Poleward Expansion of the Hadley Circulation in CMIP5 Simulations

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Abstract

Observational analyses have demonstrated that the Hadley circulation has expanded poleward in recent decades. **Important issues are what caused the widening of the Hadley circulation and whether the observed widening is related to anthropogenic forcing.** Here, we use CMIP5 simulations to analyze anthropogenic forcings on the width of the Hadley circulation. It is found that GHG forcing generates widening of the Hadley circulation in all seasons for both hemispheres. Ozone depletion causes significant widening of the Hadley circulation only in DJF for the Southern Hemisphere and MAM for the Northern Hemisphere, but no significant widening in other seasons. However, anthropogenic aerosols have no significant forcing on the width of the Hadley circulation. In contrast to that in CMIP3, AMIP-type simulations of CMIP5 show significant widening. In CMIP5 projection simulations for the 21st century, magnitudes of widening of the Hadley circulation increase with radiative forcing. **In addition, we will also show different model performances in simulating the climatology and trends of the Hadley circulation.**

Data and Methods

The model outputs from CMIP5 simulations are analyzed, including historical simulations and projection simulations.

Statistical significance levels are indicated by student's t test values.

Conclusion

1. All forcing and GHG forcing →HC widening, but weakening.
2. Ozone depletion → HC widening and strengthening.
3. Anthropogenic aerosols → no significant HC changes.
4. RCP radiative forcing increasing →HC widening increasing.
5. Midlatitude-tropics SST contrast stronger (climatology and trends by different models) → HC widening greater.
6. The changes in midlatitude vertical wind shear, which related to midlatitude-tropics SST contrasts, influence the width and trend of the Hadley circulation simulated by different CMIP5 models.

References

Tao, L., Hu, Y. and Liu J. Anthropogenic forcing on the Hadley circulation in CMIP5 simulations. Climate Dynamics (2015), DOI:10.1007/s00382-015-2772-1.

Hu, Y., Tao L. and Liu J. Poleward expansion of the Hadley circulation in CMIP5 simulations. Advances in Atmospheric Sciences (2013), DOI: 10.1007/s00376-012-2187-4.

Results

1. Poleward expansion in historical simulations

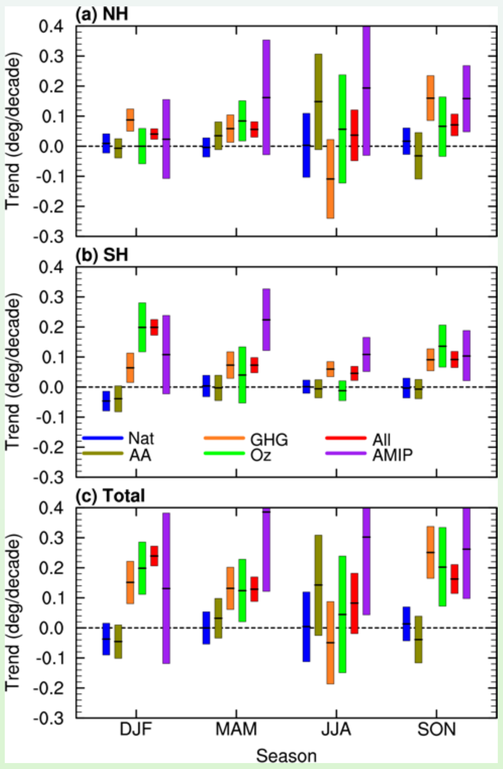

Fig. 1. Seasonal-mean poleward expansion of the Hadley circulation at 500 hPa in CMIP5 historical simulations. (a) NH cell, (b) SH cell, and (c) total expansion, unit: degree/decade.

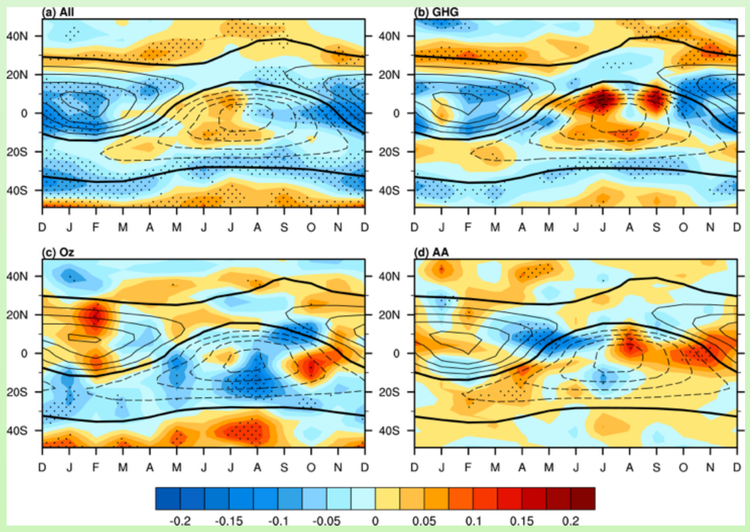

Fig. 2. Seasonal variations of climatological mass stream functions (contours) and trends (color) at 500 hPa over 1970–2005. (a) All-forcing, (b) GHG-forcing, (c) Ozone-only, and (d) Anthropogenic aerosols, and over 1970–2000. Unit: 1.0 × 10^{10} kg s^{-1} per decade.

