The Dynamics of the Monsoon Anticyclone

A Single-Layer Model Study

Philip M. Rupp & Peter H. Haynes

UNIVERSITY OF CAMBRIDGE

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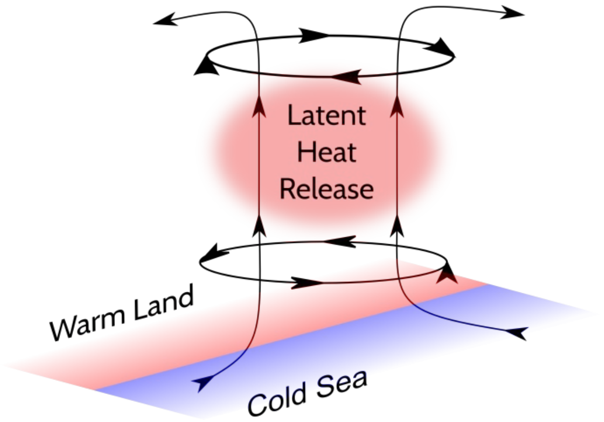
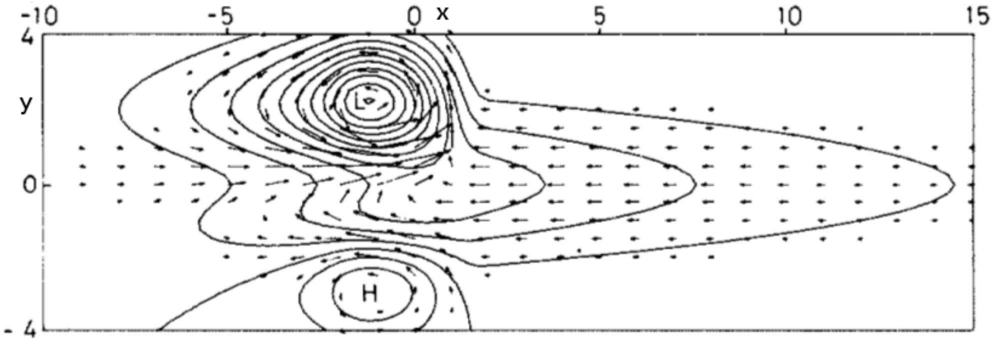
The Monsoon Anticyclone



- UTLS: anticyclone
  - Trace gases
  - Water vapour
- Troposphere: cyclone
  - Rainfall

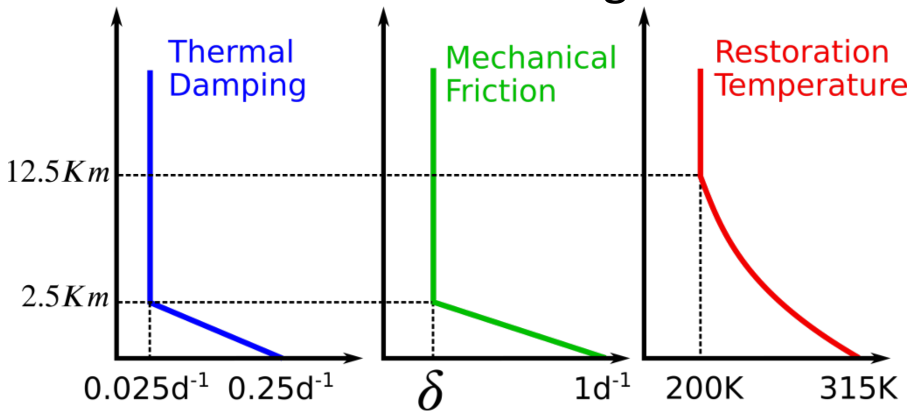
- Gill-Matsuno Model
  - Linear & Steady
  - Response to heating
  - Requires Friction



