Changes in Brewer-Dobson Circulation for 1979-2008: A Perspective from MSU/AMSU/SSU Observations

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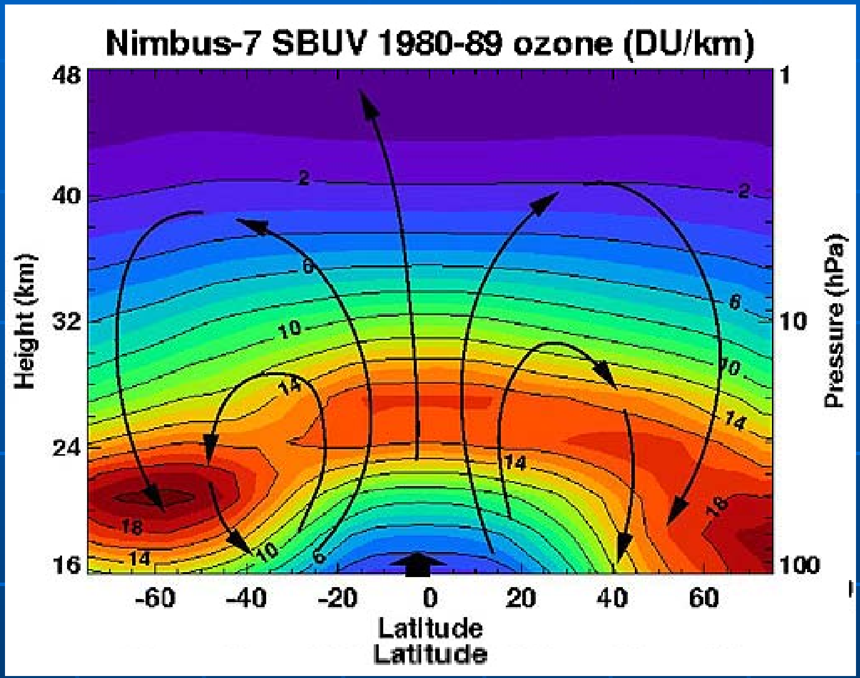
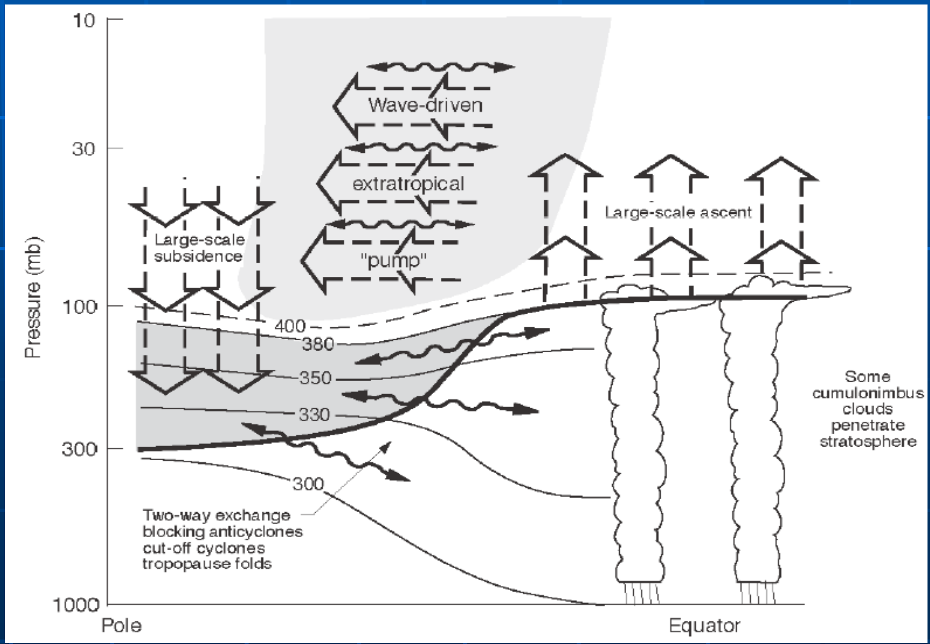
Brewer-Dobson Circulation (BDC)

(Brewer 1949; Dobson 1956)



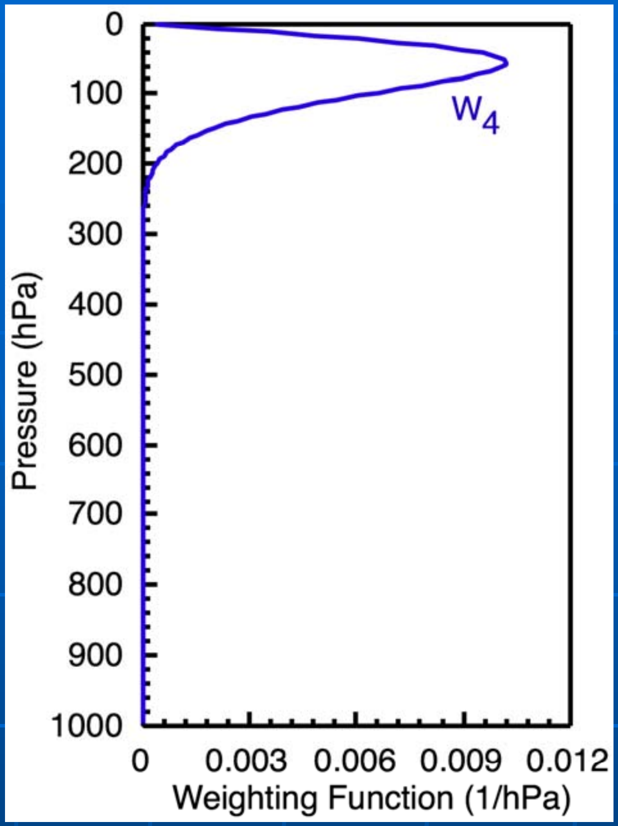


Holton et al. (1995)

- GCM studies predict an increase in the strength of the BDC throughout the year in response to both an increase of greenhouse gas concentrations and an ozone depletion (e.g., Butchart and Scife 2001; Rind et al. 2001; Eichelberger and Hartmann 2005; Butchart et al. 2006; Li et al. 2008).

