Interannual variability of tropospheric water vapour

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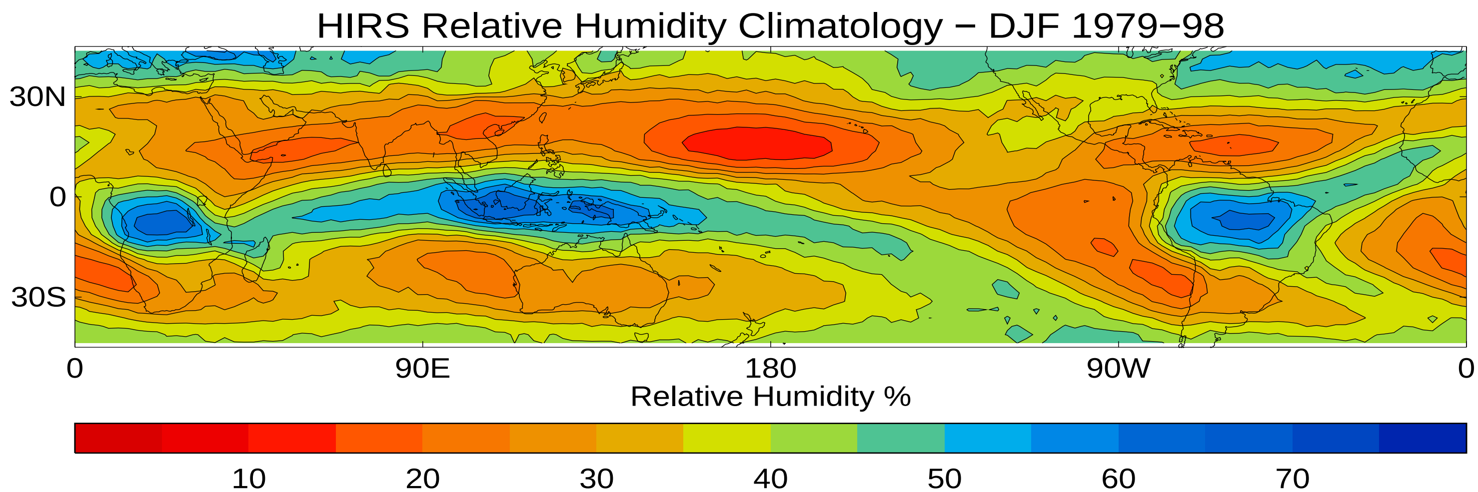
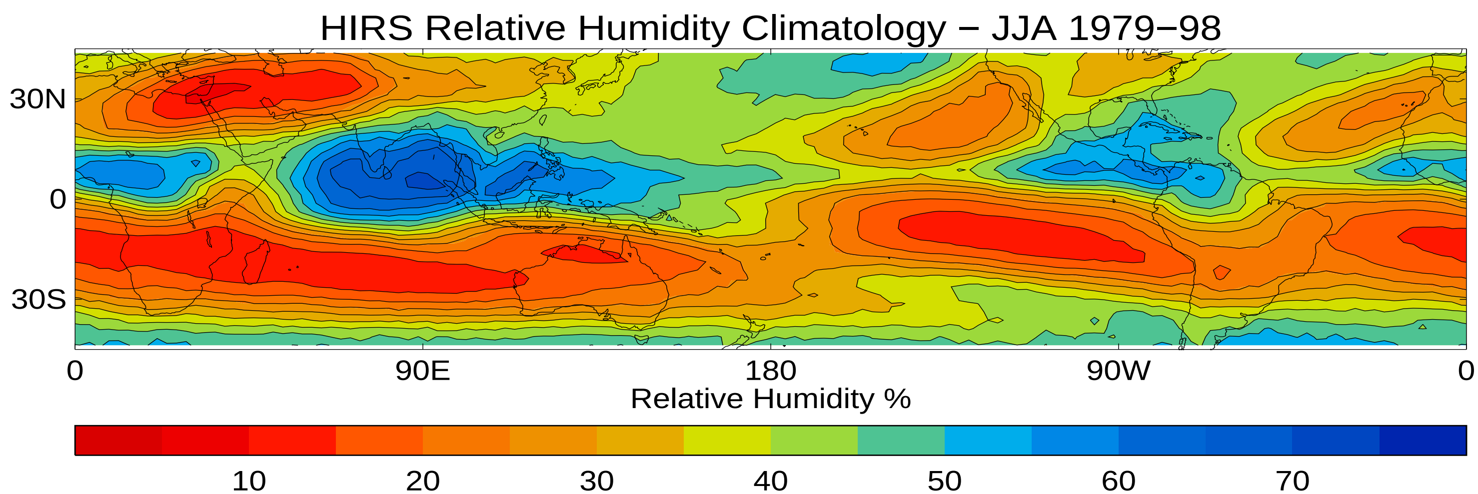
Introduction