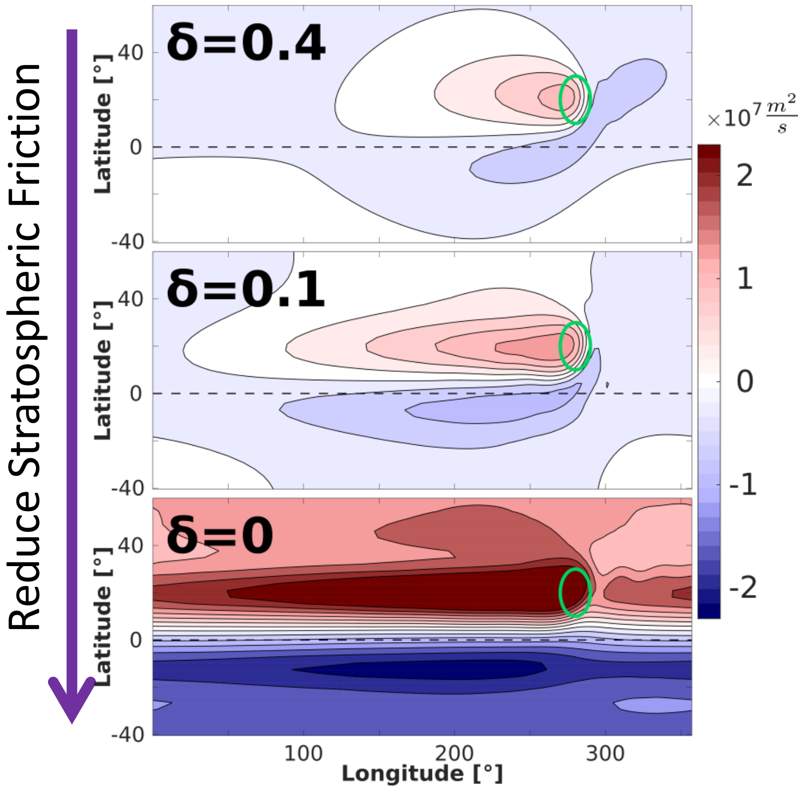
[Gill, 1980]

The Monsoon Anticyclone

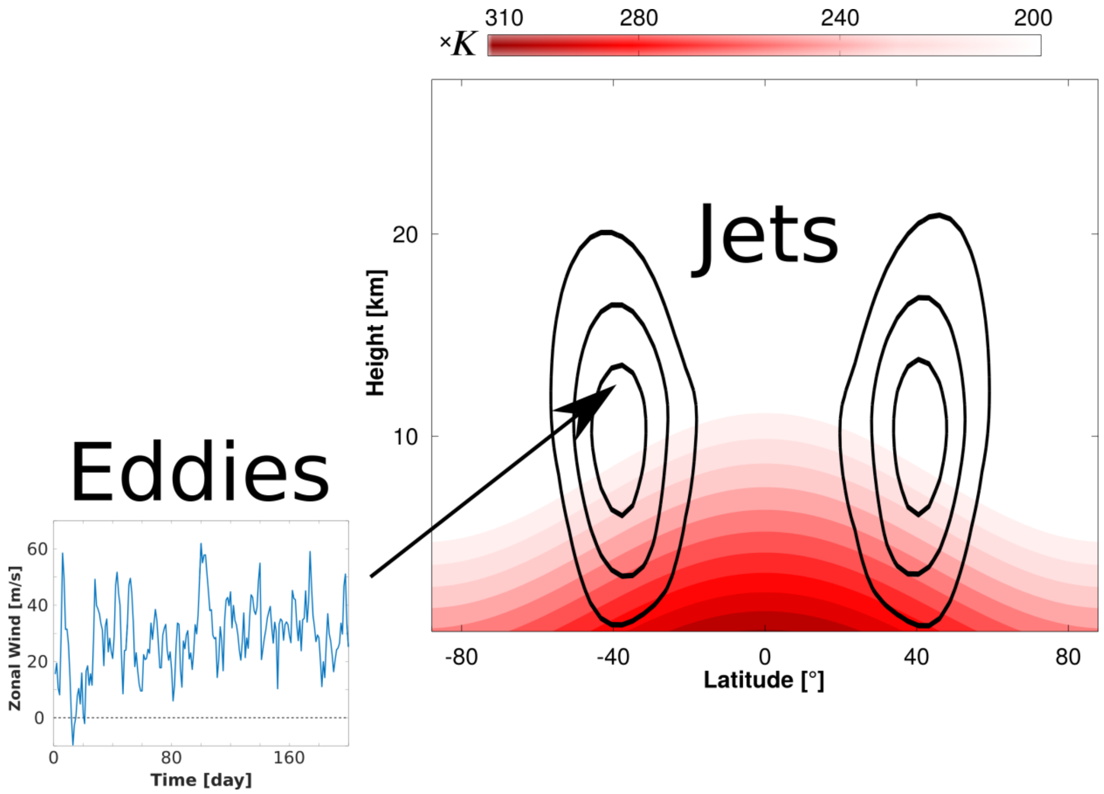
Simple 3D dynamical model with a localised heating



What else can provide a localising effect?



