Eureka Site Report

Kimberly Strong, Stephanie Conway, Dan Weaver, Joseph Mendonca,
Erik Lutsch, Sebastien Roche, Sophie Tran, Pierre Fogal

Department of Physics, University of Toronto

NDACC IRWG Meeting

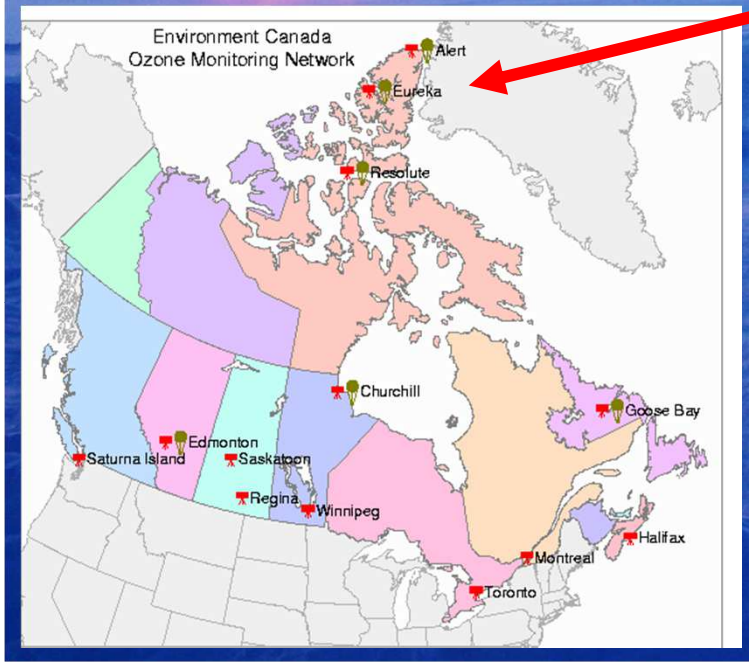
Toronto, Canada

8-12 June 2015

The PEARL at Eureka

Polar Environment Atmospheric Research Laboratory

- Formerly Environment Canada's Arctic Stratospheric Ozone Observatory
- Run by the Canadian Network for Detection of Atmospheric Change (CANDAC) since August 2005
- ~25 experiments at 3 facilities

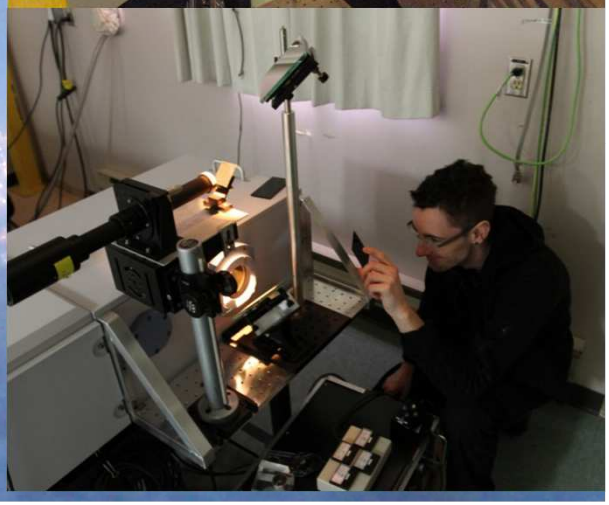


- Located on Ellesmere Island, Nunavut (80°N, 86°W)
- 15 km from Env. Canada's Eureka Weather Station
- 1100 km from North Pole

PEARL 125HR History

- Installed July 2006; mid-IR configuration
- NDACC certification February 2009
- Replaced Bomem DA8 – removed in 2009
- Joined TCCON June 2010; alternating mid-IR and near-IR measurements
- Intensive campaigns
  - ACE validation: 2007 → 2015
  - July 2007 – Bomem DA8 intercomparison
  - August-September 2009 – NIR upgrade
  - July 2010 – Relocation of 125HR
  - July 2013 – New Community Solar Tracker and Robodome installed
- Measurement days since installation:

2006: 17	2010: 92	2014: 106
2007: 117	2011: 85	**2015: 53**
2008: 121	2012: 28	
2009: 111	2013: 27	



Community Solar Tracker (CST)

Jonathan Franklin and Jim Drummond, Dalhousie University

Goals

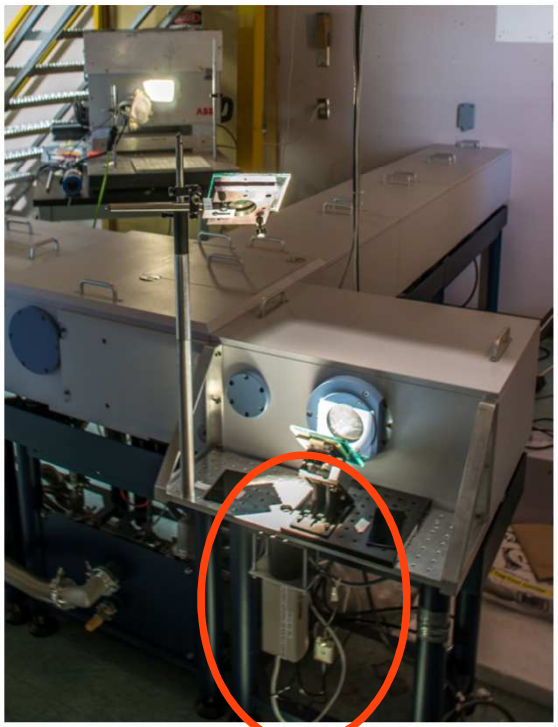
- To create an open-source tracking platform that can be shared freely and expanded upon by any lab
- To achieve an accuracy of better than +/- 36 arcseconds (TCCON ideal)

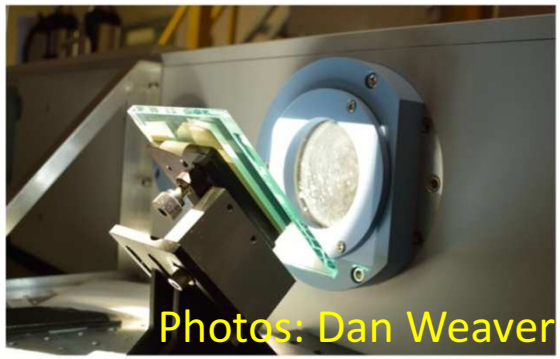
> - FTS sun tracker pointing with an accuracy of 1 mrad (~0.05°, or 3 arcminutes). This tracker requirement corresponds to an airmass error of 0.2% at 63° SZA, or 0.1% at 45° SZA. This is less strict than the other requirements, because of the practical limitations of available trackers, and may limit overall accuracy. 0.2 mrad, or 0.01°, corresponds to 0.1% airmass error at 80° SZA, and would be ideal. Tracker accuracy should be routinely monitored in one dimension using the solar-telluric shift (S-G shift).

Status

- Installed and working well at Dalhousie and PEARL
- Efforts to fine-tune the co-alignment of the Eureka 125HR with the CST are underway
- Lunar tracking to 60% illumination – maybe further

Community Solar Tracker (CST)

