

On the mutual interaction  
between eddies and the Hadley cell  
The project main lines

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# Outline

- 1 The atmosphere as a tropical-extratropical coupled system
- 2 My Work Plans

# Filling the gap between simulating and understanding climate

Isaac Held, 2005

## Simulating

- Has the aim to reproduce Earth climate
- Progressive inclusion of more and more realistic processes in climate models
- Allows to assess climate change

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- It uses comprehensive models or idealized models
- It **feedbacks** on improving simulation of climate

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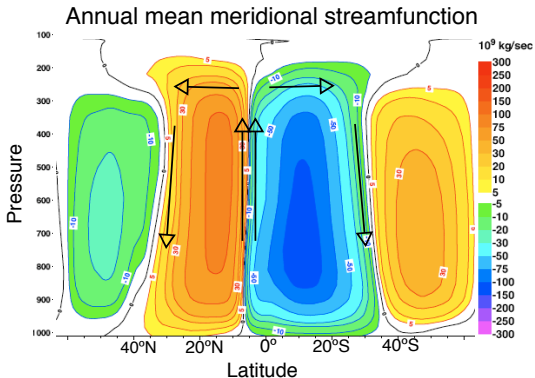
## My main topic

To research how the interaction between the tropics and the extratropics controls the **zonal mean** climate

# The Hadley circulation

What controls. . .

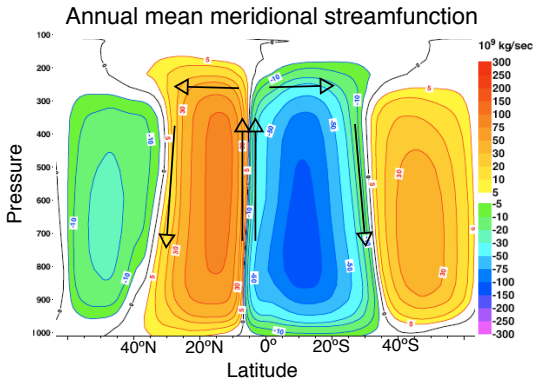
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# The Hadley circulation

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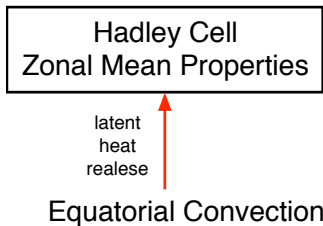
These are longly questioned features of climate  
but recent studies are calling for new theories

## The “old” picture

### Midlatitudes eddies

Held and Hou, 1980

They provided a closed theory for the intensity and the extension of the Hadley cell





## A new picture

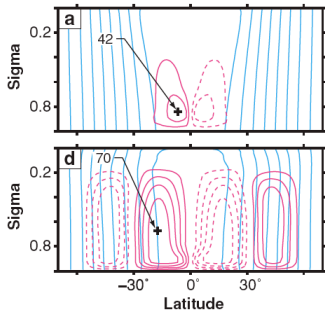
Walker and Schneider, 2006

- They used an **idealized** model to show whether **extratropical eddies** influences Hadley cell
- The model: dry, no orography, forced by linear relaxation of temperature to an unstable profile

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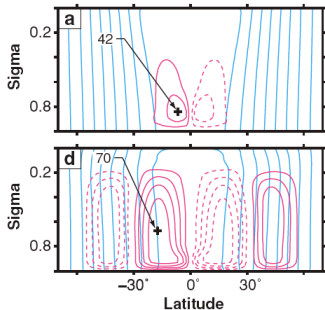
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mean meridional streamfunction:  
(a) without midlatitudes eddies,  
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**Eddy breaking** in the subtropical region strengthens and expands the Hadley cell

## It opens some questions . . .

- Are the properties found in idealized models present in more complex models or observations? How do they change?
- Is it possible to observe feedbacks between convection and eddies properties?
- Have all the eddies the same efficiency in influencing Hadley cell?

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## 1st. Selecting the variables

Selecting the most interesting variables and studying their variability.

### A list of possible variables

- Hadley cell intensity and extension
- Equatorial latent heat release
- Eddies stress and eddies stress spectra
- Subtropical jet intensity and latitude
- The vertical slope of the zero wind line at subtropics
- Upper equatorial wind

## 2nd Verifying results from idealized models

This goal, and the whole project, will be done using a hierarchy of models of different complexity:

### Models

- An idealized model like Schneider's one
- Aquaplanet GCM
- Coupled GCM and Reanalysis

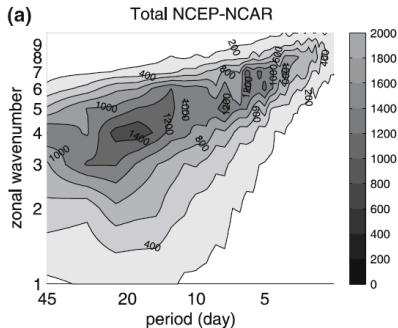
### 3rd Looking for new relationships between eddy's spectra and Hadley cell properties

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- Climate is often studied decomposing the atmospheric fields in the mean and in the deviation from the mean
- But there is a **continuous** spectrum of waves
- We will do simulations to find atmospheric properties not depending on the way the spectrum is decomposed.