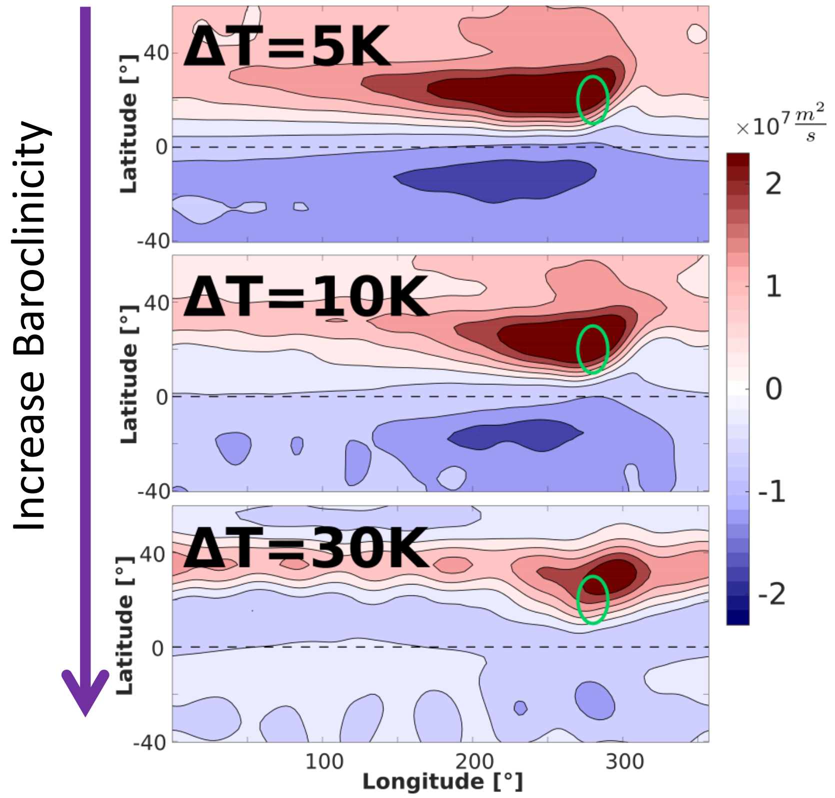
Active Extratropical Dynamics



Introduce meridional temperature gradient **ΔT**

Creation of mid-latitude jets and eddies

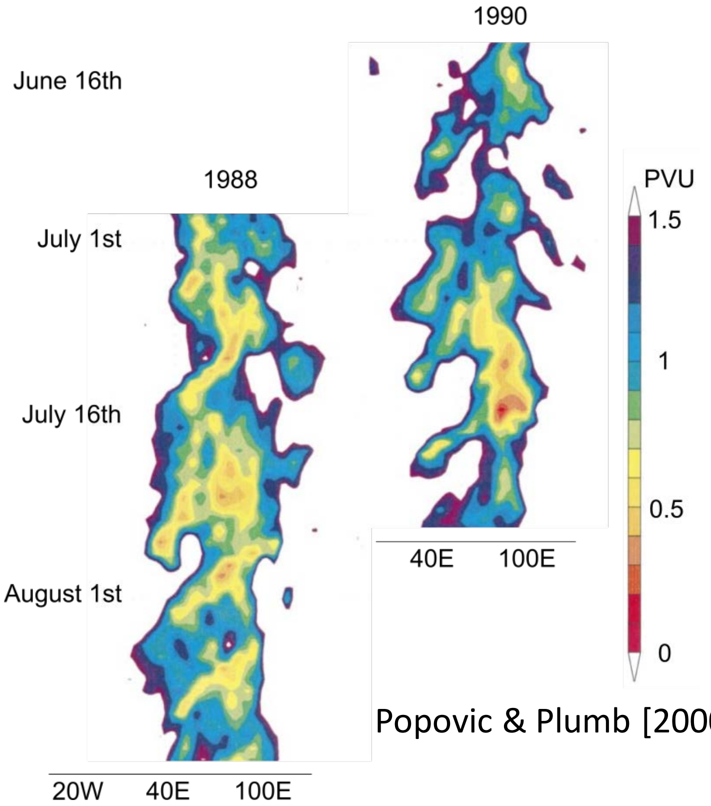
Active Extratropical Dynamics



Which processes contribute to the localisation?