- Humidity is a critical component of the climate system.
- Variability is poorly documented on annual to decadal timescales.
- Principle mode of variability is related to ENSO.
- Look at regional aspects of humidity response to ENSO by season. Review interpretations of trends.
- *Caution*: we are discussing relative humidity not absolute humidity.

Data

- High-resolution InfraRed Sensor (HIRS) channel 12 measures 6.7μm water vapour emission.
- Sensitive to RH and temperature between approx. 500hPa and 200hPa - FTRH.
- Major uncertainties stem from
  – Inter-satellite bias.
  – Conversion algorithm.
  – Cloud clearing.





Mean Distribution of FTRH (%) for DJF (top) and JJA (bottom)

EOF analysis

- EOF analysis of 20-year time-series of each season. Only physically identifiable mode is related to ENSO.
- DJF:
  - Variance explained - 25%
  - PC time-series - Niño3.4 r = 0.87
- JJA:
  - Mixed modes (15%, 13% of variance)
  - PC1 time-series - Niño3.4 r = 0.75
  - PC2 time-series - Niño3.4 (lead 2 seasons) r = -0.72

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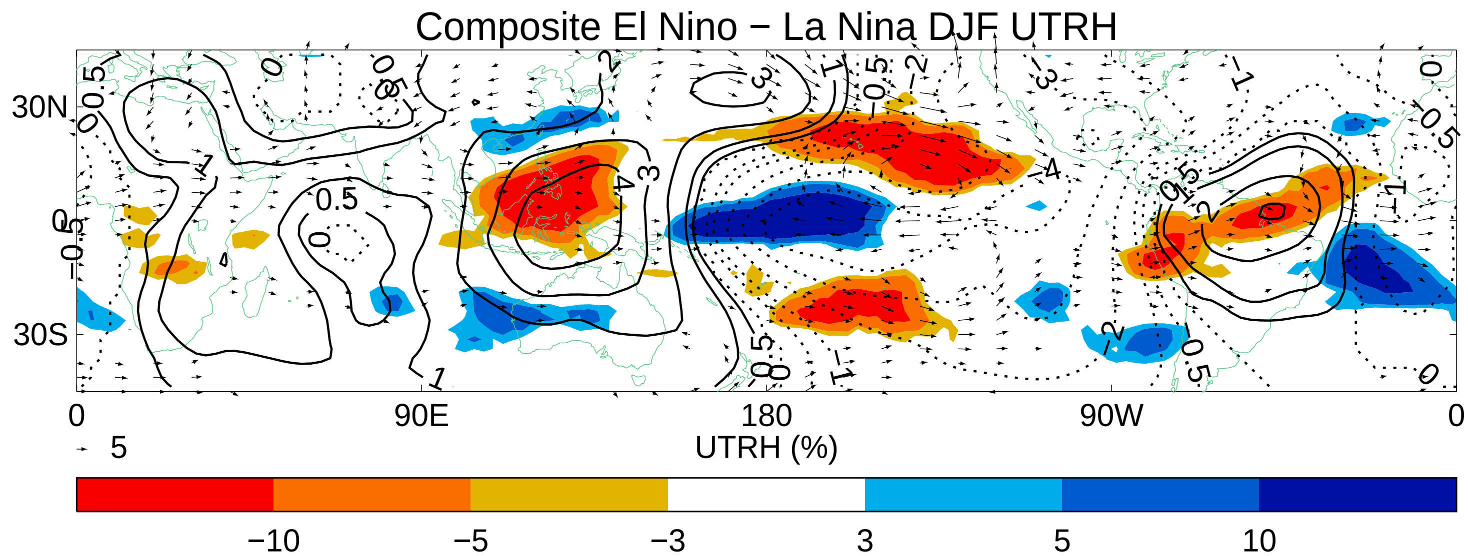
Composite difference analysis

