What Determines Tropical Tropopause Parameters?

Results from a modeling study with the AMTRAC coupled chemistry climate model

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Model and Data

- AMTRAC coupled chemistry climate model, GFDL
- CCMVal simulations (3 members)

  PAST 1960-1990

  historical forcings (SST, GHG, ODS)

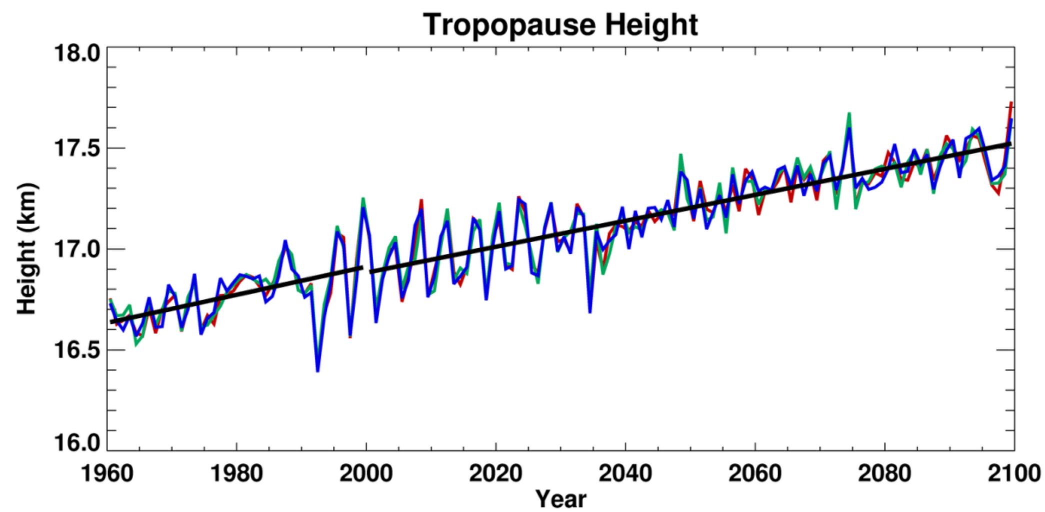
  FUTURE 1990-2100

  IPCC-A1B and WMO (2003) forcings

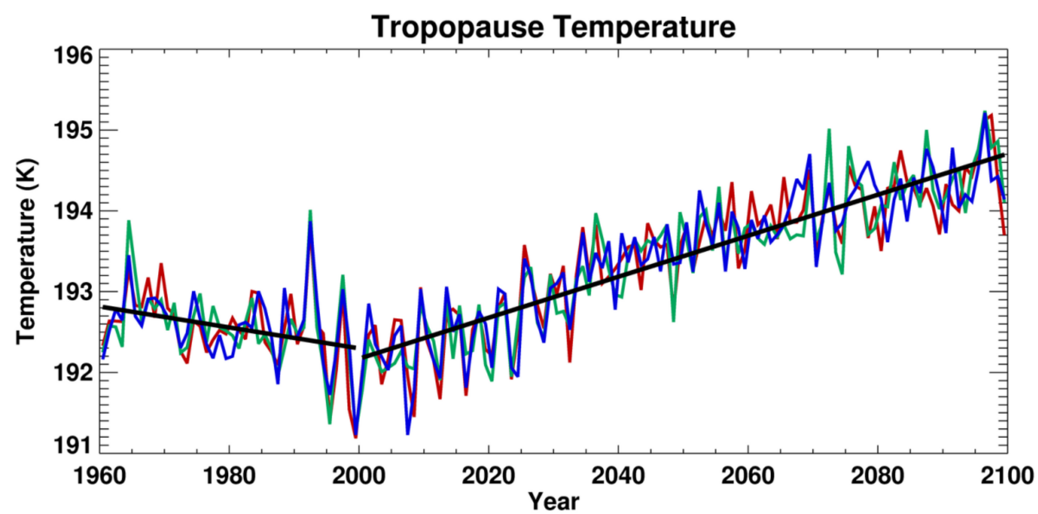
  SSTs from GFDL-CM2.1
- Tropical cold point tropopause parameters
  - pressure, height, temperature
  - annual means