Investigate using a single layer QG model

Eddy Shedding

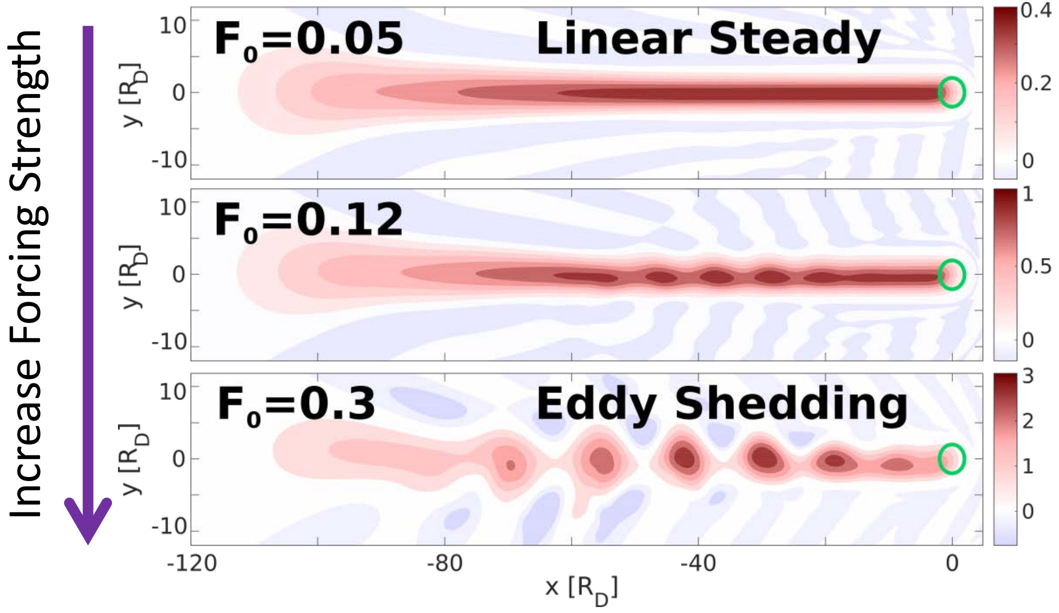


Popovic & Plumb [2000]

Observed westward shedding by the monsoon anticyclone

How important are non-linearity and temporal variability?

Eddy Shedding



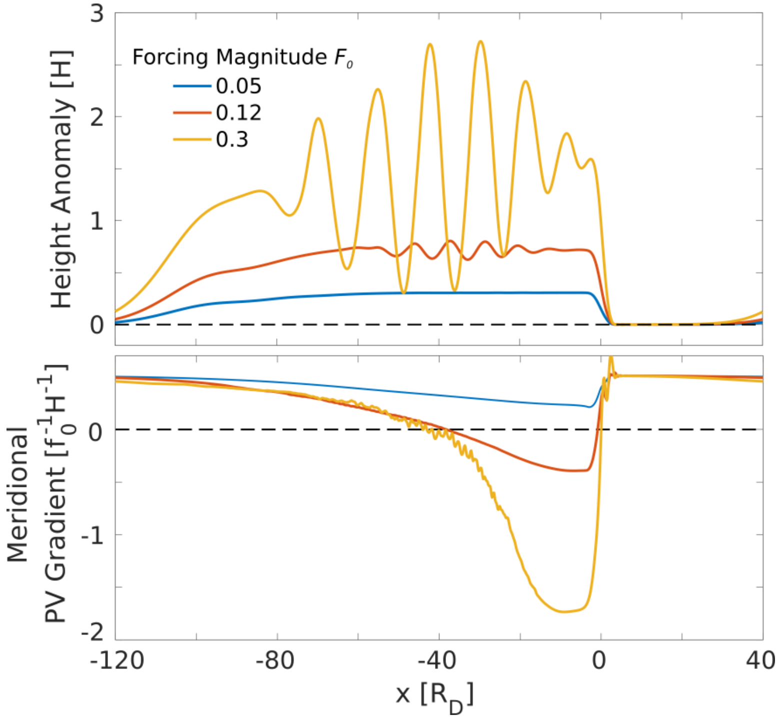
Davey & Killworth [1989]:
Eddy shedding when meridional
PV-gradient reverses

$$F_0 = \frac{\beta^2}{A}$$

$$A = \max_y \left| \int_{-\infty}^{\infty} \mathrm{d}x \ \left(\partial_y^3 - \partial_y\right) F \right|$$

