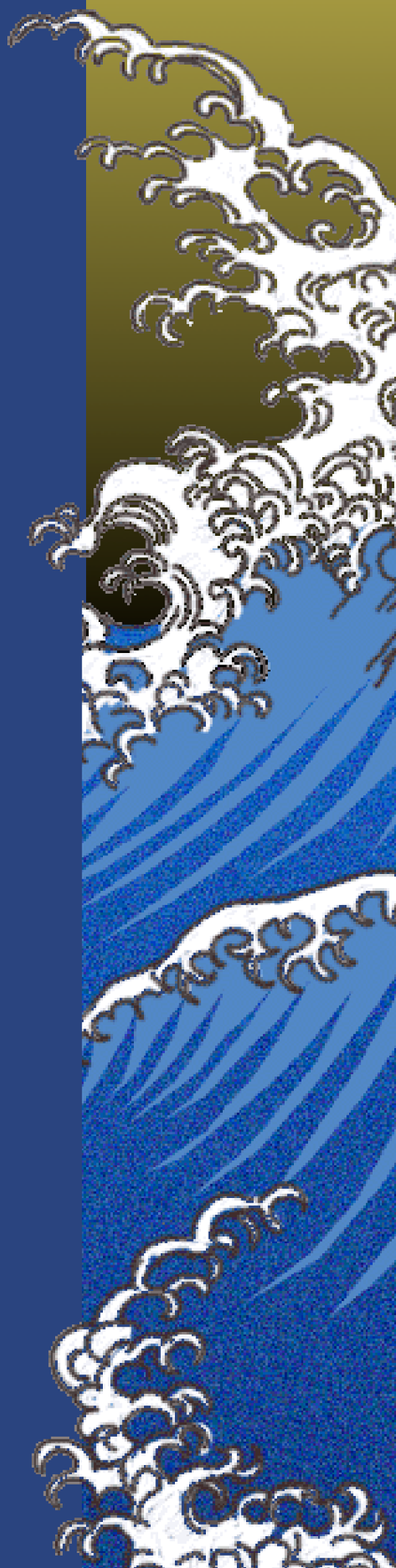
Relative Parameter Certainty in Ocean Models for Climate Prediction

Chris Brierley, Alan Thorpe, Mat Collins

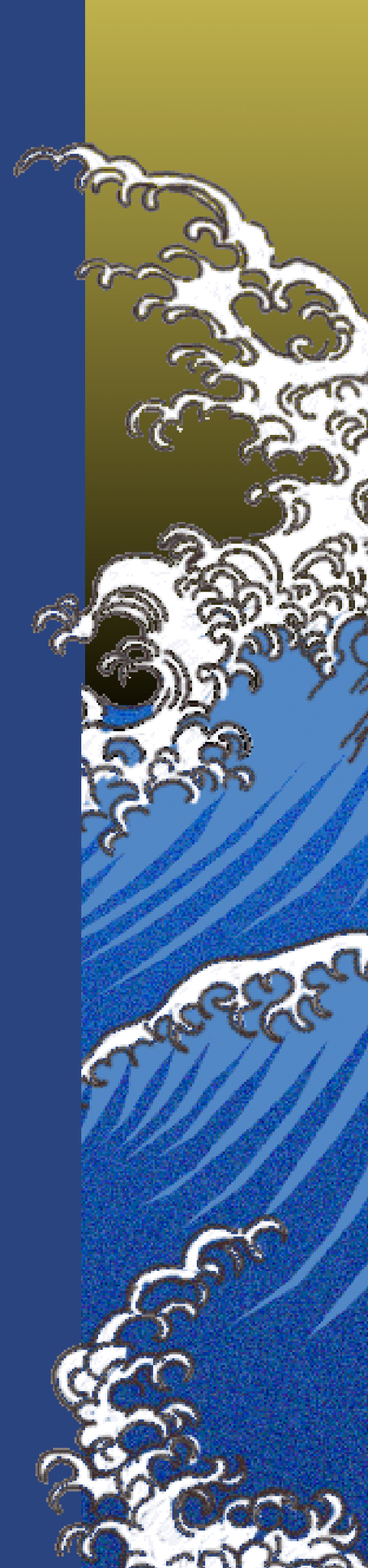


Talk Outline

- *Introduction to Uncertainty*
- *An ensemble to sample ocean model uncertainty*
- *Transient Climate Response of the Ensemble*
- *Ocean Heat Uptake*
- *Conclusions*

Sources of Uncertainty

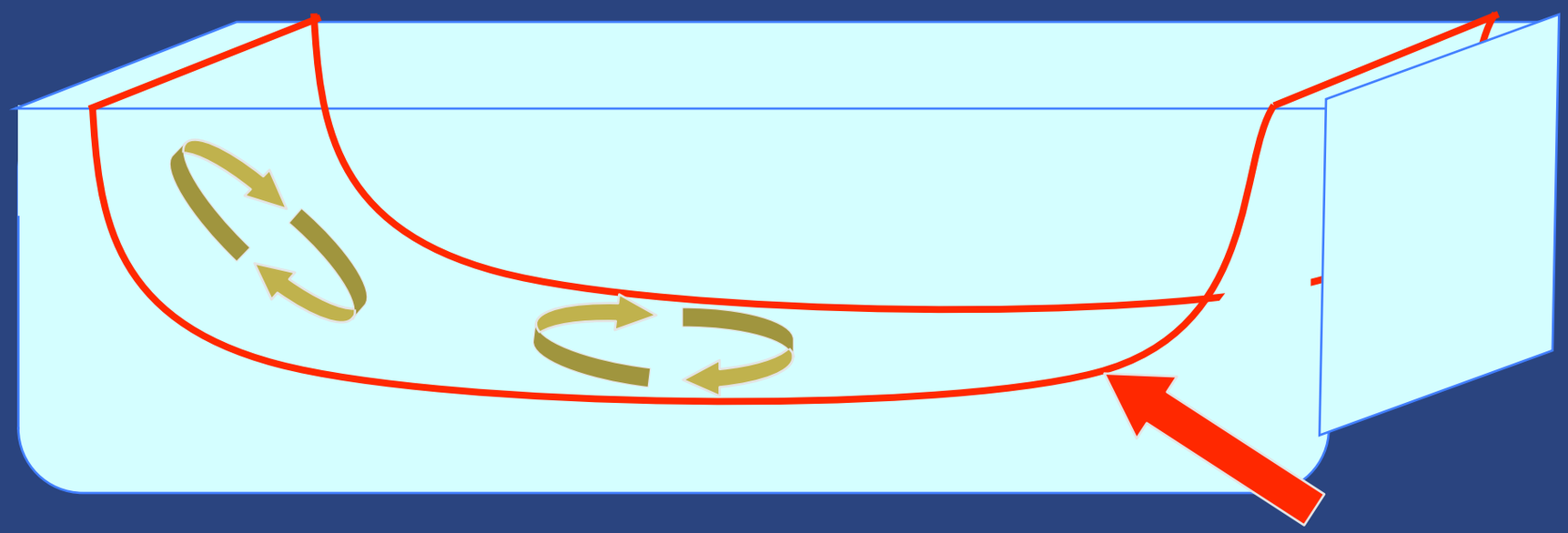
- *Initial Condition Errors*
  - *we cannot observe the climate state exactly*
  - *errors caused assimilating data*
- *Forcing Errors*
  - *Cannot predict Volcanoes*
  - *Myriad of Economic/Social factors involved in predicting gas emissions*
- *Model Errors*
  - *Structural - parameterisation scheme, grid, etc...*
  - *Parameter - Which numbers to use in the parameterisation schemes?*



What do I need to investigate?

