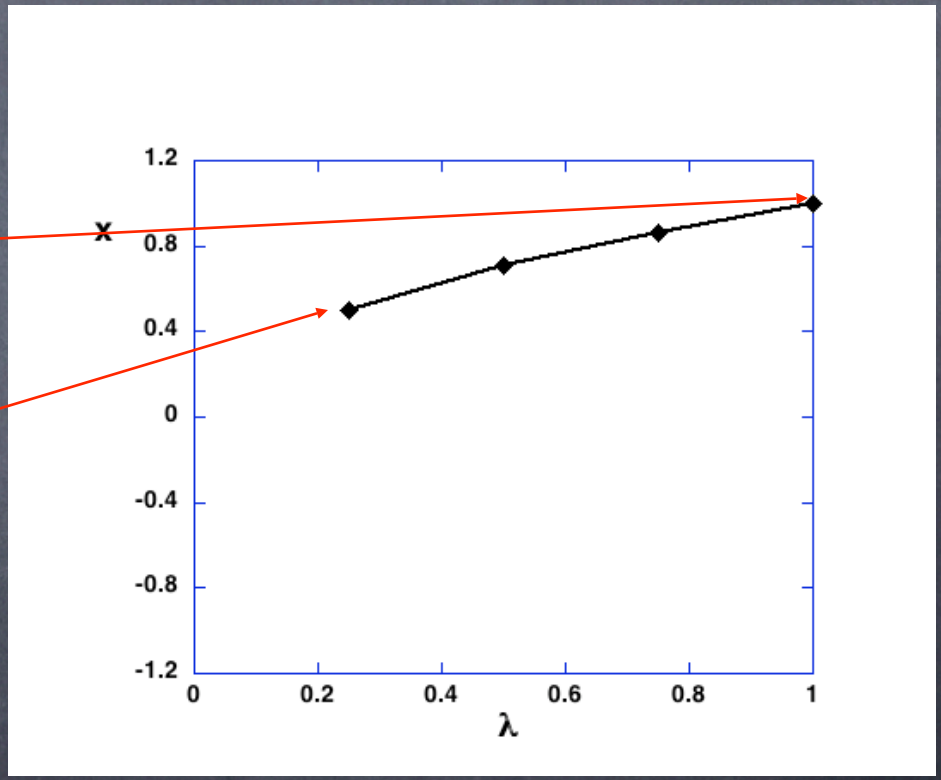

$\gamma_p$

Rahmstorf et al., GRL, (2005)

