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)
- **O₃**: 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

Except for aerosol, plots are decadally smoothed.
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 ($\Delta T_t$) and above ($\Delta T_s$) tropopause

\[
\Delta T_{trop} = \frac{\Delta T_s \cdot \gamma_t - \Delta T_t \cdot \gamma_s}{\gamma_t - \gamma_s}
\]
and
\[
\Delta Z_{trop} = \frac{\Delta T_t - \Delta T_s}{\gamma_t - \gamma_s}
\]
Testing the Simple Model

- Use model simulated temperature trends above $\Delta T_s (0, \text{LS})$ and below $\Delta T_t (0, \text{LT, UT})$ tropopause

PAST \textbf{LS} (and UT)
Testing the Simple Model

- Use model simulated temperature trends above $\Delta T_s(0)$ and below $\Delta T_t(0, LT, UT)$ tropopause

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<table>
<thead>
<tr>
<th>$\gamma_s$</th>
<th>$\gamma_t$</th>
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<tbody>
<tr>
<td>-4 K/km</td>
<td>6 K/km</td>
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</table>

FUTURE (LS and) UT
Cause and Effect Analysis

<table>
<thead>
<tr>
<th>Change per century</th>
<th>ΔZ_{trop}</th>
<th>ΔT_{trop}</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAST</td>
<td>700</td>
<td>-1.3</td>
</tr>
<tr>
<td>FUTURE</td>
<td>640</td>
<td>2.5</td>
</tr>
</tbody>
</table>

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

ΔT_{trop} • similar

PAST
ΔT_{LSO_3, UPW, GHG}

FUTURE
ΔT_{UT} GHG
### Summary

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.

<table>
<thead>
<tr>
<th></th>
<th>PAST</th>
<th>Conceptual</th>
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<tbody>
<tr>
<td></td>
<td>$\Delta T \downarrow$</td>
<td>$\Delta T_{LS} \downarrow$</td>
</tr>
<tr>
<td></td>
<td>$\Delta Z \uparrow$</td>
<td>$O_3 + \text{UPW} + \text{GHG}$</td>
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</tbody>
</table>
Thank You

More info: Austin and Reichler (2008, JGR)
Trend Analysis

(a) Climatology

(b) Trend: TRANS

(c) Trend: FUTUR

\( T \) (°C)

\( p \) (hPa)

\( w^* \) (mm/s)

\( O_3 \) (ppm)

Tropopause
## Decadal Trends

<table>
<thead>
<tr>
<th></th>
<th>Tropics</th>
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<th>Global</th>
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<tbody>
<tr>
<td></td>
<td>PAST</td>
<td>FUTURE</td>
<td>1980-2004</td>
<td>OBS</td>
</tr>
<tr>
<td>Height [m/dec.]</td>
<td>70</td>
<td>64</td>
<td>123</td>
<td>64</td>
</tr>
<tr>
<td>Pressure [hPa/dec.]</td>
<td>-1.03</td>
<td>-0.55</td>
<td>-2.6</td>
<td>-1.7</td>
</tr>
<tr>
<td>Temperature [K/dec.]</td>
<td>-0.13</td>
<td>0.25</td>
<td>-0.27</td>
<td>-0.41</td>
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</tbody>
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