Equatorial Waves in the Aquaplanet UM

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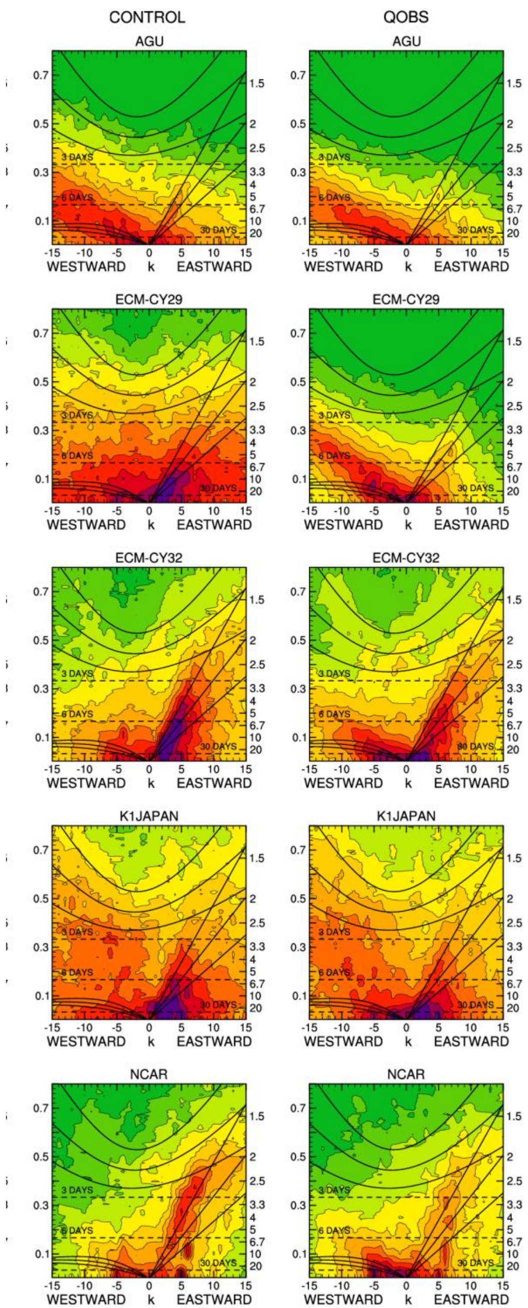
Variety of Equatorial Waves in Aquaplanet GCMs



Power Spectra from the APE Project

- Variations in
  - Intensity
  - East West Power Ratio
- With both
  - Model
  - SST profile

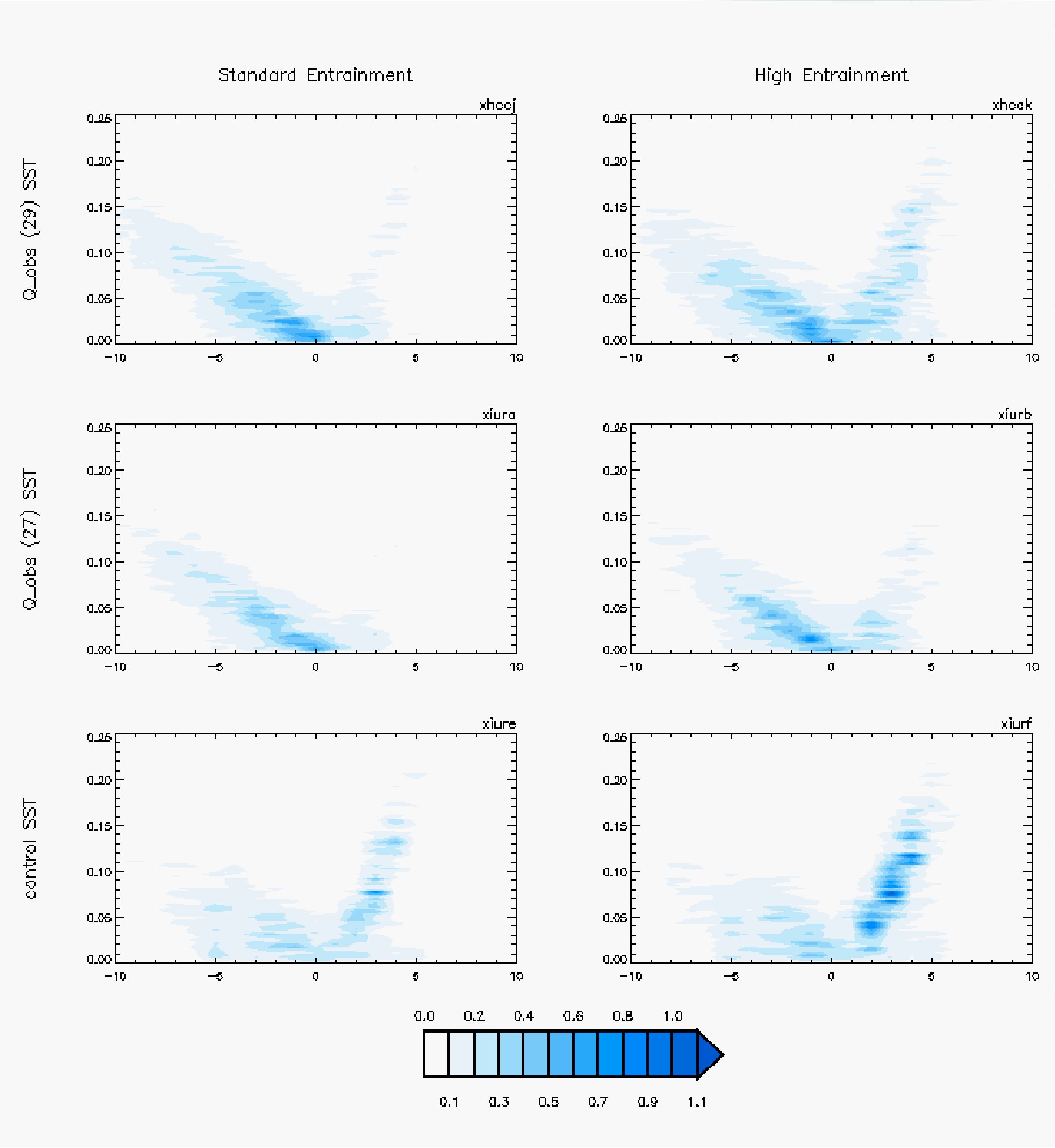
Can we understand these variations?

