An Analysis of the Meteorological Conditions Associated with Ozone Depletion Events in the Ross Island Region

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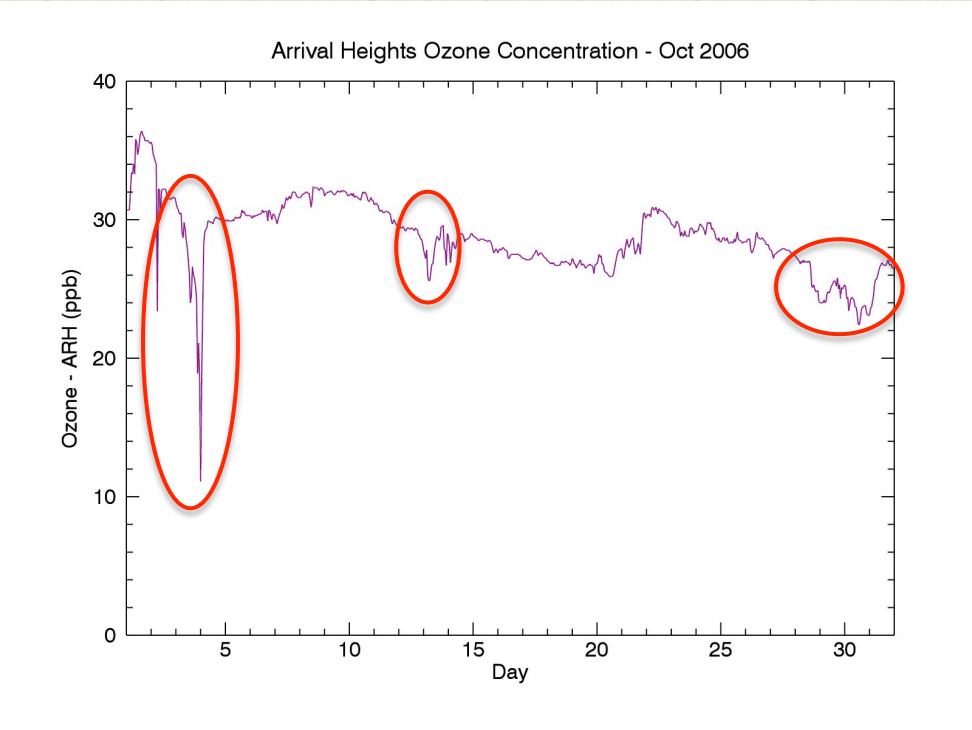
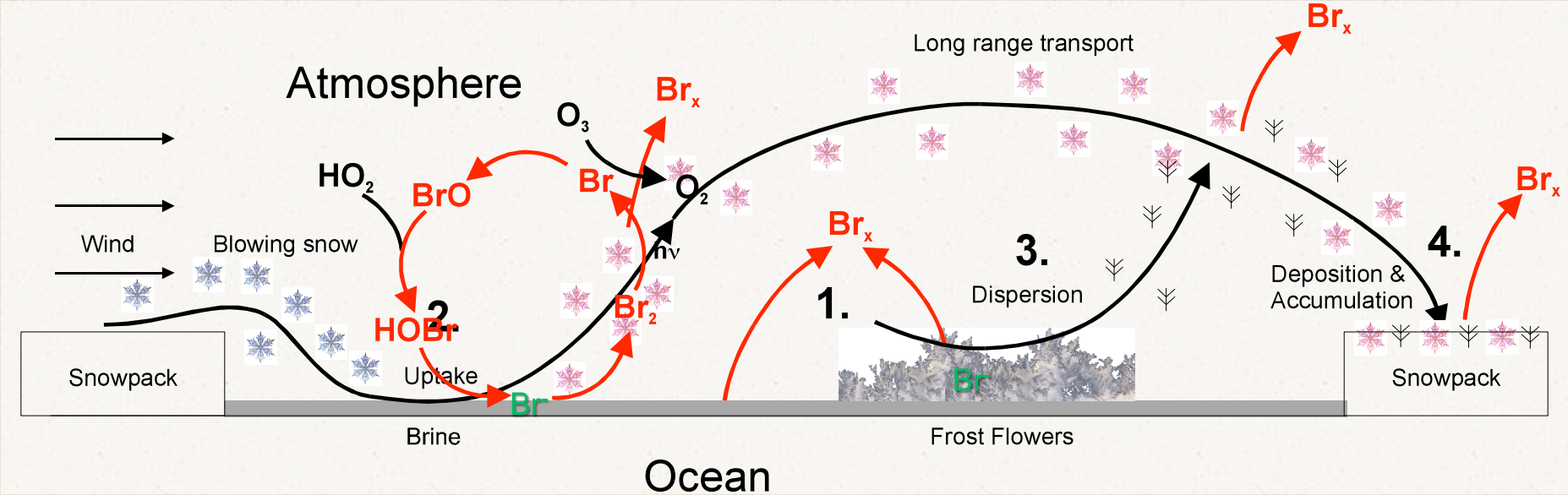
Typical Antarctic Ozone Depletion Events (ODE)

- Naturally occurring ozone depletion events have been observed during the austral spring in the Ross Island region



- Ozone depletion events need sunlight and a source of bromine
- It is still unclear how the reactive bromine is released from the sea salt – a possible meteorology connection

Possible Release Mechanisms for Reactive Bromine



1. Direct release of reactive bromine from brine and frost flowers
2. Uptake of brine by blowing snow and subsequent release of reactive bromine
3. Dispersion of saline frost flowers and subsequent release of reactive bromine
4. Deposition and accumulation of snow and ice crystals with high salinity on the snowpack and subsequent bromine release

Slide courtesy of Udo Frieß.

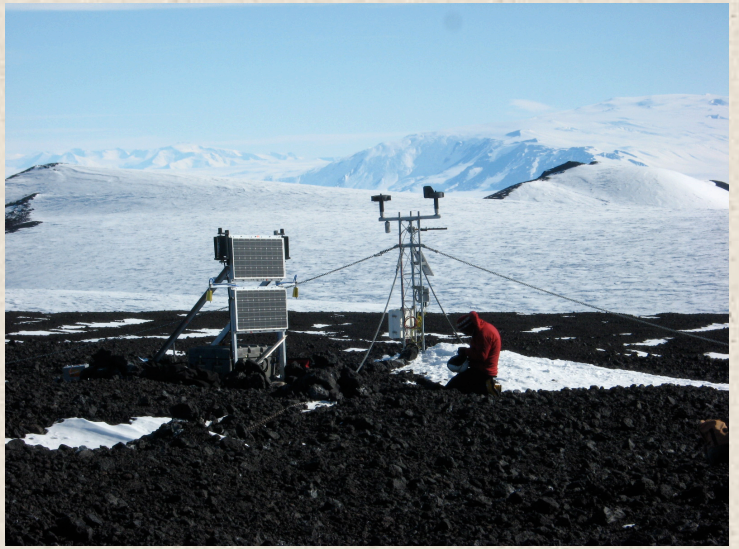
Near-Surface Tropospheric Ozone Sensors

- Five near-surface ozone sensors were installed at automatic weather station sites (AWS) during the 2011-12 field season

- The sensors failed for a variety of reasons during the first year (Spring 2012) of deployment
- The ozone sensors are currently operating with anticipation for a productive collection of ODE observations

Near-Surface Tropospheric Ozone Sensors

- The ozone sensors are low-power for year round operation and the data is transmitted in near real-time



- An understanding of the meteorology of the Ross Island region will be used to assist in establishing the source and evolution of the ozone depleted air masses

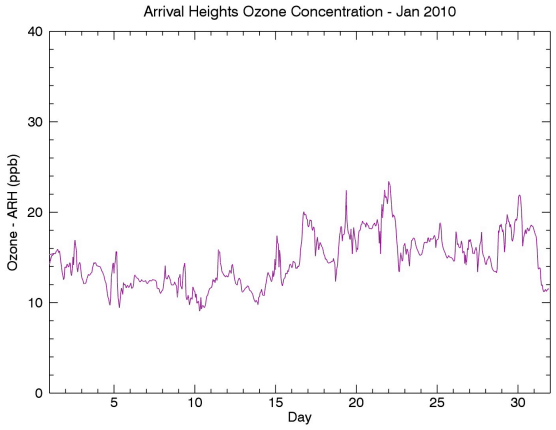
Arrival Heights – Ozone Observations

- NOAA has had an ozone instrument located at Arrival Heights (McMurdo Station) for over 10 years

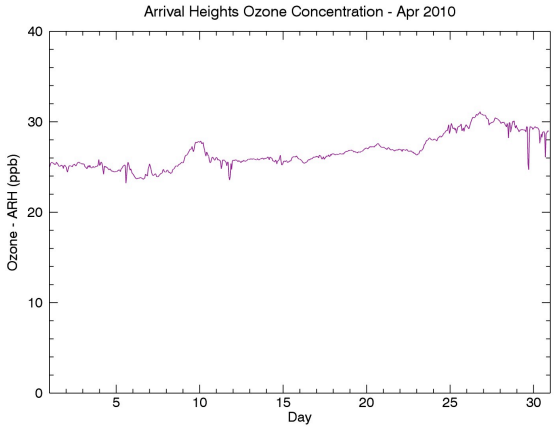
- The Arrival Heights observations provide a good characterization of the ozone climatology to establish a context of the new ozone sensor network
- Overall, the location (above the ice surface, near anthropogenic sources) has limitations in understanding ODEs