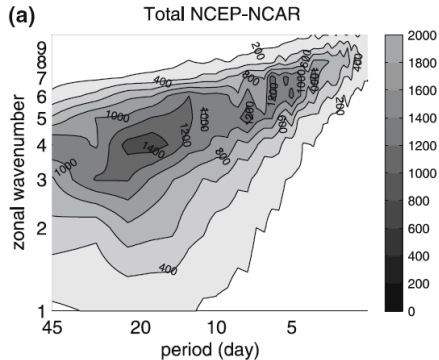


(Lucarini et al. 2007)

## A key question

Can this understanding be useful for climate simulation?

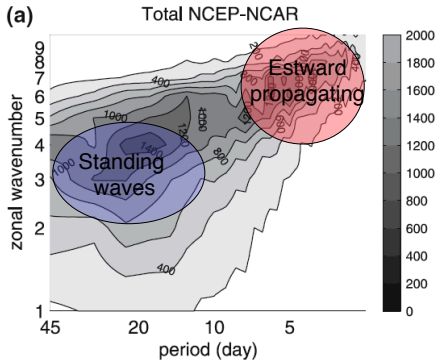
## A useful decomposition of wave spectrum



(Lucarini et al. 2007)

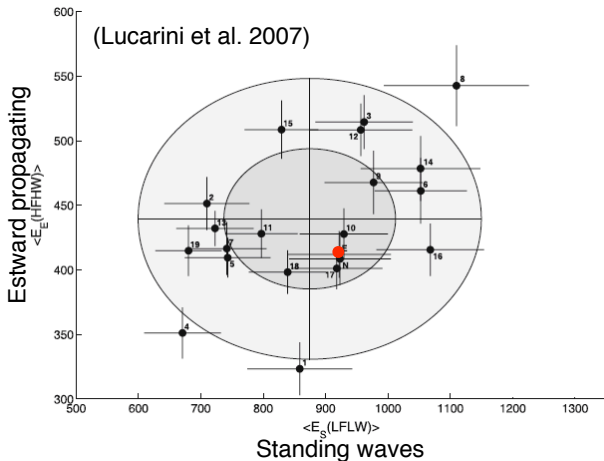
## A useful decomposition of wave spectrum

This decomposition is useful because the two subsets of waves have **different sources**



(Lucarini et al. 2007)

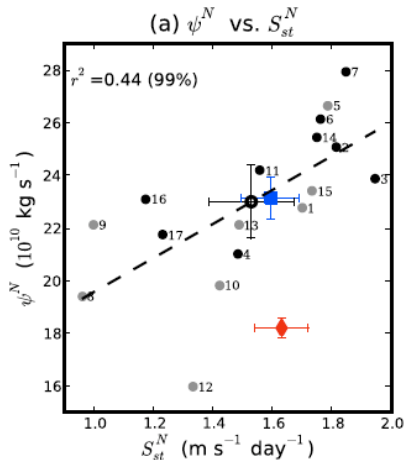
# Extratropical waves energy bias in GCMs



Scatter plot of the mean energy  
of **eastward propagating** Vs **standing** waves  
for different GCMs in NH winter season

## 4th Validating GCMs

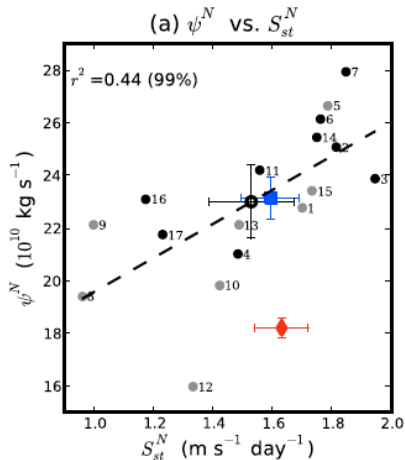
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Over: Winter Hadley cell intensity  
against Stationary Eddy breaking

