UAVs making atmospheric measurements: water vapor isotopes above the Greenland Ice Sheet

Bruce Vaughn[1], Kevin Rozmiarek[1], Valerie Morris[1],
Hans Christian Steen-Larsen[2], and Tyler Jones[1]

[1] INSTAAR- University of Colorado, Boulder; [2] University of Bergen, Norway

ARCUS — ARCTIC RESEARCH CONSORTIUM OF THE UNITED STATES

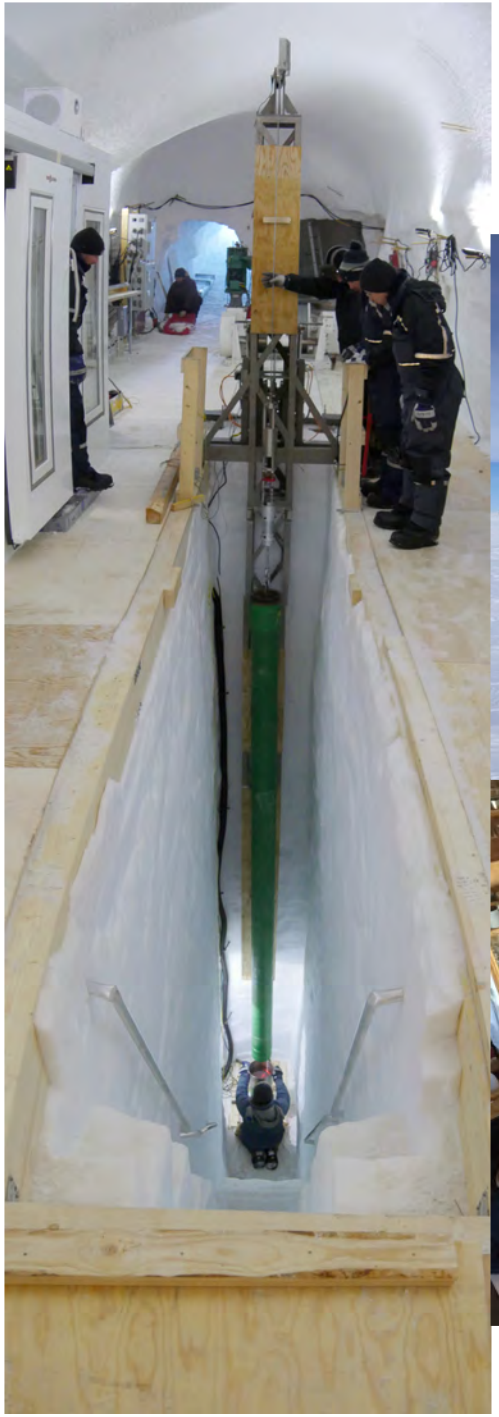
University of Colorado Boulder

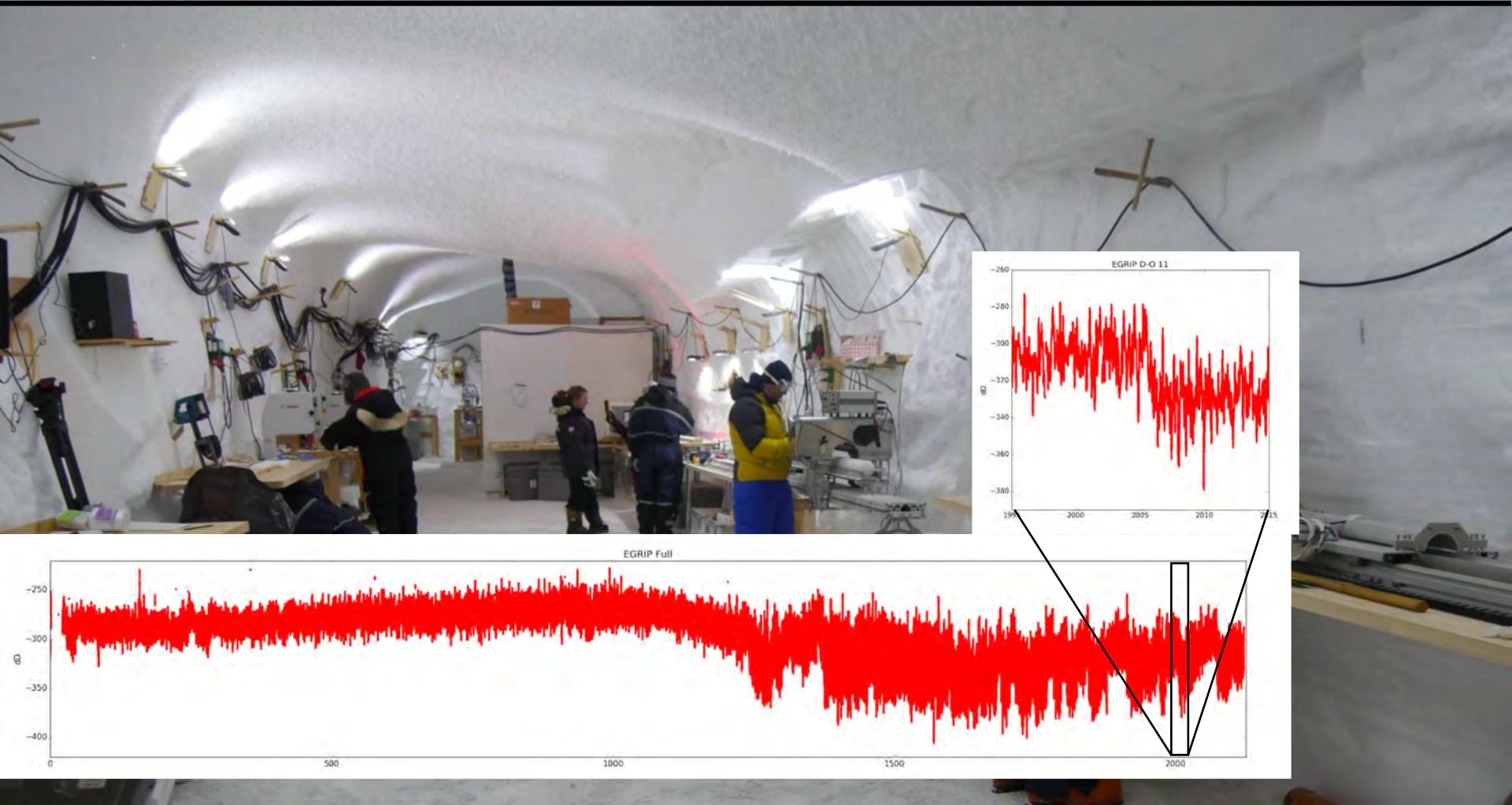
Polar Technology Conference, March 2020

EGRIP Camp 75.6°N, 36.0°W

EastGRIP Greenland

75.6°N, 36.0°W, 2708 m a.s.l. (8885 feet)