Characterizing the Arrival Heights Ozone

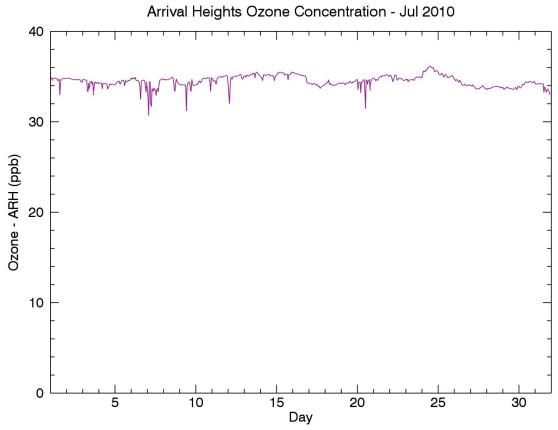
- During the summer months the ozone concentration is around 10-20 ppb
- During the fall months there is a steady recovery in the concentration of ozone leveling off during the winter months at approximately 36 ppb



January 2010



April 2010

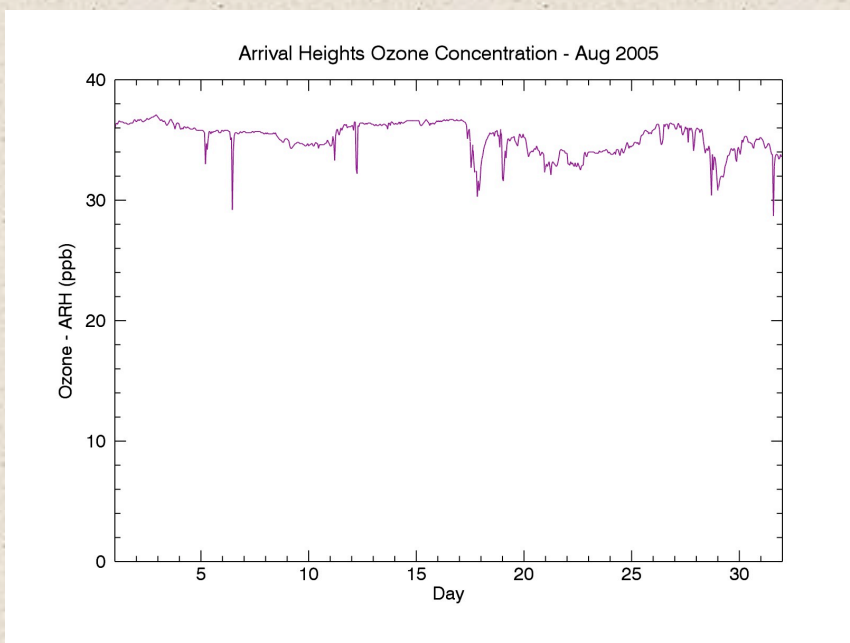


July 2010

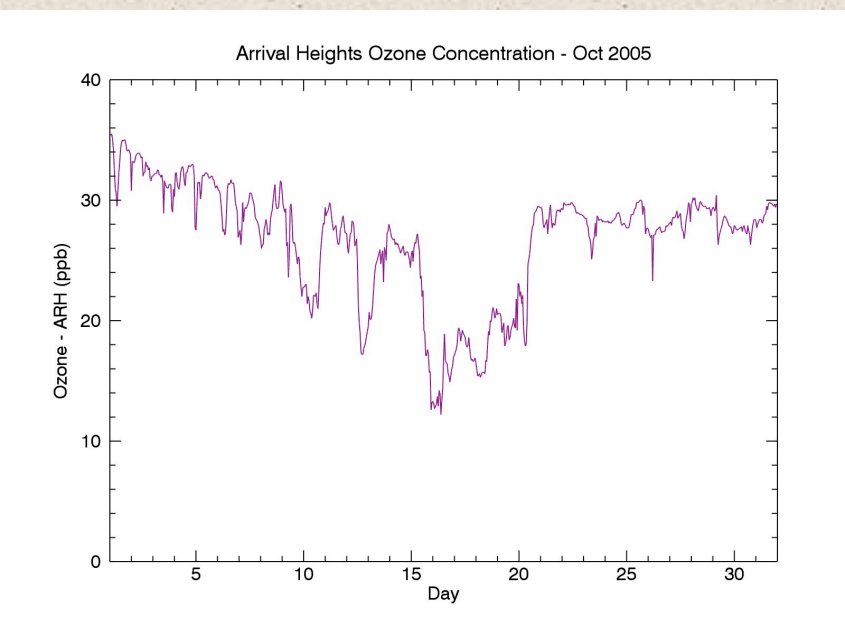
- The same general pattern is observed every year

Characterizing the Arrival Heights Ozone

- Early in the austral spring the background ozone is fairly steady
- Later in the spring and into the summer the ozone observations are more highly variable



August 2005



October 2005

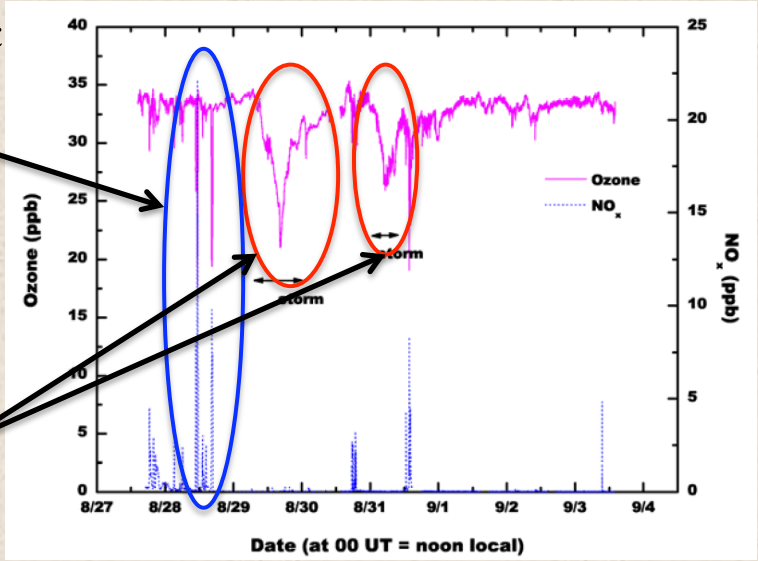
Characterizing the Arrival Heights Ozone

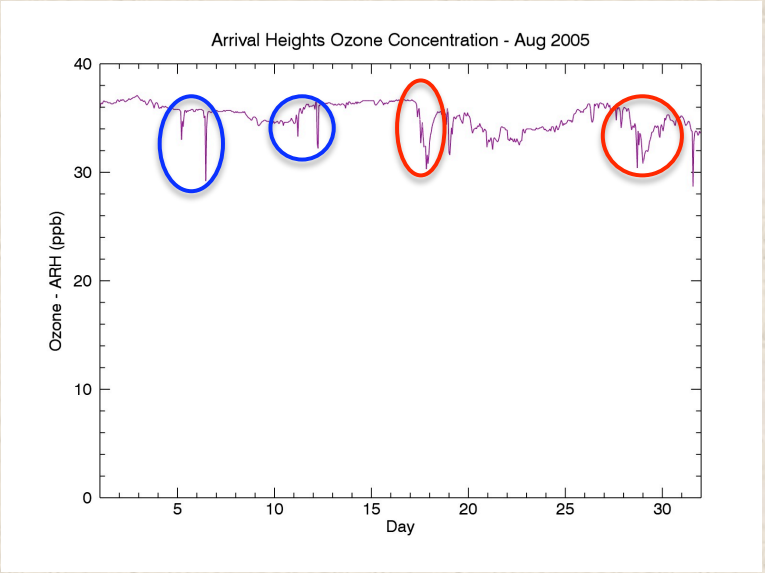
- It is critical to distinguish between anthropogenic ozone depletion and ozone depletion events (ODE)

August 2005

Anthropogenic Ozone Depletion

Ozone Depletion Events





- Anthropogenic ozone depletion is observed year round
- ODEs are primarily during the austral spring (Aug. – Nov.)

