Environment Canada Environnement Canada

Canada

Canada's Ozone Science Program

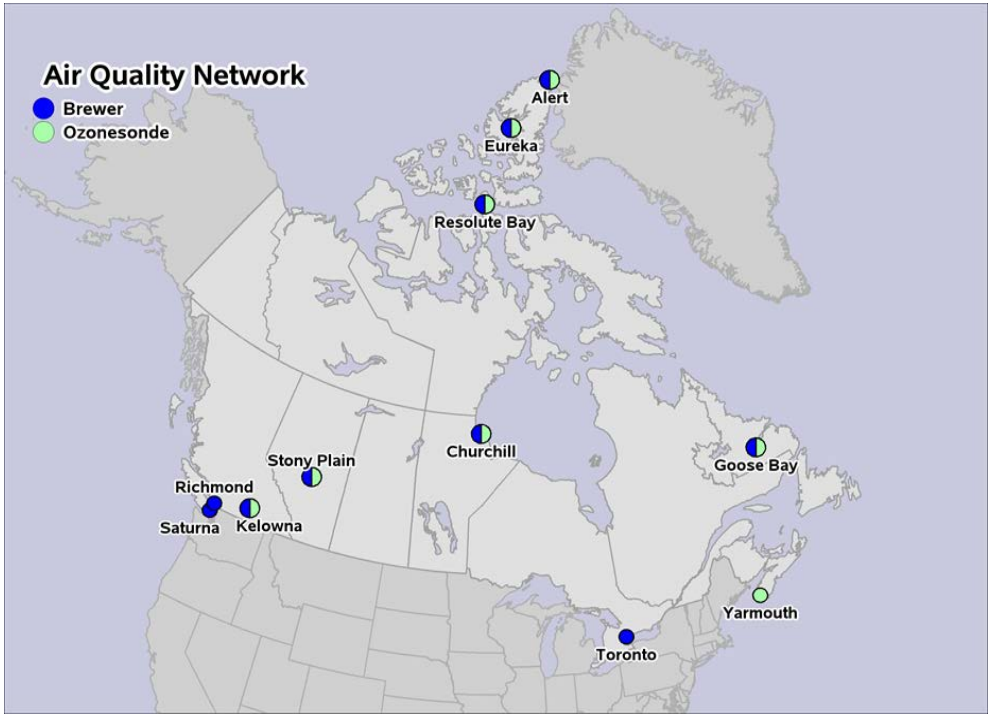
Stoyka Netcheva
Air Quality Research Division
Atmospheric Science and Technology Directorate
Environment Canada

9th Ozone Research Manager's Meeting
May 14-16 2014

Outline

- Current state of ozone monitoring in Canada
- Products and Services
- Research activities not covered by ozone monitoring
- Key scientific findings for the reporting period
- International engagement
- Concluding remarks

Canada's Ozone Monitoring Program

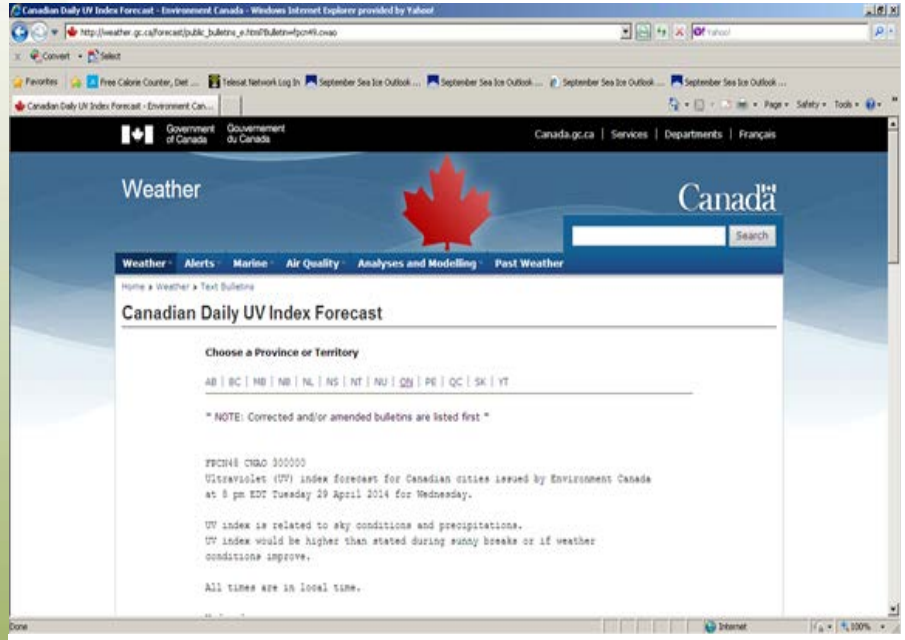


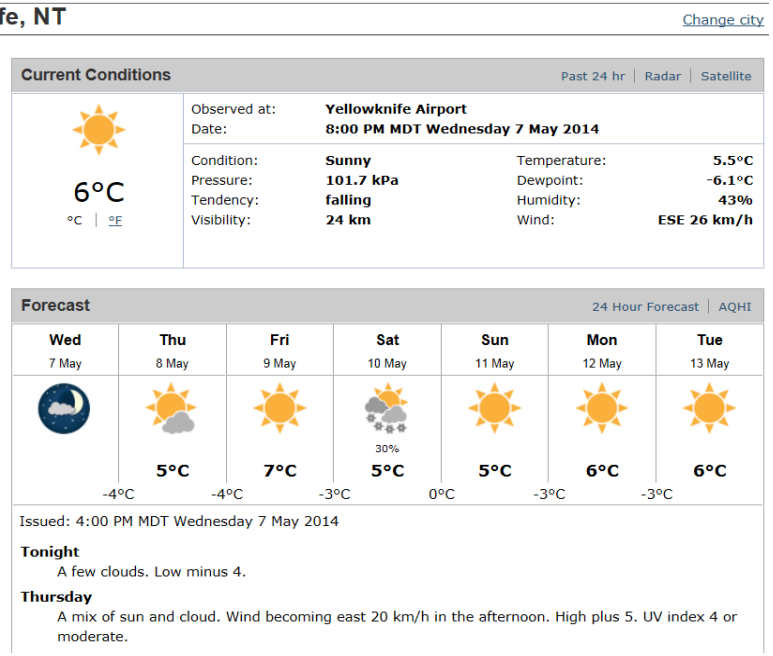
- Column measurements
  - Arctic sites: Alert, Eureka, Resolute with 3 instruments
  - mid-latitude sites: Churchill, Goose Bay, Edmonton, Saturna Island, Kelowna, Richmond and Toronto
- Weekly profile measurements at 8 sites
  - Arctic sites: Alert, Eureka, Resolute
  - mid-latitude sites: Churchill, Goose Bay, Edmonton, Yarmouth, Kelowna and Toronto

Jointly with USA-NOAA operating Brewers at Mauna Loa, Hawaii and South Pole

Brewers are operated by Canadian Universities at several stations for research purposes

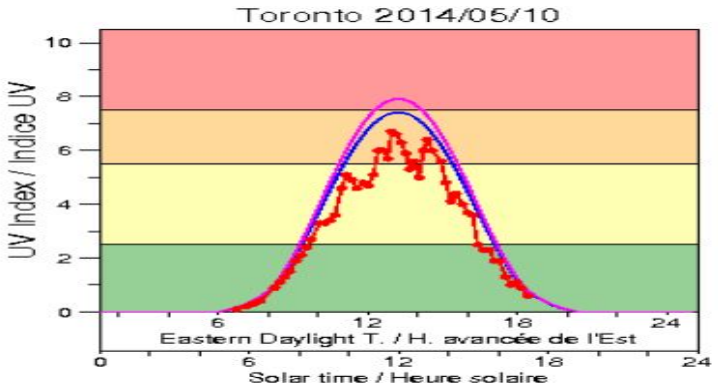
Daily products delivered to the public: UV Index forecast by Meteorological Services of Canada



