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

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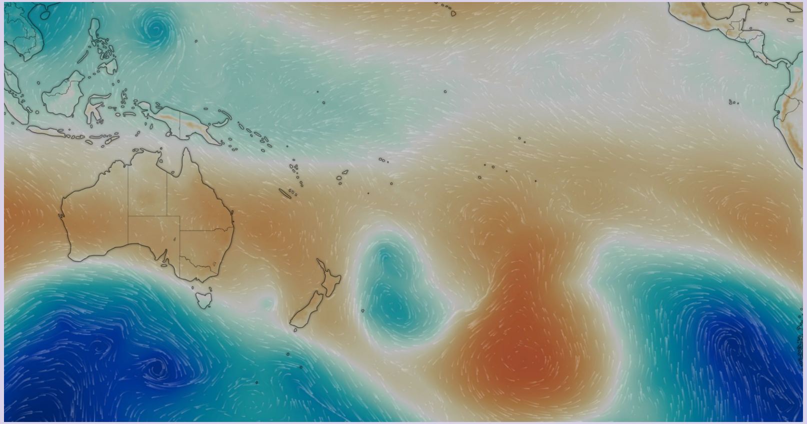
- What are mid-latitude storm tracks?
- Dynamical instability
- Moisture response



from Windy.com, surface pressure

# Storm tracks affect weather and weather extremes (precipitation below)

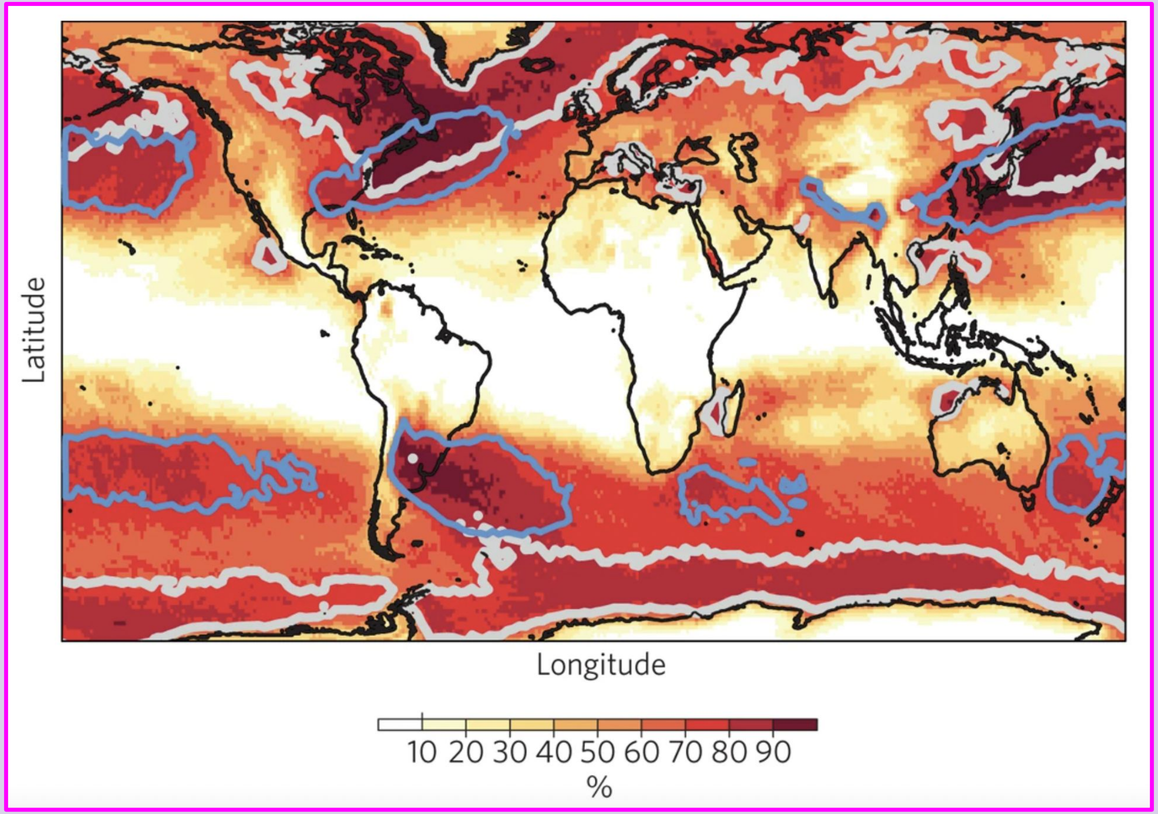
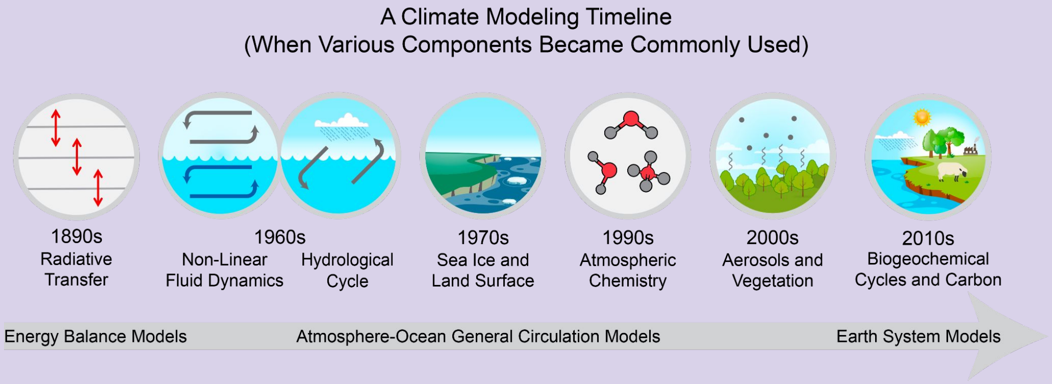