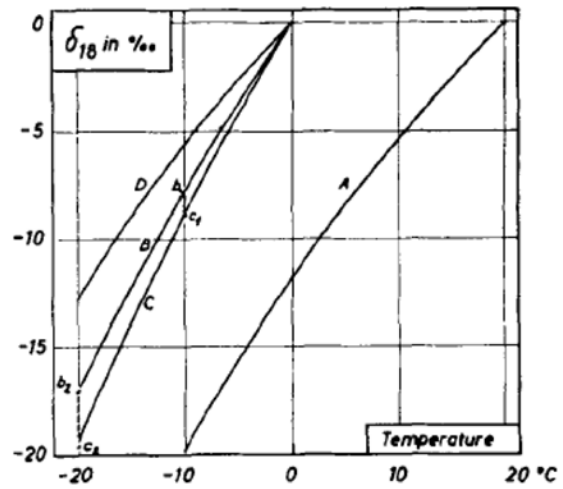


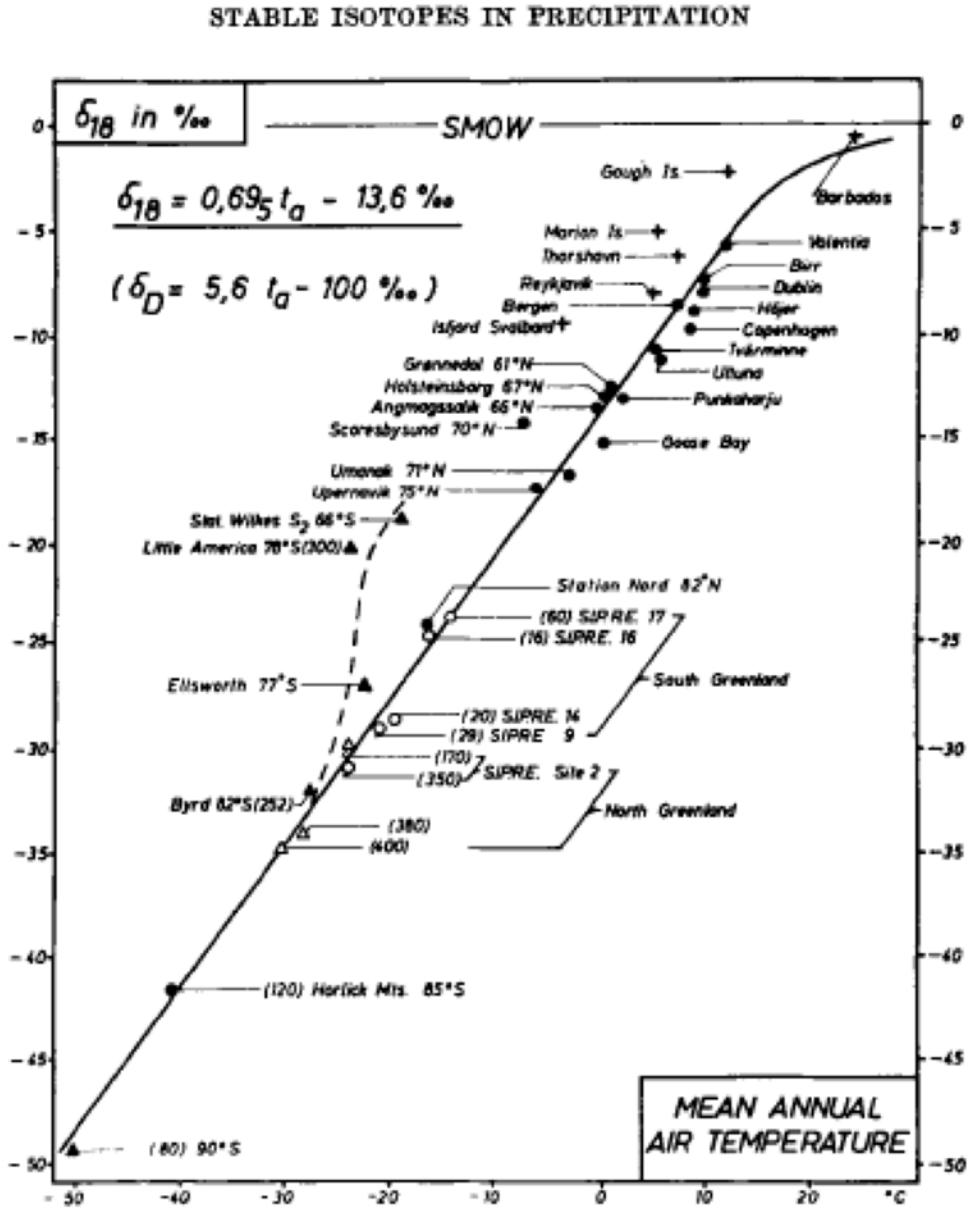


EGRIP D-O 11
dD
-260
-280
-300
-320
-340
-360
-380
2000
2005
2010

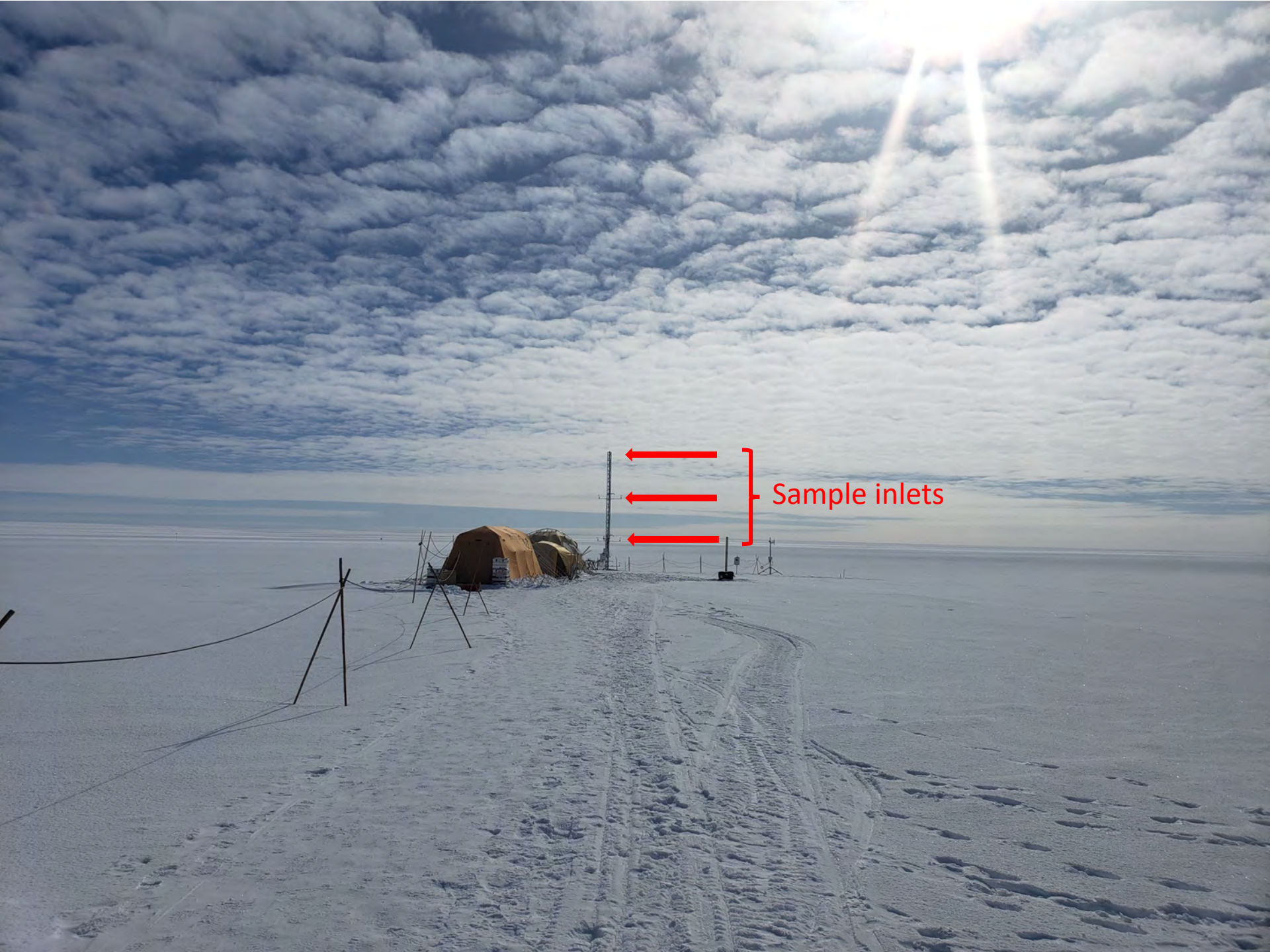
EGRIP Full
dD
-250
-300
-350
-400
0
500