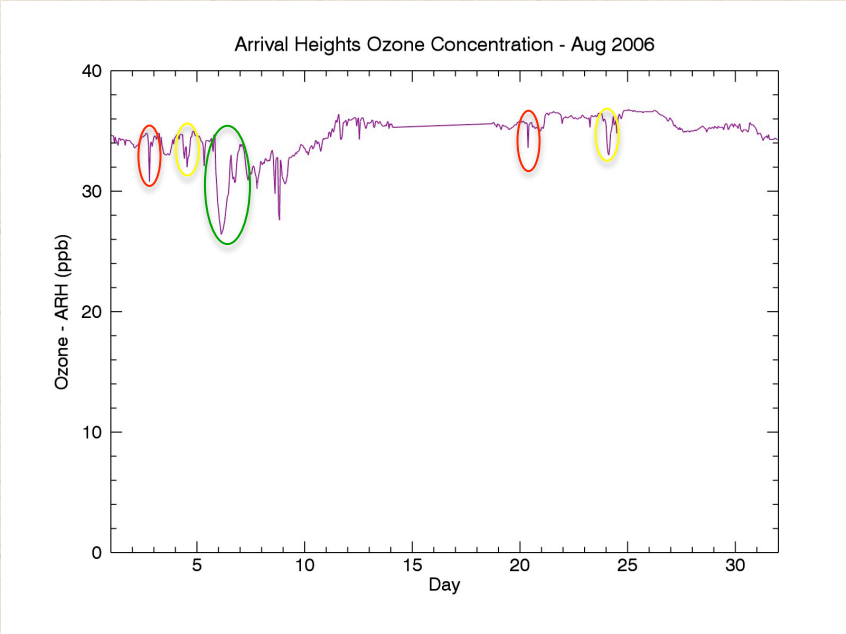
Ozone Depletion Events (ODE)

- The depletion of ozone from the surface to about 100-400 m
- Salts are transported from ocean and oxidized to become reactive halogen species
- In the Antarctic the ODEs are frequent during the austral spring (Aug. – Nov.) with the return of sunlight and the cold temperatures
- Transport-Controlled ODE – rapid at onset, significant ozone loss, rapid wind speed / direction changes
- Chemically-Controlled ODE – appear more gradual and not as intense

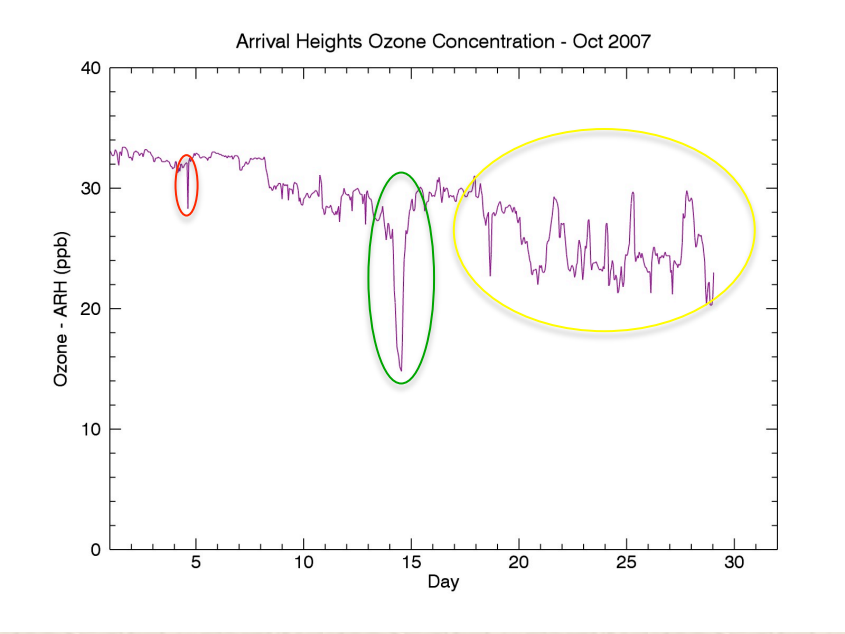
Simpson et al. (2007)

Ozone Depletion Events (ODE)

- Overall, the identification of ODEs, based solely on ozone observations, is subjective
- The magnitude and duration of the ozone depletion can vary depending on conditions and location of the event
- Late season events are particularly difficult to classify



August 2006



October 2007

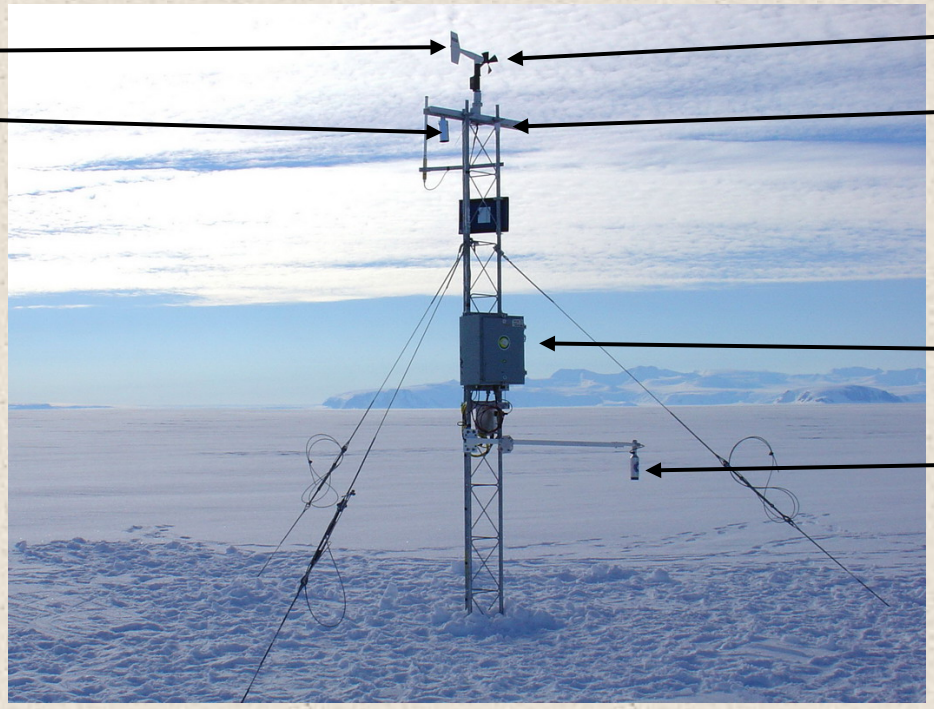
Ozone Depletion Events (ODE)

Types of Events:

- Transport-Controlled – rapid at onset, significant ozone loss, often occurs with rapid wind speed / direction changes
  - Horizontal advection of an ozone depleted air mass
  - Changes in the boundary layer depth
- Chemically-Controlled ODE – more gradual and not as intense
  - The ozone depletion chemistry is occurring locally
  - Can be amplified with increased release of bromine

Meteorology Data: Automatic Weather Stations

- University of Wisconsin AWS sites have been operating in the Ross Island region since about 1980



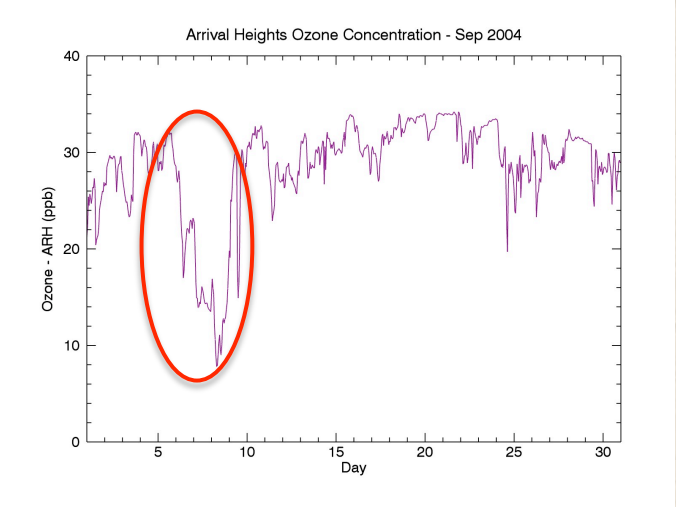
http://amrc.ssec.wisc.edu/aws/

- The observations are quality controlled and distributed in 10-minute, hourly, and 3-hourly data files