Tropical Tropopause Evolution

- Heights
  - PAST: Increase
  - FUTURE: Increase
  - 1960-2100: ca. 1 km



- Temperatures
  - PAST: Cooling
  - FUTURE: warming



Attribution analysis I

Multiple regression

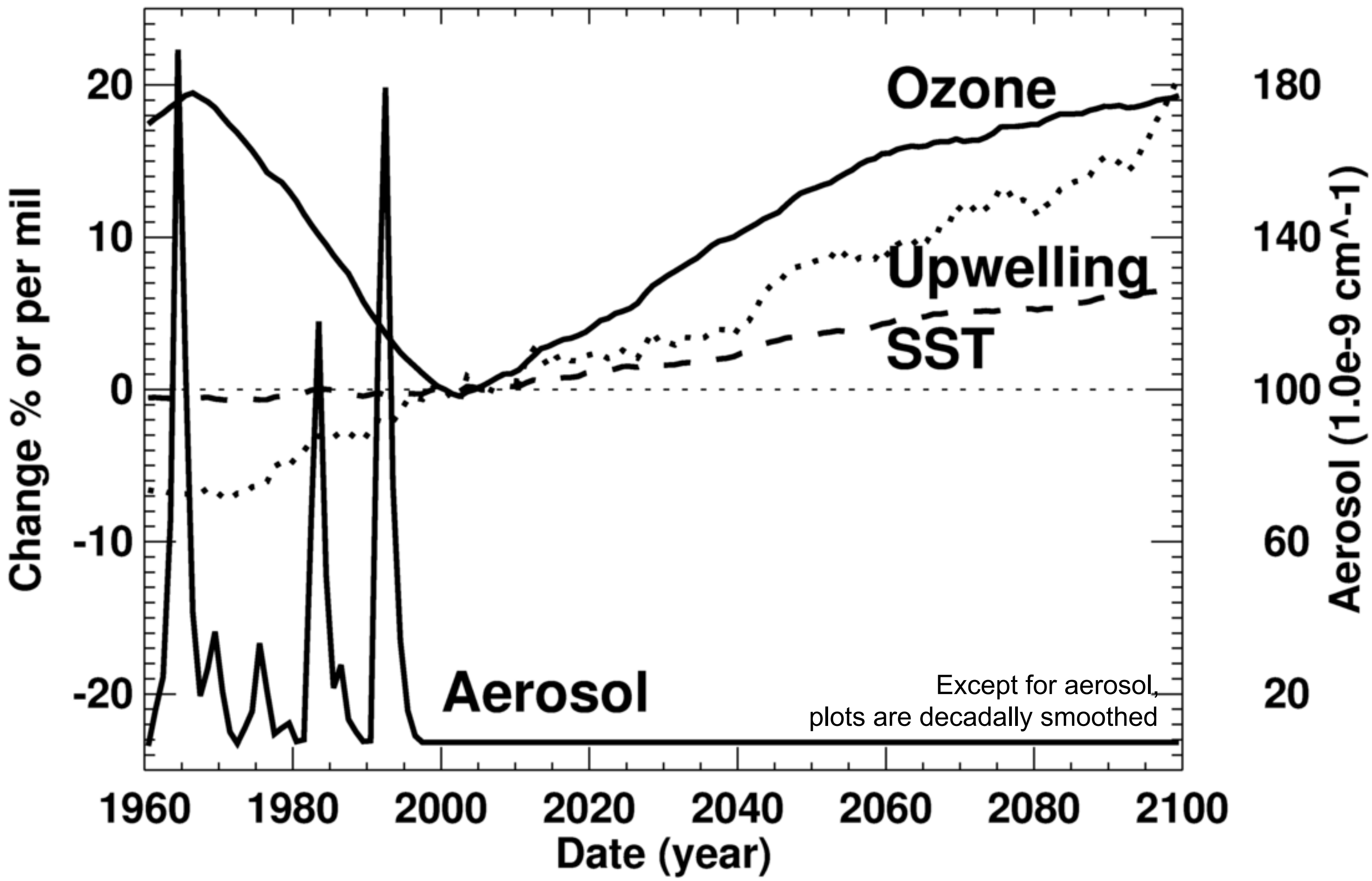
Linear Regression Model

Fit tropical tropopause parameters (temperature, pressure, height) to a linear regression model using the following four predictors:

AER Aerosols (60 hPa at equator)
SST Tropical SSTs (22S-22N)
O_3 Total ozone (globally averaged)
UPW Tropical mass upwelling (77 hPa), BDC