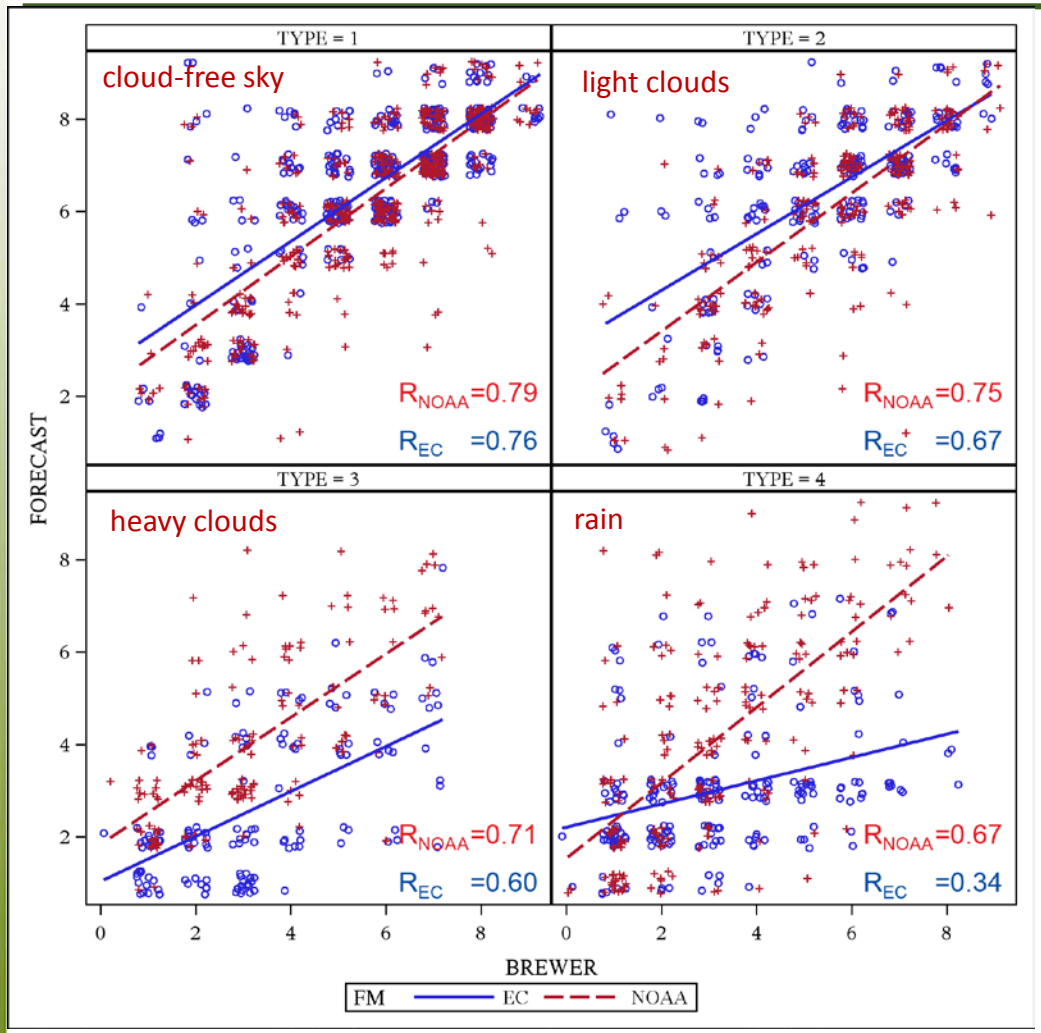


- Developed in 1992 as a health protection tool for Canadians to measure the strength of the ultraviolet radiation they are exposed to.

- Standardized by the World Health Organization (WHO) and used by 100 countries around the world.



Brewers application: UV Index forecast validation



Brewers are used for EC and NOAA UV Index forecast validation

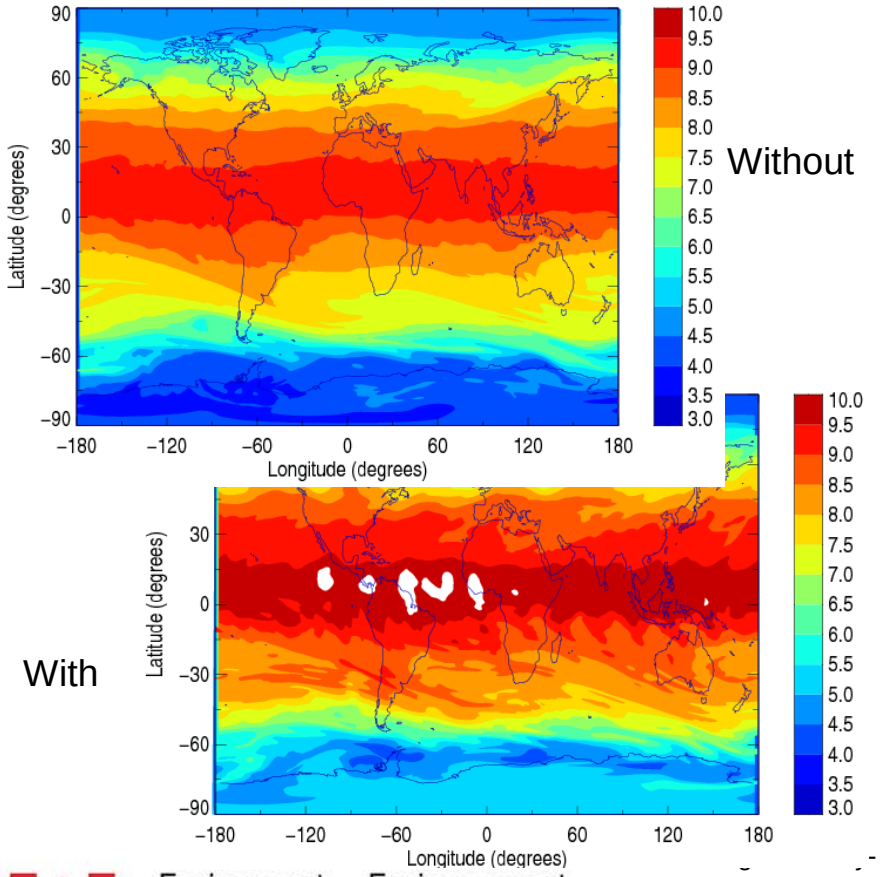
EC and NOAA forecast methods (FM) plotted against collocated Brewer measurements. Blue open circles show EC forecasts, and red plus signs show NOAA forecasts.
Four major weather types are represented: cloud-free sky (type 1), light clouds (type 2), heavy clouds (type 3), and rain (type 4).

From He et al., JAMC, 2013

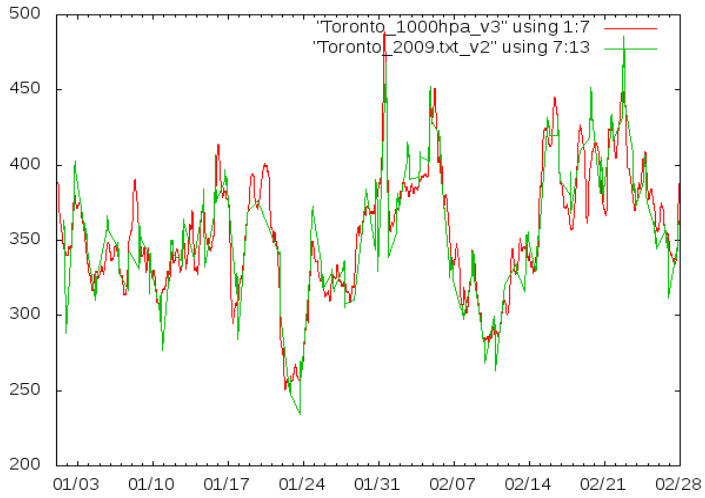
UVI attenuation: clouds, albedo, altitude improvement
7 day clear-sky and cloud affected forecast

Sample results from stratospheric ozone assimilation

Ozone field at ~10 hPa without and with assimilation of satellite ozone data (18UTC, 31 Aug 2008)



Comparison of column ozone short-term forecasts (after assimilation) and Brewer measurements in Dobson Units for Toronto (Jan-Feb 2009)

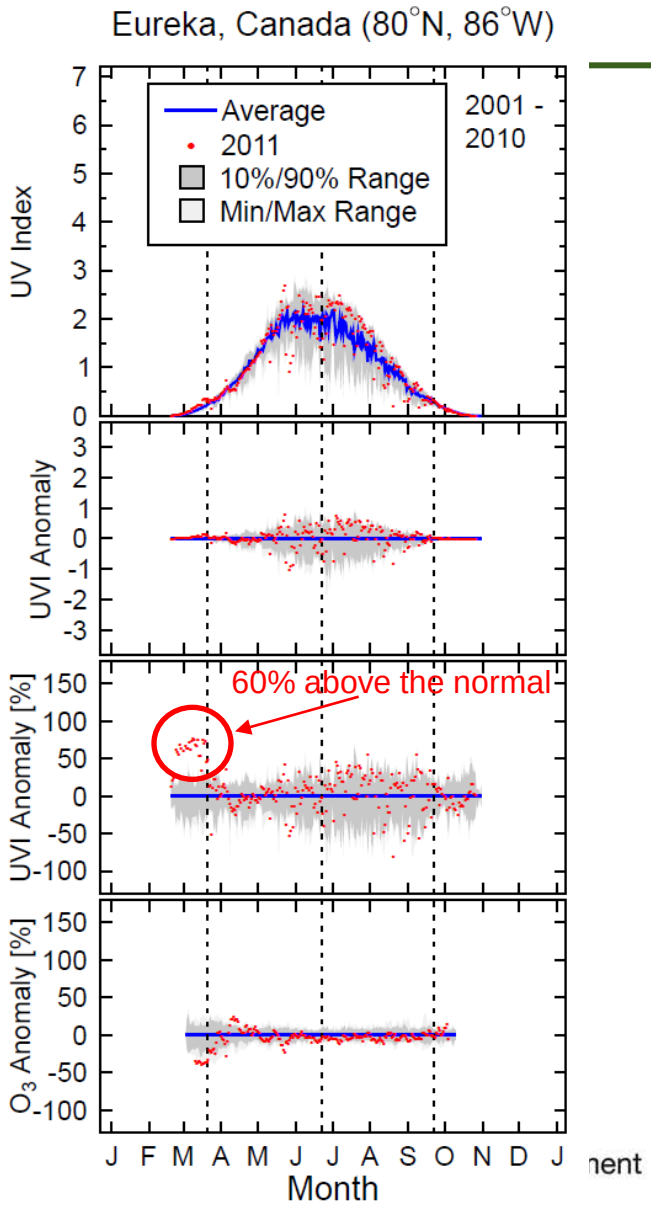


Implementation of near-real time global assimilation of stratospheric ozone for the purpose of improving UV index forecasts and providing ozone boundary conditions for regional air quality forecasts (to be completed in 2015).