**Figure 2 in Shaw et al. 2016 paper "Storm track processes and the opposing influences of climate change"**

# State of the Field

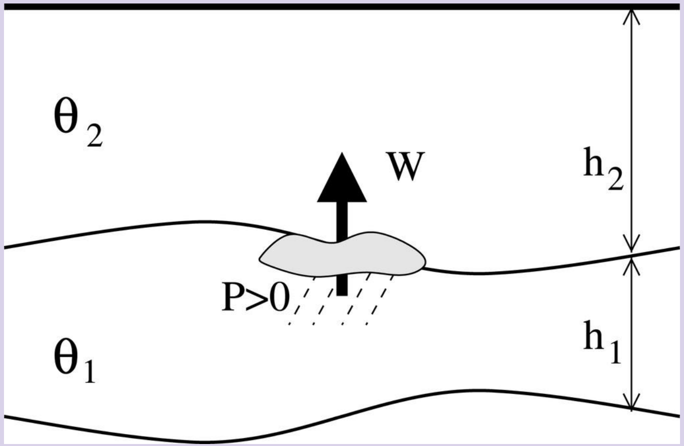
## Complex GCMs

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 → 2 equations**

- **Mass is conserved → 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

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

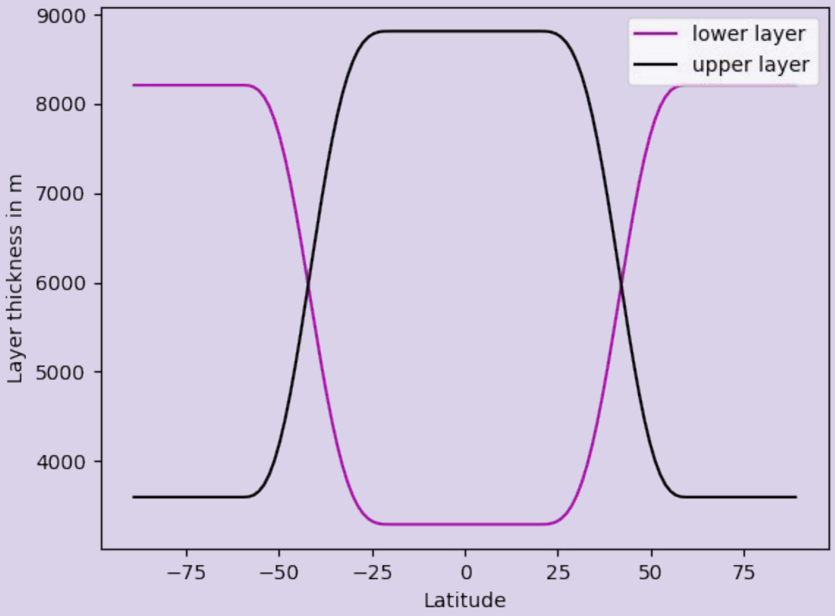
$$\partial_t h_1 + \nabla \cdot (h_1 v_1) = -\beta P$$

