Thule, Mauna Loa, and Boulder Site Reports

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NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

2019 NDACC IRWG, New Zealand

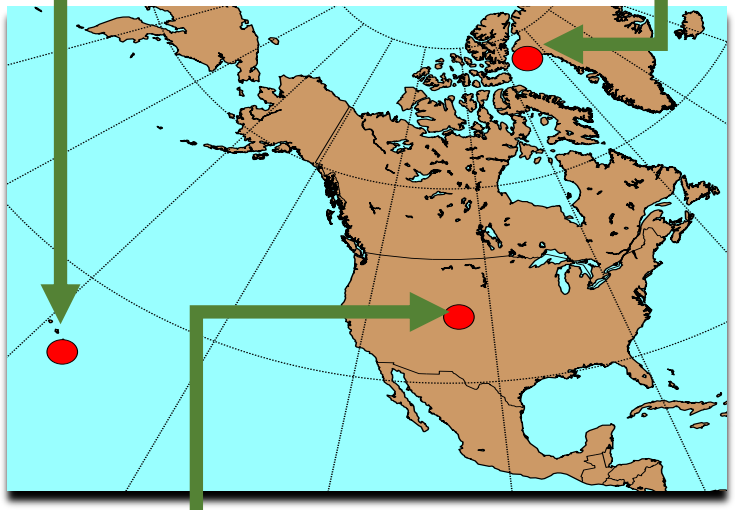
NSF

NASA

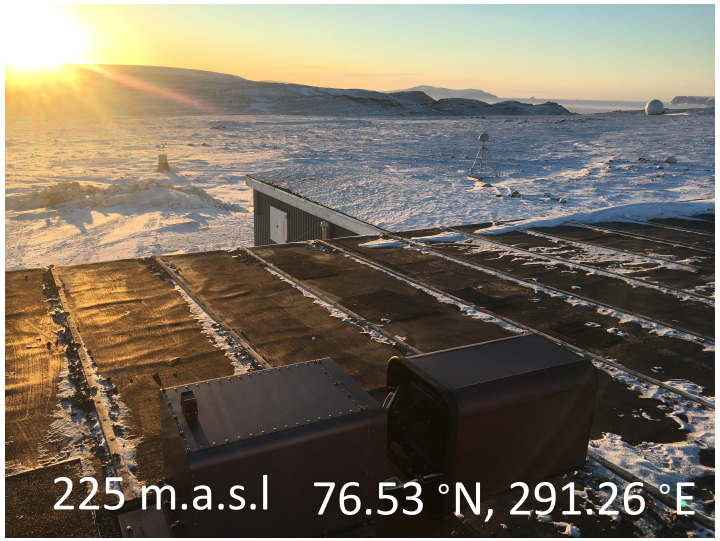
Sites

Mauna Loa, Hawaii

3396 m.a.s.l 19.54 °N, 204.43 °E

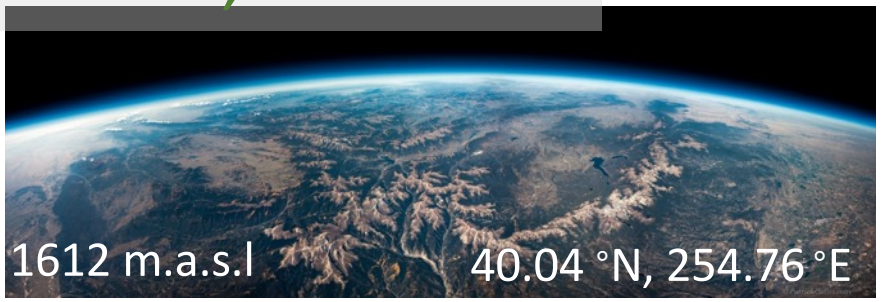


Thule, Greenland



225 m.a.s.l 76.53 °N, 291.26 °E

Boulder, Colorado



1612 m.a.s.l 40.04 °N, 254.76 °E

Thule & MLO: FTIR Remote operation components

Bruker 125HR

Precision Solar Tracker

Weather Station

TCP Data Server
- Live parameter distribution
- Remote access & control

Sun Sensor

Windows Computer: OPUS / Bruker Access

LN2 Supply / Generation

Linux Computer:
- Auxiliary data
- Weather / sun monitor
- Timing of spectral data collection
- Local & backup storage

LN2 Dewar: Daily Auto Fill InSb & MCT detectors

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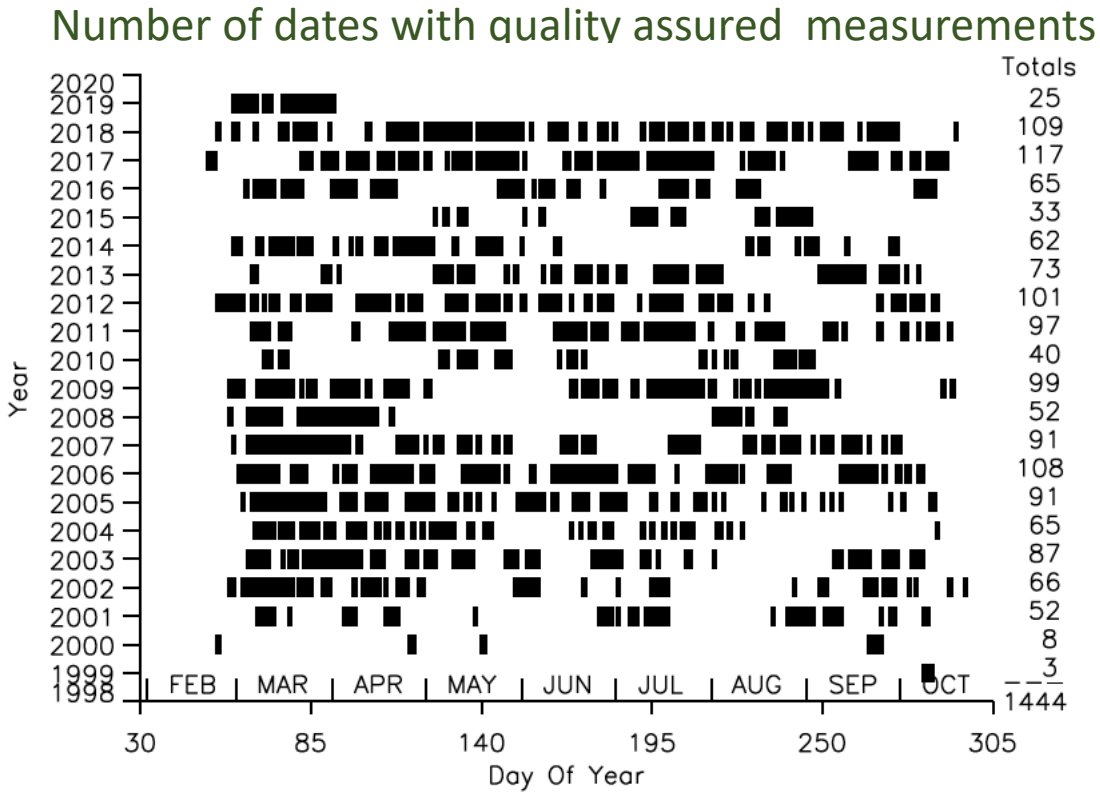
Daily download of spectral & auxiliary data, remote monitoring

