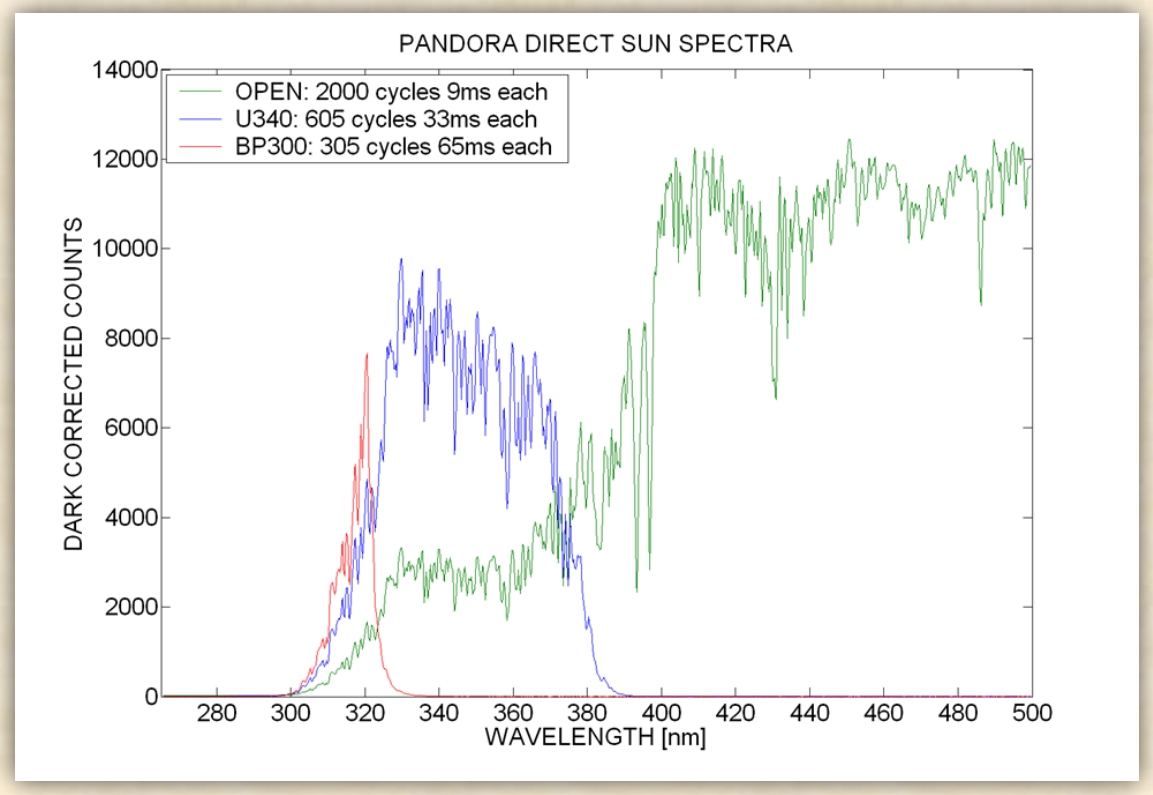
The Pandora Spectrophotometer

O_3 and multiple other species measured using a small, inexpensive package.

I. Petropavlovskikh (CIRES/NOAA),
J. Herman (U. of Maryland, NASA),
G. McConville (CIRES/NOAA),
R.D. Evans (NOAA)

What is the Pandora?

A small commercially available spectrometer optimized for detection of trace gases in the 280 – 525 nm spectral range, with 0.5 nm resolution, 4.5x oversampling)



The "Detector" connected by optic cable to an optical head (1.6^{O} field of view) mounted on a high precision (0.01^{O}) sun-sky tracker.

Recent Usage of Pandora

- The package is designed primarily for field campaigns - NASA's Discover-AQ (several aircraft based campaigns to improve the use of satellites to monitor air quality for public health and environmental benefit.)
- This summer DISCOVER-AQ and FRAPPE are in Colorado.
- Instruments operated in monitoring mode, i.e. NASA Goddard, Finland, Korea, Taiwan and at the University of Alaska.

What can you get from these spectral measurements?

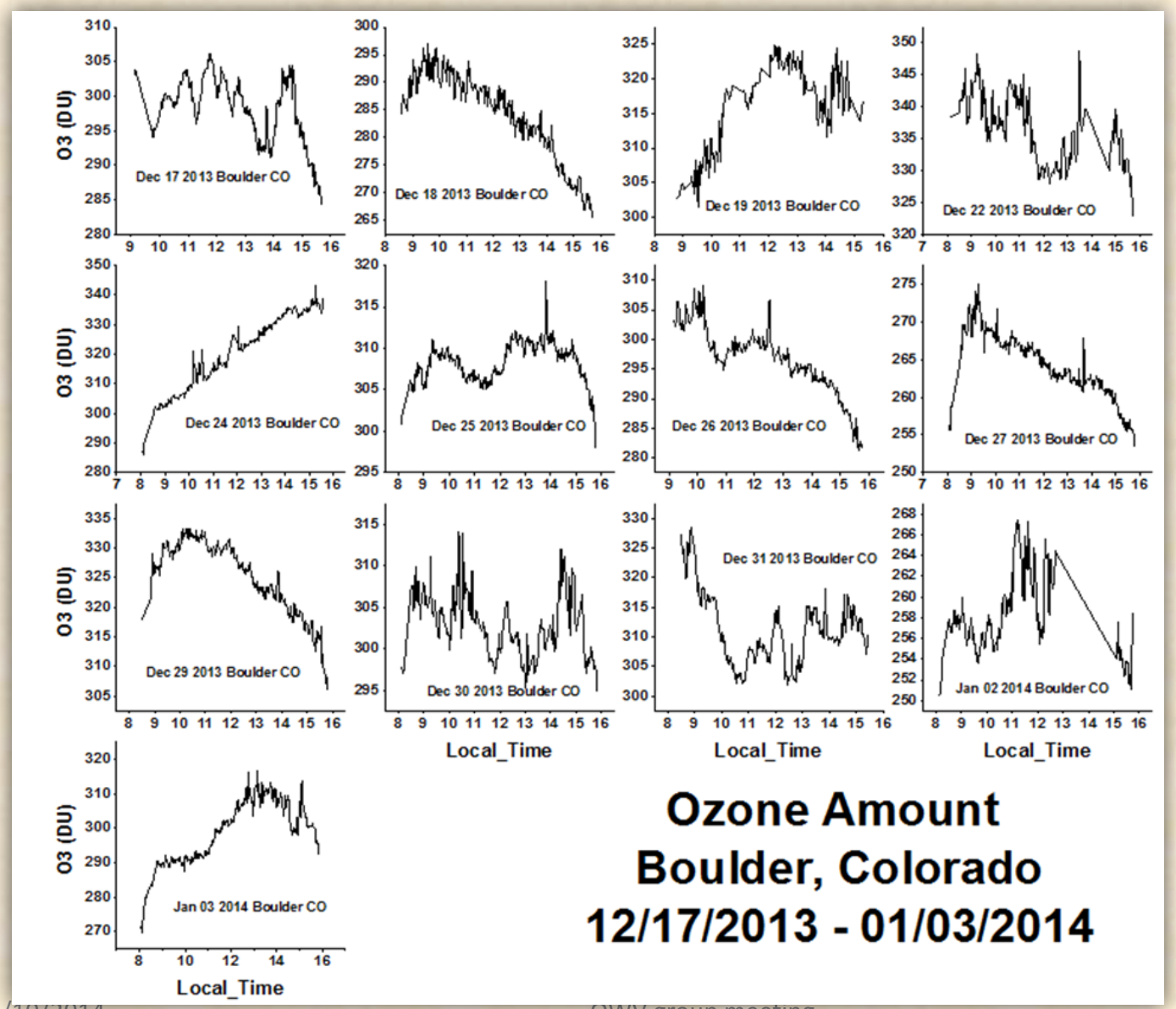
- O_3 Total Column Profiles planned
- NO_2 Total Column

