Lower Stratospheric Temperature Tendencies and their Possible Effect on Tropical Cyclone Activity

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Second Split Workshop in Atmospheric Physics and Oceanography

Outline

- Introduction
- Quality of the available observational data for deriving stratospheric temperature trends
- Causes of stratospheric cooling
- Connection between lower stratosphere/tropical tropopause layer temperature and potential intensity
- Summary

Introduction

- Hurricanes and climate
- Change in climate $\rightarrow$change in hurricane characteristics (intensity, duration, frequency).

$$V_p^2 = \frac{T_s - T_{out}}{T_{out}} \frac{F_{rad} - d\nabla \cdot \vec{F}_{ocean}}{C_D \rho |\vec{V}_s|}$$

V_p: potential maximum wind speed;
T_s: sea surface temperature;
T_{out}: entropy weighted outflow temperature;
C_D: non dimensional exchange coefficient for momentum;
d: depth of the ocean mixed layer;
F_{rad}: downward radiative flux;
$\vec{F}_{ocean}$: net heat flux in the ocean mixed layer.

Introduction

Explored:

- Response of PI to changes in SST
- Response of PI to changes in green house gases concentration

Not explored:

- Responce of PI to changes in the lower stratospheric temperature

What kind of observational data is on the market?

How accurate are the derived temperature trends in the stratosphere?

Radiosonde data

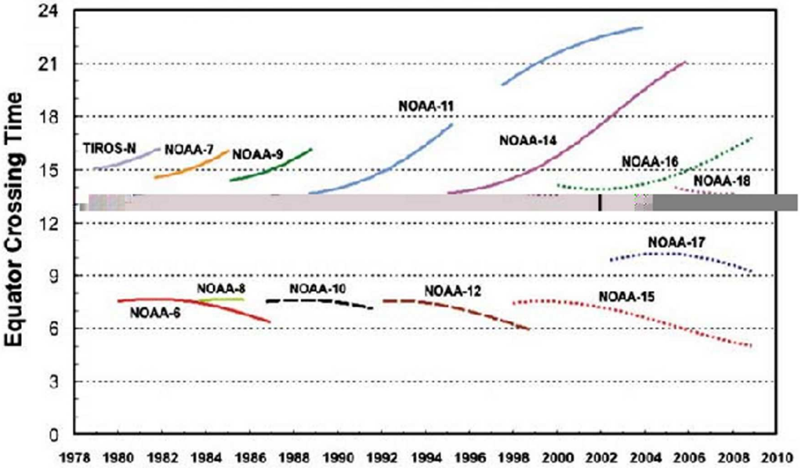
- Begin in late 1950s.
- The data contains inhomogeneities due to changes in instrumentation and observational practice.

Satellite data

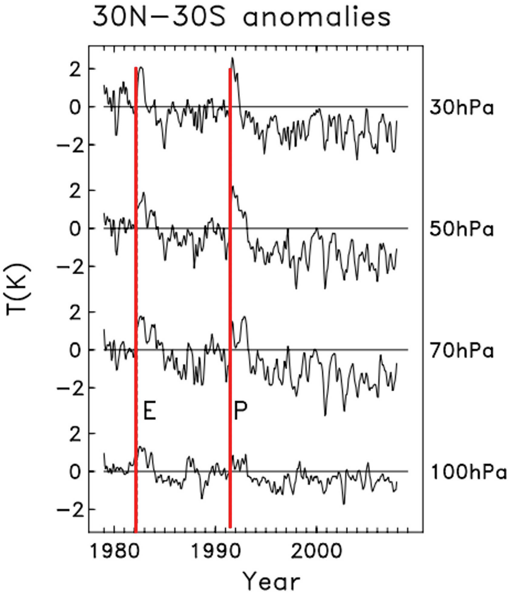
- Continuous time series since late 1970s.
- Short lived individual instruments, so that the series is derived from 13 different satellites. Very difficult!