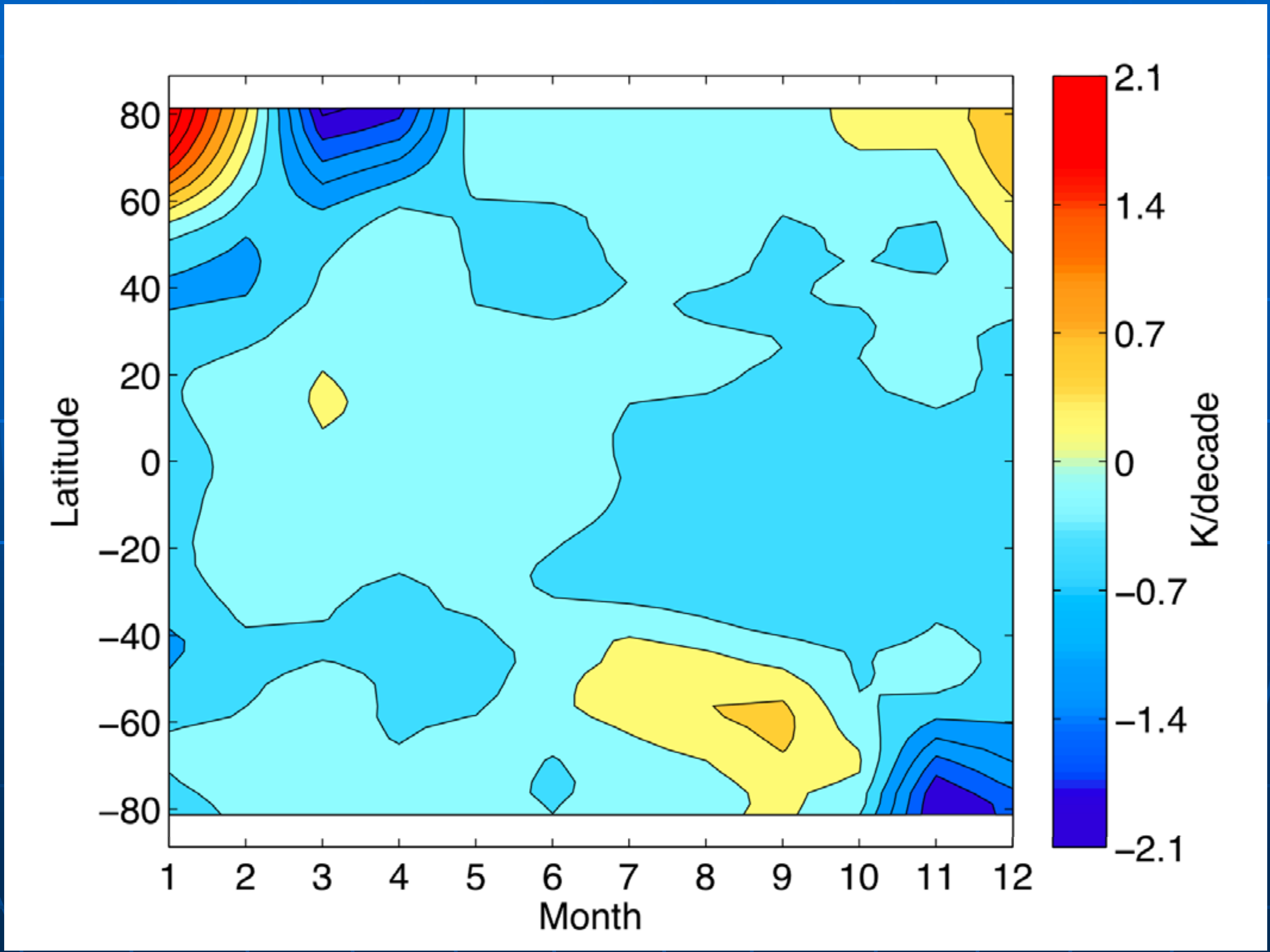
What does the observation tell us about the change of the BDC in last few decades?

- We address this question by examining the MSU/AMSU lower-stratospheric channel temperature (T_4) trends in the tropics:

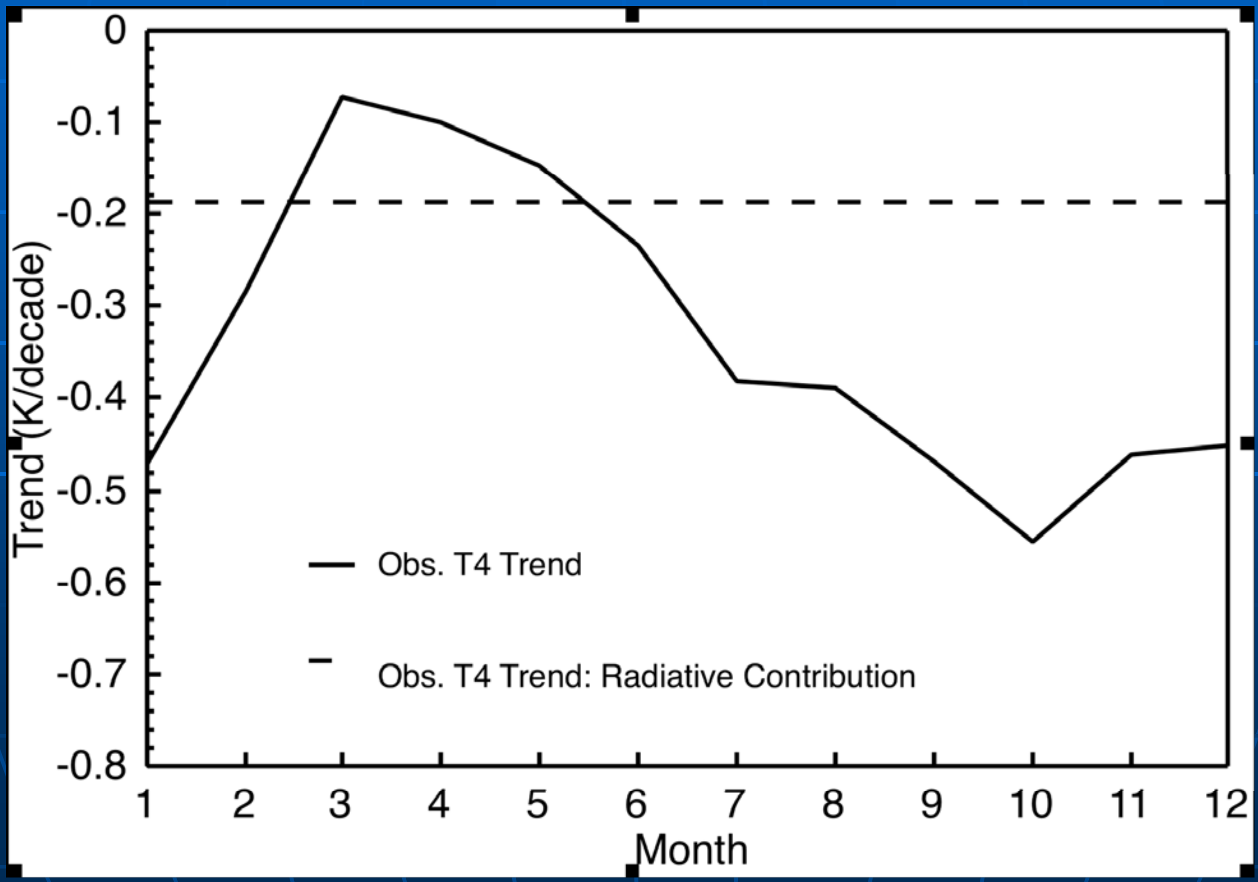


Stronger BDC -> faster tropical (high latitudes) upwelling (downwelling) -> colder (warmer) T_4 in the tropics (high latitudes).

Zonal Mean T_4 Trends versus Month and Latitudes



MSU Lower-Stratospheric Temperature (T_4) Trends in the Tropics (20ºN-20ºS) for 1979-2008