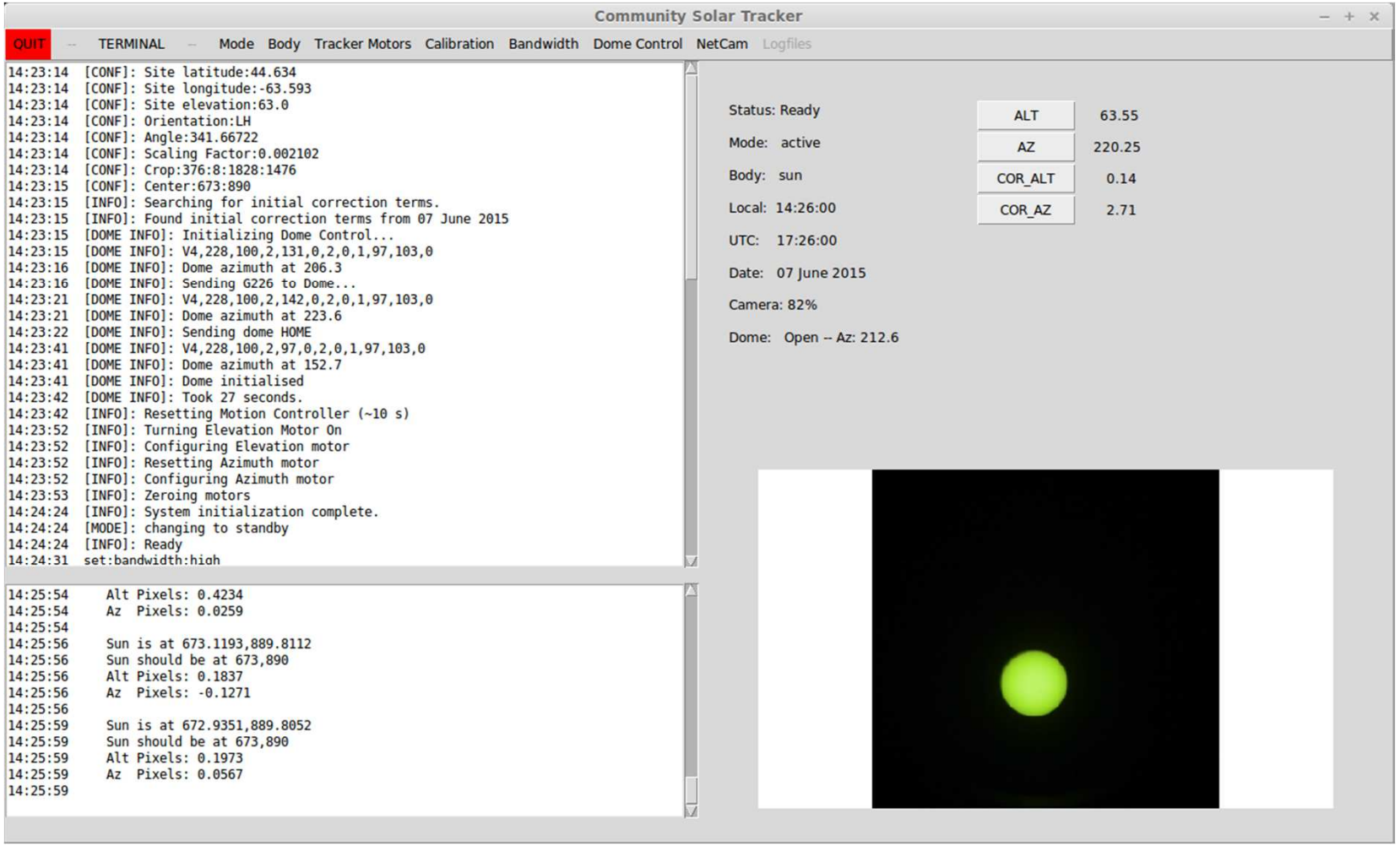




- Open-source tracking system
- Altitude – Azimuth design
- Tracking software written in Python
- Ephemeris calculations provide passive tracking
- Camera based active feedback
- Camera views solar disc directly through ND filter
- Ellipse fitting with quality control – maintain tracking by keeping center of fitted ellipse at a given x,y coordinate on camera (gives flexibility in pointing of CST)
- Remote operation
- Extensive logging

Jonathan Franklin and Jim Drummond, Dalhousie University

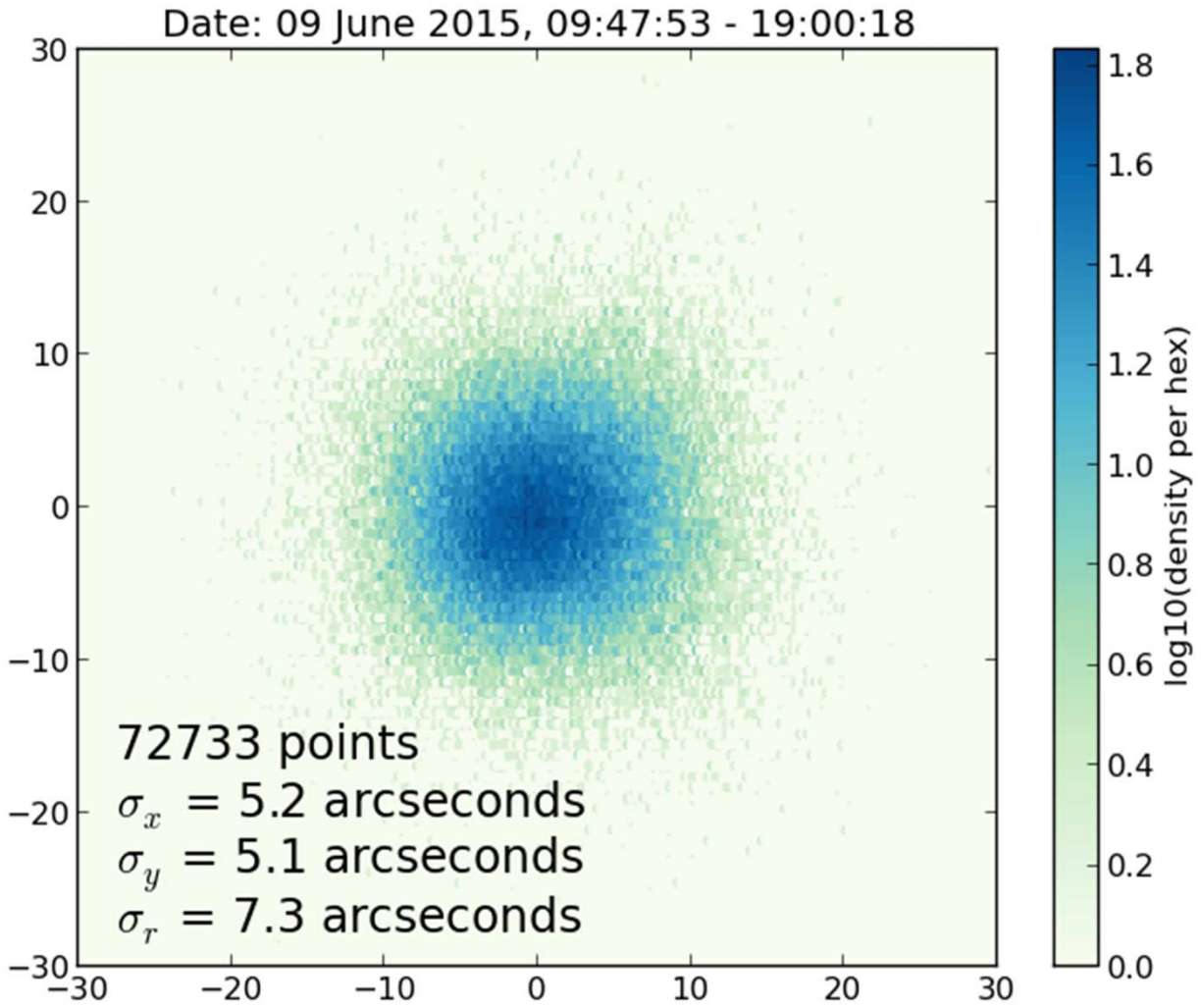
Control GUI run remotely – communicates via TCP connection



Code freely available
Manuscript in preparation
Contact: Jonathan Franklin (j.franklin@dal.ca)

Jonathan Franklin and Jim Drummond, Dalhousie University

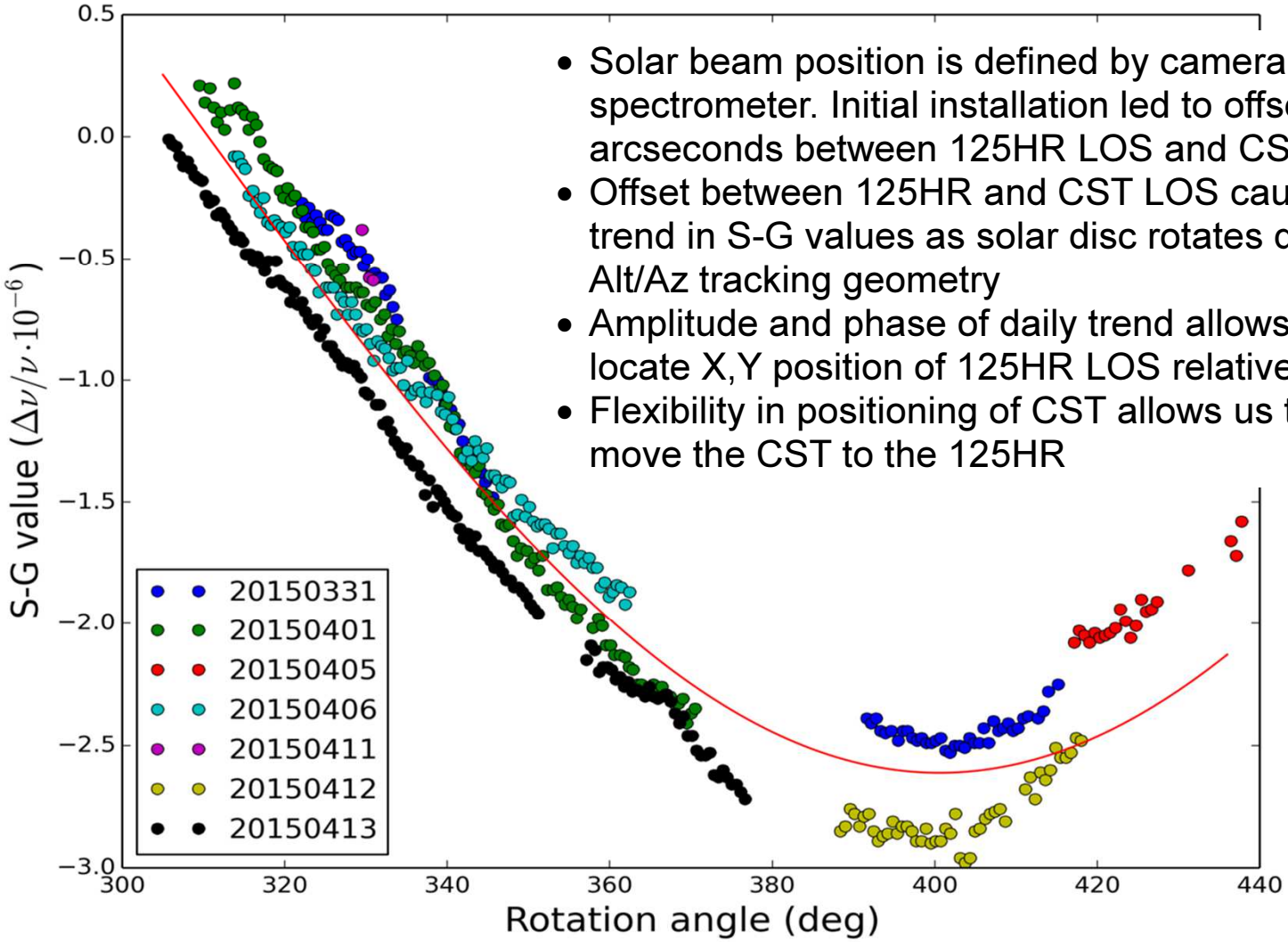
Log density plot of center of fitted ellipses over ~9 hours of tracking on Tuesday at PEARL.