Williamson et al. (*J Meteor. Soc. Japan* 2013)

Experimental Design

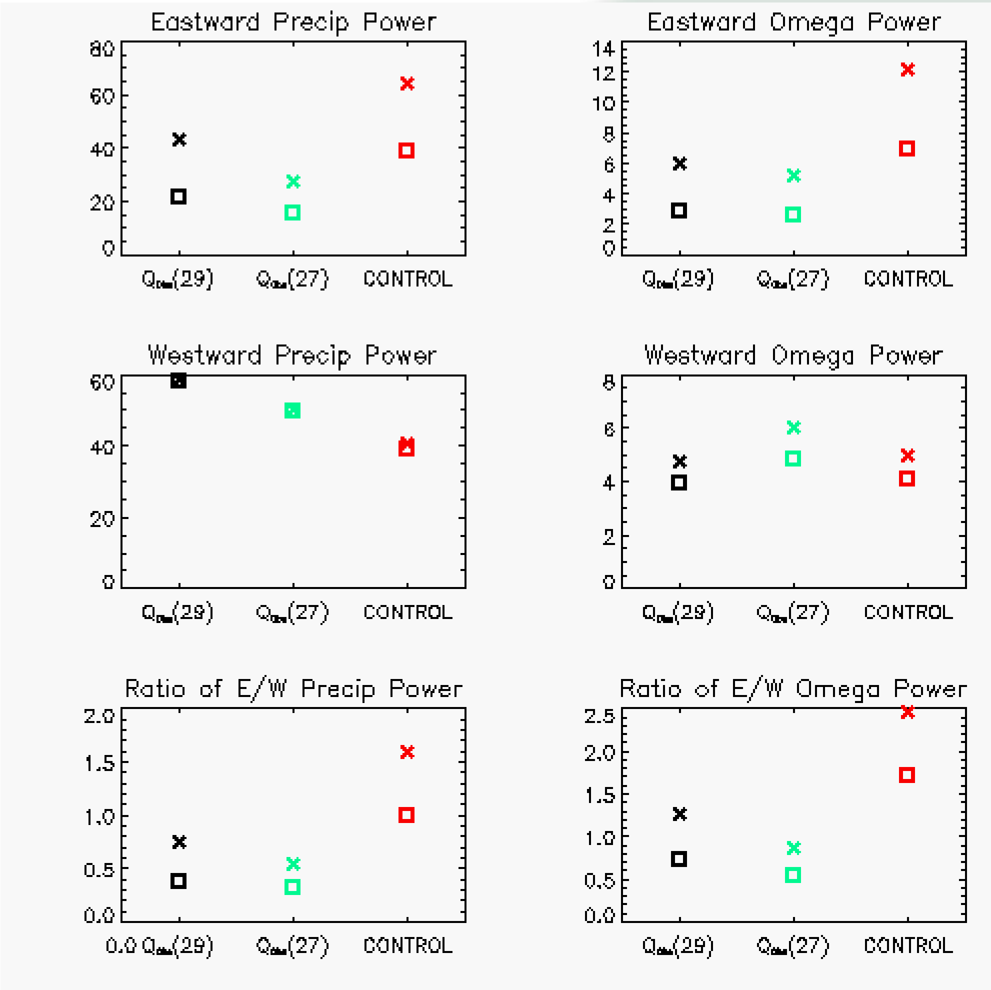
- Simplify the problem by sticking to one model and make a small change to the physics
  - Met Office Unified Model (GA3.0)
    - N96, L60 (1.875° x 1.25°)
    - 3 year integrations
  - 3 SST profiles
    - APE Q_{obs} with equatorial SST of 27°C and 29°C
  - Vary the convective entrainment and detrainment rate (shown to have an impact on the MJO in this model, Klingaman et al. QJRMS in press)
    - Control and Control x 1.5

Precipitation Spectra



- fixed SST shape
  - Higher SST has more power
- fixed SST max
  - Peaked SST has more eastward power and less westward power
- fixed profile
  - Higher entrainment has more eastward power

Precipitation and Omega Spectra



- fixed SST shape (■ vs ■)
  - Higher SST (■) has more power *(more eastward but less westward for omega)*
- fixed SST max (■ vs ■)
  - Peaked SST (■) has more eastward power and less westward power

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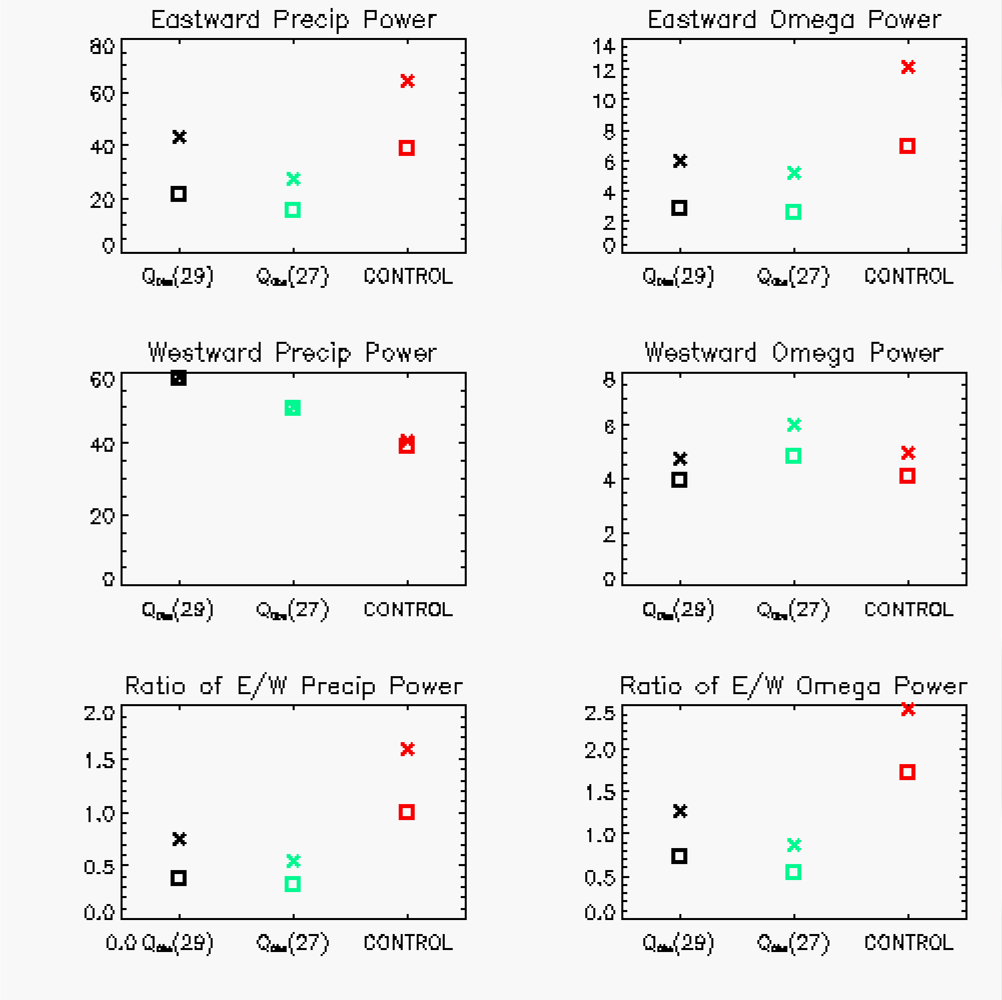

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- fixed SST max (■ vs ■)
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- fixed profile (■ vs x)
  - Higher entrainment (x) has more eastward power *(and more westward for omega)*

Framework

Kang et al. (2013) use the 2½ layer model of Wang (1988) and Wang and Rui (1990) to explain the variations with meridional SST profile.

Can we apply this analysis to understand the variations in our experiment?