- Select strongest +ve and -ve events based on Niño3.4 index of pacific SSTs
- NCEP re-analysis provides velocity potential, wind vector, and temperature fields
- *Caution*: few strong La Niña in observed period. Two 'protracted' El Niño events

El Niño	La Niña
1982/83	1984/85
1987/88	1988/89
1991/92	1995/96
1994/95	

Winter (DJF) Composite



Boreal winter (DJF) composite difference map of HIRS UTRH (filled colour) for significant regions at the 5% level. Over-plotted are 0.2σ level velocity potential contours, ($*10^6 m^2/s$) solid contours are positive, dashed contours are negative and vector wind arrows at 300hPa.

Separating Temperature and Water Vapour

- Define RH as:

$$RH' + \overline{RH} = \frac{e_a' + \overline{e_a}}{e_s' + \overline{e_s}}$$

- We find:

$$RH_t' = -\overline{RH}\,\frac{e_s'}{\overline{e_s}} \quad \text{and} \quad RH_w' = \frac{e_s}{\overline{e_s}}RH - \overline{RH}$$

- Substituting and rearranging:

$$RH' = RH_t' + RH_w' + \frac{RH_t' RH_w'}{\overline{RH}}$$

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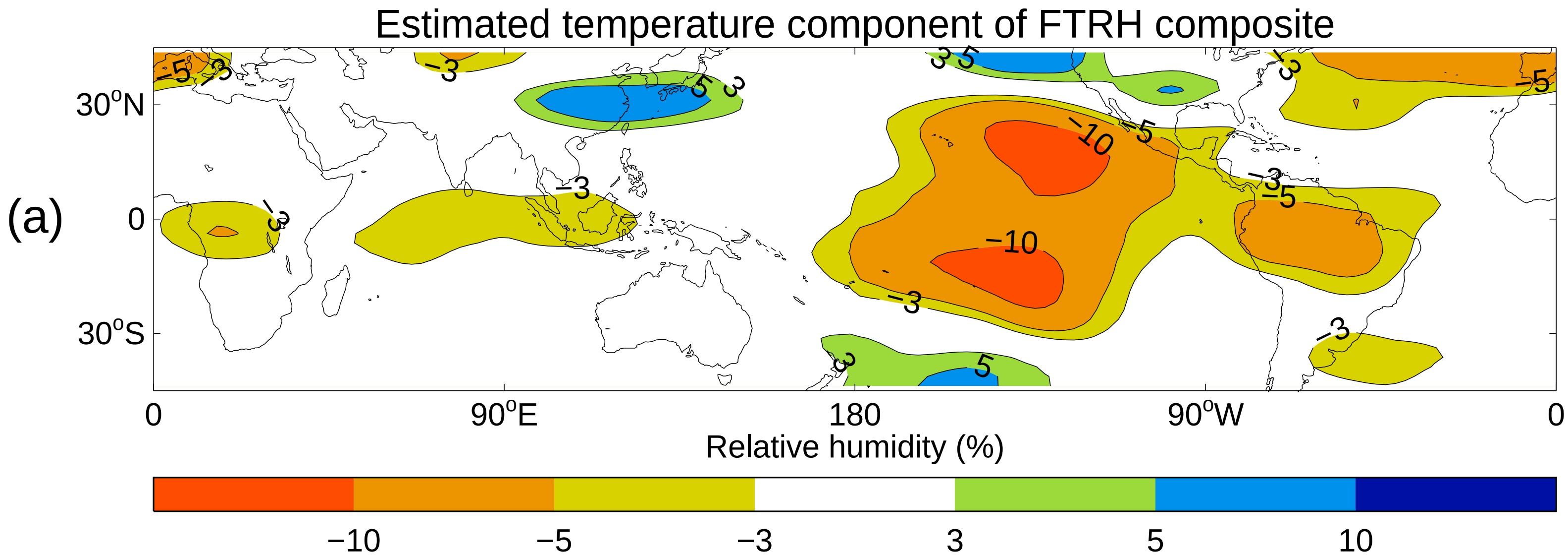
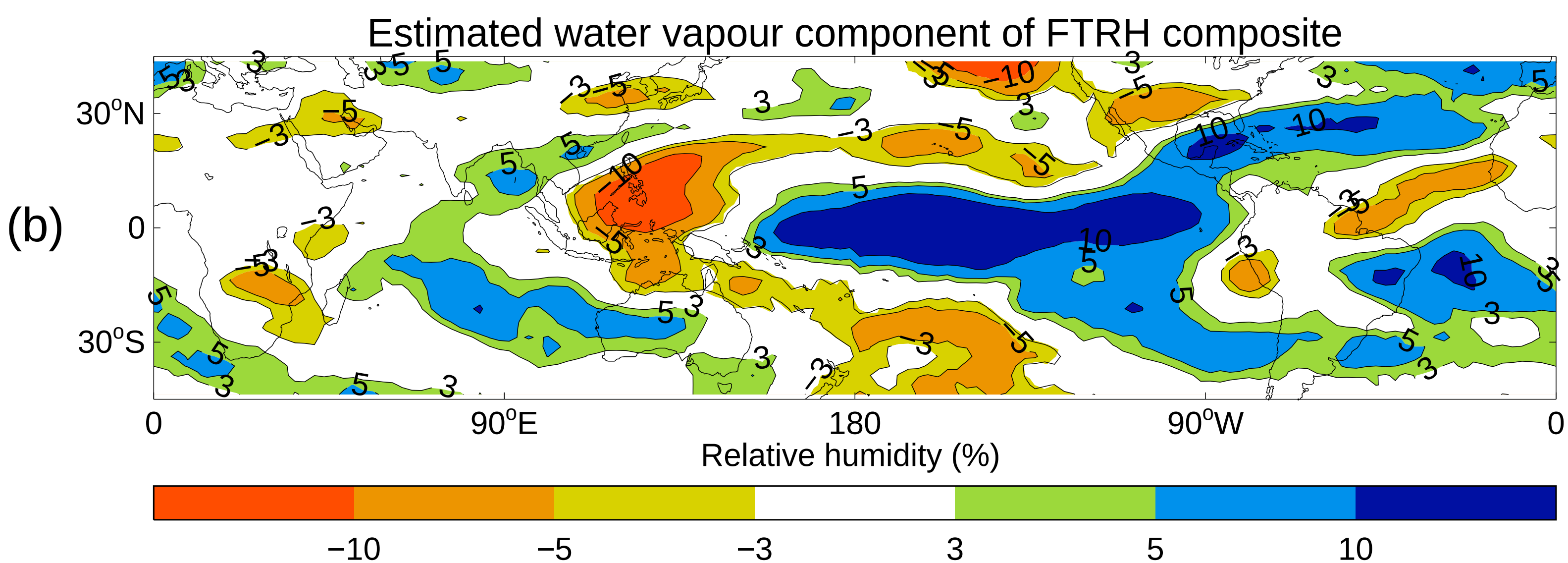
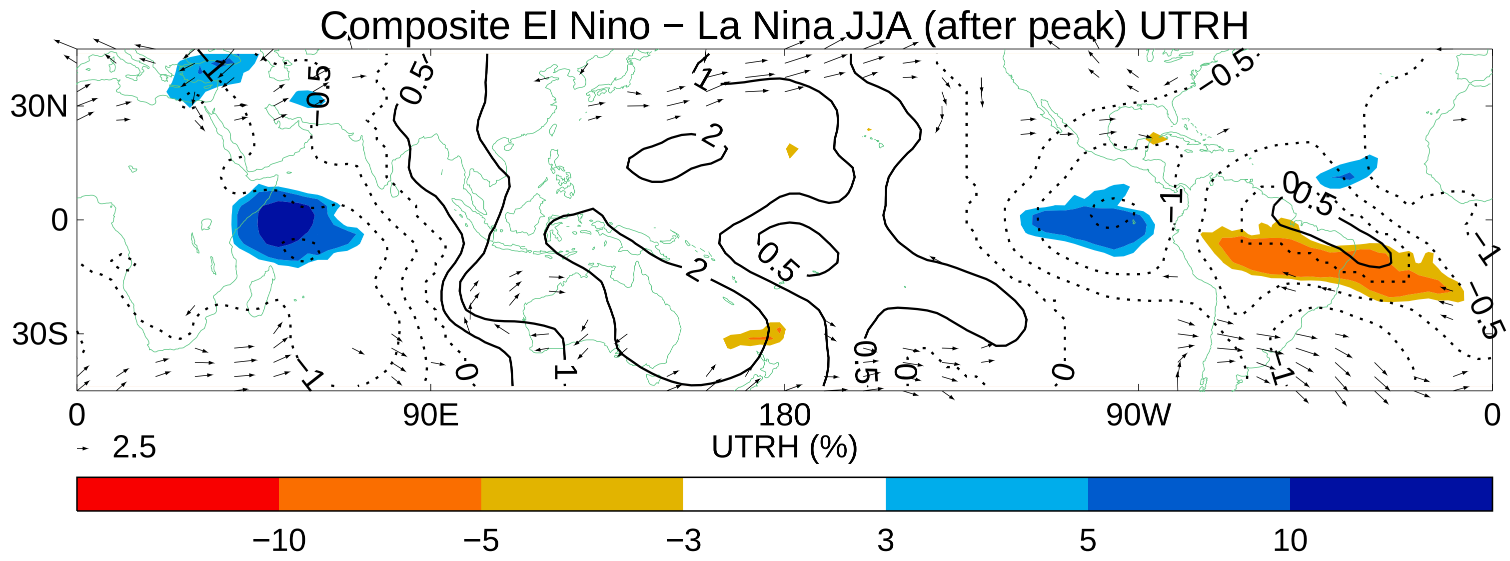