Thule: Two decades of measurements

Installed a new 125HR in 2015

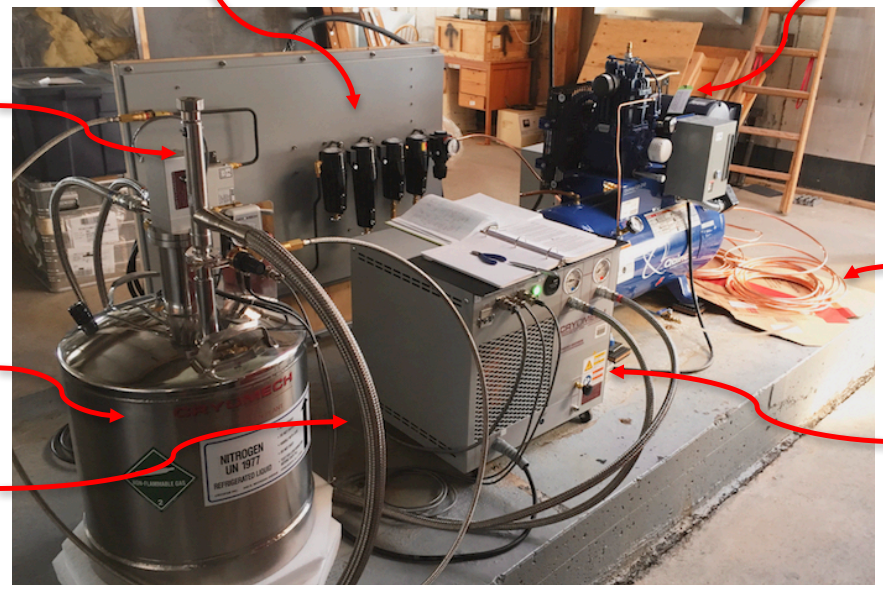
Installed 6” Au camera/ephemeris Solar Tracker in 2015



- Upgrade from 120M to 125HR in July 2015
- LN2 generator installed in April 2017 (10 L/day)
- 2018: LN2 generator motor failures
- 2019: more LN2 issues, glowbar failure

Thule: Two decades of measurements

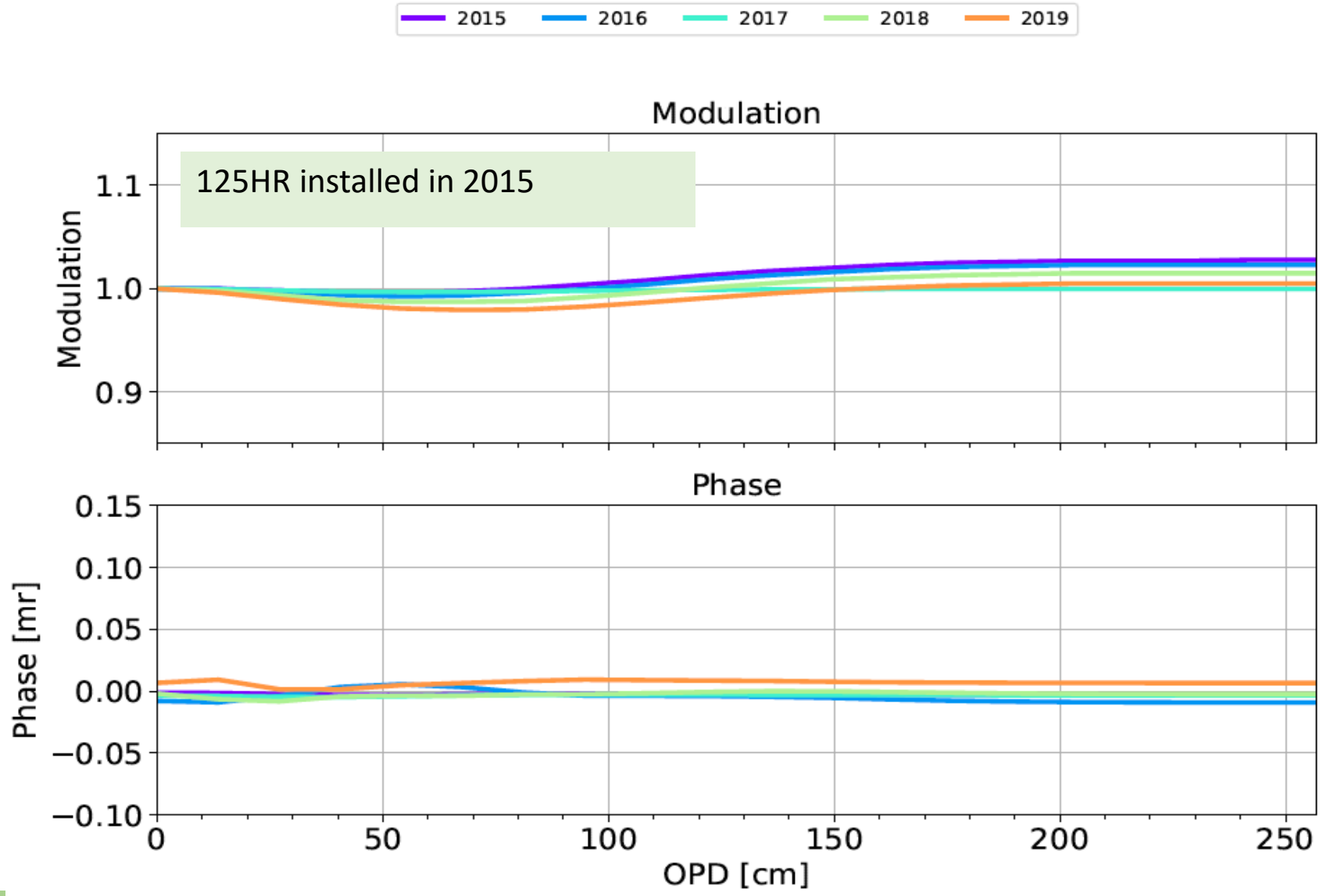
Cryomech LNP10 LN2 generator installed in 2017



- LN2 Liquefier
- Has worked without issue
- Only normal maintenance required & performed

- Air Compressor motor…
- Aug 2018: Replace Contactor & Overload switch
- Jan 2019: Start capacitor failed & replaced during March visit
- May 2019: Start capacitor failed again & replaced
- May 2019: Centrifugal switch failed and timer inserted
- Investigating replacement of motor with 3ph 2hp type