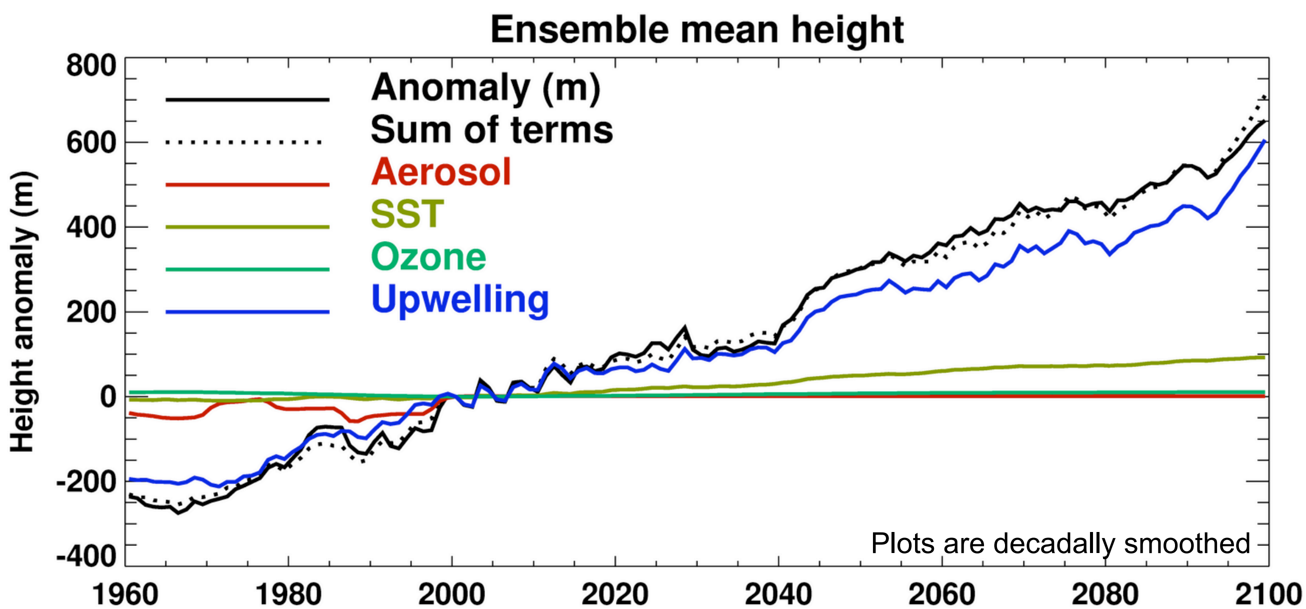
These factors represent major processes known to influence the tropopause parameters.