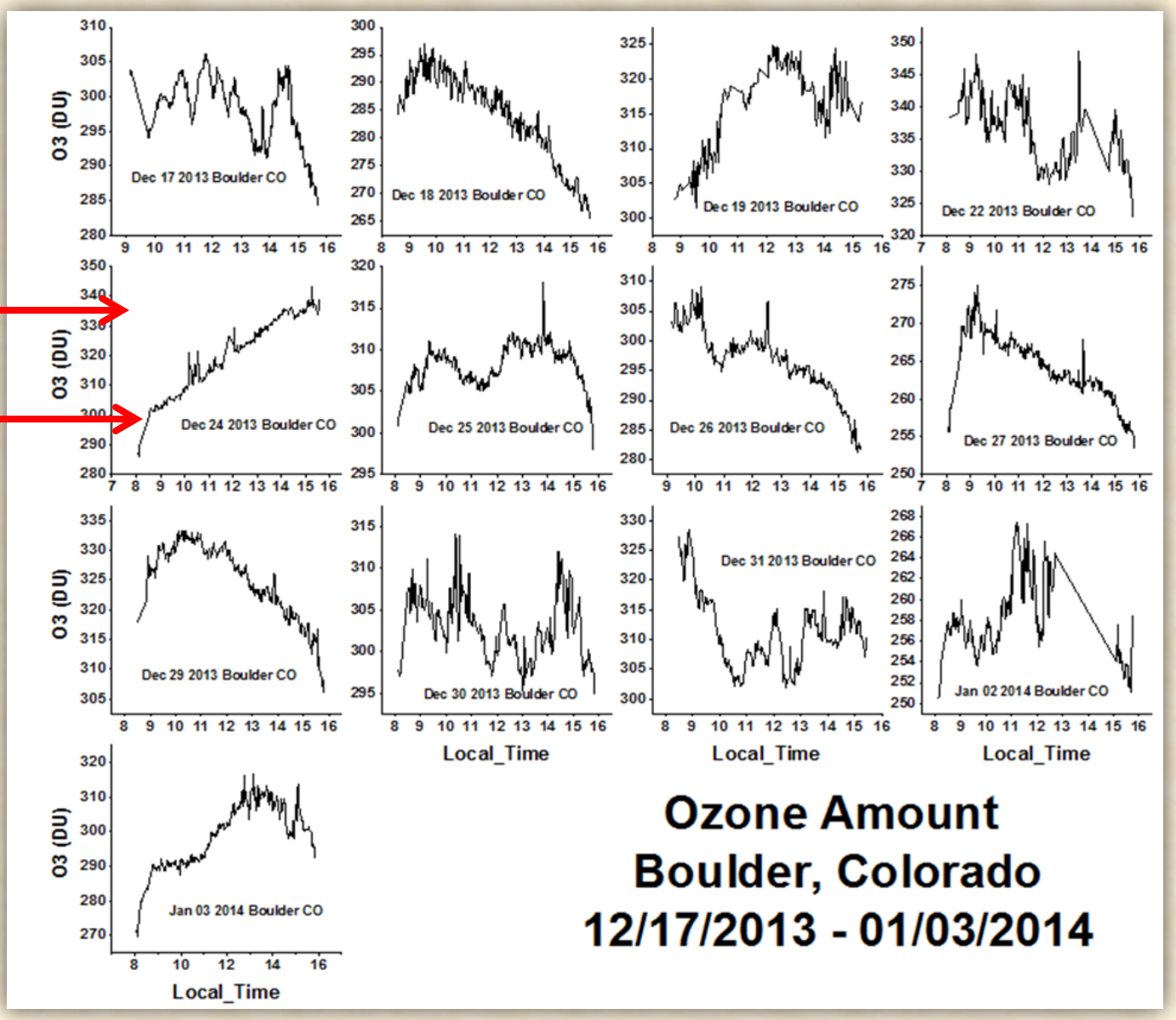
Species of interest for the Boulder area

Profiles of NO_2 and O_3 obtained at other sites

- SO_2
- H_2O
- HCHO
- O_2O_2
- BrO
- AOT(?)

Possible, not processed for Boulder as there is not enough concentration of these species locally.


