# Detection and Attribution of Climate Change, Including Extremes

Presented by

**Tom Knutson**

Geophysical Fluid Dynamics Laboratory Review

May 20 – May 22, 2014

# Understanding Internal Variability and Forced Change

- Detection and attribution of climate change, including extremes (T. Knutson).
- Understanding Atlantic multidecadal variability (AMV), AMOC, and Arctic sea ice (R. Zhang)
- ENSO predictability and dynamics (A. Wittenberg)
- Simulating regional hydroclimate variability and change on decadal scales (T. Delworth)

# Motivations for detection and attribution studies

- Detection / Attribution:
  - Brings together observations, models, and analysis ➔ synergies
  - Confronting models with observations ➔ learning
  - If past changes detected/attributed ➔ enhanced confidence in projections
  - Enhanced monitoring – e.g., BAMS articles on explaining past year's extremes from a climate perspective.
- NOAA Five-Year R&D Plan (2013-2017)

  "Over the next 5 years, NOAA aims to:

  - Assess the roles of natural variability…and changing radiative forcing in causing observed seasonal-to-multidecadal scale changes in the climate system…Assess climate-induced changes in tropical and extratropical cyclones…"

# Tropical Cyclones and Climate Change

## IPCC AR5 WG2 Summary for Policymakers

[Table SPM-1 Statements related to TCs and climate change]

Phenomenon:

- Increase in intense tropical cyclone activity

Assessment that changes occurred:

- Low confidence in long-term (centennial) changes
- Virtually certain in North Atlantic since 1970

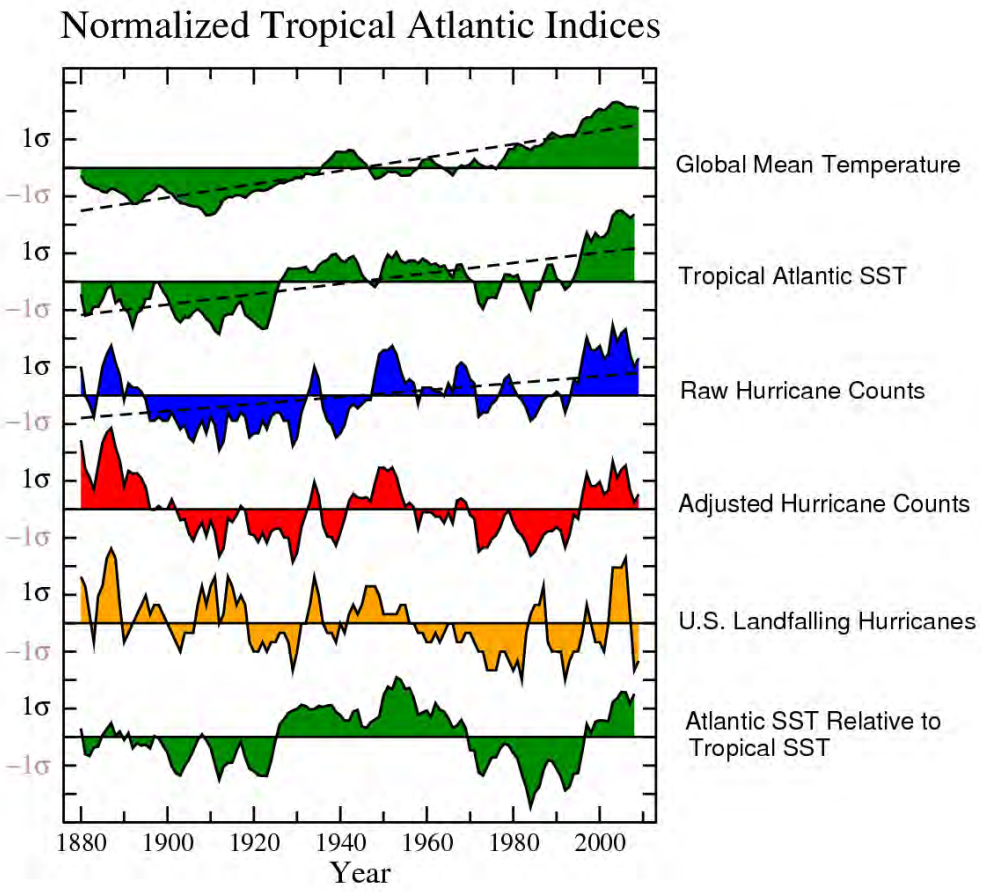
Assessment of a human contribution to observed changes:

- Low confidence
- "There is medium confidence that a reduction in aerosol forcing over the North Atlantic has contributed at least in part in the observed increase in tropical cyclone activity since the 1970s in this region."

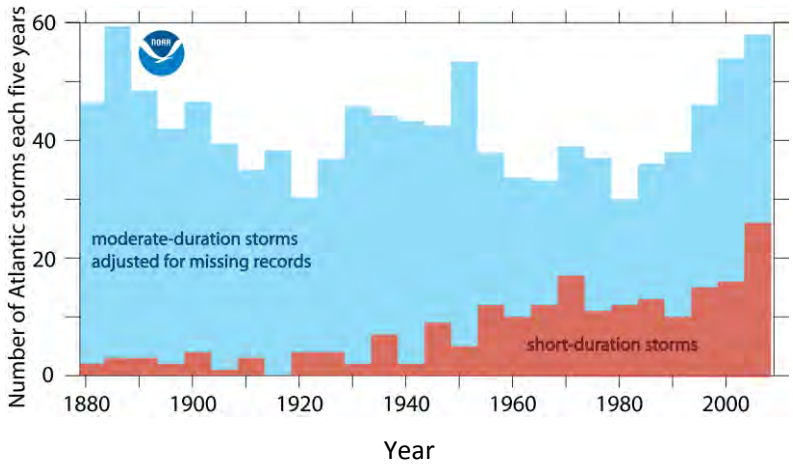
Likelihood of further changes (late 21st century):