Rochon, Stroud, Menard, DeGrandpre, EC

Environment Canada | Environnement Canada

Brewer applications: UV in the Arctic



Brewer UV from 3 Arctic Brewer sites (Resolute, Eureka, Alert) are used in NOAA Arctic Report Card, BAMS State of Climate report, and other publications

In the spring of 2011, they reported UV levels that are 60% higher than normal

Seasonal variation of the noontime UV Index at Eureka. The top (first) panel compares noontime UVI measurements performed in 2011 (red dots) with the average noontime UVI (blue line), the range between the 10th and 90th percentile (dark shading), and the range of historical minima and maxima (light shading). The second panel shows the 2011 UVI anomaly in absolute terms, calculated as the difference between measurements and the average. The third panel shows the relative UVI anomaly calculated as the percentage departure from the climatological mean. The fourth panel shows a similar anomaly analysis for total ozone derived from satellite measurements. Vertical broken lines indicate the times of the vernal equinox, summer solstice, and autumnal equinox, respectively.

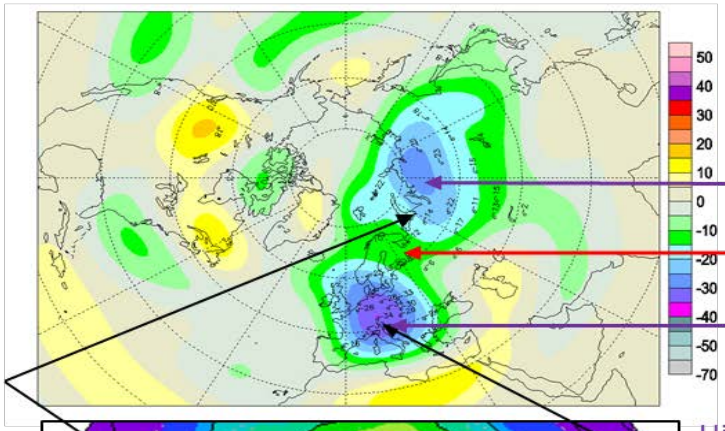
Form Bernhard et al., ACP, 2013

Canada

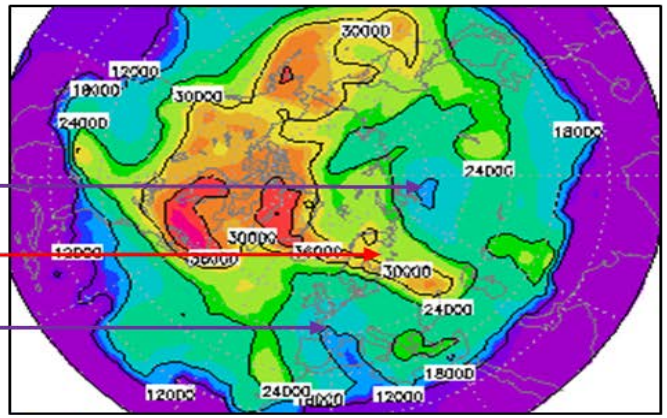
Near Real Time monitoring

March 17, 2014

Total ozone deviations from normal in %

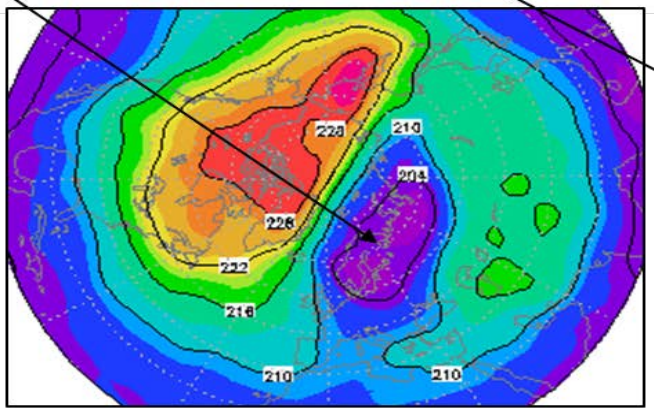


The tropopause pressure

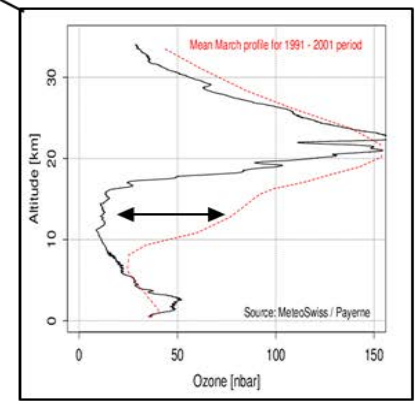


The centre of the polar vortex.

High (low) tropopause corresponds to low (high) ozone



Temperature at 50 hPa



Ozonesonde from Payerne, Switzerland.

High tropopause causes ozone deficiency below 18 km.