1000
1500
2000

Willi Dansgaard 1923- 2011

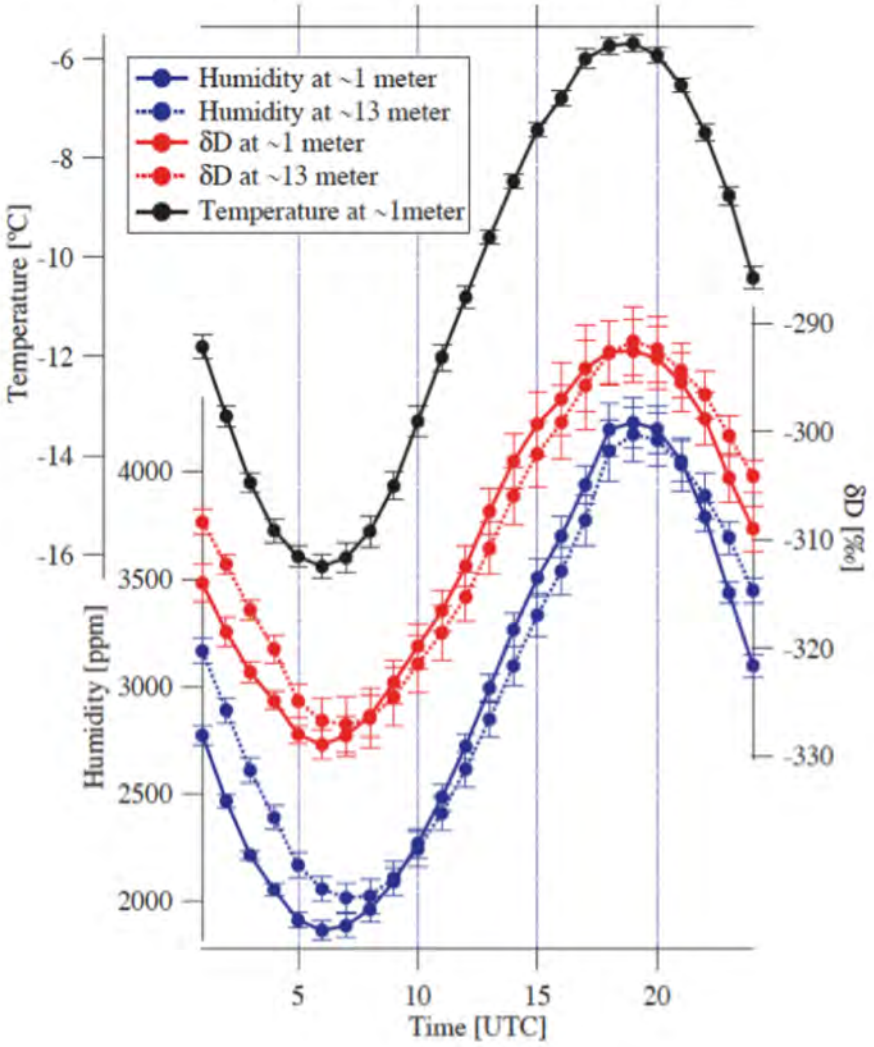




*From W. Dansgaard, **Tellus** November 1964*


Sample inlets

Closing the Water Vapor Exchange Budget between the Ice Sheets and Free Atmosphere