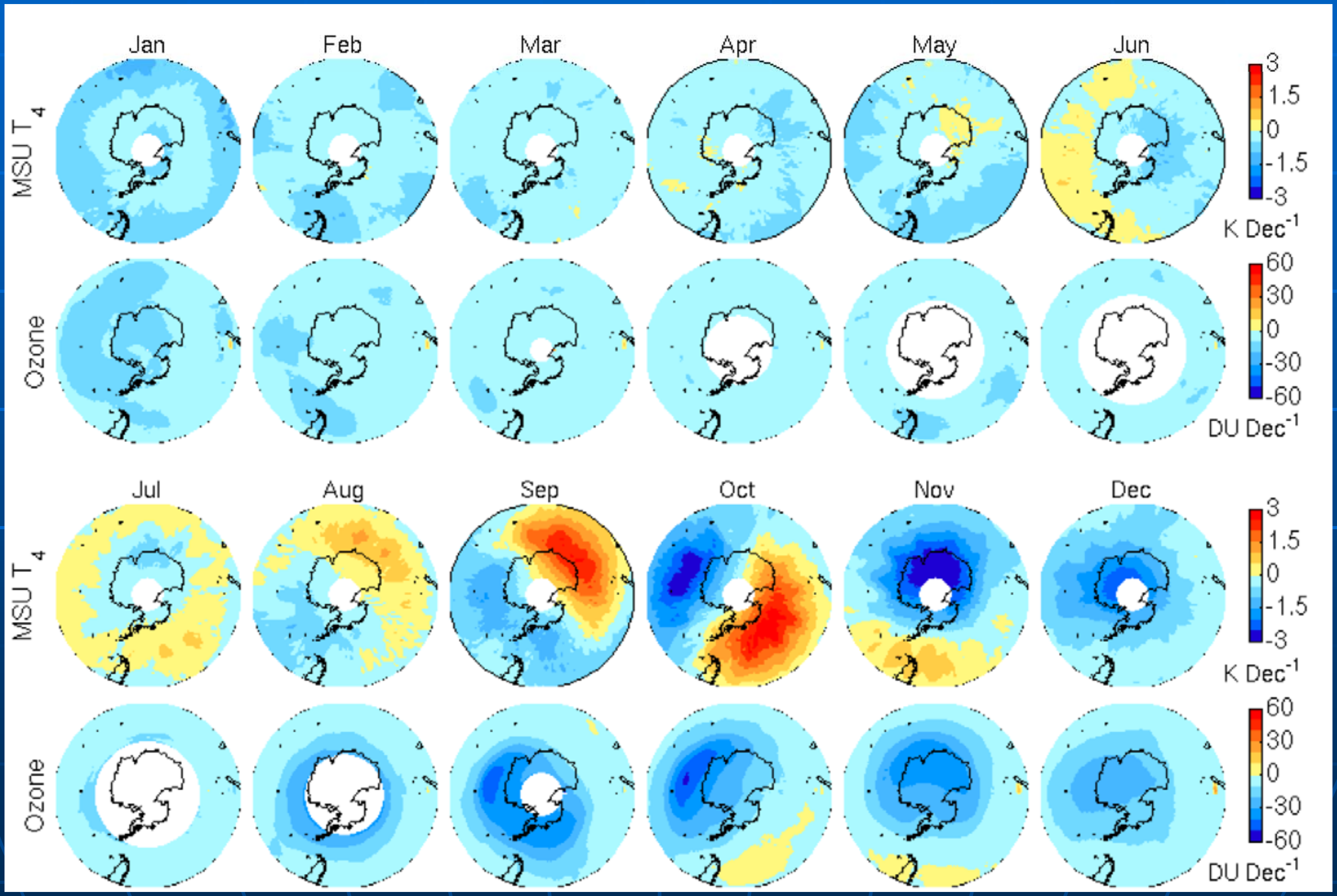


Approach

- We first quantify the high latitudes (poleward of 40°N and 40°S) T_4 trends due to the change of the BDC, which should be closely coupled with those in the tropics through the downward control principle (Holton et al. 1995).

Southern Hemisphere High Latitudes

Monthly Trend Patterns of T_4 and TOMS total Ozone for 1979-2008



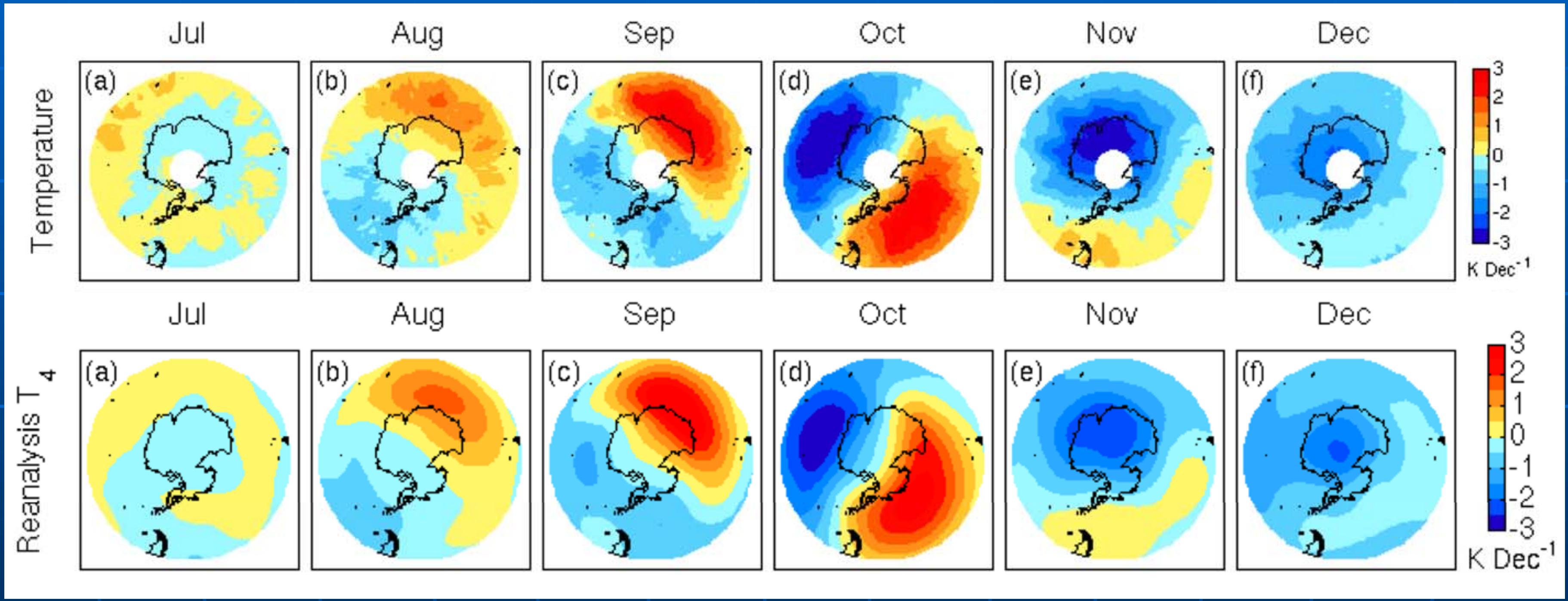
- In SH high latitudes, the observed trend patterns in winter and spring months can be attributed to the ozone-depletion induced radiative cooling, BDC-acceleration induced dynamic warming, and planetary wavenumber-1 changes (the latter has no impact on the zonally mean trend).

Lin, Fu, Solomon, and Wallace (J. Climate, 2009)

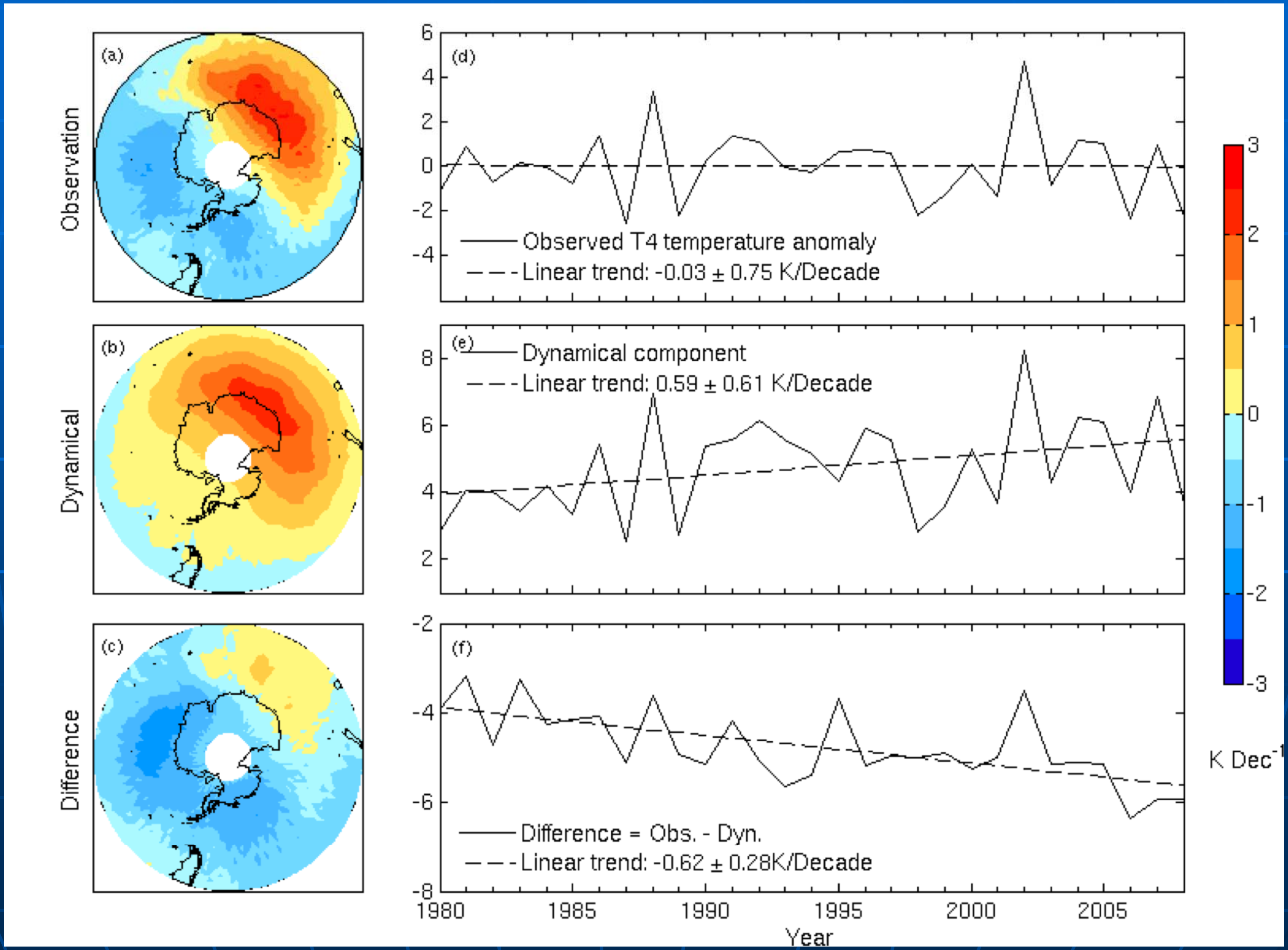
- We separated the dynamic component of the high latitude T_4 trends due to the change of the BDC as the eddy-heat-flux-congruent trend, i.e., the regression of the T_4 temperature on the eddy heat flux index times the index trend. Here, the eddy-heat-flux-index (i.e., the three-month mean eddy heat flux vertically averaged from 50-10 hPa over 40°S-90°S) is used to represent the strength of the BDC.