- More likely than not (Western North Pacific and N. Atlantic)

# Low confidence in long-term (centennial-scale) changes in TCs



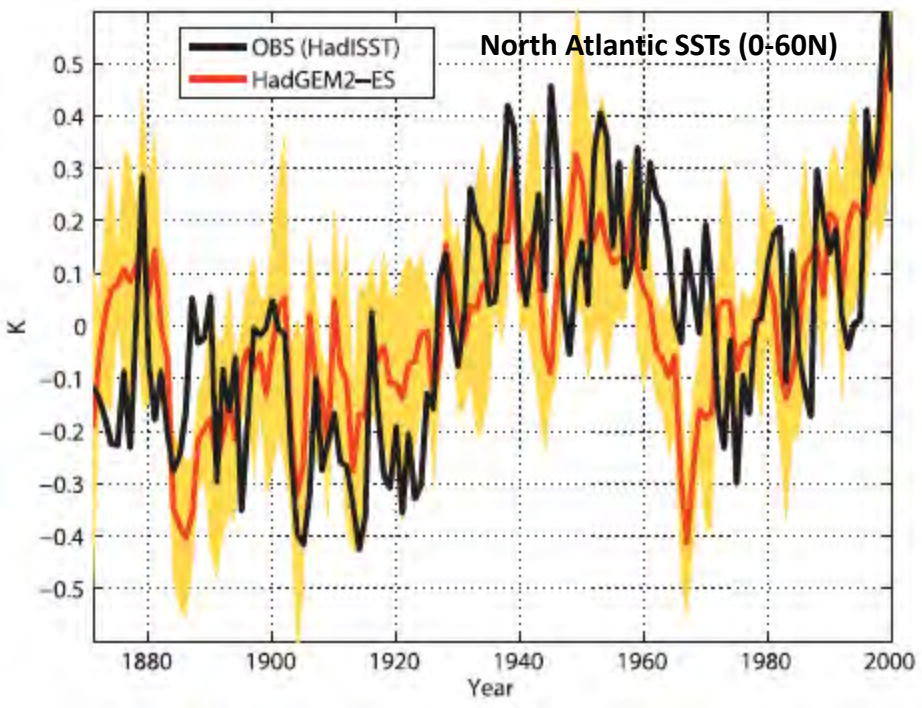

Moderate-duration tropical storms do not show a trend.

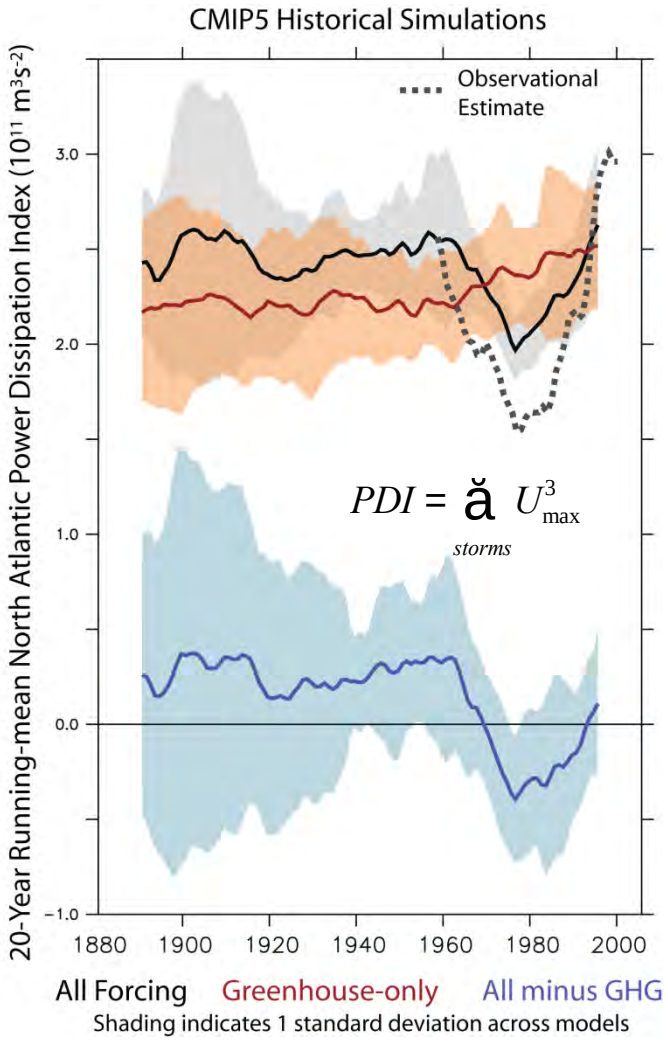



Sources: Vecchi and Knutson, *J. Climate* (2011); Landsea , Vecchi, Bengtsson, Knutson. *J. Climate* (2010).