Eddy Shedding

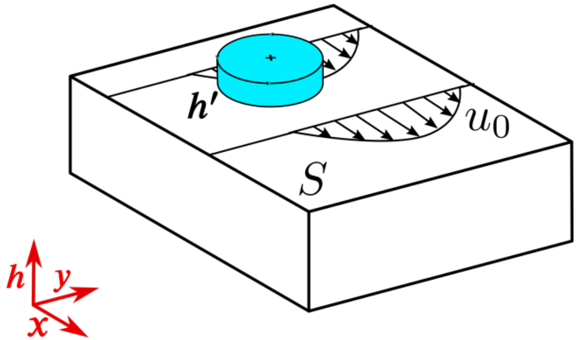
Predicted Threshold: F_0=0.09



What effect does eddy shedding have on the propagation speed?

Impacts of a Mean Wind

Investigate propagation
of single vortex dynamics



Centre of mass motion of a
confined anomaly h'
[after Davey & Killworth, 1984]

$$X_t = \frac{1}{M}\int \mathrm{d}S\ h'_t x$$

X : Centre of mass
M : Total mass
β : Long Rossby wave speed

Base velocity

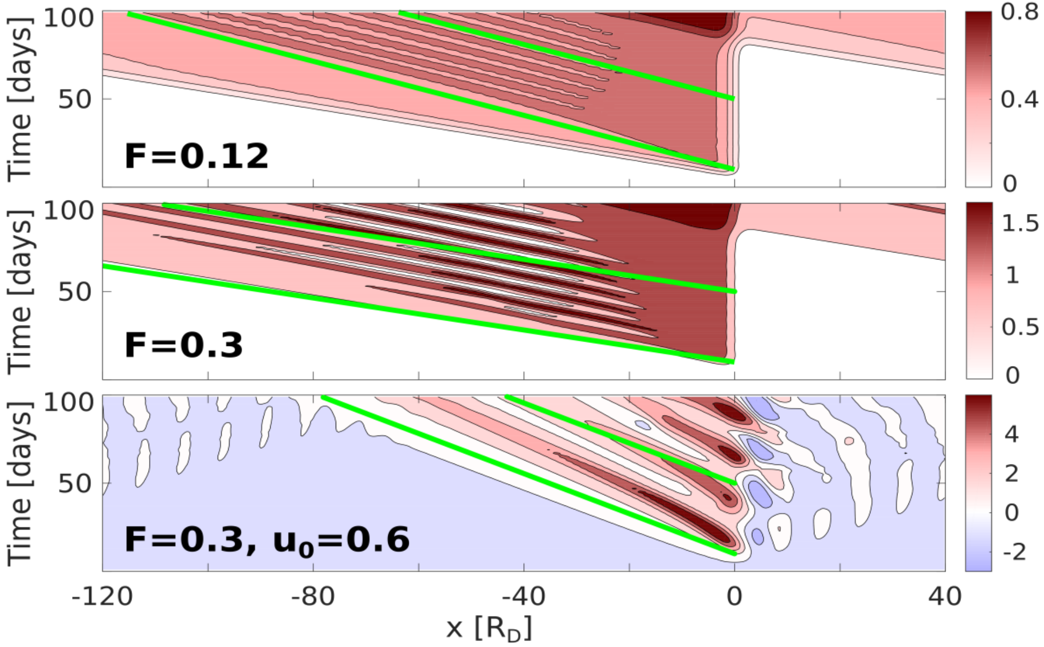
$$X_t = -\beta + \frac{\beta}{M}\int \mathrm{d}S\ h' u_0 - \frac{\beta}{2M}\int \mathrm{d}S\ h'^2$$

Effect of a background wind

Non-linear correction

Impacts of a Mean Wind

Change in forcing magnitude and background winds modify the propagation speed like predicted by theory (green lines)