- Need an ensemble that covers a spread of parameter values.
- Only oceans changed, multi-model change atmospheres too.
- Create a perturbed ocean physics ensemble
- Hundreds of possible perturbations
- Restrict analysis to those with large climate effects
- Determined top 3 parameters

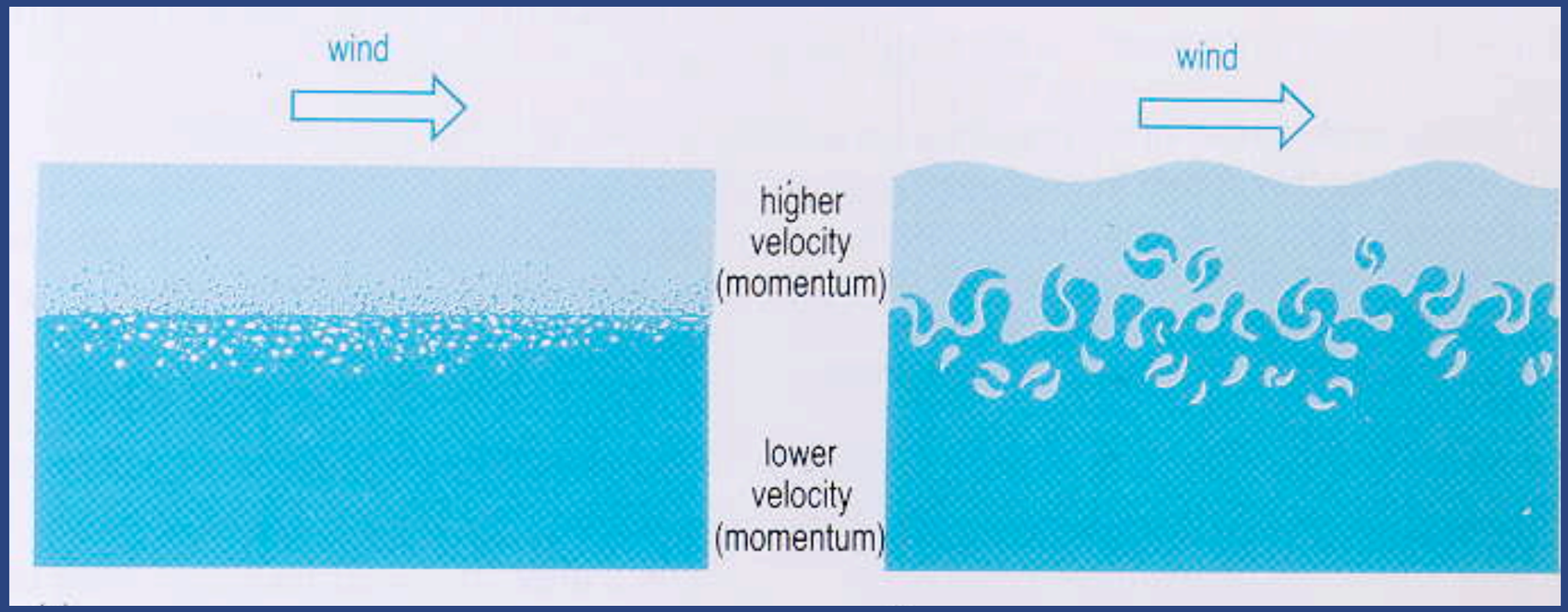
Isopycnal diffusion



line of constant density

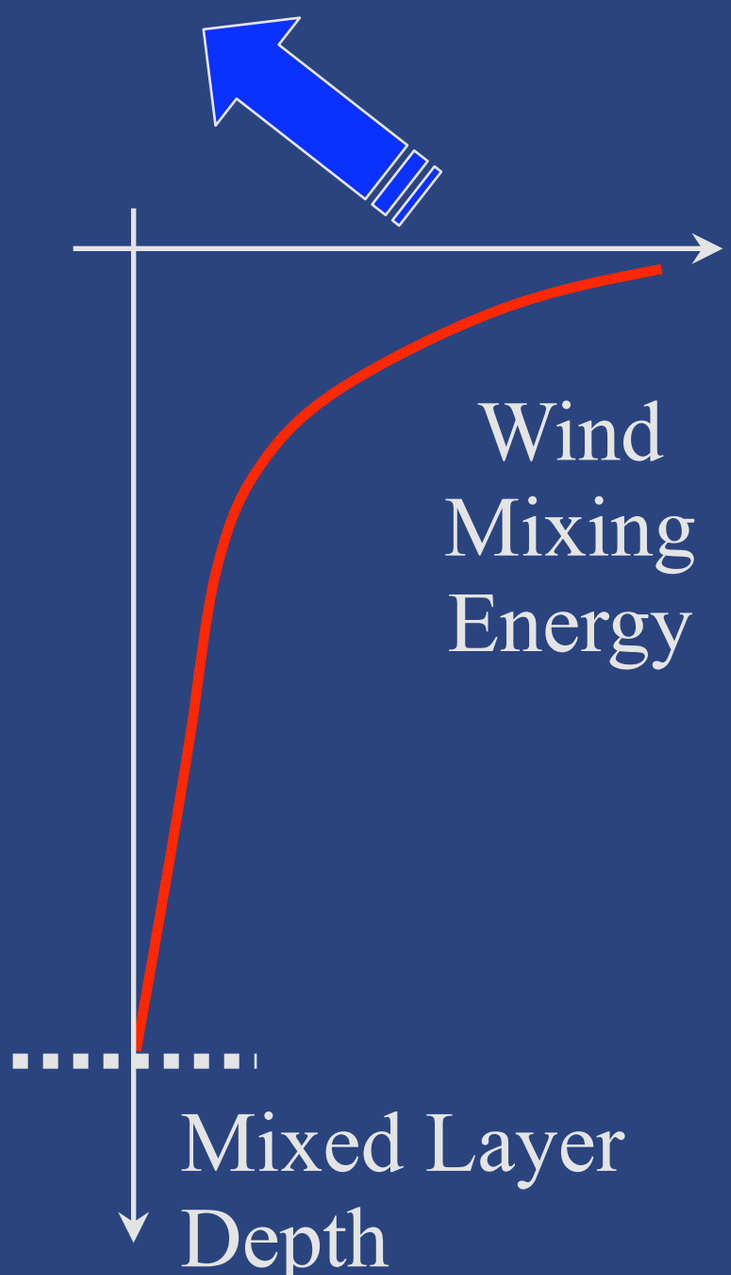
- *Parameterises effects of Mesoscale Eddies*
- *Mainly horizontal*
- *Vertical transfers possible at high latitudes*
- *Largest in Southern Ocean*

Vertical Diffusion



- *Small compared to isopycnal diffusion.*
- *However all mixing is small vertically, due to stratification.*
- *Diffusivity varies with depth.*