Very accurate tracking relative to LOS of camera.
1 sigma scatter < 10 arcsec.

Jonathan Franklin and Jim Drummond, Dalhousie University

PEARL 125HR Solar Line Shifts



- Solar beam position is defined by camera -- not spectrometer. Initial installation led to offset of ~400 arcseconds between 125HR LOS and CST LOS
- Offset between 125HR and CST LOS causes daily trend in S-G values as solar disc rotates due to Alt/Az tracking geometry
- Amplitude and phase of daily trend allows us to locate X,Y position of 125HR LOS relative to CST
- Flexibility in positioning of CST allows us to fix this - move the CST to the 125HR

Correction was made in mid-April

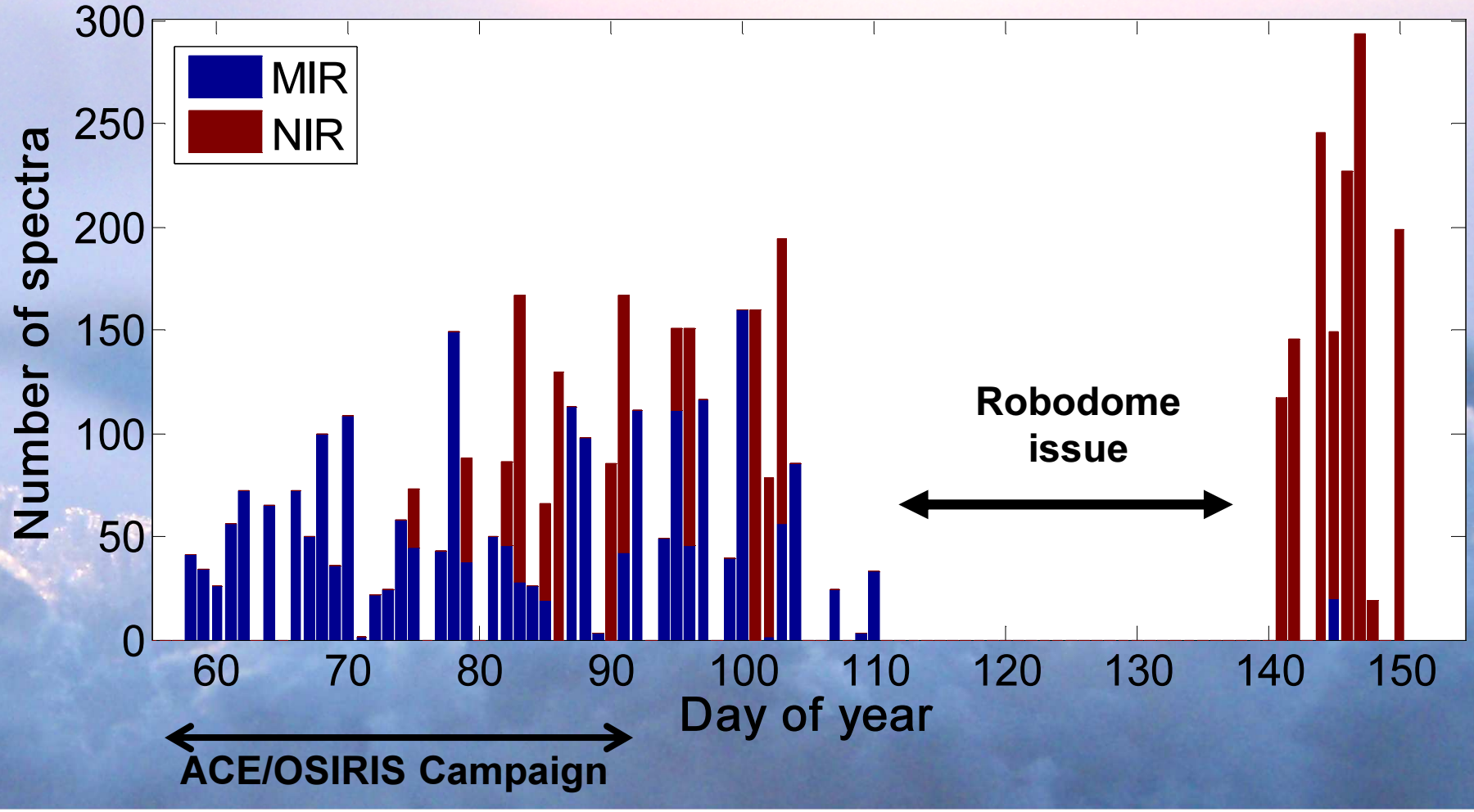
Awaiting transfer of data to confirm successful co-alignment

Jonathan Franklin and Jim Drummond, Dalhousie University

2015 Measurements

Collected **5009 solar measurements** over 53 measurement days between 27 February and 31 May 2015.

- **2690 NIR (22 days)**
- **2319 MIR (42 days)**

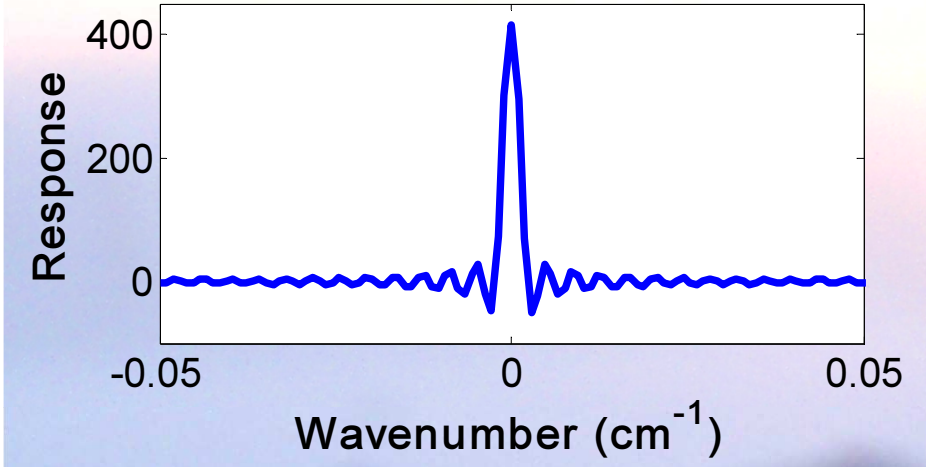


HBr Cell #30 Measurements

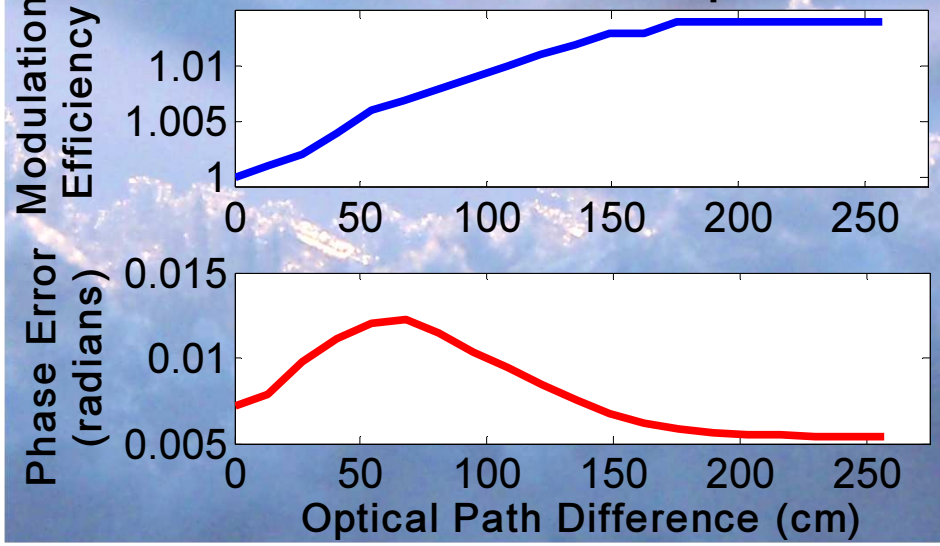
(LineFit v9)

