

US CLIVAR Working Group on the Changing Width of the Tropical Belt

Co-chairs: Kevin Grise (University of Virginia)
Paul Staten (Indiana University)

August 3, 2017





The Hadley cell and the Tropics

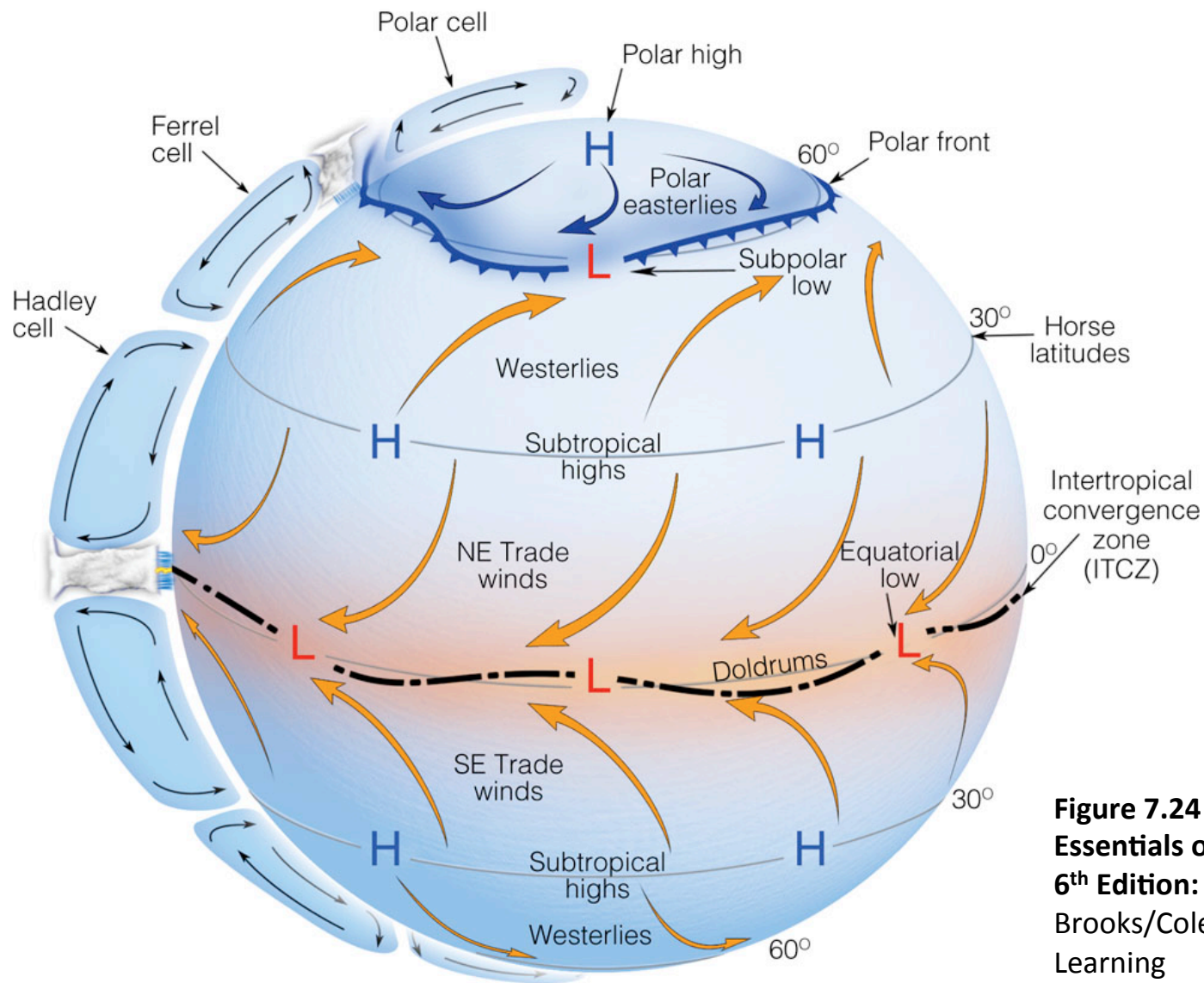
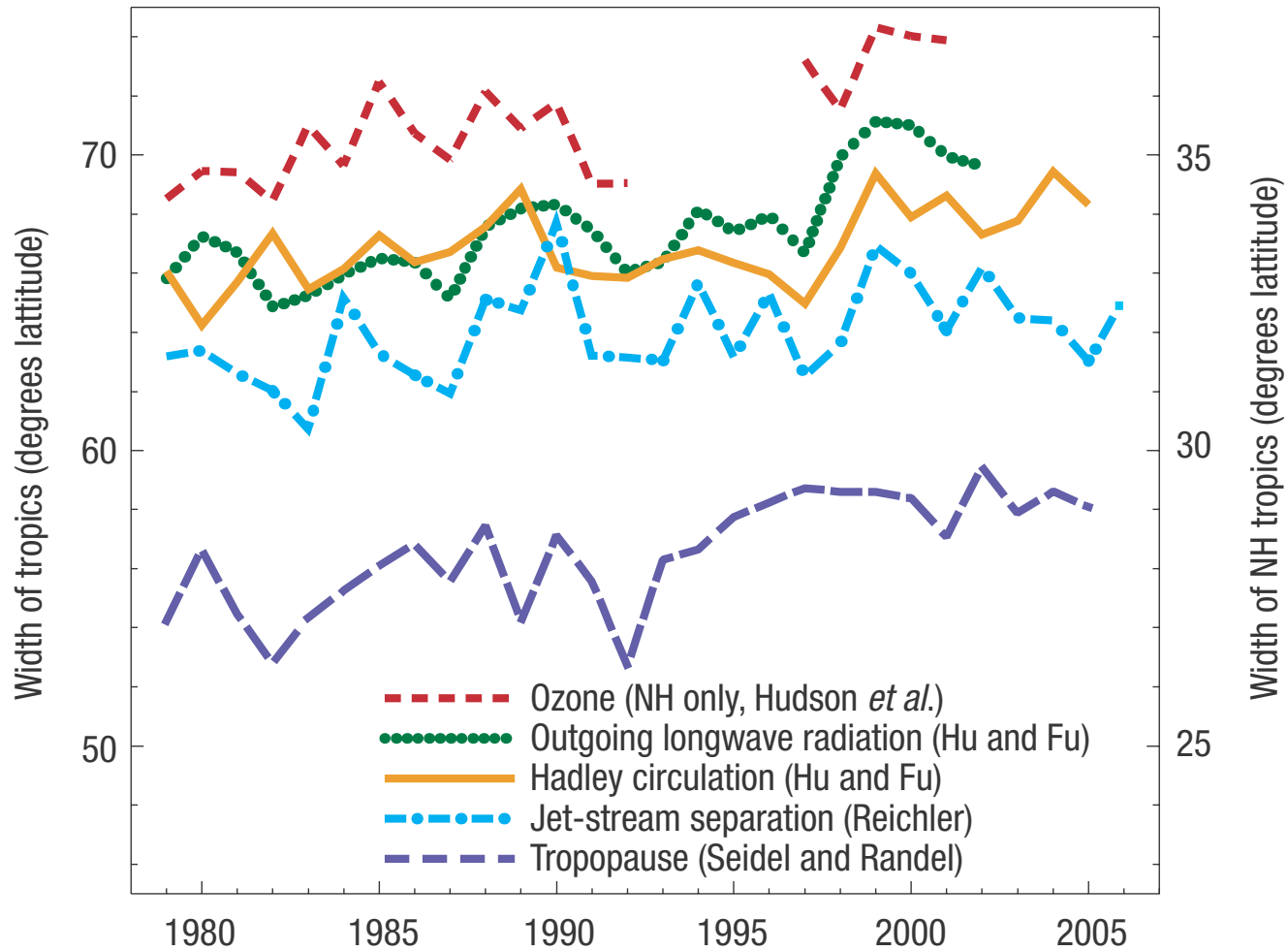


Figure 7.24 from Ahrens, Essentials of Meteorology, 6th Edition: © 2012, 2008 Brooks/Cole, Cengage Learning

Observed widening



Seidel et al., 2007

How the WG started

- The Width of The Tropics: Climate Variations and Their Impacts.