# What is a Bifurcation Diagram?

Example: $\frac{dx}{dt} = \lambda - x^2$

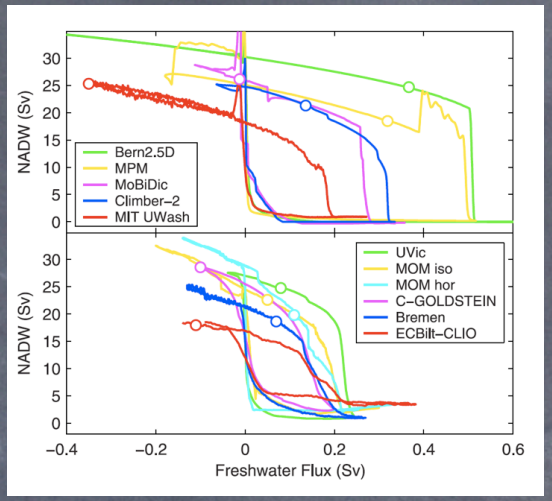


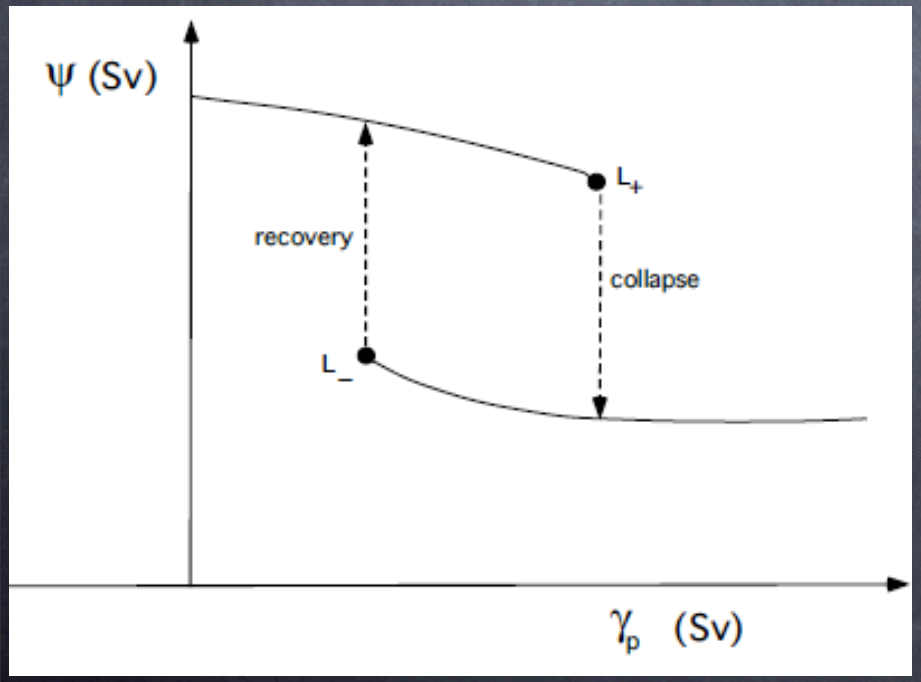



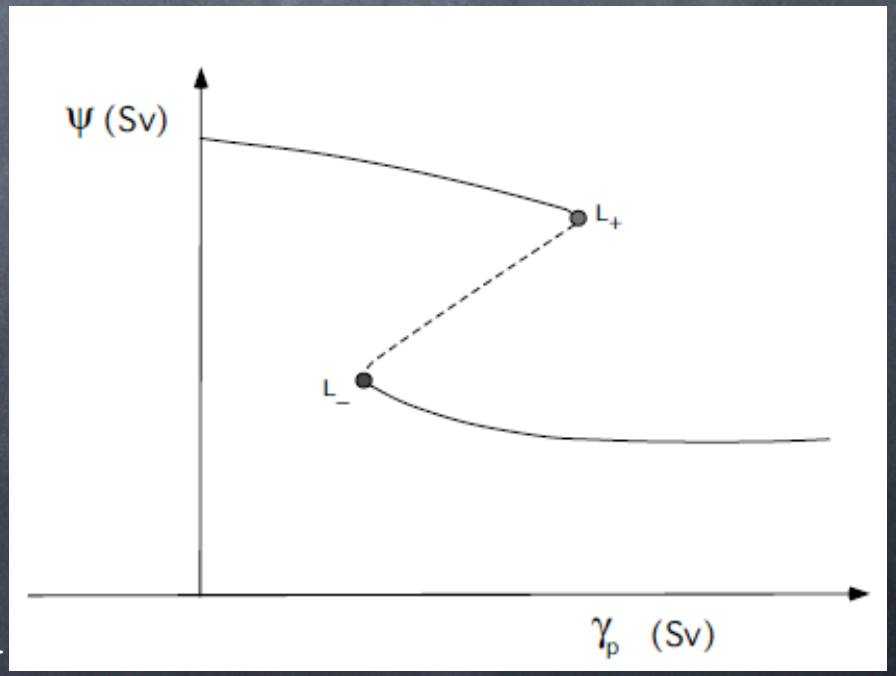