Thule: HBr cell measurements/alignment

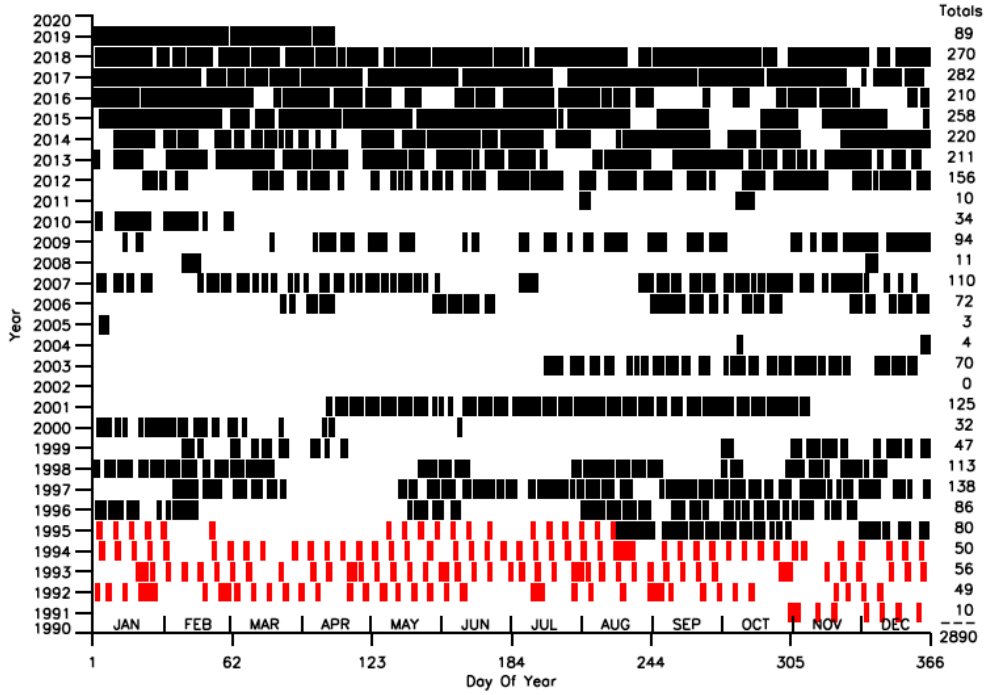


Thule: Summary

- New FTIR 125HR, solar tracker and remote control components started in 2015 with improved feedback (instrument performing well)
- 2 site visits in 2018 → LN2 Generator failed August
- 1 site visit in 2019 → LN2 Generator capacitor replacement, cell HBr/N_2O calibration & channeling spectra acquired, AERONET replaced, glowbar partial burnout
- Danish Meteorological Institute left site → NSF manages now building & logistics
- Also many issues with AERONET (new: Lunar observations) , unit replaced several times, another replacement pending
- Yet:
  - 117 days of QA obs. in 2017, 109 in 2018 (March to October)
  - NDACC standard gases are archived up to 2018.

Mauna Loa: 28 years of Obs. / 23 archived

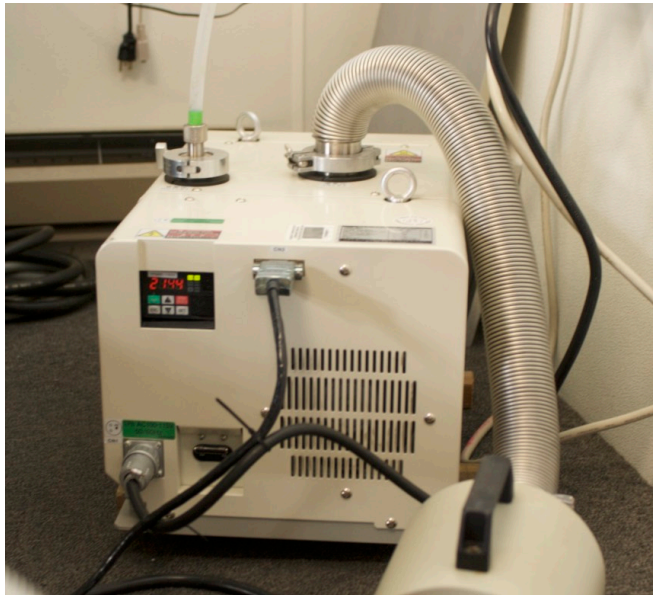
Number of dates with quality assured measurements

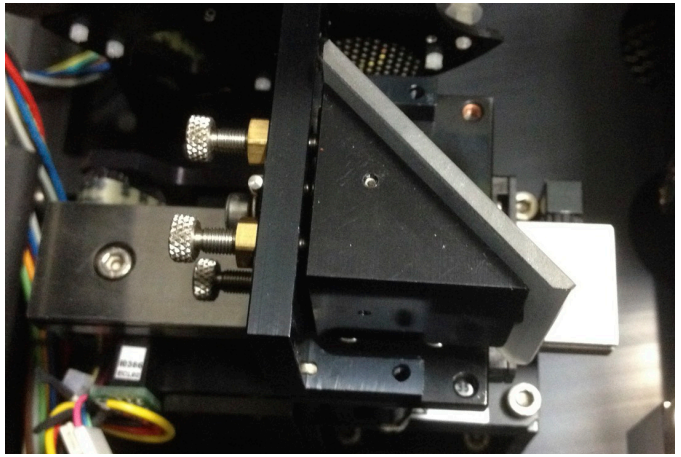


- 2017: Upgrades to Windows OPUS / Linux master PC (duplicated Thule) with more control & feedback & stability (282 days of measurements)
- 2018: No site visits but found beginnings of an issue with the MCT detector…
- 2019: 1 site visit so far (check MCT, installed a new weather station, cell measurements, minor alignment adjustment)

Mauna Loa: FTIR Timeline

- Nov 1991: Operations began by Denver Univ team with a Bomem DA-3.002
- Aug 1995: DU changes to Bruker 120HR
- 2002 – 2009: Maintenance (and data record) intermittent
- Aug 2010 - Aug 2011: Instrument sent to Bruker for 125 upgrade
- Aug 2011: 125HR observations begin with Linux OPUS
- Oct 2013: Kashiyama roots pump installed – first evacuated operations.
- Feb 2014: MCT select translation mirror failing to reach position repeatedly.
  - Change firmware to slow down/increase torque. Try several speeds.
- Feb 2015: replace MCT select translation mirror. OK
- Dec 2017: Upgrade to Windows OPUS / Linux master PC (duplicated Thule)
- 2018: Issue with the MCT detector resurfaces 'Timeout' & position errors
- May 2019: site visit
  - MCT: adjust mirror, install firmware for fast translation, pump detector
  - Installed a new weather station
  - Alignment with N2O & HBr Cells.