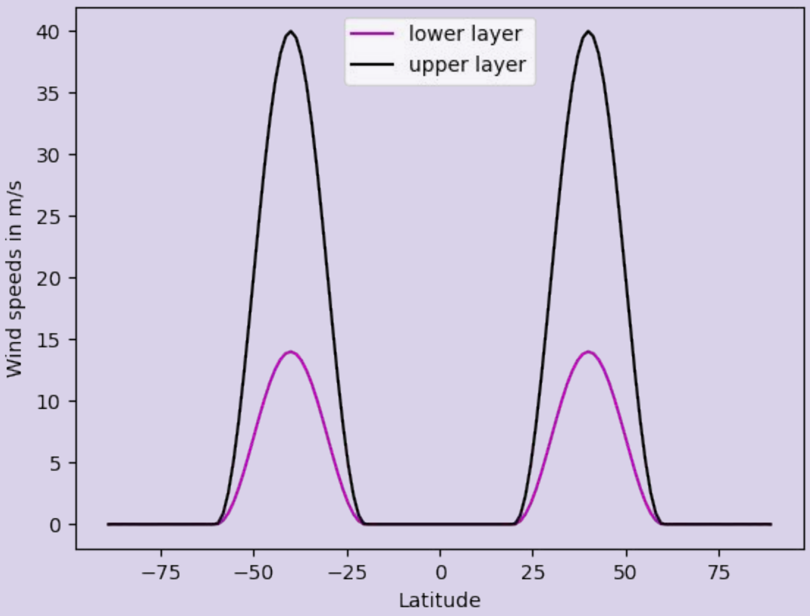
# Computation and Dedalus

- 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)

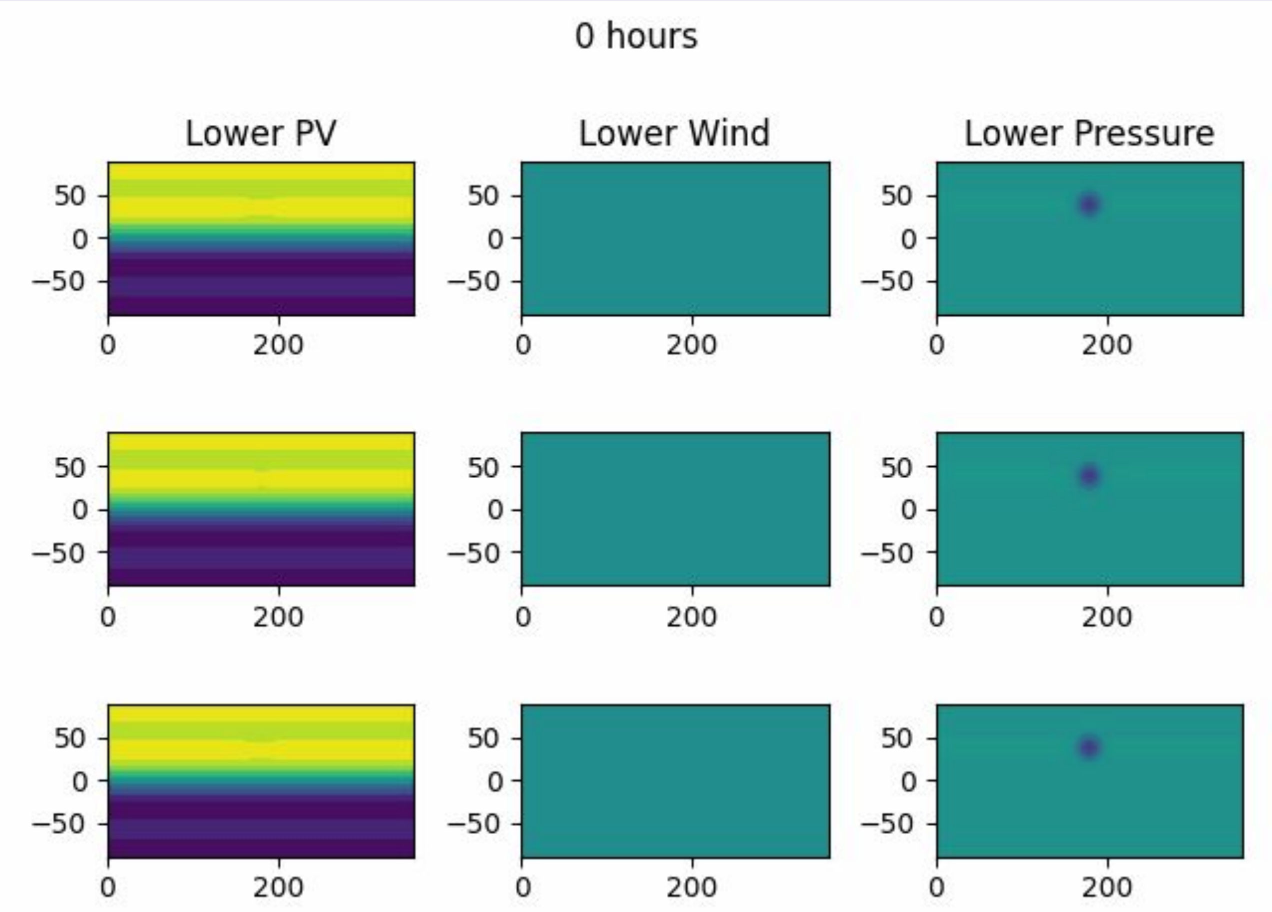
$$\Delta t(\sum_{1}^{n} \frac{u_i}{\Delta x_i}) \leq 1$$