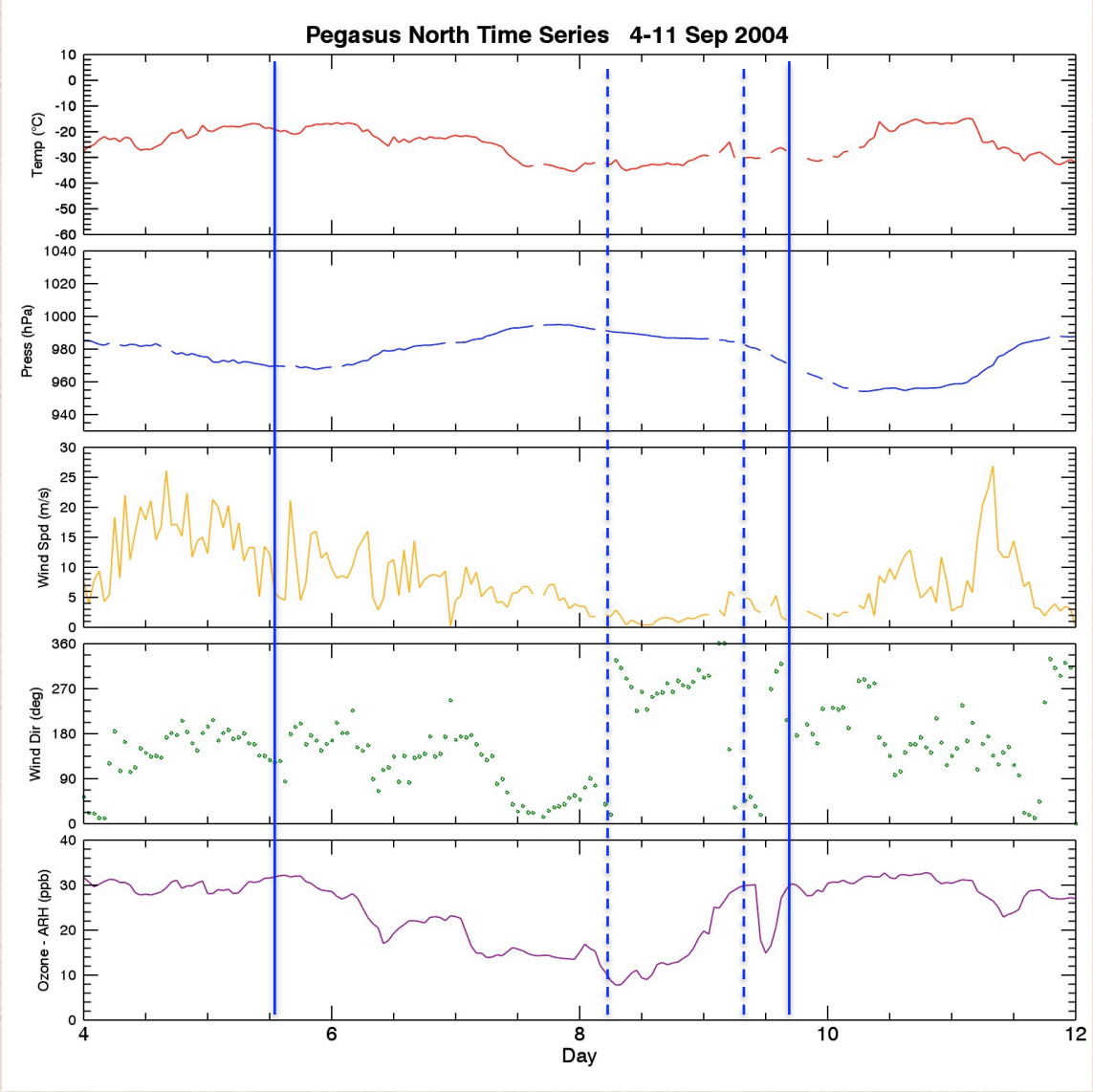
Meteorology Data: Automatic Weather Stations

- There are currently 10 AWS sites operating in the Ross Island region

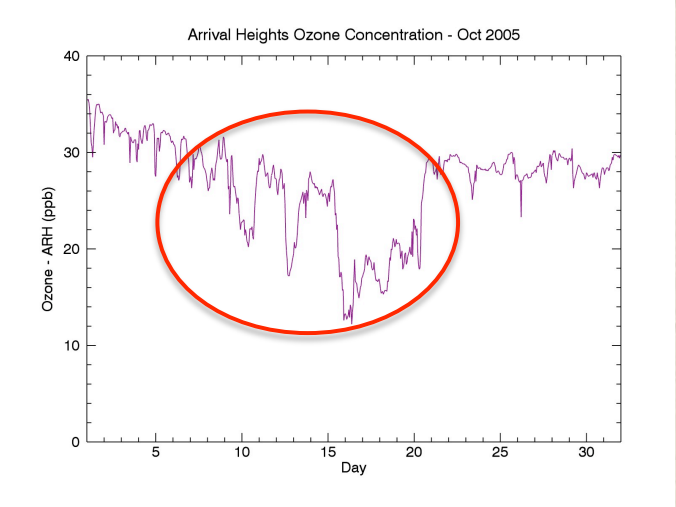
Case Study: September 2004



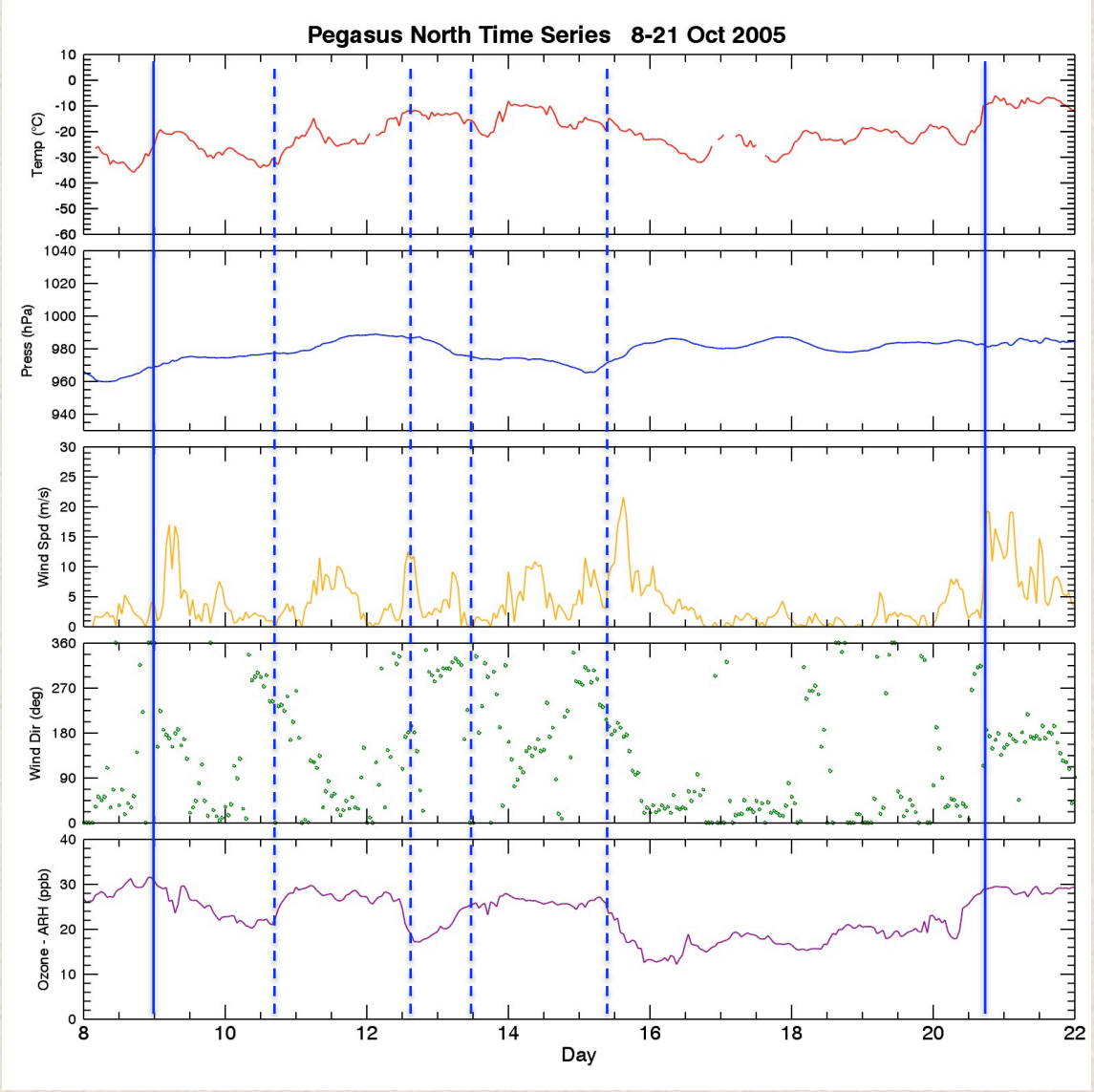
- An ozone depleted air mass is advected into the region
- The recovery of ozone begins with the change of wind direction from the NW
- The wind shifting back to the NE results in another drop in ozone