# What caused the rise in Atlantic hurricane activity since the 1970s?

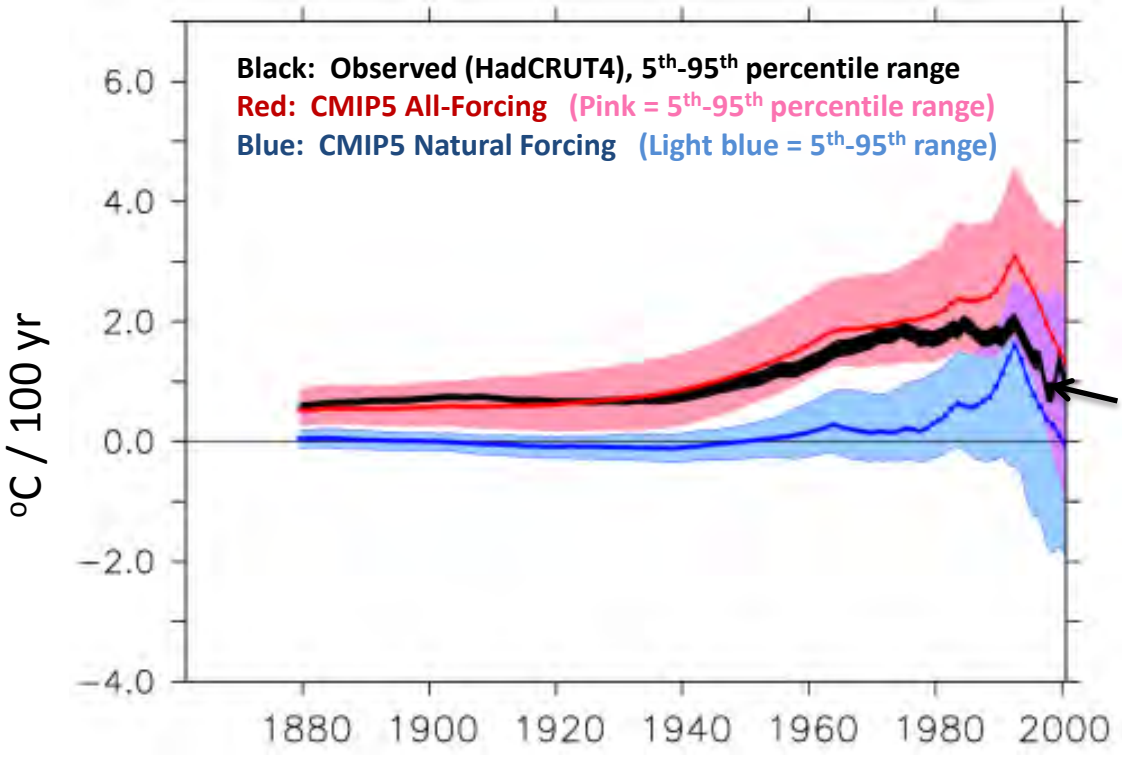
Booth et al. (2012) attribute North Atlantic multidecadal SST variations primarily to aerosol forcing. Villarini and Vecchi (2013) attribute part of the multidecadal 'lull' in Atlantic hurricanes (70s and 80s) to aerosol forcing.

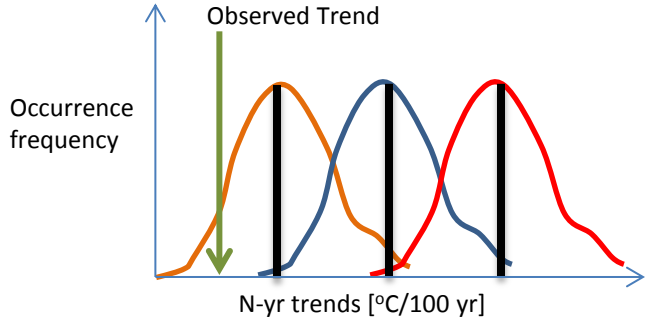



Sources: Left: Fig. 1 adapted from Booth et al., *Nature*, 2012 (Zhang et al. JAS, 2013); right: Villarini and Vecchi (J. Climate 2013).

# Global temperature attribution analysis: CMIP5 7-model ensemble



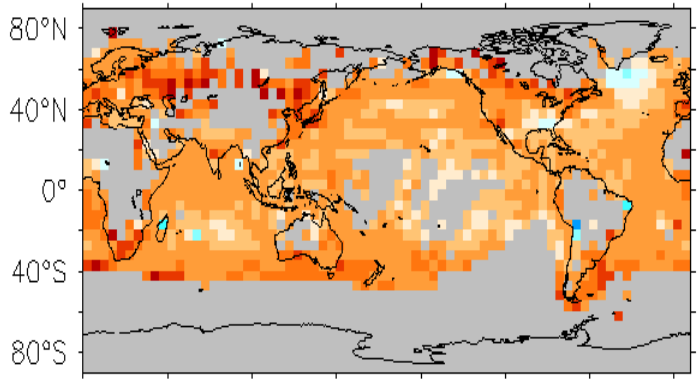

Note: Shaded regions are multi-model combined trend distributions and not formal 90% confidence intervals.

**Violet = Blue/pink overlap**

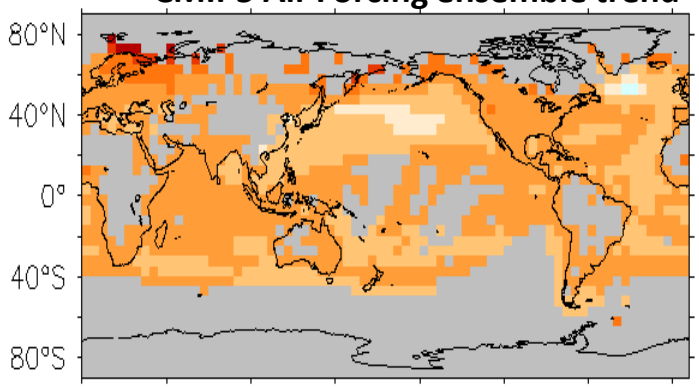
Source: Knutson, Zeng, and Wittenberg, *J. Climate* (2013)

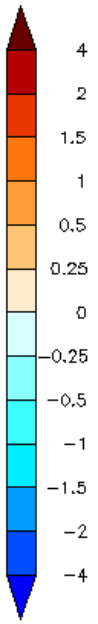
# 1901-2010 Regional Surface Temperature Trend Assessment

