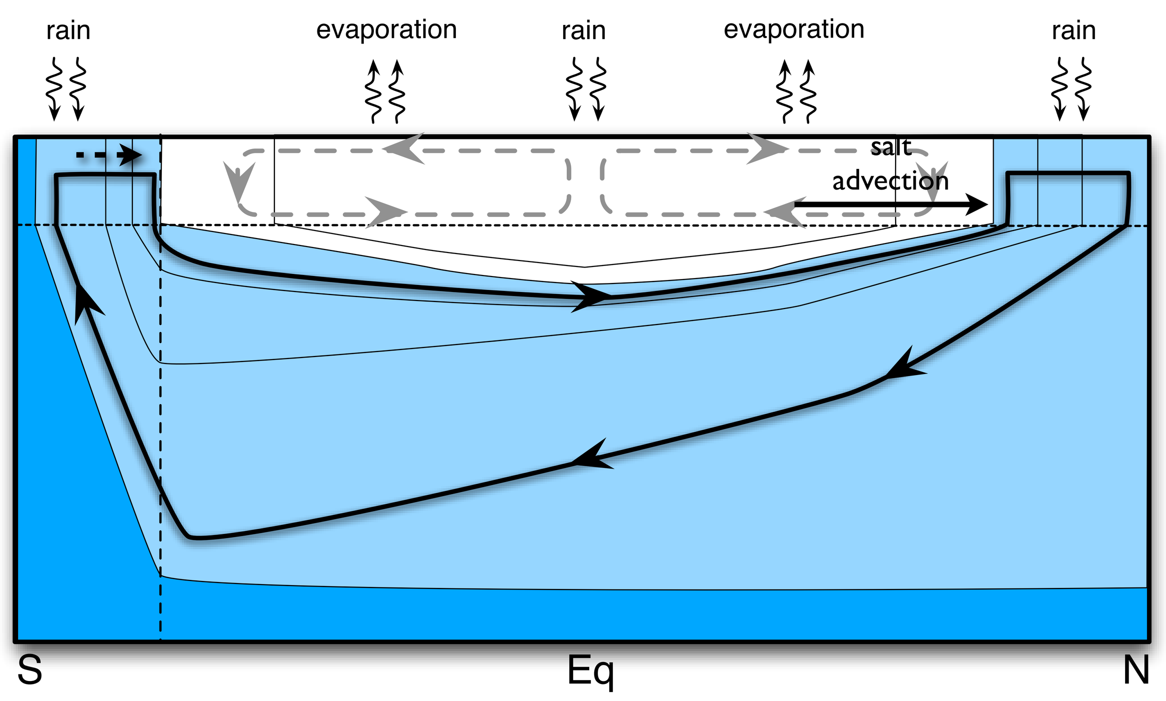
Multiple states in the Quasi-Adiabatic Pole-to-Pole Circulation

Christopher L. Wolfe[†] and Paola Cessi
Scripps Institution of Oceanography - UCSD
[†]Now at Stony Brook University

