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, CELEX Hydroclimatology Panel) and inform funding agencies of where research initiatives are needed to advance understanding.

Tropical Belt Working Group

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Motivation

Implication

WG Plan
Tropical width

- Tropical boundaries are defined by the locations of subtropical jets or the latitudes of the Hadley cell subsidence in each hemisphere.
Tropical widening in warming climate

- Poleward shift of subtropical jets $\rightarrow$ Total widening of tropics $\sim 0.7^\circ$ per decade (i.e., $\sim 2^\circ$ in last three decades).
Multiple independent analyses showed a widening of tropical belt since 1979 with a variety of metrics using satellite observations and reanalyses data.
Metrics of tropical width

DJF zonal-mean atmospheric properties used to define tropical edges

Following Davis & Rosenlof (2012) with modifications
Outstanding issue

- There is an order of magnitude disagreement among published rates of tropical widening, which range from a few tenths up to several degrees latitude per decade. It is unclear whether this large range reflects differing physical aspects of the atmosphere, the use of different methodologies to define the tropical belt, or the use of different observational datasets (e.g. satellite, in situ datasets, meteorological reanalyses) (e.g., Fu et al. 2006; Hudson et al. 2006; Seidel & Randel 2007; Hu & Fu 2007; Seidel et al. 2008; Archer & Caldeira 2008; Birner et al. 2010; Fu & Lin 2011; Zhou et al. 2011; Davis & Rosenlof 2012; Hudson et al. 2012; Ao & Hajj 2013; Nguyen et al. 2013; Davis & Birner 2013; Hartmann et al. 2013; Choi et al. 2014; Lucas et al. 2014; Adam et al. 2014).
From CMIP3 GCMs

- For 2010 - 2090
  - A2: 1.6° (0.20°/decade)
  - A1B: 1.0° (0.13°/decade)
  - B1: 0.6° (0.08°/decade)

Lu et al. (2007)
Updated from Hu et al. (2013)
Outstanding issue

- GCM simulated rate of tropical widening (0.1-0.2° decade⁻¹) is much smaller than observations, and it remains unclear what are the relative contributions to the observed tropical width trends from various anthropogenic forcings including greenhouse gases, ozone (both in stratosphere and troposphere), and aerosols, and natural variability in the ocean-atmosphere general circulation, such as the ENSO and PDO (e.g., Lu et al. 2007; Frierson et al. 2007; Chen & Held 2007; Johanson & Fu 2009; Lu et al. 2009; Lucas & Nguyen 2014; Son et al. 2010; Polvani et al. 2011; Staten et al. 2011; Allen et al. 2012; Grassi et al. 2012; Ceppi & Hartmann 2013; Hu et al. 2013; Min et al. 2013; Adam et al. 2014; Quan et al. 2014; Allen et al. 2014; Waugh et al. 2015).
Implications of tropical widening

- expansion of subtropical dry zone, resulting in desertification of marginal lands
- changes in rainfall patterns at subtropical dry zone margins
- poleward shift of cloud patterns, resulting in a climate feedback
- ...

Dryland Expansion
Aridity index (UNEP 1992): $AI = \frac{P}{PET}$

where the potential evapotranspiration $PET$ is the maximum amount of water capable of being lost from the surface for given atmospheric condition with well supplied surface water (i.e., **the evaporative demand of the atmosphere**).

e.g., at Tucson

$P/PET = 0.12$
Changes in (a) P/PET and (b) RH (1980-1999 to 2080-2099) under scenario RCP85

Sherwood & Fu (2014, Science)
Causes of a drier climate in a warming world

In a warming world, the increase of PET over land is faster than the increase of evaporation over ocean.

Fu and Feng (2014)
Dryland expansions

Projected changes in dryland coverage to drier types for 2071-2100 under scenario RCP8.5 relative to 1961-1990

Feng and Fu (2013)
Temporal variations of global dryland areas for (a) the total and individual components of (b) dry subhumid, (c) semiarid, (d) arid, and (e) hyper-arid regions.

- An expansion of global drylands is a robust feature in both GCM simulations and observations but the simulated rate is much smaller than observations in last 60 yr.

Feng and Fu (2013)
The Key recommendations of this meeting were:

• to investigate what each metric physically represents about the edge of the tropics, to explore how the metrics relate to one another, and to recommend a smaller subset of metrics to be used, consistently and reproducibly, in future studies;

• to address the role of coupled atmosphere-ocean natural variability in the width of the tropical belt, and how changes in the Hadley circulation might feed back on the general circulation of the ocean;

• to make a better connection between the zonal-mean expansion of the Hadley circulation and changes in the regional circulations of the tropical and subtropical zones.
A three-year US CLIVA Working Group on the Changing Width of the Tropical Belt is established to implement the recommendations from the recent AGU Chapman conference.

Co-Chairs: Kevin Grise & Paul Staten
The WG plan to complete the following tasks:

- Publish a peer-reviewed journal article to provide the community with a comprehensive assessment of tropical width metrics and to recommend a subset of metrics to be used by subsequent studies (to better aid in comparison among studies across published literature);
- Compare and contrast the impacts of anthropogenic forcing and coupled atmosphere-ocean variability on decadal variability in tropical width. Synthesize our understanding of coupling between tropical width and sea surface temperatures;
- Inform linkages between global-scale circulation changes and the regional-scale circulation changes most relevant for impacts, setting the stage for a session at the AGU Fall Meeting on global and regional impacts of tropical circulation change.

Three sub-groups were formed to address various aspects of tropical widening: metrics, variability, and regional impacts.
Closely relevant activities

- "Tropical Width Diagnostics Intercomparison Project" (PI: Sean Davies) was funded by the International Space Science Institute (ISSI) under their 2016 call for International Teams in Space and Earth Sciences: Under this program ISSI provides meeting resources (i.e., space, lodging, per diem) for a small scientific group (~10 people) to meet twice over the course of 18 months in Bern, Switzerland to work on a tightly focused research project.

- A white paper “Long-term Observations of Tropopause Parameters for Climate Change Detection and Model Assessments” led by C.O. Ao from JPL was submitted in response to the 2017-2027 Decadal Survey for Earth Science and Applications from Space.