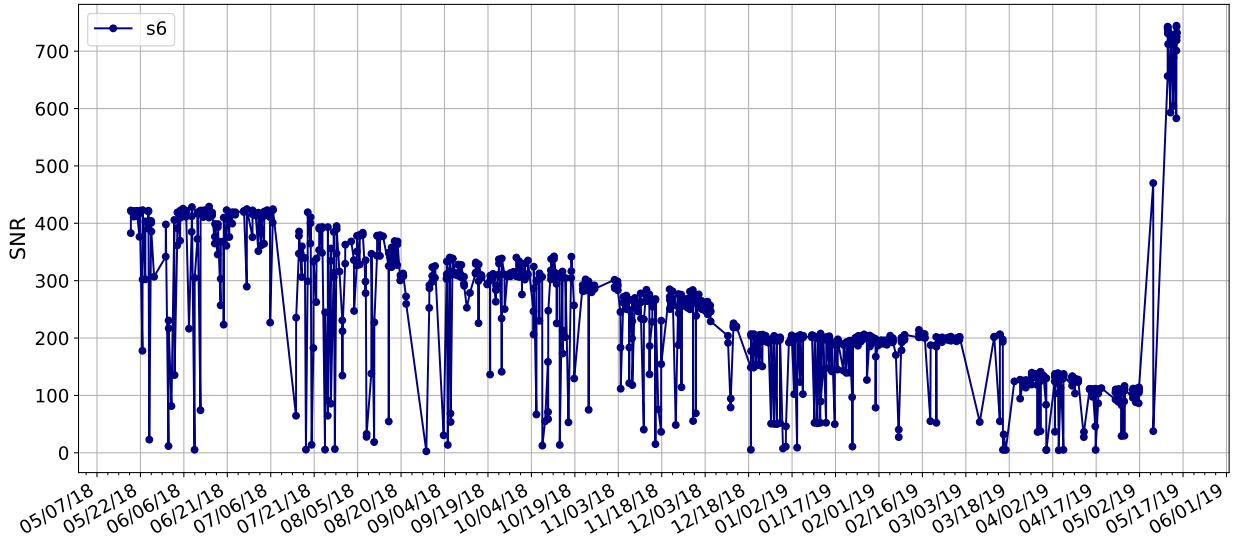




Mauna Loa: Detector Select Translating Folding Mirror

- Feb 2014: Det. select translating folding mirror failing to reach position repeatedly.
  - Change (motor) firmware to slow down/increase torque and try several speeds (from 2.5/40/60/80 secs) :
    - ✓ Intermittent success.
  - Feb 2015: replace MCT select translation mirror:
    - ✓ OK seems to work, signal acceptable.
- Jan 2018: upgrade to M16 firmware ver 2.485
- Jul 2018: Slow decline in MCT SNR begins, intermittent 'Timeout' OPUS errors & apparent stepwise position errors.
- Apr 2019: Severe drop in F6 SNR – unusable spectra.
- May 2019: site visit:
  - Adjust mirror pointing signal increase x5,
  - Install firmware for fast translation (2.5s),
  - Pump detector dewar
    - ✓ SNR back to ~700

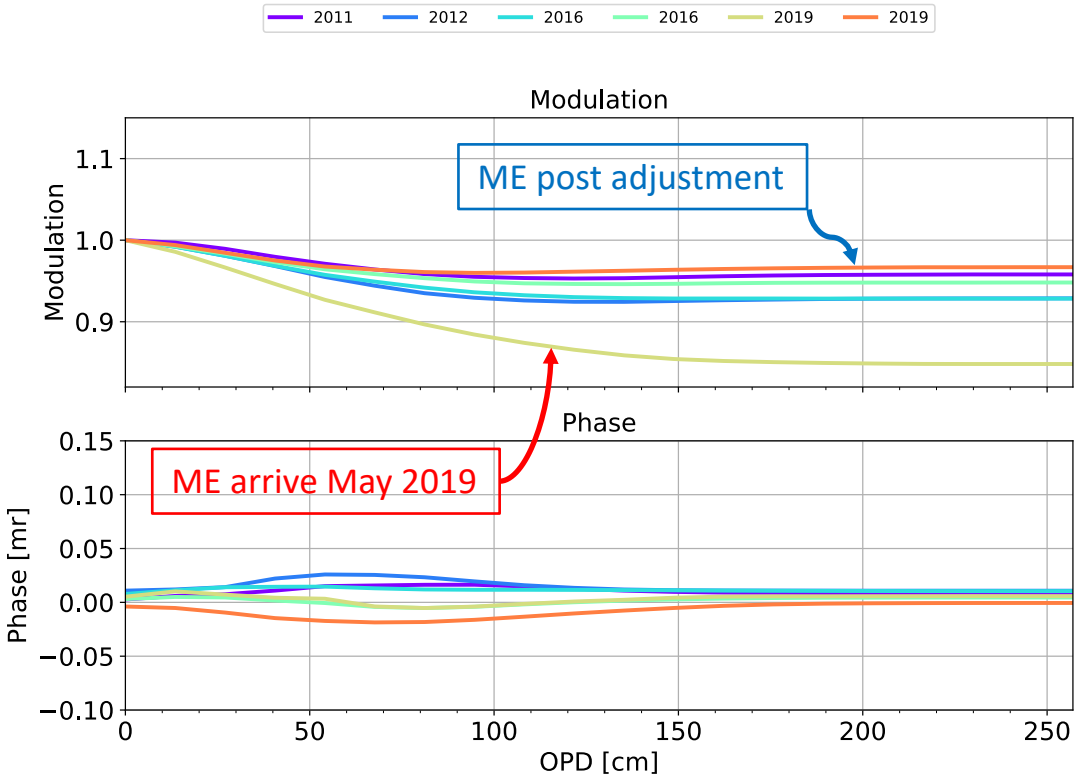
MCT Issue in 2018: Time series of MCT SNR decrease seemingly stepwise manner. Current SNR after mirror adjustment ~700



$$\text{SNR metric} = \frac{\text{(Peak Band Signal)}}{\text{(out of band RMS noise)}}$$

Mauna Loa: Alignment adjustment required

- From Linefit V14 & both HBr (250cm) & N_2O (180cm + background) cell measurements: ME dropped to .9 at 75cm and .84 at 150.
- Alignment tools not available, including scope…
- Iterative LF results (ME/phase) very similar for 2 scans vs. 50
- Iteratively & systematically adj. b/s folding mirror and exit aperture folding mirror
  - ➢ Really only 1 horizontal adjustment to b/s folding mirror 5º
- Compensation though to improve ME & signal included larger adj. and vertical as well
  - ➢ Existing optical may path not optimal
  - ➢ Increase (InSb) ~30% ifgm peak



Improving the retrieval of $ClONO_2$ at Low Latitude

- The retrieval of $ClONO_2$ is difficult at MLO:
  - $ClONO_2$ absorption is weak,
  - CO_2 interference,
  - Precision is limited due to spectral noise.
  - ➢ Hence, coadded spectra is part of a solution to improve trends analysis. (Rinsland et. al., 2003)