Near Real Time Monitoring

Ozone observations

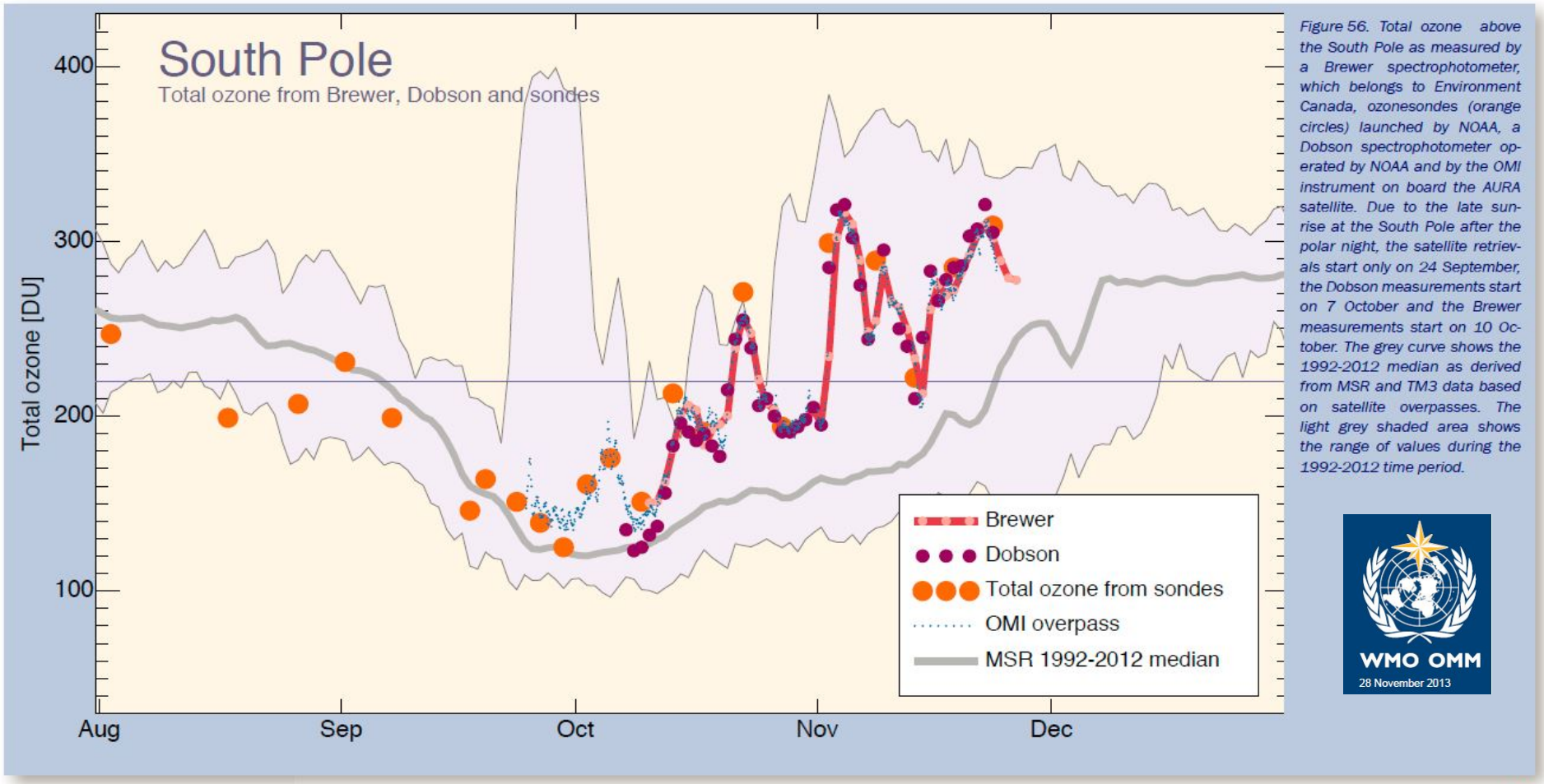


Figure 56. Total ozone above the South Pole as measured by a Brewer spectrophotometer, which belongs to Environment Canada, ozonesondes (orange circles) launched by NOAA, a Dobson spectrophotometer operated by NOAA and by the OMI instrument on board the AURA satellite. Due to the late sunrise at the South Pole after the polar night, the satellite retrievals start only on 24 September, the Dobson measurements start on 7 October and the Brewer measurements start on 10 October. The grey curve shows the 1992-2012 median as derived from MSR and TM3 data based on satellite overpasses. The light grey shaded area shows the range of values during the 1992-2012 time period.

WMO OMM
28 November 2013

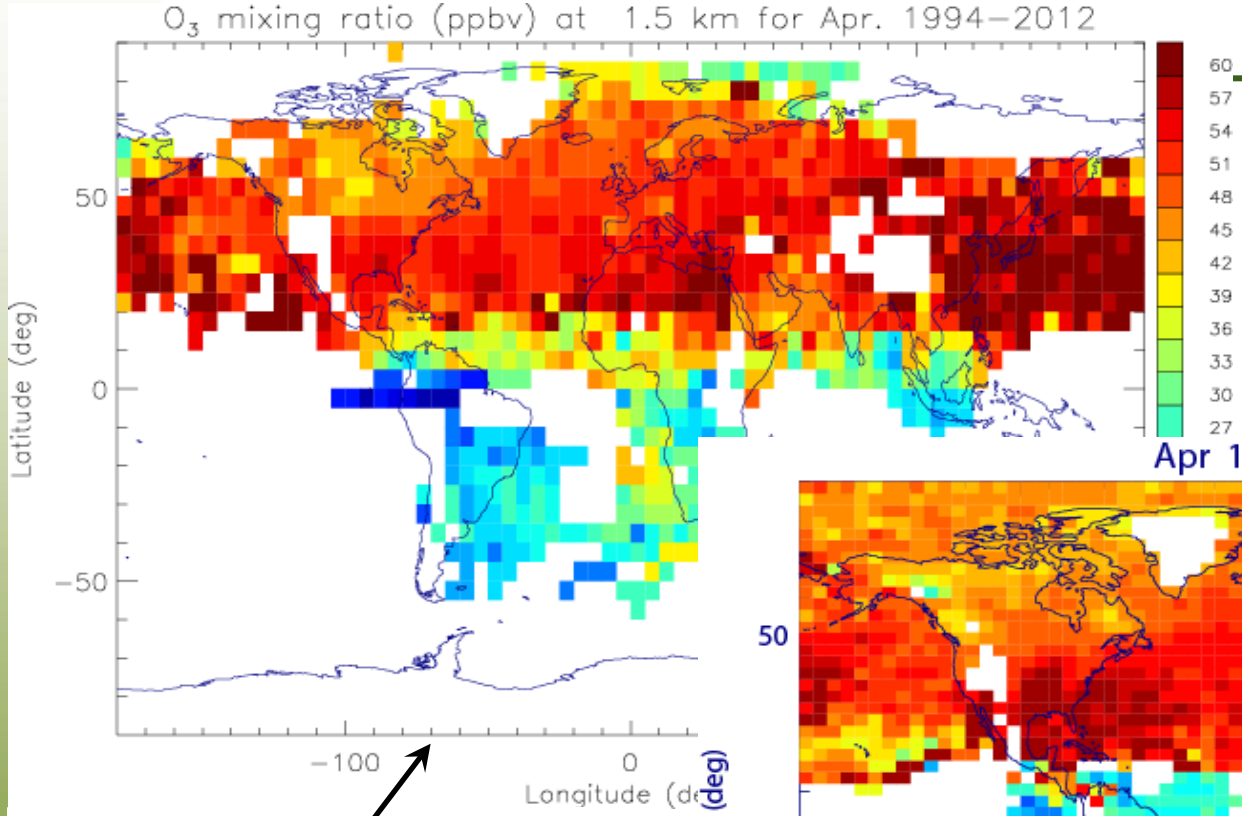
Canadian ozonesonde network
Re-evaluation Results: reduced uncertainty

Tropospheric changes: increases of up to 5% after 1979; up to 20% before 1980 (Brewer-Mast sondes), reducing with altitude.

Stratospheric changes: decreases of up to 6% before 1980, less below 25km. Increases of ~1% in 1980s, ~2-3% in 1990s; little change in 2000s.

	Mean K	Std Dev	Trend
BM data			
Original	1.27	0.303	2.7%/decade
Renormalized	1.20	0.198	
Response correction	1.03	0.179	2.2%/decade
ECC data			
Original	0.97	0.101	-2.6 +/- 0.6 %/decade
All corrections	0.99	0.087	0.6 +/- 0.5 %/decade

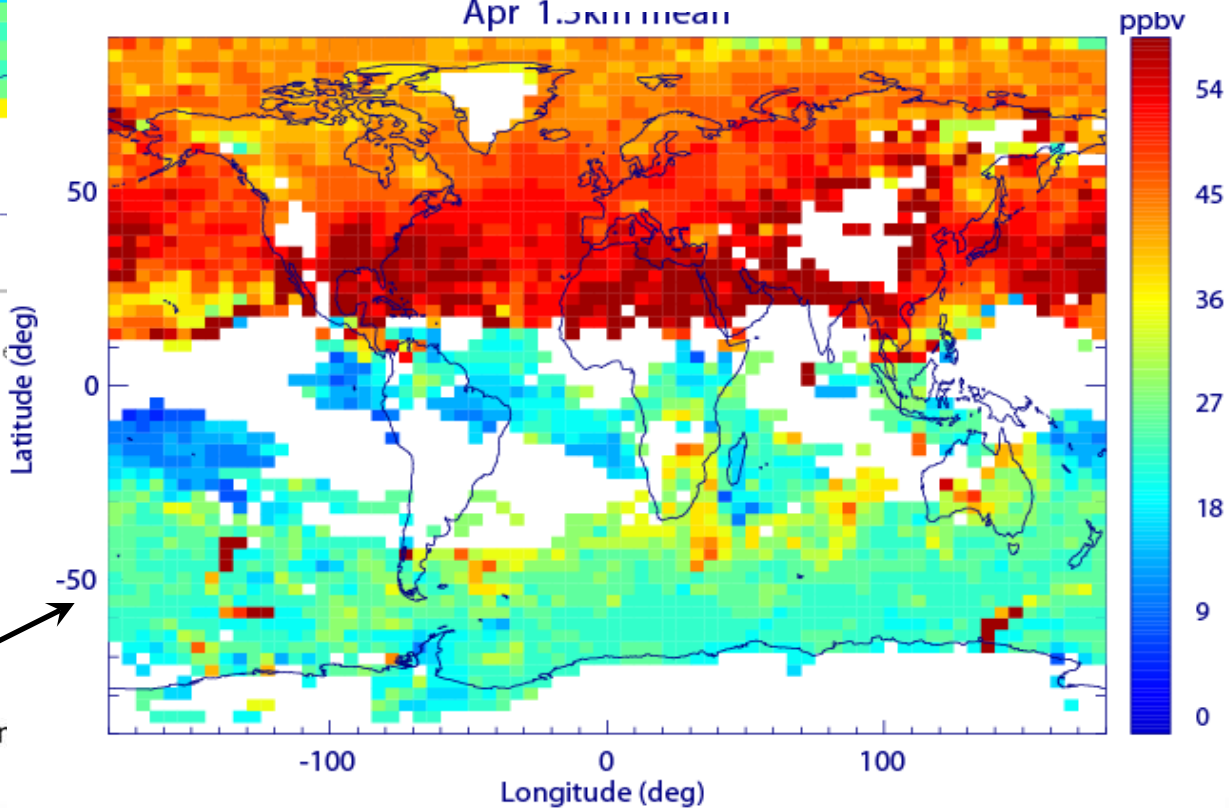
Global 3D data set



- Ozone data from sparse measurements projected using meteorological winds (air parcel trajectories). *More detail, longer record than satellites.*