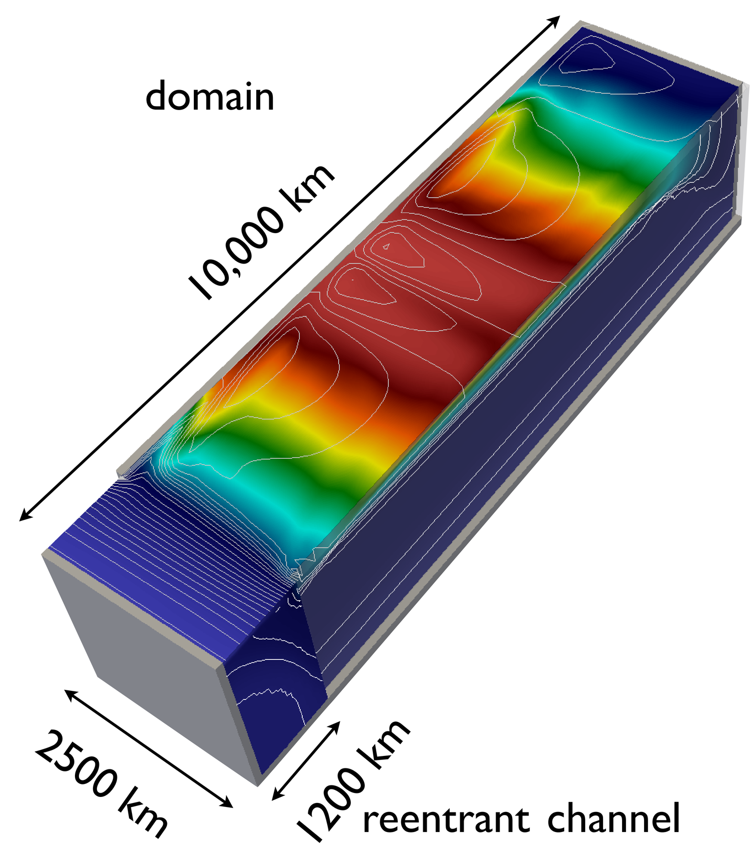
Salt Advection Feedback

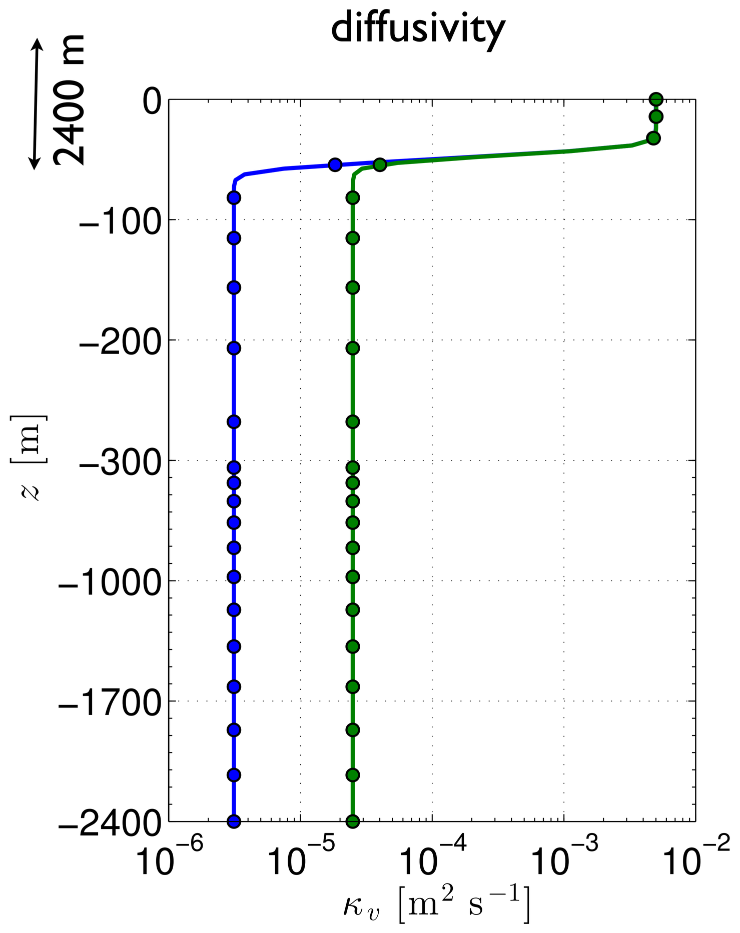
MOC initially "forward"