- Agreed: The Hadley cell has widened on multidecadal timescales
- Unsure: The Hadley cell has widened due to anthropogenic forcings



THE MYSTERY OF THE EXPANDING TROPICS

AS EARTH'S DRY ZONES SHIFT RAPIDLY POLEWARDS, RESEARCHERS ARE SCRAMBLING
TO FIGURE OUT THE CAUSE — AND CONSEQUENCES.

BY OLIVE HEFFERNAN

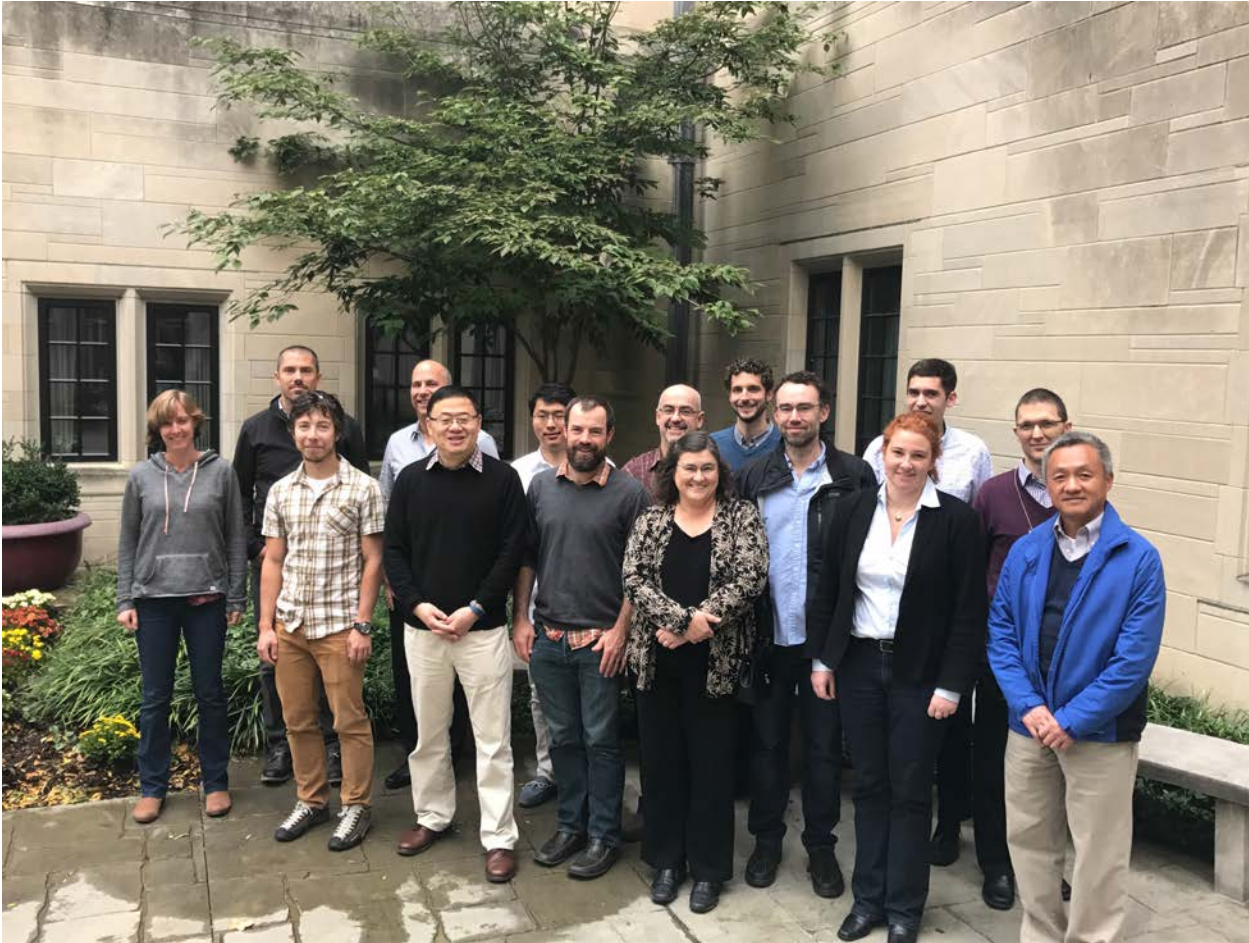
How the WG started

- The Width of The Tropics: Climate Variations and Their Impacts.



- Agreed: that metrics working group was needed
- Agreed: Regional impacts were woefully poorly understood

Working Group Members



Ori Adam (Hebrew Univ.)
Bob Allen (UC Riverside)
Thomas Birner (CSU)
Gang Chen (UCLA)
Kerry Cook (U. Texas)
Sean Davis (NOAA/CIRES)
Qiang Fu (U. Washington)
Kevin Grise (U. Virginia)
Kris Karnauskas (U. Colorado)
Jim Kossin (NOAA)
Chris Lucas (BOM Australia)
Amanda Maycock (U. Leeds)
Tim Merlis (McGill Univ.)
Xiao-Wei Quan (NOAA/CIRES)
Karen Rosenlof (NOAA)
Isla Simpson (NCAR)
Paul Staten (Indiana Univ.)
Caroline Ummenhofer (WHOI)
Darryn Waugh (Johns Hopkins)

Changing Width of the Tropical Belt Working Group

The US CLIVAR Working Group on the Changing Width of the Tropical Belt was formed in April 2016. The intent of the working group is to further the understanding of new insights that call into question the prevailing view about the nature and causes of changes in the width of the tropics.

The main objectives of the working group are:

1. Provide guidance on which metrics are most appropriate to quantify key impacts of the changing width of the tropical belt.
2. Identify how anthropogenic forcing and natural atmosphere–ocean variability contribute uniquely to decadal timescale changes in the width of the tropical belt.
3. Address how the global–scale widening of the tropics is manifested through regional–scale impacts.
4. Coordinate efforts with other international programs (e.g., SPARC DynVar; WCRP Grand Challenge on Clouds, Circulation, and Climate Sensitivity; GEWEX Hydroclimatology Panel) and inform funding agencies of where research initiatives are needed to advance understanding.



Working Group Timeline

April 2016 Working Group Formed

October 2016 Workshop #1 (Bloomington, IN)

March 2017, ISSI meeting 1

NOW Performing analyses for synthesis papers

October 2017 Workshop #2 (Boulder, CO)

January 2018 Session at AMS Annual Meeting (Austin, TX)

Write and submit synthesis papers

June 2017, ISSI meeting 2

Dec. 2018 Session at AGU Fall Meeting (Washington, DC)