O3 (DU)
Dec 17 2013 Boulder CO
Dec 18 2013 Boulder CO
Dec 19 2013 Boulder CO
Dec 22 2013 Boulder CO
Dec 24 2013 Boulder CO
Dec 25 2013 Boulder CO
Dec 26 2013 Boulder CO
Dec 27 2013 Boulder CO
Dec 29 2013 Boulder CO
Dec 30 2013 Boulder CO
Dec 31 2013 Boulder CO
Jan 02 2014 Boulder CO
Jan 03 2014 Boulder CO
Local_Time
Ozone Amount
Boulder, Colorado
12/17/2013 - 01/03/2014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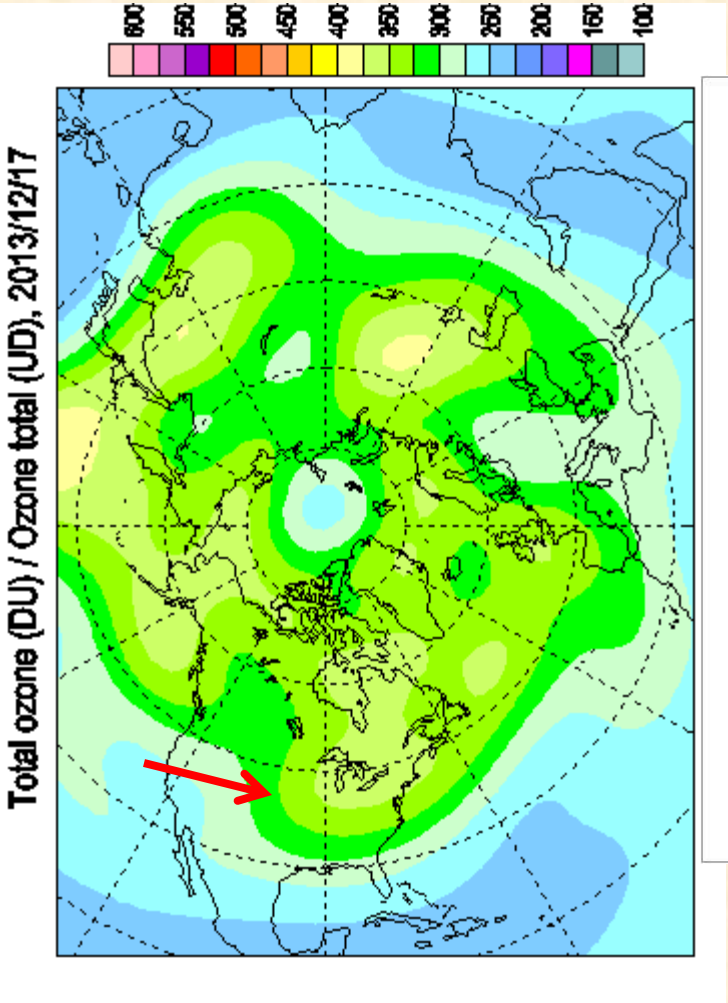
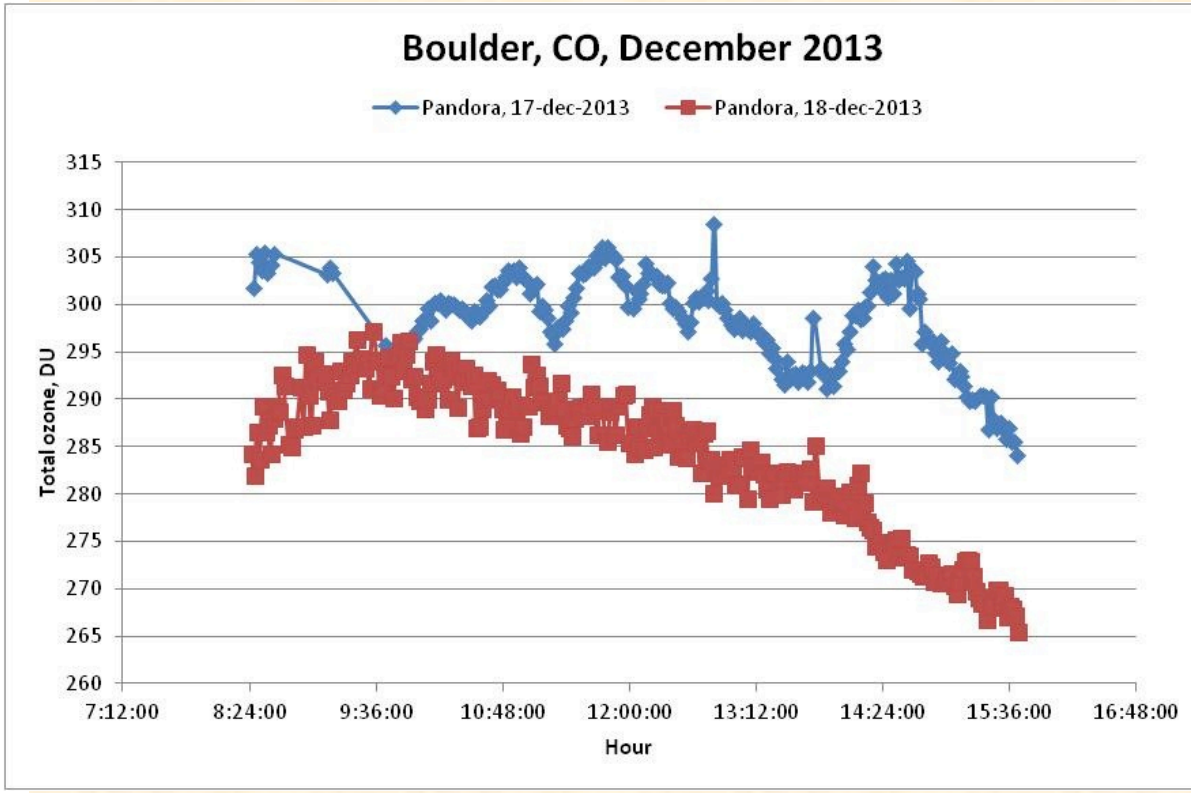
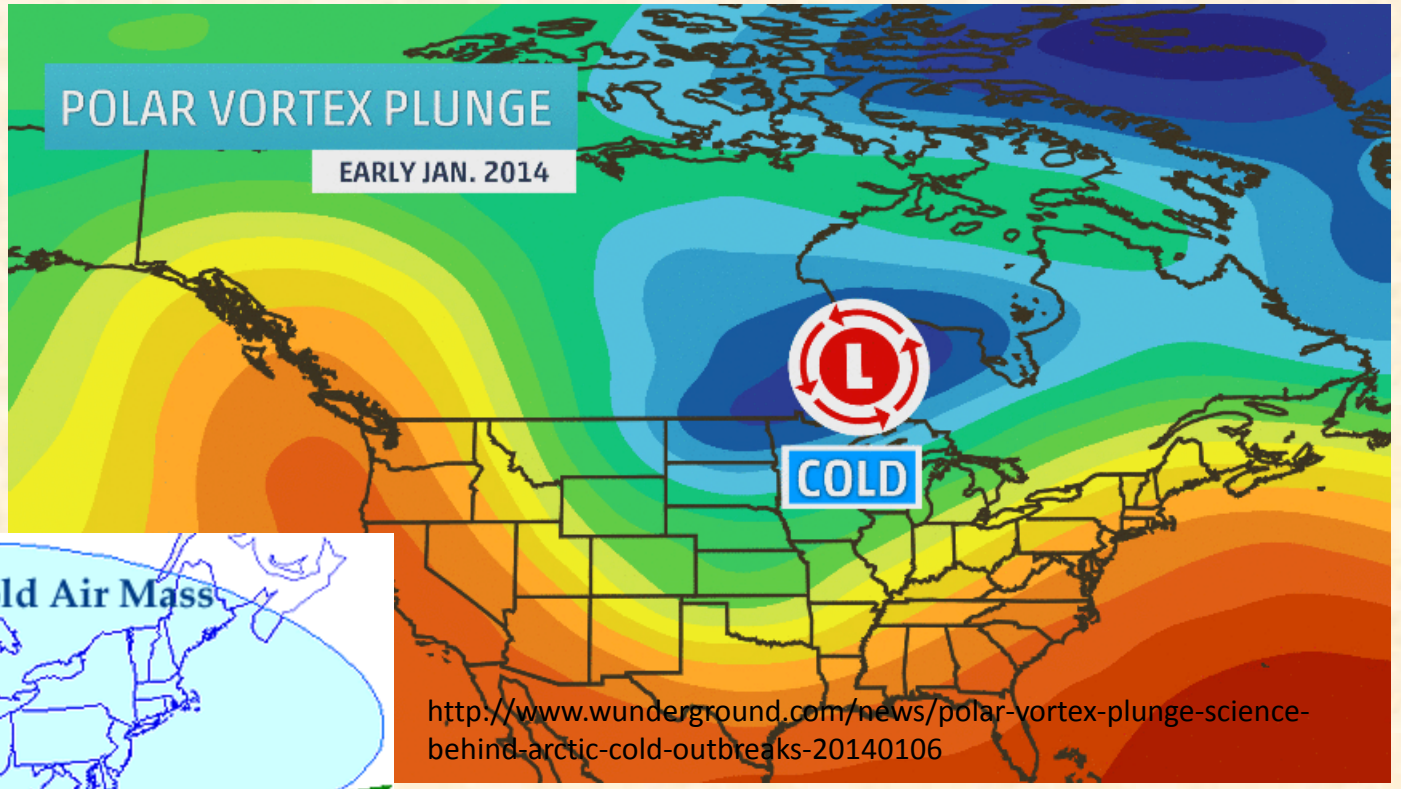
O3 (DU)
Local_Time
Ozone Amount
Boulder, Colorado
12/17/2013 - 01/03/2014

