The Ozone Radiative Seasonal Cycle and its Contributions to Tropical Cyclone Potential Intensities

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Quadrennial Ozone Symposium, 09.07.2016

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Some figures from Gilford and Solomon (submitted, J. Climate, 08/16)
Ozone plays an important radiative role in the lower stratospheric seasonal cycle.

- Chae and Sherwood used a radiative-convective model with upwelling and ozone variations to show that ozone amplifies the lower stratosphere T seasonal cycle.
- Fueglistaler et al. (2011) used a purely radiative method to show similar results.

**Chae and Sherwood (2007)**
Near-tropopause temperatures could be radiatively sensitive to the vertical structure of ozone seasonality.
Data and Methods

**Ozone**  
Aura Microwave Limb Sounder (MLS), version 3.3 [Livesey et al. 2011]  
- Ozone concentrations, 2005-2013  
- 5° x 5°, 316–0.02 hPa, 39 vertical levels

**Radiation**  
Parallel Offline Radiative Transfer (PORT) model [Conley et al. 2013]  
- 1.9° x 2.5°, Surface–3.5 hPa, 26 Hybrid vertical levels  
- Seasonally Evolving Fixed Dynamical Heating (SEFDH) assumption, One-year simulations with 4 month spin-up time (16 months total)
Radiative Calculations and Sensitivity Experiments

Apply ozone seasonal cycles to PORT background

Run PORT with SEFDH, retain heating rates

Analyze resulting Temperature Adjustments

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Radiative Calculations and Sensitivity Experiments

**Methods**

- Apply ozone seasonal cycles to PORT background
- Run PORT with SEFDH, retain heating rates
- Analyze resulting Temperature Adjustments

![Graph showing O3 Anomaly from Mean (%) for August](image)

- No seasonal cycle above
- Between the tropopause and 56 hPa or 85 hPa layers

~Tropopause
Ozone radiative seasonal cycles are sensitive to the overlying seasonal cycle structure

Tropical Temperature or Radiative Seasonal Cycles (K), 85hPa

![Graph showing different ozone seasonal cycles above 85 hPa and their significance for lower levels, linked to LW emission.](image)
Ozone’s radiative seasonal cycles are heterogeneous across the tropics

- We define tropical cyclone (TC) development basins following Wing et al. (2015)
- Ozone will likely have different radiative effects on TC outflow temperatures in different basins
Tropical Cyclone Potential Intensities depend on Outflow Temperatures near the tropopause

The potential intensity (PI) of a TC is defined as (e.g. Bister and Emanuel 1998):

\[ PI^2 = c \frac{T_s - T_0}{T_0} \cdot E \]

**PI increases with:**
- Warmer SSTs ($T_s$)
- Cooler outflow temperatures ($T_0$)
- Increases in thermodynamic disequilibrium ($E$)

Environmental conditions from MERRA

Emanuel (2006)
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with:

- Warmer SSTs ($T_s$)
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Environmental conditions from MERRA

What do the TC PI **seasonal cycles** look like, and [how] do near-tropopause radiative seasonal cycles affect them?
Baseline tropical cyclone seasonal cycles in NA and WNP show different dependencies on outflow temperatures.

**NA seasonality strongly linked to SSTs**

**WNP has very little seasonality because of competing To and SSTs**

\[
Eff = \frac{T_s - T_0}{T_0}
\]
Baseline tropical cyclone seasonal cycles in NA and WNP show different dependencies on outflow temperatures.

NA seasonality strongly linked to SSTs

WNP has very little seasonality because of competing To and SSTs

We next linearly remove the profiles of ozone radiative seasonal cycles in WNP: What are their impacts on To and TC PI?

\[ E_{\text{eff}} = \frac{T_s - T_0}{T_0} \]
Ozone radiation can amplify outflow seasonal cycles by up to ~40%.

\textit{WNP} only, solid: full stratosphere seasonal cycle, \textit{dashed}: 85 hPa sensitivity experiment

- **Results**
  - Differences = effects of including ozone
  - Ozone amplifies outflow temperatures
  - Flattens the PI seasonal cycle by ~40%
  - Much of the signal is lost if you do not include ozone seasonality at 70 hPa and above
Summary

Ozone Radiative Seasonal Cycles
→ Ozone’s radiative seasonal cycle account for 30% of the temperature seasonal cycle in the tropical lower stratosphere

→ Longwave emissions from the ozone seasonal cycle at 70 hPa and above contribute at least a third of ozone’s seasonal radiative impact in the lowermost stratosphere

Tropical Cyclones and Implications
→ WNP TC PI seasonal cycle is sensitive to outflow temperatures, the NA basin TC PI seasonality depends on SSTs

→ Ozone seasonal cycles (mainly at 70 hPa and above) amplify outflow temperatures by ~1.5K (peak-to-peak), which damps the TC PI seasonal cycle in the WNP by up to 40%.