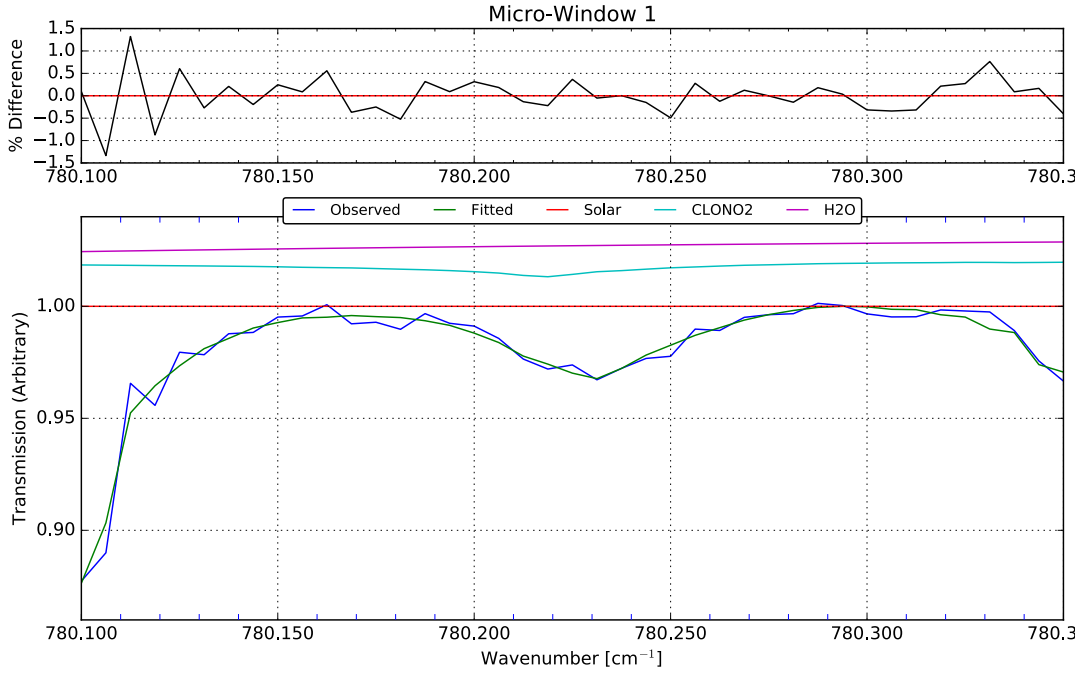
- We developed a script to coadd spectra testing several options:
  - Minimum OPD necessary,
  - SZA range,
  - Number of days,
  - Minimum number of spectra.

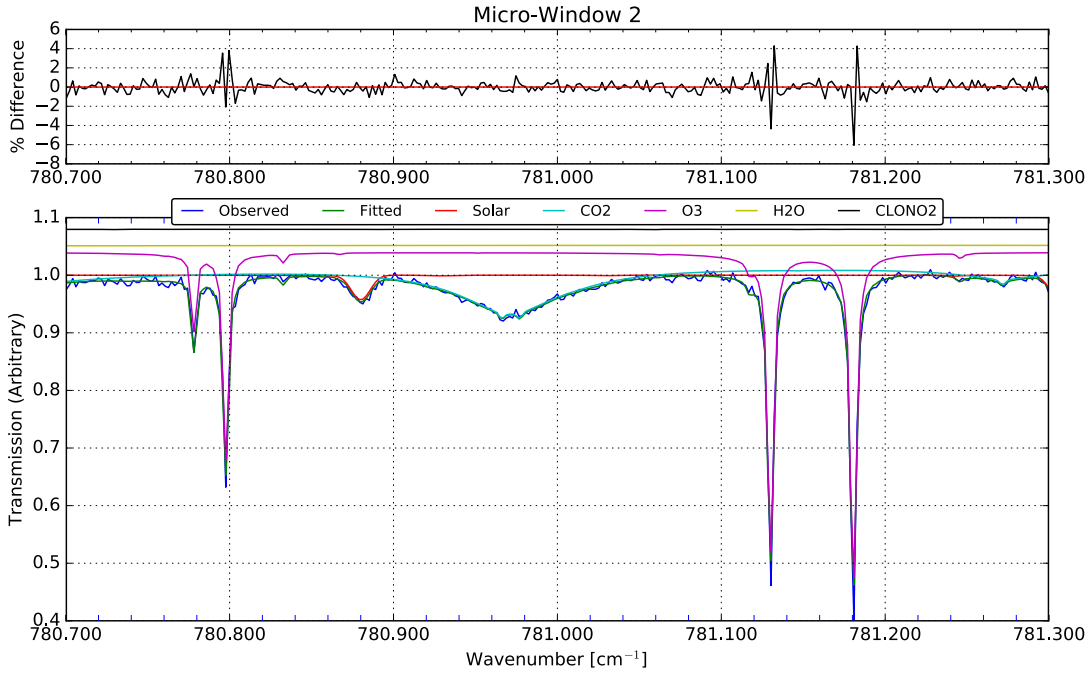
Required µ-w [cm-1]	Optional µ-w [cm-1]	OPD [cm]	Interfering species	A priori	Column or Profiles
780.10-780.35		> 50	H_2o	WACCM	Column
	780.0-781.3		CO_2, O_3		
	779.0-780.0		H_2O		