Revise synthesis papers

March 2019 Working Group Concludes

Changing Width of the Tropical Belt Working Group

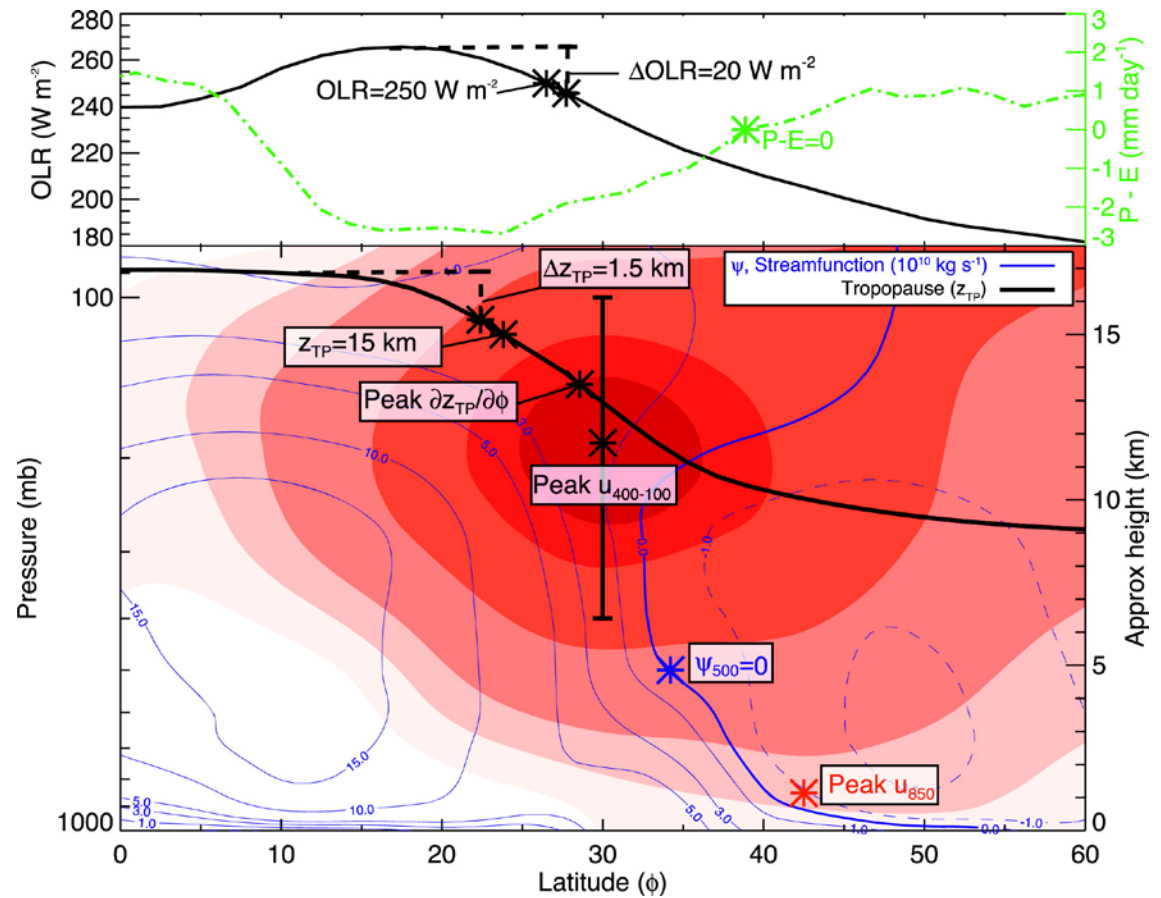
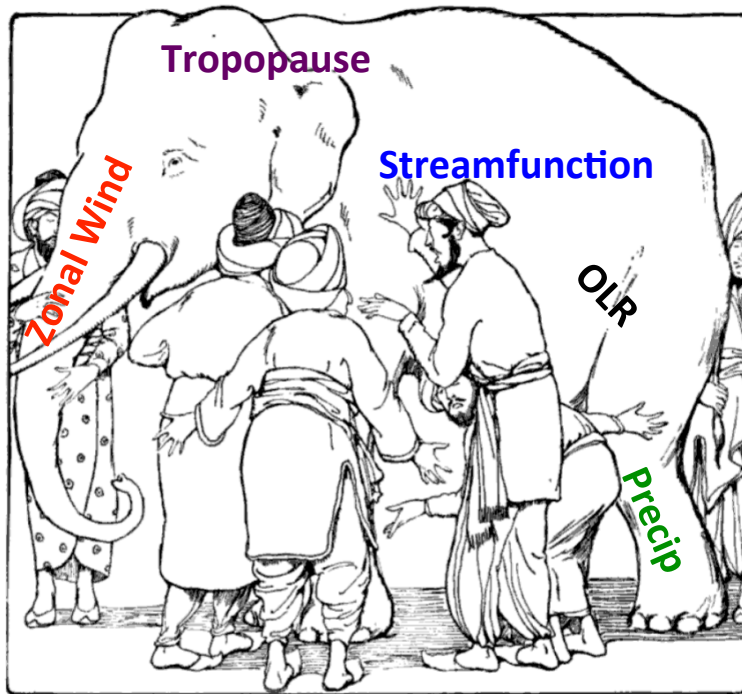
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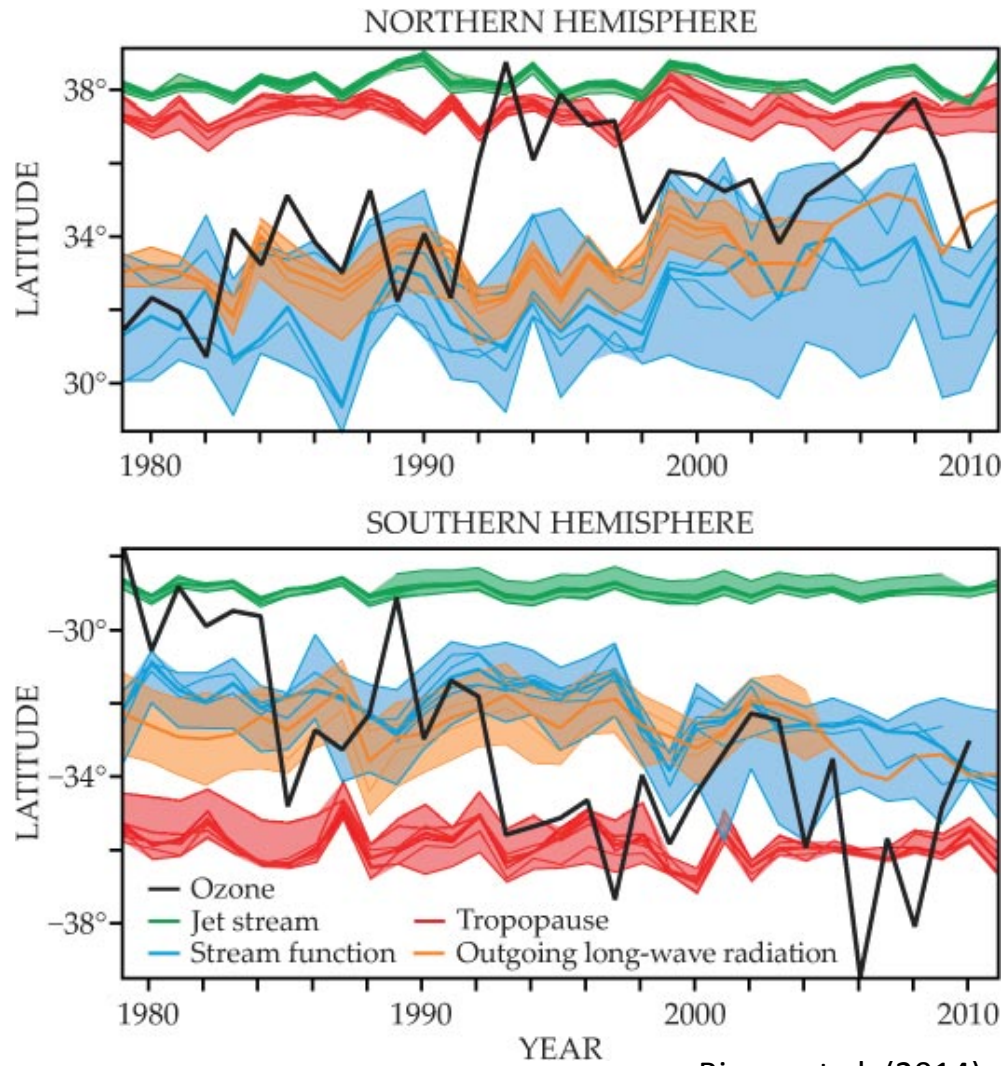


How do you measure tropical expansion?



Davis and Rosenlof (2012)

How do you measure tropical expansion?



Birner et al. (2014)

The rate of tropical expansion over the last three decades is highly dependent on the metric (and also the data set) chosen.