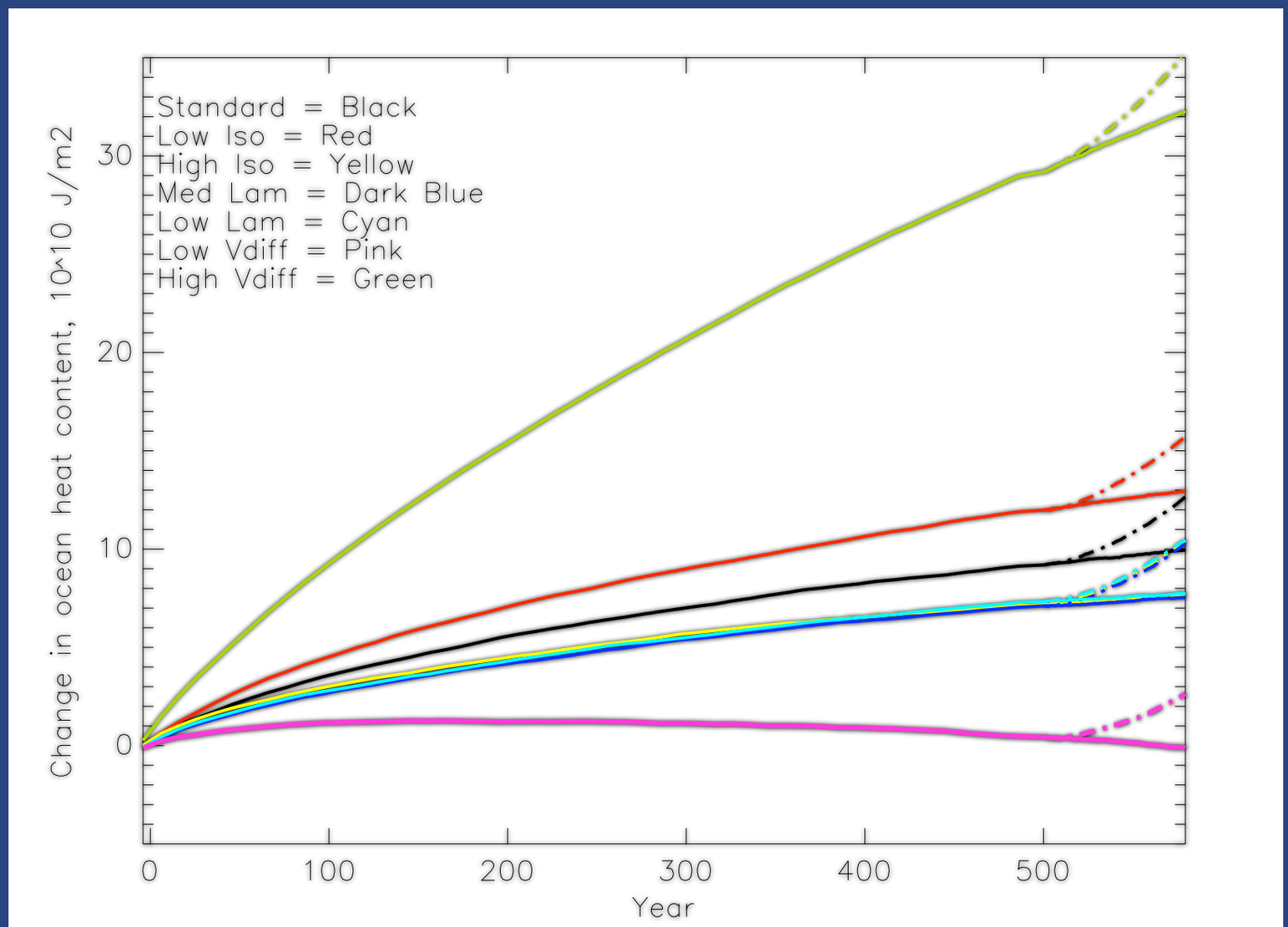
Mixed Layer



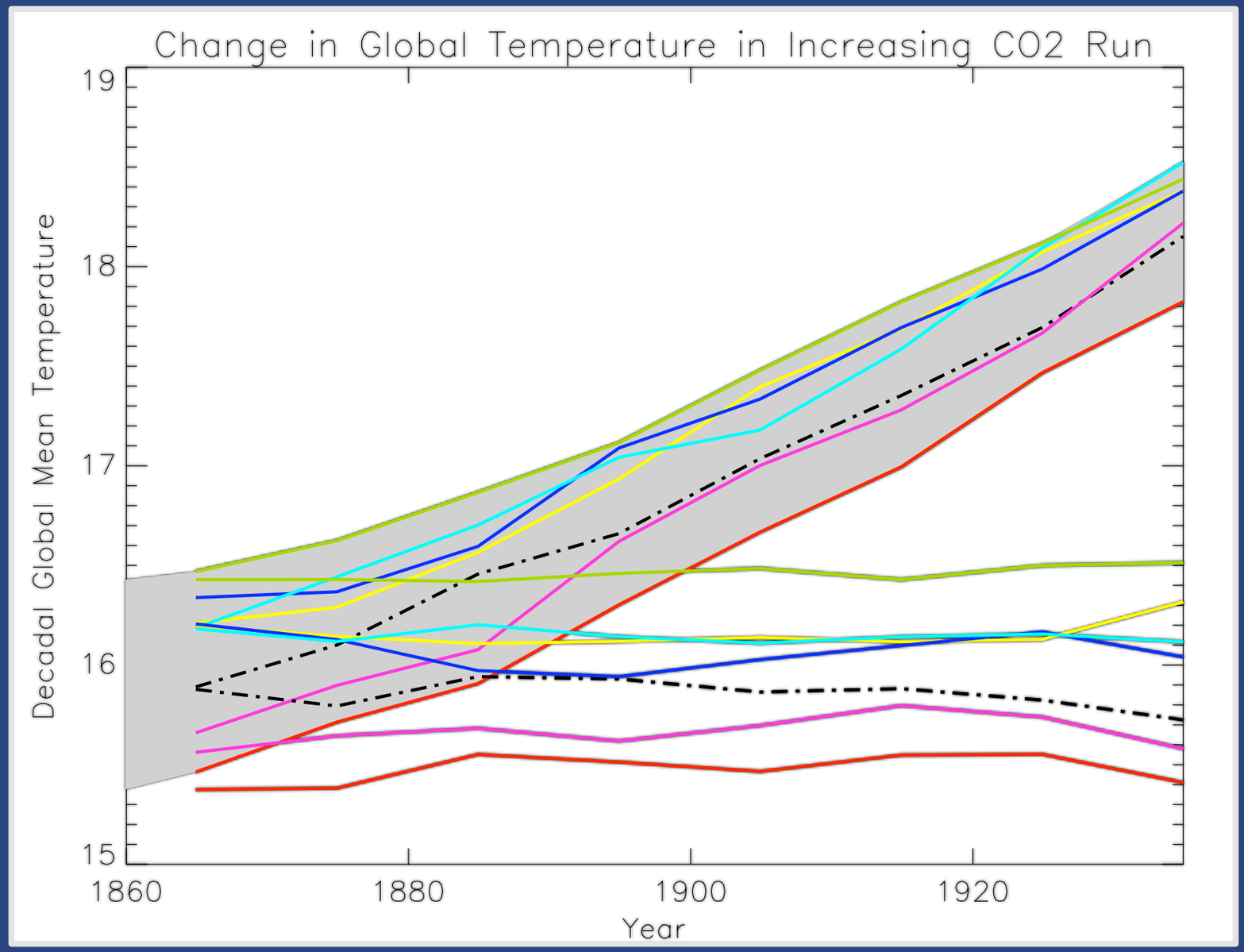
- *Parameterise the mixed layer by working out MLD and then mixing above (Kraus-Turner).*
- *Mixed Layer Depth is when turbulent energy runs out.*
- *Scheme has 2 parameters - fraction and a decay length*

Experiment

- *500 years of spinup*
- *80 year control run*
- *80 year with CO2 increasing at 1% per year (CMIP)*