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Framework

Essence of the Wang model for the baroclinic mode is given by the equation

$$\left(\frac{\partial}{\partial t}+N\right)\phi+(1-I)\nabla.\mathbf{v}=\omega_e(B+I-2)$$

where ω_e is a frictionally induced vertical motion at the top of the boundary layer and is related to the geopotential field

$$I=\gamma(q_l-q_u)/S$$

$$B=\gamma(2q_b-q_l-q_u)/S$$

$$S=2C_p p_m C_0^2/(RL_v\Delta p)$$

I and B are non-dimensional coefficents of heating induced by wave and boundary layer convergence,
γ is the fraction of moisture convergence which precipitates
S is a measure of the static stability of the basic state

Framework

Some results from Wang and Rui (1990) and Kang et al. (2013)

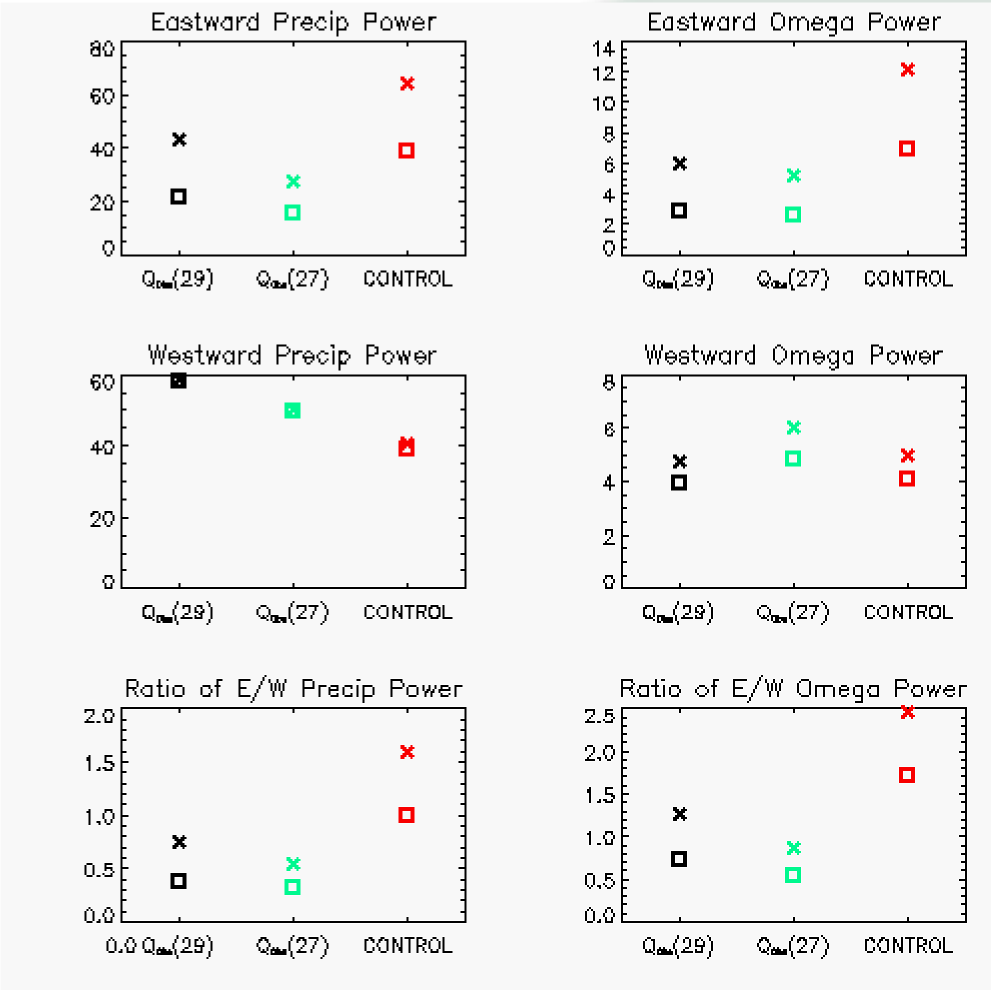
- Generation of Potential Energy given by $\overline{\omega_e \phi}(B+I-2)$

- Kelvin Waves grow more quickly as SST (and hence B, I) increase

- Rossby Waves damped more strongly as SST increases

- Meridionally peaked SSTs (and hence B, I) favours growth of Kelvin Waves and makes Rossby waves more damped

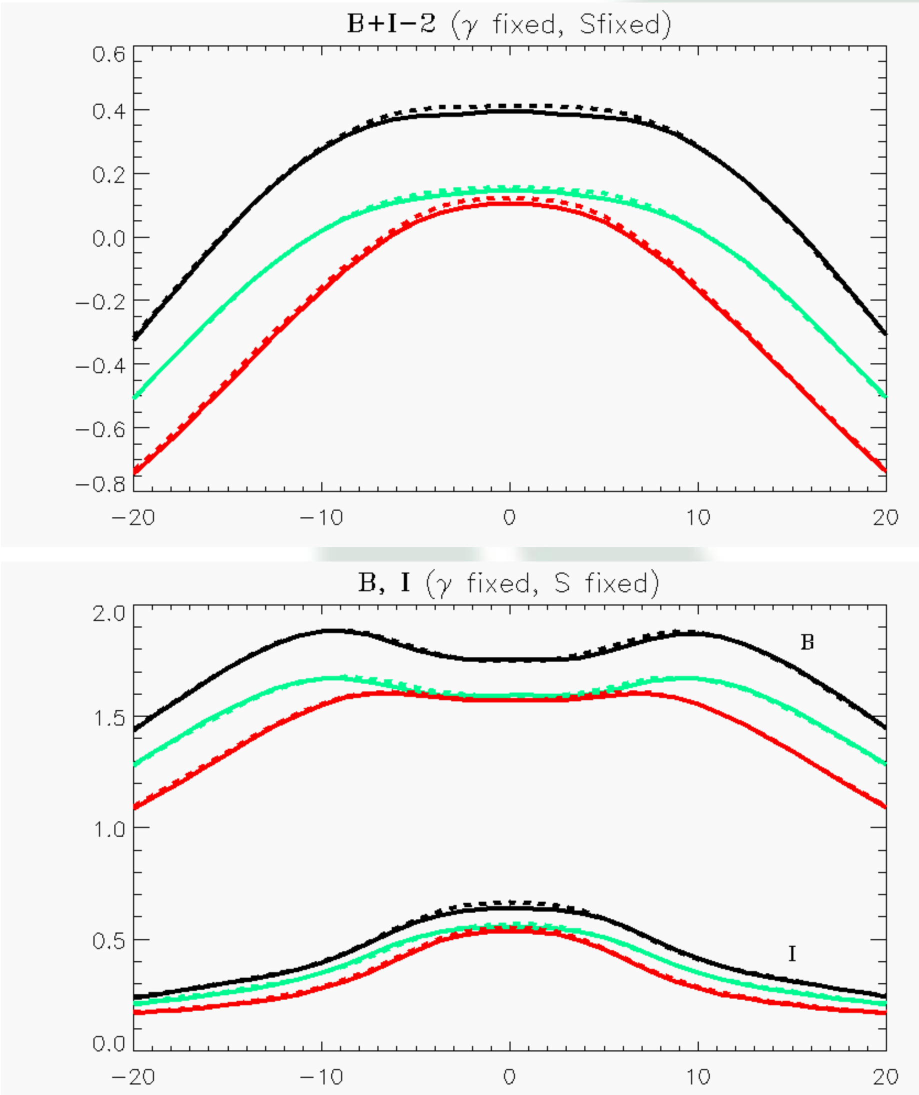
Changes in SST



- fixed SST shape (■ vs ■)
  - Higher SST (■) has more power *(more eastward but less westward for omega)*
  - Consistent with previous results for omega (?westward for precip)
- fixed SST max (■ vs ■)
  - Peaked SST (■) has more eastward power and less westward power
  - Consistent with previous results