From Tarasick, PAHA WS

Trajectory-mapped ozone data from commercial aircraft (MOZAIC)

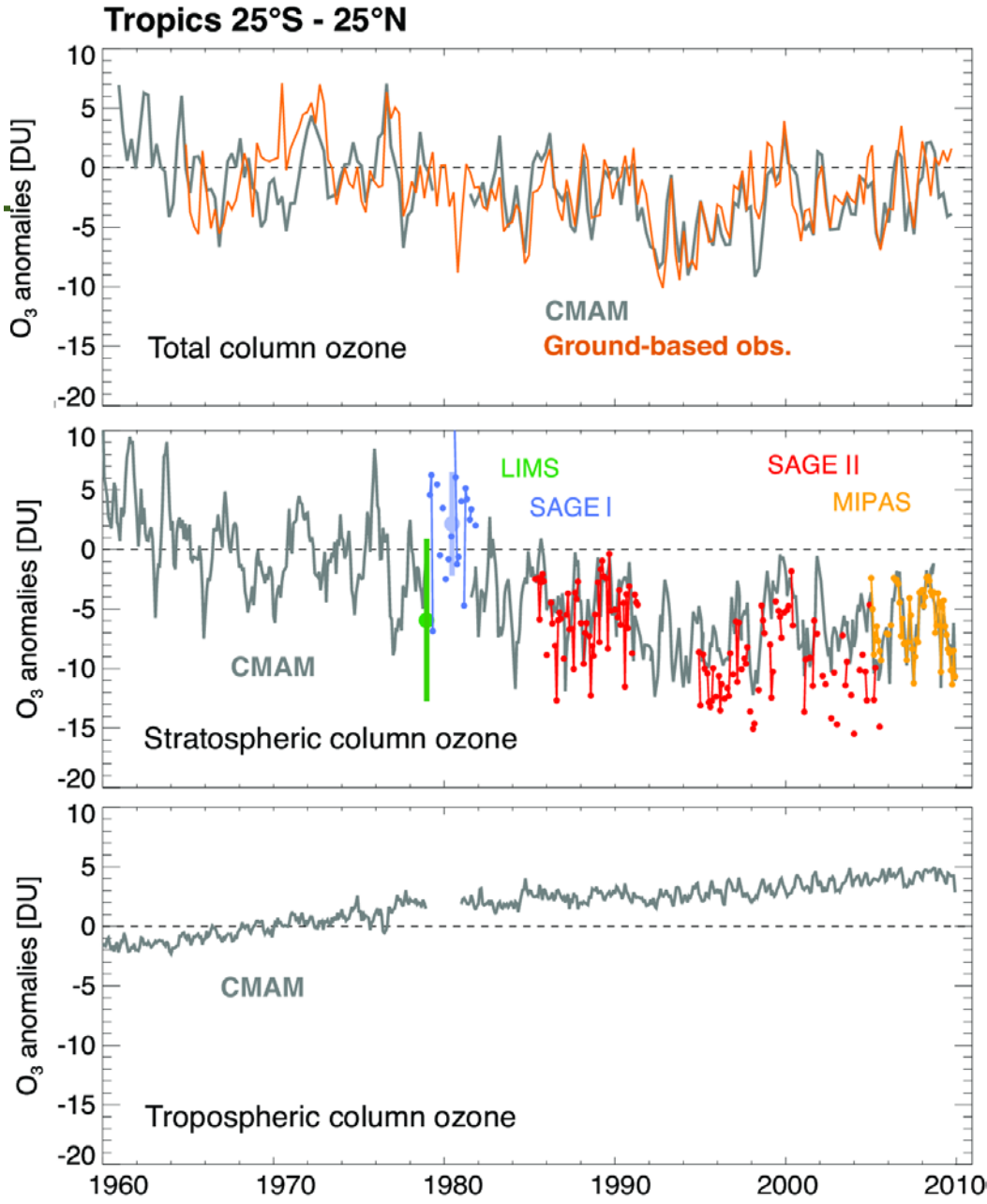


And from ozonesondes

Environment Canada Environnement Canada

Canadian Middle Atmosphere chemistry-climate Model

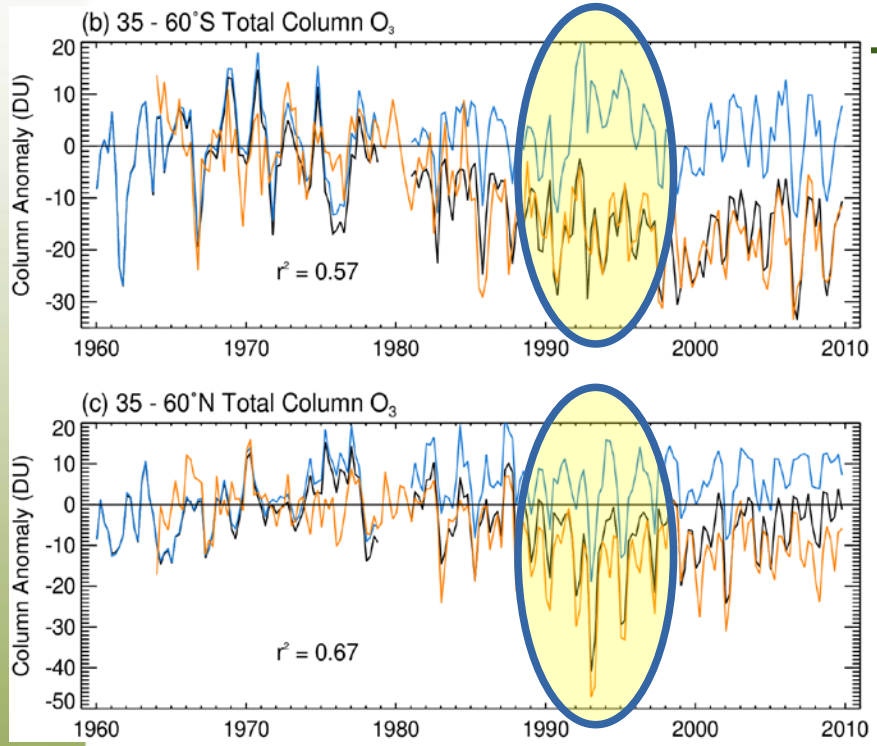
- Compared to the full record of available ground-based observations, the CMAM chemistry-climate model, constrained to observed meteorology, is able to reproduce a large degree of the variation in total column ozone
- The model also shows good agreement with available satellite observations of the stratospheric partial column, though the satellite record is discontinuous
- To reconcile the near-constant total column since 1980, with the stratospheric decrease since 1980, the model calculates an increase in tropospheric ozone

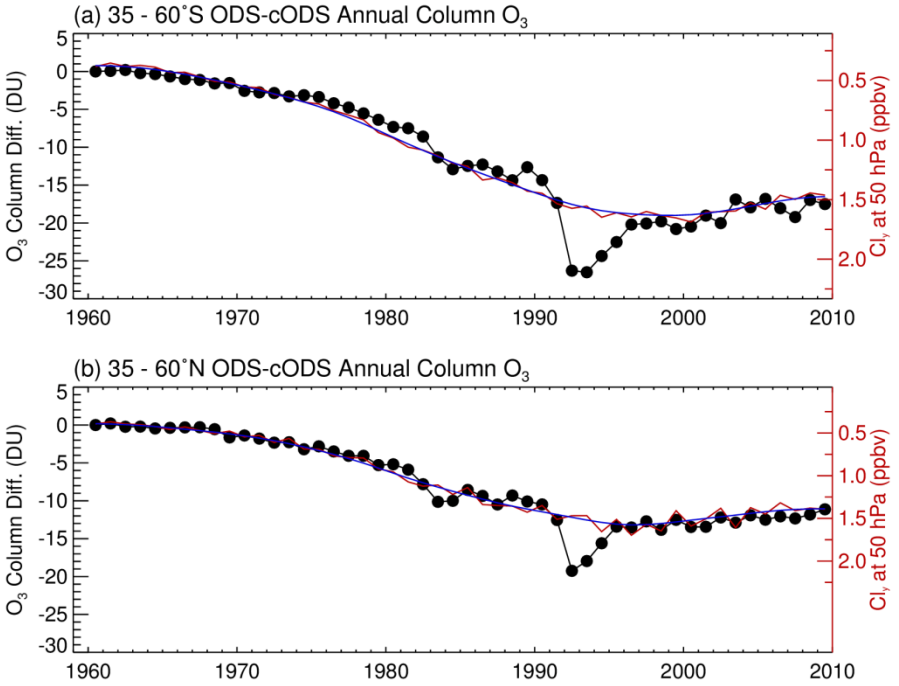


From Shepherd et al. Nature Geosc. 2014

Canada

Canadian Middle Atmosphere chemistry- climate Model: recent results





Black line – standard model simulation
Orange line – ground-based total column obs.
Blue line – model with ODSs held at 1960 levels

Following the eruption of Mt. Pinatubo, little ozone enhanced ozone depletion was seen in the Southern Hemisphere mid-latitude.