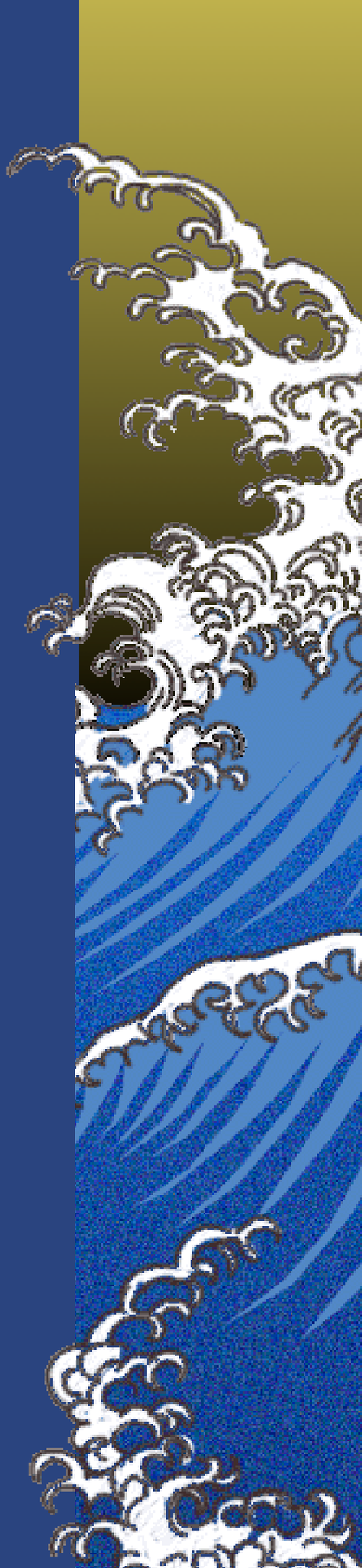


Effect on Global Mean Temperature

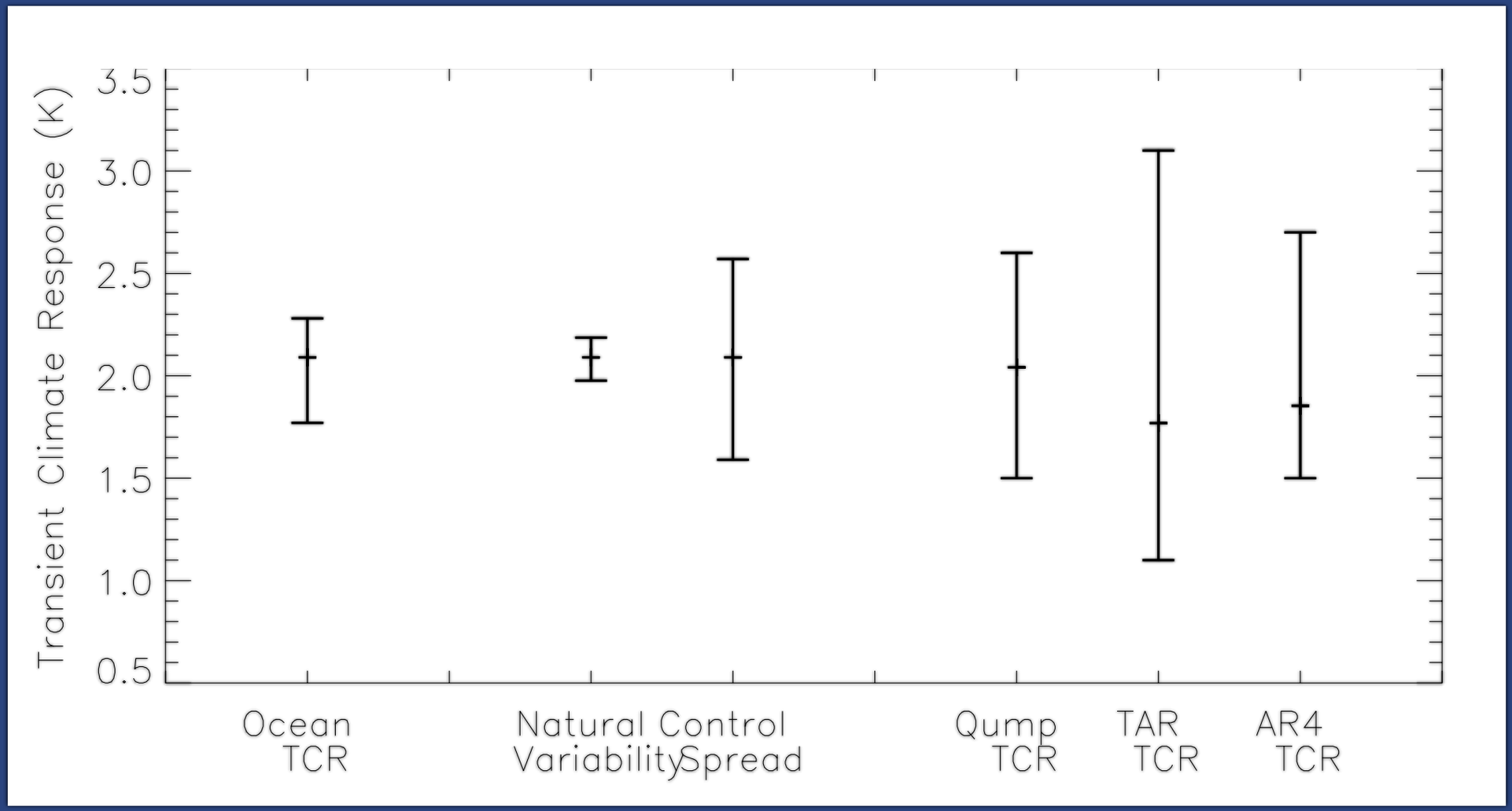


Transient Climate Response (TCR)

- *Difference between 20 year average global mean 1.5m air temperature centred about doubling of CO2 and the same period in the control run.*



Comparison of TCR

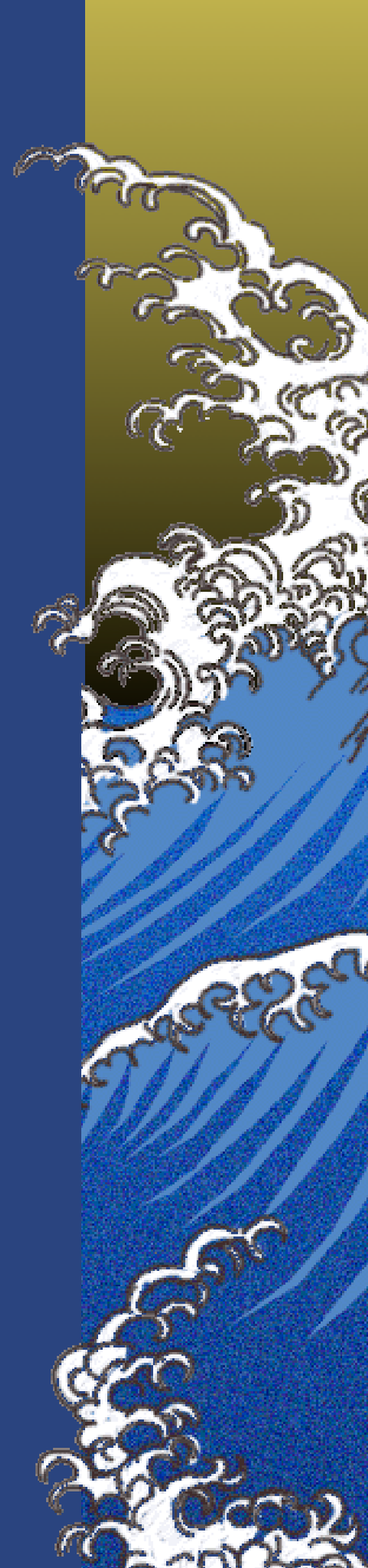


Possible Reasons

- *Ensemble does not represent uncertainty*
  - *Ranges are too conservative*
  - *Wrong parameters chosen*
  - *Single perturbations hide non-linearities*
- *Compensation is occurring:*
  - *between different regions*
  - *between different warming processes*
- *Ocean Model Uncertainty is just smaller!*

Testing these possibilities

- *Only if can discount all other options can we say that the uncertainty is small.*
- *Start with reconsulting experts...*
- *....can't justify extending any ranges.*



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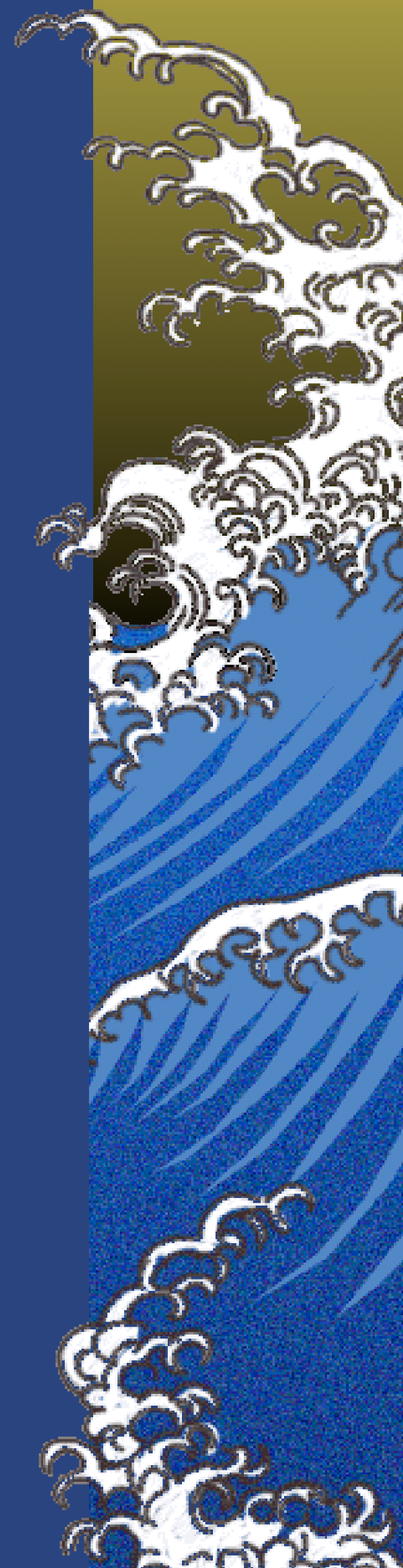
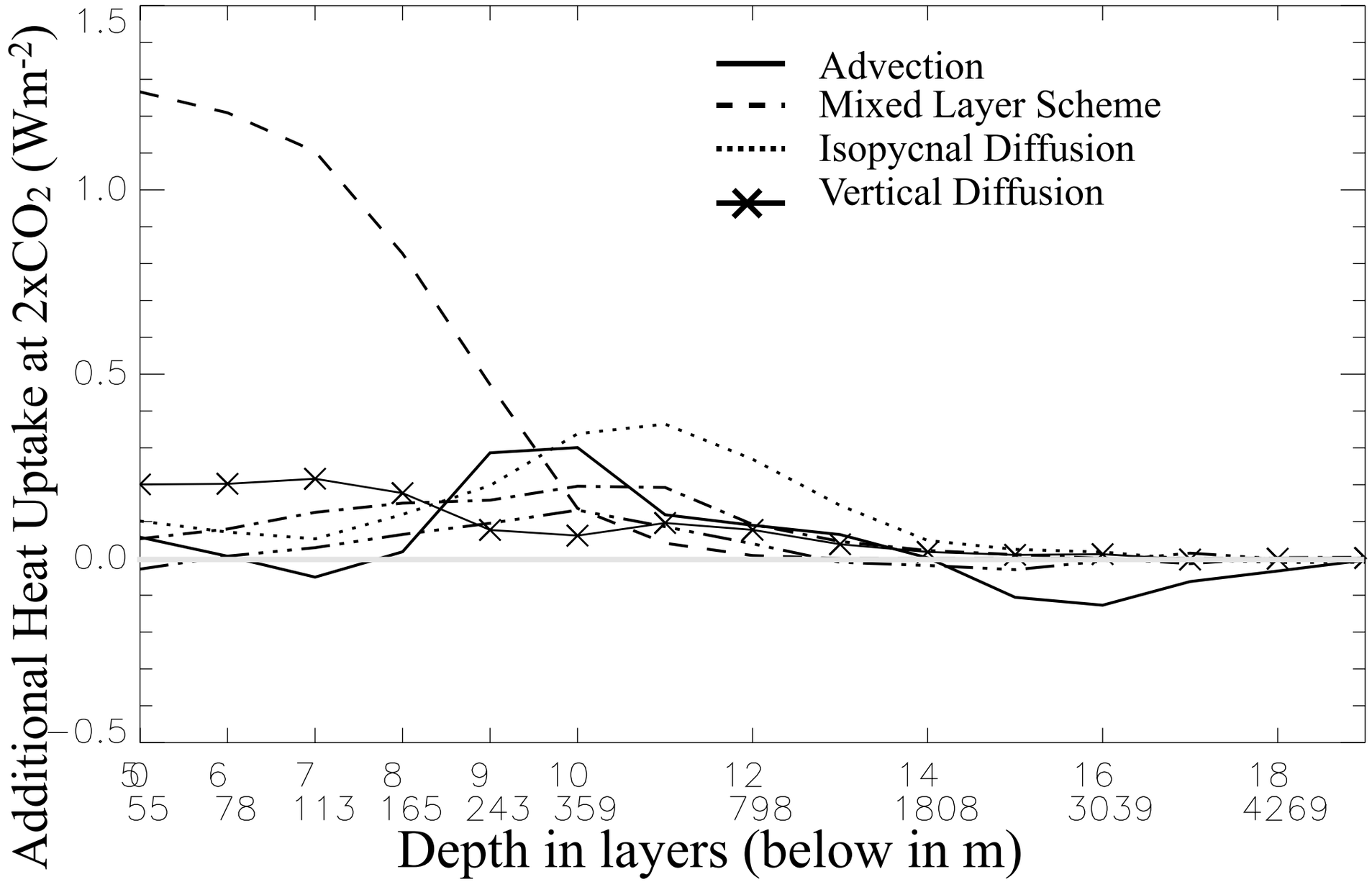