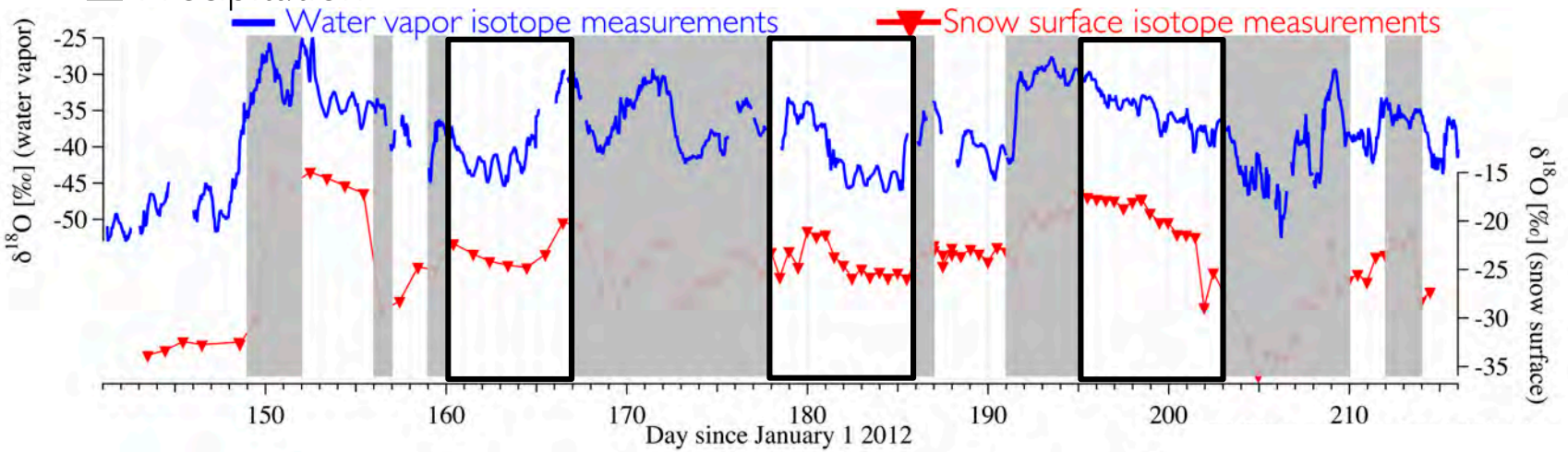
The mean diurnal cycle on days with clear sky and calm weather.
Stacked based on diurnal cycles between Julian days 180 and 190.

(From Steen-Larsen et al. 2013)

Water **vapor** isotopes challenge assumptions

New surprises

The snow isotopes change with the atmospheric water vapor isotopes



(Steen-Larsen et al. 2014)