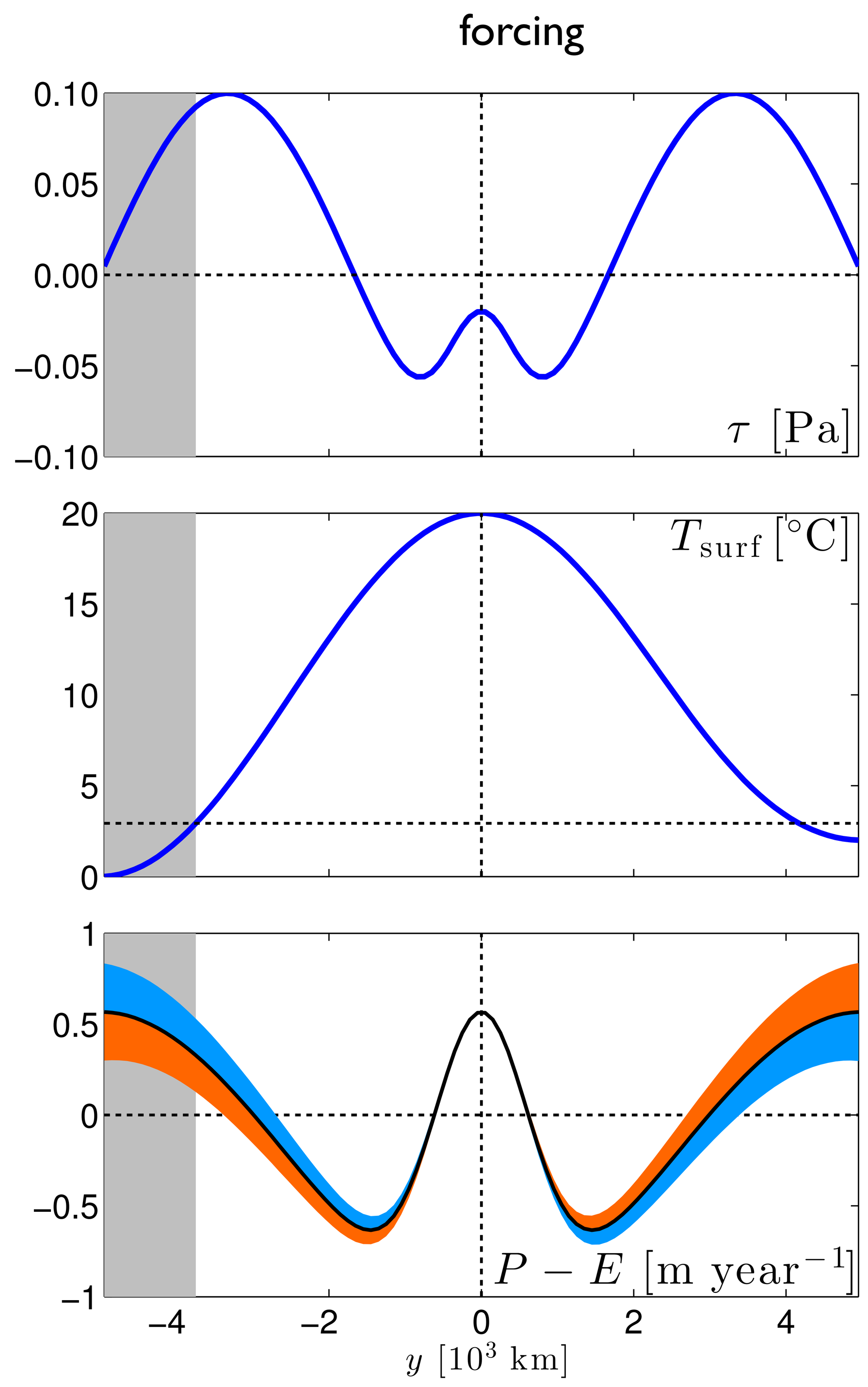


- Advection from subtropics keeps northern hemisphere salty
- South gets fresher and lighter
- Isopycnal window increases, residual overturning strengthens
- Positive feedback that leads to multiple regimes