Difference in Pandora over two consecutive days in December

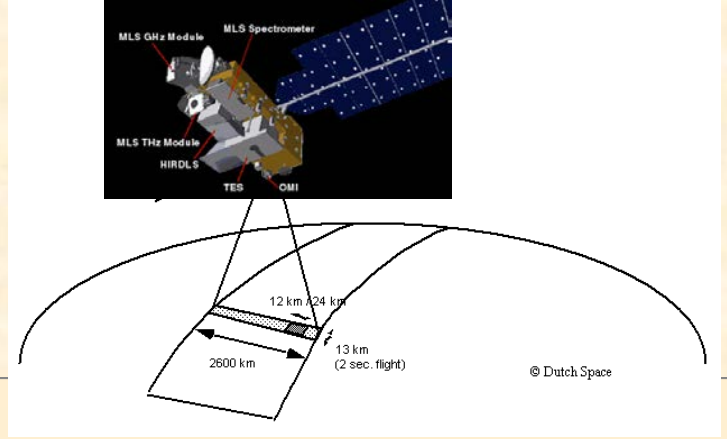


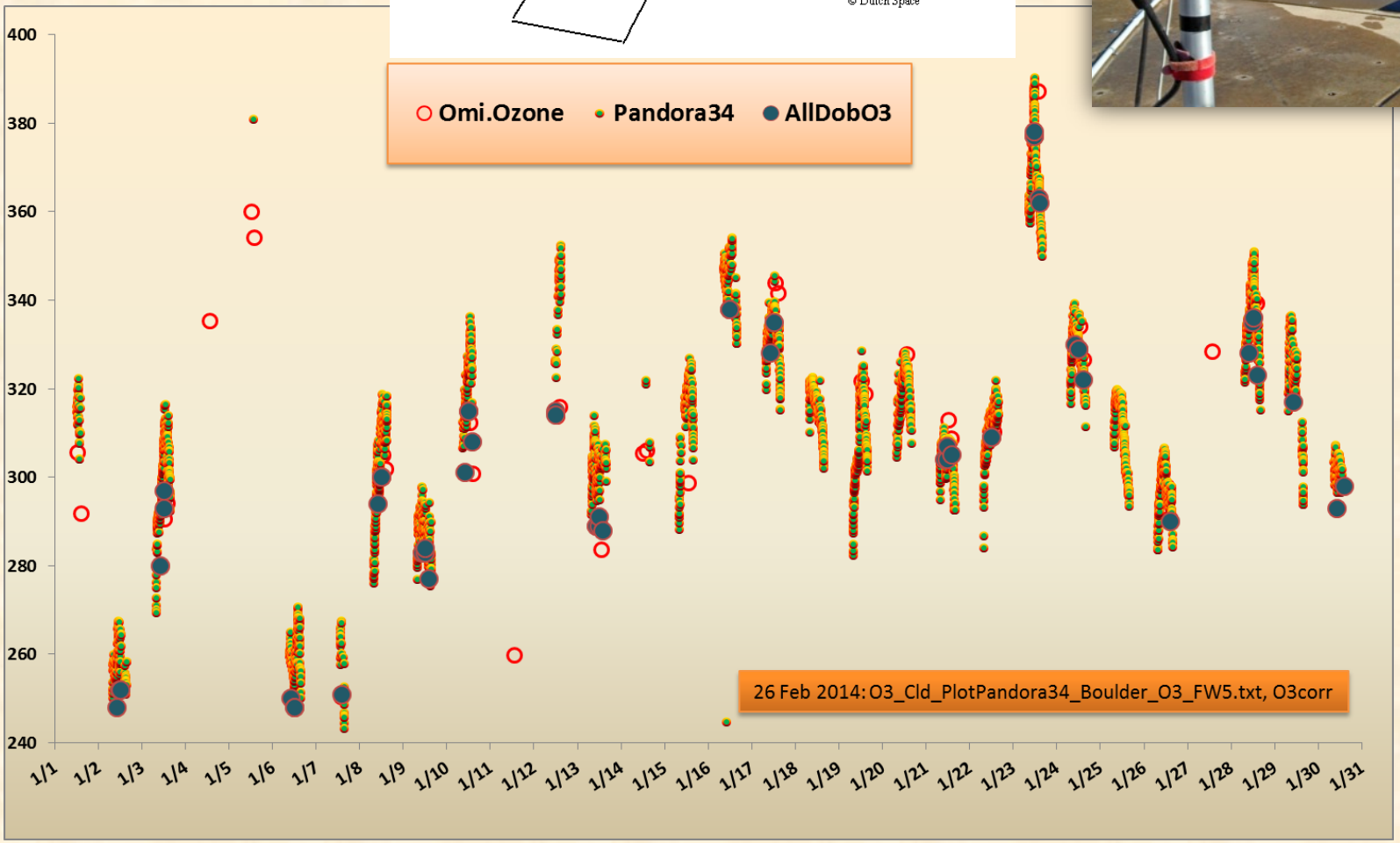


Infamous Polar vortex?



http://www.wunderground.com/news/polar-vortex-plunge-science-behind-arctic-cold-outbreaks-20140106


MLS GHz Module
MLS Spectrometer
MLS THz Module
HIRDLS
TES
OMI
12 km / 24 km
2600 km
13 km
(2 sec. flight)
© Dutch Space


Omi.Ozone
Pandora34
AllDobO3
400
380
360
340
320
300
280
260
240
1/1
1/2
1/3
1/4
1/5
1/6
1/7
1/8
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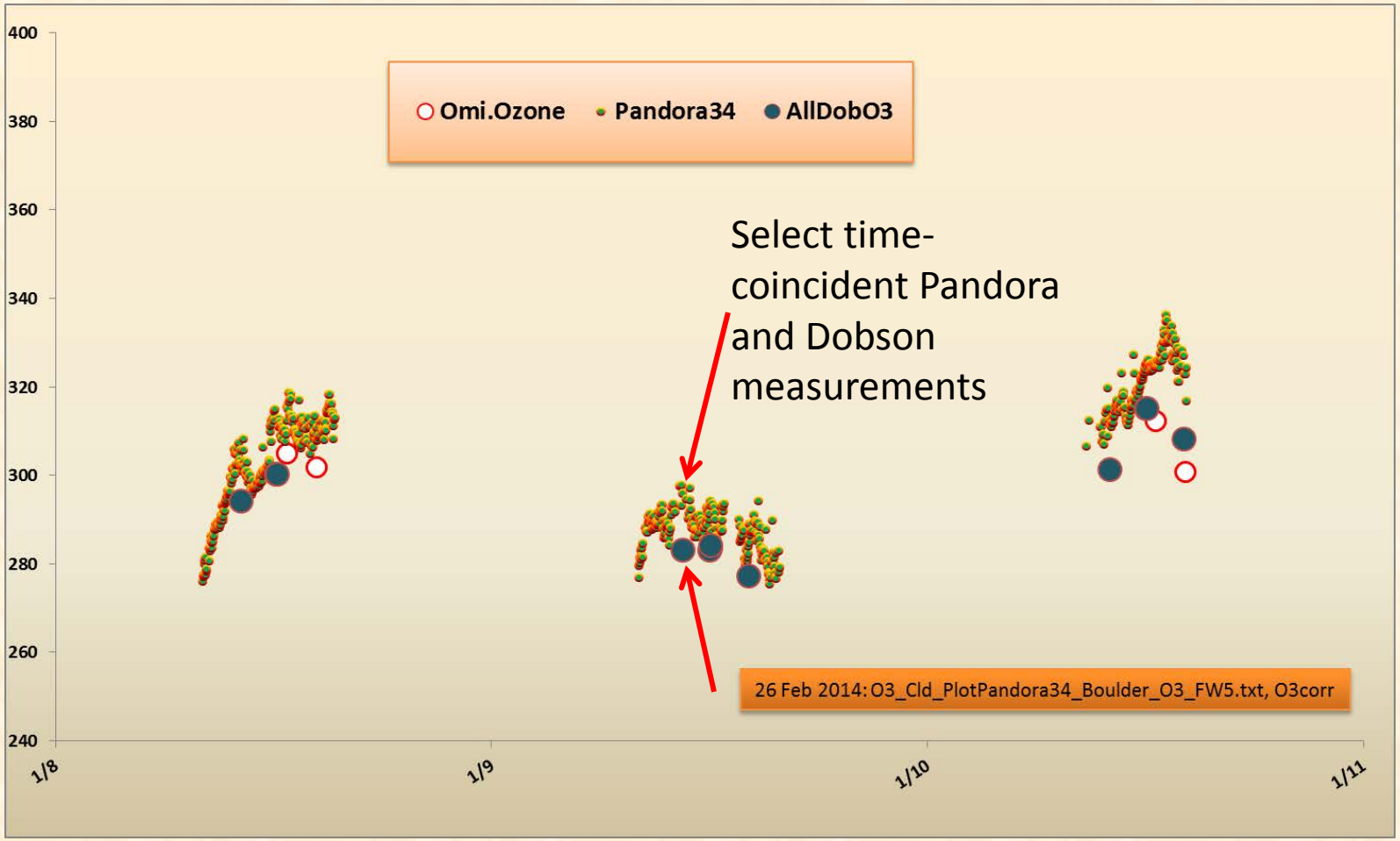
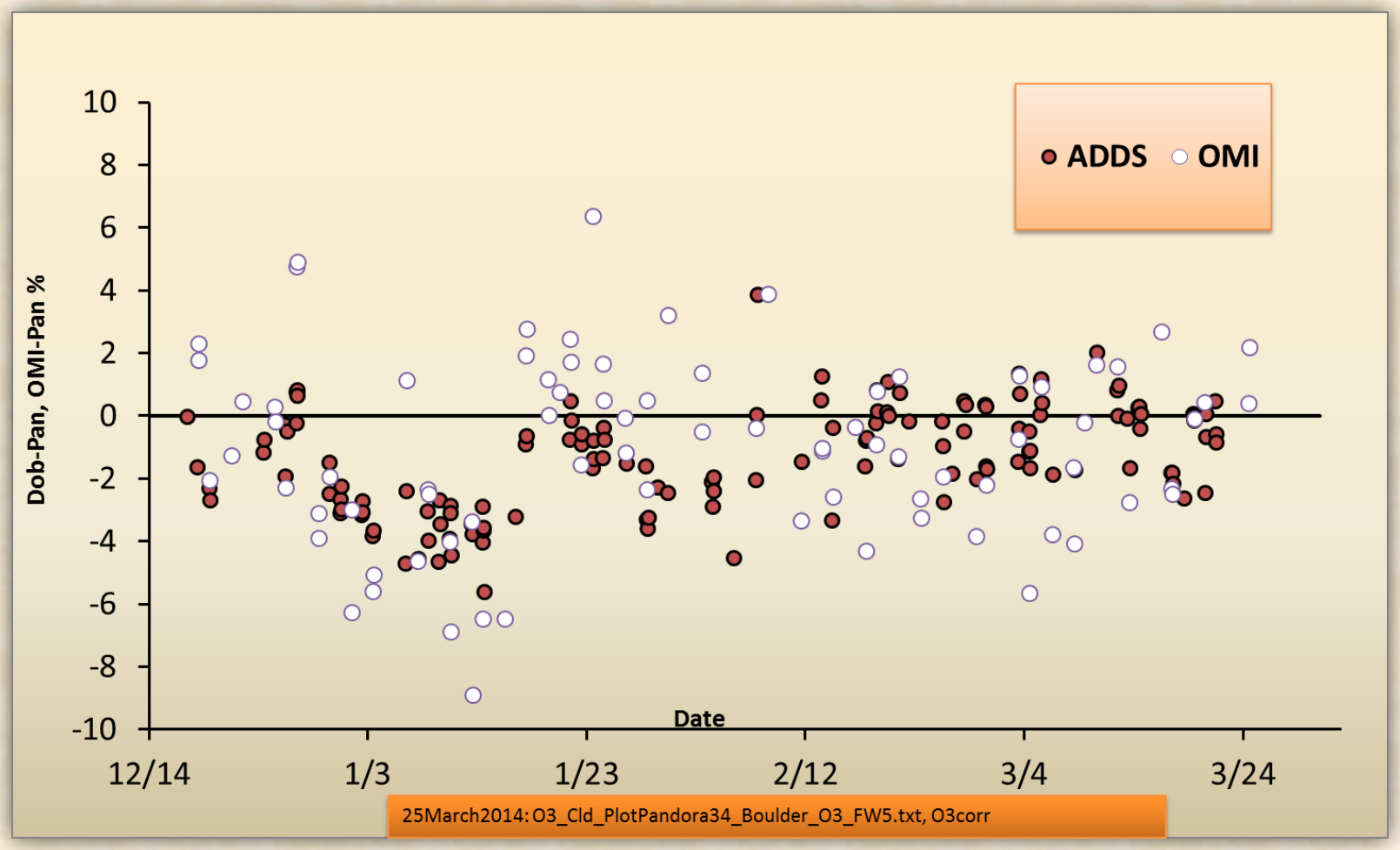
26 Feb 2014: O3_Cld_PlotPandora34_Boulder_O3_FW5.txt, O3corr