Ice core isotopes are not only governed by precipitation isotopes

PARADIGM SHIFT

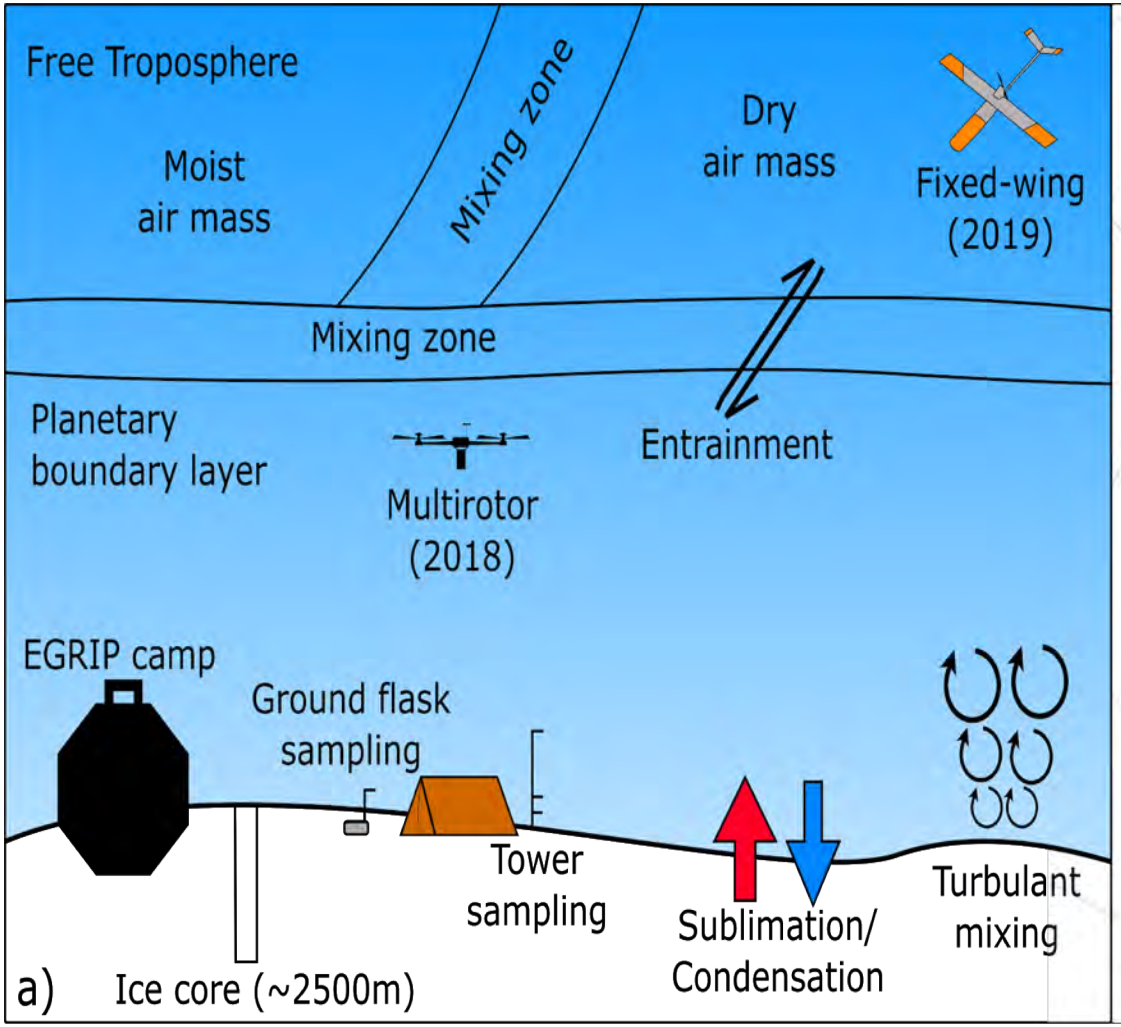
This challenges 50 years of assumptions

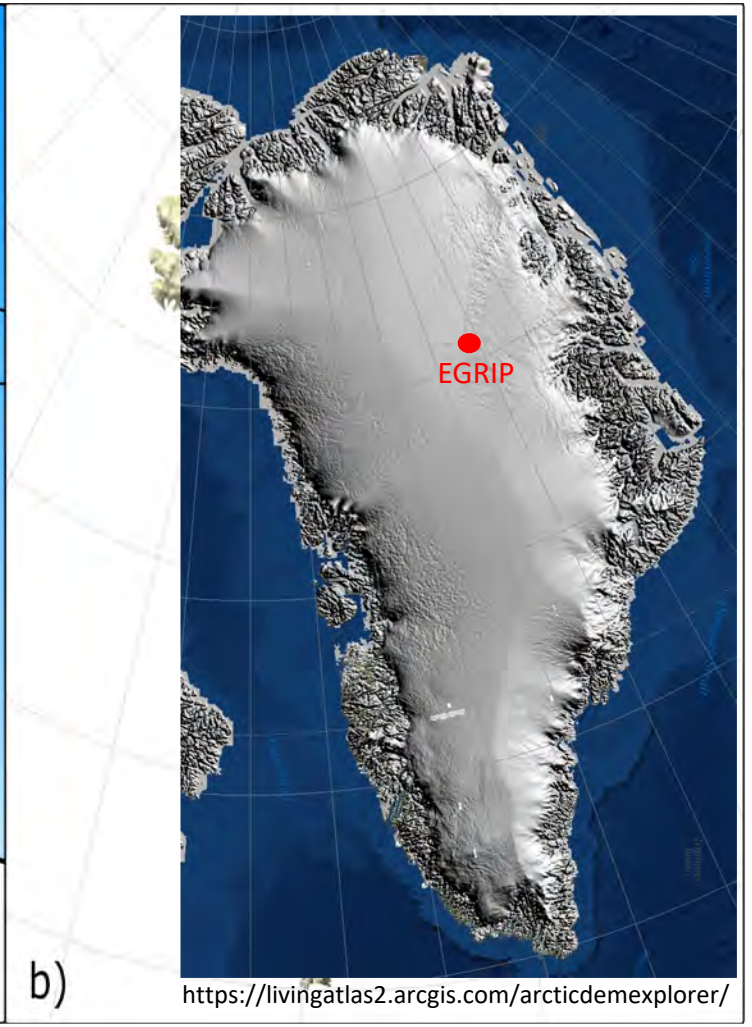
What controls the water vapor isotope flux between the snowpack and the atmosphere and how important is it?

Why Measure Water Vapor Isotopes?

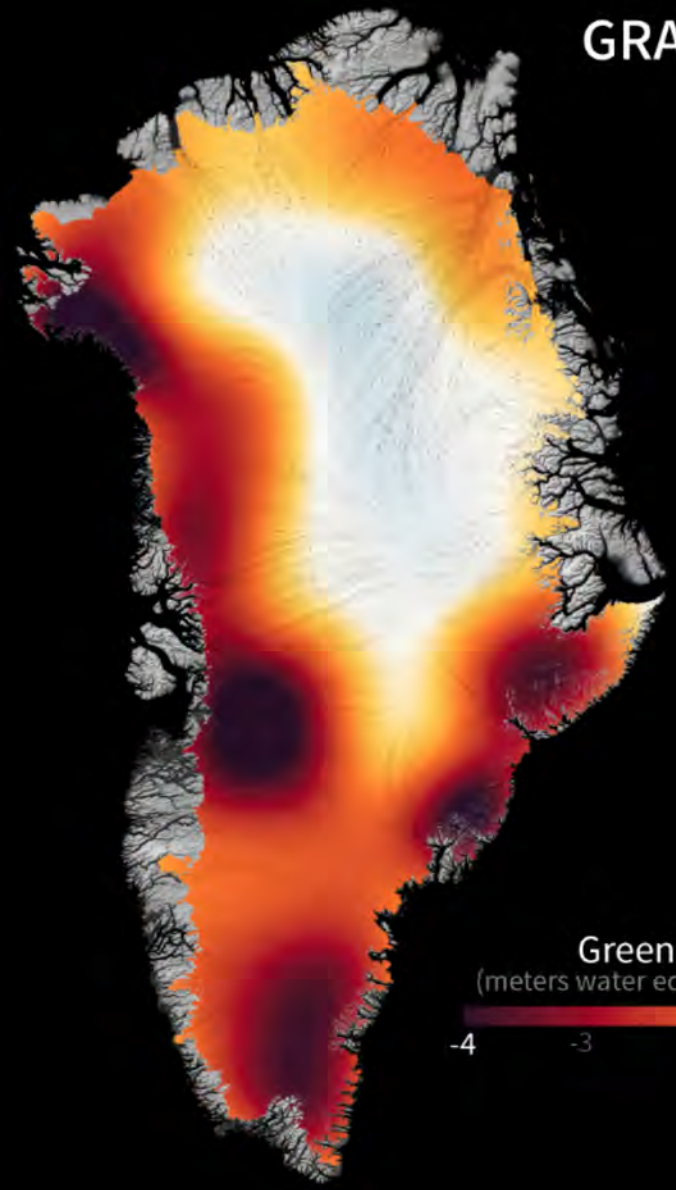
- Water vapor is the strongest natural greenhouse gas and transports large amounts of energy through latent heat.
- Important for: radiative transfer, cloud formation, weather and climate
- Water vapor deposition and sublimation are largely unconstrained terms in surface mass balance of the Greenland ice sheet.
- Uncertainty remains in water vapor in the atmospheric boundary layer above the ice sheet, and how much is exchanged with the free troposphere.
- Ground truth is needed for satellite data and atmospheric models
- Better understanding of the transfer function of climate from the atmosphere to the ice core isotope record.