Model

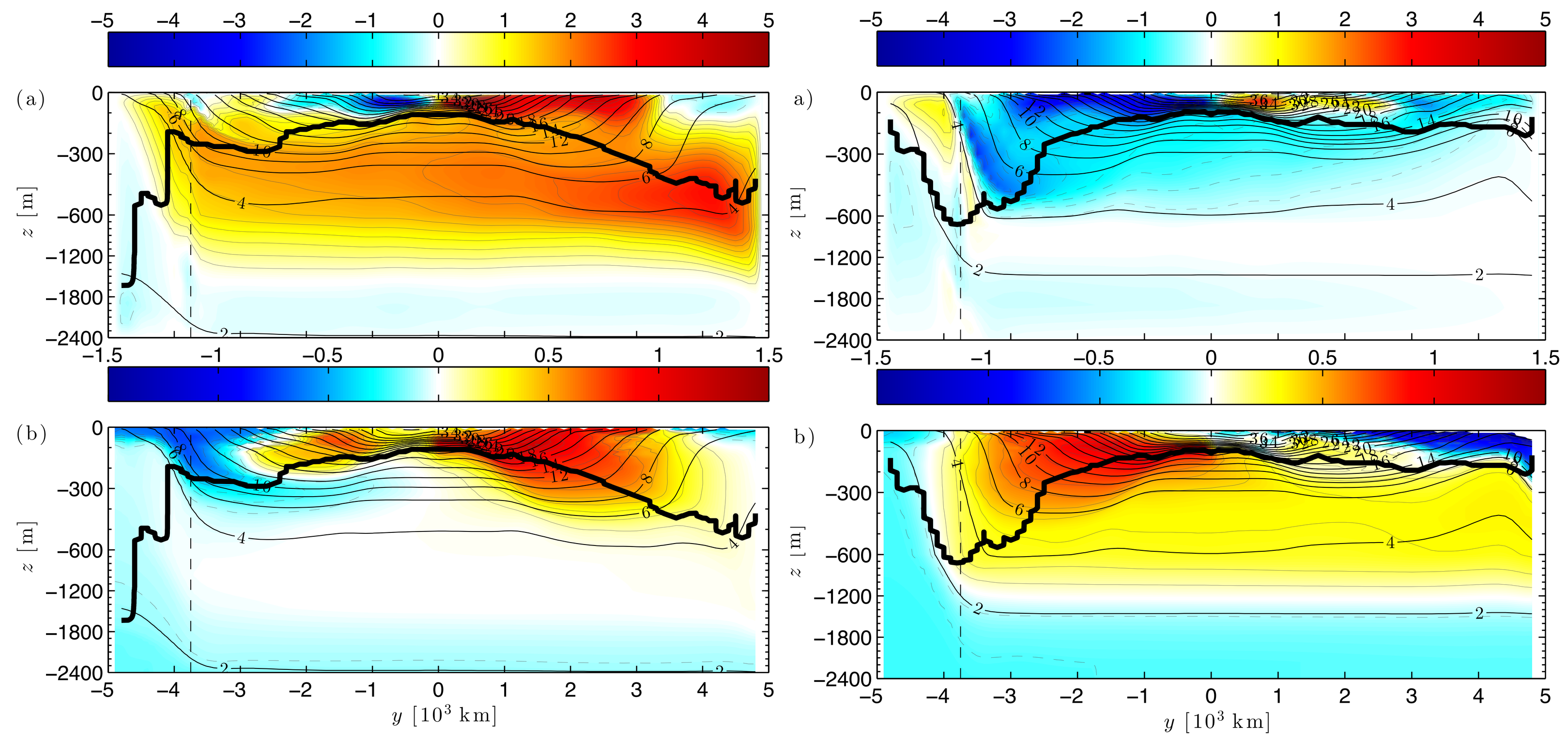






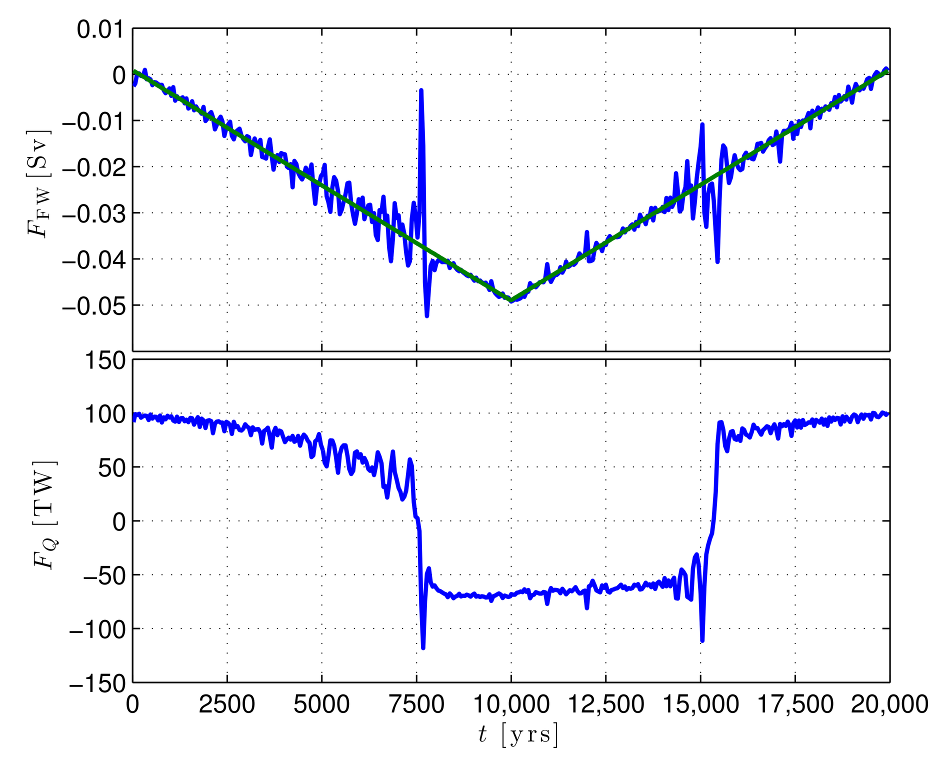
- 100 km grid
- GM eddies: $\kappa_{\mathrm{GM}} = 500\ \mathrm{m^2\ s^{-1}}$
- Isopycnal mixing (Redi): $\kappa_{\mathrm{I}} = 500\ \mathrm{m^2\ s^{-1}}$
- Linear equation of state: $b = g\alpha(\theta - \theta_{\mathrm{ref}}) - g\beta(S - S_{\mathrm{ref}})$