Zoomed in on three days

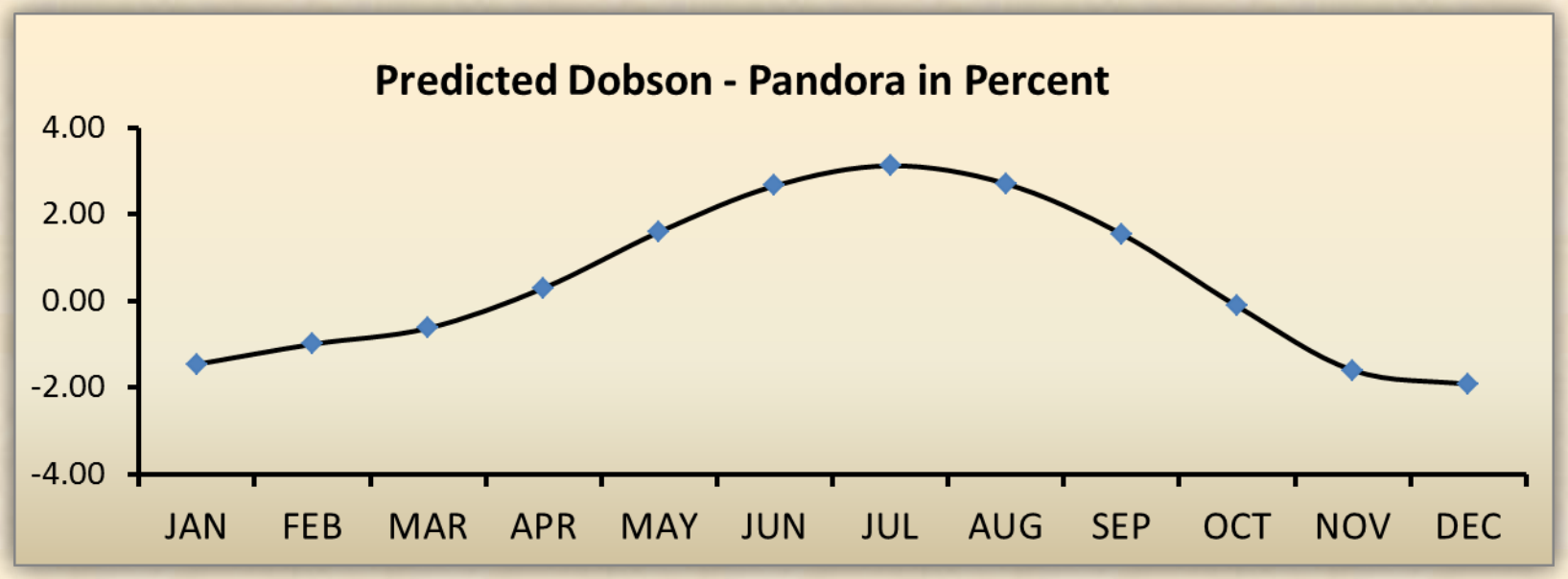


Dobson/OMI vs Pandora offset



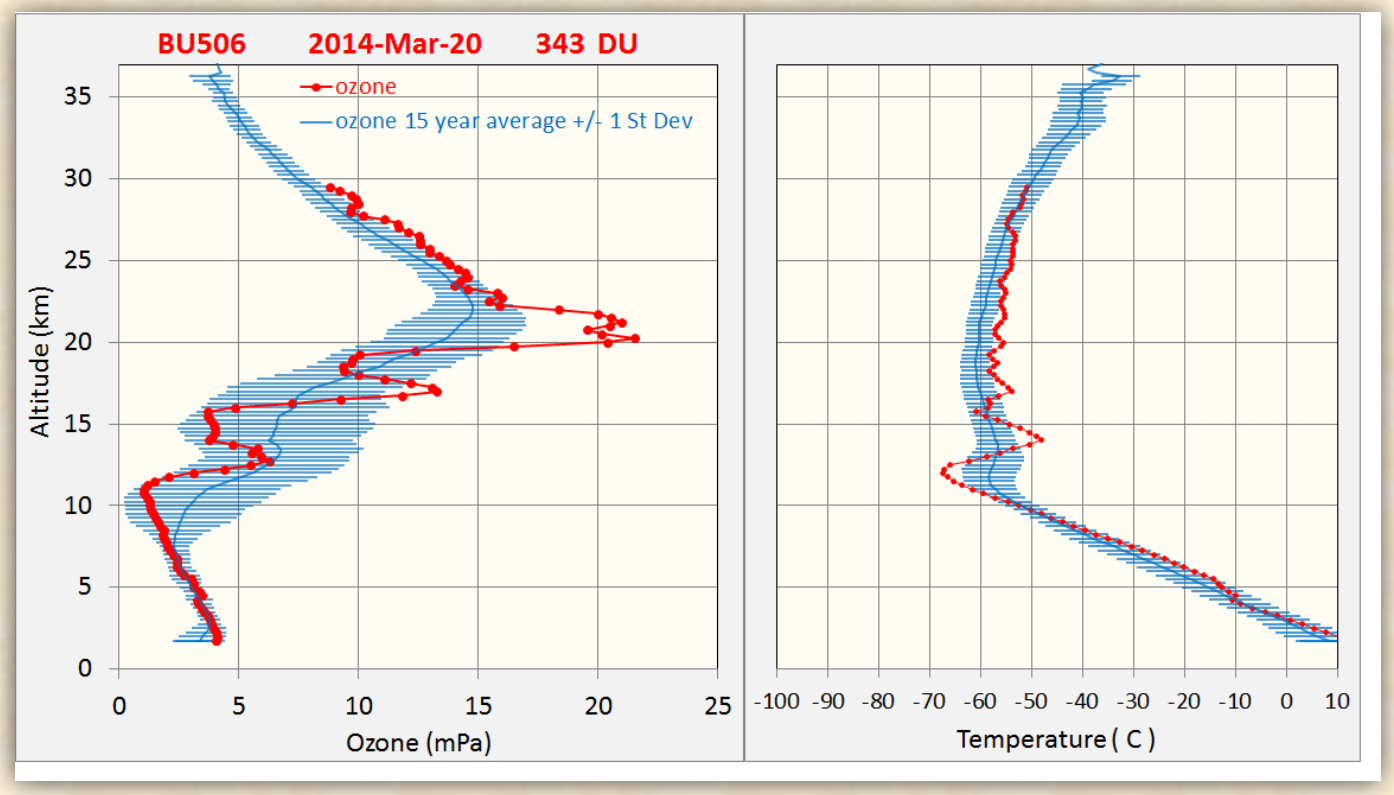
The differences were expected, as both instruments use algorithms with a fixed stratospheric ozone weighted temperature.