trajectories

(partial) bifurcation diagram

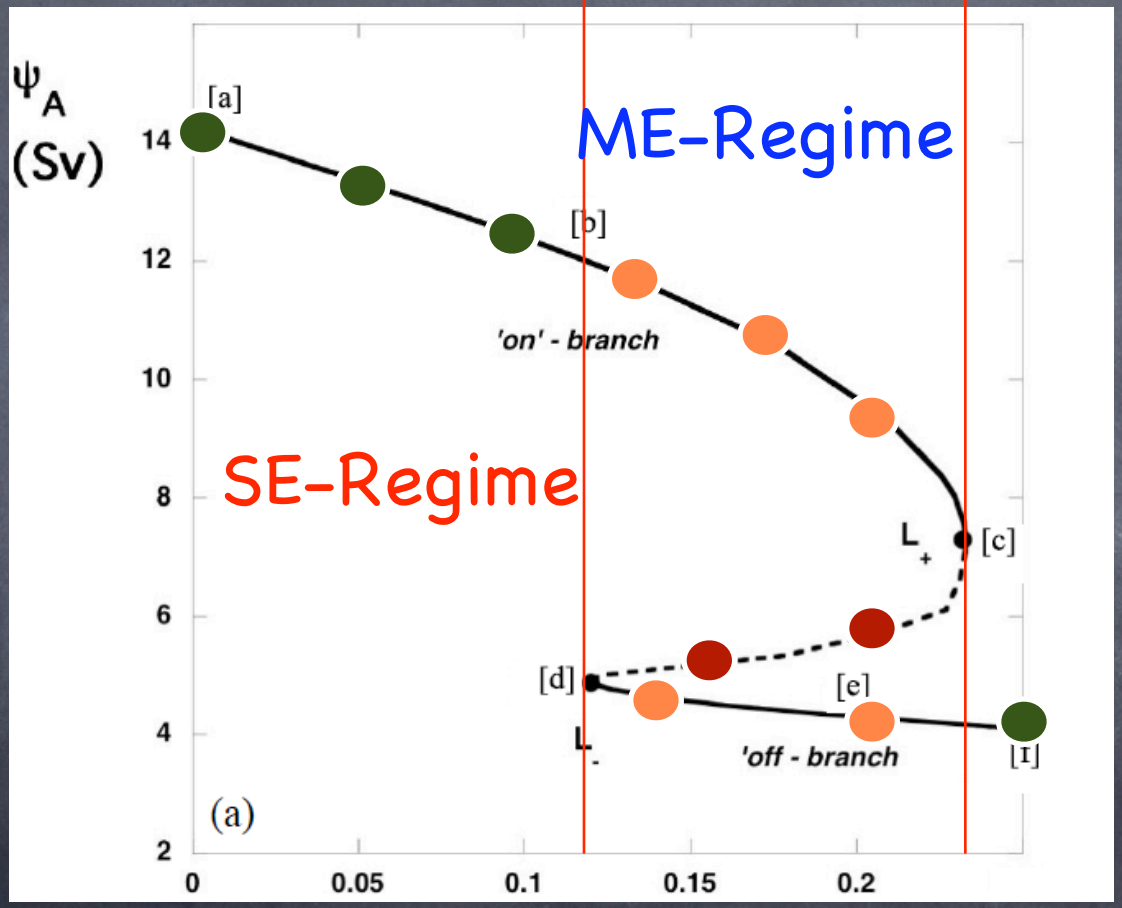
# Correspondence between quasi-equilibrium calculations and bifurcation diagrams, II