Reanalysis data based on the radiosonde and satellite data.

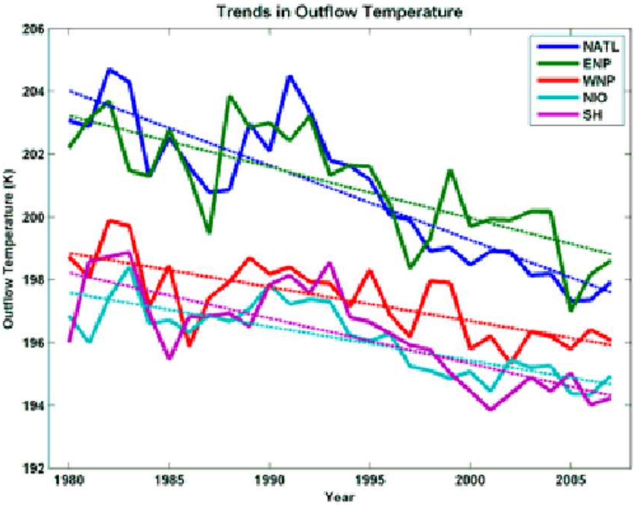
Observations



(Randel et al., 2009): Equatorial crossing time and life span of the individual instruments used since 1978.

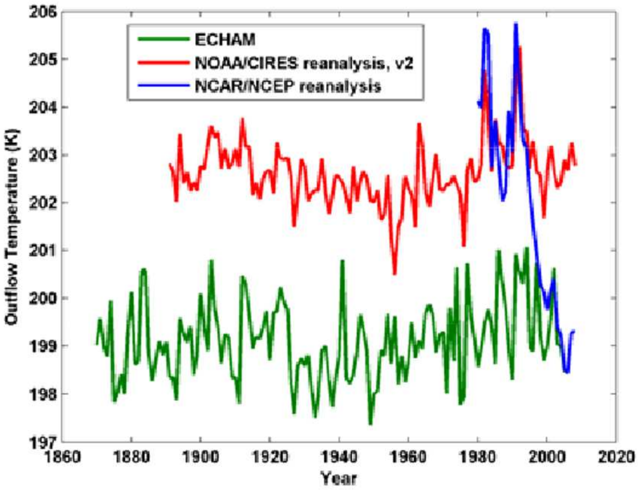


(Randal et al., 2009): Time series of tropical lower stratosphere temperature anomalies, derived from radiosonde data. The red lines denote the major volcanic events, El Chichon and Pinatubo.



(Emanuel, 2010): Outflow temperature trends for 5 regions of the tropical oceans. From NCEP reanalysis data.

Outflow Temperature
Reanalysis data



Causes of stratospheric cooling

What stands behind this long term cooling trend of the stratosphere?