Regression Parameters Evolution



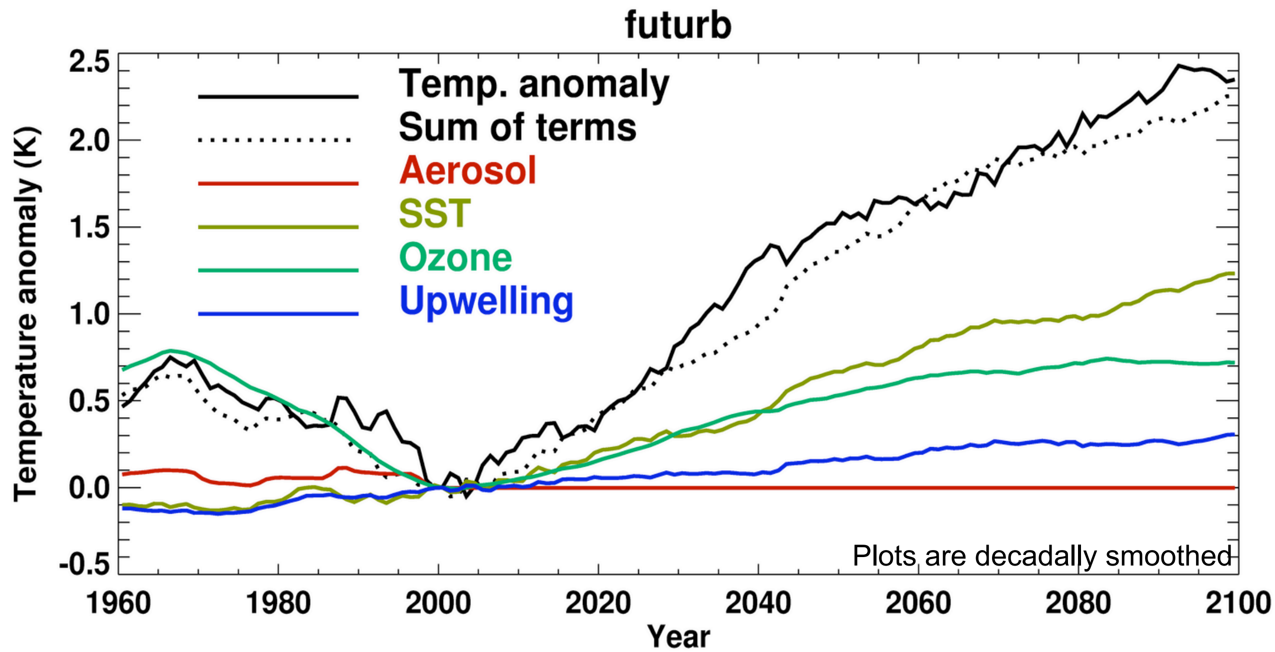
Regression Analysis: Heights

Contribution of each term to tropopause height



Tropical upwelling (UPW) is most important predictor for tropopause height change; SST change is also important

Regression Analysis: Temperatures



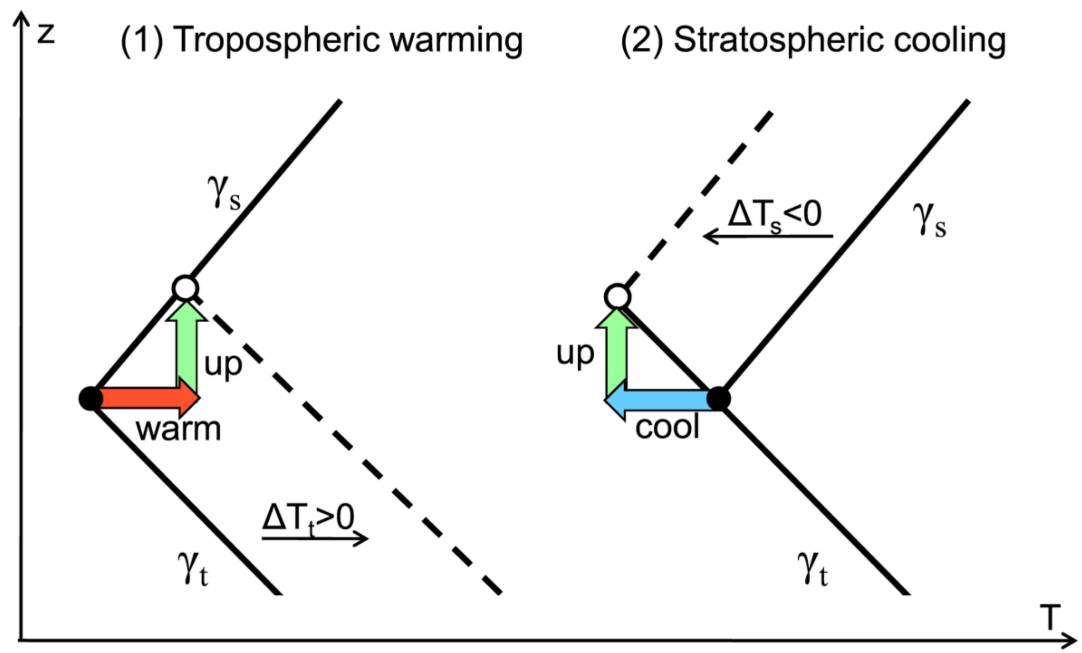
- O_3 dominates PAST
- SST dominates FUTURE

Attribution analysis II

Conceptual tropopause model

Conceptual Tropopause Model

- Shepherd (2002): Tropopause at intersection of constant lapse rate profiles
- Explain tropopause change by temperature change below (ΔT_t) and above (ΔT_s) tropopause



- Staten and Reichler (2008):

$$\Delta T_{trop} = \frac{\Delta T_s \cdot \gamma_t - \Delta T_t \cdot \gamma_s}{\gamma_t - \gamma_s} \quad \text{and} \quad \Delta Z_{trop} = \frac{\Delta T_t - \Delta T_s}{\gamma_t - \gamma_s}$$