- For the Dobson, the static temperature is 46C, sensitivity is -0.13%/DegC
- For the Pandora, the static temperature is 48C, sensitivity is +0.33%/DegC
- Using Richard D. McPeters and Gordon J. Labow's *Climatology 2011: An MLS and sonde derived ozone climatology for satellite retrieval algorithms*

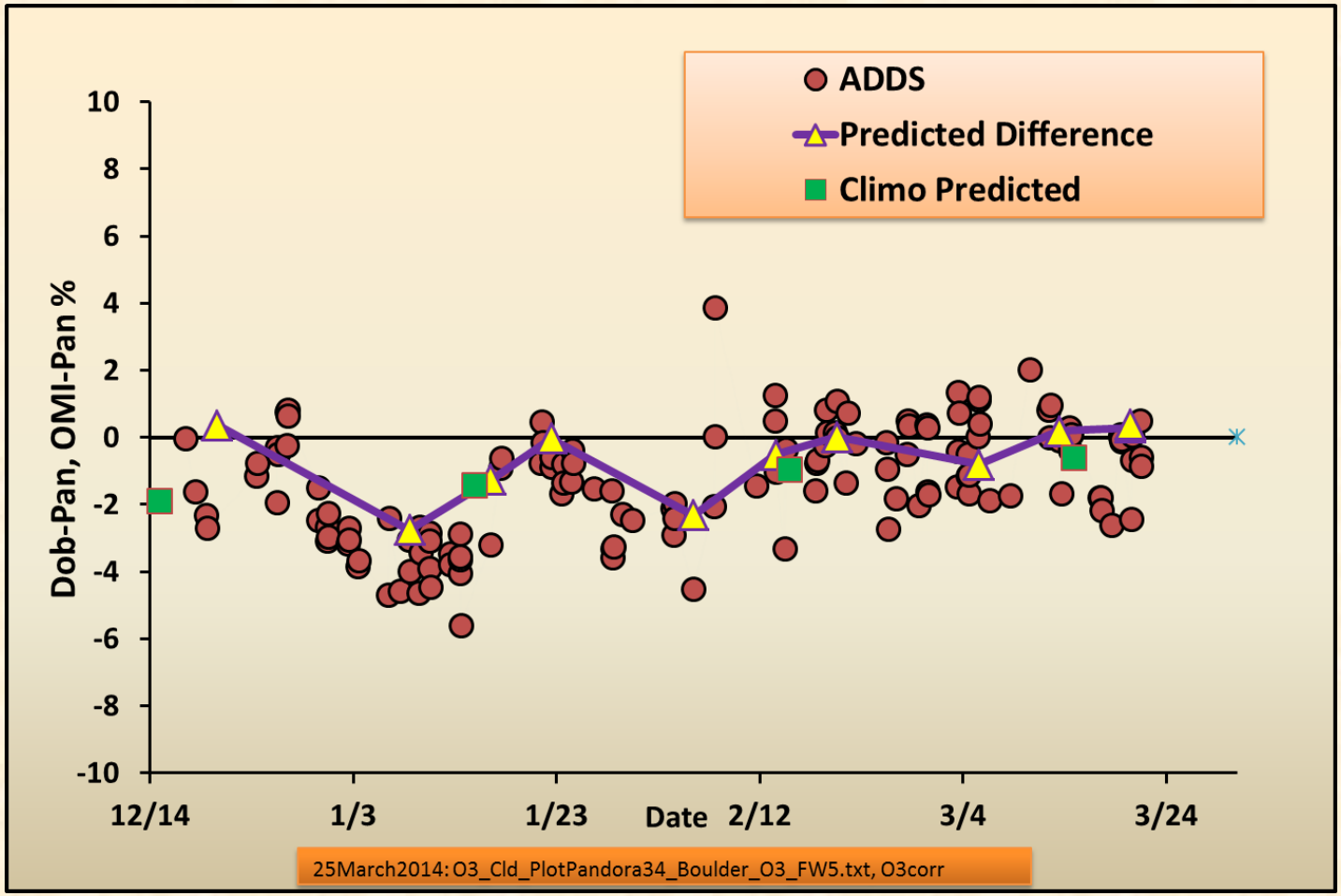


A step further: Ozonesondes

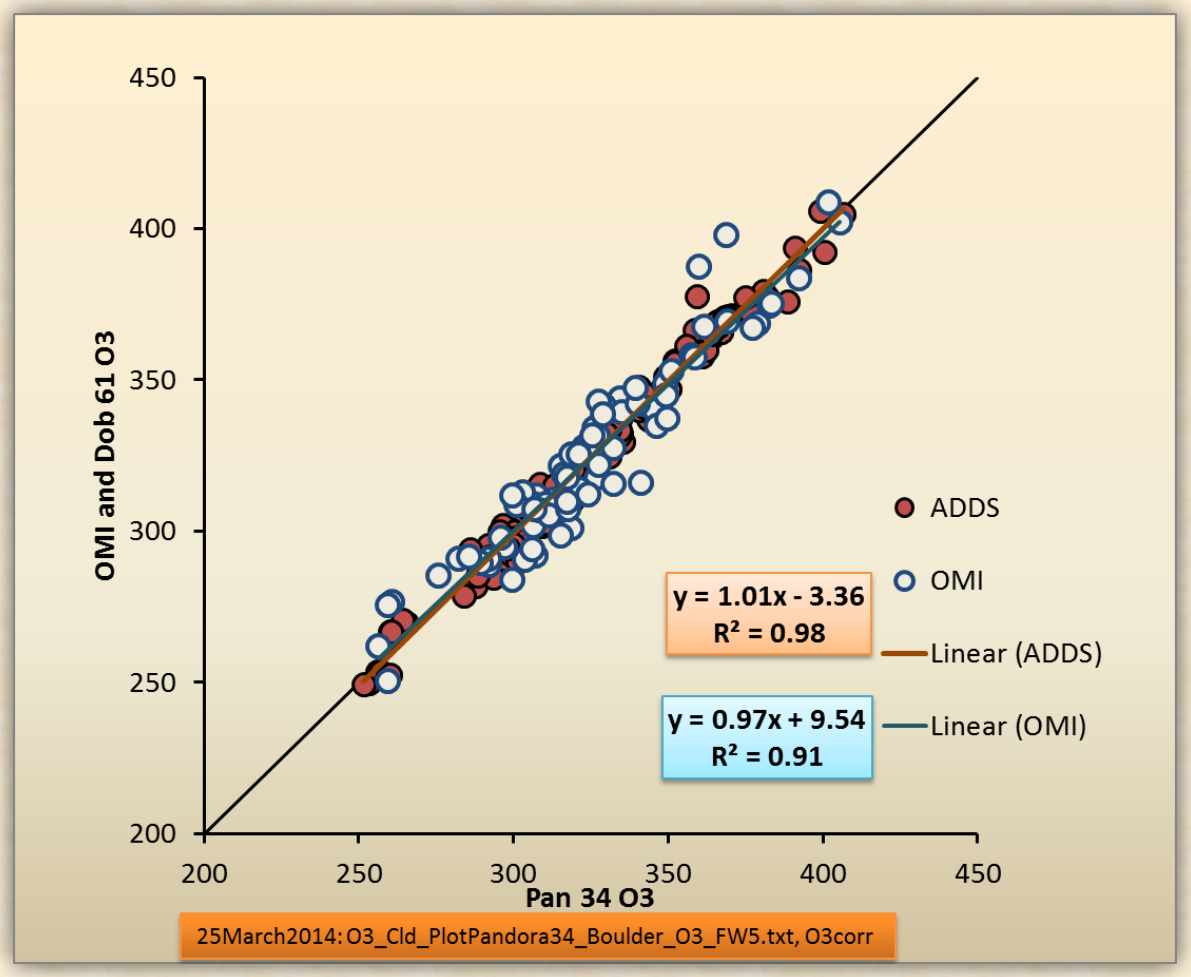
- We have weekly ozonesondes, retrieving ozone and temperature profiles.
- Using that information, the difference on a individual day can be predicted.