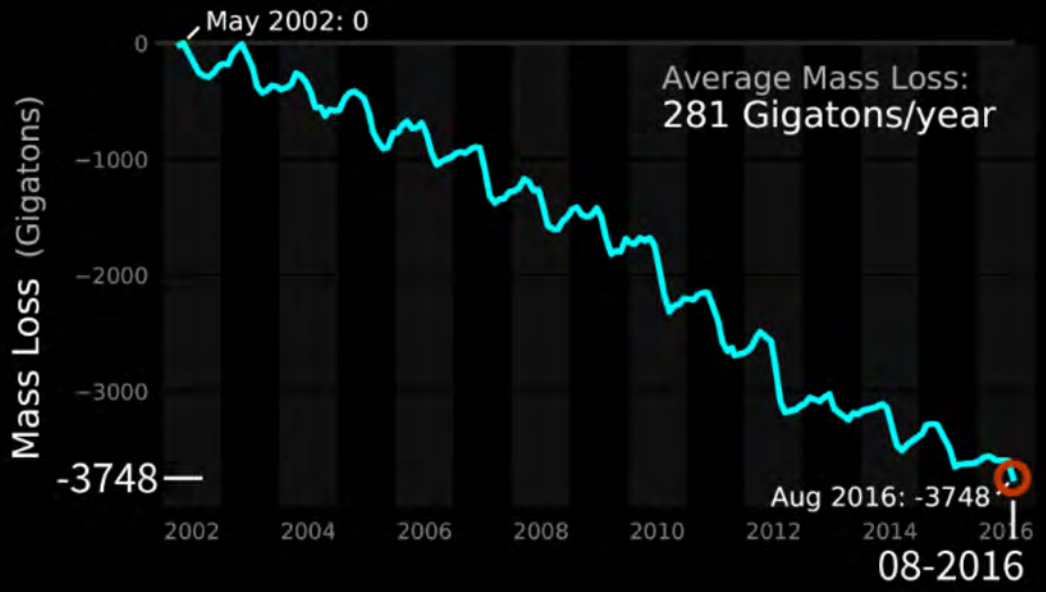
Surface Science at EGRIP (**E**ast **GR**eenland **I**cesheet **P**roject)





GRACE Observations of Greenland Ice Mass Changes





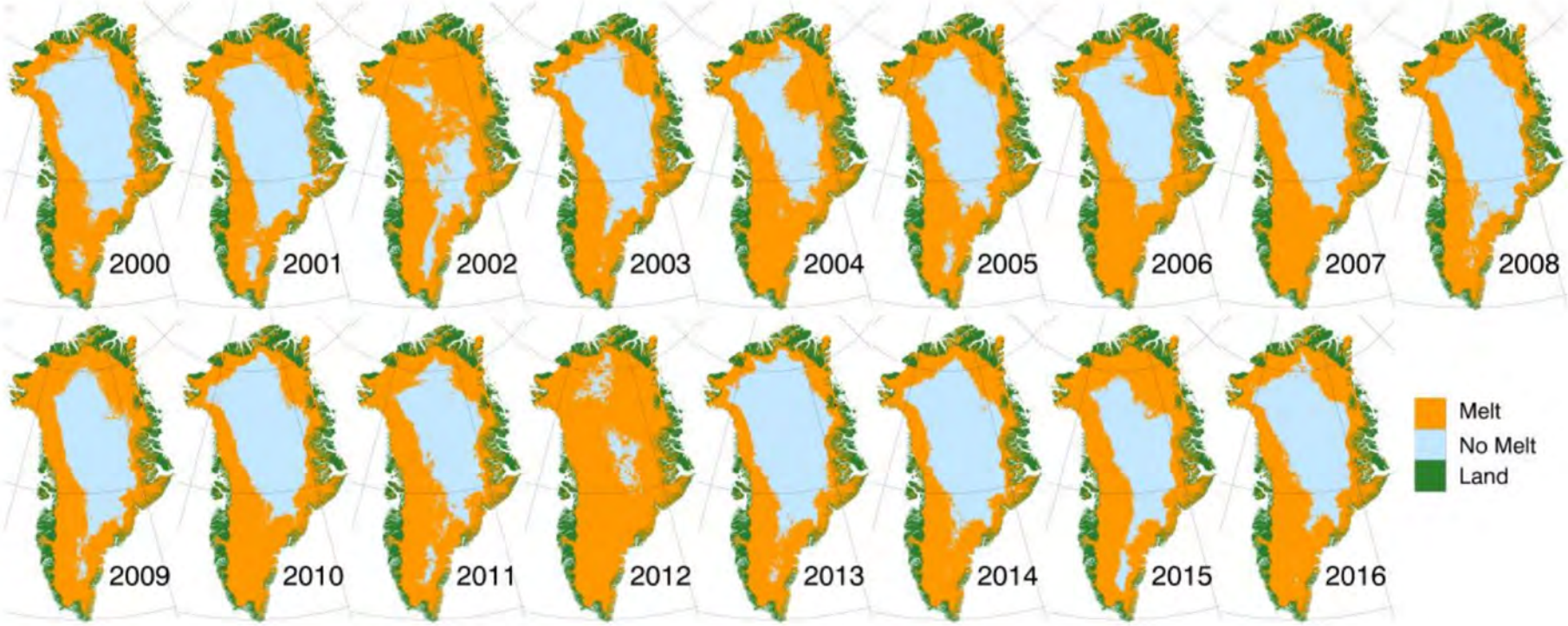
Greenland Ice Loss
(meters water equivalent relative to 2002)

-4 -3 -2 -1 0 0.5

NASA JPL
Jet Propulsion Laboratory
California Institute of Technology

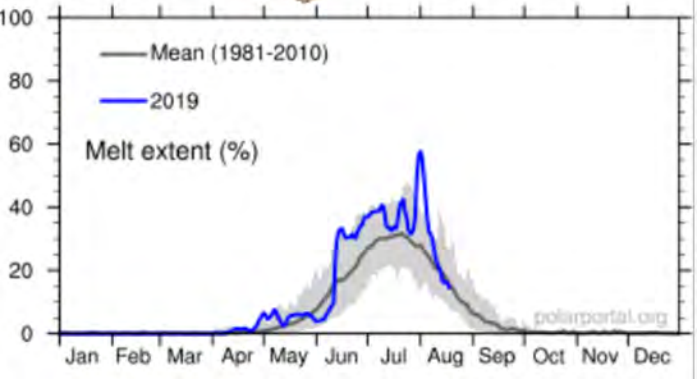
Mass balance changes from surface melt and ice berg calving