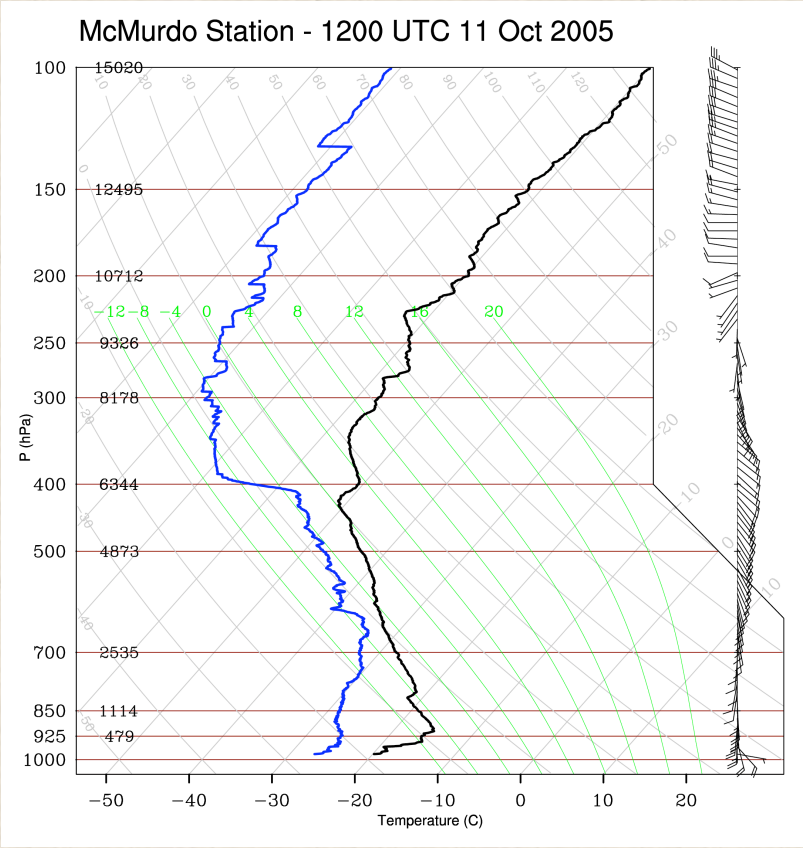
Case Study: October 2005

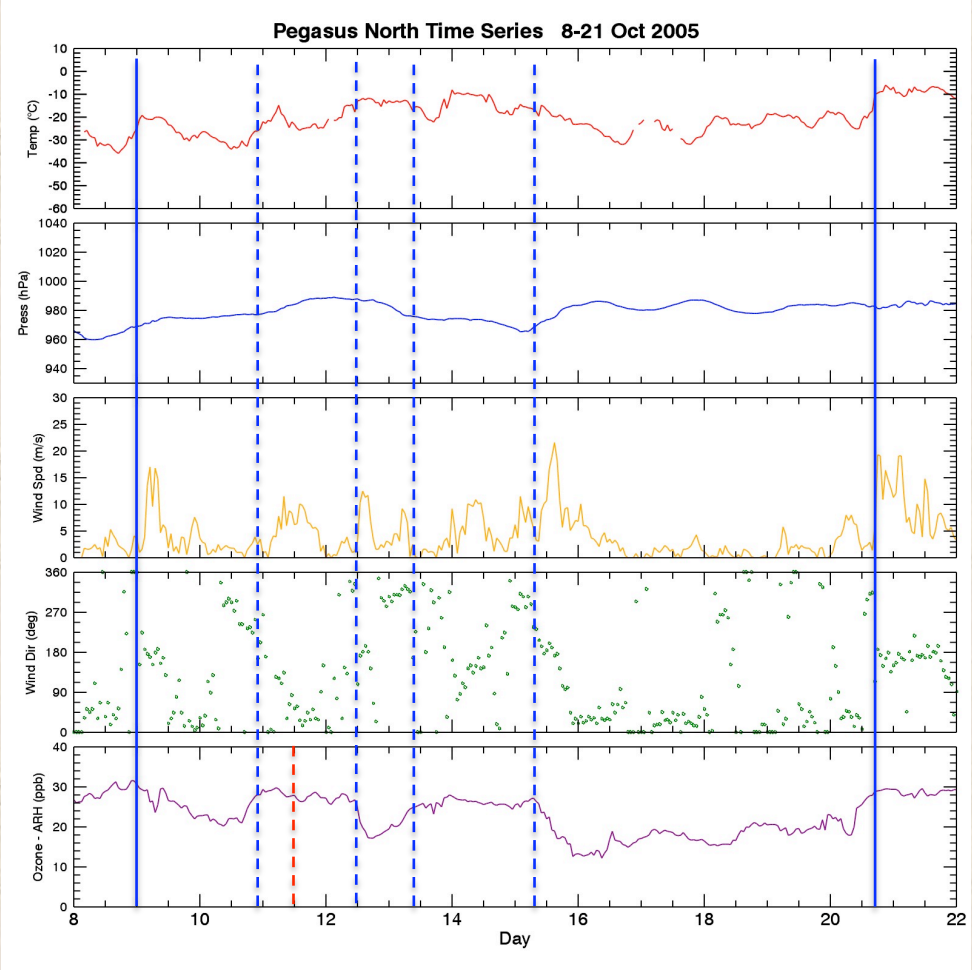


- Ozone depleted air is advected into the region
- Possible changes in boundary layer depth results in differences in the presence of ozone depleted and non-depleted air



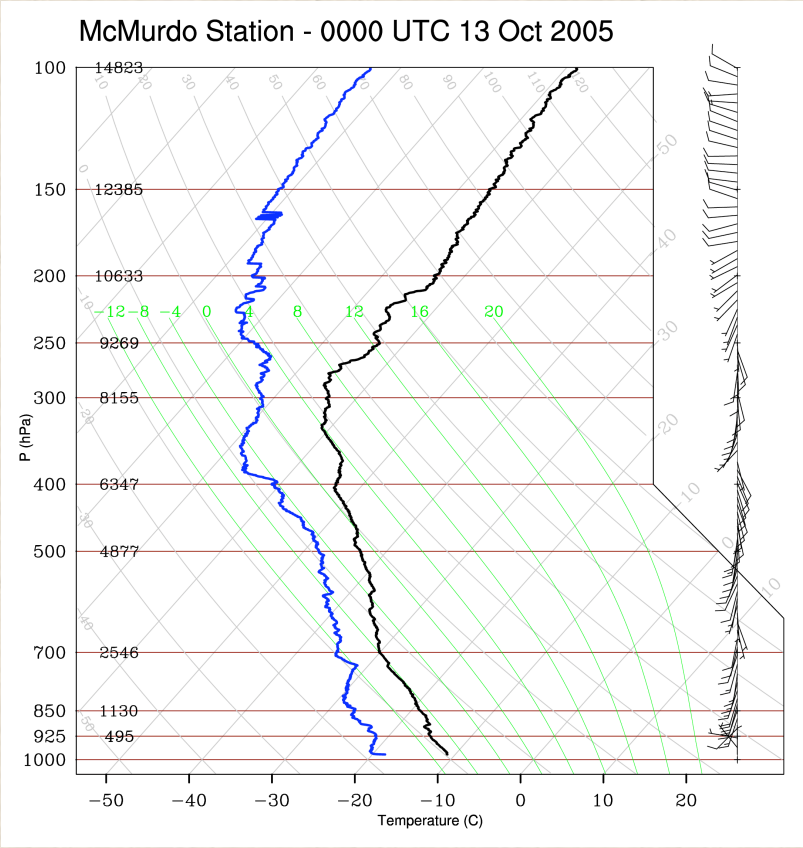
Case Study: October 2005

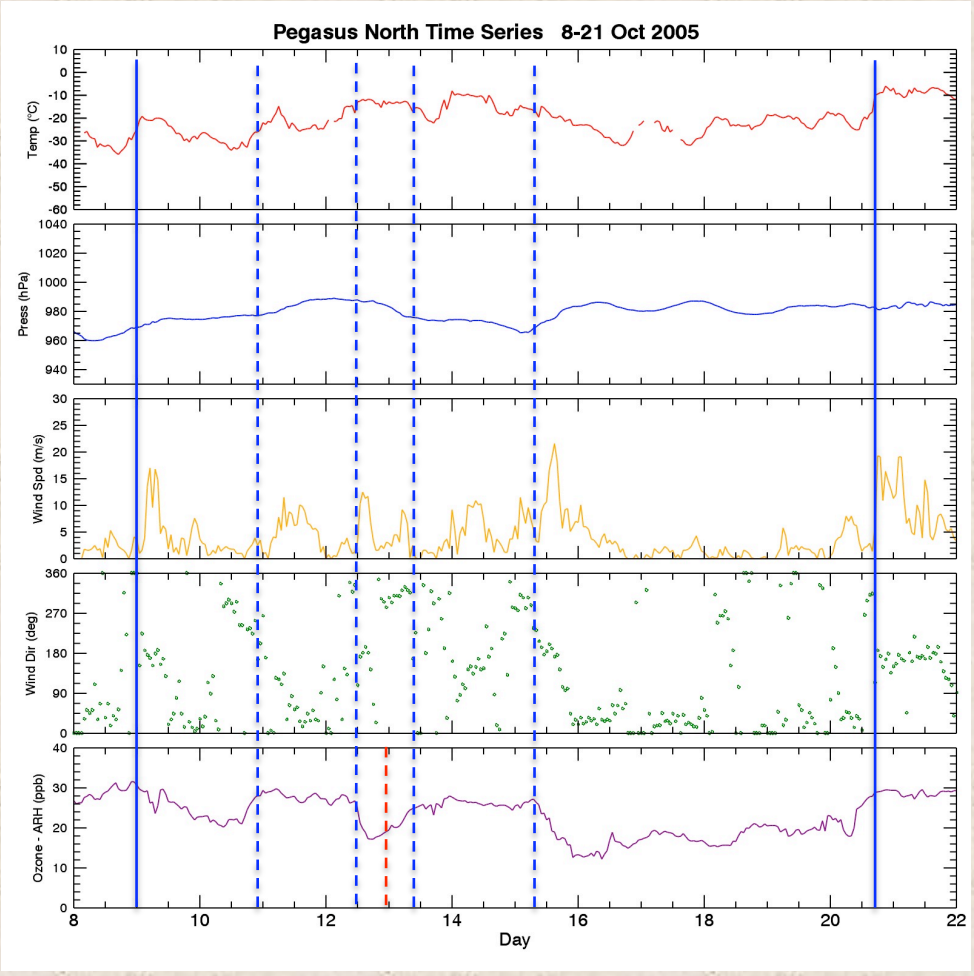




- The depth of the boundary layer is limited to heights below Arrival Heights and the ozone depleted air is not present at Arrival Heights