Important Processes in Heat Uptake



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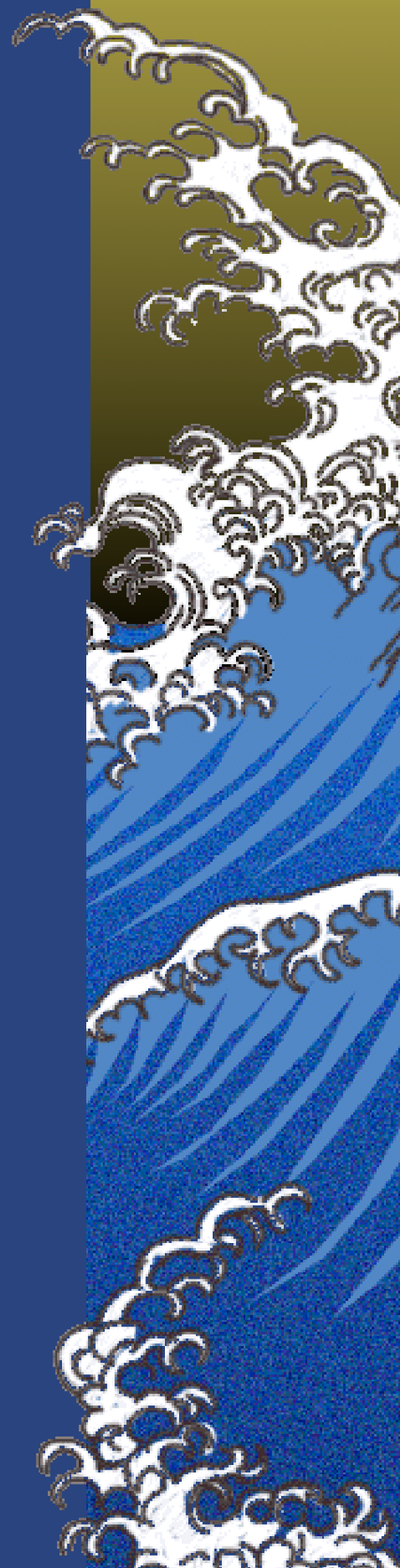
Single Perturbations hide non-linearities

- *Previous studies show effects of perturbations don't just add up.*
- *Only way to test would be to run another ensemble with multiple parameter perturbations.*
- *Being investigated further by* climate*prediction*.net *(results from spinups don't show signs of any large non-linearity, but this is only for constant* CO_2*)*



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Conceptual Model of Temperature Response

$$F = Q - \Lambda \Delta T$$

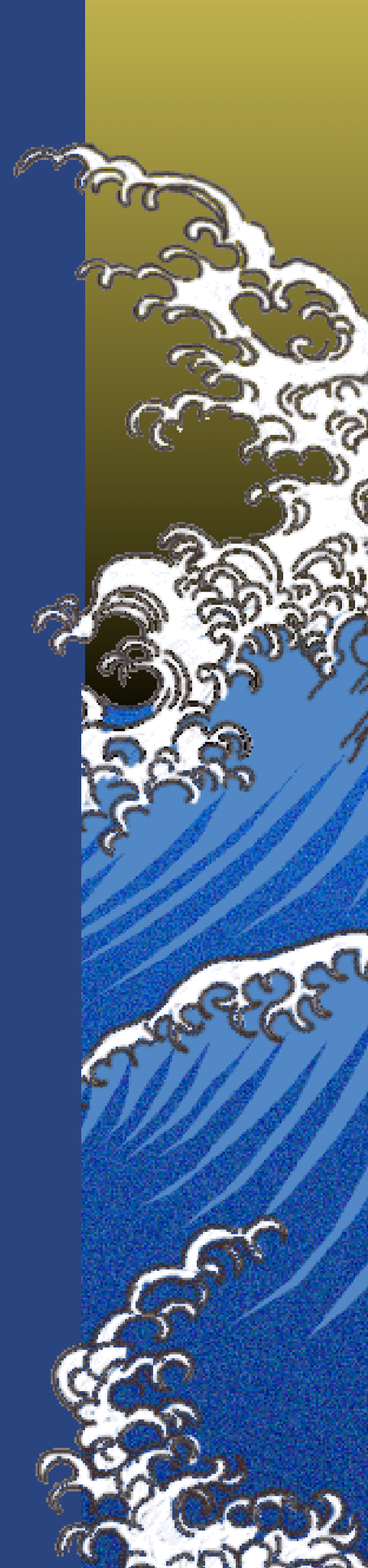
F is the flux imbalance at any time

ΔT is the change in global mean temperature

Q is the imposed radiative forcing

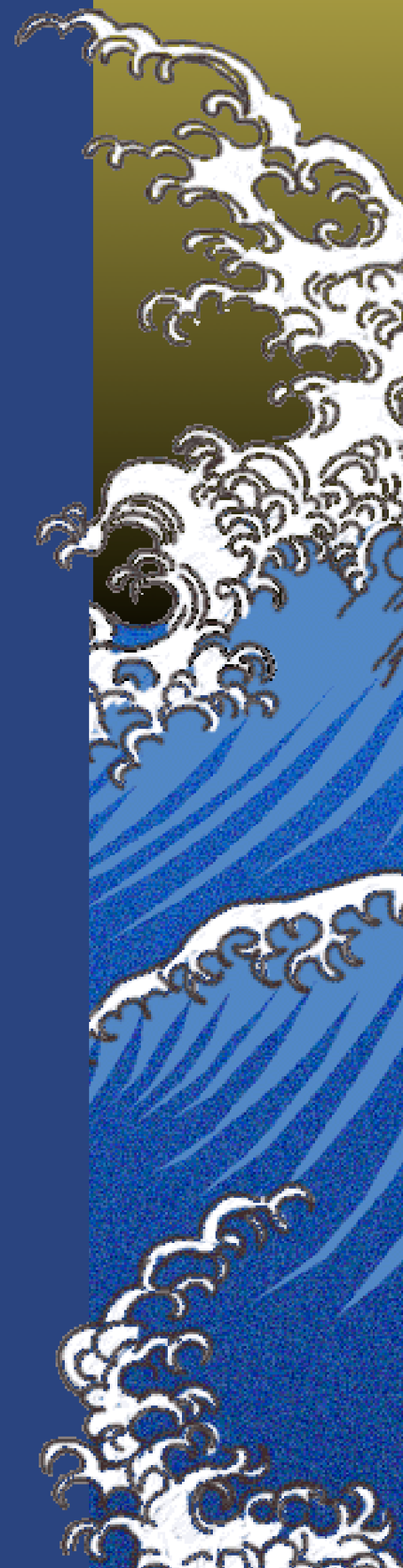
Λ is the climate feedback parameter, related to the climate sensitivity by:

$$\Lambda = Q_{2xCO_2} / \Delta T^{eq}_{2xCO_2}$$

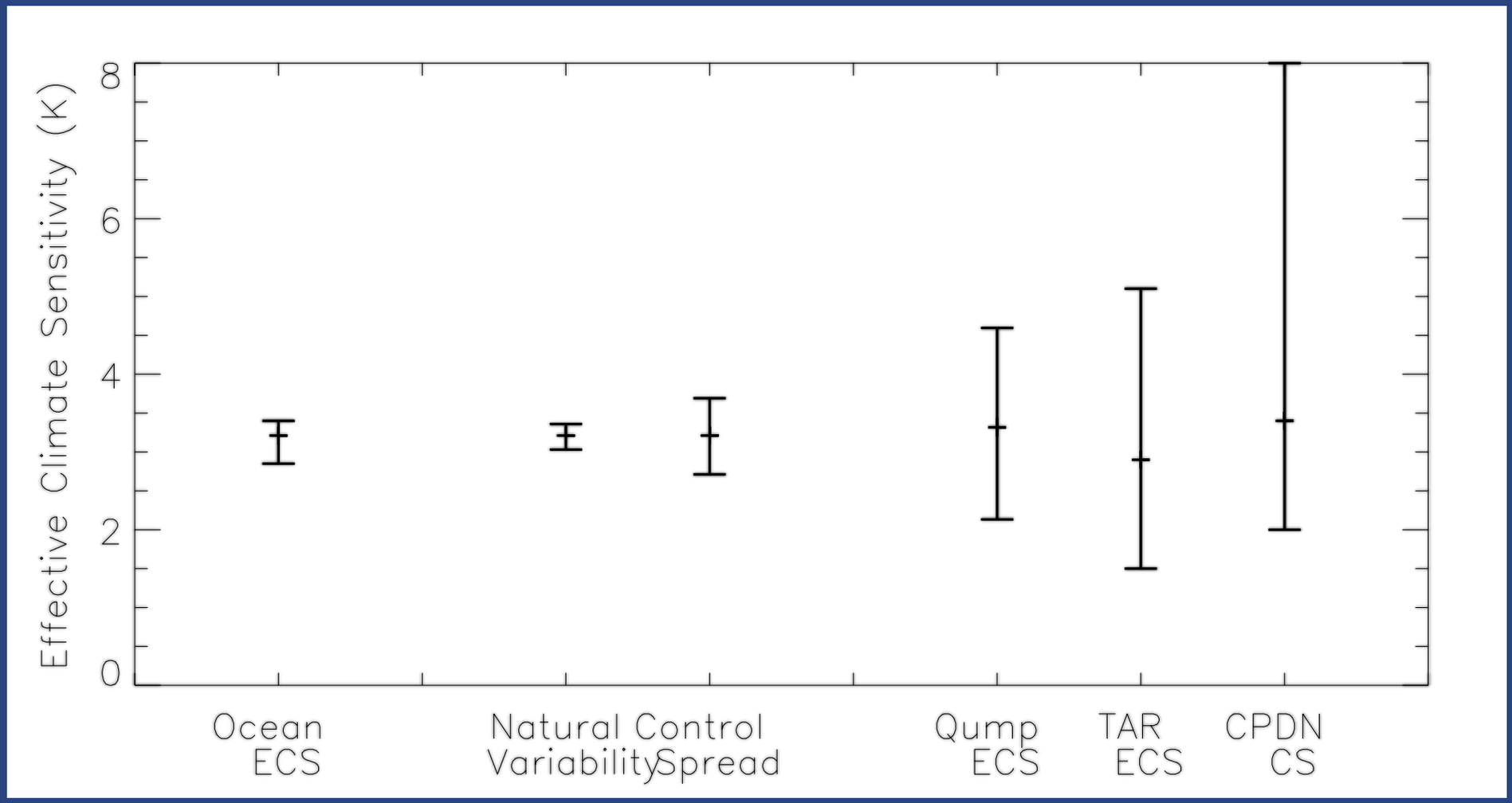


Climate Sensitivity Changes

- *Main feedbacks:*
  - *Blackbody,*
  - *Water Vapour,*
  - *Ice-Albedo,*
  - *Cloud,*
- *Do not expect ocean parameters to have large effect on any of these.*
- *Ensemble has a range of 2.9 - 3.6 K*
- *Small compared to 1.5-4.5K of TAR and 2-8K of* climate*prediction*.net



Comparison to other effective climate sensitivities



Small range of Climate Sensivities.

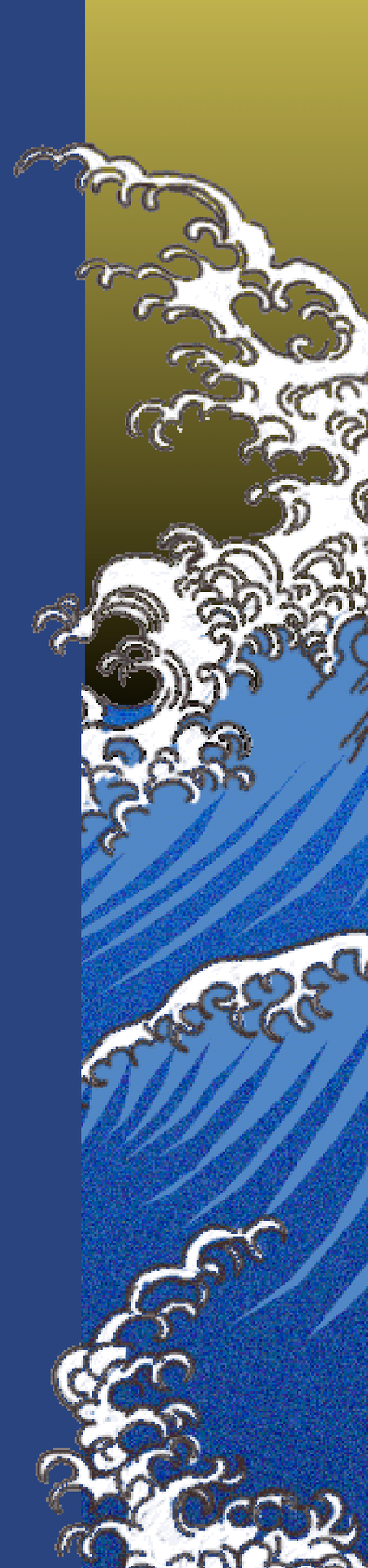
Effective Heat Capacity.....

$$F = Q - \Lambda \Delta T$$

- *Ocean is slow to warm due to its high heat capacity :.*

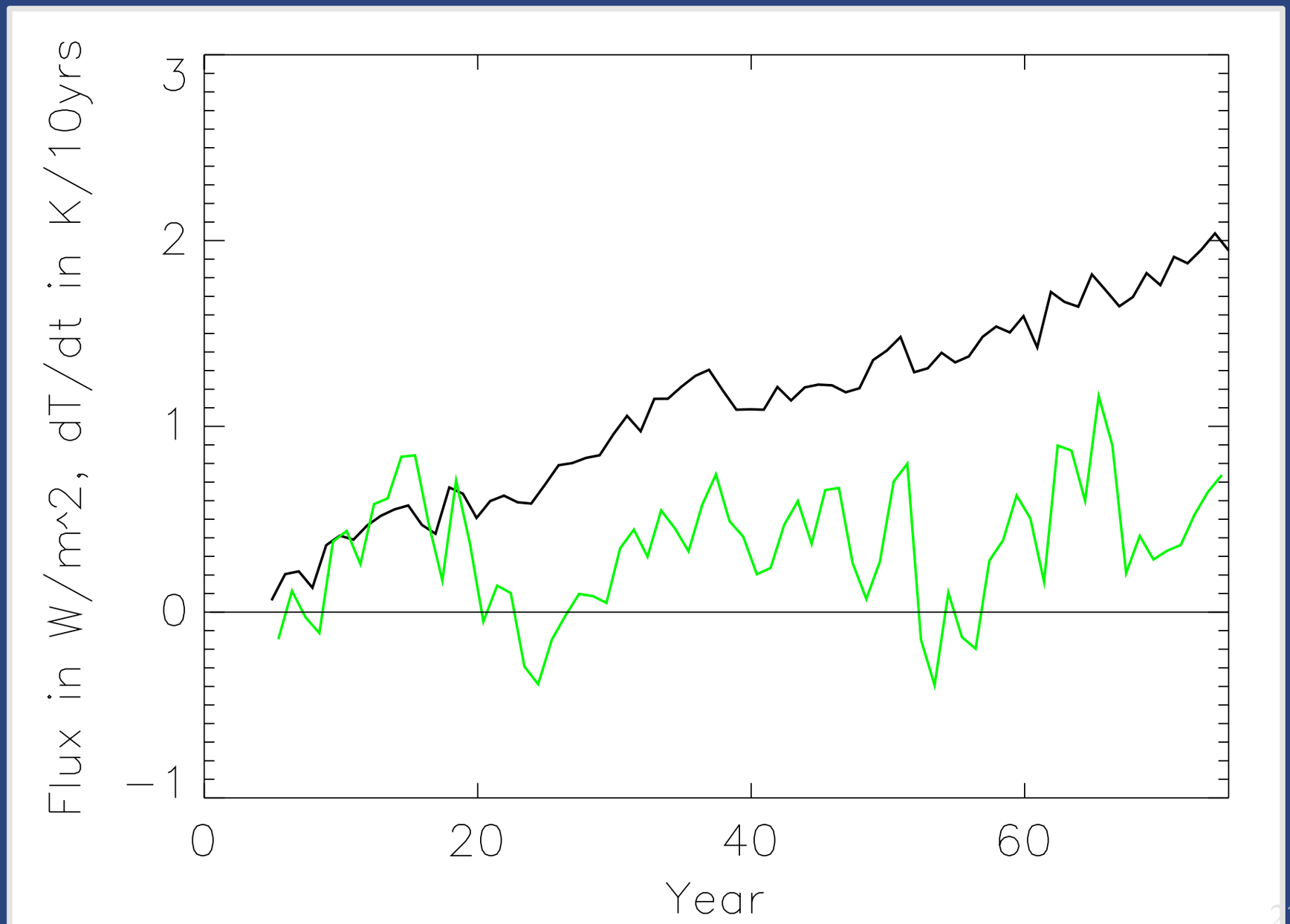
$$C_{eff}\, d\Delta T/dt = F$$

- *Ensemble gives range equivalent to 230-300m of water.*
- *Observations gives 25-490m (from Levitus and HadCRUT - Frame et al).*