The pattern in the differences are suggested by the Stratosphere Temperature



Boulder, CO, 17 Dec2013-24 Mar2014 - Matched Pan, Dob and OMI O3 compared, 15 Minutes max difference in time, but with Dobson and Pandora results adjusted using McPeters and Labow's *Climatology 2011…* Pandora 0.2% higher than Dobson, and OMI



The standard deviation of 3.0% for OMI and 1.6% for Dob differences

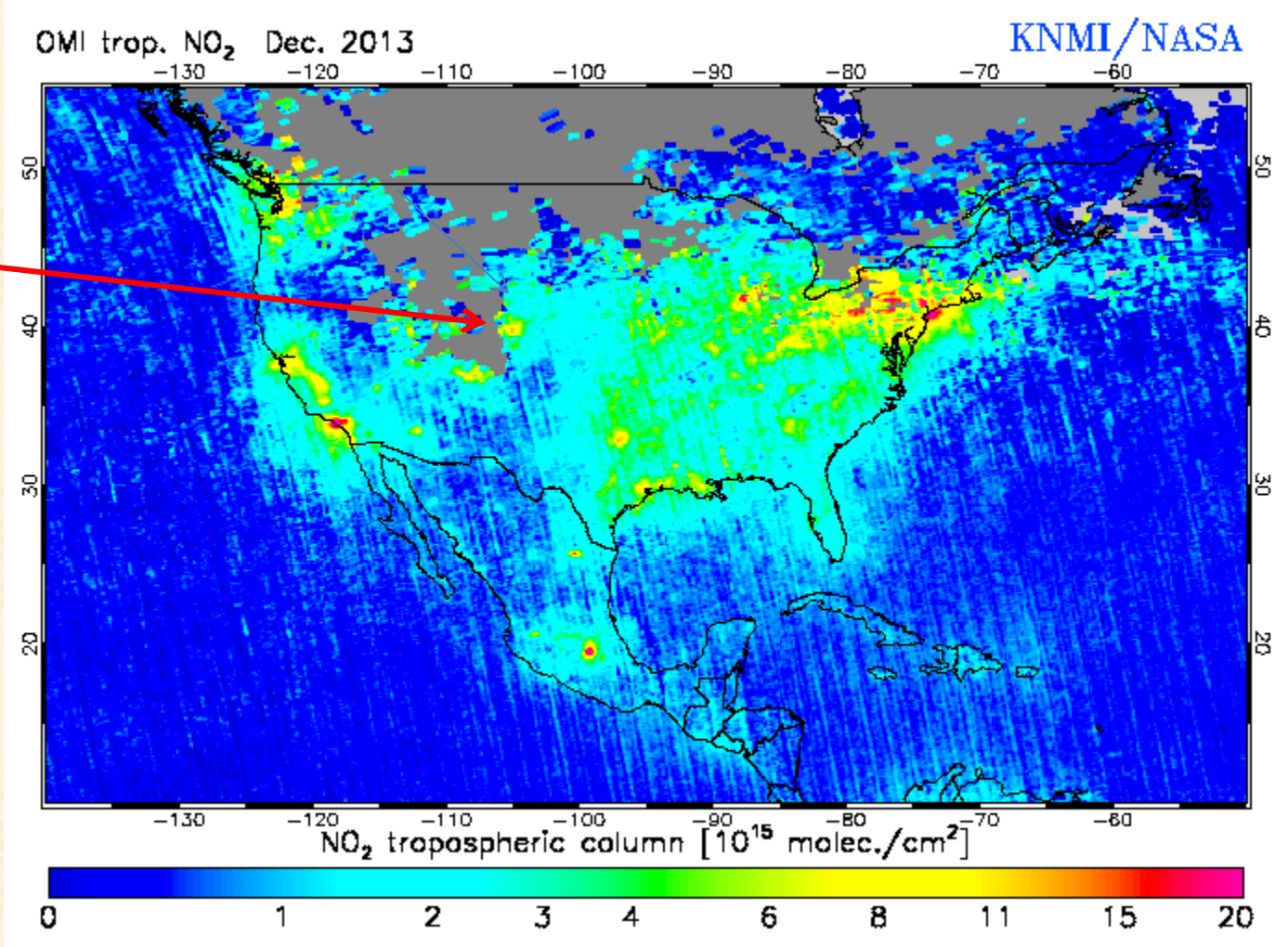
What have we learned in 4 months?

- **The difference between Dobson and Pandora derived total column ozone strongly depends on the stratospheric temperature variability.**
  - Using ozone and temperature climatological mean profiles reduces the average Pandora-Dobson difference to ~0.2%.
- **Potential for automated operations is considered**
  - This instrument survived the Boulder winds, but control computer had problems with outside temperature below approx -10C.
  - The longevity of the tracker head, and the neutral density filter stability is unknown.
- **The instrument could be used as a replacement for Dobson instruments** at NWS stations, and at TDH or Summit NOAA observatories, if
  - a data handling protocol suited for long term monitoring is defined.
  - A more permanent mounting and electronics enclosure were designed.
  - For Summit, the tracker head would likely have to redesigned to work in the very low temperature.
- **Further benefits**: addition of SO_2, NO_2 and HONO/BrO monitoring for air-quality

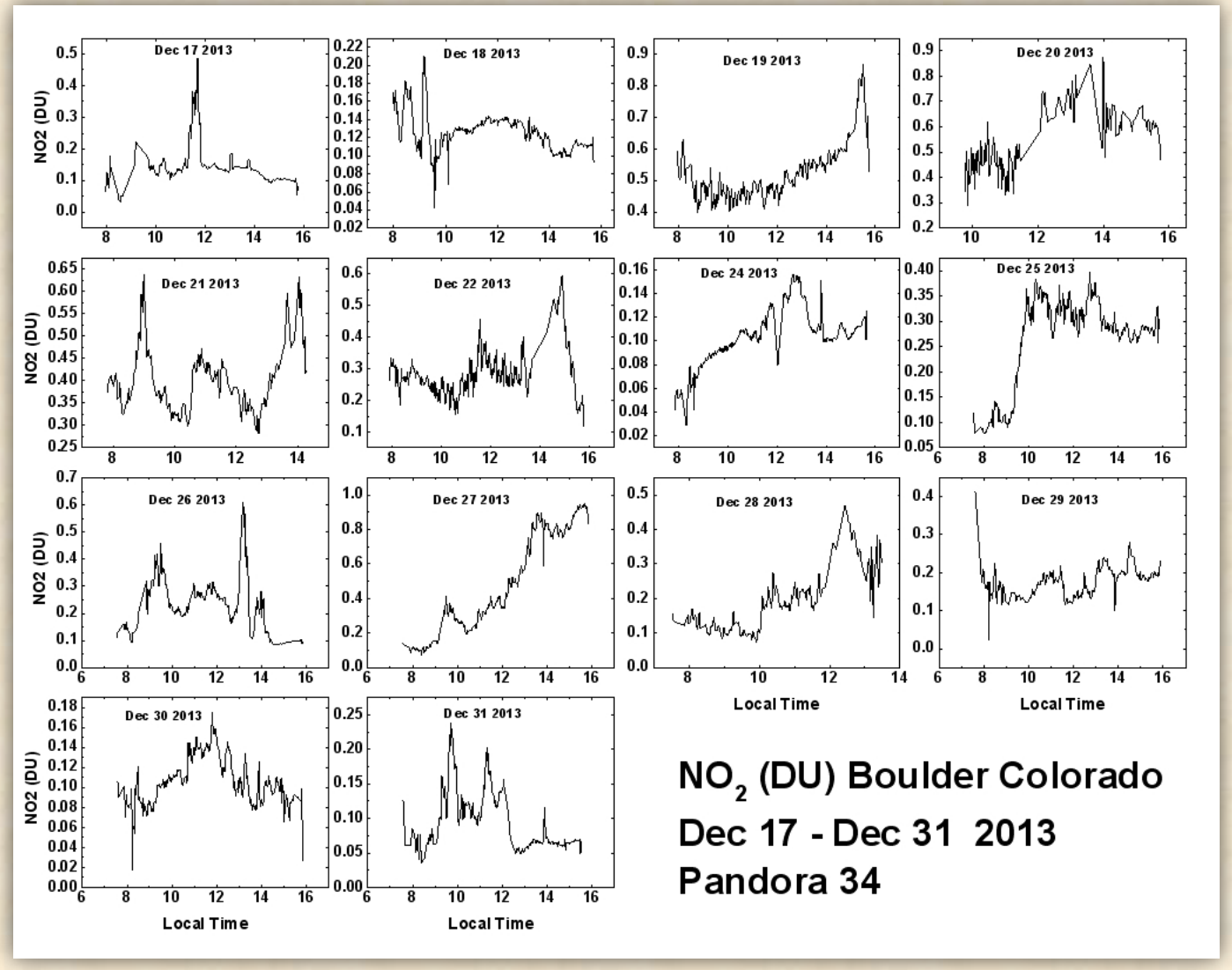
Richard D. McPeters and Gordon J. Labow's *Climatology 2011: An MLS and sonde derived ozone climatology for satellite retrieval algorithms*