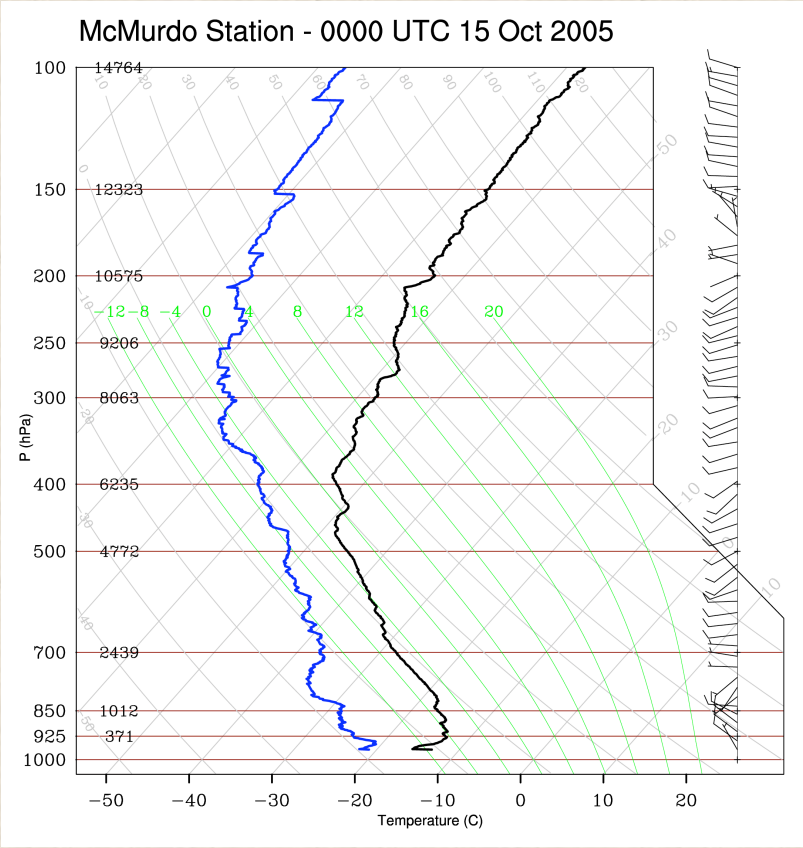
Case Study: October 2005

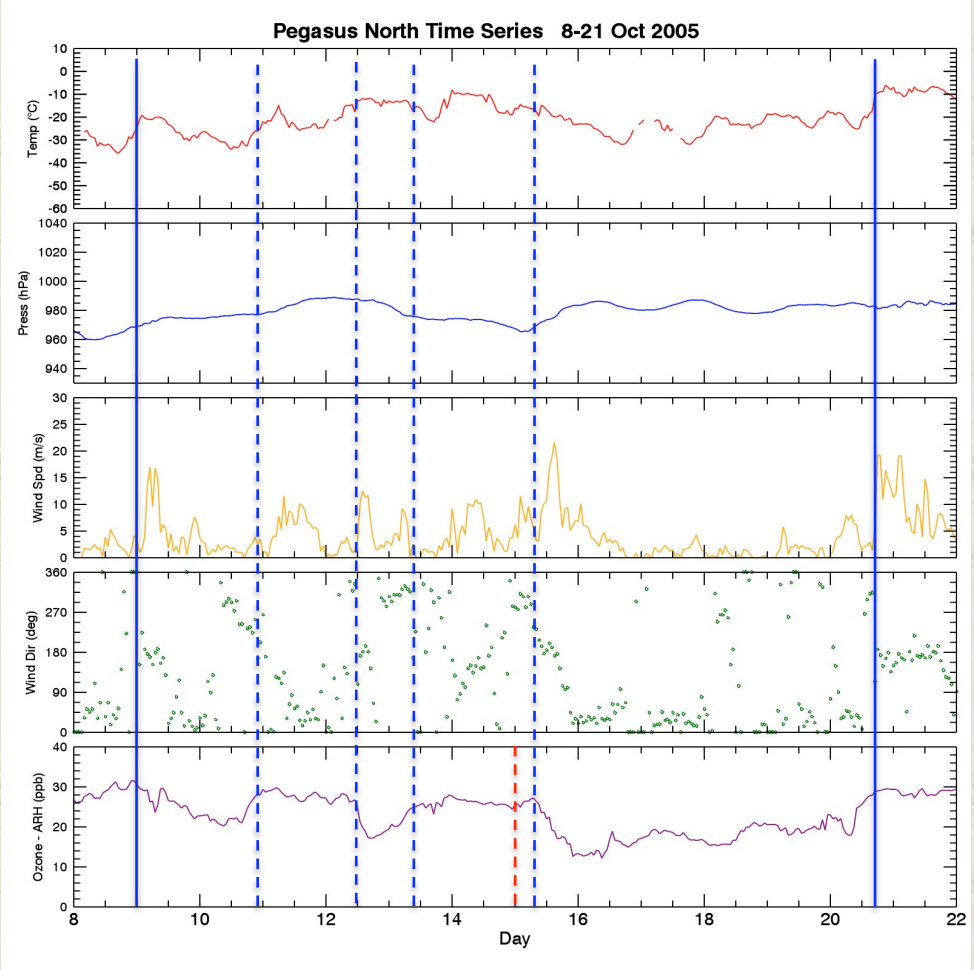




- The boundary layer air extends to heights above Arrival Heights and the ozone depleted air is present