Multiple Equilibria



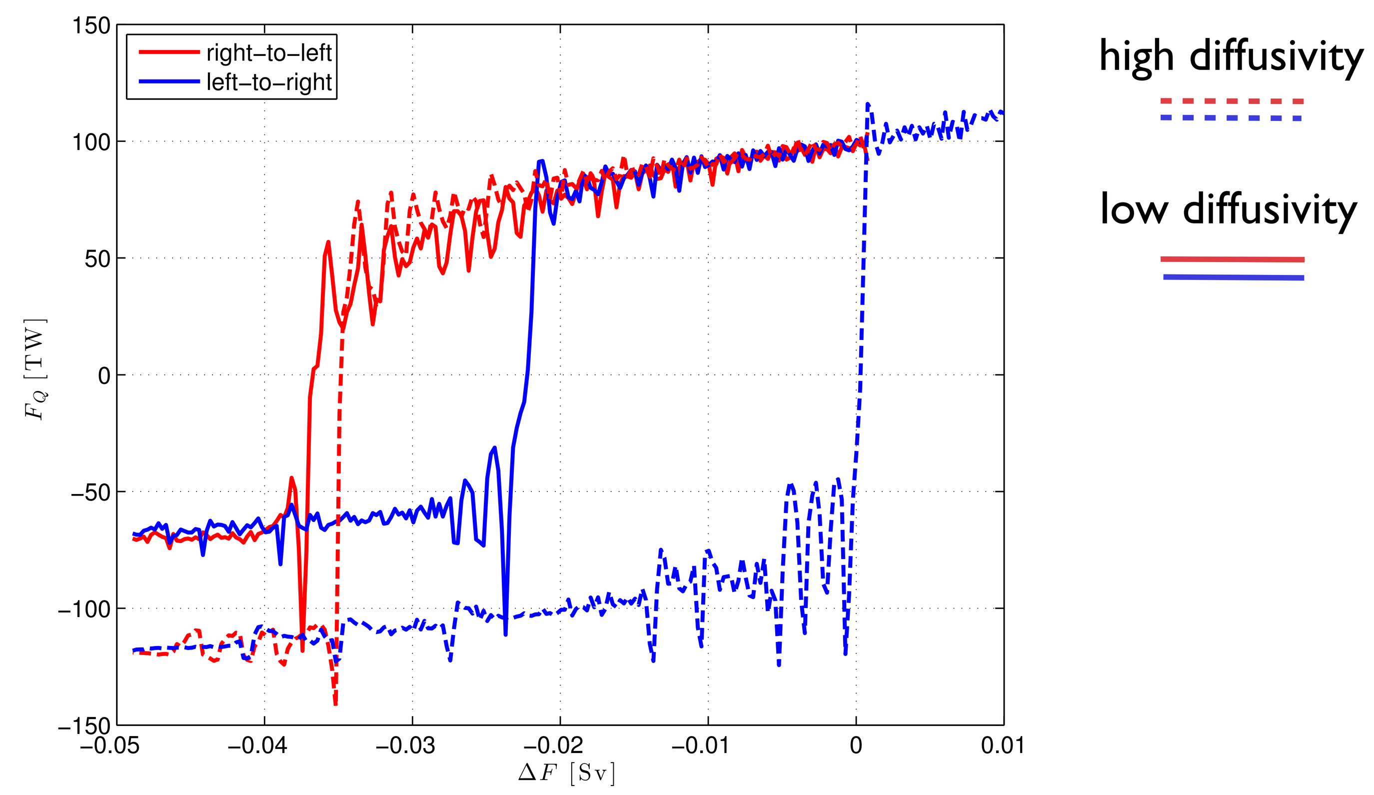
- Forward ROC (top left - color) is stronger and quasi-adiabatic. Reversed ROC (top right) does not involve the channel region and is diffusive (mixed layer - thick line)
- Stratification is shallower for forward ROC (top - black lines): $\kappa_{\mathrm{GM}}\, z_y = \dfrac{\tau}{\rho f} + \psi_{ROC}$
- Salinity (bottom - color) is always higher on the downwelling side