2. Poleward expansion in projection simulations

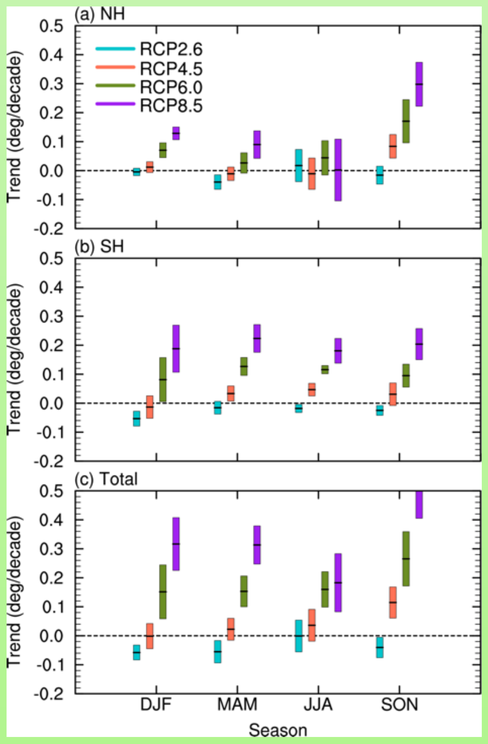

Fig. 3. Seasonal-poleward expansion of the Hadley circulation in CMIP5 21st simulations. Trends are calculated over 2040–2100. (a) NH cell, (b) SH cell, and (c) total expansion, unit: degree/decade.

3. Relationship between SST Patterns and the width of the Hadley Circulation

(a) Climatology

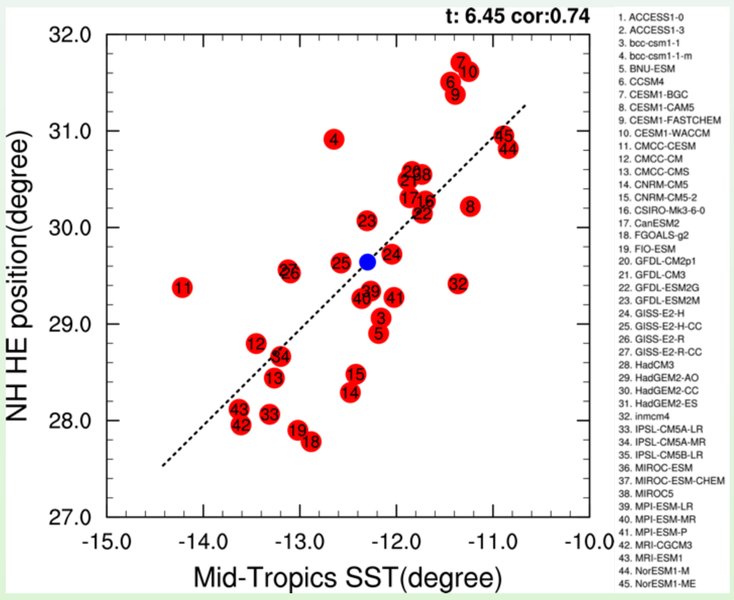

Fig. 4. Scatter plot between annual mean poleward edge latitudes of NH Hadley circulation and midlatitude-tropics SST contrasts in CMIP5 historical simulations with all forcing.

(b) Trend

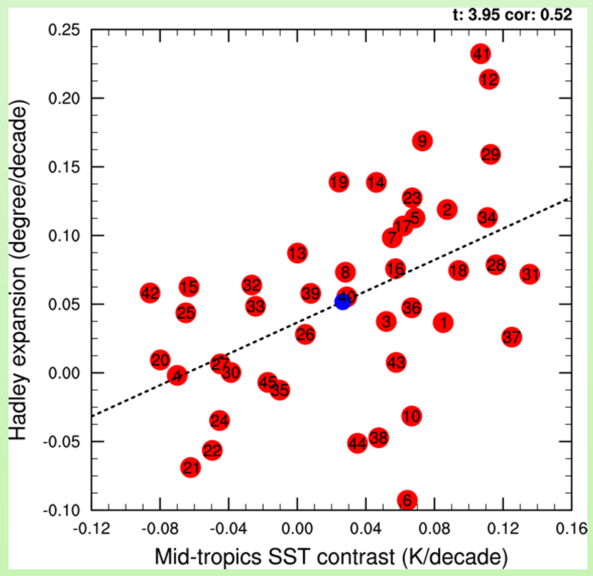

Fig. 5. Same as Fig. 4, but for **the trend** over 1970-2005.

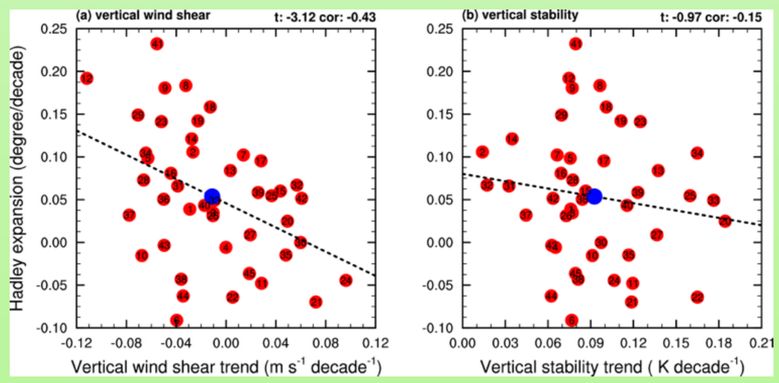

Fig. 6. Scatter plots between the poleward expansion of the northern Hadley circulation and (a) vertical wind shear trend and (b) vertical stability trend **in Midlatitude** in CMIP5.

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