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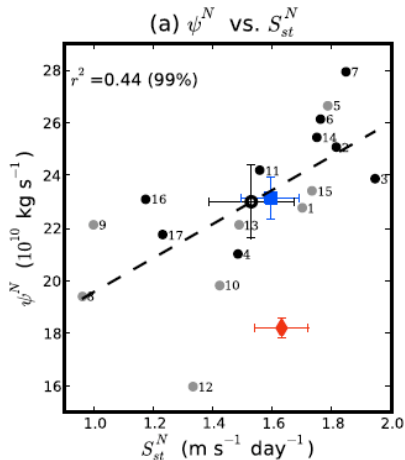
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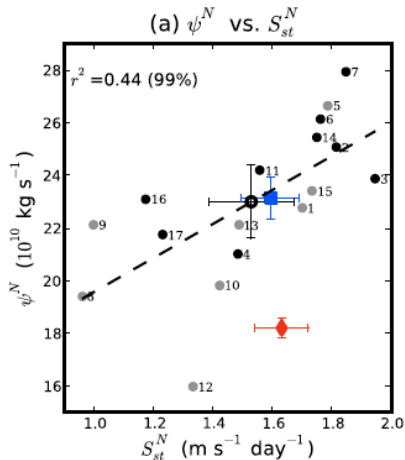


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- Models have bias in extratropical waves spectra
- Wave breaking influences Hadley cell
- Are the bias in extratropical waves **forcing** the bias in the Hadley cell?



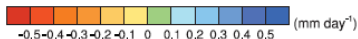
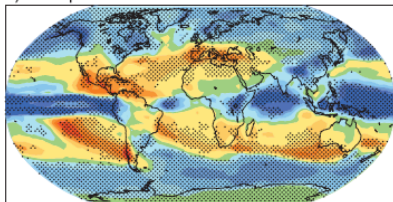
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## 5th An application to climate change

A (robust) feature of climate

The widening of the Hadley cell  
in **global warming** scenario.

a) Precipitation



(IPCC, AR4)

Over: Multimodel Mean  
precipitation changes from  
1980/99 to 2080/99 in A1B  
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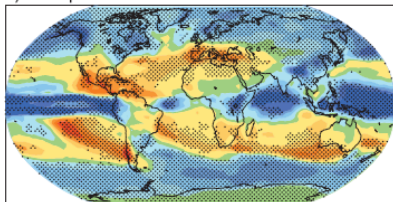
## 5th An application to climate change

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- But a complete theory is missing
- We will test the role of the found mechanisms respect to the widening of the Hadley cell

a) Precipitation

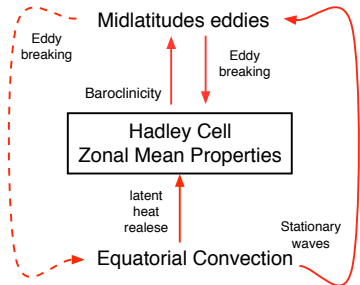


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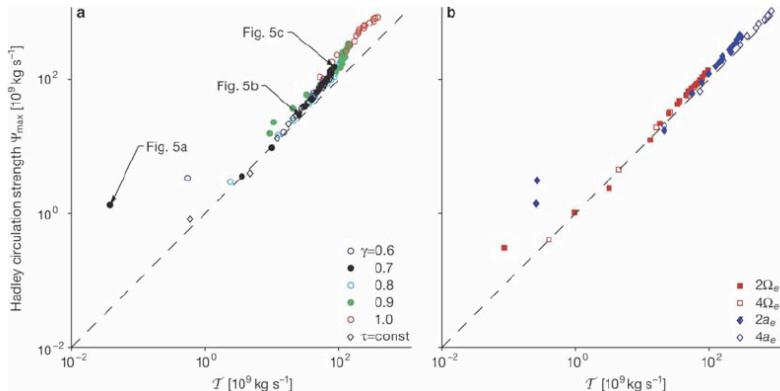
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## Conclusions

- The atmosphere seems to reasonably be a coupled tropical–extratropical system.
- Hadley cell features could be good measures of the resulting interaction
- Through the study of these mechanisms we can:
  - Increase the understanding of climate system
  - Validate climate models
  - Raise the confidence in climate change forced Hadley cell expansion



## Idealized models



(Walker and Schneider 2006)

Hadley cell mean intensity correlates with the eddy breaking stress in Walker and Schneider idealized model

## Angular momentum cycle

Approximate angular momentum balance in the upper branch of the Hadley cell (Caballero 2007)

$$f\bar{v}\left(1 - \frac{\bar{\xi}}{f}\right) \sim S \quad (1)$$

- $\bar{v}$ : mean meridional velocity
- $\bar{\xi} = -\frac{1}{a \cos \phi} \frac{\partial \cos \phi \bar{u}}{\partial \phi}$ : vorticity
- $S = \frac{1}{a \cos^2 \phi} \frac{\partial}{\partial \phi} (\cos^2 \phi [\bar{u}\bar{v}])$ : eddy breaking