Corresponding model simulation with ODSs held at 1960 levels (blue line) shows enhanced transport of ozone in Southern Hemisphere.

Plotting the difference between the two CMAM runs, giving the ozone destruction due to ODSs, clearly shows enhanced ozone destruction in both hemispheres following Mt. Pinatubo.

From Shepherd et al. Nature Geosc. 2014

Canada

Canadian Network for the Detection of Atmospheric Change (CANDAC)

(PI J. Drummond)

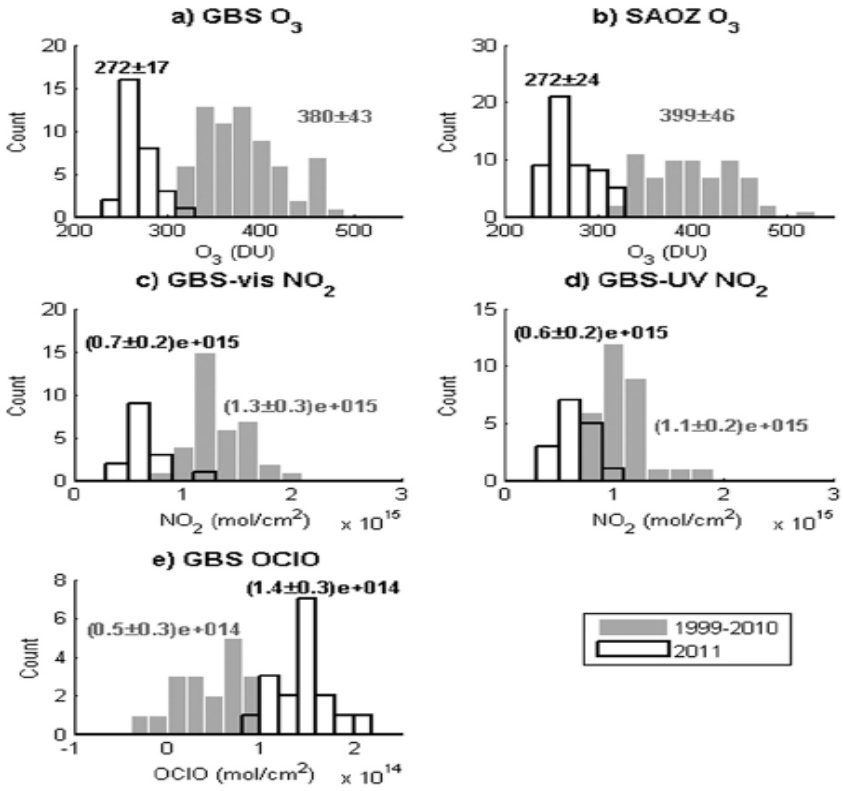


Figure 2. Histograms of (a) GBS ozone, (b) SAOZ ozone, (c) GBS-vis NO_2, (d) GBS-UV NO_2, and (e) GBS OClO. Measurements were taken inside the vortex for days 55–80 (24 February to 19/20 March), with 1999–2010 in gray and 2011 transparent with thick black lines. N ± M denotes the average (N) and 1σ standard deviation (M) in the measurements.

From Adams et al, Geophys. Res. Lett, 2012, K. Strong, K. Walker p. communications

The Polar Environment Atmospheric Research Laboratory (PEARL)

- PEARL based measurements to validate Canadian SCISAT/ACE and Odin/OSIRIS ozone measurements
- stratospheric ozone loss in spring 2011
- anomalous dynamics and chemistry during the final stratospheric warming
- partial and total column measurements of trace gases, trends in halogen containing species and other atmospheric constituents and parameters controlling the ozone budget
- stratospheric and tropospheric ozone research under new PAHA project (Probing the Atmosphere of the High Arctic): Composition Measurements (CM) - Ozone and Related Species (CM-O3)

Toronto

- FTIR measurements of stratospheric composition to identify mid-latitude polar vortex intrusions over Toronto

Large Measurement Campaigns: national and international scale

- PEARL, Canadian universities (Dal, UofT, others): measurements of ozone and related species using IR and UV/VIS spectrometers
  - Springtime validation campaigns for Canadian SCISAT/ACE and Odin/OSIRIS,
  - MATCH - Determination of Stratospheric Polar Ozone Losses
- BORTAS (Quantifying the impact of BOReal forest fires on Tropospheric oxidants over the Atlantic using Aircraft and Satellites) – international study with many collaborators

International Engagement

- Support capacity building initiative of WMO through Brewer Trust Fund ($30,000 U.S. per year)
- Provide experts to WMO Experts' Committees
  - GAW SAG-Ozone
  - GAW SAG-UV
  - GAW Data Centre Managers
- Maintain the WMO World Brewer Ozone Calibration Centre
- Maintain and provide the Global Brewer Travelling Standard Instrument to WMO
- Operate the World Meteorological Organization (WMO) World Ozone and Ultraviolet Data Centre (www.woudc.org)

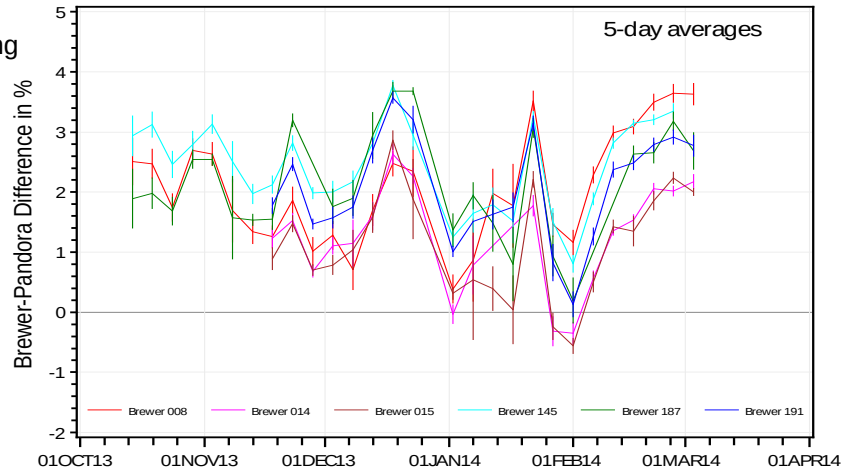
World's Brewer Calibration Centre activities 2011-2014

- Absolute calibration of Triad instruments took place in October 2013
- Established Triad of double monochromator instruments
- Comparison between 2 Triads is in progress
- USA-NOAA #109 calibrated against Triad in May 2013
- 2 instruments of Japan Meteorological Agency calibrated in March 2014
- Traveling standard #017 used to calibrate 115 instruments in 43 countries through WMO
- Inter-comparison of aTriad instrument with the Standard of Regional Calibration Centre Europe in progress
- Comparison between Dobson and Brewer measurements at Mauna Loa, Hawaii in progress

Pandora Spectrometer and Brewer Triads

- Sun and sky spectrometer – measures solar spectra
- Designed for satellite validation and pollution monitoring
- Operation and software design are similar to these for the Brewer spectrophotometer (commands, schedules)
- Automated, established algorithms, data available in real time
- Specifications:
  - Czerny-Turner spectrometer with backthinned CCD detector (Avantes)
  - 270-530 nm at 0.6 nm spectral resolution, 4 pixels oversampling
  - Wavelength independent FOV of 1.5° (FWHM)
  - T stabilized spectrometer (enclosed insulation under improvement)
  - High temporal resolution (<30 seconds per measurement)
  - Simultaneous measurements of various trace gases incl. O_3, NO_2, SO_2, BrO, HCHO, water vapour
  - Small size and portability (20 kg)
  - Cost: ~$40k
- Two instruments were deployed in 2013 (McKay and Toronto)
- Continue comparison with Brewer Triad instruments in Toronto.