Fu, Solomon, and Lin (Atmos. Chem. Phys., 2010)

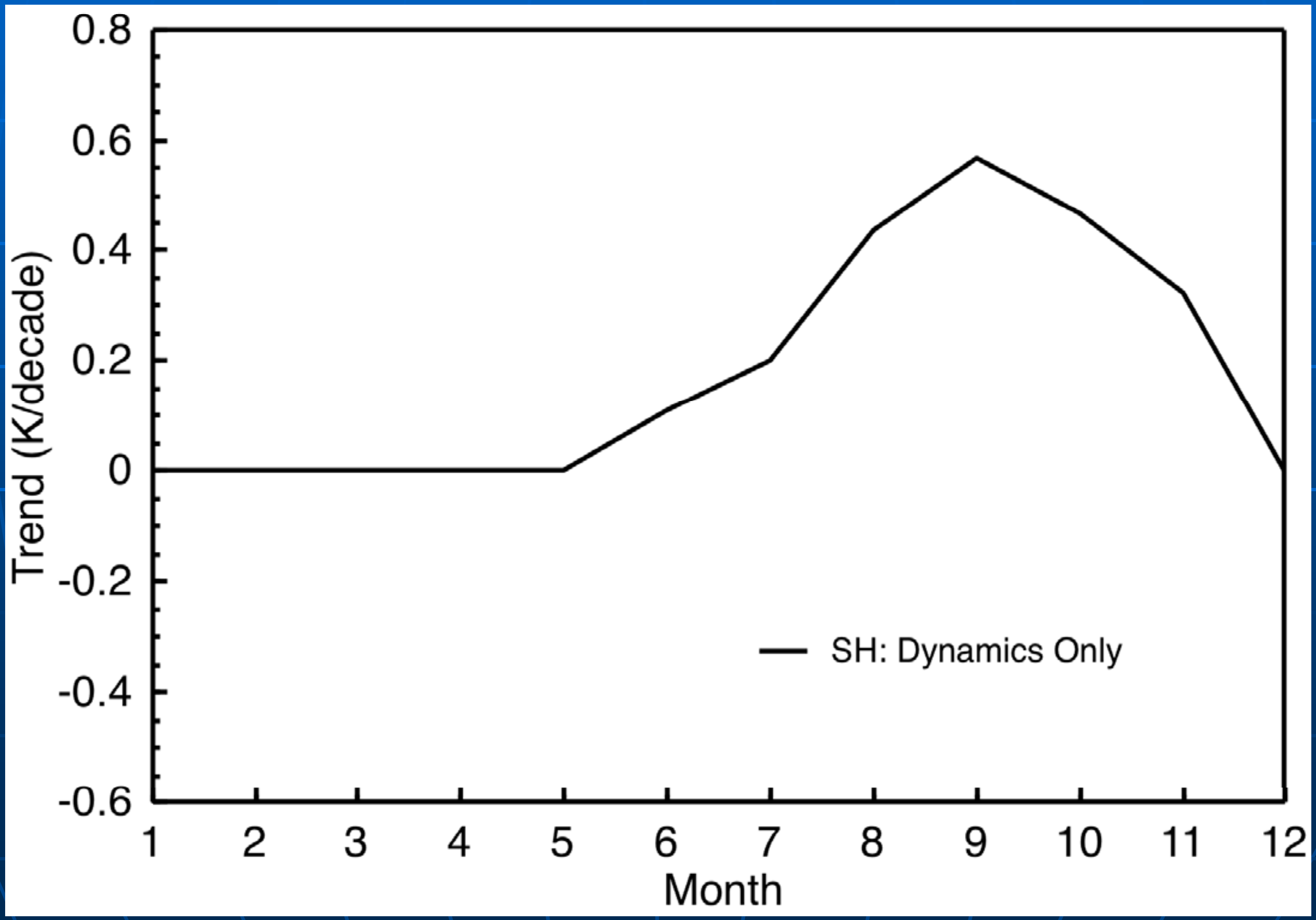
- Eddy heat flux: NCEP/NCAR reanalysis (Kalnay et al. 1996)



September (SHHL)