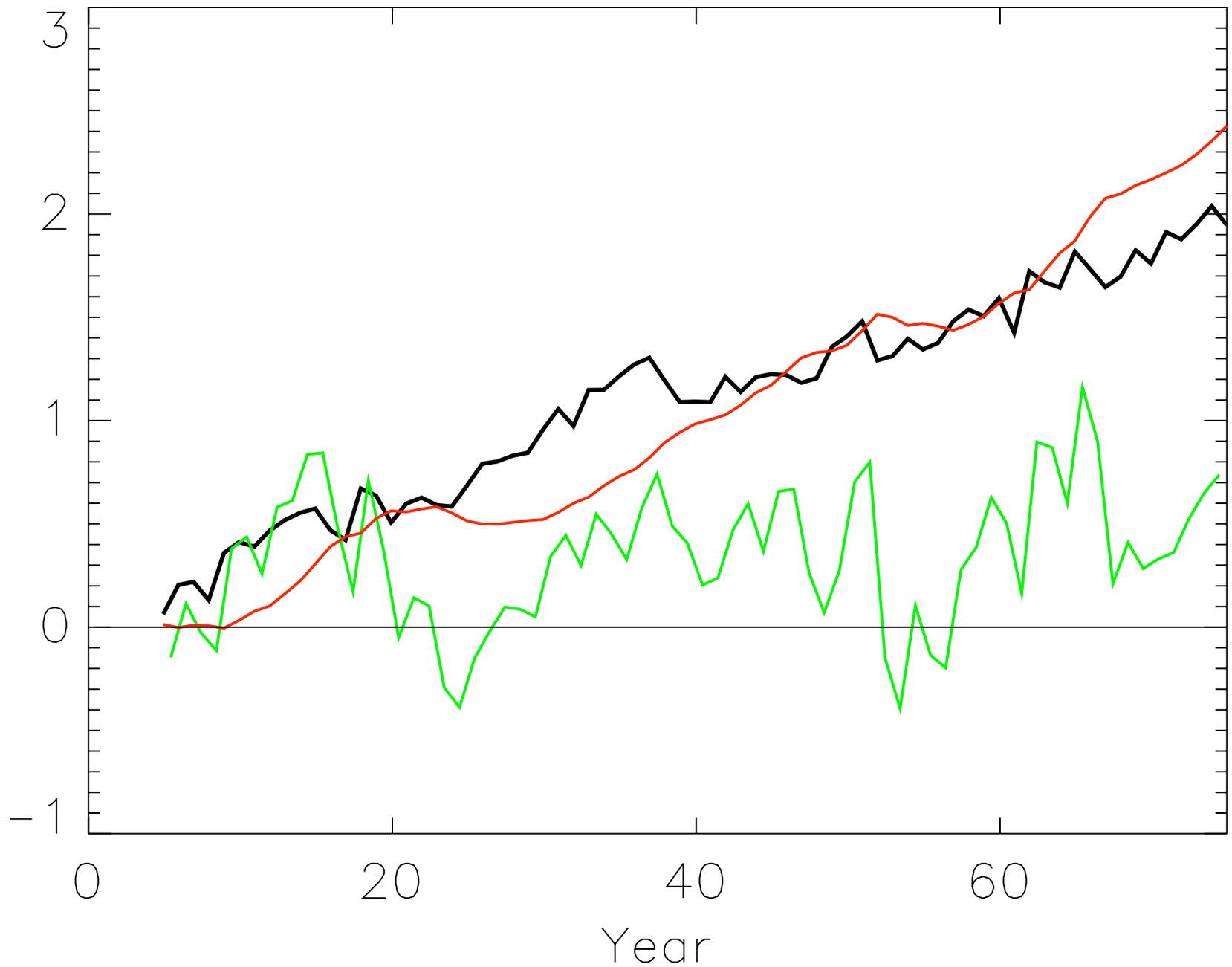


Effective Heat Capacity 2

- *Is it a fair assumption that F∝dΔT/dt?*



Ocean Heat Uptake Efficiency



- *The heat flux into the ocean is proportional to the temperature change.*

Ocean Heat Uptake Efficiency

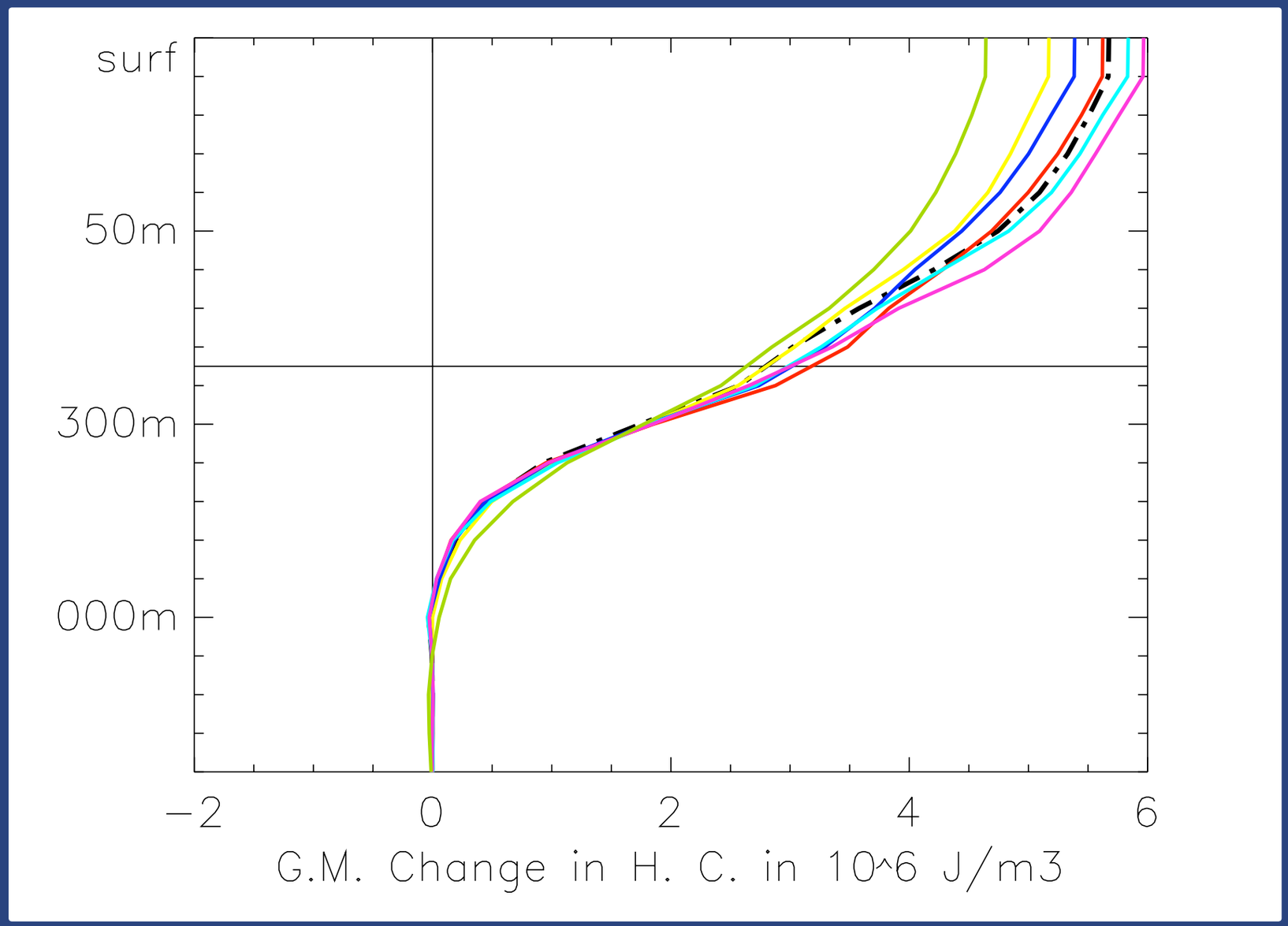
- *The heat flux into the ocean is proportional to the temperature change.*
- $$\kappa \Delta T = Q - \Lambda \Delta T$$
- *Range of 0.57-0.77 $Wm^{-2}K^{-1}$*
- *Range of 0.58-0.88 $Wm^{-2}K^{-1}$ from CMIP.*
- *Range of 0.54-0.73 $Wm^{-2}K^{-1}$ from QUMP Atmosphere ensemble.*