Estimated temperature component of FTRH composite
(a)
30°N
0
30°S
0
90°E
180
90°W
0
Relative humidity (%)
−10
−5
−3
3
5
10


Estimated water vapour component of FTRH composite
(b)
30°N
0
30°S
0
90°E
180
90°W
0
Relative humidity (%)
−10
−5
−3
3
5
10

Upper tropospheric temperature

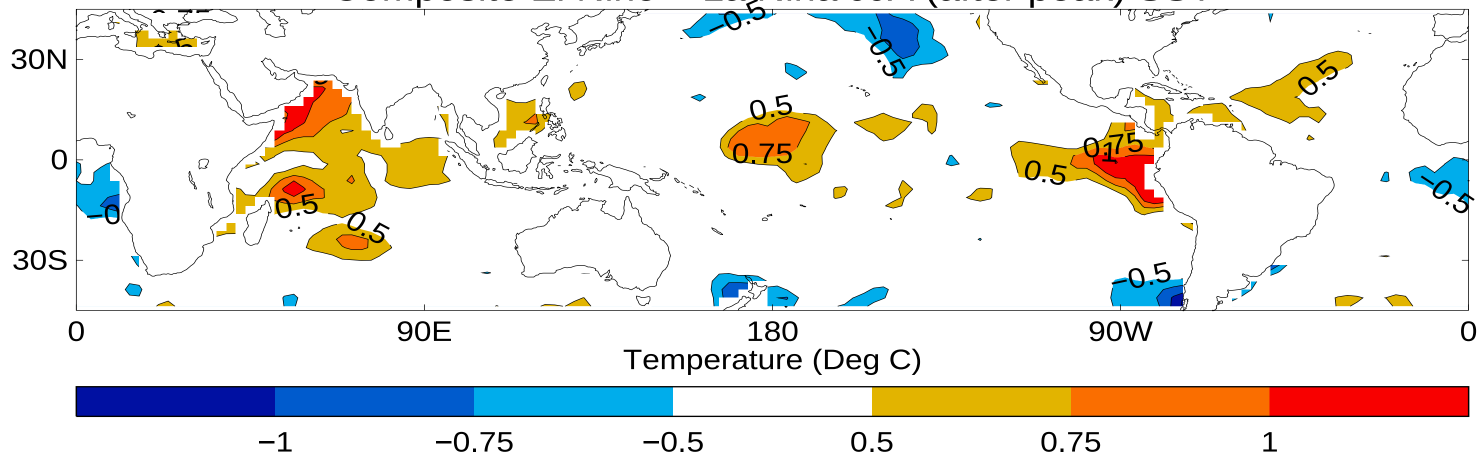
- Estimate sat. vap. press. from NCEP reanalysis temperatures.
- 50%-70% of RH anomaly in East Pacific can be explained through temperature changes.
- 30°N-30°S El Niño-La Niña DJF
  - Composite difference -0.62 (RHt=-2.4, Rhw=+1.87)
  - Extreme events 82/83 (-1.11), 88/89 (+1.79) dominated by RHt.

