Plan

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1 Introduction

1.1 Arctic Ocean

An, albeit relatively brief, description of the Arctic Ocean. This will focus on:

- Defining the Arctic water masses based upon the vertical profile and stratification.
- Observed circulation in the Arctic, particularly in the Atlantic Water Layer.
- A brief mention of Sheldon's budget calculations using boundary fluxes etc.

An area that I've not touched on yet is eddies in the Arctic, mostly because the literature is still very sparse. Papers like Zhao 2014 give some idea of their prevalence, at least in the halocline. The Woodgate paper is also useful for this.

1.2 Mean-Eddy Interaction Theory

Overview of the development of eddy parameterisations over the years along the lines of what was briefly described in the Transfer of Status report. A discussion of how modern climate models implement eddy parameterisations as well as the positives and limitation of current eddy parameterisation techniques. This is more specifically a conversation on the development of the Gent and McWilliams parameterisation. How it is implemented, what it does and how it demonstrates itself in the Arctic.

$$\frac{\partial \tau}{\partial t} + (\boldsymbol{u} \cdot \boldsymbol{\nabla})\tau = -\boldsymbol{\nabla}(\kappa \sigma \boldsymbol{\nabla} \tau)/\sigma, \tag{1}$$

- MITgcm uses GM as a tracer mixer (see GMREDI)

A discussion alternative approaches to parametrising eddies, such as potential vorticity closure and the Neptune Effect, and how this leads onto the Eliason-Palm Tensor. Schematic c.f. A&M00 but basin instead of sea mount.

1.3 Numerical Models of Arctic

AOMIP and attempts to have predictive models of the Arctic Ocean. This includes attempts to implement the Neptune effect or other parameterisations such as MEP as well as the increased success of using higher resolution eddy permitting models.

Somewhere amongst either this section or the previous I'd like to mention Yang 2005, the PV balance explanation for a cyclonic Atlantic Water Layer.

2 Developement of Shallow Water Equations

The theoretical advancement made as part of this thesis, as well as the technical development needed to test hypotheses. The development of the multi-layered shallow water approximation case of the Eliason-Palm eddy closure theory.

2.1 Shallow Water Theory

Rational for using shallow water equations and description. I.e. Arctic water masses, strong stratification. Development of the eddy closure theory in the shallow water case including examining certain nuances the approximation includes, such as the description of physical quantities, like potential and kinetic energy, on the discontinuous jump between layers.

Note the use of Rigid Lid approximation in simulations.

2.2 Model Discretisation

Continuous model to discontinous discrete model. Technical description of the models. C-grid, AB time stepping, Preconditioned CG solver. Parallelisation. Forcing and Dissipation used in the model. The form of wind stress and bottom friction in shallow water models (e.g. $\boldsymbol{\tau}/h$ and $-r\,|\boldsymbol{u}|^2\,\boldsymbol{u}/h$). Viscosity: laplacian, biharmonic as well as Smagorinsky. Linear, quadratic and n-polynomial bottom friction.

Example model output.

2.3 Eddy Stresses

Thickness weighted mean of the shallow water equation. Form of the momentum and pv eddy stresses. Thickness weighted PV vs PV derived from thickness weighted equations.

Eddy energy and eddy enstrophy. State equations with possible application in terms of carrying them in the system.

Time averaged diagnostics. Explain that this requires steady state dynamics. Need configurations with a unique mean steady state.

3 Analysis of a hierarchy of models

A description of the different dynamics that evolve in the models by using the forcings and dissipations described above. Different forcings such as different wind stresses or regional heating and cooling. Different dissipation from linear bottom friction to higher order bottom friction.

Break down of the tendency terms for the mean dynamics. A look at how the eddy stresses are in balancing the mean states (usually through balancing the ageostropic component of the momentum tendency).

A closer look at the eddy stress, their bounds and the available eddy budgets.

3.1 Zero-Mean Wind Forced Models

Model where the mean forcing is effectively zero. Hence the model is forced by a wind stress which is absent from the mean system and hence forces the system by invoking a turbulent cascade. Hence Eddy-Mean interaction is entirely from the eddy to the mean.

3.2 Comparison of Mean PVs

An examination of the similarities and differences of the two definitions of potential vorticity. A discussion of whether the thickness weighted and tracer decomposition forms of the PV eddy stresses can be used interchangeably. This will be done by examining models with different structures of potential vorticity.

3.3 Strong Flow Models

more interesting situations, such as, models with a strong mean state, which hence generate there own eddy fields. E.g. Jets in channels or double gyres. Hopefully allowing for the investigation of configurations where Eddy Enstrophy is the constraining bound.

4 Diagnostic Summary and Eddy-Mean Interaction Predictions

Naïve attempt to parameterise eddies using the results from the previous chapters, depending on what can be said about how the eddy stress can be characterised and constrained by the topography, eddy energy, eddy enstrophy etc.

Likely will need to carry the time and spatial evolution of eddy energy and eddy enstrophy and have some sort of step function to turn on and off the "GM like" and "holloway like" parts of the parametrisation at appropriate moments.

5 conclusions and discussions

Summary of results. Future work (keep this as unexplored possible ideas for now)