IRWG Retrieval Parameters

Improving the retrieval of $ClONO_2$: fit example

Jan 1 2019, SZA: 70 - 75

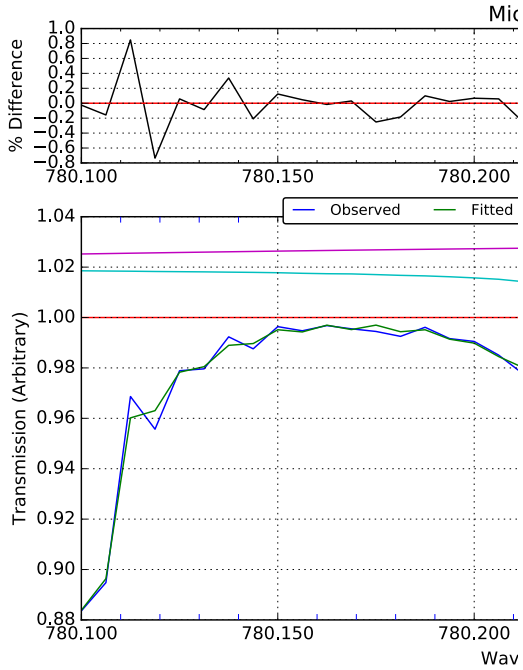




# of spectra	RMS [%]	DOF	SNR	Column [molec/cm2]
1	0.81	0.37	342	4.13×10^{14}

Improving the retrieval of $ClONO_2$: fit example

Jan 1 2019, SZA: 70 - 7



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1
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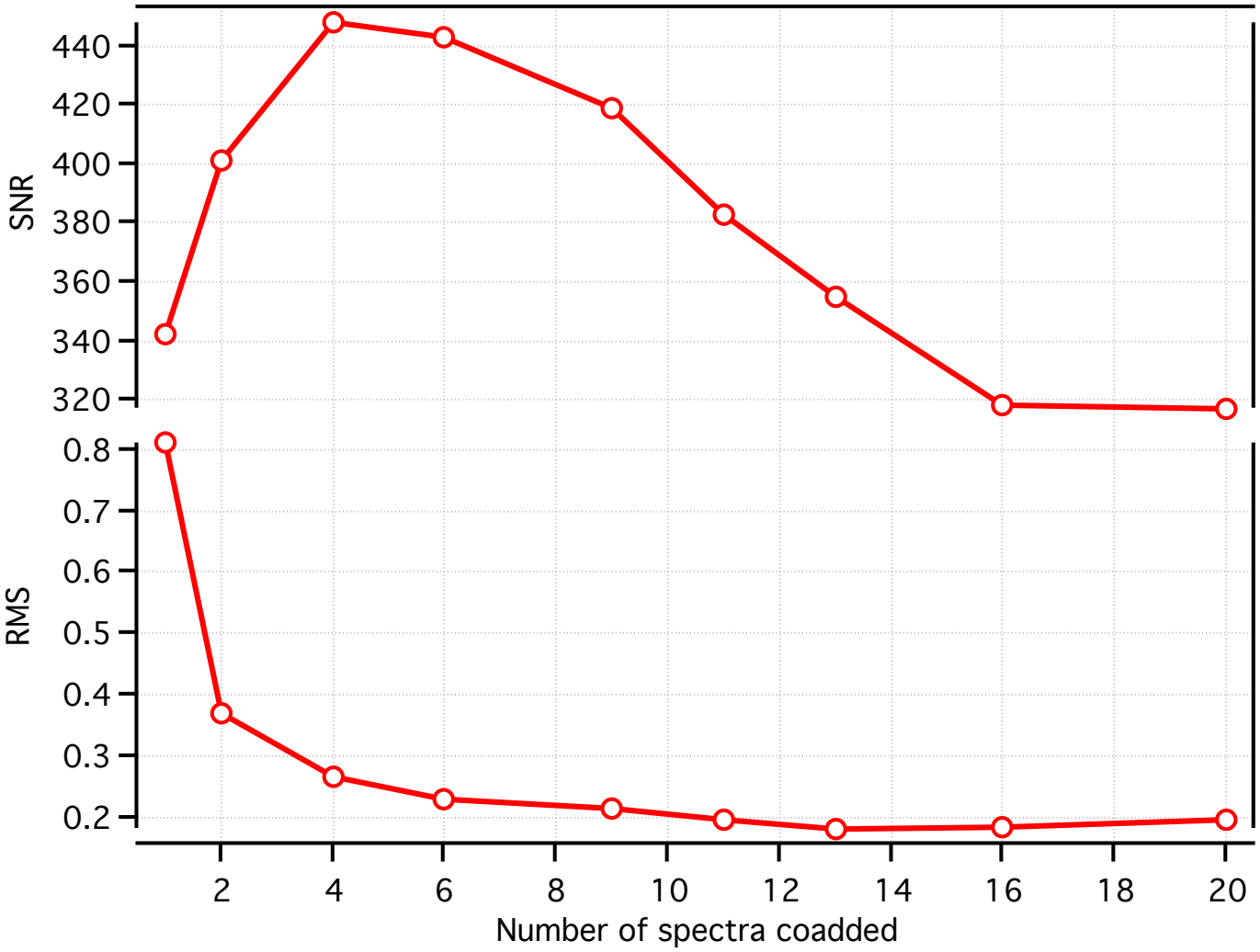
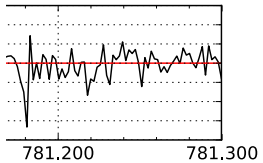
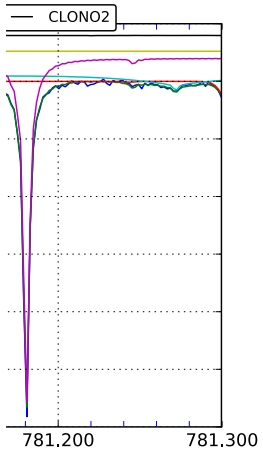
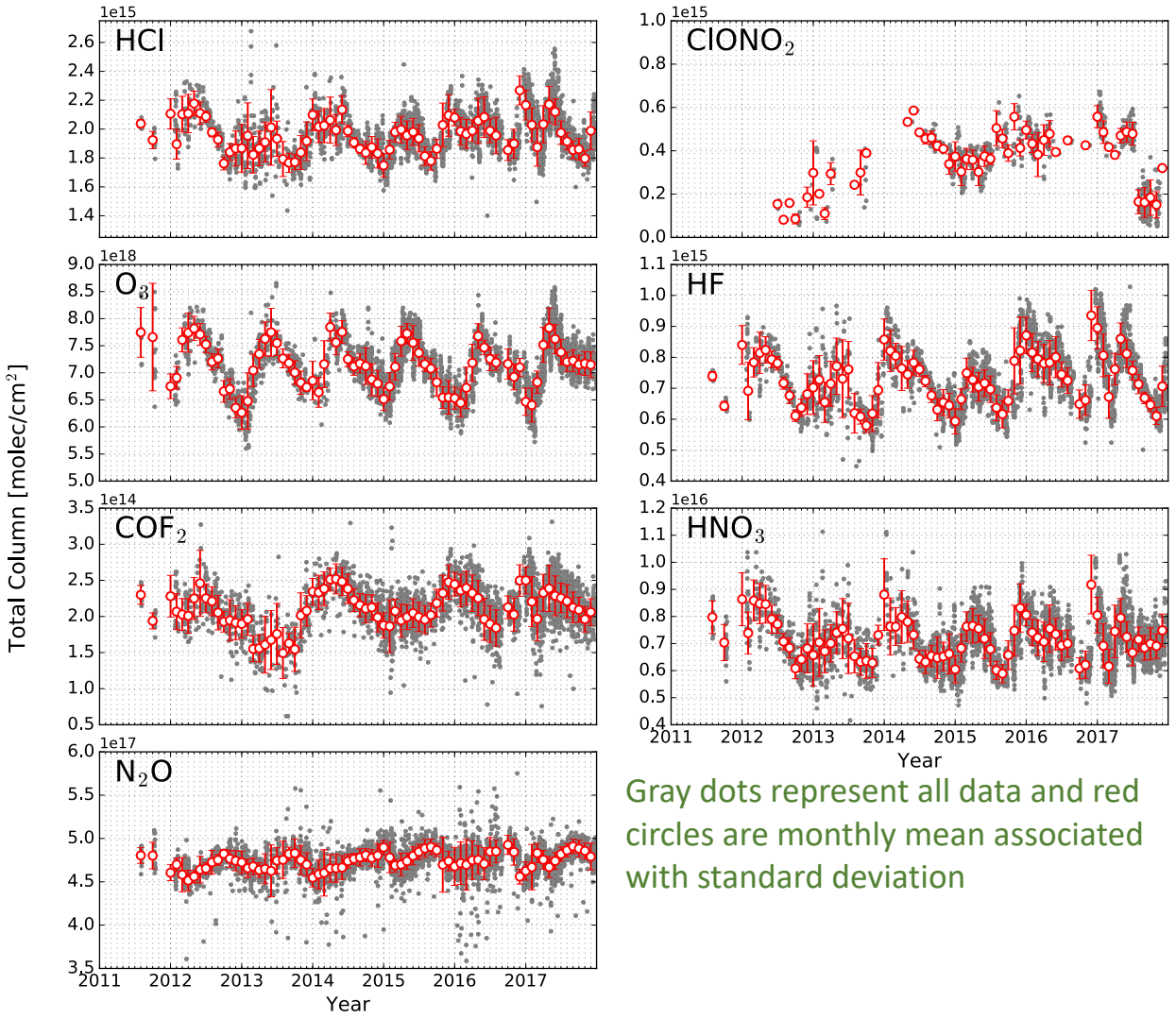