February 27, 2014

Retrieved Instrument Line Shape

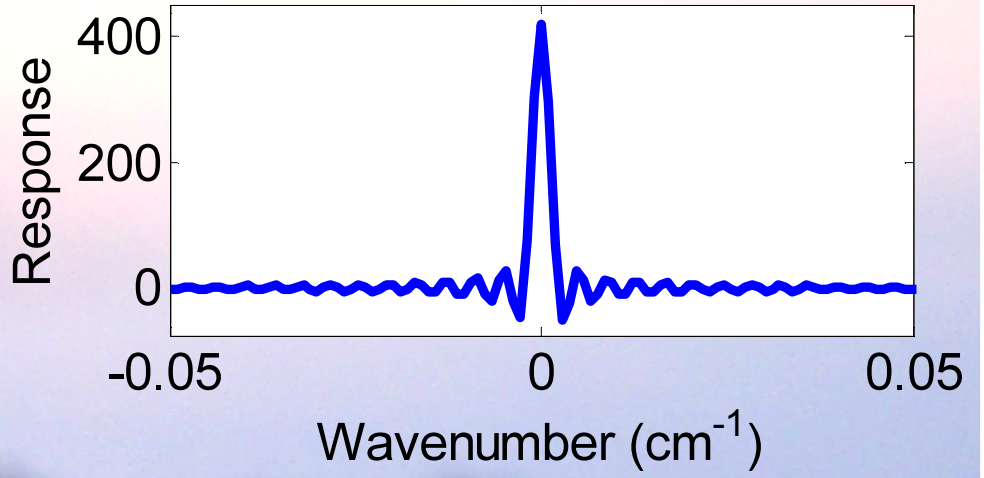


Modulation Efficiency and Phase Error from ilsparms

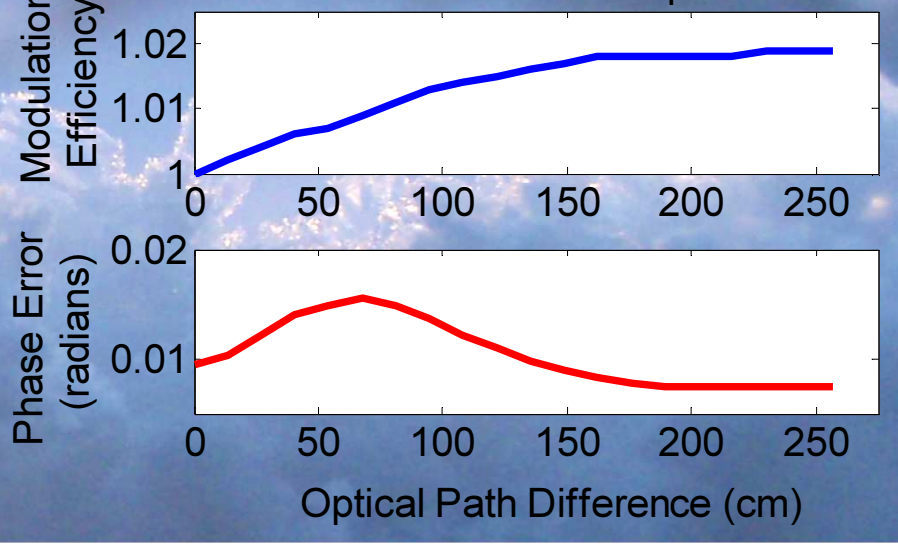


March 14, 2015

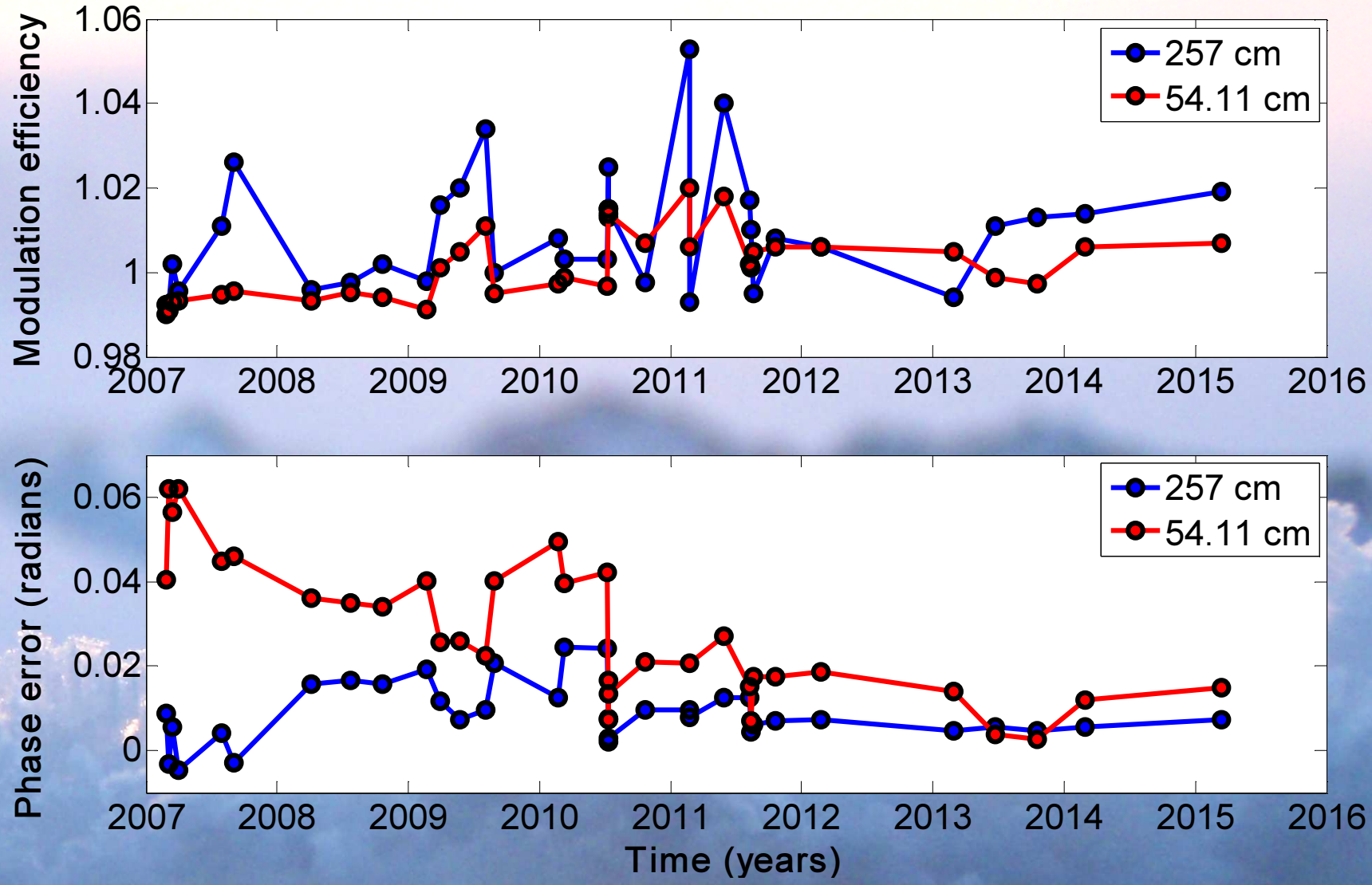
Retrieved Instrument Line Shape



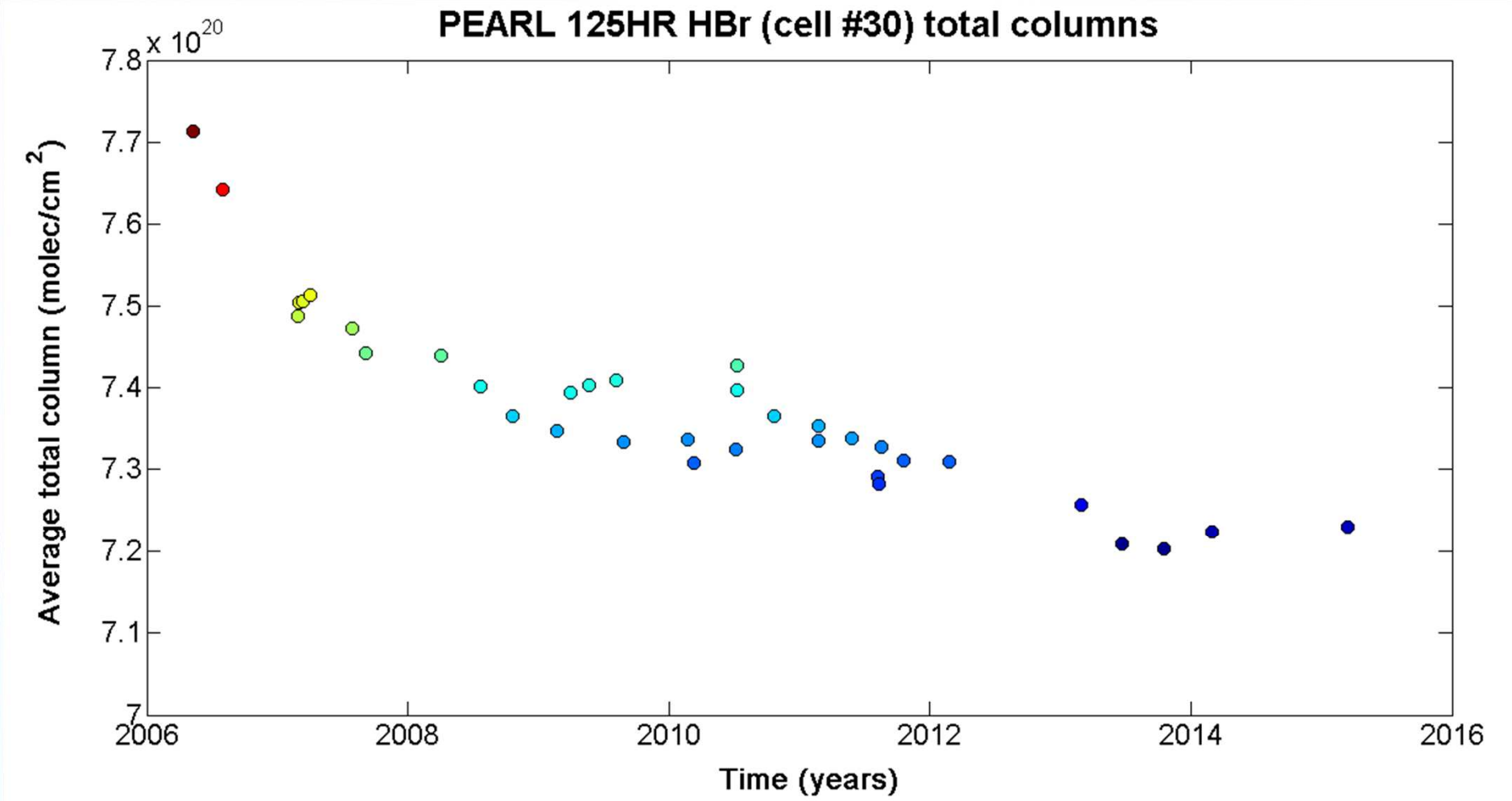
Modulation Efficiency and Phase Error from ilsparms