Summer (JJA) composite

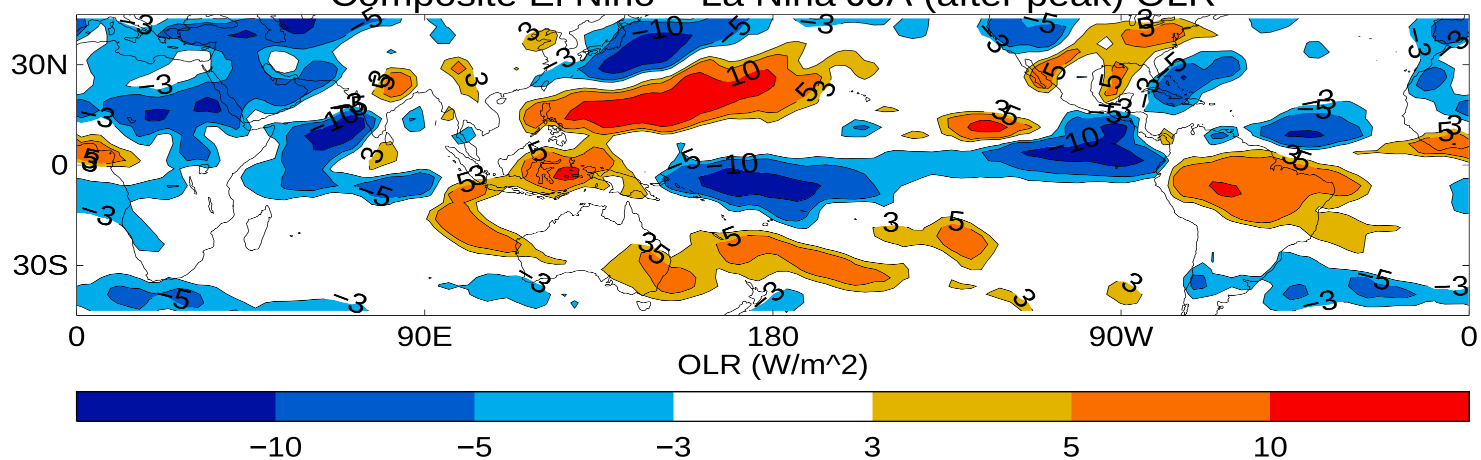


- Delayed response over Indian and Atlantic oceans
- Regions of strong horizontal humidity gradients

Composite El Nino − La Nina JJA (after peak) SST



Composite El Nino − La Nina JJA (after peak) OLR

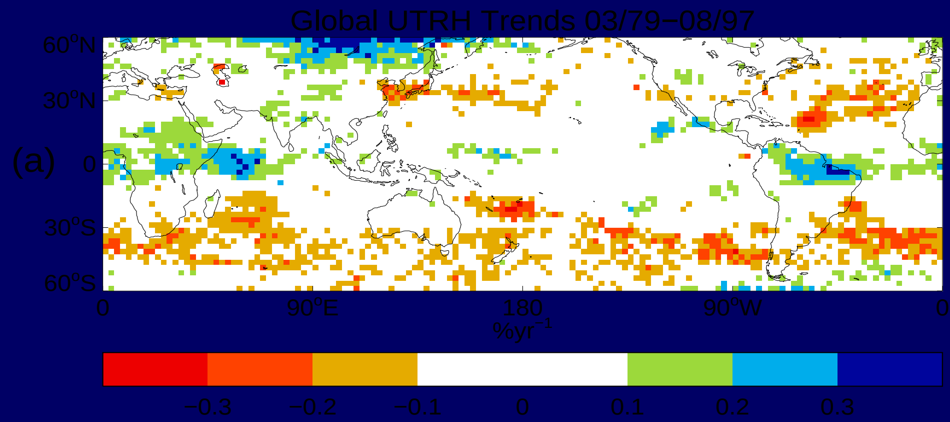


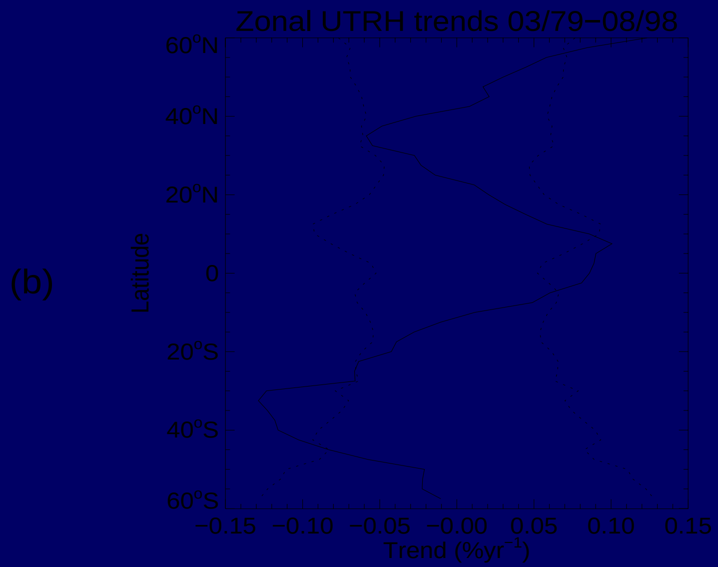
Ocean-atmosphere interaction

Correlations	SST (JJA)	Nino3.4 (DJF)
UTH (JJA)	0.60	0.49
Nino3.4 (DJF)	0.72	

- Remote ocean warming. ref: Klein et al (April 1999), Xie et al (April 2002) both J.Clim.
- Anomalous convection in the Indian ocean.
- No significant correlation with Indian rainfall data.