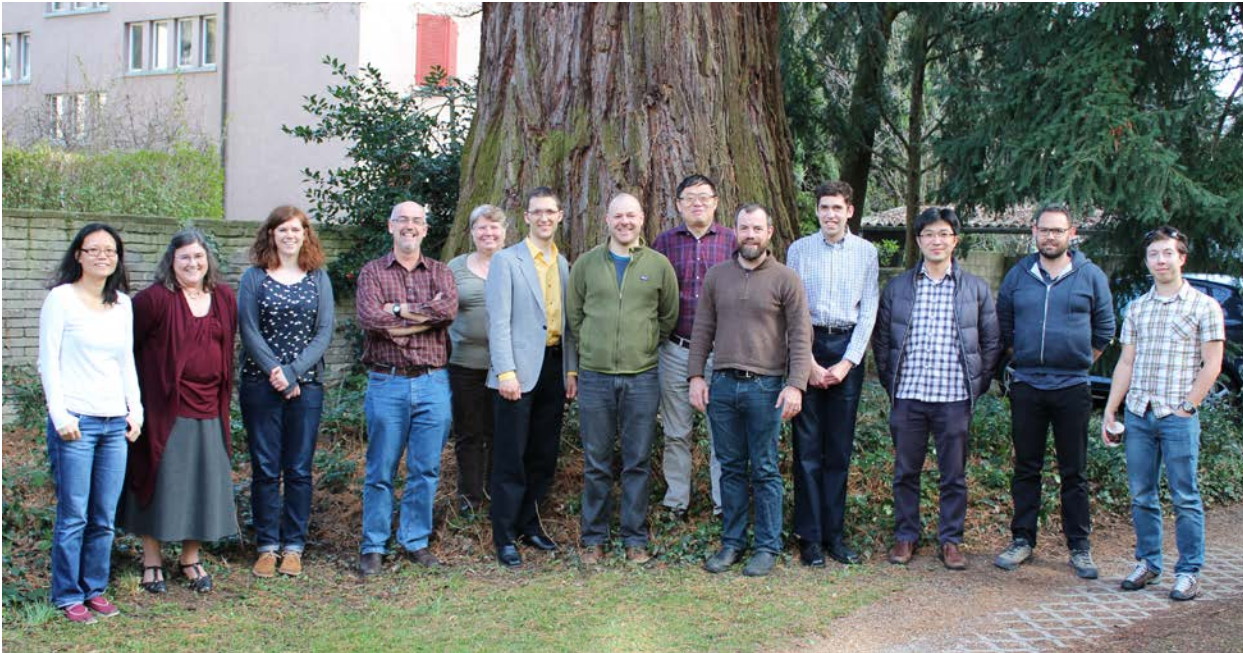
This makes it very difficult to intercompare results from previous studies, most of which use unique metrics and/or data sets!

Metrics: Working Group Action Items

- Provide recommended list of metrics for tropical expansion. Eliminate duplicate and error-prone metrics.
- Provide technical guidance on how to properly calculate these metrics.

Joint Effort with ISSI Team

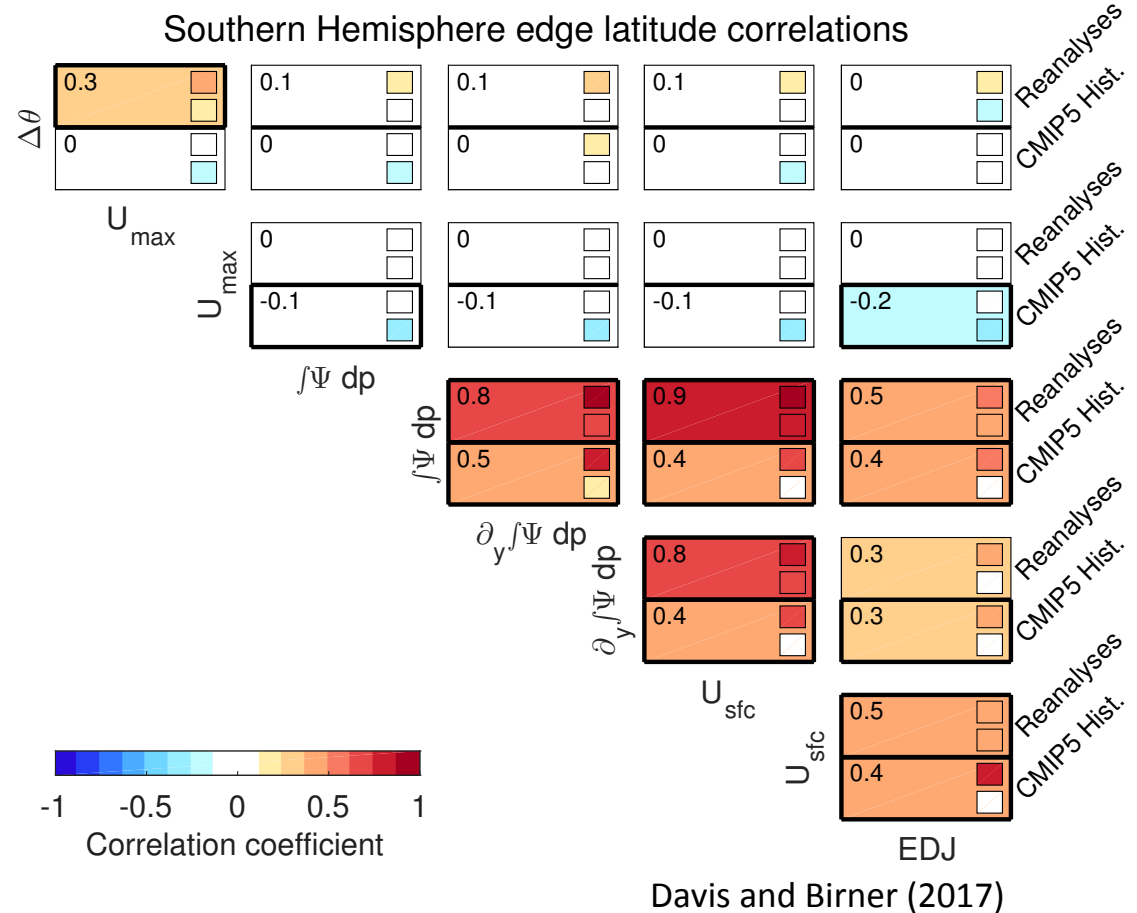
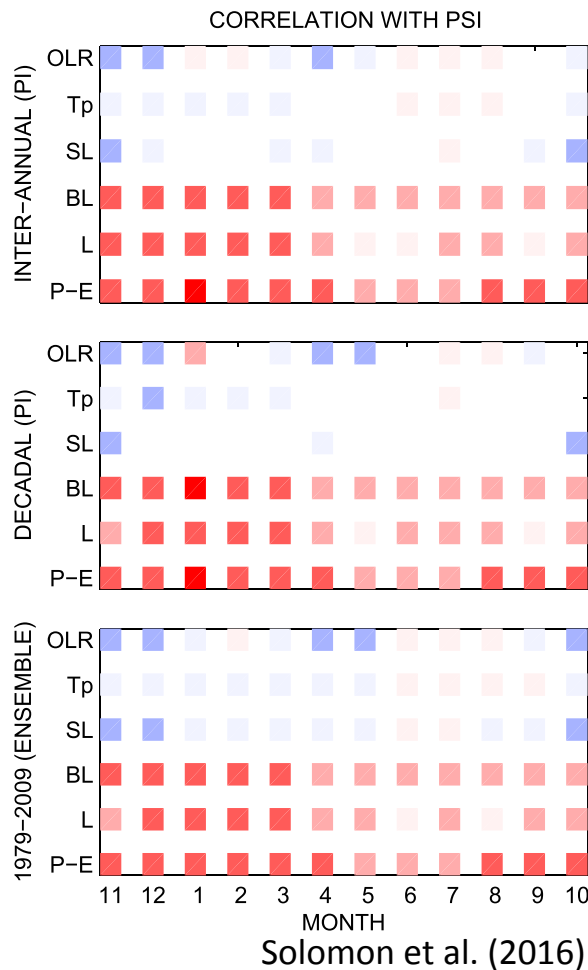
Tropical Width Diagnostics Intercomparison Project