**Observed trend (HadCRUT4)**



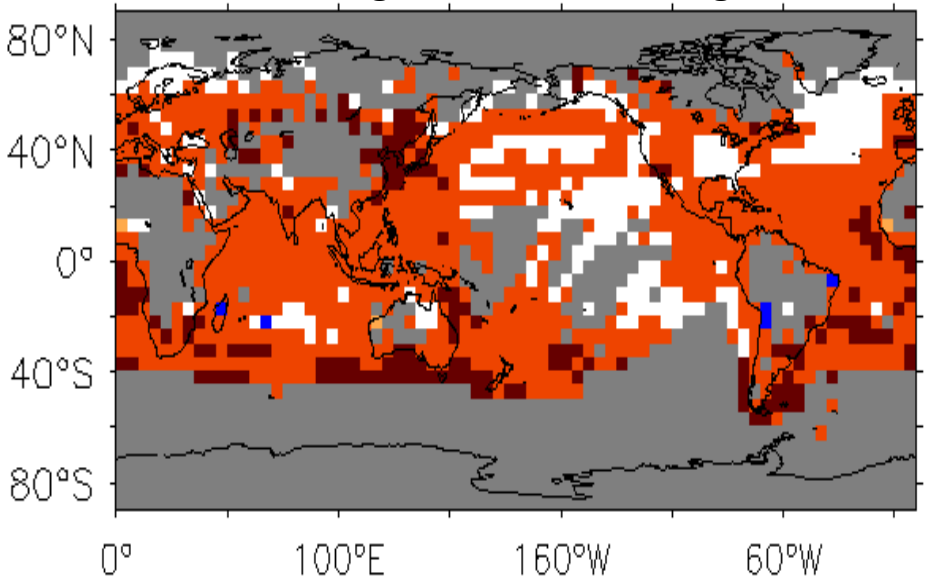

**CMIP5 All-Forcing ensemble trend**




°C/100yr

**CMIP5 All-Forcing vs. Natural-Forcing assessment**

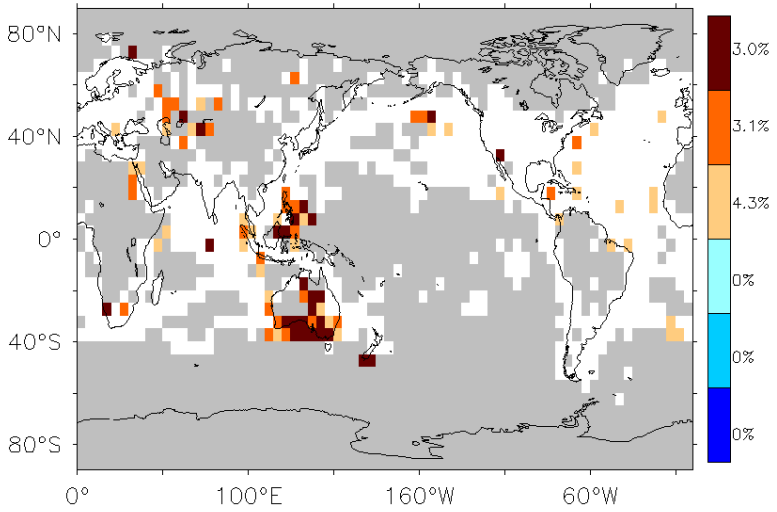



- **Attrib. anthro. warming, but > simulated**
- **Attrib. & consistent anthro. warming**
- **Detectable warming: < simulated**
- **No detectable trend**
- **Detectable cooling: < simulated**
- **Attributable anthropogenic cooling**
- **Detectable cooling: > simulated**

Source: Knutson, Zeng, and Wittenberg, *J. Climate* (2013)

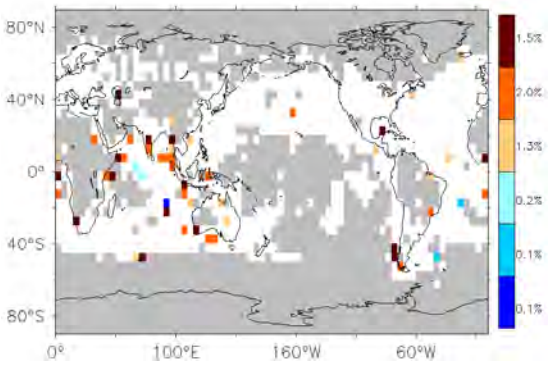
# Surface temperature seasonal- or annual-mean extremes for 2013

Annual means: 2013 extremes

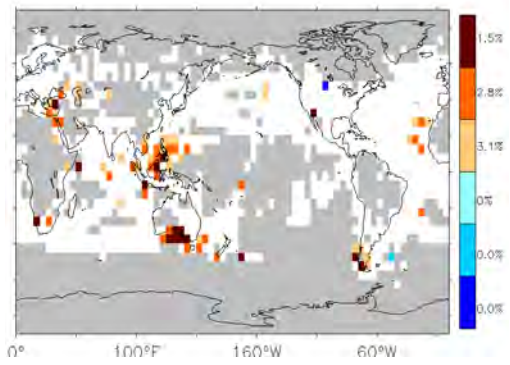



| Map Legend |
|---|
| Highest |
| 2nd highest |
| 3rd highest |
| 3rd lowest |
| 2nd lowest |
| Lowest |