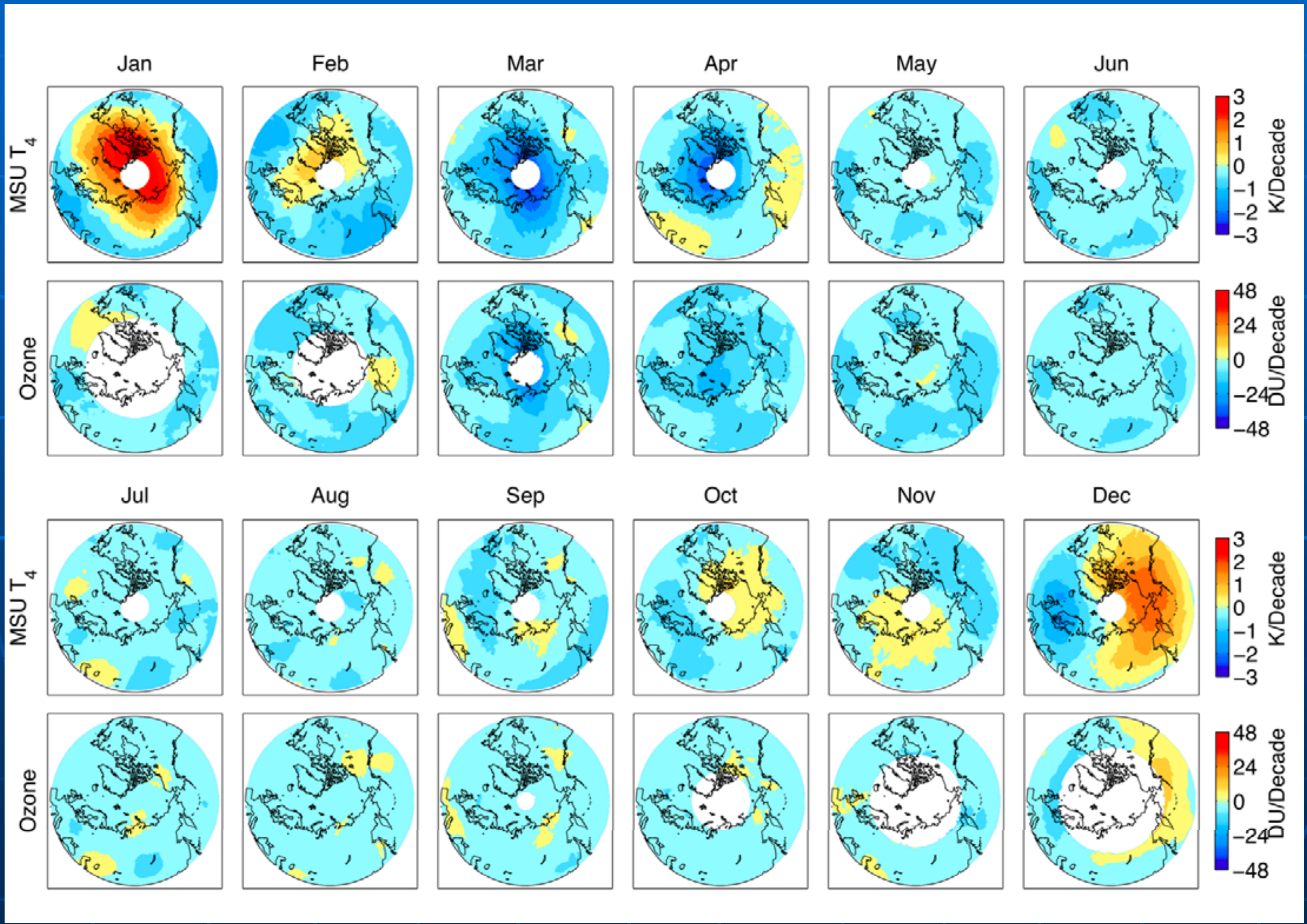


T_4 Trends due to Dynamical Contribution in SH High Latitudes (poleward of 40°S)

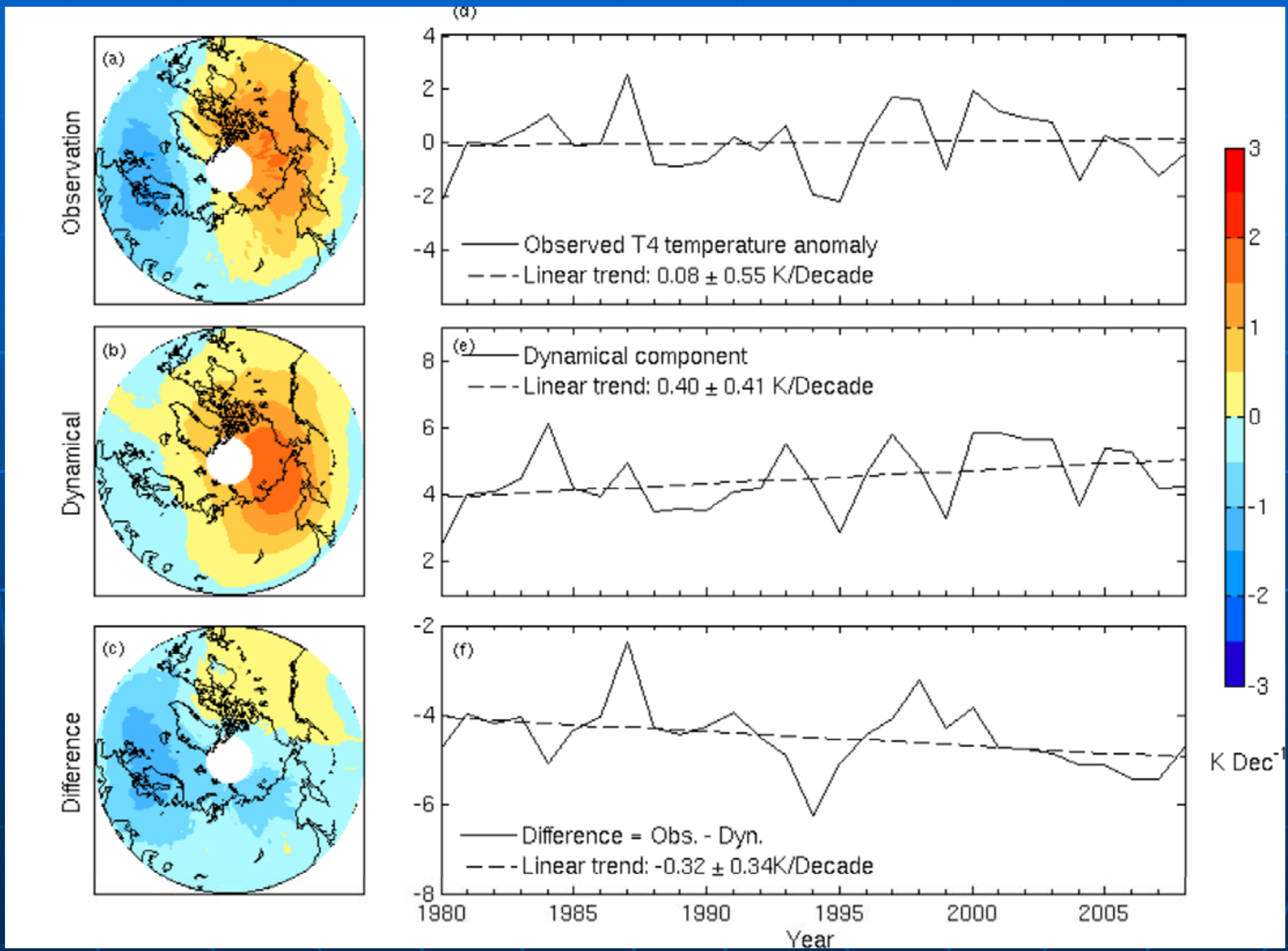


Northern Hemisphere High Latitudes

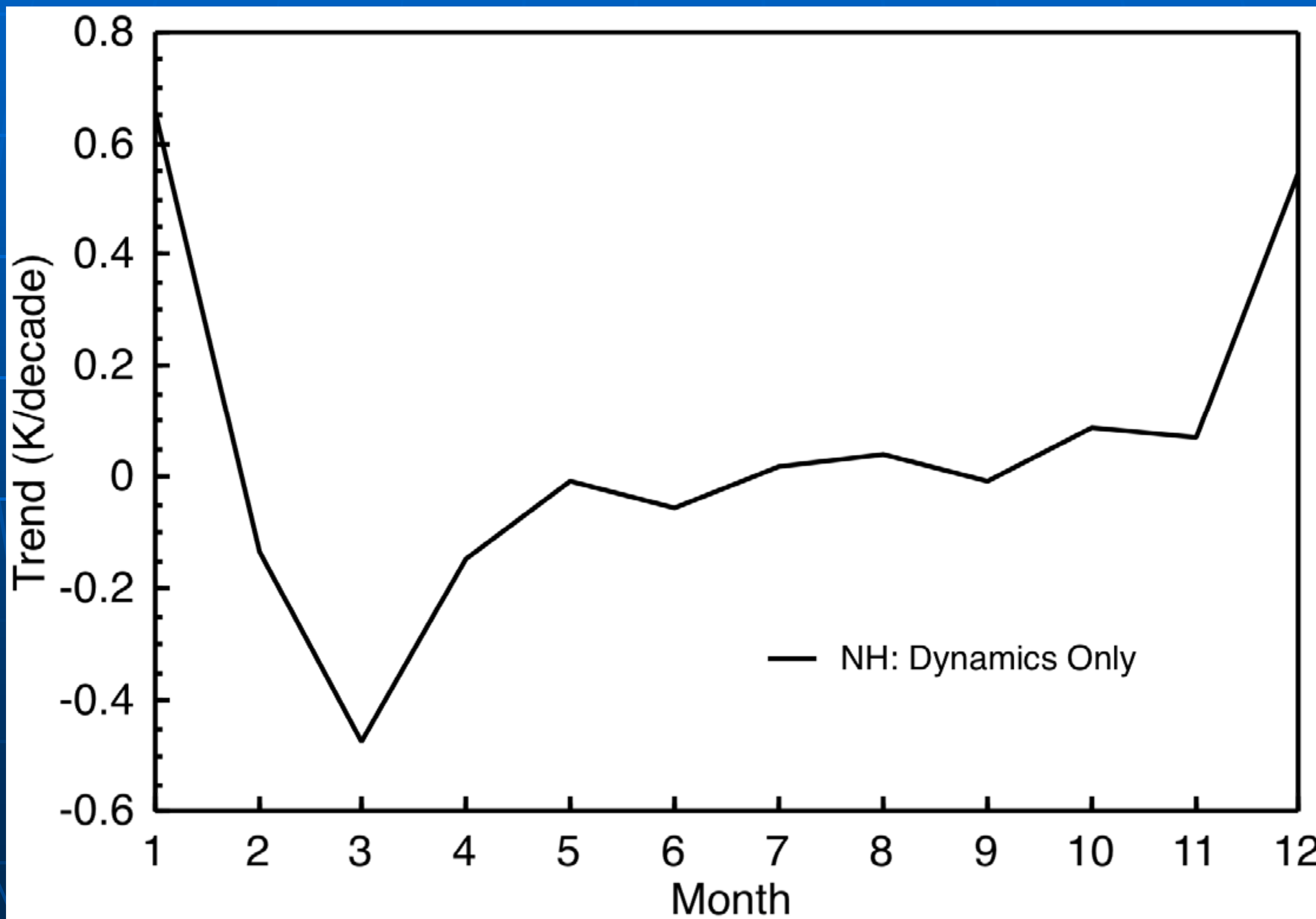
Monthly Trend Patterns of T_4 and TOMS total Ozone for 1979-2008