First Meeting: March 2017
Second Meeting: June 2018

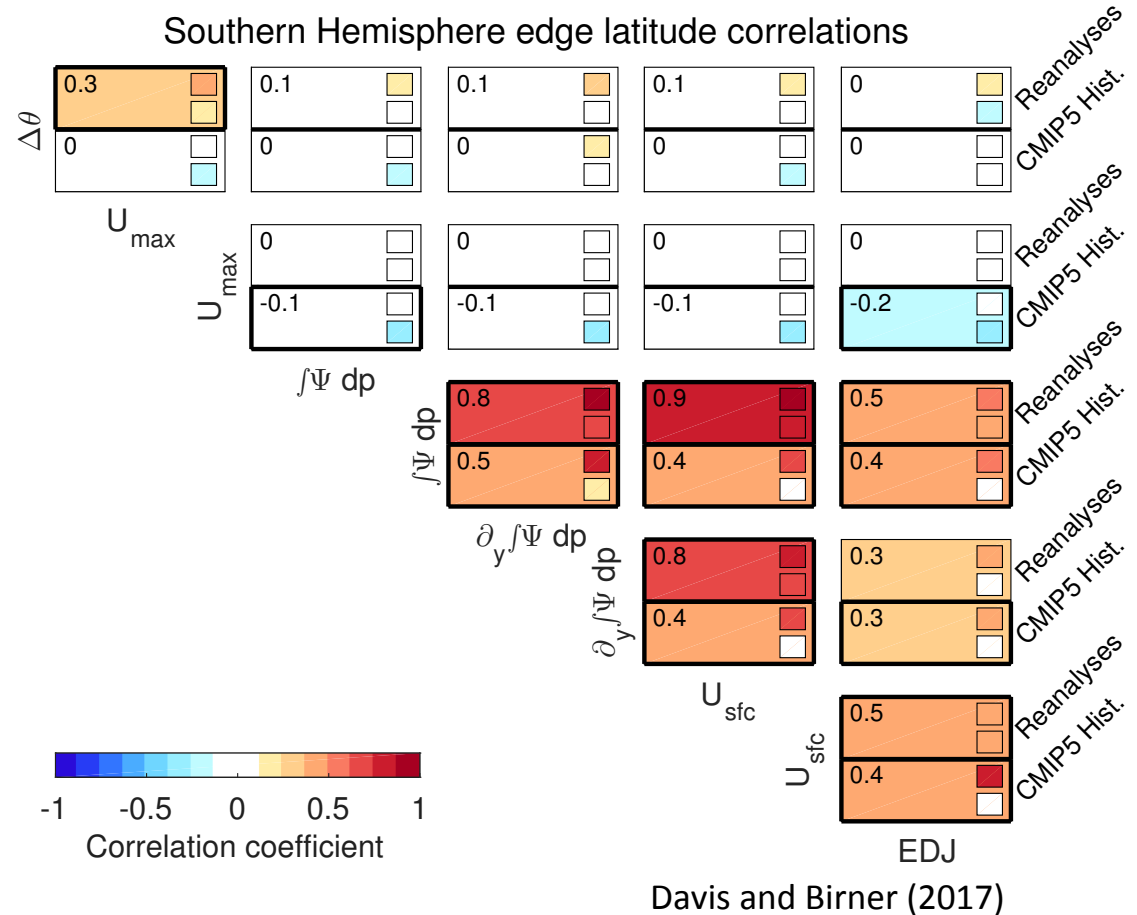
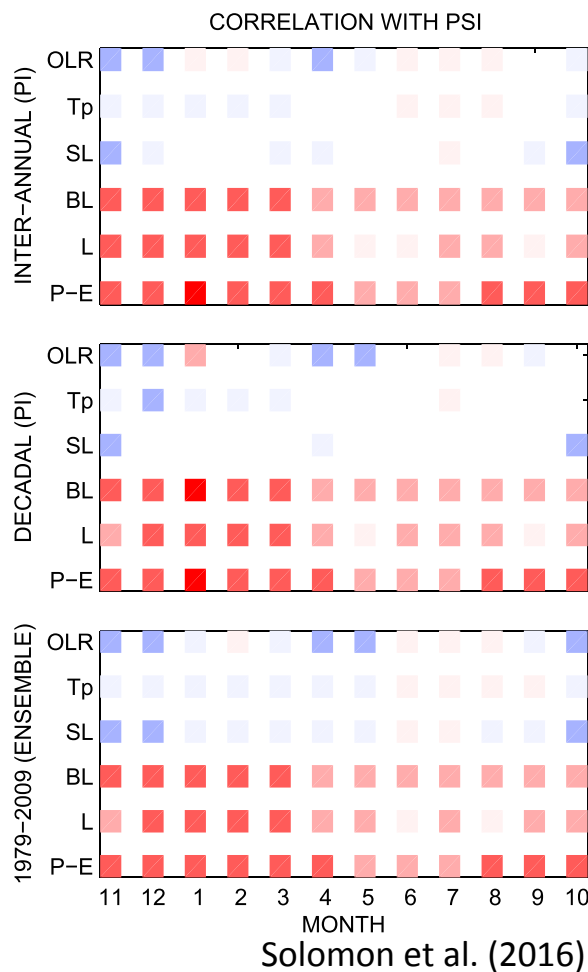
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Thomas Birner (CSU)
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Qiang Fu (U. Washington)
Hella Garny (DLR Germany)
Kevin Grise (U. Virginia)
Amanda Maycock (U. Leeds)
Alison Ming (Cambridge)
Karen Rosenlof (NOAA)
Seok-Woo Son (Seoul Nat. U.)
Paul Staten (Indiana Univ.)
Gabrielle Stiller (KIT)
Darryn Waugh (Johns Hopkins)

Metrics: Working Group Results



Upper tropospheric metrics (OLR, tropopause height, subtropical jet) are poorly correlated with surface impacts (sea level pressure, precipitation).

Metrics: Working Group Results



OLR and tropopause height are appealing metrics to study because they allow for a reanalysis independent estimate of tropical expansion.

Metrics: Working Group Results

- MATLAB/Python Code Package
 - Developed by Ori Adam
 - Currently being Beta tested by ISSI and US CLIVAR working group members
 - Will be publicly available in effort to standardize calculation of circulation metrics among studies
- Technical guidelines documentation associated with code
 - Paper in preparation
 - Recommendation that any new proposed circulation metrics must be compared with existing metrics

Changing Width of the Tropical Belt Working Group

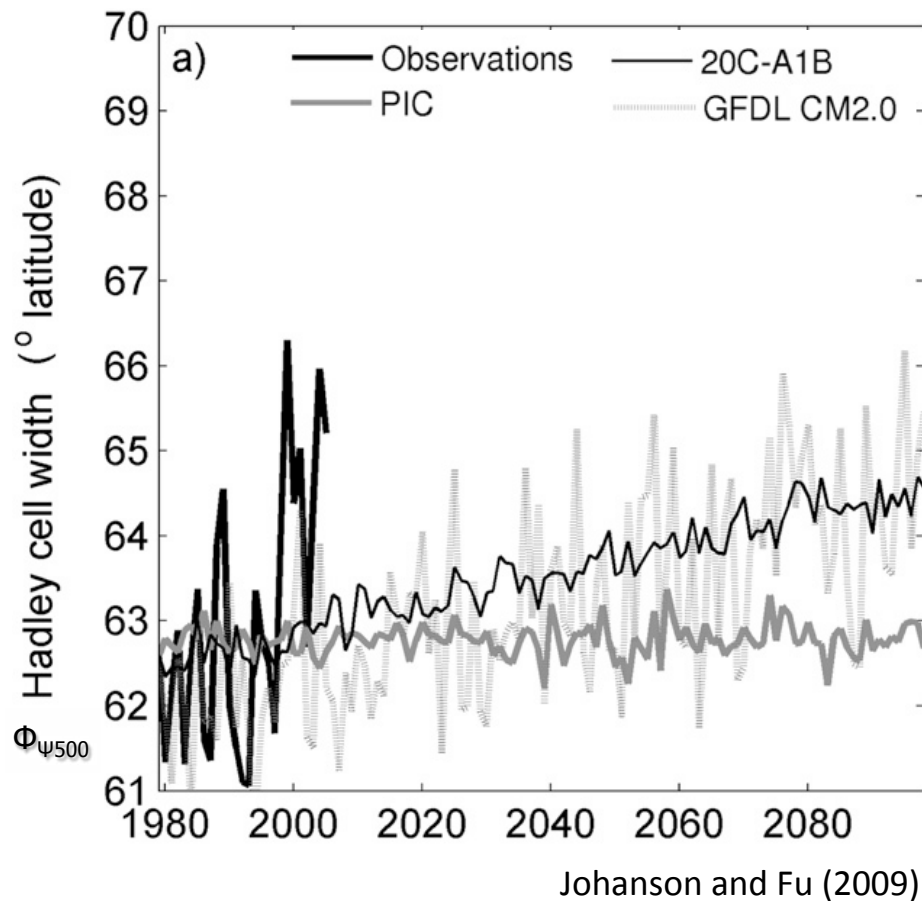
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Tropical Expansion: Natural Variability or Forced Response?