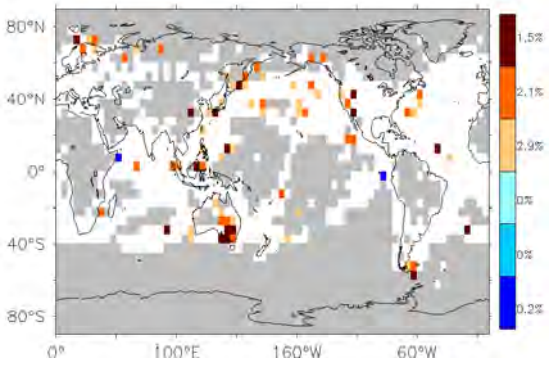
Dec.-Feb. 2013 seasonal extremes



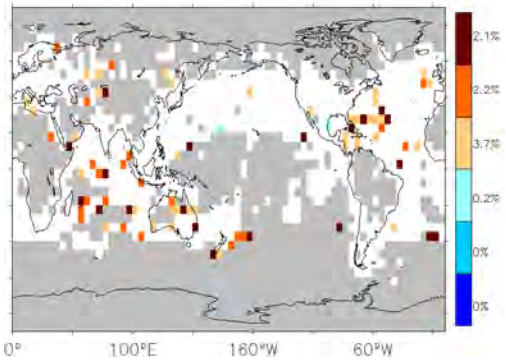

Mar.-May 2013 seasonal extremes




June-Aug. 2013 seasonal extremes



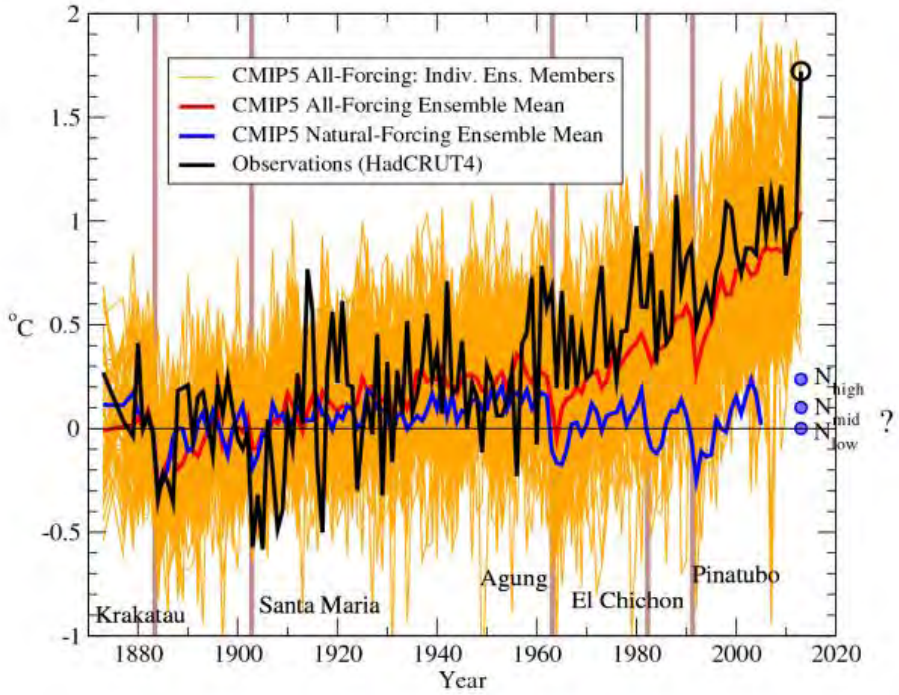

Sept.-Nov. 2013 seasonal extremes

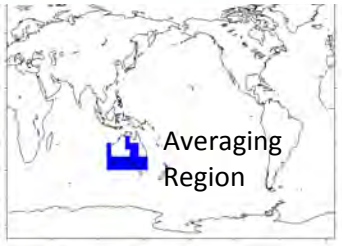



Source: Knutson, Wittenberg, and Zeng, *BAMS,* submitted.

# Australia 2013 annual warmth: Risk attributable to anthropogenic forcing

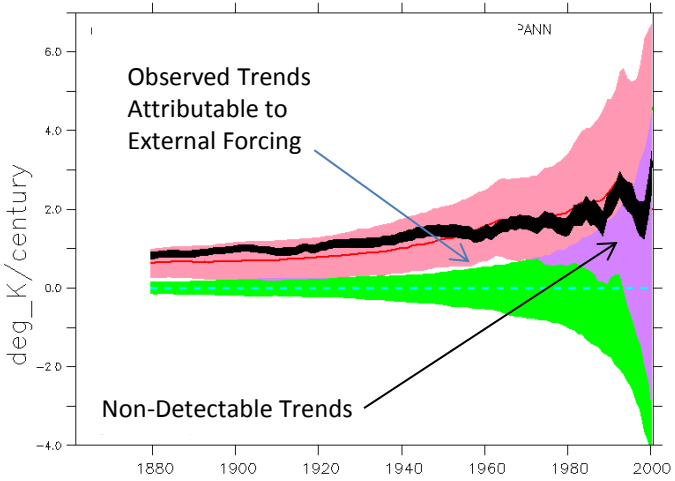
## Australia Region: Annual Temperatures



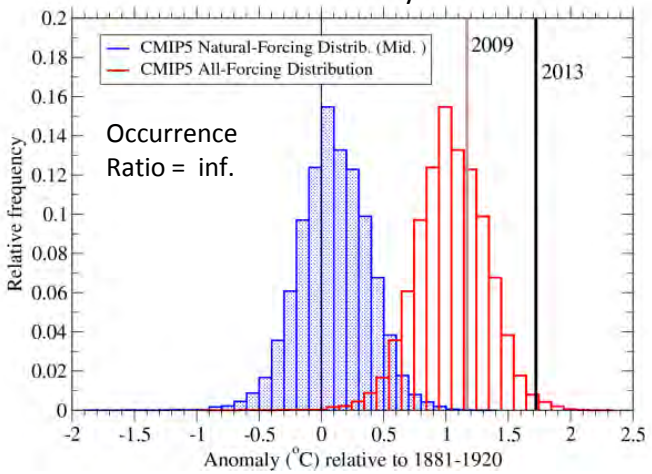




Ratio = $\frac{p_{ALL}}{p_{NAT}}$

## CMIP5 Sliding Trend Analysis (23 models)



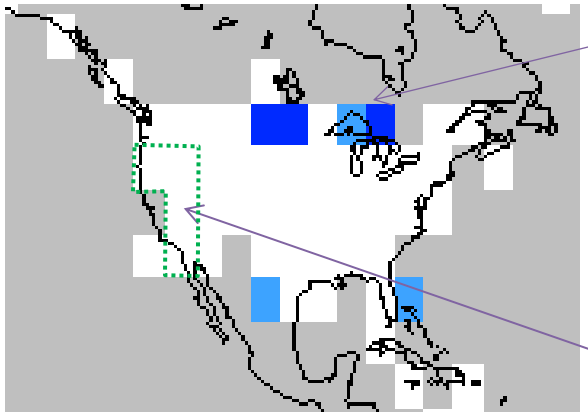

## Attributable Risk Analysis




Source: Knutson, Wittenberg, and Zeng, *BAMS,* submitted.