December (NHHL)

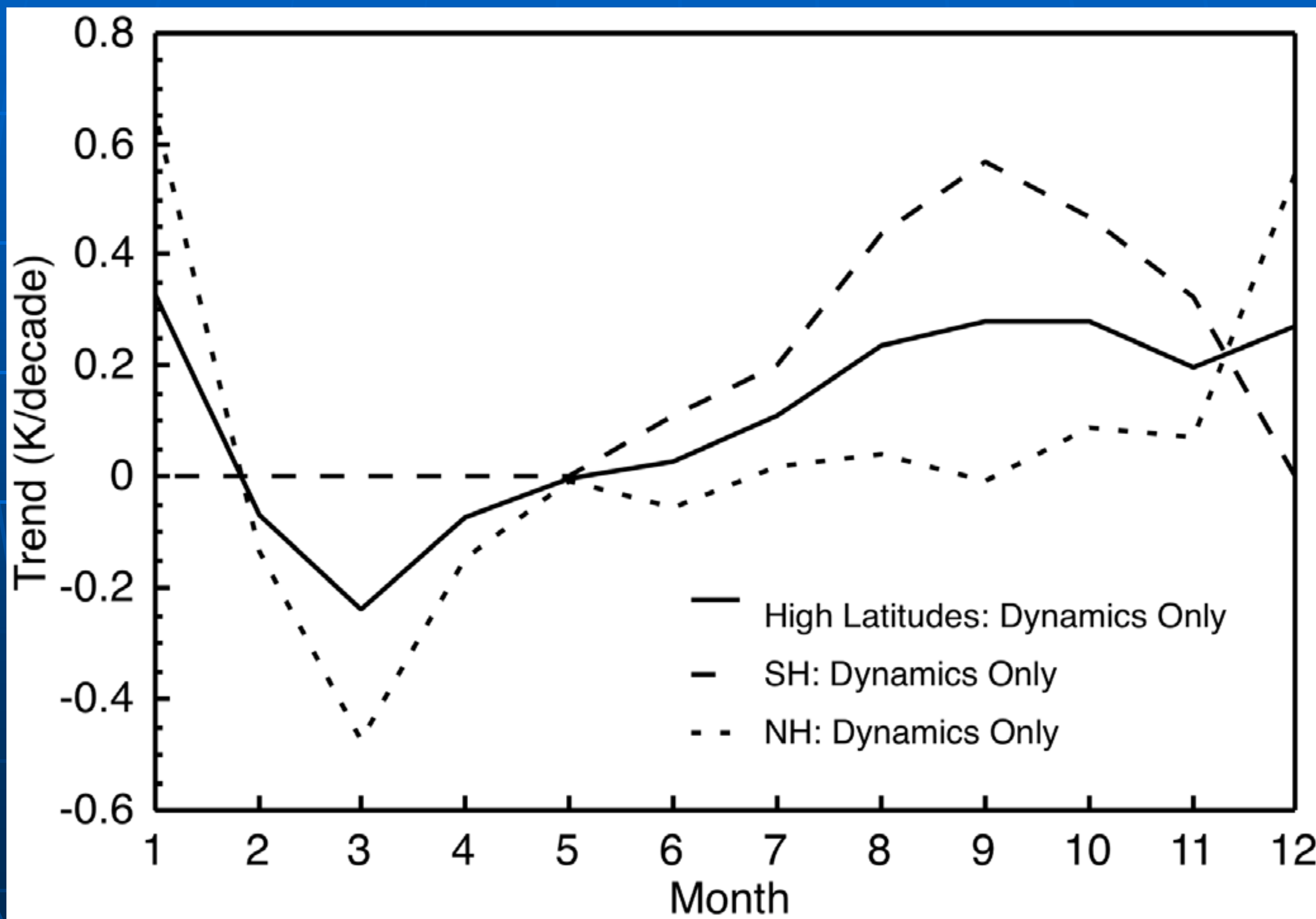


T_4 Trends due to Dynamical Contribution in NH High Latitudes (poleward of 40°N)



From High-Latitudes to Tropics

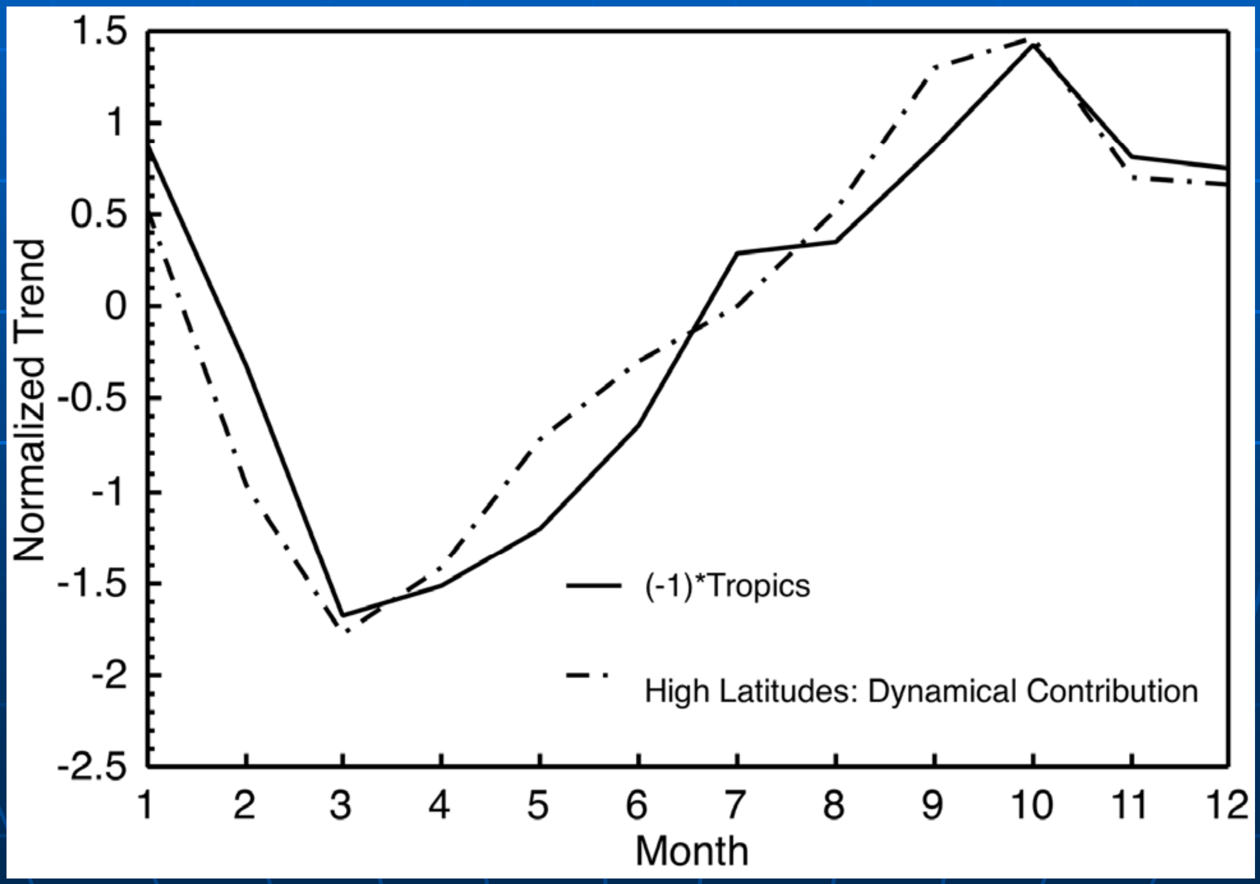
T_4 Trends due to Dynamical Contributions in High Latitudes (poleward of 40°S and 40°N)