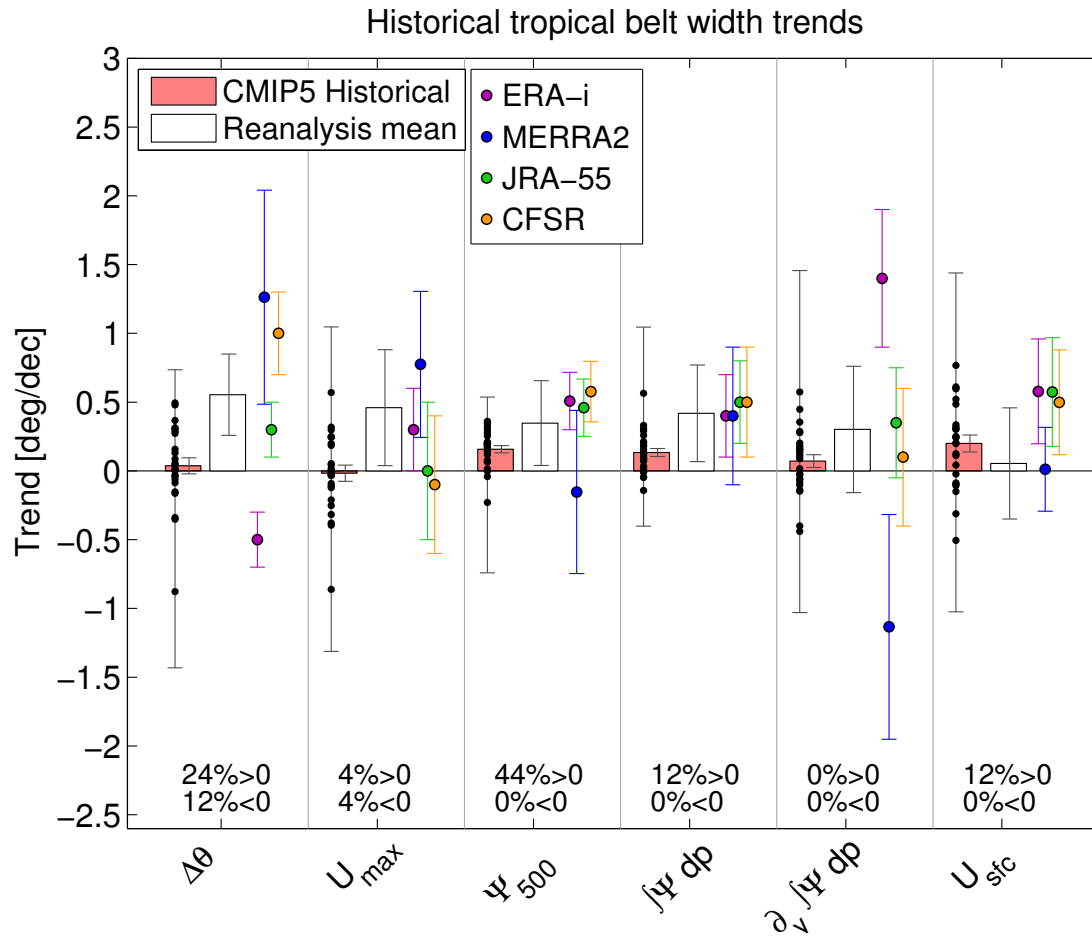


It is commonly reported that global climate models cannot capture the magnitude of recent tropical expansion.

(Johanson and Fu 2009; Hu et al. 2013)

This conclusion is based upon comparison of the observed trends with the **multi-model-mean** trend from CMIP models.

Tropical Expansion: Natural Variability or Forced Response?



Davis and Birner (2017)

Trends in some **individual** CMIP5 historical runs are comparable to observed trends.

(Davis and Birner 2017)

Model ensembles forced by observed sea surface temperatures (AMIP) better capture the magnitude of the observed tropical expansion. (Allen et al. 2014; Garfinkel et al. 2015)

Tropical Expansion: Natural Variability or Forced Response?

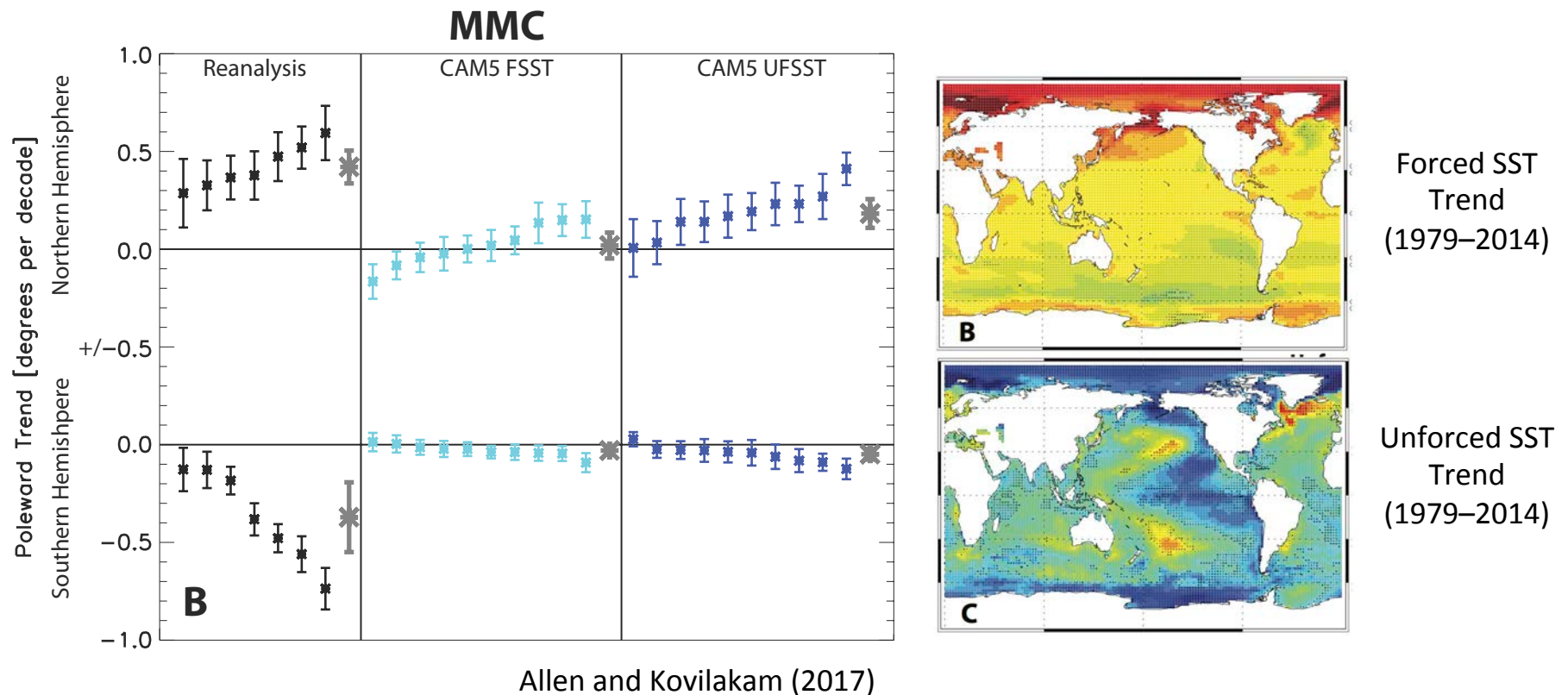
- Recent expansion of the tropics has been attributed to a number of different causes, including:
 - Increasing greenhouse gases/Warming temperatures
(Staten et al. 2012; Adam et al. 2014; Quan et al. 2014; Norris et al. 2016)
 - Anthropogenic aerosols
(Allen et al. 2012; Allen et al. 2014)
 - Stratospheric ozone depletion
(Son et al. 2010; Polvani et al. 2011; McLandress et al. 2012; Waugh et al. 2015)
 - Natural variability (Pacific Decadal Oscillation)
(Allen et al. 2014; Garfinkel et al. 2015; Allen and Kovilakam 2017)

There is a general lack of consensus among previous studies.