# 2013 Annual-mean Precipitation Extremes: Attribution is Difficult

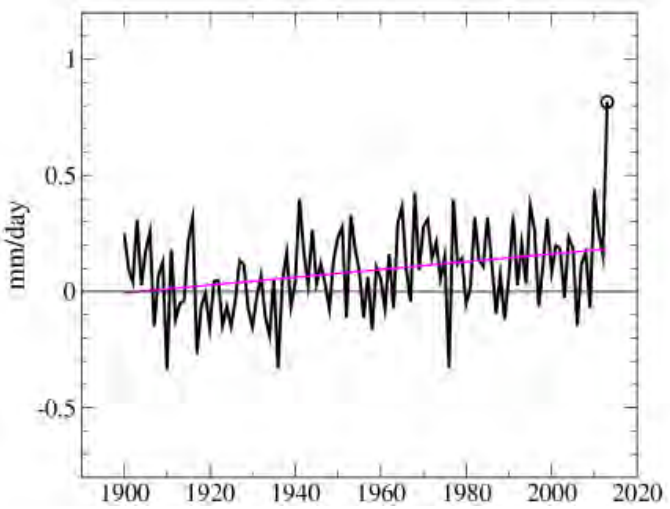
Annual 2013 Extremes - Precipitation



Highest
2nd highest
3rd highest
3rd lowest
2nd lowest
Lowest

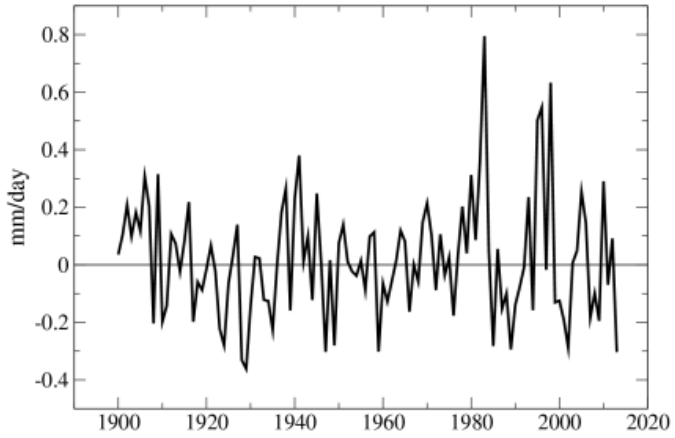
**Map Legend**

U.S./Canadian border region




U.S./Canadian border region—ANN:
Significant increasing trend;
Trend partly attributable to
Anthro. + Natural Forcing combined

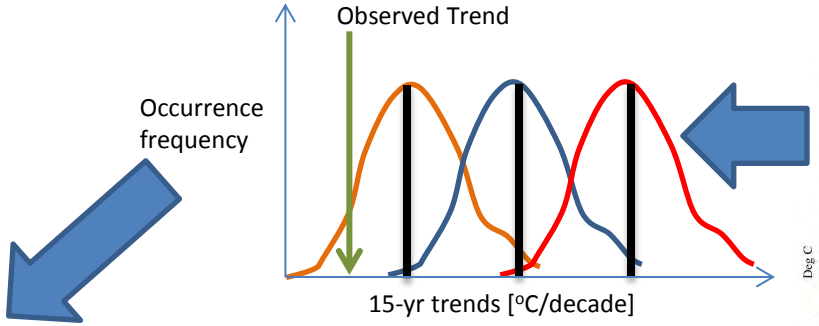
California region

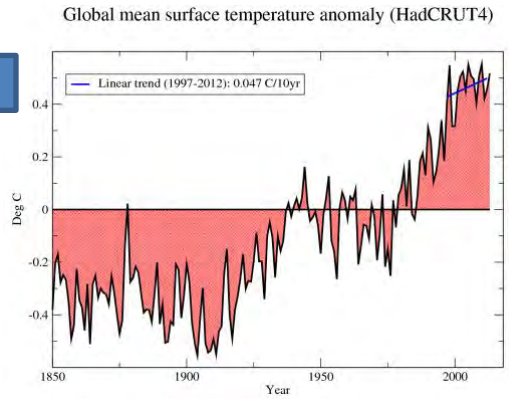


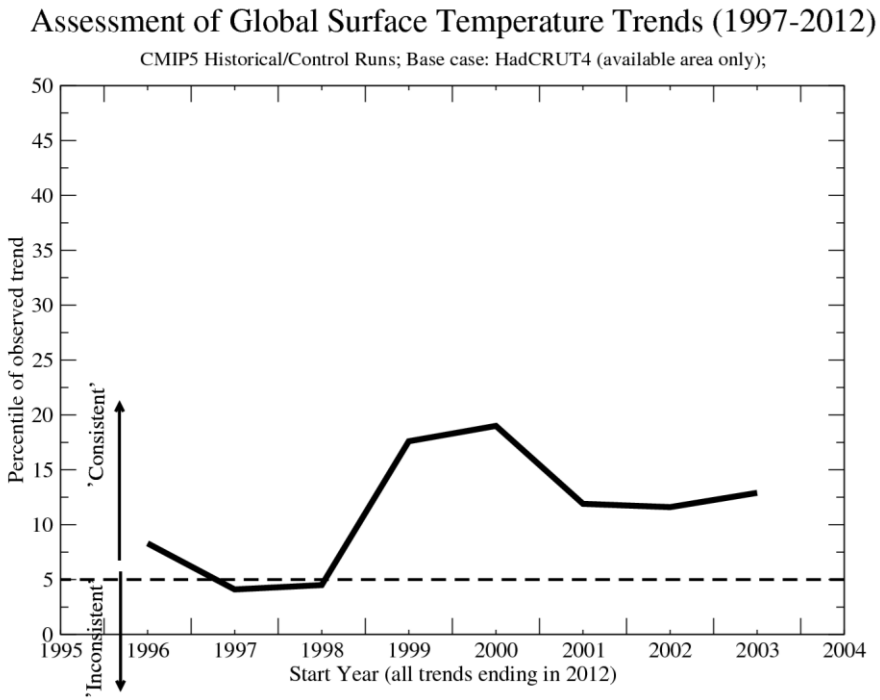

California region -- ANN:
Non-significant trend

Source: Knutson, Wittenberg, and Zeng, *BAMS,* submitted.