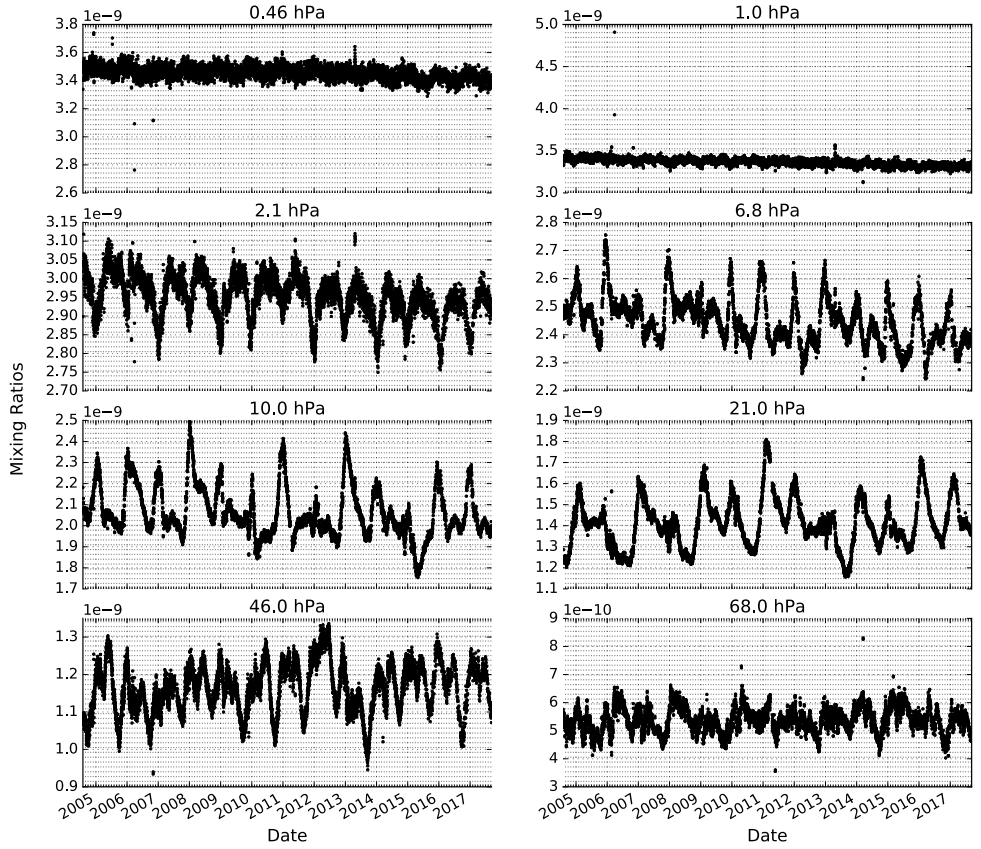
Improving the retrieval of $ClONO_2$: time series

Time series of stratospheric gases



Gray dots represent all data and red circles are monthly mean associated with standard deviation

MLS HCl at different pressures (20 - 40 N). Note suppression on the annual cycle in 2014-15.

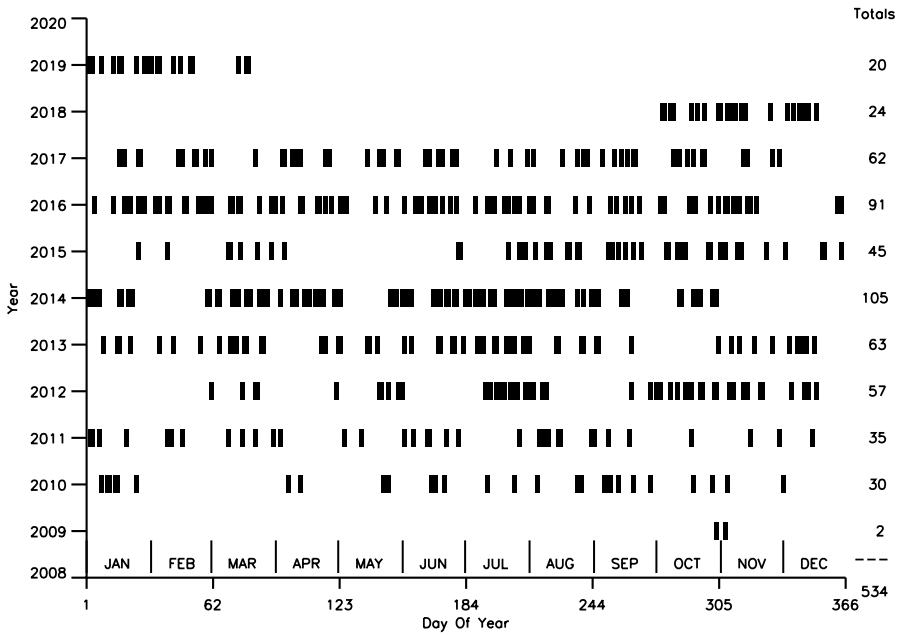


Mauna Loa: Summary SR

- Analyzed dataset from 1995, upgrade 2011 120HR -> 125HR, Acquisition upgraded 2017 same as TAB.
  - Improved reliability, feedback.
- Excellent NOAA technical support → LN2 and other minor issues,
- 282 days of QA measurements in 2017 (record),
- Signal optimization via signal & preamp gains for each spectrum in OPUS macro,
- Standard gases are archived up to 2017 (except $ClONO_2$) + some RD for CO, H_2CO, CH_4, O_3 in 2018,
- Early May 2018 Kilauea activity increased,
- Alignment improved, full alignment pending