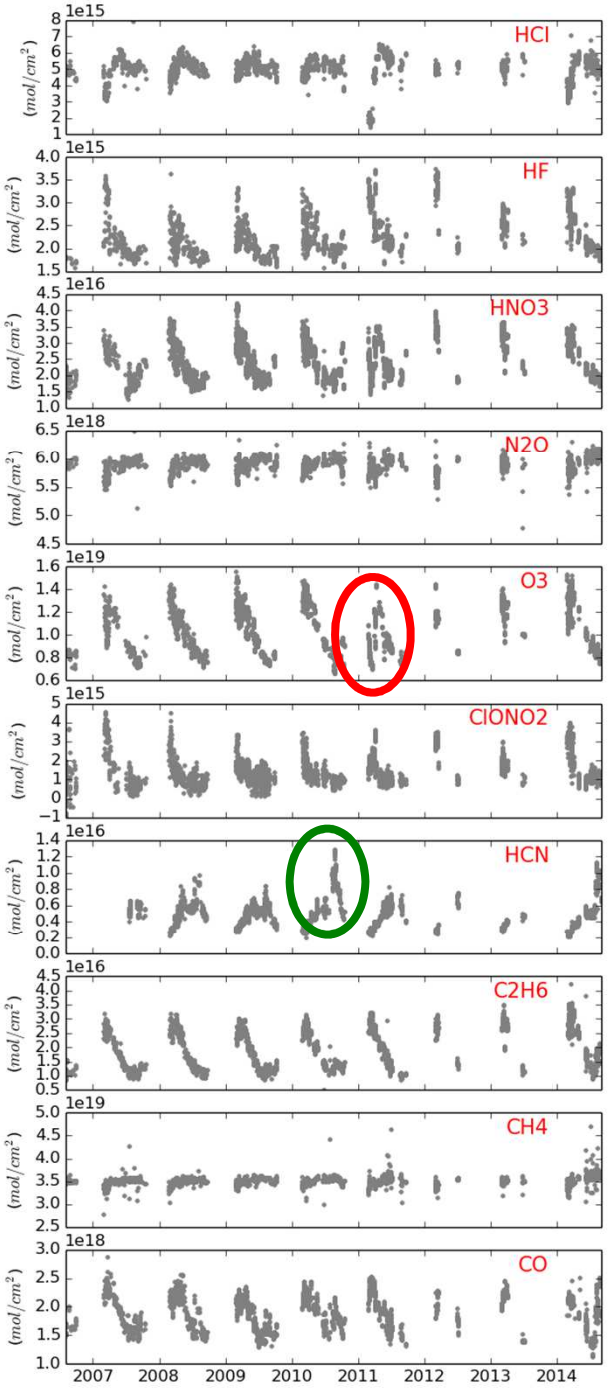


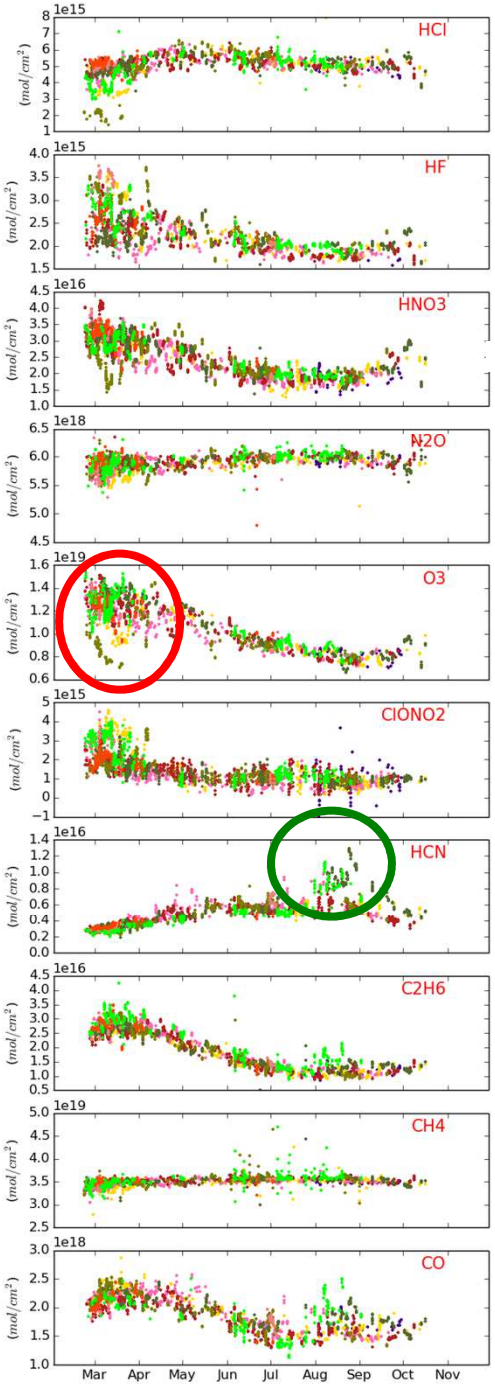
Eureka FTIR HBr Cell #30 Lineshape
(Linefit v9)



Eureka FTIR HBr Cell #30
Retrieved Columns







PEARL FTIR Time Series: 2006-2014

2006
2007
2008
2009
2010
2011
2012
2013
2014

Total columns

Stephanie has reanalyzed the FTIR dataset (2006-14) using SFIT4 for NDACC database

This extends the 1993-2008 springtime dataset acquired by Environment Canada's Bomem DA8 FTIR
(H. Fast, R. Mittermeier)

Status of NDACC Data Submission

- First two archivings
  - SFIT2 v3.92c, HITRAN 2004 + updates, NASA Ames
  - Included O_3, HCl, HF, $ClONO_2$, HNO_3, N_2O, CO, CH_4
  - September 2010 (August 2006 to July 2010)
  - October 2012 (February 2010 to September 2011)
- Third archiving: October 2013
  - Reanalyzed the complete data set (August 2006 – April 2013) and submitted in HDF format
  - O_3, HCl, HF, HNO_3, $ClONO_2$, CO, N_2O, CH_4, HCN, C_2H_6
  - SFIT4 V0.9.4.1, HITRAN 2008, IRWG microwindows, WACCM v6, random error for each retrieval, average systematic errors
- Next archiving: imminent
  - Have reanalyzed complete data set using SFIT4:V0.9.4.4 with full error analysis, updated retrieval schemes, and addressed some issues with *a priori* profiles

Activities Over the Past Year

- Running with a combination of remote operation and on-site operator, alternating MIR and NIR measurements
- Streamlined automated operation
- New FTIR computer installed
- ACE, Odin/OSIRIS validation (see Pierre's talk)
- Dan Weaver – water vapour intercomparisons (see talk)
- Stephanie Conway – strato-mesospheric species and CFCs and HCFCs (see talk)
- Erik Lutsch – biomass burning (see talk)
- Joseph Mendonca – TCCON & lineshape analysis (see talk)
- Sophie Tran – E-AERI studies (see poster)
- Contributed data to:
  - Bruno Franco's ethane study
  - Whitney Bader's methane study

NDACC Publications

- C. **Viatte**, K. Strong, K.A. Walker, and J.R. Drummond. Five years of CO, HCN, C_2H_6, C_2H_2, CH_3OH, HCOOH, and H_2CO total columns measured in the Canadian High Arctic. *Atmos. Meas. Tech.*, **7**, 1547-1570, 2014.
- E. **Sepúlveda** et al., Tropospheric CH_4 signals as observed by NDACC FTIR at globally distributed sites and comparison to GAW surface in-situ measurements. *Atmos. Meas. Tech.*, **7**, 2337-2360, 2014.
- C. **Viatte**, K. Strong, J. Hannigan, E. Nussbaumer, L. Emmons, S. Conway, C. Paton-Walsh, J. Hartley, J. Benmergui, and J. Lin. Identifying fire plumes in the Arctic with tropospheric FTIR measurements and transport models, *Atmos. Chem. Phys*, **15**, 2227-2246, doi:10.5194/acp-15-2227-2015, 2015.
- S. **Barthlott** et al., Using XCO_2 retrievals for assessing the long-term consistency of NDACC/FTIR data sets. *Atmos. Meas. Tech.*, **8**, 1555-1573, 2015.

