Studying mid-latitude storm tracks using a moist 2 layer shallow water model

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- What are mid-latitude storm tracks?
- Dynamical instability
- Moisture response

(from Windy.com, surface pressure)
Storm tracks affect weather and weather extremes (precipitation below)

Figure 2 in Shaw et al. 2016 paper “Storm track processes and the opposing influences of climate change”
State of the Field

Complex GCMs

Fig 4.3 of the Fourth National Climate Assessment

Simplified Models on a Plane

Fig. 1 from Lambaerts et al. 2012
Project Goals

1. Idealized model of storm track
2. Use shallow water equations on a sphere
3. Add moisture
4. Look at impact of moisture on storm tracks

IMPLEMENTATION → using Dedalus to solve system of PDEs

EXPERIMENT → running the model with varying initial moisture profiles and measuring the response of atmospheric circulation to moisture
Model

- Physical forces present include gravity, Coriolis force, and surface friction

- Five unknowns: $Q, h_1, h_2, u_1, u_2$

- Momentum is conserved $\rightarrow$ 2 equations

- Mass is conserved $\rightarrow$ 3 equations
Adding moisture

- Moisture in lower layer

- Convective parameterization

\[ P = \frac{H(Q - Q_s)}{\tau} \]

- Latent heating due to precipitation in lower layer is treated as a mass (and momentum) flux from the lower to upper layer

\[ \partial_t u_2 + g\nabla (h_1 + \alpha h_2) + f\hat{\kappa} \times u_2 = -u_2 \nabla u_2 + \frac{u_1 - u_2}{h_2} \beta P \]

\[ \partial_t h_1 + \nabla \cdot (h_1 v_1) = -\beta P \]
Computation and Dedalus

- Open source python package using pseudo-spectral methods to solve PDEs
- Specify initial flow, perturb and step through SWEs
- Using adaptive timestepper to ensure numerical stability (CFL conditions)

\[ \Delta t \left( \sum_{1}^{n} \frac{u_i}{\Delta x_i} \right) \leq 1 \]
Initial Flow
Results - dry vs 99.5%
Eddy Energy Evolution

- no precip
- 55%
- 75%
- 95%
- 99.5%

(hours)

1e8
Next steps:

1. Investigating energetics of moisture in the model further

2. Moving from weather to climate