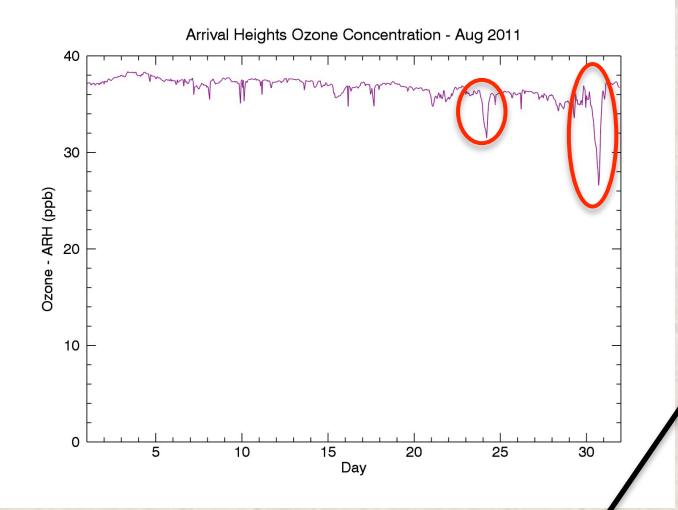
Case Study: October 2005

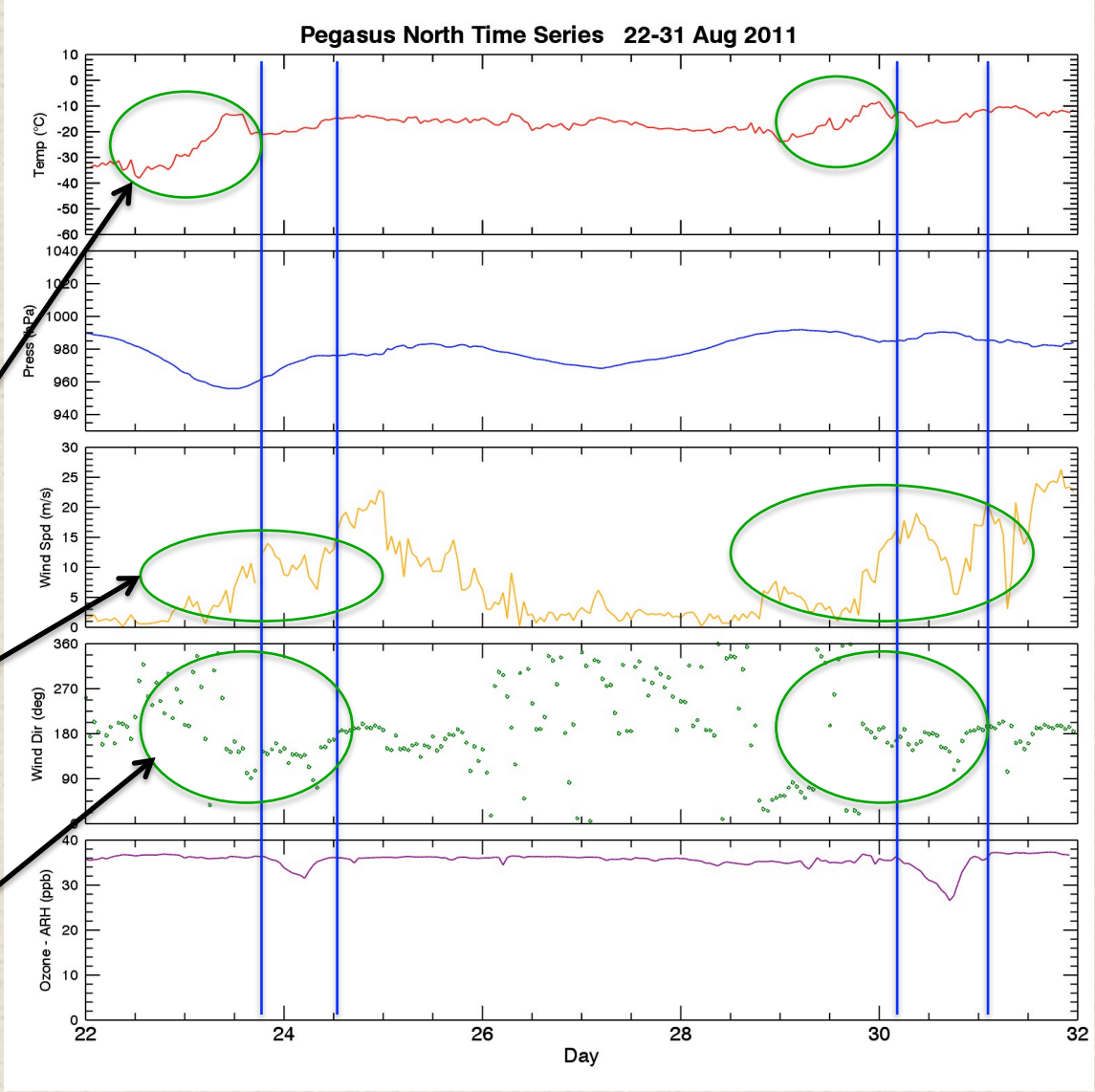




- Once again, the boundary layer depth is shallow and the ozone depleted air is not present at Arrival Heights

Case Study: August 2011





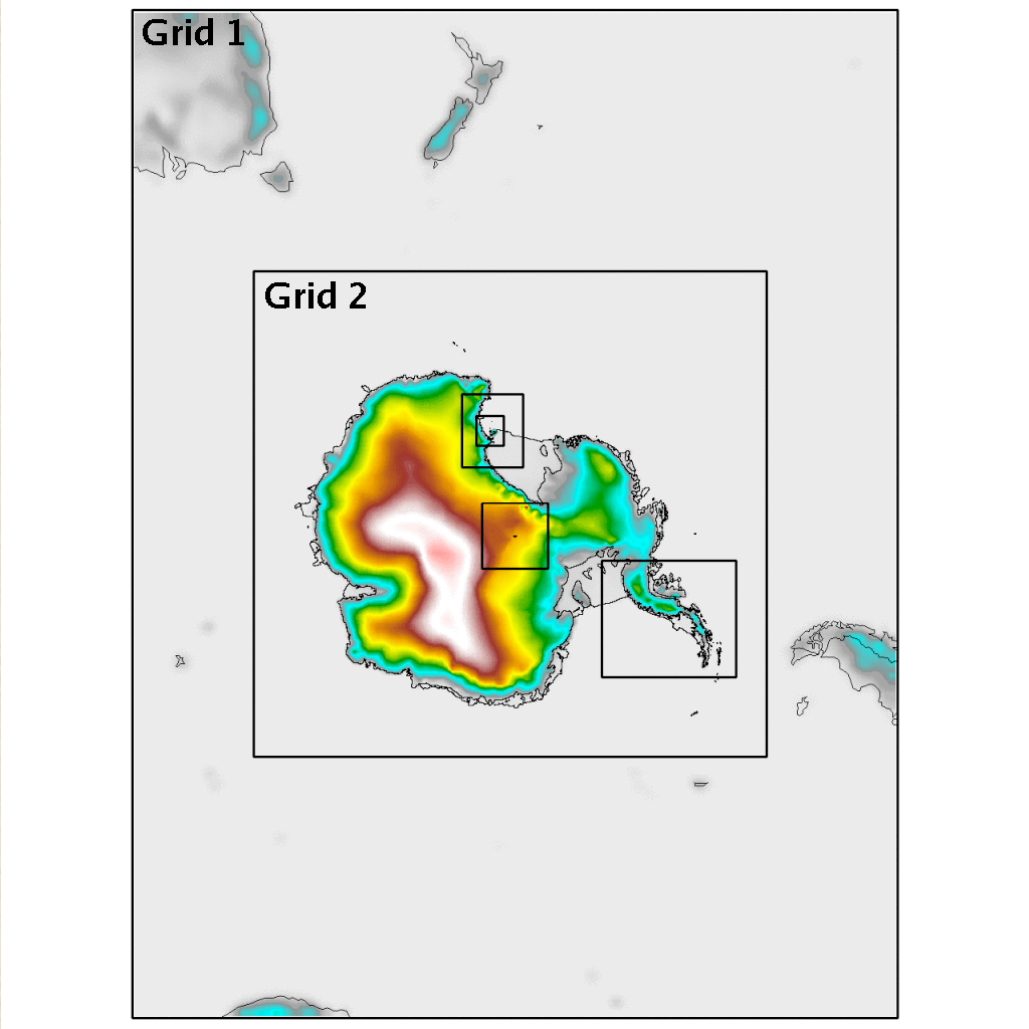
- There is a warming prior to the onset of the ODE
- The winds are light and from prior to the ODE, then increase in speed
- The wind is from the NW prior to the onset, and then shifted to the S.
- A transport related event

Future Work – Meteorology Data: Antarctic Mesoscale Prediction System (AMPS)

- Real-time numerical weather prediction for Antarctica
- Run twice daily at 00 and 12 UTC
- Currently using the Weather Research and Forecasting (WRF) model
- AMPS domains:

  45km-15km-5km-1.67km

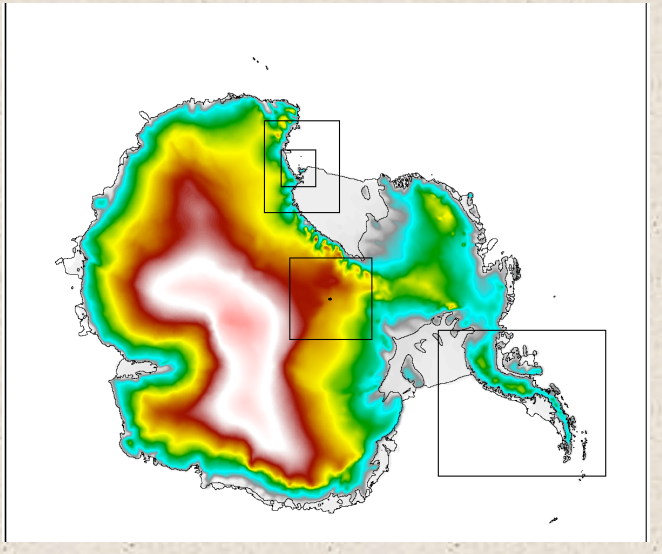
Powers et al. (2003)

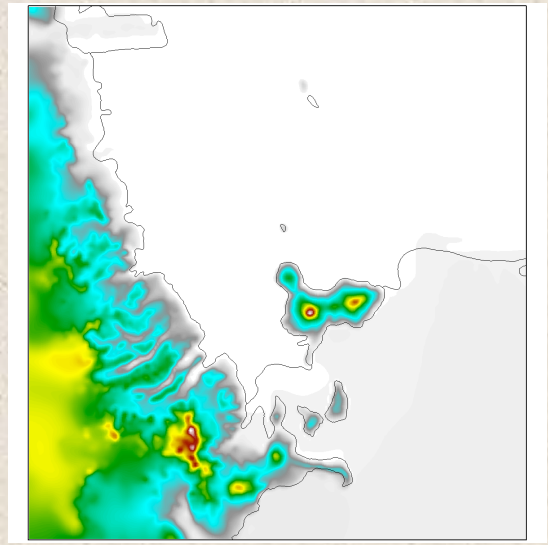


http://www.mmm.ucar.edu/rt/wrf/amps/

Meteorology Data:
Antarctic Mesoscale Prediction System (AMPS)