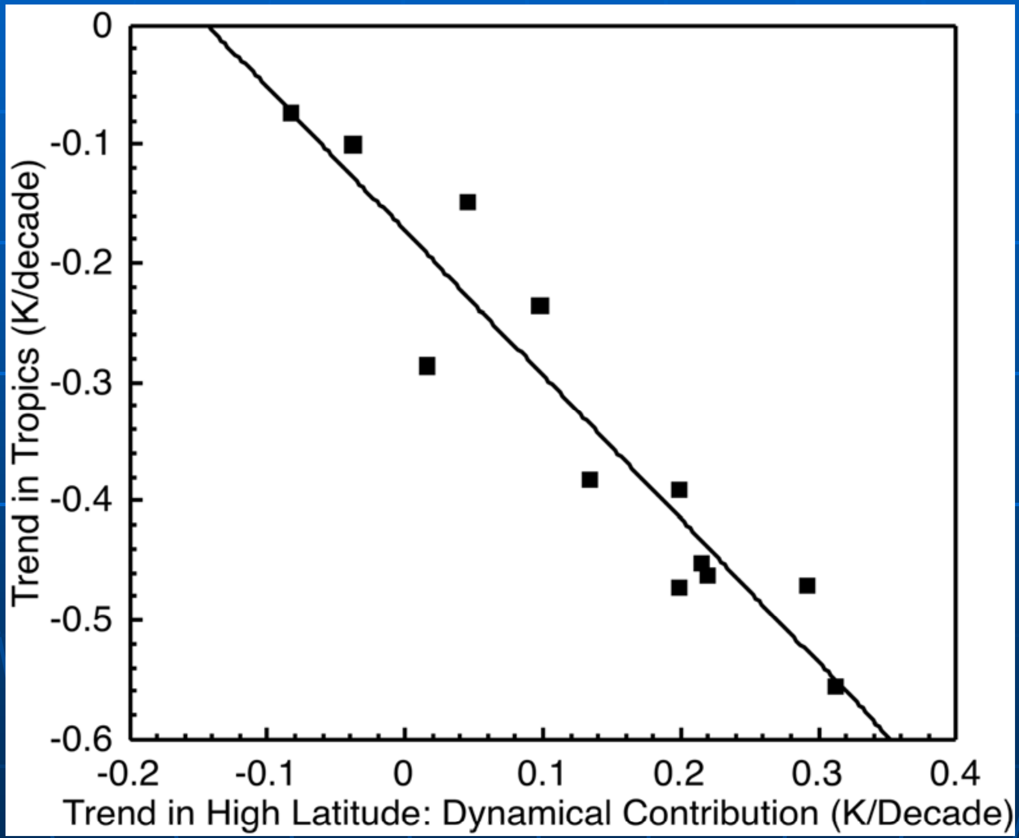
Normalized Trends

$$(x_i - \overline{x}) / (\sum_{i=1}^{12} (x_i - \overline{x})^2 / 12)^{1/2}$$

Comparison of T_4 Trends (normalized) in Tropics with Dynamically Induced T_4 Trends (normalized) in High Latitudes