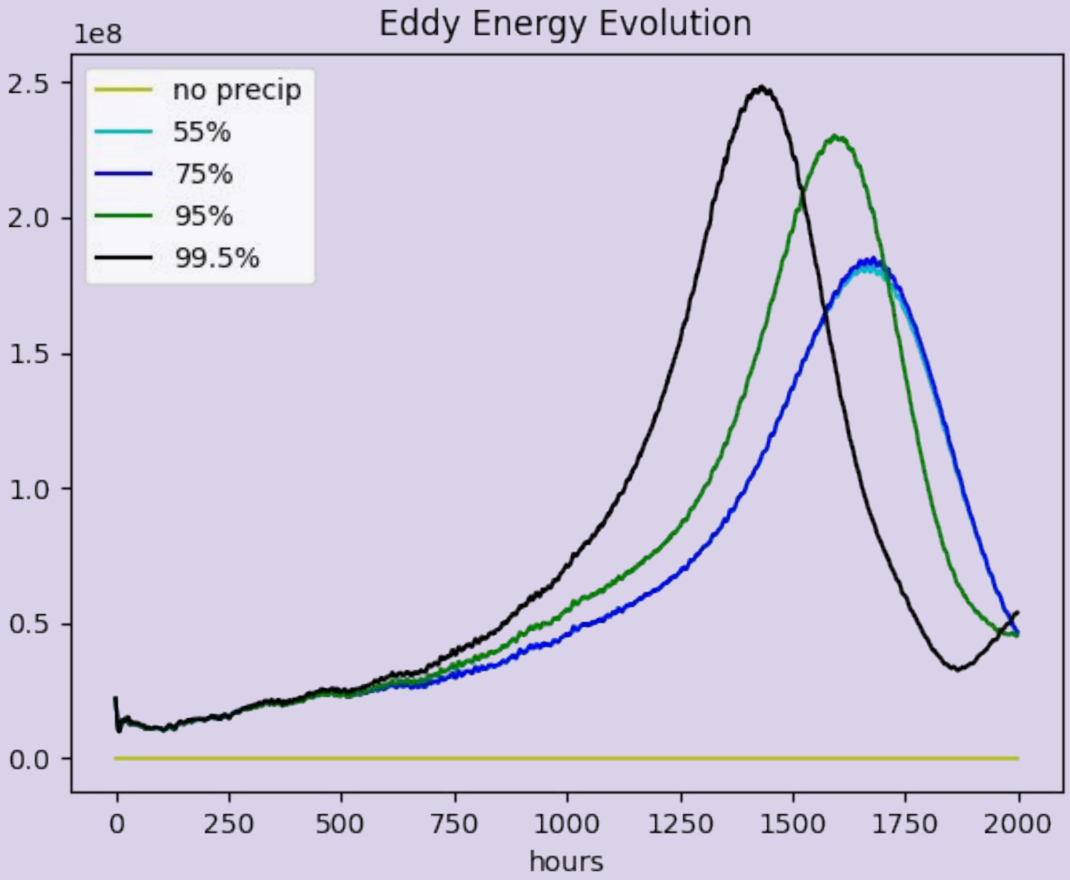
# Initial Flow



# Results - dry vs 99.5%





Eddy Energy Evolution
1e8
2.5
2.0
1.5
1.0
0.5
0.0
no precip
55%
75%
95%
99.5%
0
250
500
750
1000
1250
1500
1750
2000
hours

# Next steps:

1. Investigating energetics of moisture in the model further

2. Moving from weather to climate