Hypothetical TCRs

	All Variations of Λ and κ	*With standard model's Λ*	*With standard model's κ*
Ocean	*1.8-2.3*	*2.0-2.2*	*1.9-2.3*
Atmosphere	*1.7-2.8*	*2.0-2.2*	*1.6-2.6*

- *Can use κ and Λ to compare importance of these ranges.*
- *Changes in Climate sensitivity more important!*

Depth Variation



- *Some compensation, esp. with green (High Vertical Diffusion)*

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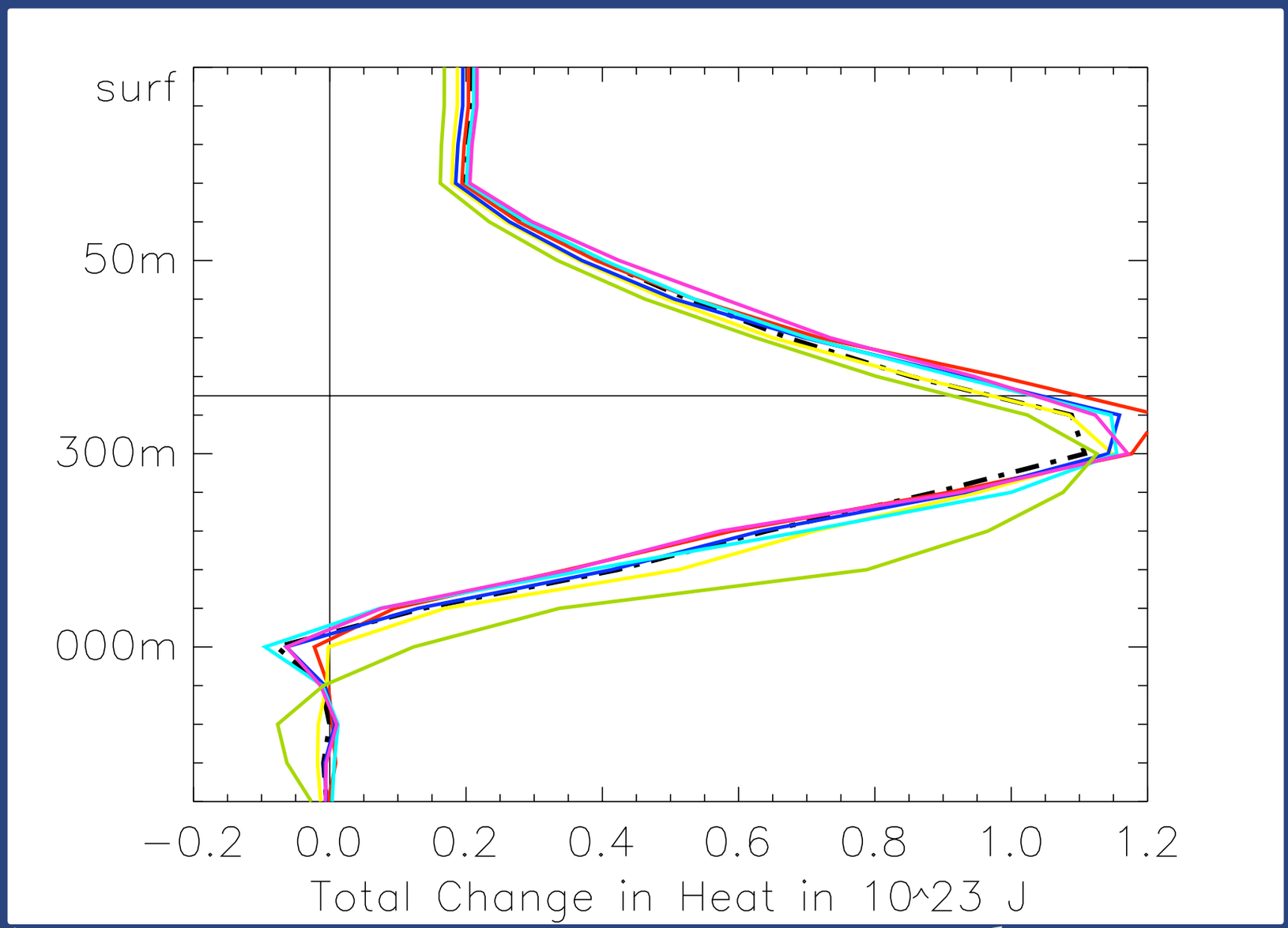


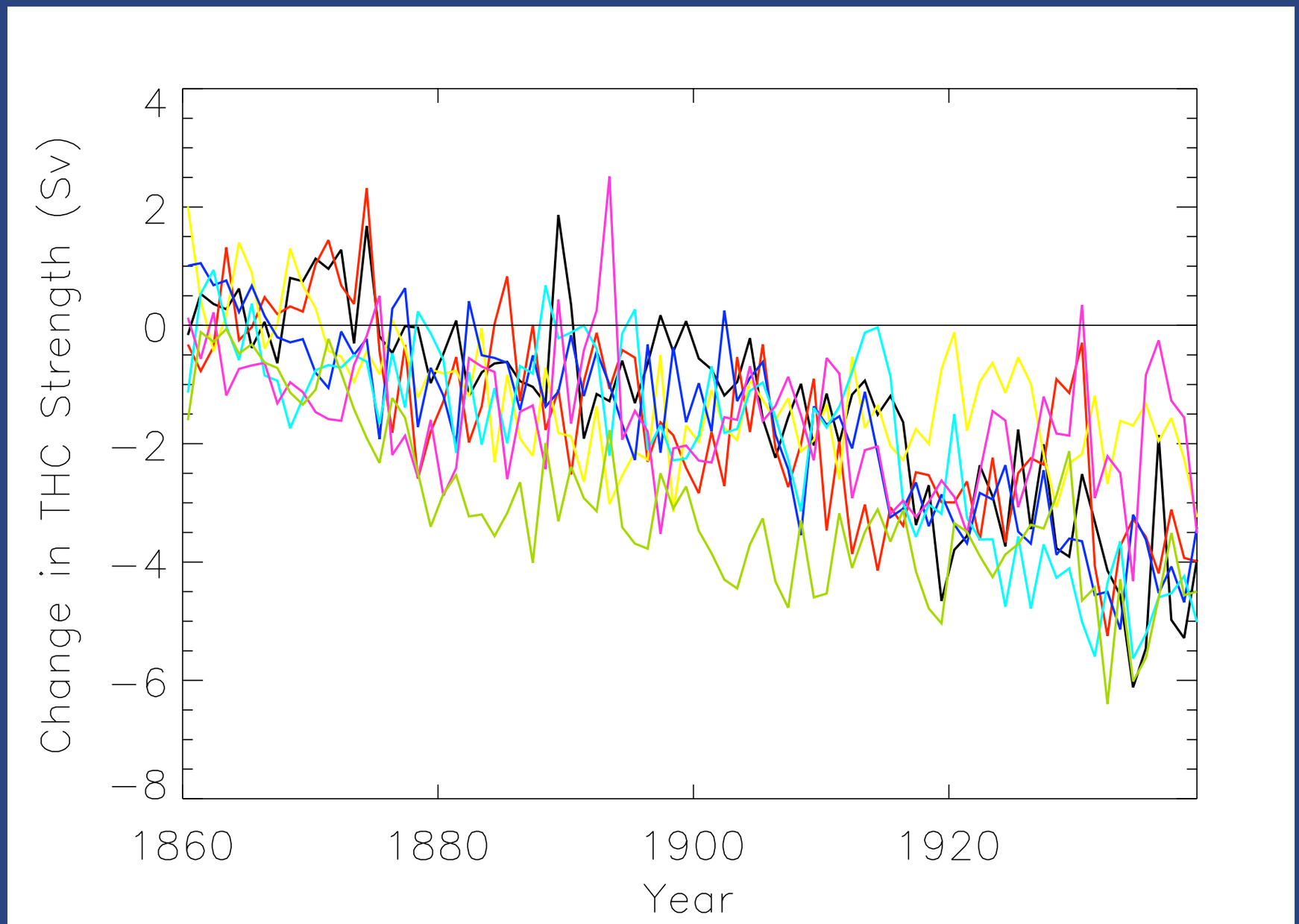
- *Some compensation, esp. with green (High Vertical Diffusion)*

Atmosphere controlling heat uptake?

- *Perturbations determine at which depth the extra heat is stored.*
- *Does this imply a pre-determined amount of extra heat?*
- *If the ocean parameters are not fully determining ocean heat uptake, what is?*

Regional Compensation left

- *I haven't covered regional differences.*



Conclusions

- *An ensemble has been created which samples ocean model uncertainty.*
- *Global mean effects on transient climate change investigated.*
- *OMU has a small effect on TCR.*
- *Primarily due to changes in climate sensitivity rather than the rate of ocean heat uptake.*
- *Regional effects need further investigation.*