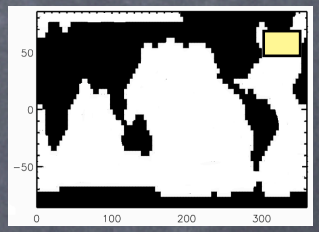


# Bifurcation Diagram of a Global Ocean Model

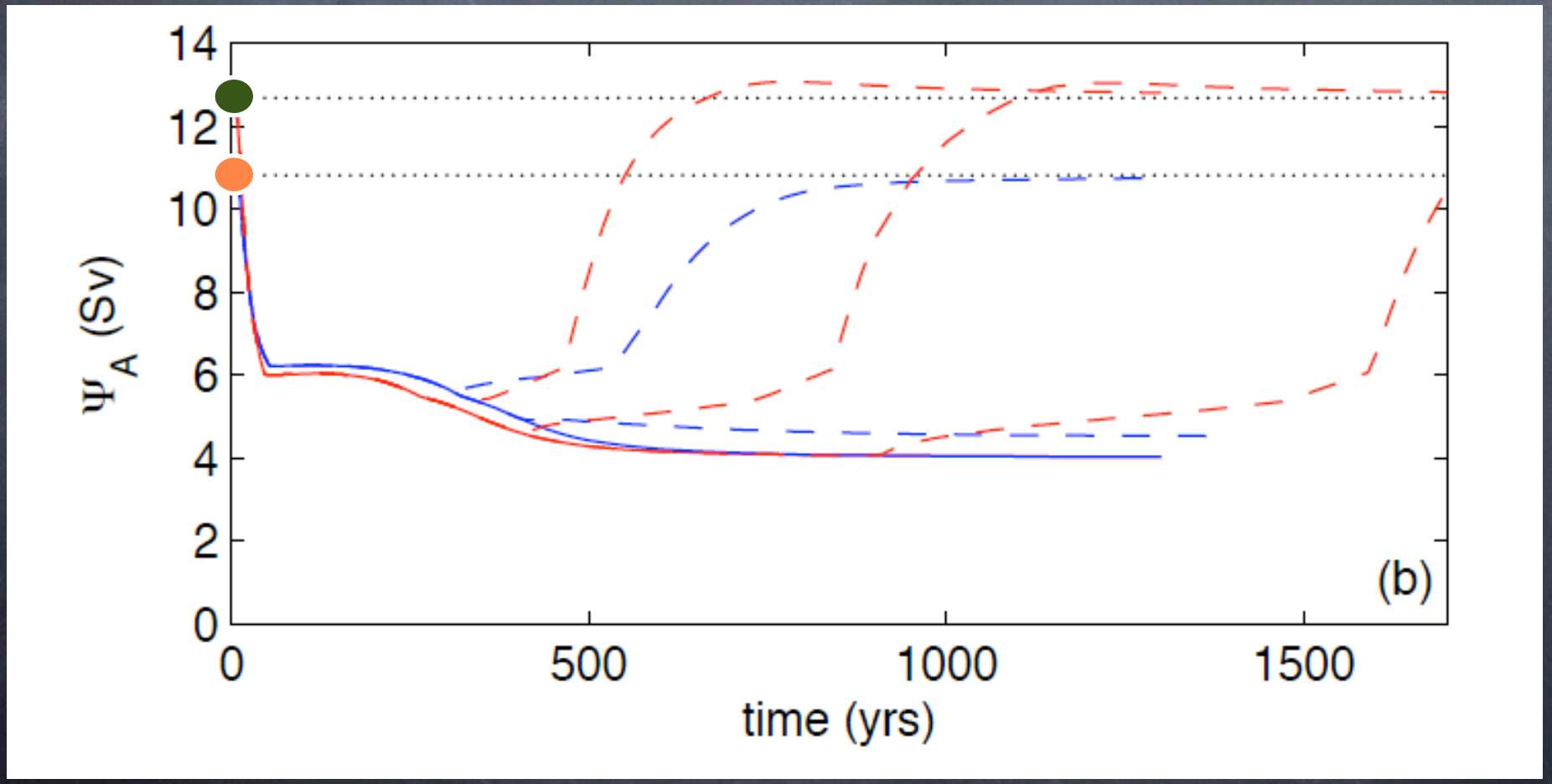


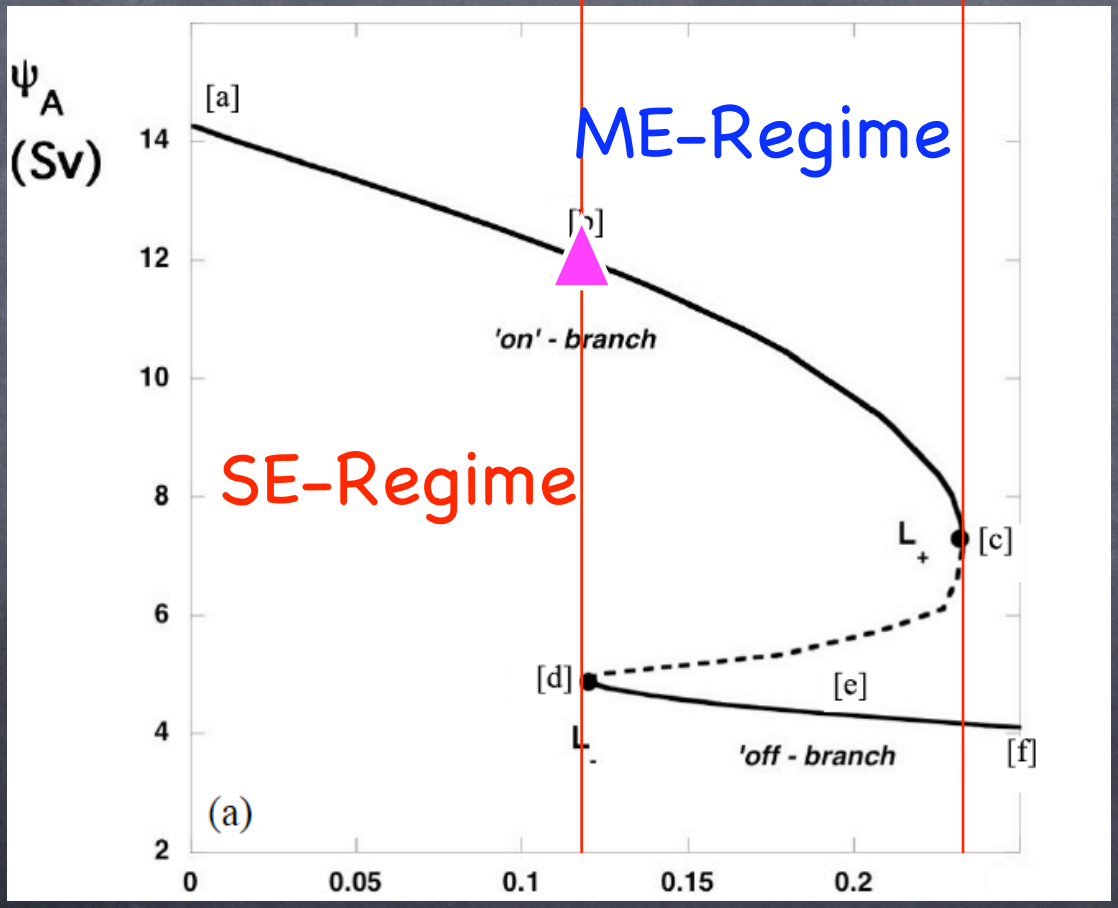

$\gamma_p$

Dijkstra and Weijer, JPO, 2005

# Temporal development of perturbations

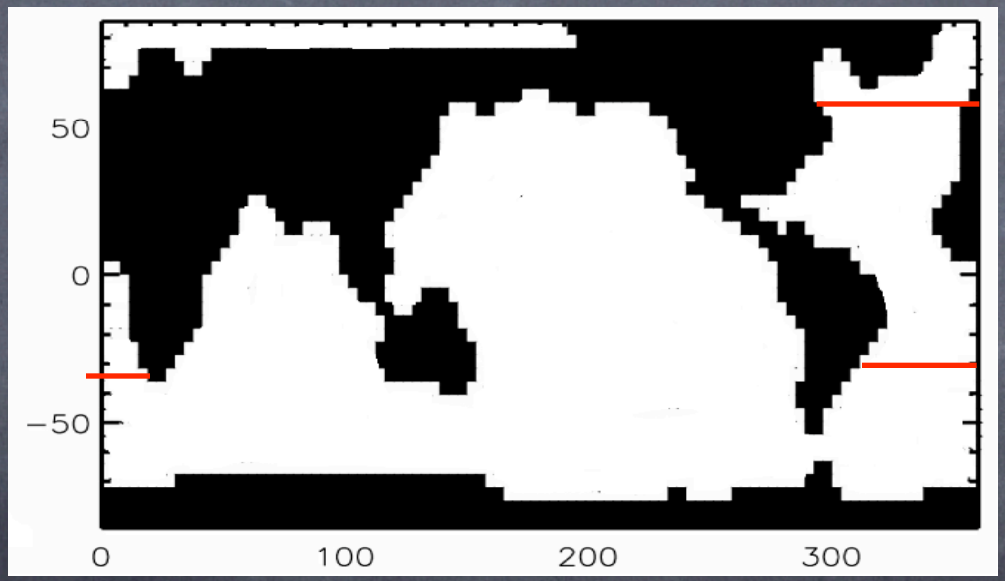


# What physics characterizes the MOC solution at the value of $\gamma_p$ at the saddle-node L_ ?



# Freshwater budget over the Atlantic

$$\int_{S_{Atl}} F_S \; r_0^2 \cos\theta \; d\phi d\theta \; = \; -\frac{1}{S_0}(\Phi(\theta_n) - \Phi(\theta_s)).$$




$\theta = \theta_n$

$\theta = \theta_s$

$$\Phi(\theta) = \int_{S_\theta} (vS - \frac{K_H}{r_0}\frac{\partial S}{\partial \theta}) \; r_0 \cos\theta \; d\phi dz$$