Boulder: One Decade of Measurements

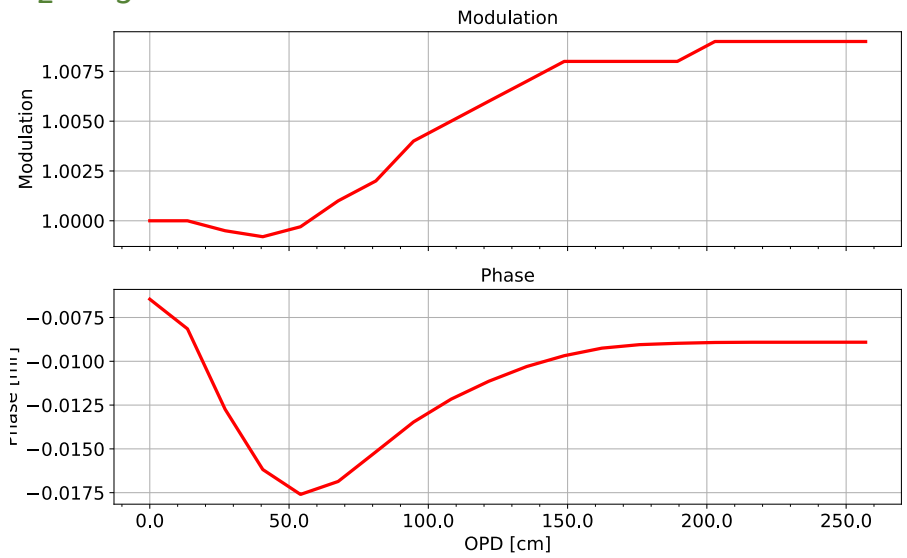
- 2008: Bruker 120HR (A. Goldman / DU) installed,
  - OPD = 600cm, OS2!,
- DU ‘Gondola’ dynamic tracker,
- Limited programmatic support (none?),
- Regular atmospheric observations started 2010,
- Dec 2017 – Sep 2018 at Ettlingen for upgrade,
  - Operations to visible
- Supported studies:
  - NH3 / Dammers et al., 2016,
  - C2H6 / Tzompa-Sosa et al., 2017
  - C2H6 / Franco et al., 2016
  - C2H6, NH3 / Kille et al., 2017
  - Tropospheric species analysis / Ortega et al., in prep 2019



Boulder: One Decade of Measurements

Next steps

- Acquisition automation, LN2 fill, tracker control, wx decisions
- Duplicate Thule tracker 2019-2020
- Prep for eventual TEMPO mission tropospheric
  - Geostationary H_2CO, NO_2, O_3
- Apply to NDACC



Installation / Performance September 2018

Current Projects

- OCS / IRWG → James Hannigan
  - Network tropospheric/stratospheric OCS partial columns analysis – near completion
- C_2H_6 / IRWG → Emmanuel Mahieu
  - Network-wide trends
- H_2CO / IRWG → Corinne Vigouroux
  - Harmonization & TROPOMI validation
- Biomass Burning → Erik Lutsch
  - Effects in Arctic
- N_2O & HBr Cells → Frank Hase
  - Network QA - Near Completion
- SFIT4 updates → Mathias Palm & Hannigan
  - Workshop in November 2019
- Tropospheric Analysis → Ivan Ortega
  - Boulder site trends, model comparisons, O&NG (C2H6), Feedlot (NH3) and CH4 attribution
- H2O & Isotopes → Joe Galewsky
  - MLO, isotope fractionation

Publications

- **The Network for the Detection of Atmospheric Composition Change (NDACC): history, status and perspectives.** M. De Maziere, et al., Atmospheric Chemistry and Physics, 18(7):4935–4964, 2018. doi: 10.5194/acp-18-4935-2018.
- **MLS measurements of stratospheric hydrogen cyanide during the 2015–2016 El Nino event.** H. C. Pumphrey, et al., Atmospheric Chemistry and Physics, 18(2):691–703, 2018. doi:10.5194/acp-18-691-2018.
- **Discovery of New Coronal Lines at 2.843 and 2.853 µm.** Jenna E. Samra, et al., The Astrophysical Journal Letters, 856(2):L29, 2018.
- **Tropospheric Ozone Assessment Report: Present-day distribution and trends of tropospheric ozone relevant to climate and global atmospheric chemistry model evaluation.** A. Gaudel, et al., Elem Sci Anth, 6, 2018. doi:10.1525/elementa.291.
- **Volcanoes: Composition of Emissions.** J. W. Hannigan and M. T. Coffey. Encyclopedia of Atmospheric Sciences, chapter Elsevier Ltd., 2019, in Press.
- **High cadence visible and infrared spectra of the Sun during eclipse.** P. Judge, S. Tomczyk, R. Casini, J. W. Hannigan and S. Sewell. Astrophysical Journal, Submitted 2019
- **Solar Eclipse Observations from the Ground and Air From 0.31 to 5 microns**. Phillip Judge, B. Berkey, A. Boll, P. Bryans, J. Burkepile, P. Cheimets, E. E. DeLuca, G. de Toma, K.Gibson, L. Golub, J. W. Hannigan, C. Madsen, V. Marquez, J. E. Samra, S. Sewell, S. Tom- czyk and A.Vira. Astrophysical Journal, in Pres 2019
- **Separation of methane emissions from agricultural and natural gas sources in the Colorado Front Range.** Natalie Kille, Randall Chiu, Matthias Frey, Frank Hase, Mahesh K. Sha, Thomas Blumenstock, James W. Hannigan, Johannes Orphal, Daniel Bon and Rainer Volkamer. Geophysical Research Letters, 0(ja), 2019/03/21 2019. doi:10.1029/2019GL082132.
- **Unprecedented NH3 emissions detected in the high-Arctic from the 2017 Canadian wildfires.** Erik Lutsch, et al., Journal Geophysical Research - Atmospheres, 2019, in Press.

Publications

- **Tropospheric water vapor profiles obtained with FTIR: comparison with balloon-borne frost point hygrometers and influence on trace gas retrievals.** I. Ortega, R. R. Buchholz, E. G. Hall, D. F. Hurst, A. F. Jordan and J. W. Hannigan. Atmospheric Measurement Techniques, 12(2):873–890, 2019. doi:10.5194/amt-12-873-2019.
- **Tropospheric Ozone Assessment Report: Tropospheric ozone observations – How well do we know tropospheric ozone changes?** David Tarasick, et al., Elementa, 2019-Submitted.
- **Atmospheric Implications of Large C2-C5 Alkane Emissions From the U.S. Oil and Gas Industry.** Z. A. Tzompa-Sosa, et al., Journal of Geophysical Research: Atmospheres, 124(2):1148–1169, 2019/03/12 2019. doi:10.1029/2018JD028955.
- **NDACC harmonized formaldehyde time-series from 21 FTIR stations cov- ering a wide range of column abundances.** Corinne Vigouroux, et al., Atmospheric Measurement Techniques, 11(9):5049–5073, September 2018. doi:10.5194/amt-11-5049- 2018.
- **An intercomparison of total column-averaged nitrous oxide between ground-based FTIR TCCON and NDACC measurements at seven sites and comparisons with the GEOS-Chem model.** M. Zhou, et al., Atmospheric Measurement Techniques, 12(2):1393–1408, 2019. doi:10.5194/amt-12-1393-2019.

end

Thule: High Arctic Atmospheric Observatory

- Danish Meteorological Institute (DMI) has left site
- NSF assumed site management with USAF

Current Suite of measurements

- FTIR
- Lidar – Tropospheric-Stratospheric Aerosol, Temperature
- GMBS Ground-Based Millimeter-wave Spectrometer – Stratospheric CO, HNO_3, N_2O, O_3
- HATPRO microwave radiometer and Heitronics pyrometer –Tropospheric temperature profiles
- The Vaisala DigiCora 2 sounding system - O_3 & H_2O sondes
- water Vapor Emission Spectrometer for Polar Atmospheres at 22 GHz (VESPA-22) – Strat-Mesosphere
- AERONET (solar, lunar AOD +)
- Whole Sky Imager, Radiometers (IR, PAR, SW)
- Room for more instrumentation