Monthly mean NO2 from OMI, Dec

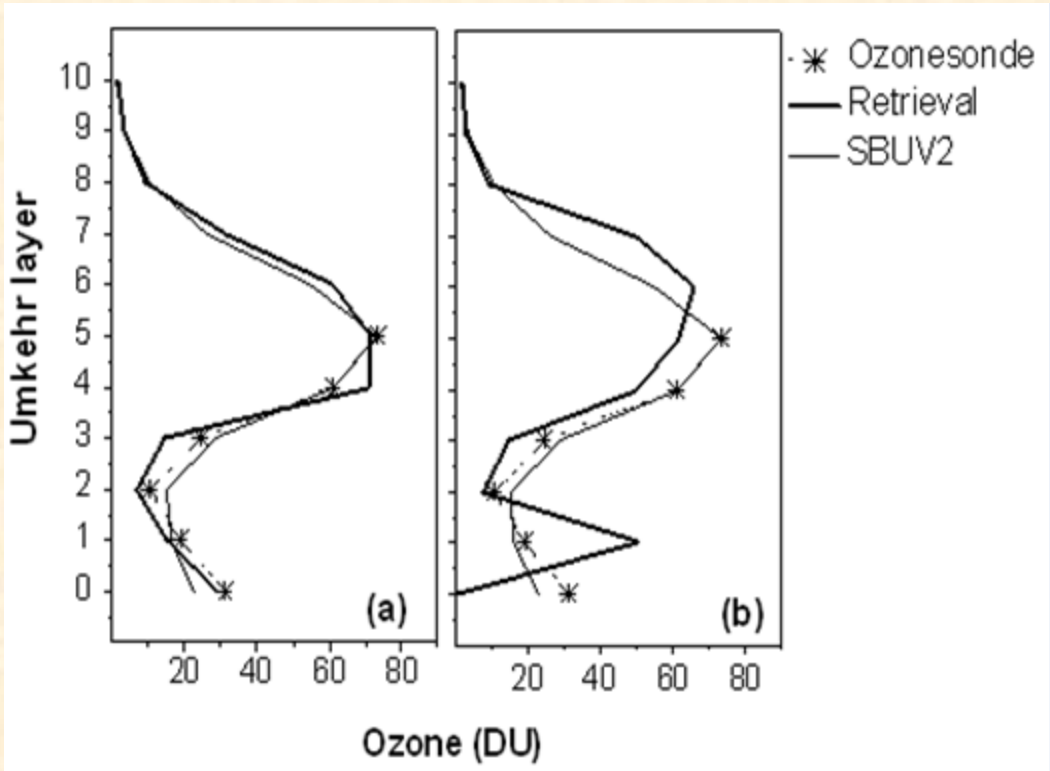
Boulder, CO



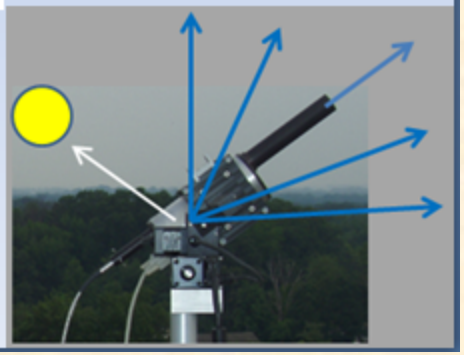
NO_2 column Data



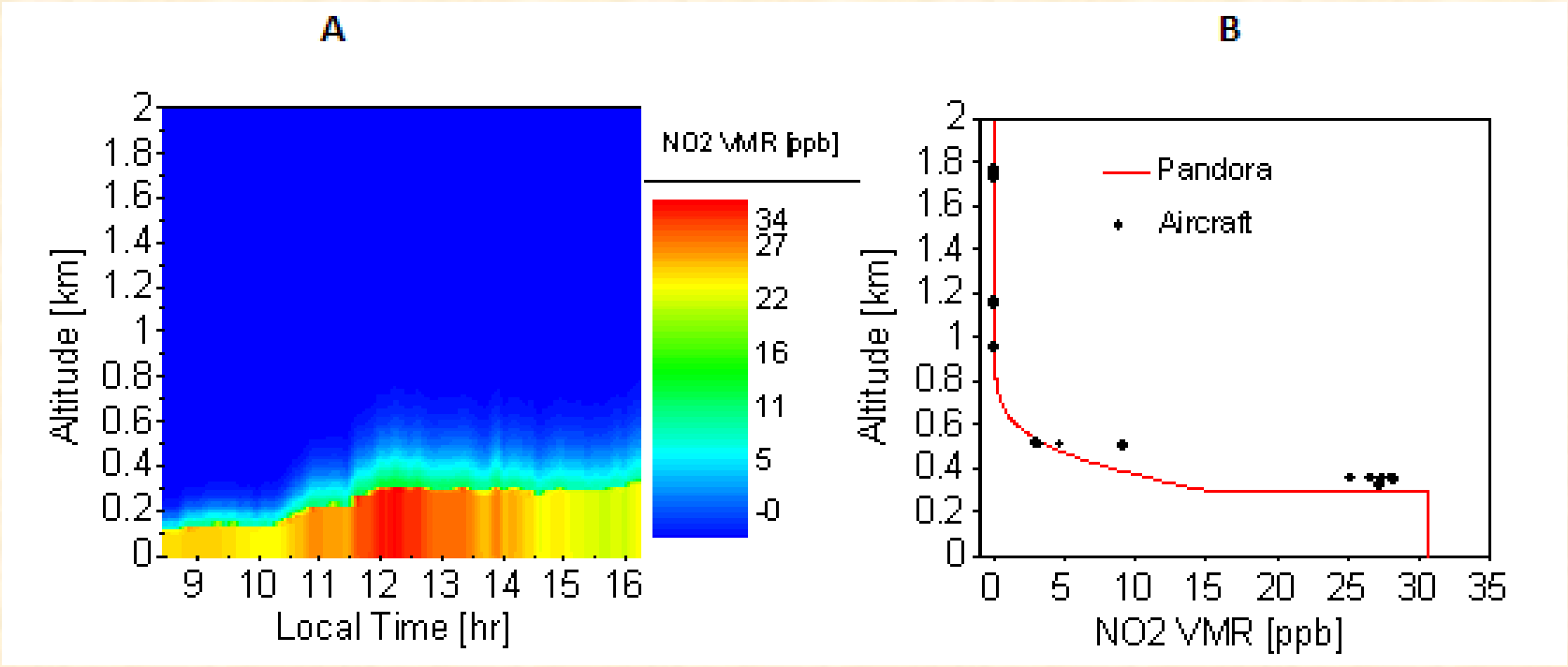
Profiles of O_3



Test O_3 profile retrieval (sza=75^O) for GSFC (a) for the real atmosphere with aerosols and (b) neglecting aerosols with a pure Rayleigh atmosphere. The SBUV2 O_3 profile (grey) and the ozonesonde results (*) are shown in comparison to the retrieval (black).



Profiles of NO_2



NO_2 profiles derived from Pandora direct-sun and MAXDOAS observations over Fresno, California on 18-Jan-2013

Comparison of Pandora retrieval to aircraft (P3B) measured NO_2 profile (Fresno California).