Variability: Working Group Action Items

- Write synthesis/review paper dealing with the following questions:
 - 1) Do global climate models have a realistic representation of tropical width variability?
 - 2) What is the primary cause of the recent tropical expansion over the last several decades?
 - 3) When will forced tropical expansion emerge from natural variability?

Variability: Working Group Results



“Bulk of recent tropical widening – particularly in the Northern Hemisphere – is due to unforced, natural sea surface temperature variability, primarily related to recent ENSO/PDO variability.”

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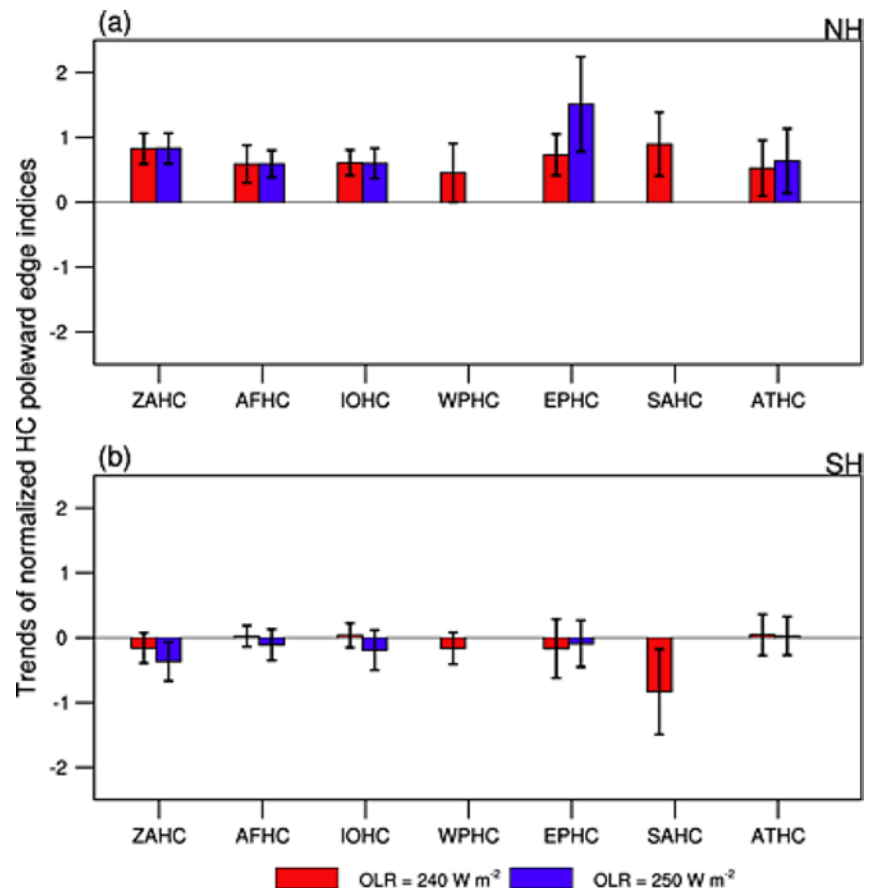
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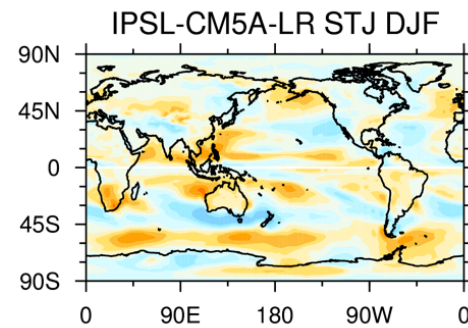
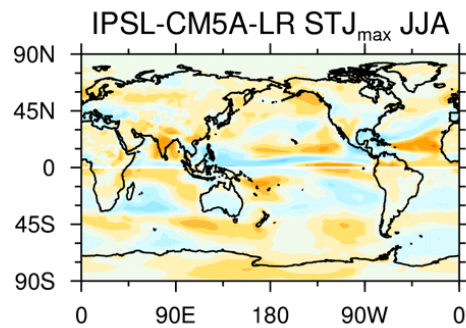
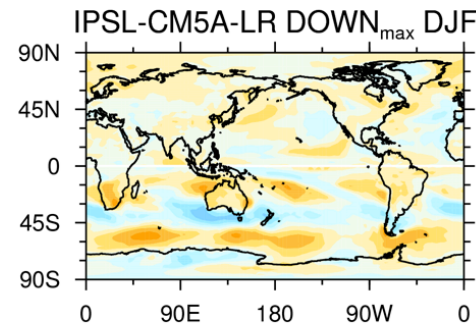
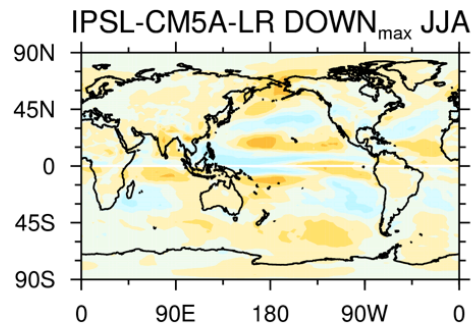
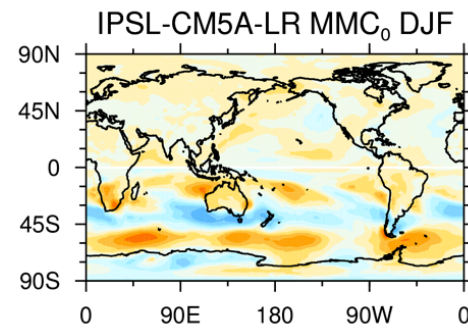
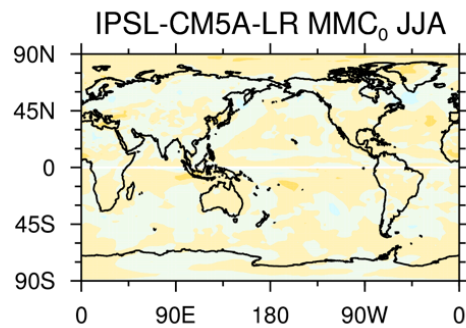
Tropical Expansion: Regional Metrics

- Hadley cell is a zonal mean circulation. Most trends and theory apply specifically to the zonal mean. But impacts occur at the regional level.
- Changes in width and intensity of regional overturning contribute to zonal mean.
- Metrics are also an issue at the regional scale (Chen et al., 2014)