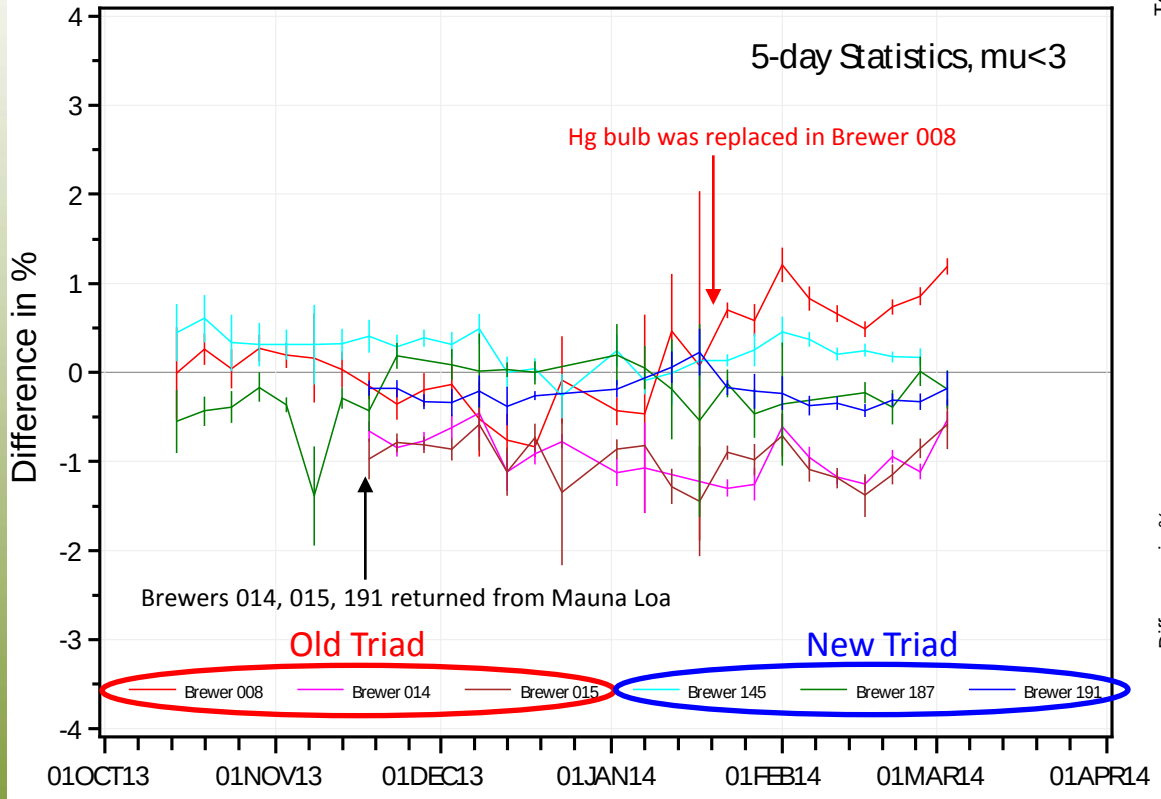
The Pandora-Brewer difference



There is a 0% to 4% systematic difference between Brewer and Pandora total ozone caused likely by the difference in ozone absorption coefficients and their temperature dependence.

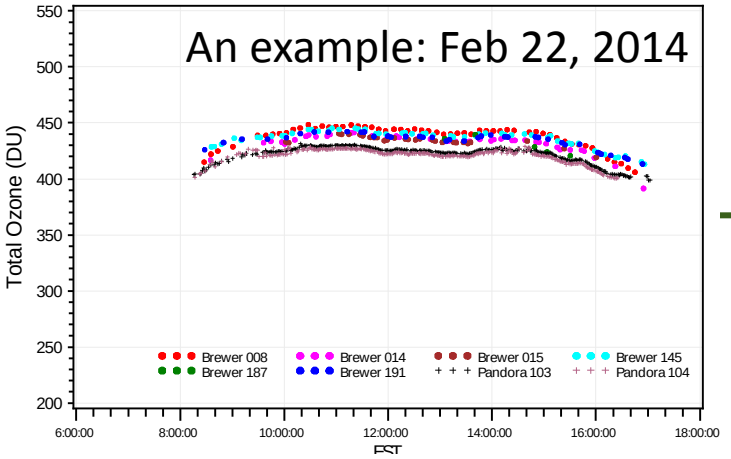
The triad update - 2014

The old and new triads agree within 1%, but there are some systematic differences likely due to stray light. The long-term instrument stability is a challenge.

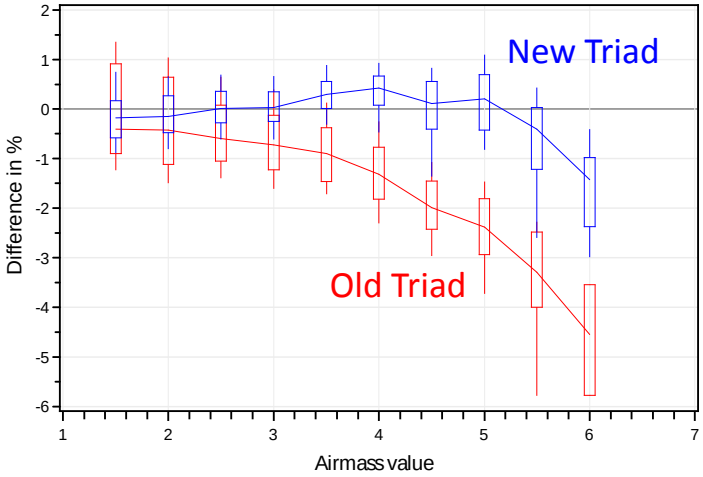


The biases between individual Brewer triad instruments and the "baseline." The baseline was established using high-frequency Pandora measurements adjusted for the Pandora-Brewer bias: The biases between Pandora and the new triad due to different ozone cross-sections were removed on a daily basis.

The error bars represent 95% confidence limits for 5-day mean differences



Brewer and Pandora measurements at Toronto. Pandora measurements with 1.5 minute frequency were used to account for the difference in ozone due to difference in observation time between individual Brewer measurements.



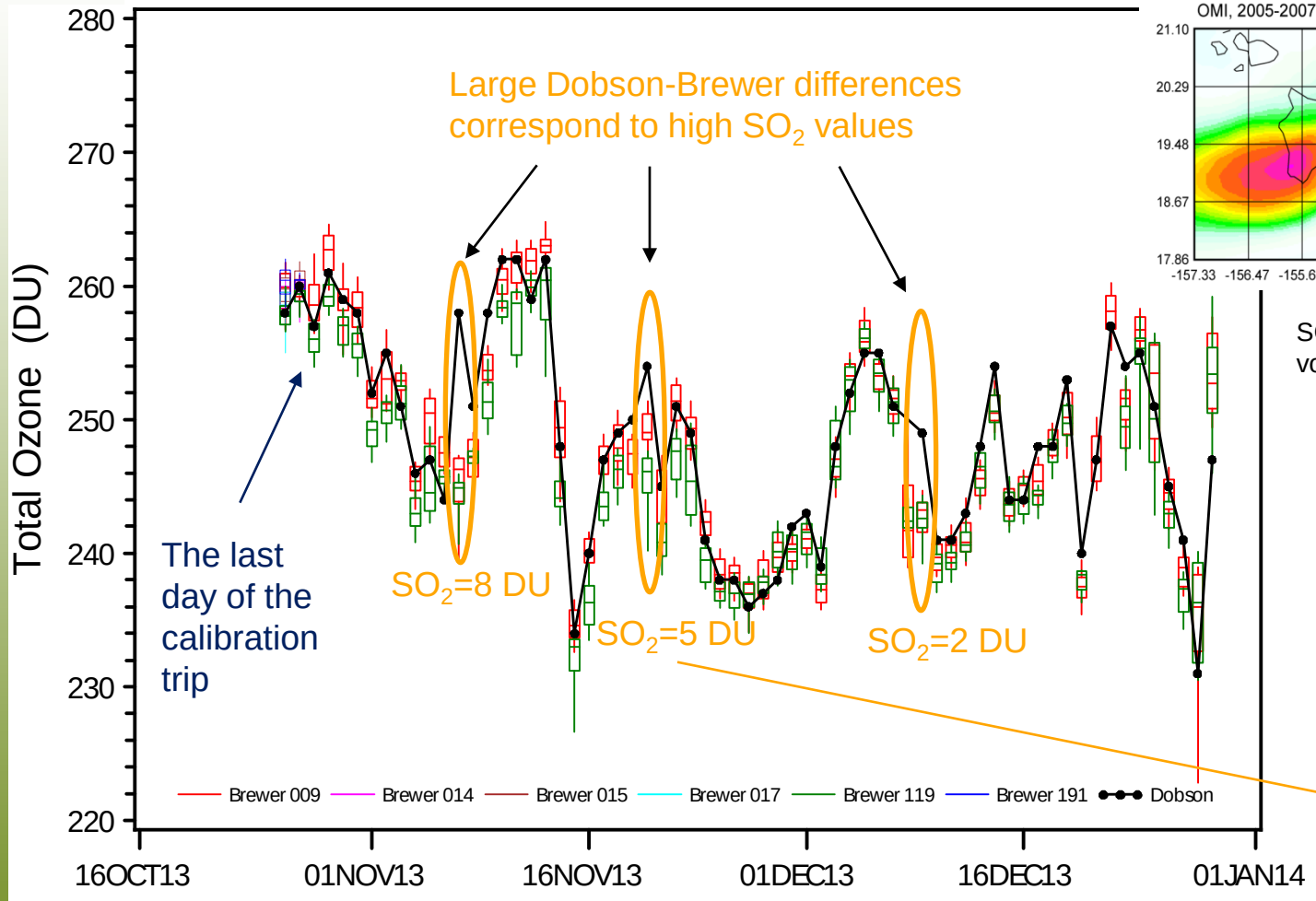
Stray light causes an underestimation of ozone values by the single Brewer. Pandora measurements adjusted for the bias were used as a reference.