Radiative forcings in a coupled atmosphere-ocean model

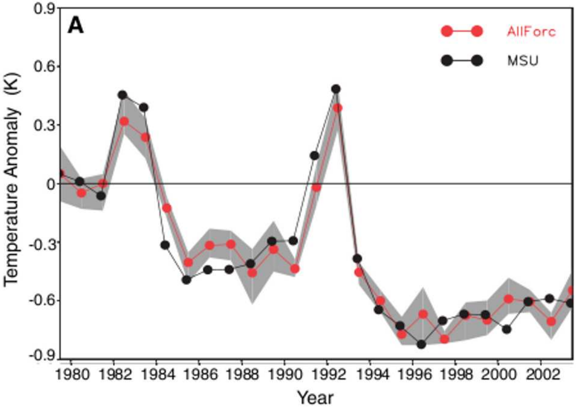
Natural forcings

- Solar irradiance
- volcanic aerosols

Anthropogenic forcings

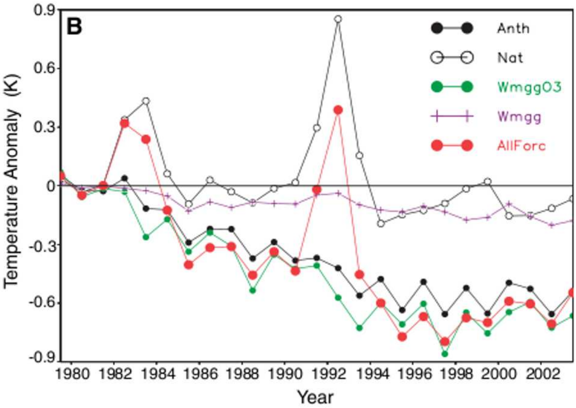
- well-mixed green house gases
- ozone depletion
- tropospheric aerosols
- land use

Causes of stratospheric cooling



(Ramaswamy et al. 2006): Observed (black line) and model-simulated ensemble mean (red line) of the globally and annually averaged temperature anomalies relative to their respective 1979-1981 averages.

Causes of stratospheric cooling



(Ramaswamy et al. 2006): Model-simulated ensemble mean of the globally and annually averaged temperature anomalies (relative to their respective 1979-1981 averages) due to particular forcing.

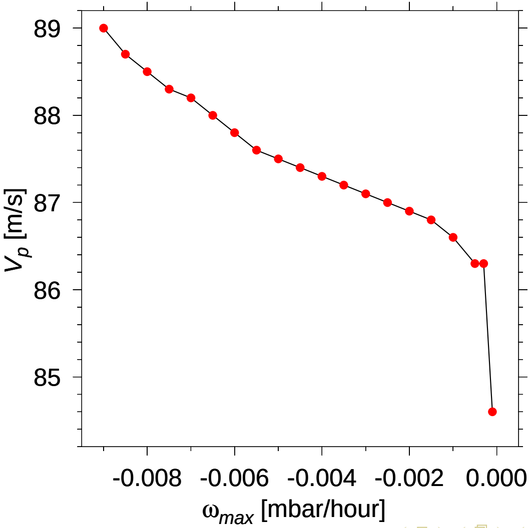
Lower Stratospheric Temperature and PI

What is the potential intensity response to changes in the lower stratospheric temperature?

Single column model with a dynamical forcing.

- Obtain radiative-convective equilibrium (RCE) state
- Start from the equilibrium state, apply dynamical forcing and run it till RCE
- Do numbers of simulations with different magnitude of the forcing and plot.

Radiative-convective equilibrium state (with no vertical velocity):
$SST = 29^o C$, $V_p = 68.8\, m/s$, $T_{min} = -68.9^o C$



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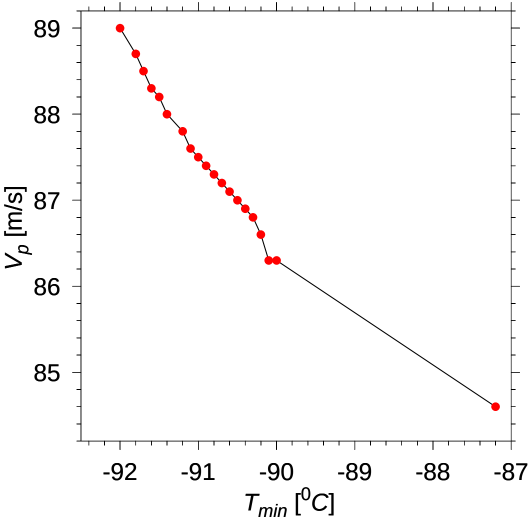

Summary

- Over the last 3 decades a cooling trend of the lower stratosphere has been observed.
- The cooling is a result of combined natural and anthropogenic forcings, with the biggest contribution from ozone depletion.
- The cooling trend of the lower stratosphere is likely to contribute significantly to the observed upward trend of the potential intensity.
- Not all the GCMs capture the decline in the outflow temperature.