(Almost) Linear wavestate
Flow propagates according to Rossby wave theory

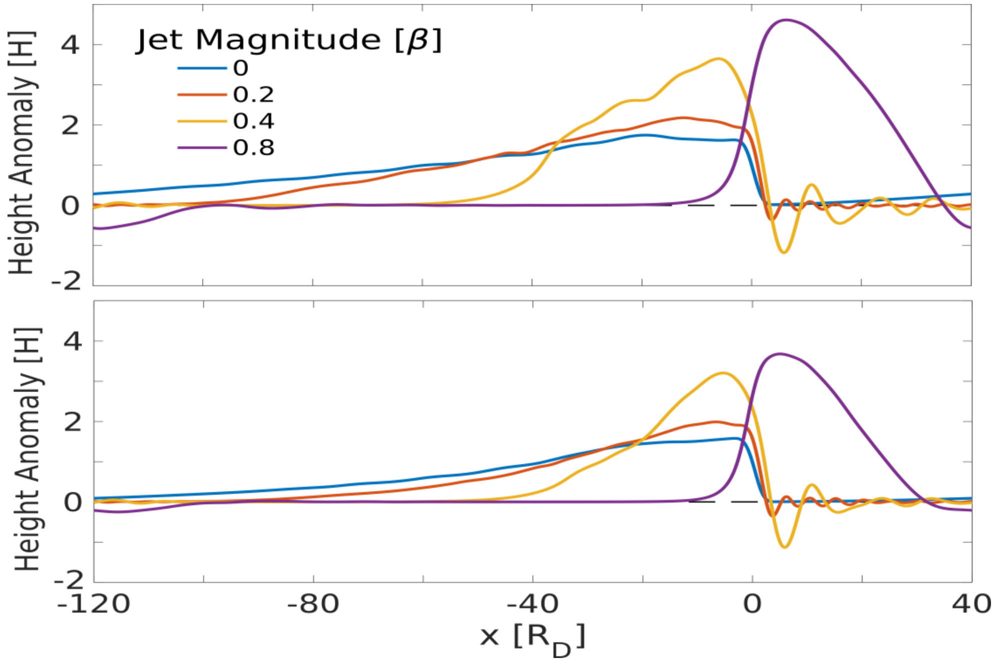
Eddy shedding state
Eddies travel with long Rossby wave speed

Mean wind effect
Zonal wind reduces vortex speed and shedding frequency

Impacts of a Mean Wind

Background jet limits propagation range of response within given time

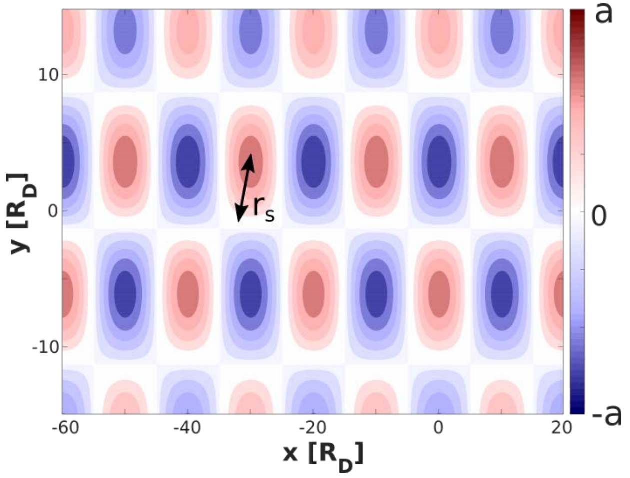
(Weak) Thermal damping can lead to localised and steady state



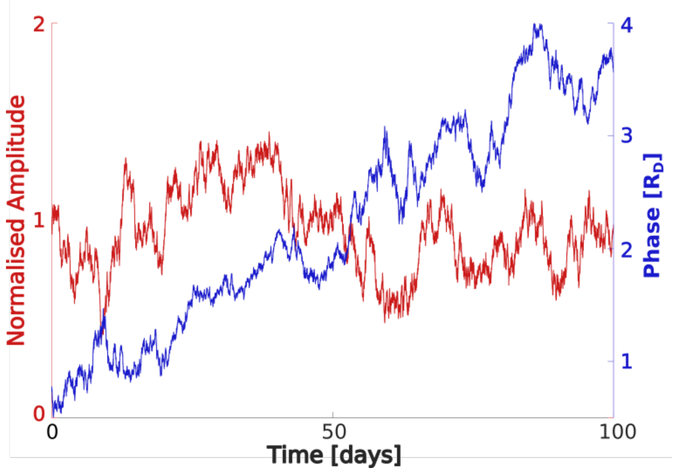
Impacts of External Stirring

Introducing a random stirring field representing the effects of mid-latitude eddies