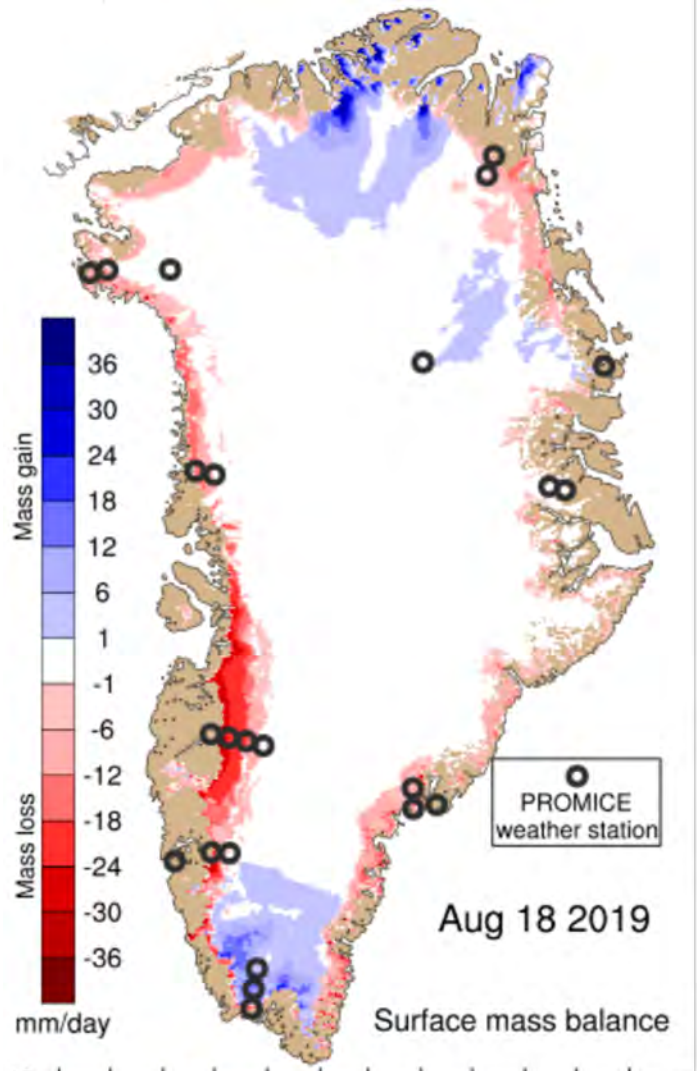
MODIS

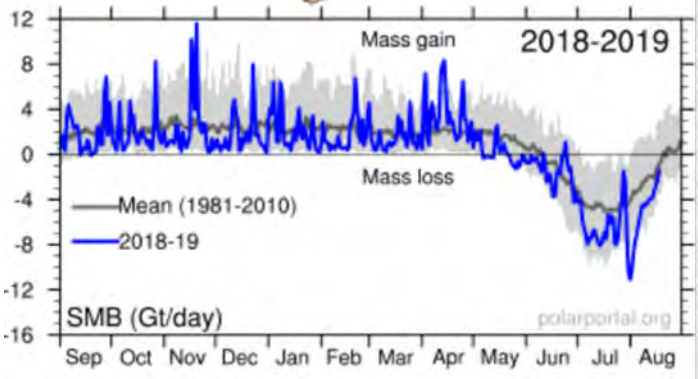


(From Hall et al. 2018)

The 2019 Melt year in Greenland



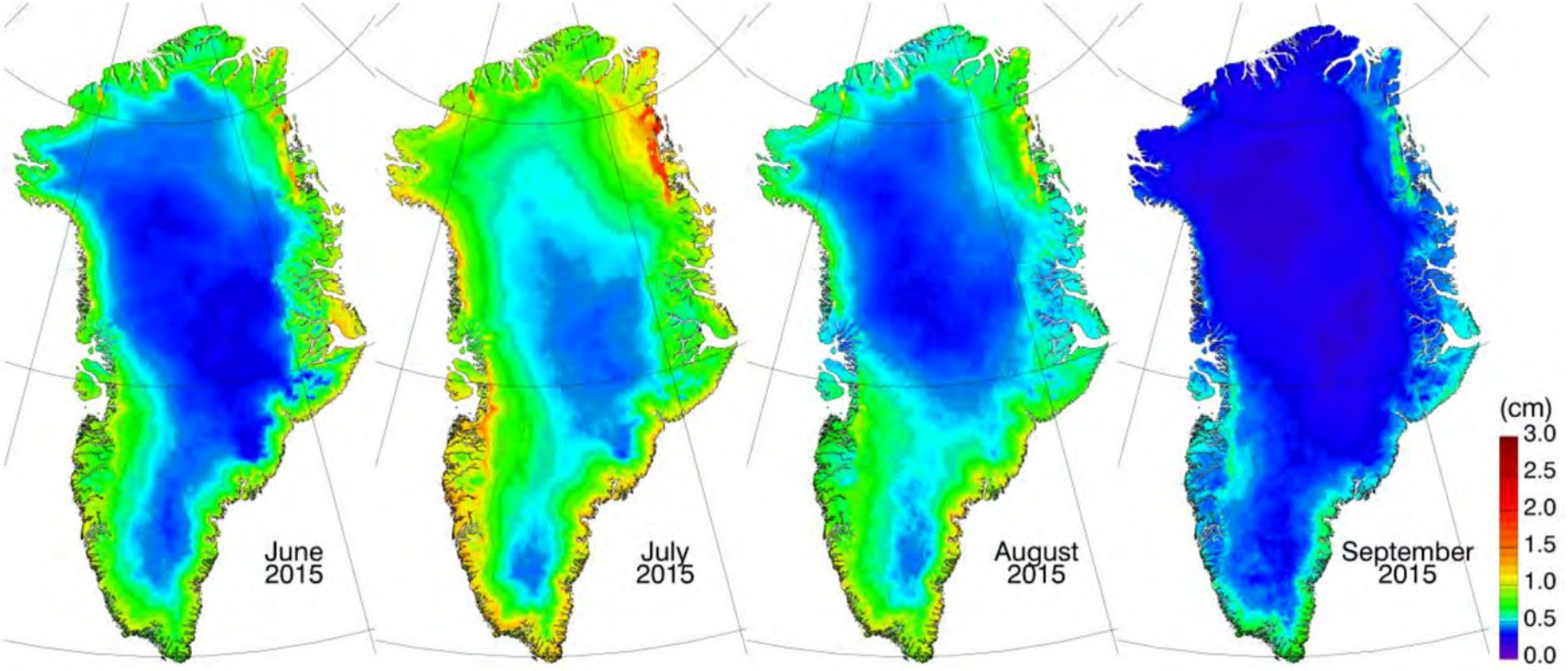




Data from Danish Meteorological Institute
polarportal.dk/en/greenland/surface-conditions/