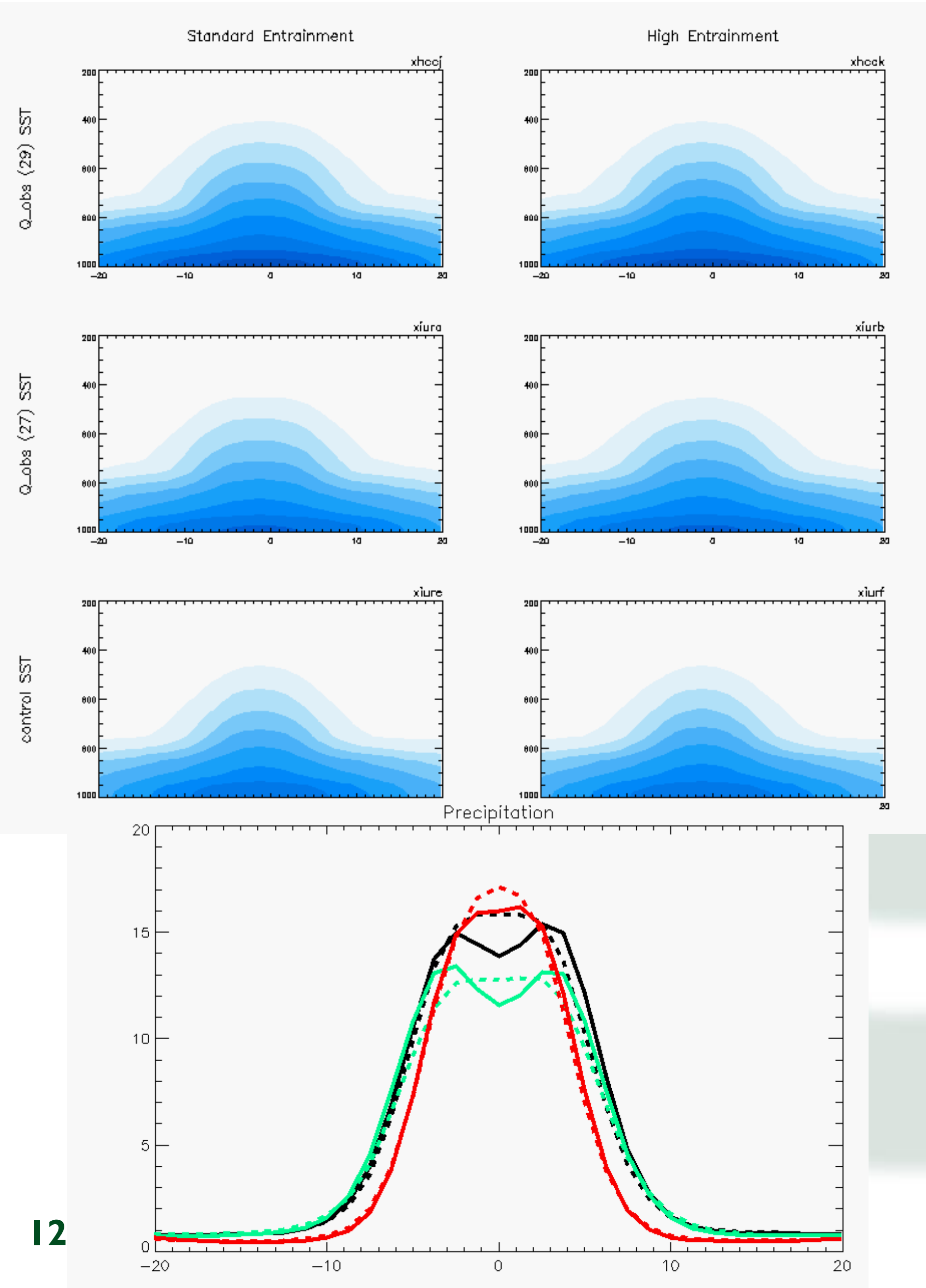
Note that sensitivity of Kelvin Waves to shape is larger than to SST max

Variations in non-dimensional parameters



- Equatorial B,I, or B+I not clearly related to amplitude of K-wave directly
- Suggests shape may be more important

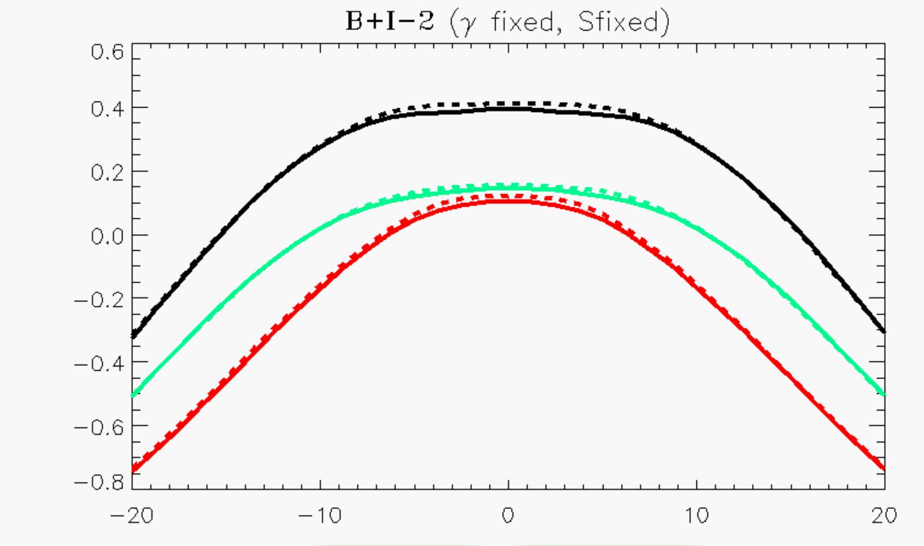
Changes in basic state

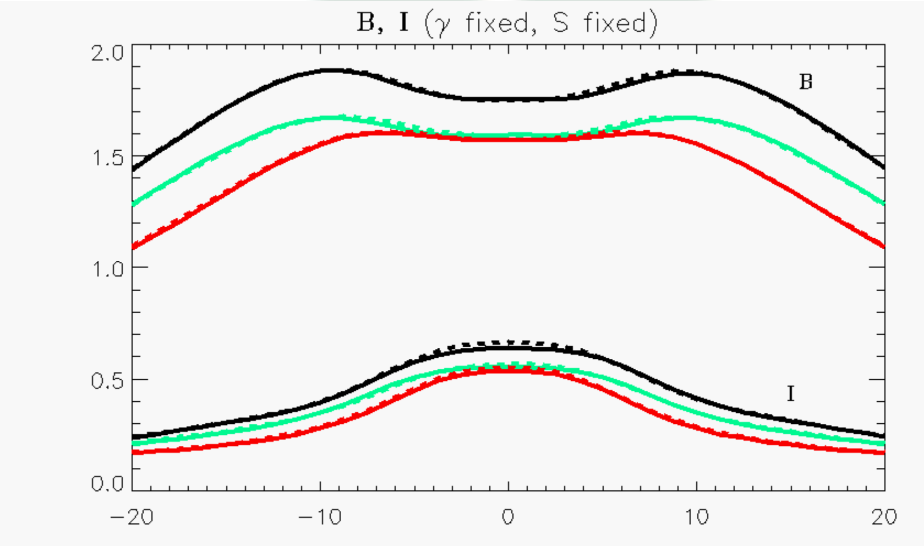


- By eye only small variations in humidity structures with entrainment rate, much greater sensitivity to SST profile