Spatial Structure

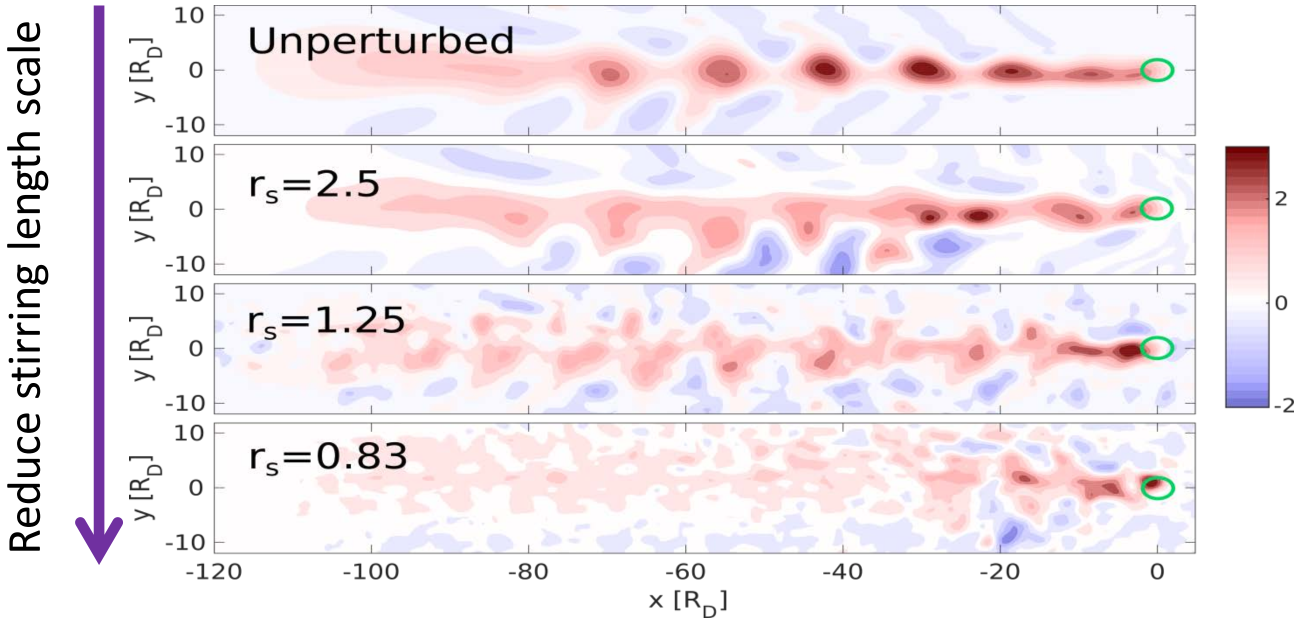


Temporal Evolution

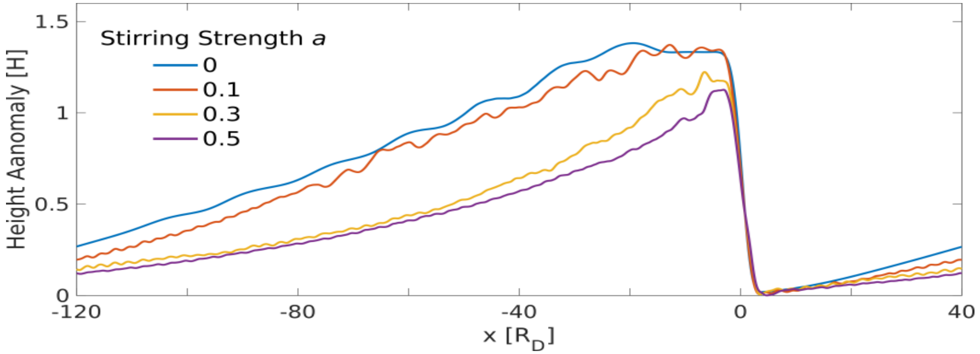


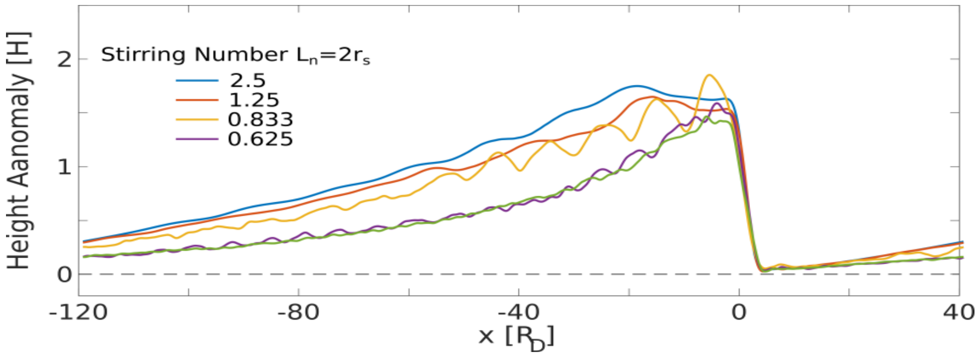
Impacts of External Stirring

Coherent vortex structure gets disrupted
for small stirring scales



Impacts of External Stirring



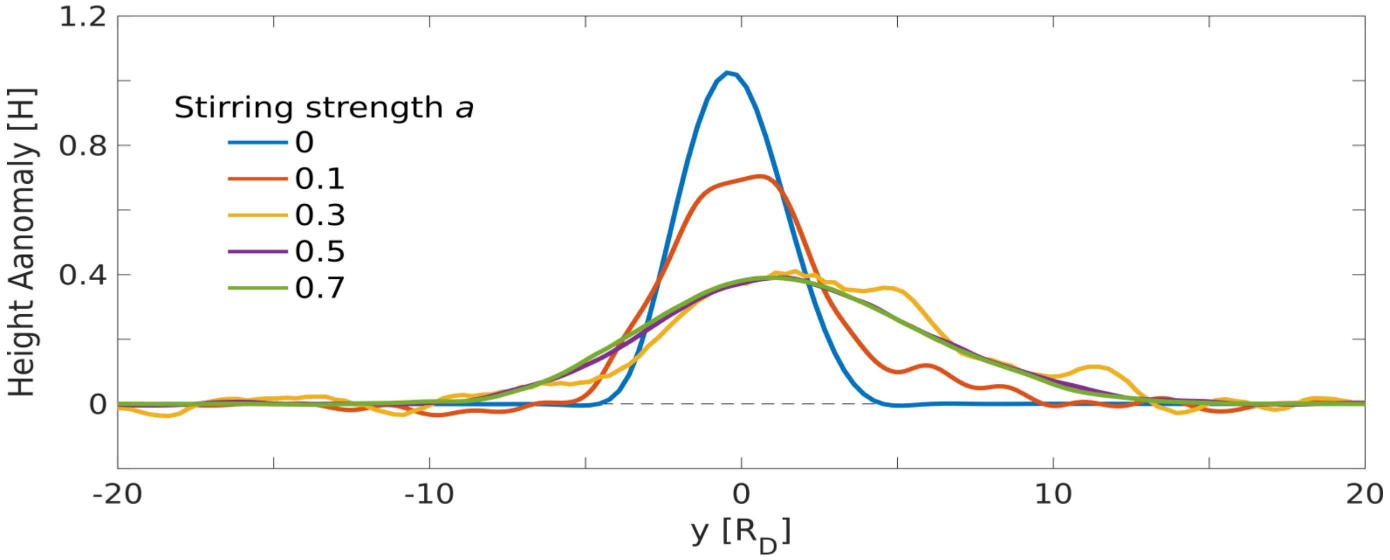


Zonal localisation depending on stirring strength (a) and scale (Ln)

However, localisation effect seems to be limited

Impacts of External Stirring

Stirring field leads to a meridional shift on top of a diffusive effect



Summary

- Shedding of discrete Vortices for strong forcing
- Unrealistic stretching of the anticyclone without large scale momentum damping
- Active extra-tropical dynamics has a localising effect on an extended monsoon anticyclone
  - Mid-latitude jet coupled to weak thermal damping
  - Stirring due to baroclinic eddies

- Future Work: Relative importance of processes in explaining the 3D model results

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