# Indicators of salt export

$$M_{ov}(\theta) = -\frac{\eta}{S_0}\int \langle v\rangle(\langle S\rangle - S_0)\, dz \;;\; M_{az}(\theta) = -\frac{\eta}{S_0}\int \langle v'S'\rangle\, dz.$$

$$v' = v - \langle v\rangle \qquad S' = S - \langle S\rangle$$

$$\eta = \int r_0 \cos\theta\, d\phi \;;\; \langle F\rangle = \frac{1}{\eta}\int F r_0 \cos\theta\, d\phi$$

$M_{ov} > 0 \rightarrow$ MOC exports salt

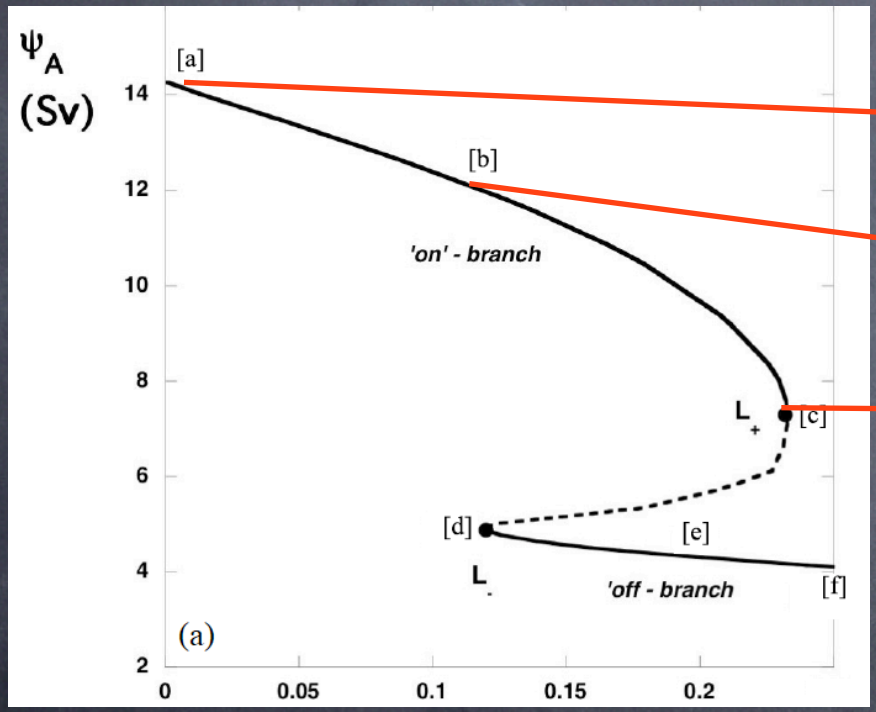
$M_{ov} < 0 \rightarrow$ MOC exports fresh water