- Zen Mariani, PhD thesis, Infrared Emission Measurements of Radiation and Trace Gas Variability in the High Arctic, September 2014

Work in Progress

- **Weaver** et al., Intercomparison of water vapour measurements in the Canadian high Arctic
- **Mendonca** et al., Taking line mixing and speed dependence into account to improve CO_2 retrievals from TCCON spectra
- **Holt** et al., Methane cross-validation between three Fourier Transform Spectrometers: SCISAT ACE-FTS, GOSAT TANSO-FTS, and ground-based FTS measurements in the Canadian high Arctic
- **Franklin** et al., The Community Solar Tracker -- development of an open-design tracker
  - **Griffin** et al., Investigating the stratosphere and troposphere of the High Arctic between 2006 and 2013: instrument intercomparison and validation

Funding Outlook

- Five-year science funding for PEARL from NSERC's Climate Change and Atmospheric Research Program (2013-2018)
  - Probing the Atmosphere of the High Arctic (PAHA)
- Additional funding for students and science
  - CSA support for GOSAT validation has just ended (2010-2015)
  - Three-year CAFTON funding from CSA (2012-2015)
  - Six-year NSERC CREATE Training Program in Arctic Atmospheric Science (2010-2016)
  - Renewed CSA support for the Canadian Arctic ACE Validation Campaign project (2015-2017)
  - Several smaller NSERC science grants

Acknowledgements

We gratefully acknowledge support from the following groups:

PEARL/CANDAC

- ARIF, AIF/NSRIT, CFCAS, CFI, CSA, EC, GOC-IPY, INAC, NSERC, NSTP, OIT, ORF, PCSP, SEARCH

ACE Arctic Campaigns

- Co-PI Kaley Walker
- CSA, EC, NSERC, NSTP

Logistical and operational support at Eureka

- The wonderful team at the EC Weather Station
- CANDAC/PEARL PI James R. Drummond
- PEARL site manager Pierre Fogal
- The CANDAC operators
- Former team members: Rebecca Batchelor, Rodica Lindenmaier, Zen Mariani, Camille Viatte

The University of Toronto Atmospheric Observatory: Site Report

Kimberly Strong, Stephanie Conway, Orfeo Colebatch, Brendan Byrne, Tailong He, Erik Lutsch, Sebastien Roche, and Ilya Stanevich

Department of Physics, University of Toronto

NDACC IRWG Meeting

8-12 June 2015

Toronto, Canada

U of Toronto Atmospheric Observatory (TAO)

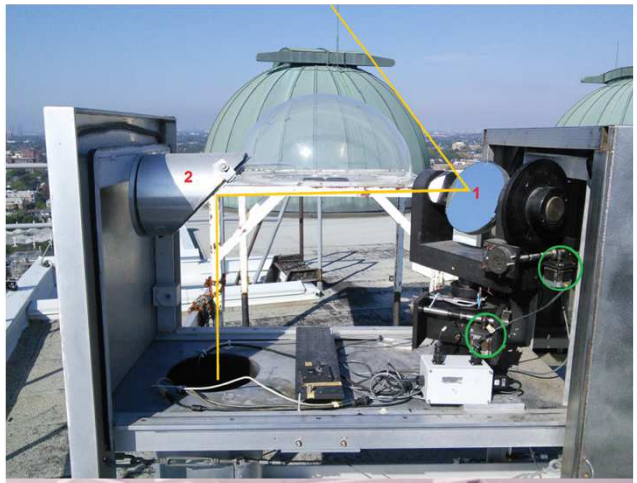
- Location: 43.66°N, 79.40°W, 174 masl

Instrumentation

- Primary instrument: Bomem DA8 FTIR
- Solar tracker with housing
  - coupled to FTIR
- Weather station
  - upgraded to Davis Vantage Pro 2 Plus, and installed new Vaisala PTU300 in February 2013
  - T, p, humidity, precipitation, winds
- Brewer spectrophotometer
  - installed March 2005, on loan from Environment Canada
- SAOZ and UofT UV-visible grating spectrometers
  - when not in the field
- PARIS-IR (g-based version of ACE-FTS)
  - when not in the field

Solar Tracker

- Replaced four-photodiode tracking system with CCD camera
  - Old Aim Controls heliostat had issues with reliability and accuracy
- Kept original alt-azimuth optics
- Adapted the active tracking component of the Community Solar Tracker, which applies an ellipse-fitting algorithm to the image of the sun and gives its pixels coordinates
- Under clear sky conditions, the pointing accuracy is 10-20 arcseconds (0.0028 degrees)



Community Solar Tracker Performance

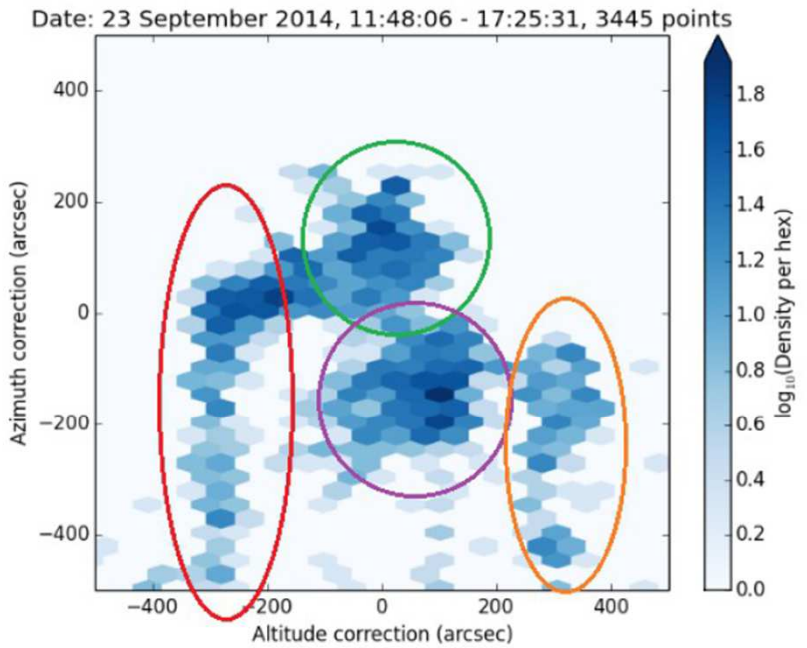
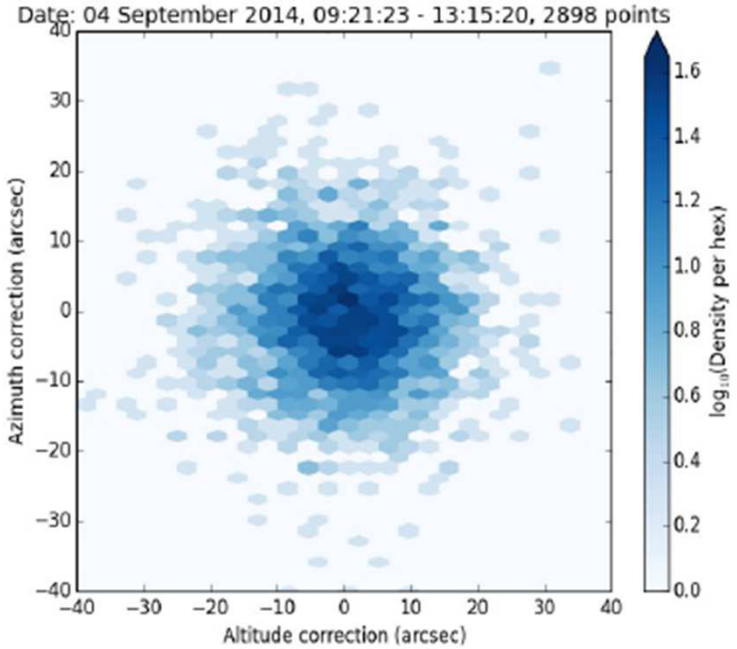


Figure 11: tracking accuracy of the quadrant-diode tracking system for September 23rd 2014. Coloured circles represent different time periods: orange for noon-1pm, red for 1pm-3pm, green for 3pm-4pm and purple for 4pm-5pm. At 1 pm tracking loss occurred (recurring bug with the old system code), at 3 pm the beam had moved off the filter and at 4pm the tracking was interrupted due to a lone cloud passing over for several minutes. Each time the beam was re-centered and a new center of the sun had to be chosen on the CCD image to retrieve corrections. I believe the "tails" come from the fact that errors kept being given while I was manually placing the solar beam.

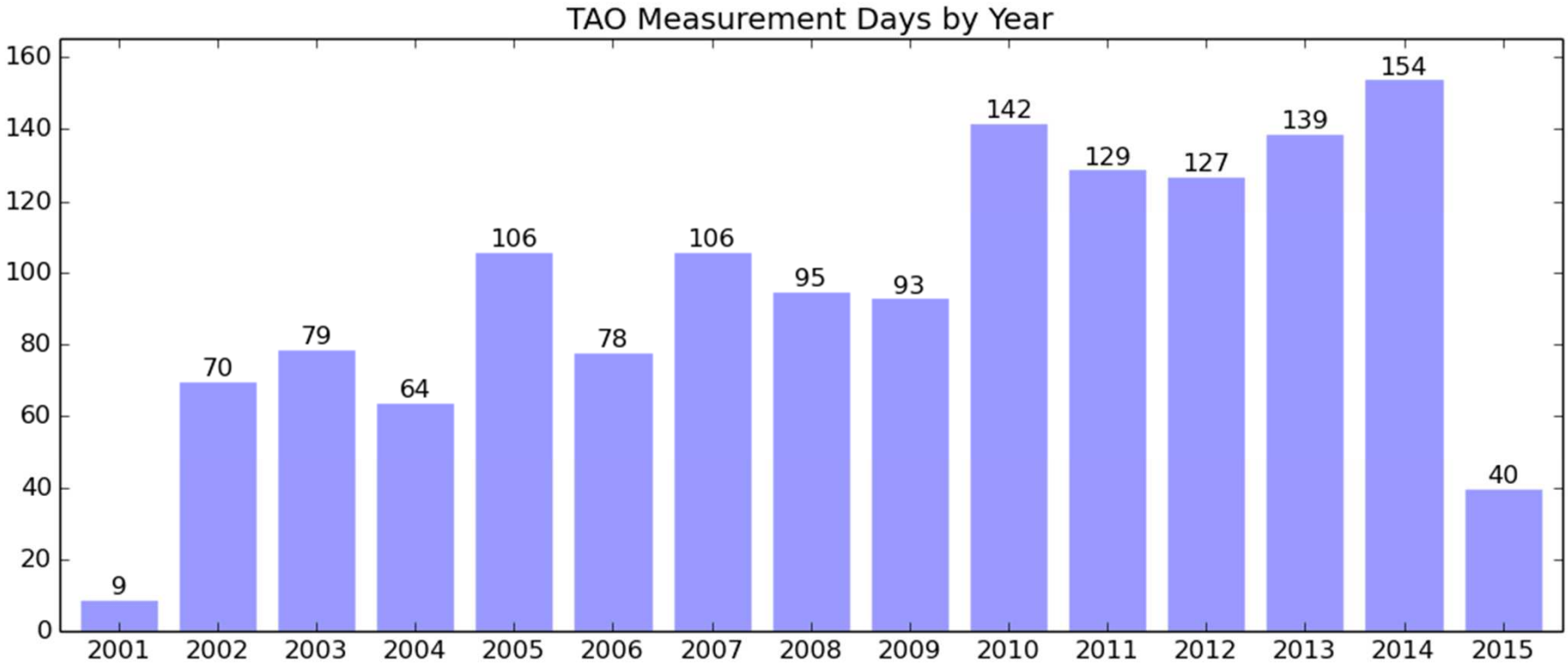


Pointing accuracy of the new tracking system at TAO September 4th 2014 under clear sky conditions