# Are CMIP5 model simulations consistent with the global warming 'hiatus'? Maybe…



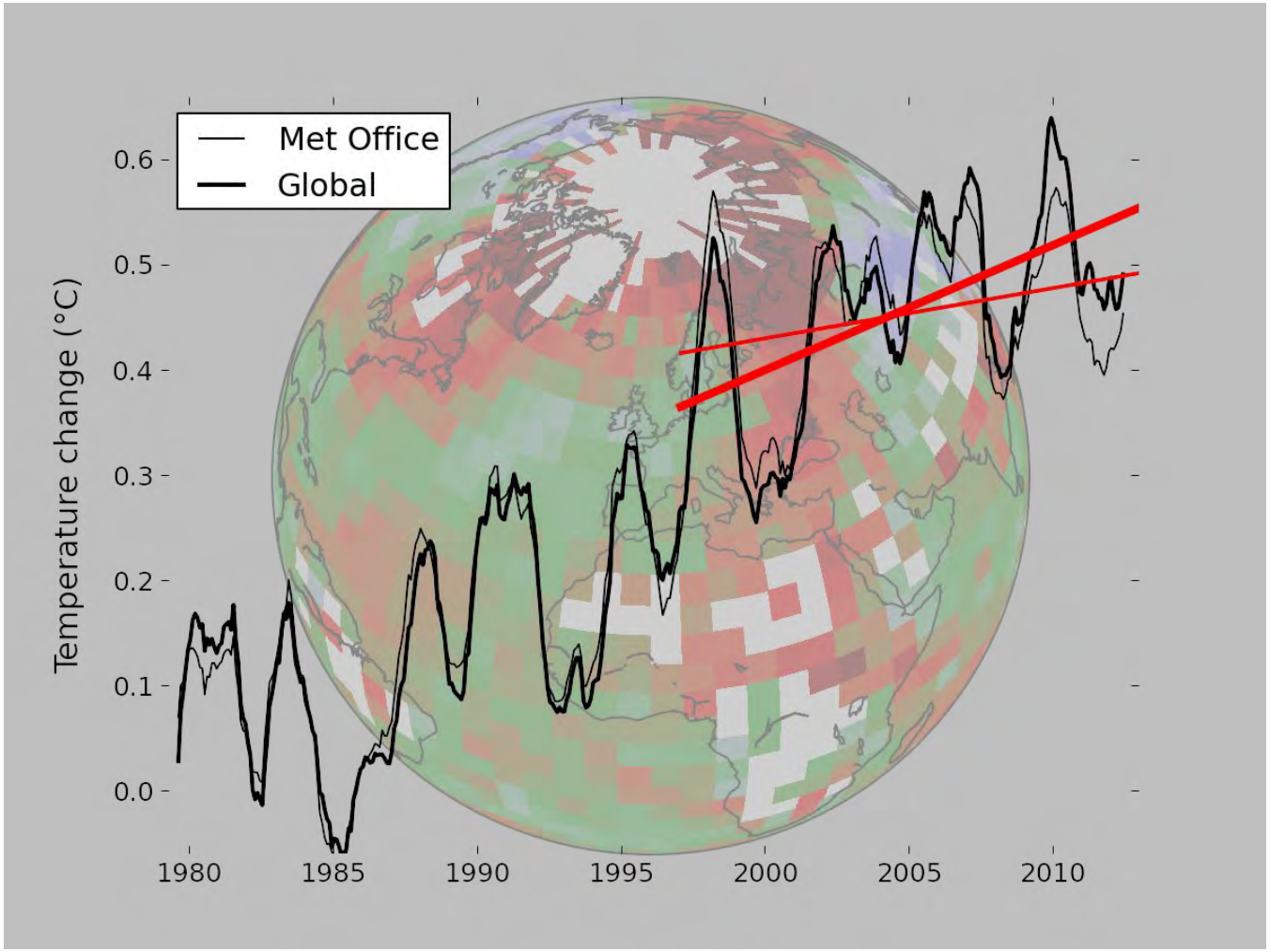




Potential sources of inconsistency:

- Forcing issues
- Response to forcings
- Underestimated internal variability
- Observation issues

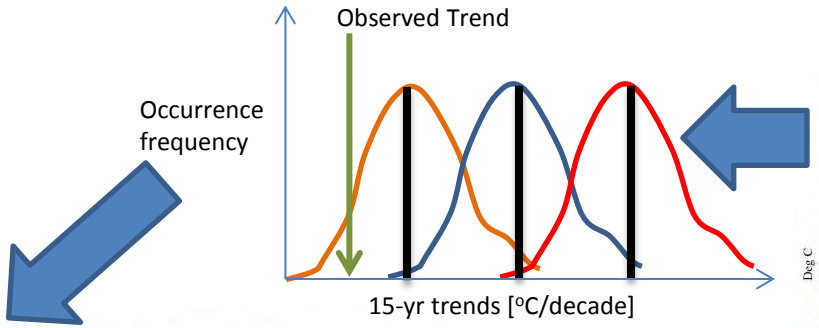
Source: Knutson, Zeng, and Wittenberg: in preparation

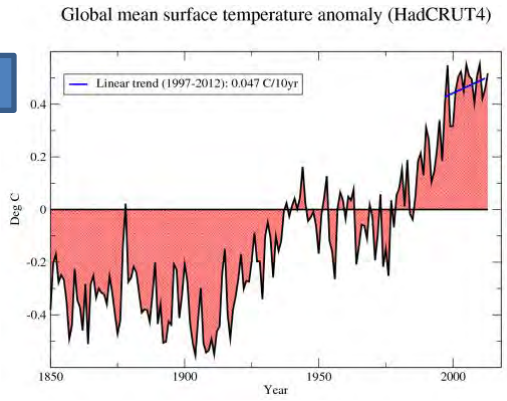
# Impact of missing temperature observations on the warming hiatus?