Salt&Heat Flux at Equator



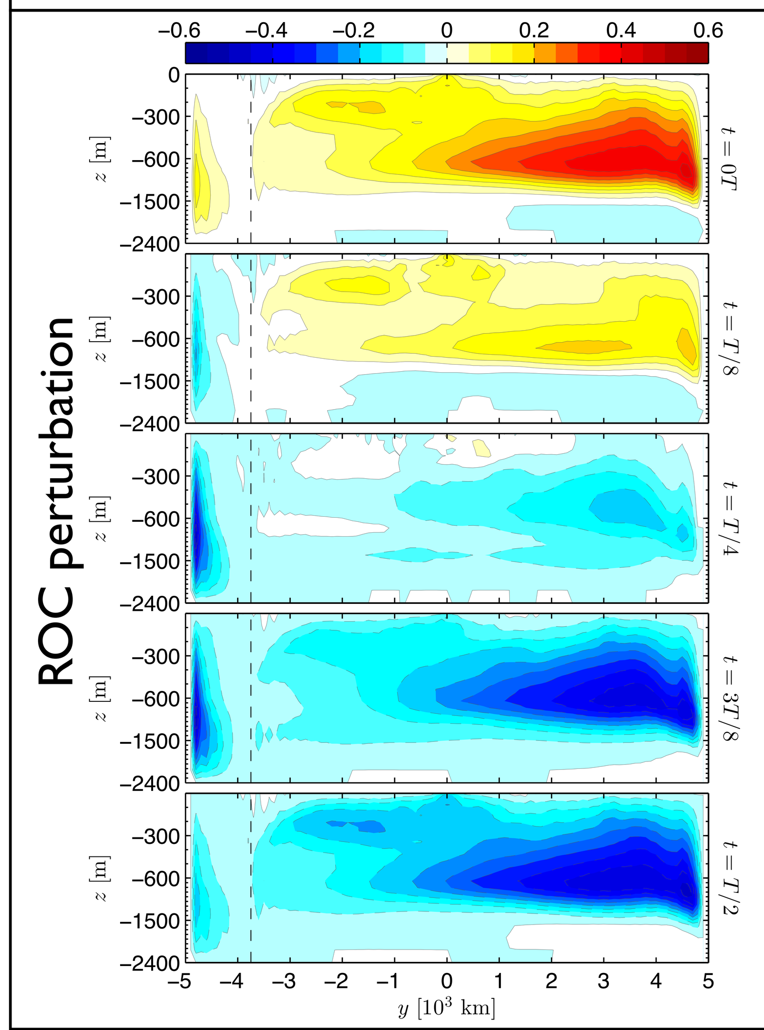
- Change the surface salt flux slowly (green line)
- As the salt flux is varied the ROC reverses
- Flickering (variability) near the threshold