- Much larger variations in precipitation profile with entrainment

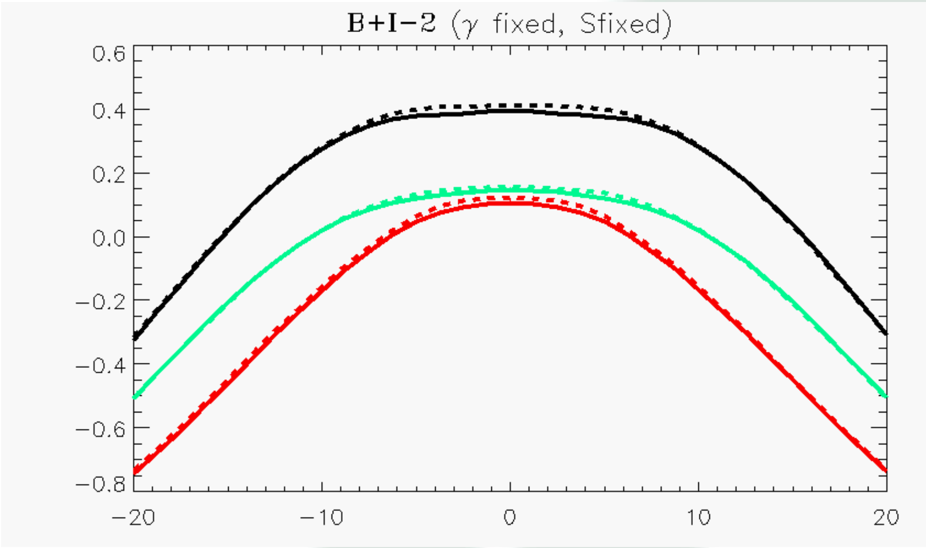
Variations in non-dimensional parameters

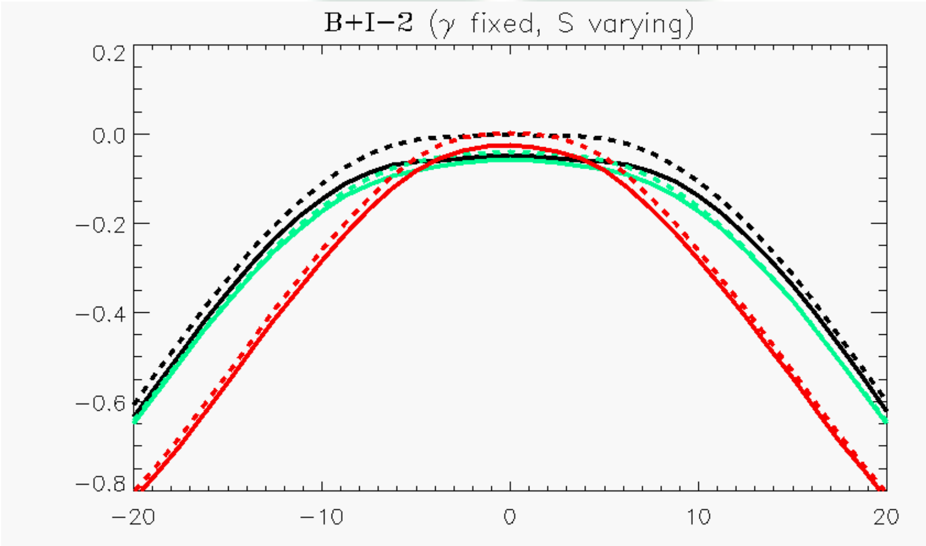




- Equatorial B,I, or B+I not clearly related to amplitude of K-wave directly
- Suggests shape may be more important
- Note that S,γ fixed

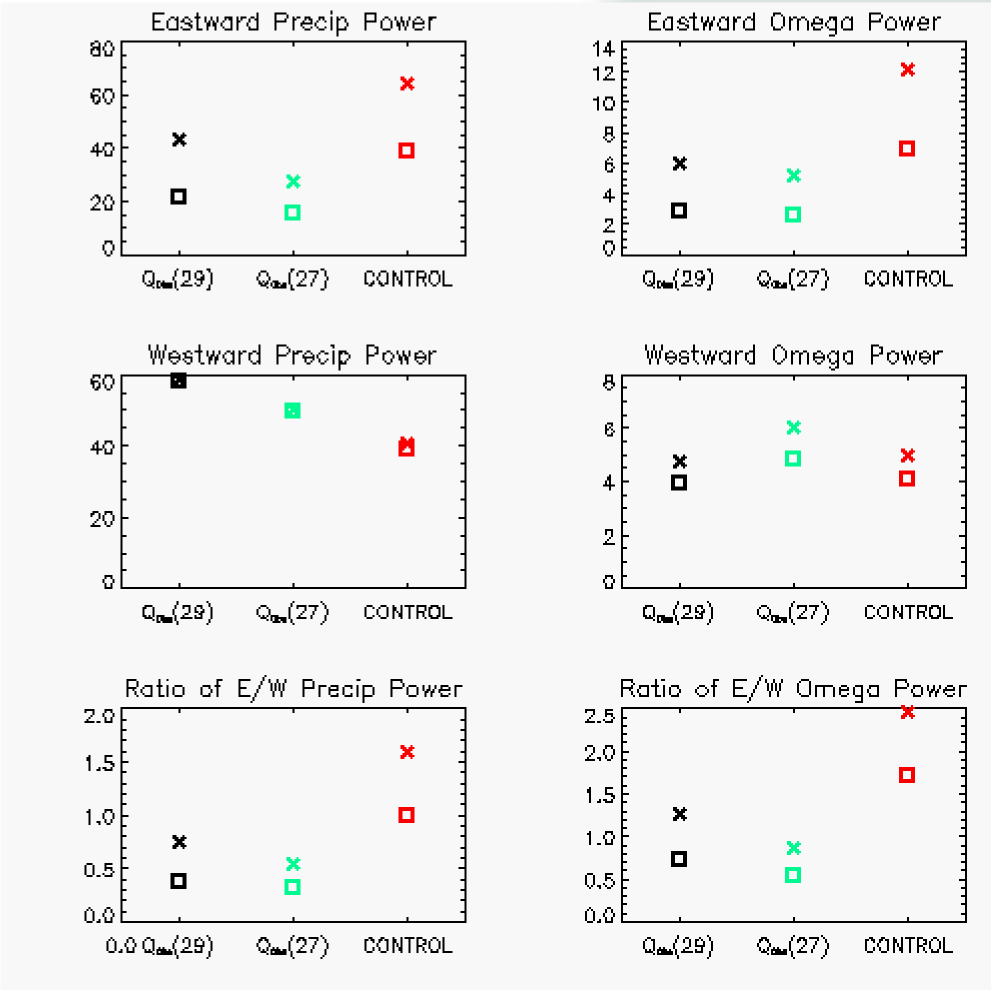
Variations in non-dimensional parameters





- Equatorial B,I, or B+I not clearly related to amplitude of K-wave directly
- Suggests shape may be more important
- Accounting for variations in S, as measured by the model, may change this but difficult to interpret