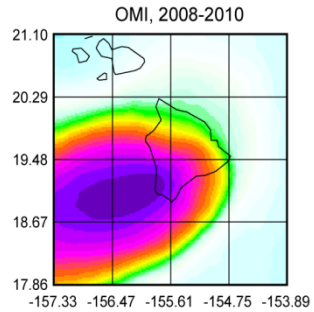
The whiskers represent 5st and 95st percentiles, the box edges represent the 25th and 75th percentiles, the centre is drawn at the median value

Environment Canada Environnement Canada

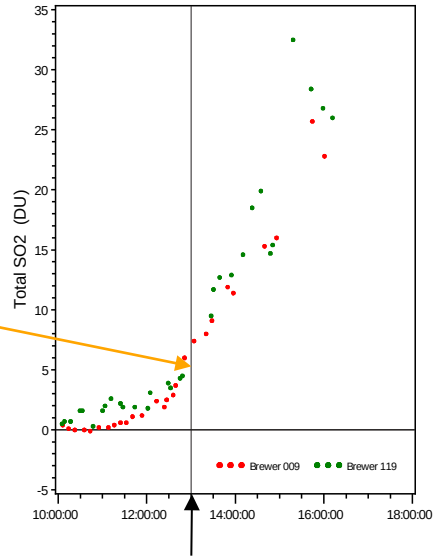
MLO Brewer and Dobson observations

Brewer ozone retrievals are not sensitive to SO_2, while Dobson overestimates ozone in presence of SO_2





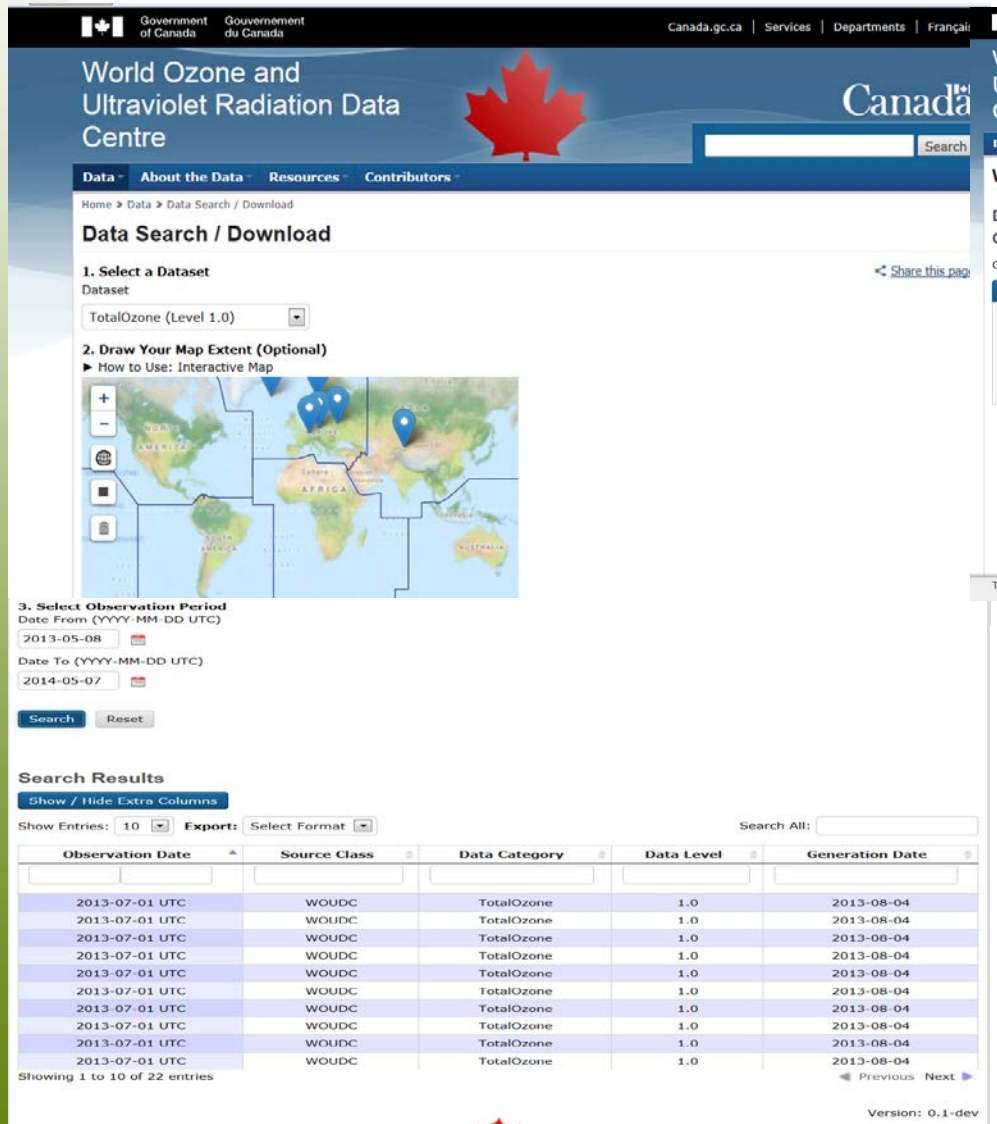
SO2 mean total values for Kilauea volcano derived from OMI

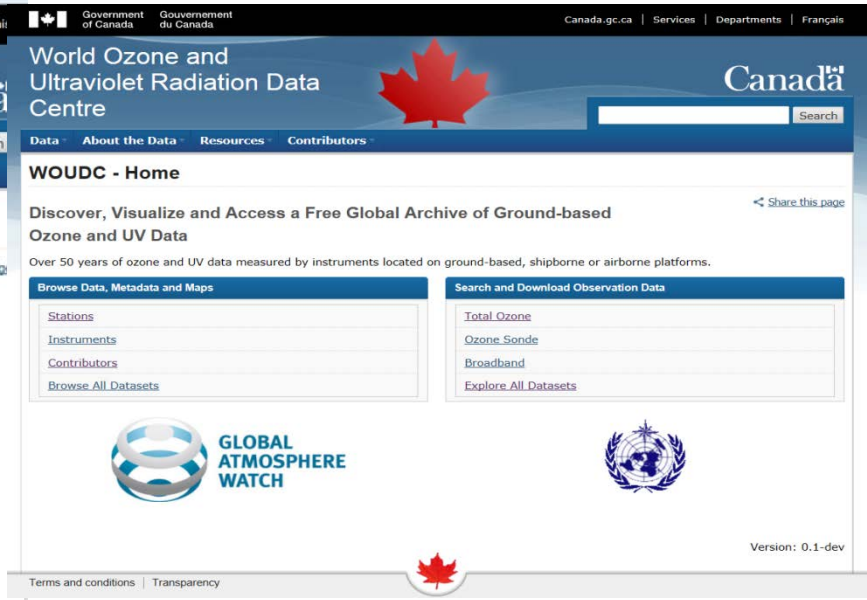


Dobson measurement was at 13:00 HAST

The whiskers represent 10st and 90st percentiles, the box edges represent the 25th and 75th percentiles, the centre is drawn at the median value. Dobson measurements (direct sun or blue zenith) are taken once a day near local noon. Dobson data were provided by NOAA.

World Ozone and Ultraviolet radiation Data Centre (WOUDC) managed by Meteorological Services of Canada





Renewal objectives:

- Enhance the data submission mechanism and infrastructure
- Effective and efficient data management approach
- Modernize data access mechanisms
- Improve accessibility and usability of the website

WOUDC managed by Meteorological Services of Canada- update on data records

	May 12th, 2014 Report				Data Increase Since Last Report – May 2011 (%)
Data Category	Platforms	Number of Files	Temporal Range	Number of New Platforms	
Lidar	2	~700	1991-1998	0	No change
Ozonesonde	141	~78000	1962-2014	2	20%
Total Column (Daily)	287	~72000	1926-2014	0	13%
Total Column (Hourly)	26	~69000	1984-2014	4	60%
Umkehr	64	~10000	1951-2014	0	No change

Concluding remarks

- **Arctic ozone levels continue to be difficult to forecast**
- **Research is on-going in improving ozone in numerical forecast through chemical data assimilation**
- **OSIRIS and SCISAT are beyond their design life**
- **New real-time products can be instituted when the necessary data and related product becomes available**
- **Research is on-going in enhancing our understanding of the relationship between ozone and climate**