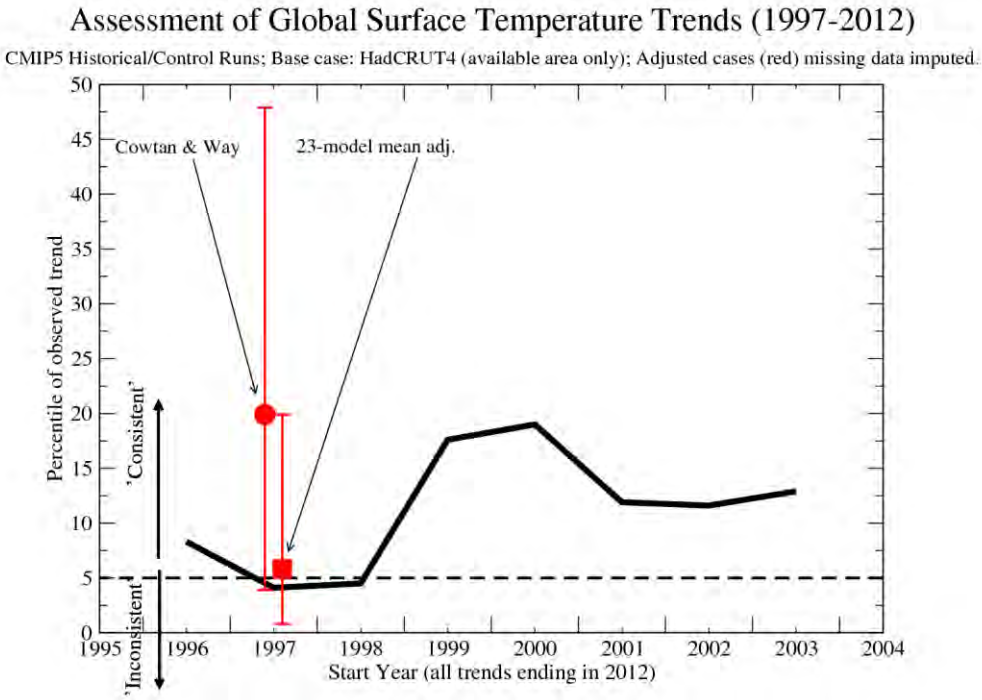


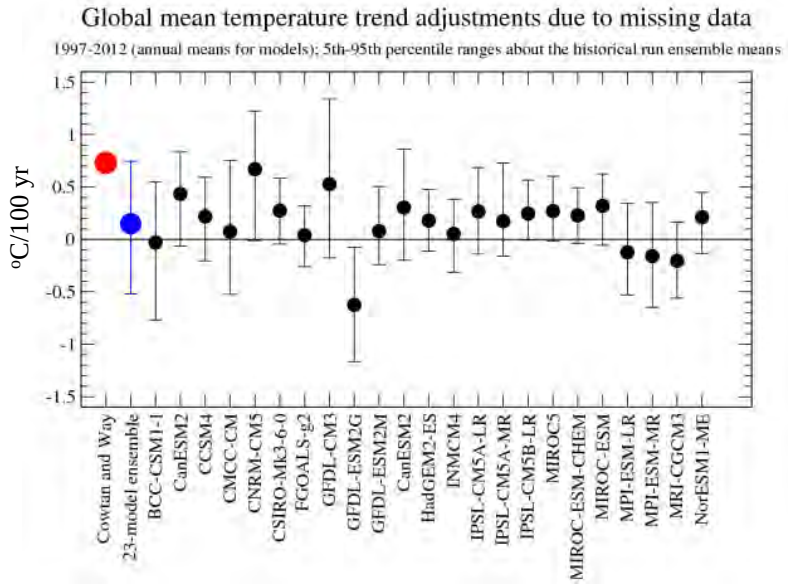

Source: Realclimate.org (Rahmsdorf, Nov. 13, 2013, after Cowtan and Way, QJRMS, 2014.).

# Are CMIP5 model simulations consistent with the global warming 'hiatus'? Maybe…




Source: Knutson, Zeng, and Wittenberg: in preparation

# Summary

- No detectable centennial-scale increases in tropical cyclone activity. Medium confidence in some contribution of reduced aerosol forcing to the increase in Atlantic hurricane activity since the 1970s. *[Future work: modeled changes]*
- Anthropogenic influence on surface temperature is detectable even at the grid-point scale in many regions. *[Future work: heat stress, drought/precip]*
- Extreme event attribution (using CMIP5 models): *[Future work: new events]*
  - Temperatures : Australia region (extreme annual means, 2013) – increased risk of such an event is fully attributable to anthropogenic forcing according to the CMIP5 models
  - Precipitation: Northern U.S. region (extreme annual means, 2013) – increasing trend partly attributable to anthropogenic + natural forcing
- The "global warming hiatus": *[Future work: causes of the hiatus]*
  - CMIP5 historical runs/RCP4.5 are inconsistent with observed trends since 1997 or 1998 (data-available regions).
  - Observational coverage may affect this conclusion for the global domain.