Changes in physics

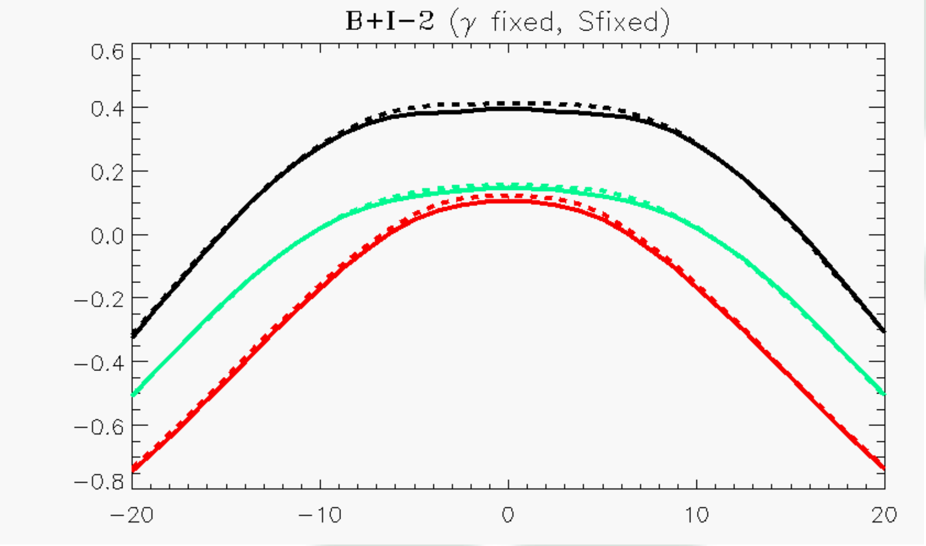


- fixed profile (■ vs x)
  - Higher entrainment (x) has more eastward power *(and more westward for omega)*

Can we interpret this in terms of the same non-dimensional parameters?

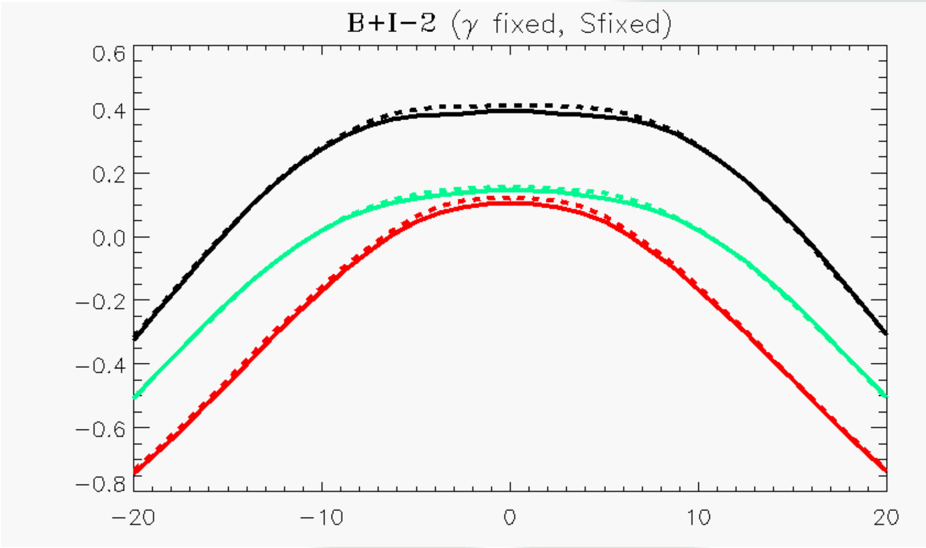
Unlikely as we see an increase in power for both eastward and westward waves

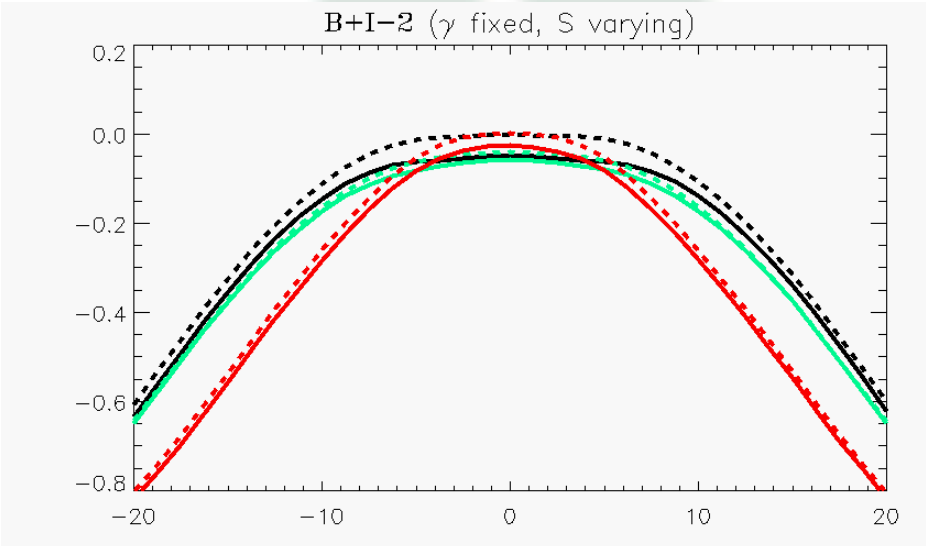
Variations in non-dimensional parameters



- fixed S, γ
  - little variation with entrainment

Variations in non-dimensional parameters





- fixed S, γ
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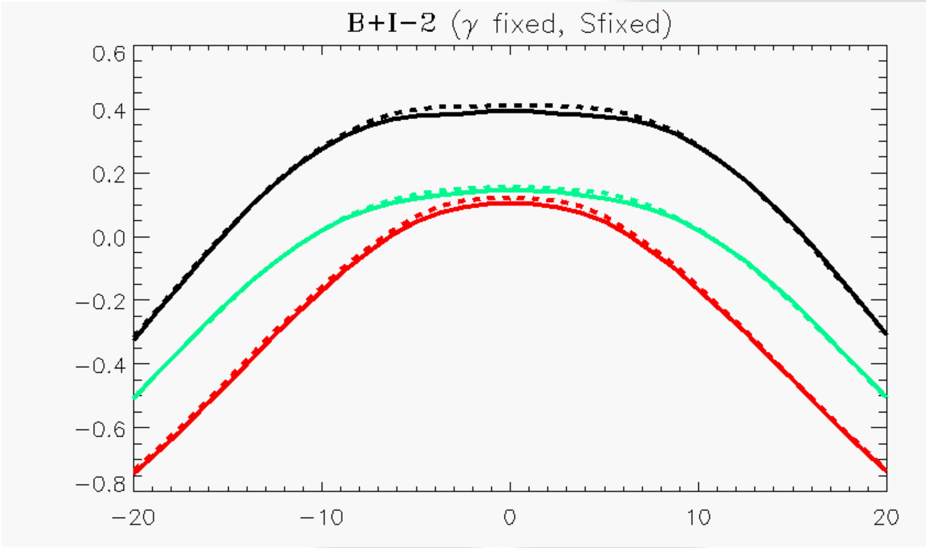
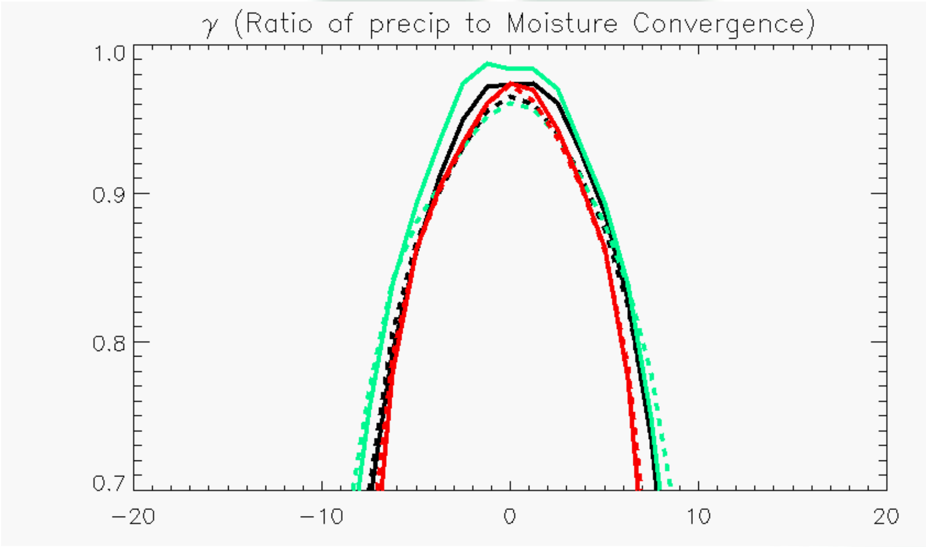
- S varying
  - larger changes in Q_{obs}(29), CONT
  - small impact for Q_{obs}(27)
- All account for changes in the basic state, what about changes in the physics?