Testing the Simple Model

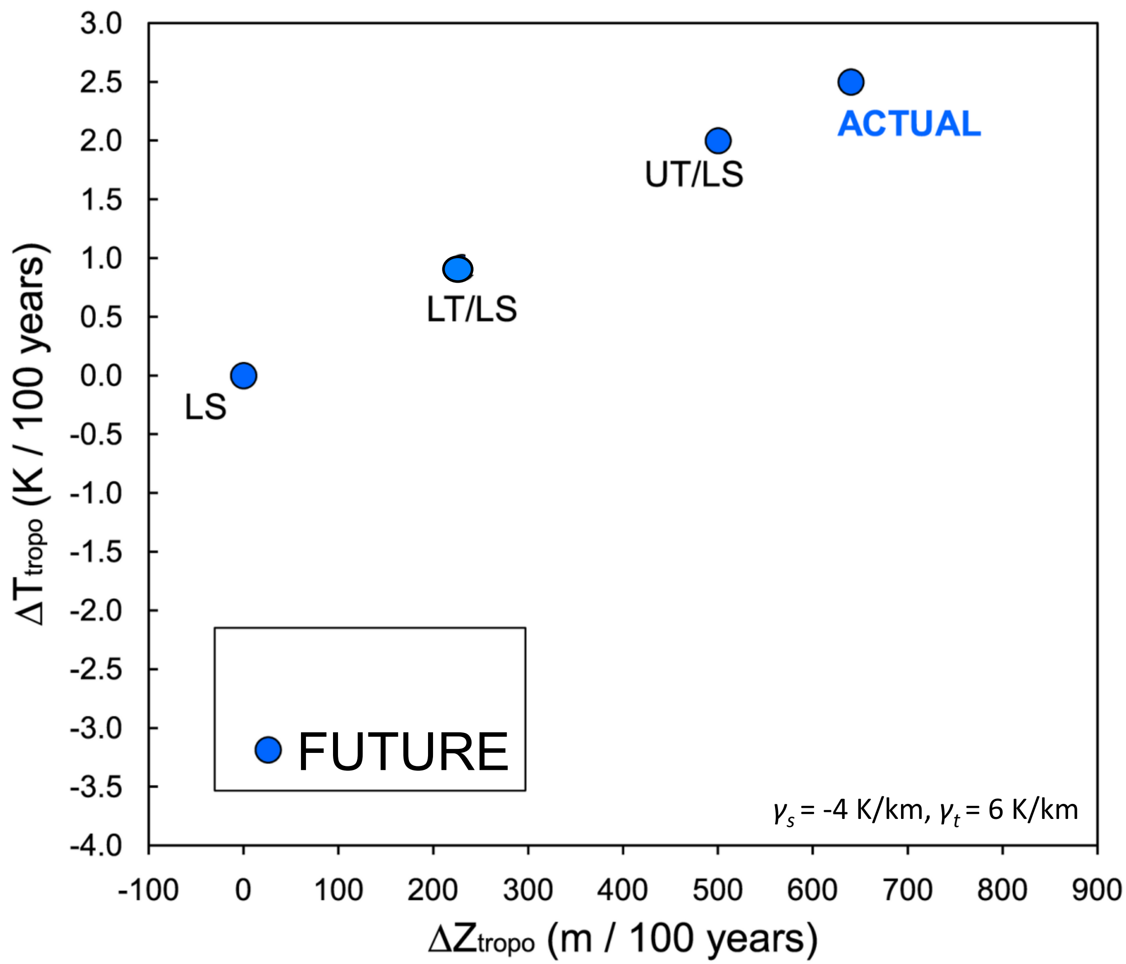
- Use model simulated temperature trends above ΔT_s (0, LS) and below ΔT_t (0, LT, UT) tropopause

PAST **LS** (and UT)

Testing the Simple Model

- Use model simulated temperature trends above ΔT_s (0) and below ΔT_t (0, LT, UT) tropopause

