Tropical upwelling and sea surface temperatures

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Introduction

T trend 1979-2003 (radio sondes)

adapted from Thompson & Solomon, (2005)
Introduction

Tropical lower stratosphere: indications of local

- max. cooling (*see also* Fu et al., 2010)
- max. ozone decrease (*e.g.* Randel et al., 2006)

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Tropical lower stratosphere: indications of local

- max. cooling (see also Fu et al., 2010)
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→ Hypothesis: stronger tropical upwelling

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Thompson & Solomon, (2005)
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Hypothesis backed up by most chemistry-climate models (CCMs)  
(e.g. Butchart et al., 2006, 2010)

... also by our CCM E39C  
(Deckert and Dameris, 2008; Garny et al., 2009, 2011; Runde et al., in prep.)
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- Higher sea surface temperatures (SSTs) → stronger tropical upwelling
- Mediation via enhanced wave dissipation
  (e.g. Sigmond et al., 2004; Fomichev et al., 2007; Oman et al., 2009; Garny et al., 2011)
Introduction

Stronger wave dissipation

What mechanisms?

Here:
Dissipation of stationary waves in tropical lower stratosphere
Mechanisms

Wave production
1. More convective excitation \textit{(Deckert and Dameris, 2008)}

Wave propagation (background state)
2. More focusing towards equator \textit{(Garcia and Randel, 2008)}

Wave dissipation (background state)
3. Less dissipation in troposphere \textit{(Garny et al., 2011)}
Mechanisms

Wave production
  1. More convective excitation (*Deckert and Dameris, 2008*)

Wave propagation (background state)
  2. More focusing towards equator (*Garcia and Randel, 2008*)

Wave dissipation (background state)
  3. Less dissipation within troposphere (*Garny et al., 2011*)

Show our E39C results from studies 1 and 3 to
  - demonstrate mechanisms
  - investigate differences
Simulations with our CCM E39C

„globe“ 
(Deckert and Dameris, 2008)
1. Warm: model SSTs
2. Cool: obs. SSTs
   ➢ GHGs differ

„tropics“ 
(Garny et al., 2011)
1. Warm: model SSTs + anomaly
2. Cool: model SSTs
   ➢ GHGs identical
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Annual mean

\[ \Delta \text{mass stream-function} \ (5 \times 10^9 \text{ kg/s}) \]
Annual mean

„globe“

\[ \Delta \text{mass stream-function} \]
\[ (5 \times 10^9 \text{ kg/s}) \]

„tropics“

\[ \Delta \text{flux & } \Delta \text{divergence} \]
\[ \text{(Eliassen-Palm)} \]

40%
JJA: "globe"
JJA: "globe"

Δ liquid water (10^{-6} kg/kg)
JJA: „globe“

More convective excitation

Δ liquid water (10^{-6} kg/kg)
JJA: „tropics“
JJA: „tropics“
JJA: „tropics“

Less dissipation in troposphere
DJF: „globe“ & „tropics“

Inconclusive results for DJF

→ Fourier decomposition
DJF: wave 1
DJF: wave 1

More focusing towards equator
DJF: wave 1

More focusing towards equator

„tropics“
DJF: wave 1

","tropics""

More convective excitation
DJF: wave 1

„globe“

„tropics“

More convective excitation
JJA: waves 2 & 3

More convective excitation
Conclusions

Most CCMs reveal for warmer climate

- Stronger tropical upwelling
- Importance of SSTs
- Mediation via enhanced wave dissipation

Here:
stationary waves in tropical lower stratosphere
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Here: stationary waves in tropical lower stratosphere
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Mechanisms depend on
- Scenario details: mainly SST patterns, also GHGs
- Season
- Wave number

Here: stationary waves in tropical lower stratosphere
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Brewer-Dobson circulation may be unaffected!
(e.g. Engel et al., 2008)
Sensitivities

Transient sensitivity  (Deckert and Dameris, 2008)
1. Warm: IPCC A1b, model SSTs for 2000-2019 (HADGEM1)
2. Cool: GHGs for year 1980, observed SSTs for 1970-1979

Time-slice sensitivity  (Garny et al., 2011)
1. Warm: as cool, but higher SSTs between 30°N-30°S
2. Cool: model SSTs (HADGEM1) for average 1995-2004
   ➢ Identical GHGs for year 2000
DJF: all waves
DJF: waves 2 & 3
JJA: wave 1
JJA: waves 2 & 3
DJF: liquid water
JJA: liquid water
DJF: $u$
JJA: $u$
JJA: convective rain rate
DJF: convective rain rate
Annual mean: T