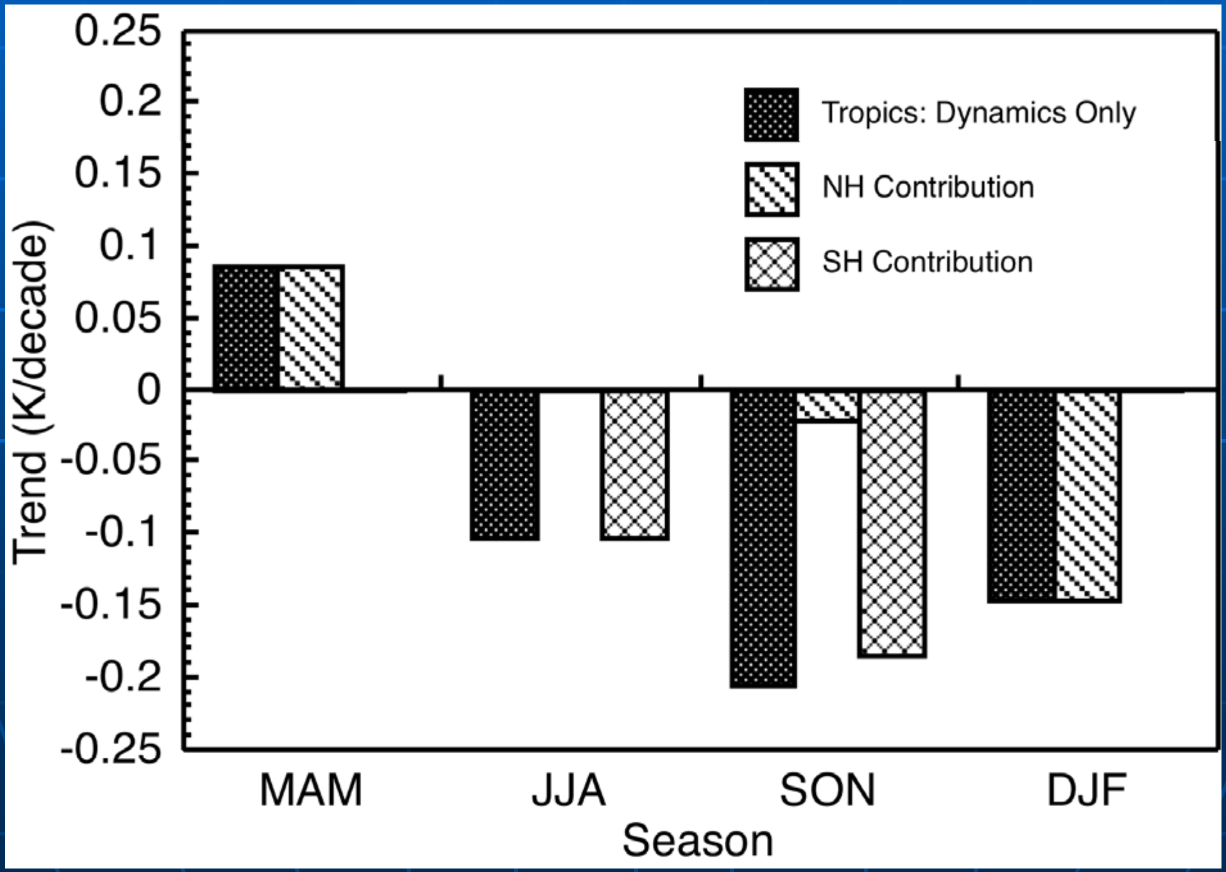


T_4 Trends in Tropics versus Dynamically Induced T_4 Trends in High Latitudes

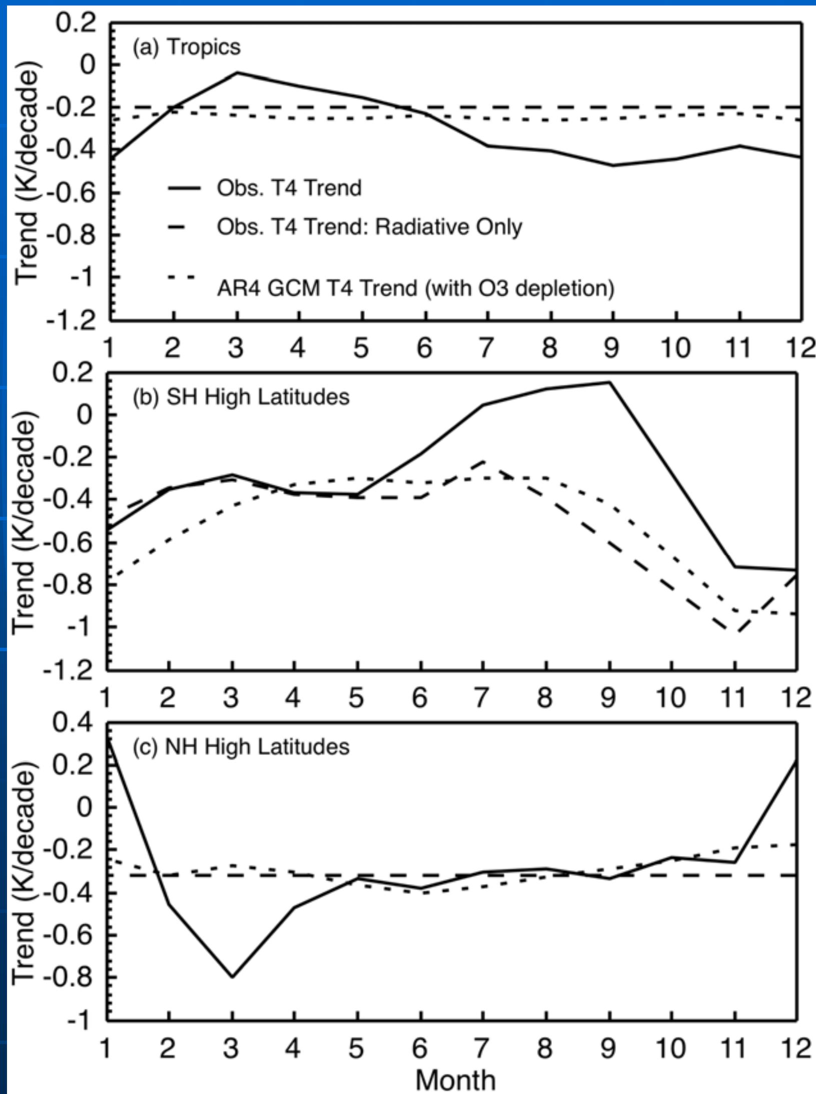


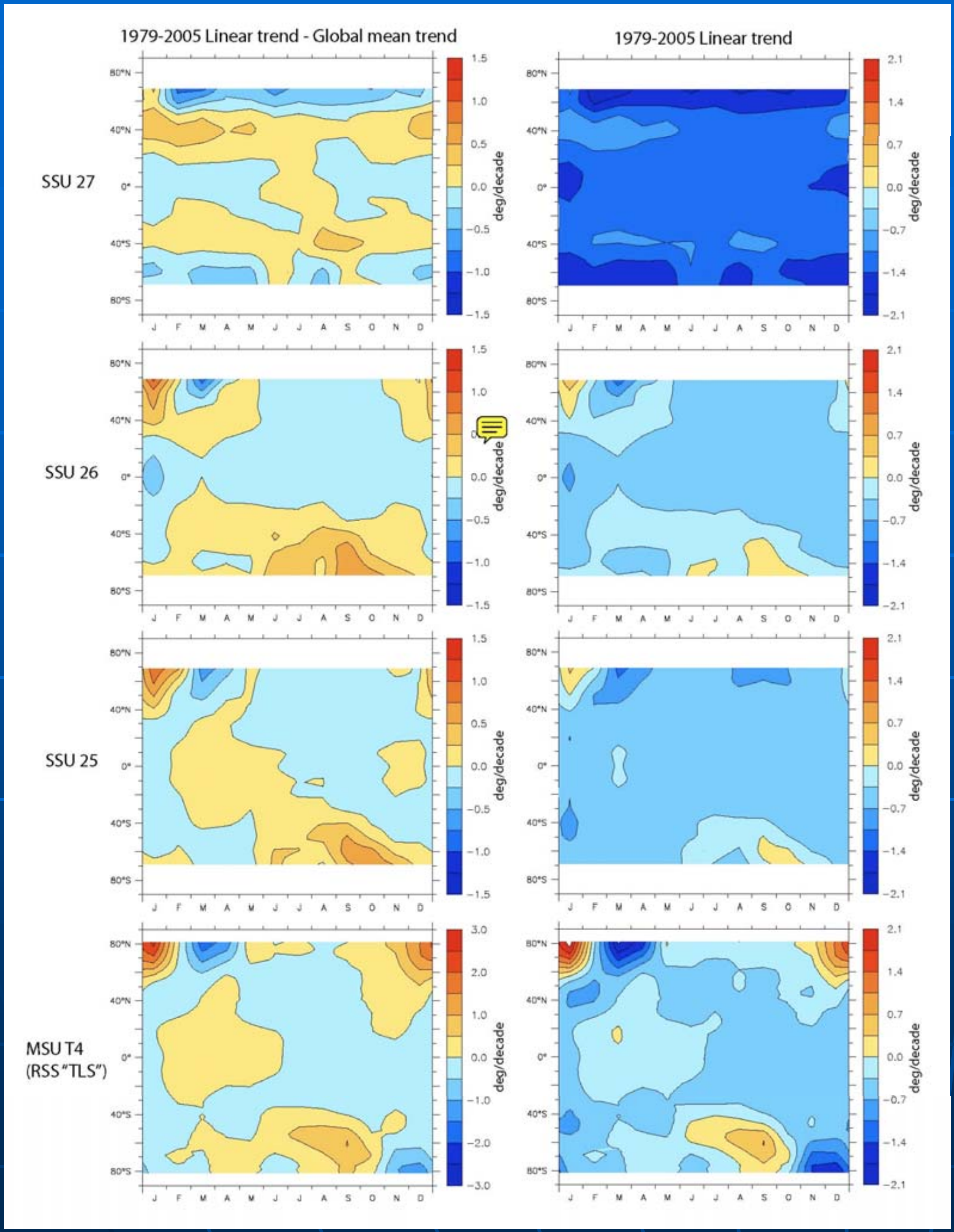
$T_{4,Tropics} = -0.19 - 1.1 * T_{4,High\_Lati,\ Dynamical\ Contri.}$; R = -0.95

T_4 Trends in the Tropics due to the Dynamical Contribution and its Partitioning between the NH and SH



IPCC AR4 GCMs versus Obs.





Young et al.
(to be submitted to J. Climate)

Conclusions

- The seasonality of tropical lower-stratospheric temperature trends is largely driven by the change of BDC;
- We estimated that the tropical lower stratospheric cooling due to the radiative forcing is -0.19 K/decade;
- The BDC is strengthening since 1979 in July-November related to the SH and in December-February to the NH. The BDC is weakening in March-May through its NH cell.
- The above novel observational evidence has important implications for the understanding of climate change in the stratosphere as well as testing climate model simulations.