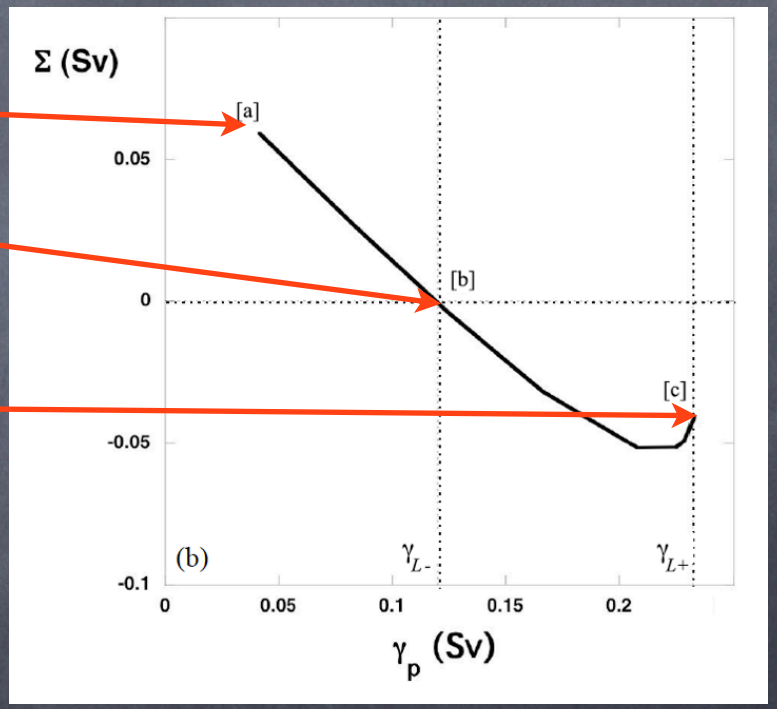


De Vries and Weber, GRL, 2004

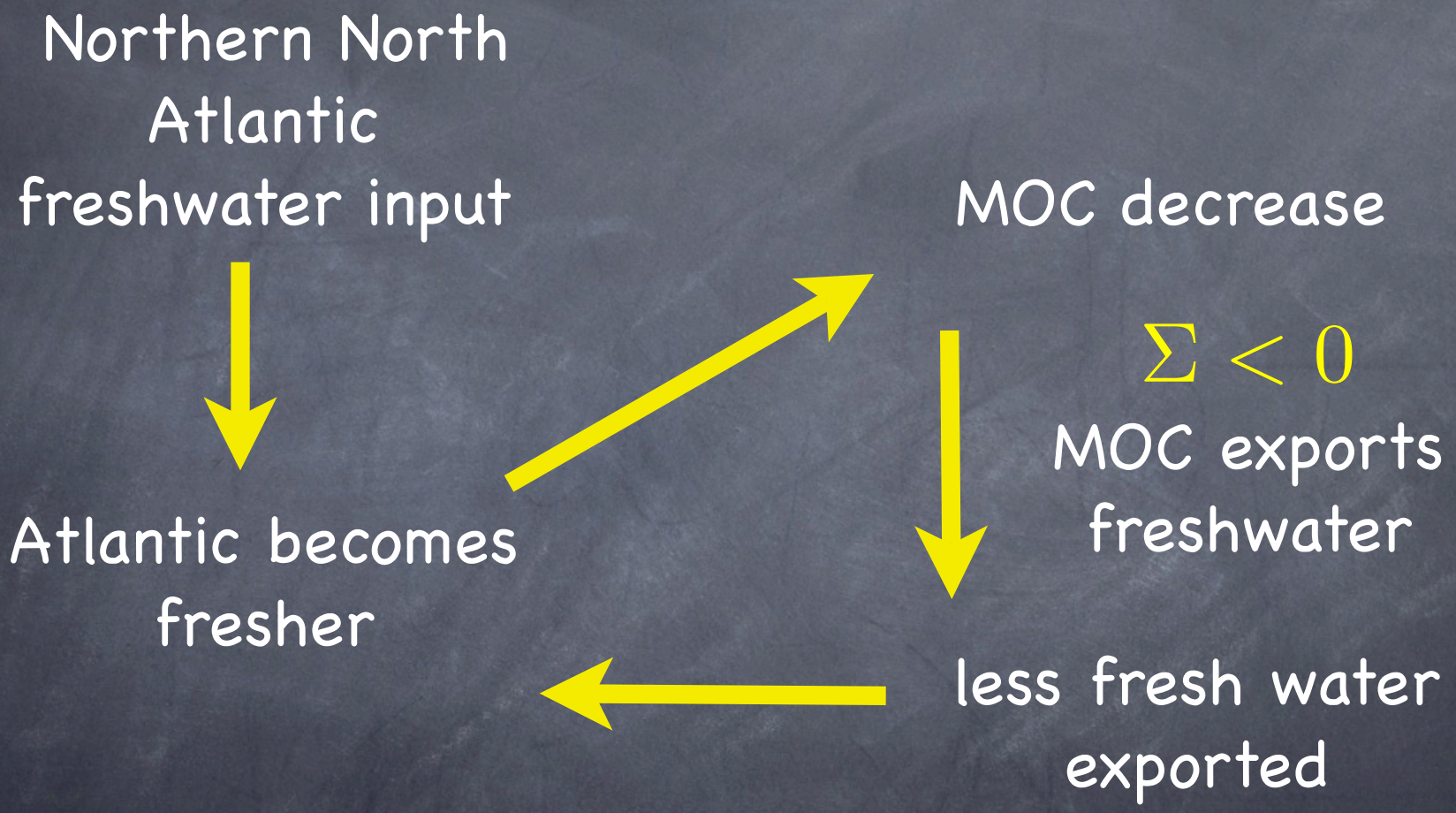
# A MOC stability indicator

$$\Sigma(\theta_n, \theta_s) = M_{ov}(\theta_s) - M_{ov}(\theta_n)$$



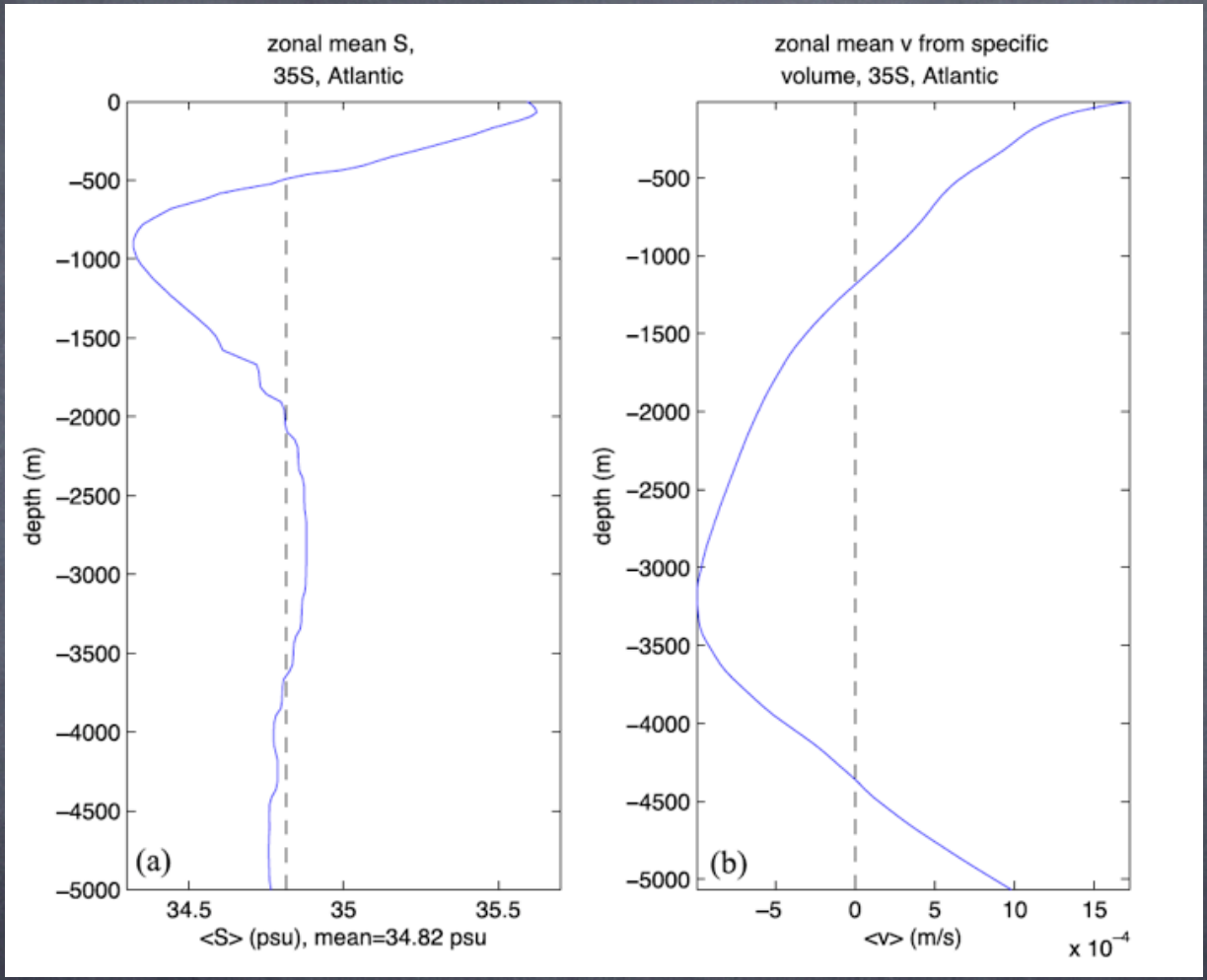



# `Schematic' Physics




Precise physics: Huisman et al. JPO, (2009)

# Rough estimates of $\Sigma$




Weijer et al. (1999): -0.3 Sv

Huisman et al. (2010): -0.1 Sv

# Conclusions

The sign of the freshwater export by the MOC may be an indicator of the stability of the MOC

To obtain more accurate values of this indicator, additional observations along the southern boundary of the Atlantic are required