Variations in non-dimensional parameters





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- γ changes lead to wrong sign of changes for (B+I)

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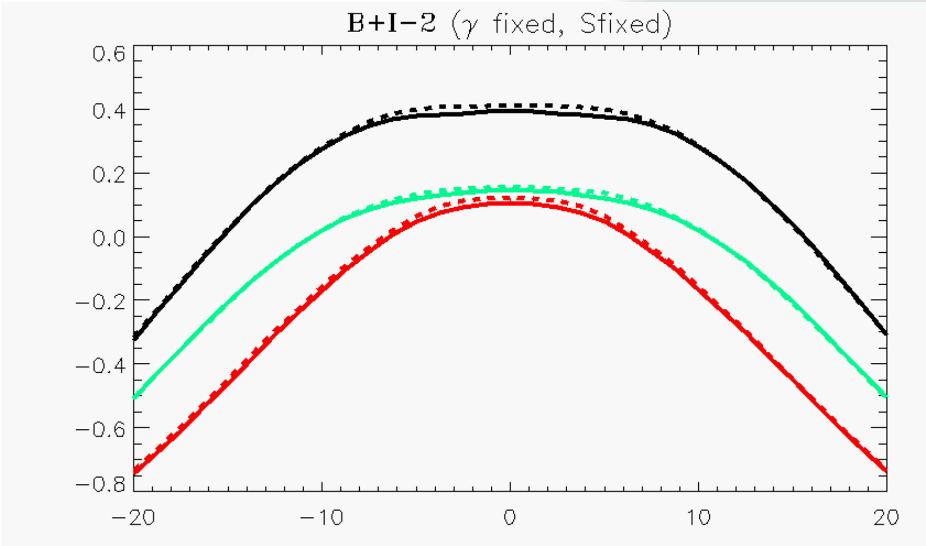

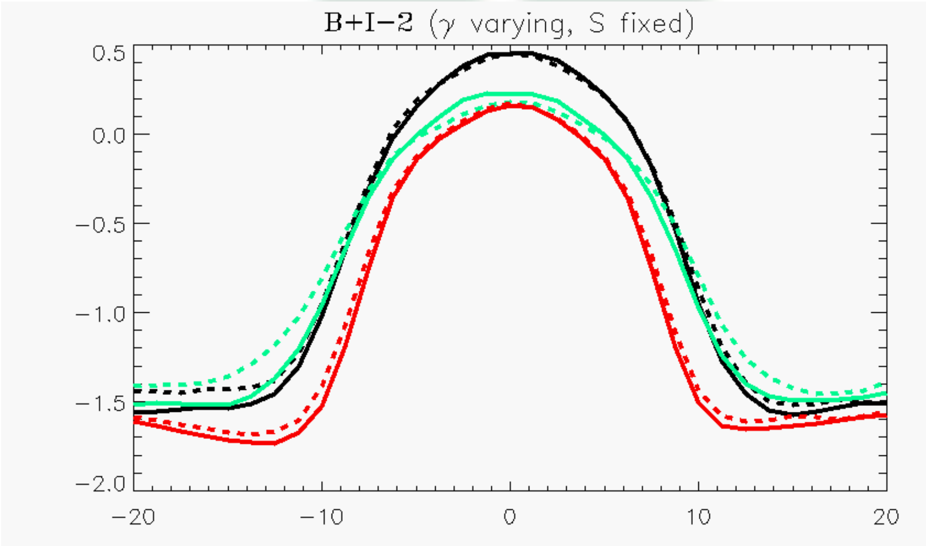

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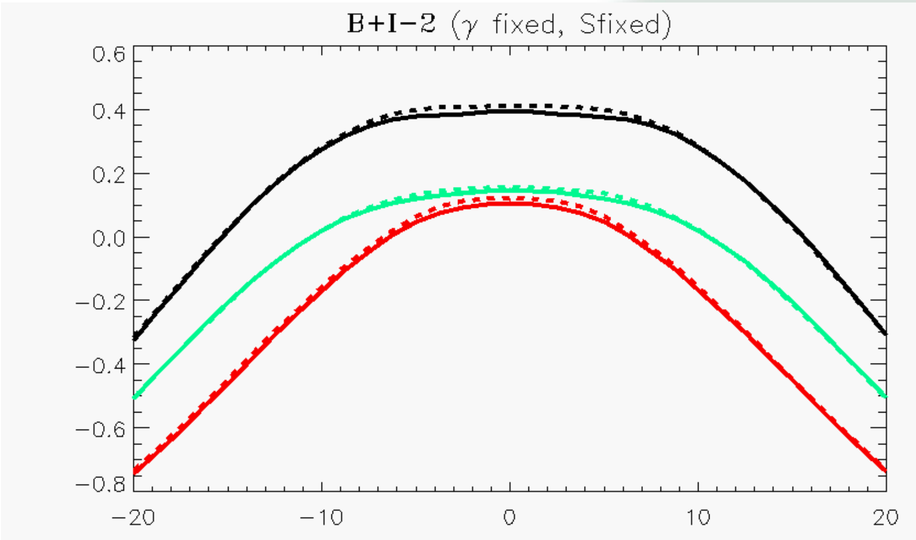

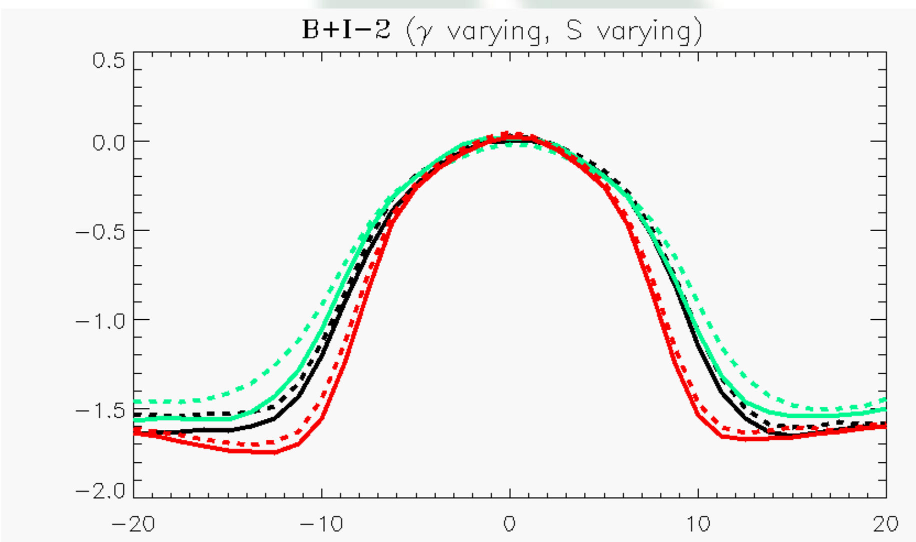

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For full variations all the changes are away from the equator

