Identifying and forecasting deep stratospheric ozone intrusions over the western United States from space

Meiyun Lin
Princeton University & NOAA GFDL

Stratospheric intrusions drive a substantial portion of springtime high surface O$_3$ events in U.S. West

Daily max 8-hr average surface O$_3$ at Boulder (~2 km a.s.l.), Colorado

Insights from a global Hi-Res model and multi-platform obs [Lin et al., 2012; Langford et al., 2012]

- Stratospheric intrusions can episodically increase surface MDA8 O$_3$ by 20-40 ppb, including on days when observed O$_3$ exceeds the standard (75 ppbv)

**The policy challenge:**
1) Screening of “exceptional events”
2) Advanced warning of incoming intrusions

→ Can Aura (OMI) and Aqua (AIRS) sensors help to predict these events?
Total column $O_3$ retrievals capture the **dynamical variability** of $O_3$ due to a stratospheric intrusion (N$\rightarrow$S)

Aqua AIRS Ascending, May 23, 2010

[V5.2; Susskind et al., 2003]

**Consistent dynamic features in AIRS, PV, model and lidar measurements**

[see also Pan et al., 2007; Pittman et al., 2009; Wei et al., 2010]
AIRS captures **day-to-day progression** of upper dynamics conducive to deep stratospheric intrusions over the western U.S.

**AIRS total column O₃ animated every 12 hours from May 25-29, 2010**

2010.05.25T01:30am

Western U.S. is prone to deep intrusions → Co-varying O₃ enhancements in the UT/LS and in the lower trop
**Spatial pattern:** Surface $O_3$ is highest to the SE of where OMI column and mid-trop $O_3$ are enhanced (May 23-25, 2008 example)

**OMI/X. LIU, Total Column**

**OMI/X. LIU, ~550-350 hPa**

**Surface MDA8 $O_3$**
Towards a predictive relationship:
Correlations of daily AIRS UT/LS ozone and surface ozone

Daily max 8-hr average surface O\textsubscript{3} at Chiricahua NM, AZ

Correlation coefficient of observed O\textsubscript{3} and AM3 O\textsubscript{3}S at CHA surface site, respectively, with AIRS 300 hPa O\textsubscript{3} at each 1°x1° grid using daily datasets from April-May in 2011
Forecasting surface destinations of transported O$_3$-strat:
AIRS variability ~5°x5° NW of a receptor site indicates incoming intrusions

Using daily datasets from April-June, 2003-2011

Stronger potential for accurate prediction in ~1 day as to where the intrusion will reach the surface
The spatial pattern of correlations varies interannually: Links to ENSO

Correlation coefficient of AM3 surface $O_3S$ at Grand Canyon NP with AIRS total $O_3$ at each $1^\circ \times 1^\circ$ grid, 0-3 days prior using datasets from April-June.
This first scoping study suggests potential for developing space-based indicators for day-to-day variability in stratospheric influence at WUS surface sites.

Potential AQ Applications:
- Screening of “exceptional events”...combined with suborbital observations
- Advanced warning of regional high $O_3$-Strat events with a lead time of ~1-3 days (more skill in 1 day)
- Qualitatively promising …ongoing work for a quantitative relationship ($\Delta O_3$)
- Utility of other Aura ozone products, e.g. MLS and TES?

Correlation coefficient of AM3 surface $O_3$S at Grand Canyon NP with OMI data on the previous day using daily datasets from April-June, 2005-2008.
**e90 tropopause tracer and O₃-Strat tagging in GFDL AM3**: showing a deep intrusion over Hawaii on March 9, 2004

**e90 vertical cross-section at 150W**

**AIRS total column O₃**

---

**Dynamically varying e90 tropopause tracer** [Prather et al., 2011]:

1) Emitting at the surface uniformly and statically; 90-day e-folding lifetime

2) Differentiate **stratospheric** (< 85 ppb) vs. **tropospheric** (>= 85 ppbv) air

**Stratospheric O₃ tracer (O₃S)** [Lin et al., 2012b]:

1) Set to simulated O₃ in stratospheric air; allowing multiple tropopauses

2) Subject to chemical and depositional loss in tropospheric air

---

**Transport of O₃, O₃S, and e90 fully driven by meteorology...**