Results: correlation between precipitation and tropical width metrics

Amanda Maycock, ISSI meeting



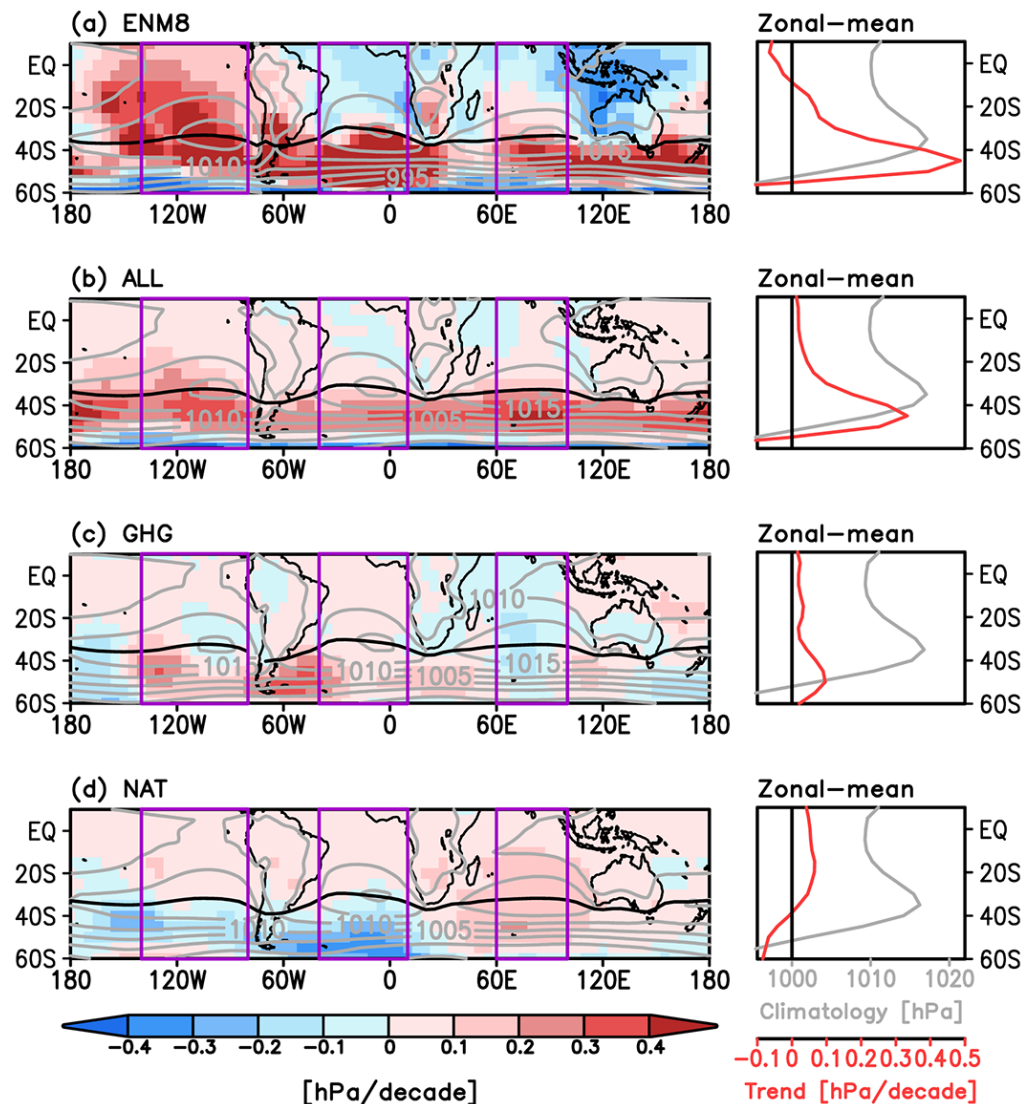
Tropical Expansion: Regional Factors

- Tropical-midlatitude connections:
 - Xiao et al., 2016: East Asian polar jet strengthens, subtropical jet weakens 5d later
- Zonal dynamics augment Hadley dynamics
 - Karlsruhkas & Ummenhofer, 2014: East-west thermal wind creates regional Hadley-wise circulations
- Thermodynamical dry zone expansion clear
 - Fu et al. 2016: warming and moisture availability imply increased aridity, in spite of increased precipitation

Tropical Expansion: Regional Impacts

- Different forcings produce different regional subtropical pressure patterns. This distinction aids attribution.

Kim, Y.-H., S.-K. Min,
S.-W. Son, and J.
Choi (2017), GRL

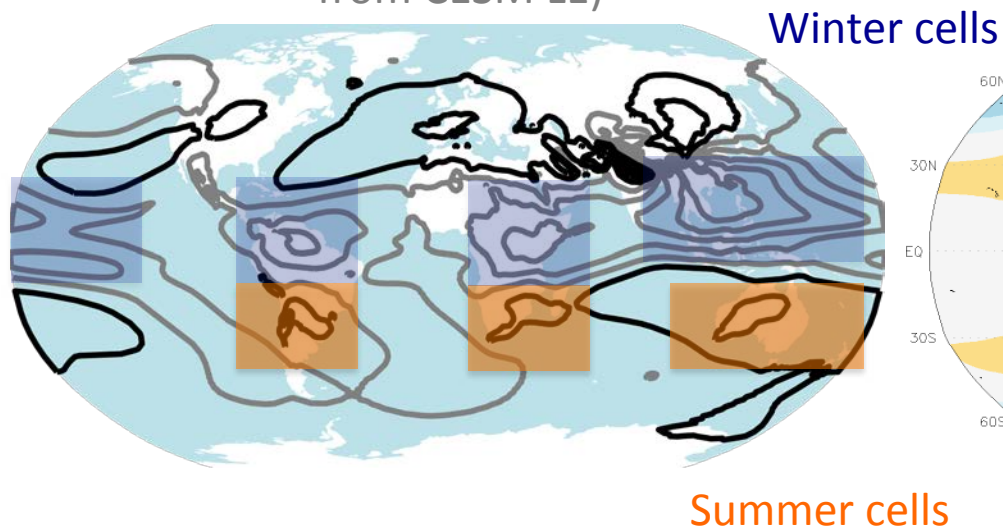


Regional Impacts: Working Group Action Items

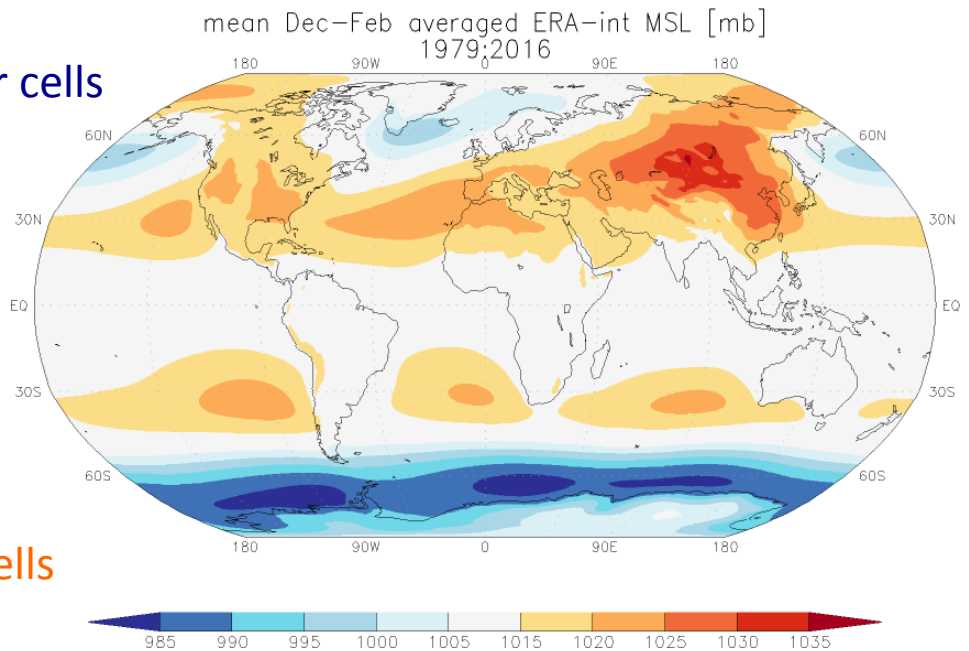
- Write a research paper to
 - Document regional impacts associated with tropical widening due to anthropogenic forcings
 - Isolates regions likely to be impacted by a globally widening tropical overturning *circulation*, as well as thermodynamics

Regional Impacts: Working Group Results

DJF Hadley cell decomposition, Staten
(irrotational meridional stream function
from CESM LE)



DJF SLP climatology



Future Plans/Action Items

- 2017
 - Telecon in August
 - Workshop in Boulder in October
 - NCAR lecture in October
- 2018
 - AMS meeting in January
 - Write review/synthesis papers
 - ISSI meeting in June
 - AGU meeting in December