Summary so far

- Qualitative changes with SST can be understood with this framework (similar to previous studies)
- Some hint that changes in the basic state might explain part of the sensitivity to entrainment
- Need to extend this analysis to be me more quantative

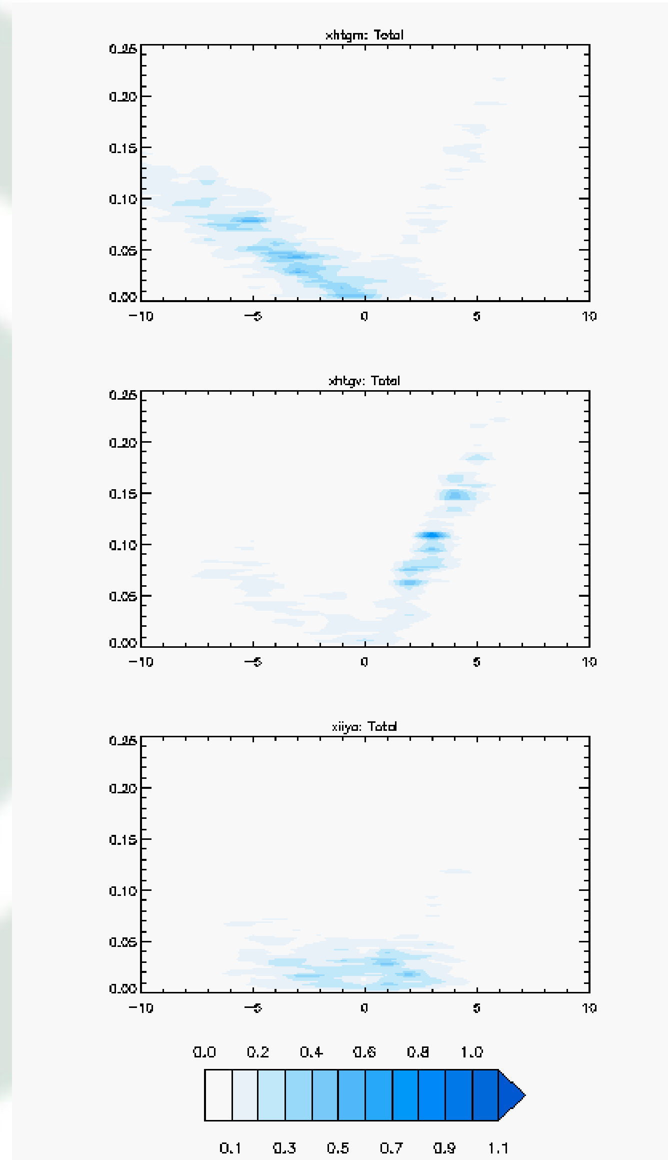
- Some of you will have noticed that (B+I-2) not much bigger than 0 which implies small instability
  - Sensitive to S and γ which are not easily diagnosable
  - Other instability mechanisms?
    - evaporation?
    - radiation?

A little bit more – role of evaporation and radiation

- Some additional runs (note the control is not quite the same) as Q_{obs}(29)

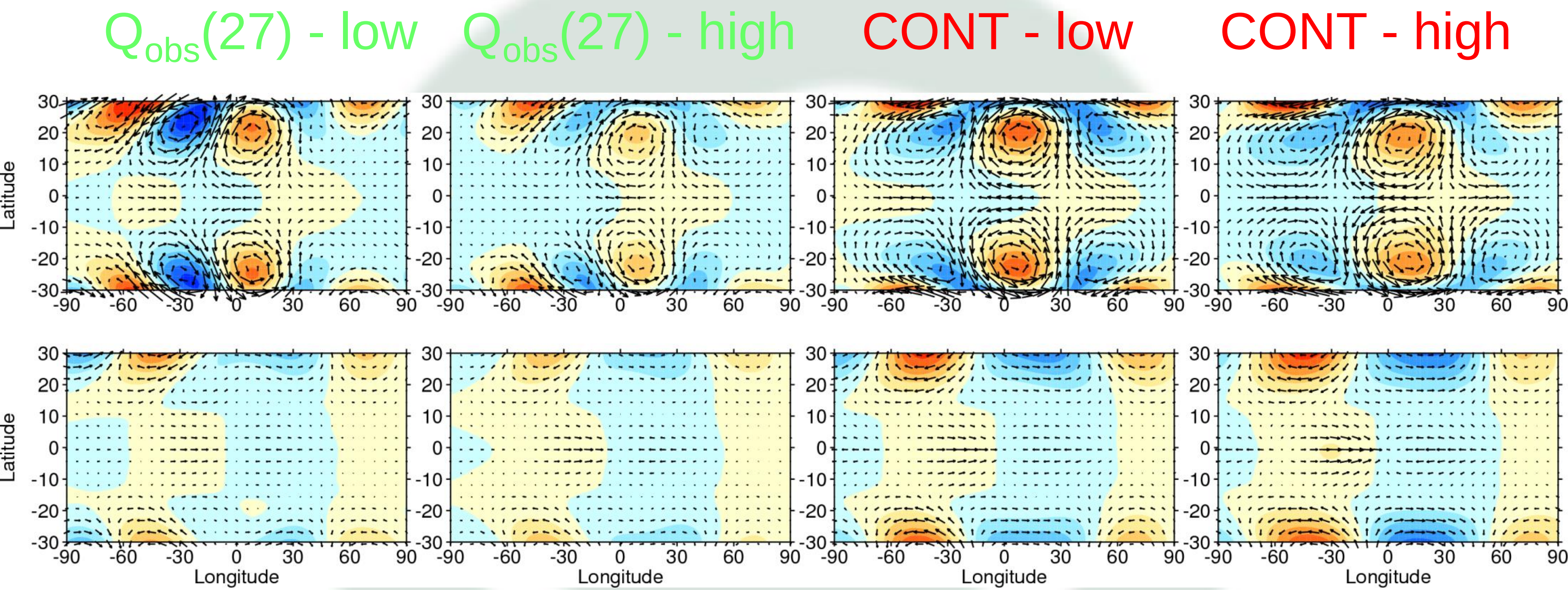
- Fixed radiation
  - Virtually wipes out westward propagating systems
  - Much enhanced Kelvin Waves

- Fixed radiation and surface fluxes with Newtonian Cooling
  - Virtually wipes out all waves



Need to modify analysis to account for these

A little bit more – Horizontal Structure



- Low level has characteristics of Kelvin Wave, but upper level has strong Rossby Wave component
- Clear links to mid-latitude disturbances
- Characteristic Structures very similar

A little bit more – GP correlation