Long-term Trends





- No significant global trend
- Cancellation of significant regional trends
- Stable to removal of ENSO

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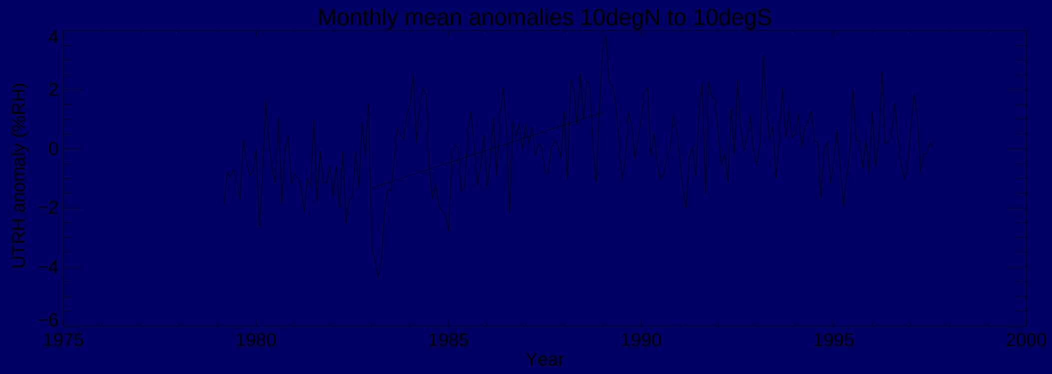
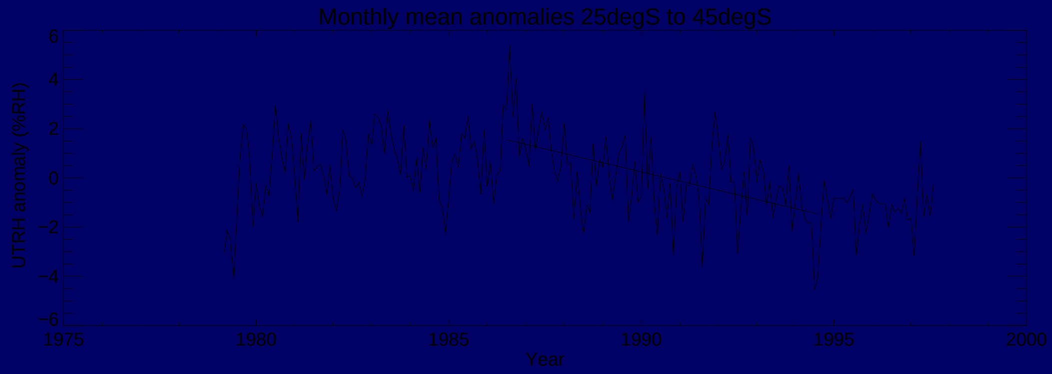
Zonal trends





- Intensified Hadley circulation not adequate to describe time period of zonal mean trends.

Model Evaluation

- Comparison with set of HadAM3 simulations forced with SSTs and greenhouse gases.
- Overactive hydrological cycle in HadAM3
- ENSO represents equivalent fraction of model inter-annual variance.

Model Evaluation

- Model does not reproduce HIRS12 trends.
- Small negative trends at southern midlatitudes.

Conclusions

- Simple changes in ENSO and hydrological cycle are not adequate to describe trends in tropical UTRH.
- Issues surrounding ‘trends’:
  - Further analysis of inter-satellite calibration issues. Lessons learned from MSU.
  - Uncertainties in temperature trends.
  - Potential decadal scale ocean-atmosphere variations projected onto 20 year time series.

Conclusions

- HIRS12 useful for diagnosing seasonal to inter-annual scale variability of FTRH both from observations and in GCMs.
- Further research into temperature-humidity relationships in the tropical atmosphere on long time-scales required.
- Current and future HIRS instruments place channel 12 higher in the troposphere - compromising the stability of HIRS12 datasets for use in climate research.

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