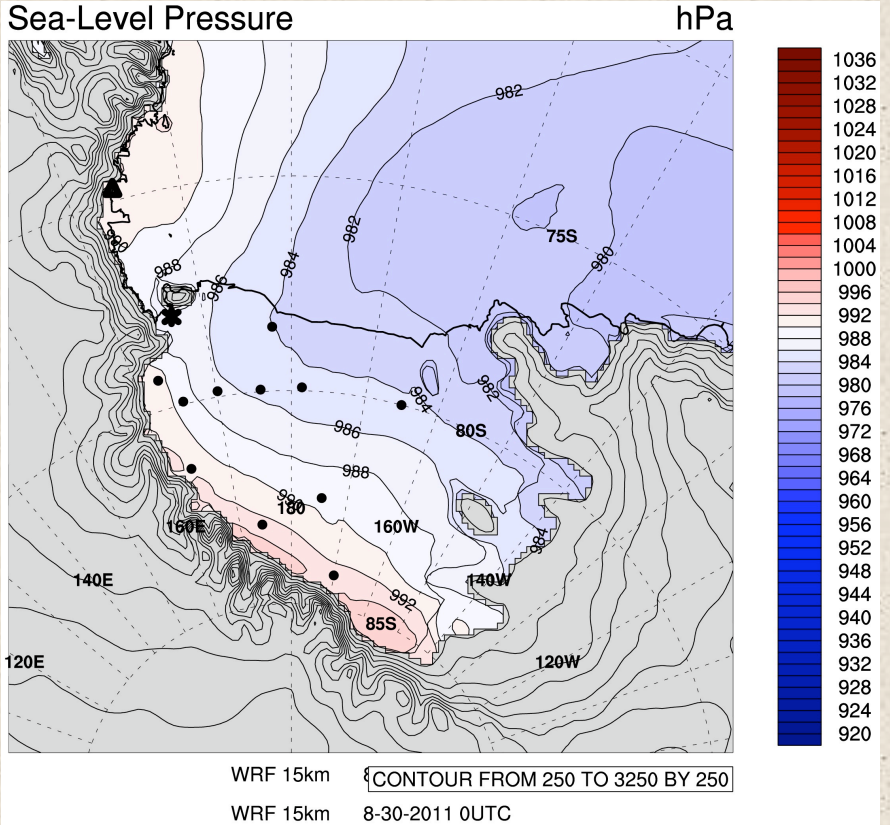
- Domain 2: 15 km resolution
  - Used to capture an understanding of the larger synoptic environment
  - 3 hourly output interval
- Domain 5: 1.67 km resolution
  - Used to capture the high resolution atmospheric circulation and transport
- Splice together successive 12-23h AMPS forecasts to create a continuous time series of atmospheric data

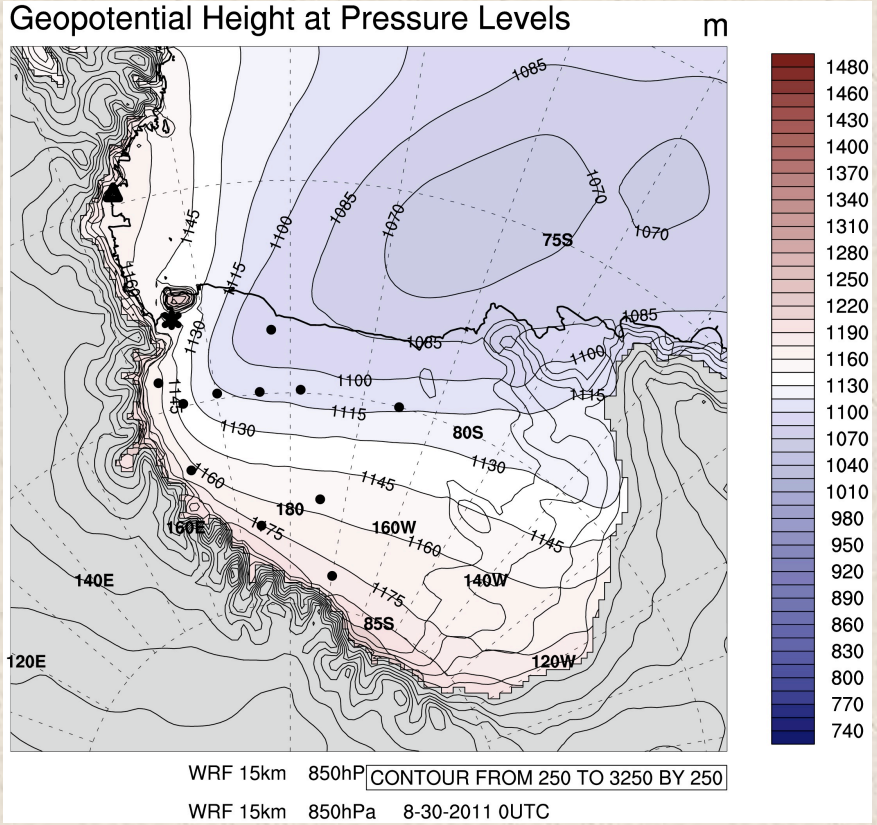




Case Study: AMPS 15 km – 30 August 2011

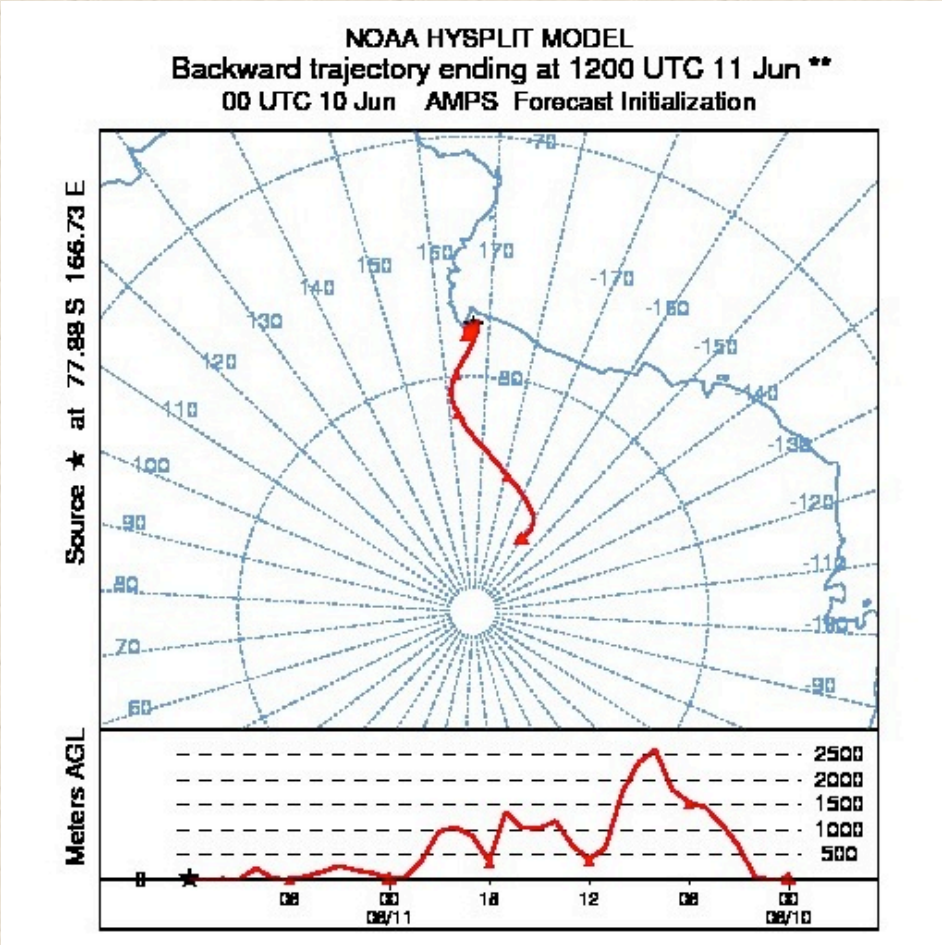
- The AMPS data provides information on the synoptic setting





AMPS – Back Trajectories

- Created in real-time using AMPS GRIB files from Ant-IDD
- Created using AMPS archived wrfout files



The Next Year

- The Arrival Heights characterization and climatology of ODEs will be submitted for publication
- The focus of the observations will be on the upcoming austral spring at the polar sunrise
- A similar analysis from the Arrival Heights observations will be applied to the observations from the ozone sensor network
- Additional tools will be developed for more in-depth analyses

Conclusions:

- Ozone depletion events frequently occur during the austral spring during in the Ross Ice Shelf region, Antarctica
- A network of low-power ozone sensors have been installed in the region to observe and understand the chemistry and meteorological processes associated with the ozone depletion
- Ozone observations from Arrival Heights (McMurdo Station) covering 10 years provides a context to better understand the observations from the field program
- Ozone depletion is the result of advection of ozone depleted air into a region as well as local ozone destruction

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- The installation, operation, and processing of the automatic weather stations observations are supported by the National Science Foundation: ANT-0838834

Simplified Mechanism for the Depletion of Ozone

$$2 \times (Br + O_3 \rightarrow BrO + O_2)$$

$$BrO + BrO \rightarrow Br_2 + O_2$$

$$Br_2 + h\nu \rightarrow 2Br$$

$$\text{Net: } 2O_3 \rightarrow 3O_2$$

- Ozone depletion events need sunlight and a source of bromine
- It is still unclear how the reactive bromine is released from the sea salt – a possible meteorology connection