Jonathan Franklin (Dalhousie), Orfeo Colebatch, Sebastien Roche

TAO FTIR Measurements

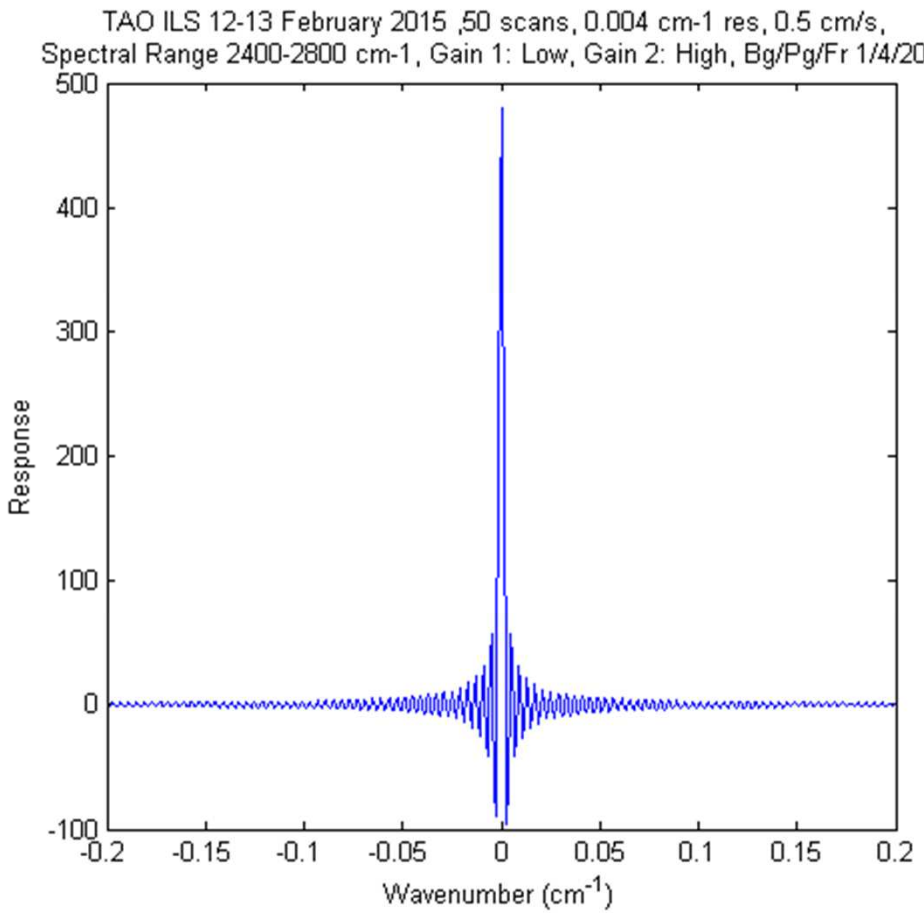
- October 2001 – Bomem DA8 operational
- May 2002 to present – regular solar measurements
- March 2004 – NDACC station