FUTURE (LS and) **UT**



Cause and Effect Analysis

Change per century	ΔZ_{trop}	ΔT_{trop}
PAST	700	-1.3
FUTURE	640	2.5

ΔZ_{trop}
- PAST: LS cooling dominates
- FUTURE: UT warming dominates

ΔT_{trop}
- similar

PAST ΔT_{LS} O_3, UPW, GHG

FUTURE ΔT_{UT} GHG

Summary

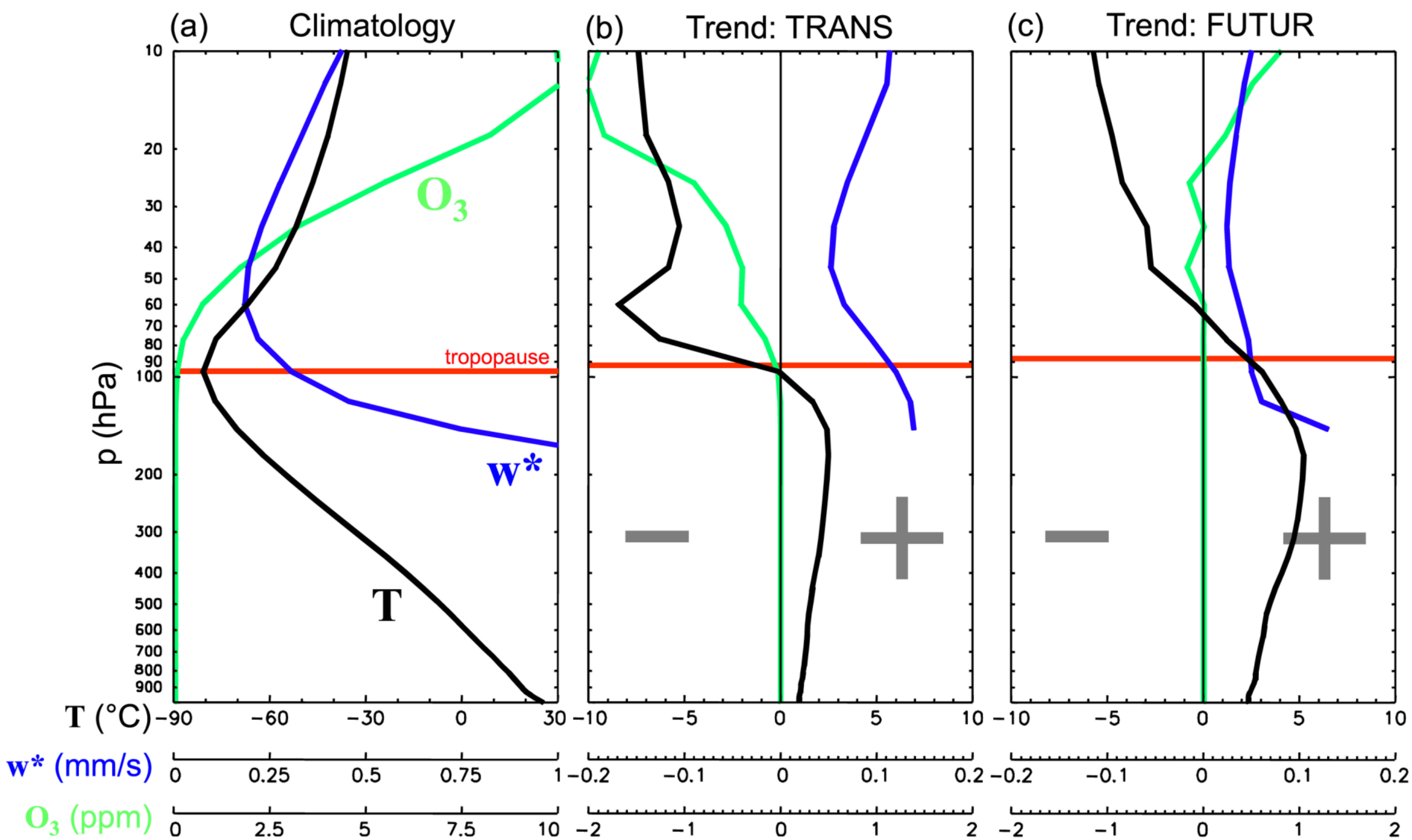
		Conceptual
PAST	$\Delta T \downarrow$ $\Delta Z \uparrow$	$\Delta T_{LS} \downarrow$ O_3 + UPW + GHG

- In the PAST, lower **stratospheric cooling** was most important for **cooling and lifting** of the tropopause
- In the FUTURE, upper **tropospheric warming** will be most responsible for **warming and lifting** of the tropopause

Thank You

More info: Austin and Reichler (2008, JGR)

Trend Analysis



Decadal Trends

	Tropics		Global	
	PAST	FUTURE	1980-2004	OBS
Height [m/dec.]	70	64	123	64
Pressure [hPa/dec.]	-1.03	-0.55	-2.6	-1.7
Temperature [K/dec.]	-0.13	0.25	-0.27	-0.41

Seidel and Randel (2006)