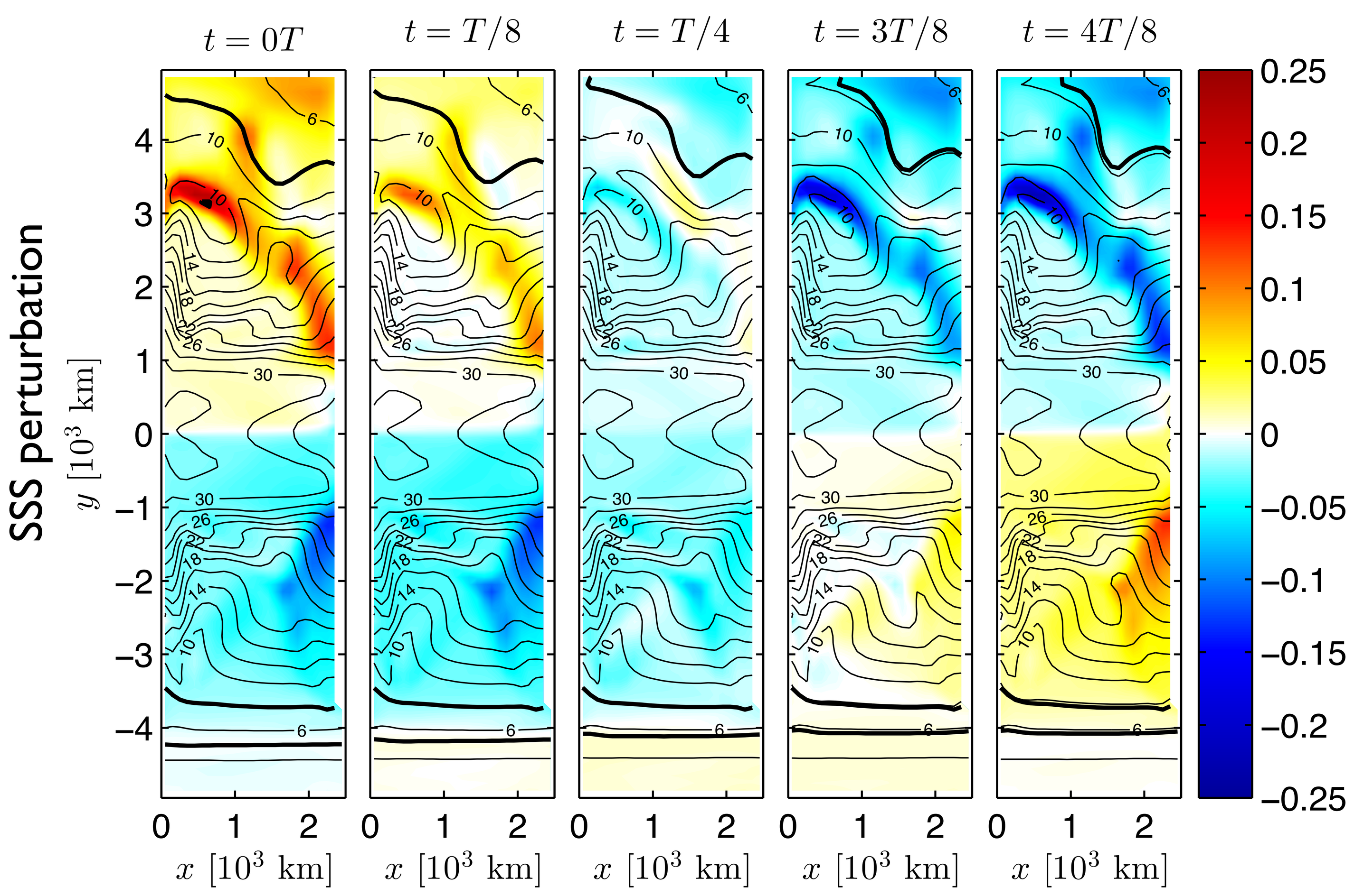
Hysteresis



- Forward state is independent of diffusivity, unlike reversed cell
- For lower diffusivity the region of multiple states is smaller: fluctuations drive the system away from the reversed state

Multi-centennial Oscillations





Salt advection to opposite hemisphere slows down ROC with delay of 100 years

Size of shared buoyancy window oscillates

SSS perturbations change sign across equator

ROC perturbations migrate from NH to SH

Conclusions

- Positive salt feedback increases shared surface buoyancy between ACC and NH
- Multiple regimes are found: forward quasi-adiabatic pole-to-pole ROC or weak diffusive reversed cell
- Difference in end-points buoyancy is decreased (opposite to diffusive box-models)
- Hysteresis region is smaller for low diffusivity: larger oscillations drive system in more stable attractor
- Multicentennial oscillations mediate transition to reversed circulation regime