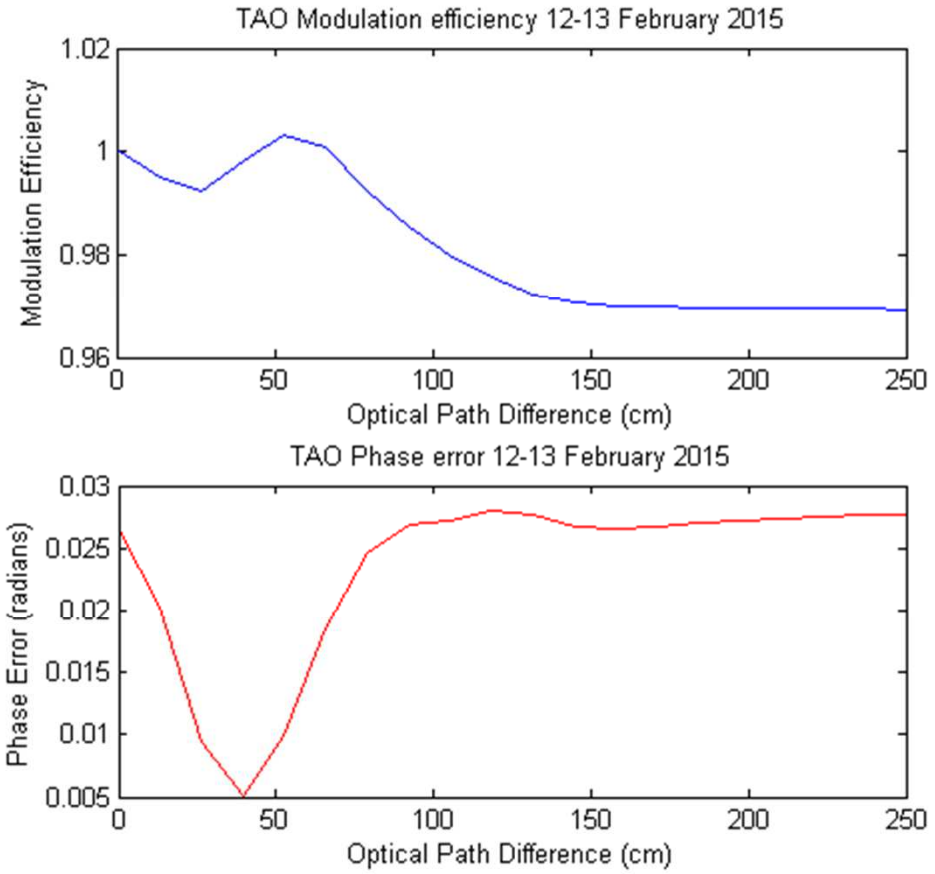


- Measurement days from **1 Apr 2014 → 1**

HBr Cell Measurements: ILS

Cell #48, Measurements from February 12th, 2015

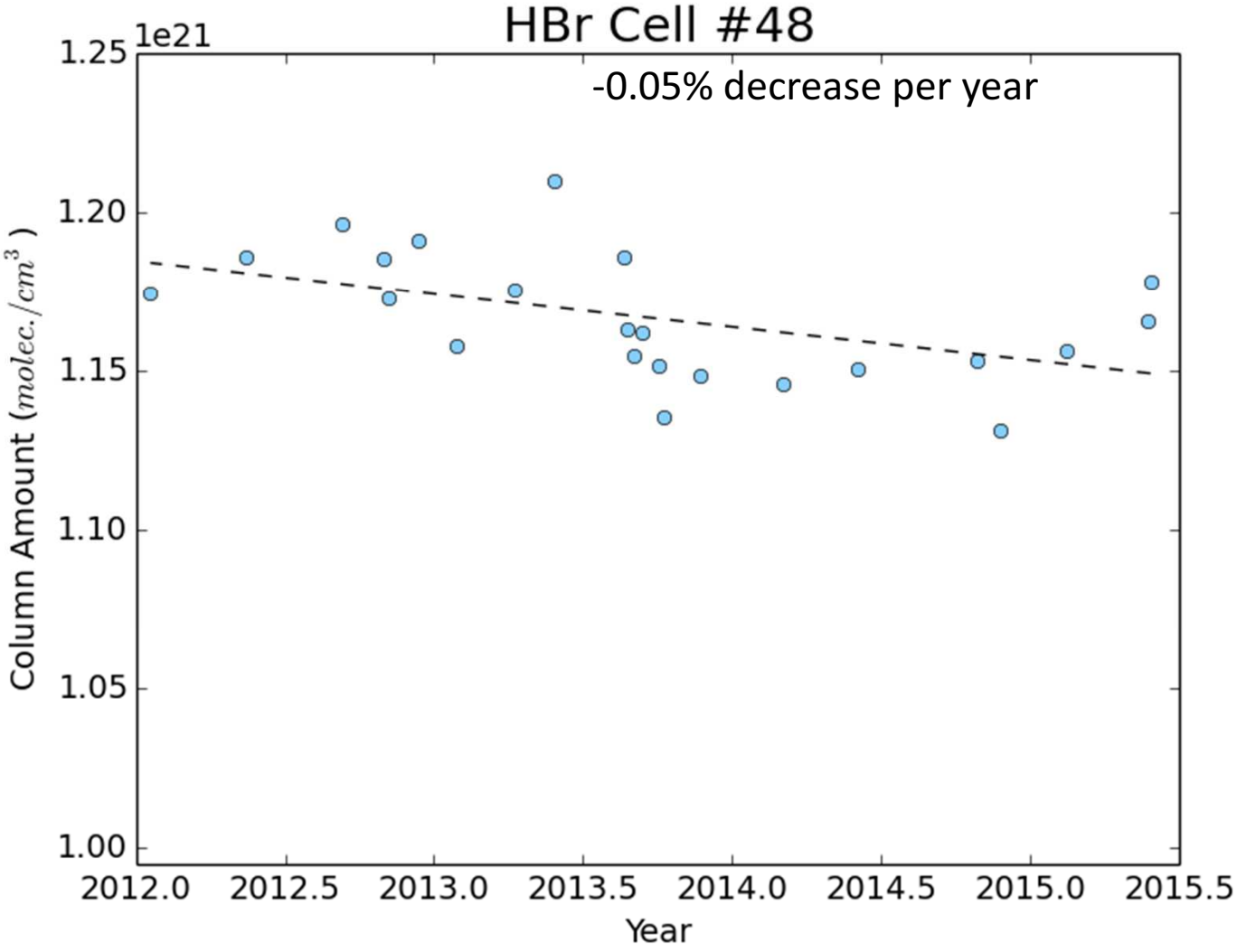




- Current version of ILS software – using LINEFIT V9
- In the process of moving to LINEFIT 14

HBr Cell #48: Retrieved Columns

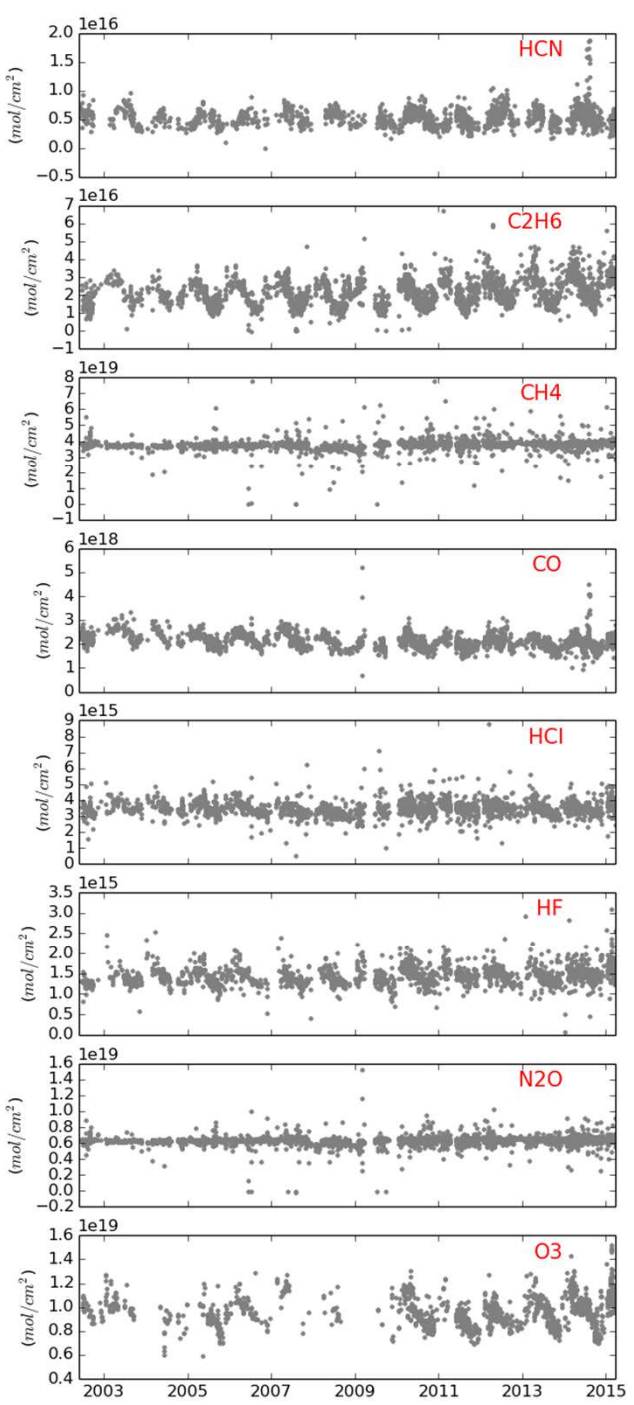
Switched to #48 from old cell #13 in 2012

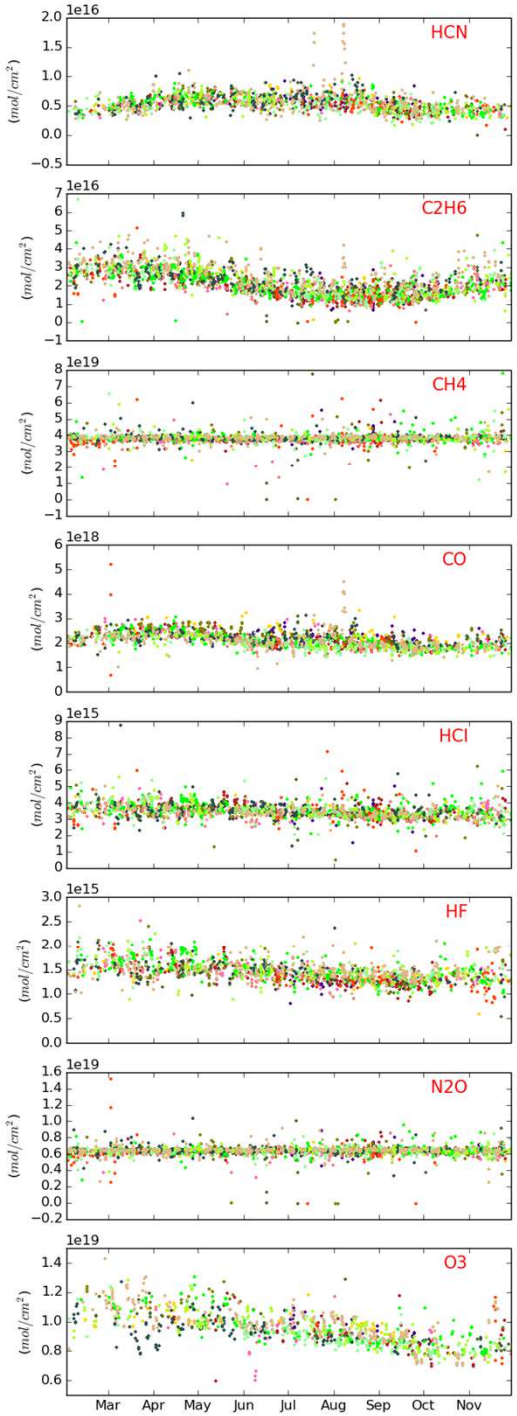


Toronto FTIR Time Series

Total columns

Stephanie has reanalyzed the FTIR dataset (2002-2014) using SFIT4 for NDACC database





Status of NDACC Data Submission

- First three archivings
  - Used SFIT2 v3.82, HITRAN 2004, NASA Ames format
  - Included O3, HCl, HF, NO, NO2, N2O, CH4
  - June 2005 (October 2001 to December 2004)
  - September 2007 (January 2005 to December 2006)
  - September 2010 (January 2007 to December 2009)
- Fourth archiving: October 2013
  - Reanalyzed the complete data set (2002-2012) and submitted in HDF format: O3, HCl, HF, N2O, CH4, CO, HCN, C2H6
  - Used SFIT4 V0.9.4.1, HITRAN 2008, IRWG recommended microwindows, WACCM v6, random error for each retrieval, average systematic errors
  - Other constituents, including NO, NO2, OCS, C2H2, HCOOH, and H2CO, are also retrieved, but not included in latest archiving
- Next archiving: imminent
  - Have reanalyzed complete data set using SFIT4:V0.9.4.4 with full error analysis, SNR calculated from spectra, optimized retrieval strategy

Activities Over the Past Year

- Instrument
  - Ongoing semi-automated daily measurements
  - Optimizing measurement procedures
  - Remote desktop functionality added to TAO computer
  - Monitoring performance of new Community Solar Tracker camera and code
- Research
  - Cyndi Whaley, PhD thesis, Improvements to our Understanding of Toronto-Area Atmospheric Composition, August 2014
    - Whaley, K. Strong, D.B.A. Jones, T.W. Walker, Z. Jiang, D.K. Henze, M. Cooke, C.A. McLinden, M. Pommier, R.L. Mittermeier, and P.F. Fogal. Improvements to our understanding of urban ozone air pollution: Sources of Toronto-area ozone during poor air quality events. Submitted to *J. Geophys. Research*.
  - Stephanie Conway – strato-mesospheric species and CFCs & HCFCs (see talk)
  - Erik Lutsch – biomass burning (see talk)
  - Ilya Stanevich – regional CH4 flux inversions (see talk)
- Contributions to other studies
  - NH_3 → Enrico Dammers, University of Amsterdam
  - C_2H_6 → Bruno Franco, University of Liège
  - CH_4 → Whitney Bader, University of Liège

Outlook

- Ongoing measurements, analysis, interpretation
- Automation of suntracker cover, further evalution of solar tracking
- Integration of measurement and modelling activity within CAFTON (CAnadian FTir Observing Network)

Funding

- National Science and Engineering Research Council of Canada
- Canadian Space Agency (GOSAT and CAFTON projects)