The Pandora Spectrophotometer

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

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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° field of view) mounted on a high precision (0.01°) 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?

- \( \text{O}_3 \) Total Column Profiles planned
- \( \text{NO}_2 \) Total Column
- \( \text{SO}_2 \)
- \( \text{H}_2\text{O} \)
- HCHO
- \( \text{O}_2\text{O}_2 \)
- BrO
- AOT(?)

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

Profiles of \( \text{NO}_2 \) and \( \text{O}_3 \) obtained at other sites

Species of interest for the Boulder area
Ozone Amount
Boulder, Colorado
12/17/2013 - 01/03/2014
Ozone Amount
Boulder, Colorado
12/17/2013 - 01/03/2014
Difference in Pandora over two consecutive days in December

Boulder, CO, December 2013

Total ozone (DU) / Ozone total (UD), 2013/12/17
Infamous Polar vortex?

Zoomed in on three days

Select time-coincident Pandora and Dobson measurements

26 Feb 2014: O3_Cld_Plot_Pandora34_Boulder_O3_FW5.txt, O3corr
Dobson/OMI vs Pandora offset

25March2014: O3_Cld_PlotPandora34_Boulder_O3_FW5.txt, O3corr
The differences were expected, as both instruments use algorithms with a fixed stratospheric ozone weighted temperature.

- For the Dobson, the static temperature is 46°C, sensitivity is -0.13%/DegC
- For the Pandora, the static temperature is 48°C, 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 an individual day can be predicted.
The pattern in the differences are suggested by the Stratosphere Temperature

![Graph showing Dob-Pan, OMI-Pan % over dates from 12/14 to 3/24]
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 SO₂, NO₂ 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

NO$_2$ (DU) Boulder Colorado
Dec 17 - Dec 31 2013
Pandora 34
Profiles of O$_3$

Test O$_3$ profile retrieval (sza=75°) 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).