Model estimates are from DMI's regional climate model HIRHAM5

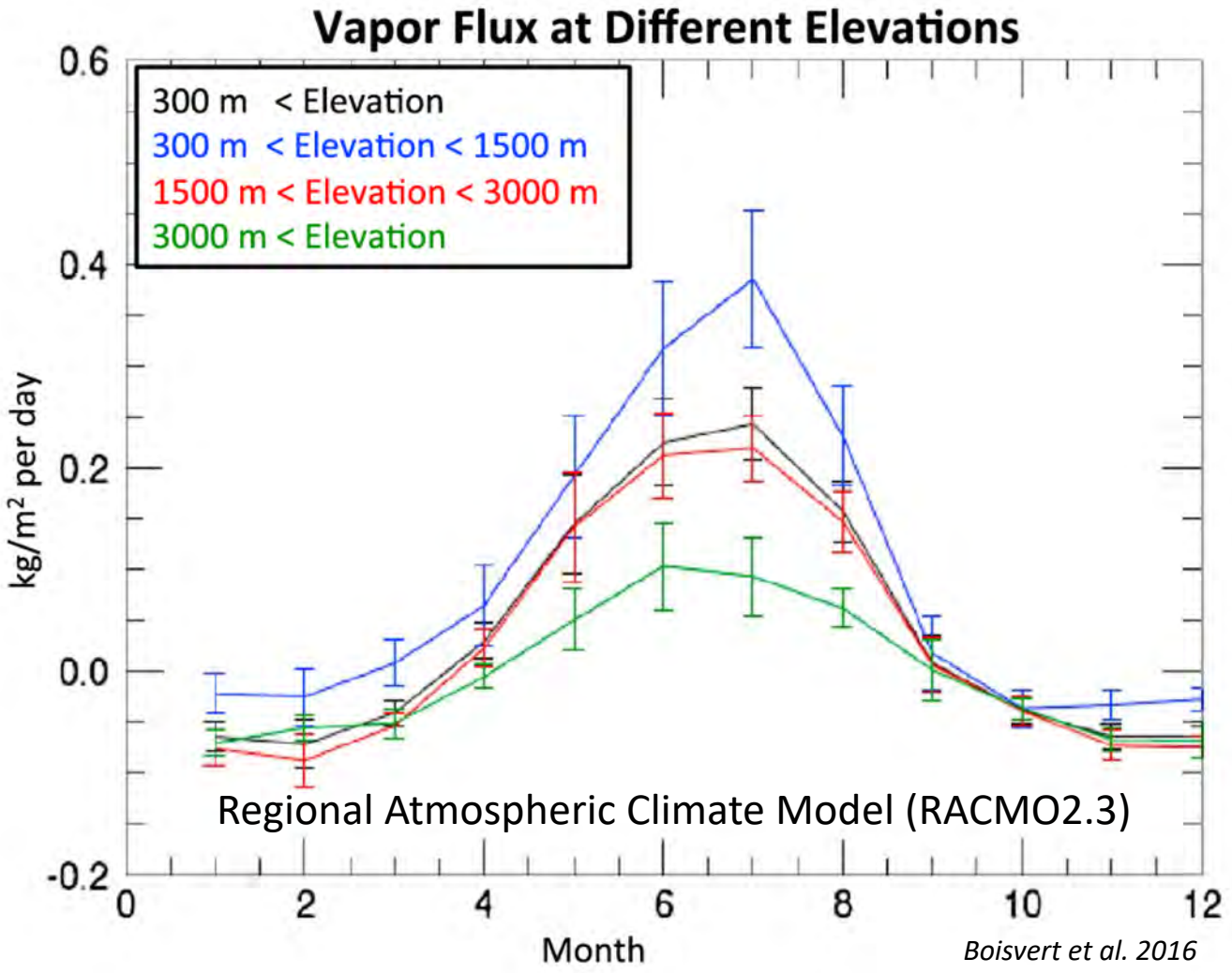
Water vapor



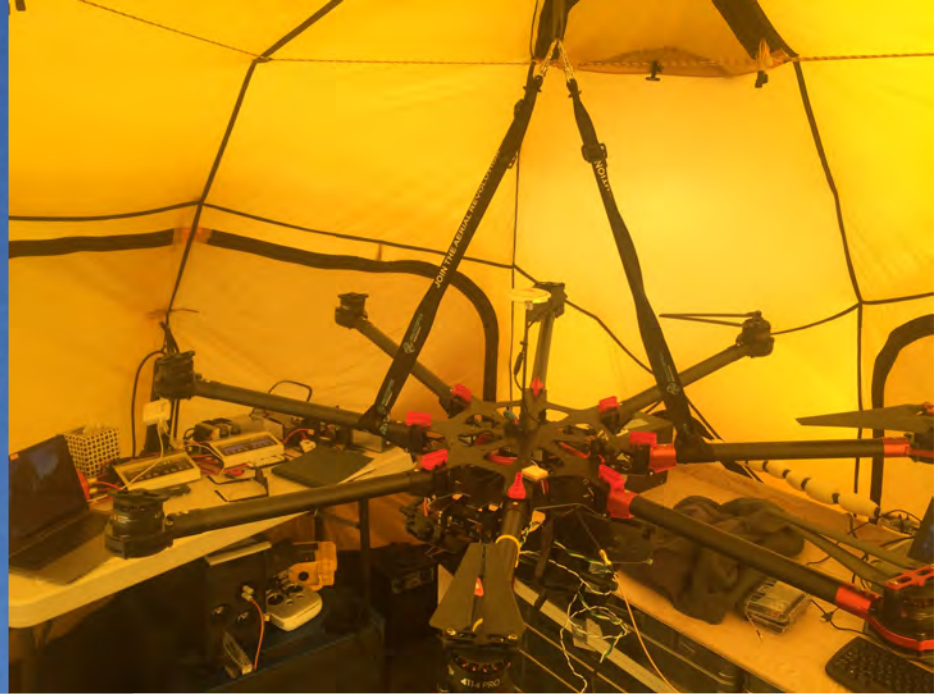
Examples of water vapor maps of the Greenland Ice Sheet derived from the Collection 6 MOD05 standard MODIS product, for June through September 2015 (*from Hall, et al. 2018*).

Note: The water vapor below clouds is not seen by MODIS near-IR channels; **this could result in biases when using a time series of WV data.**

Greenland Average daily vapor flux estimates

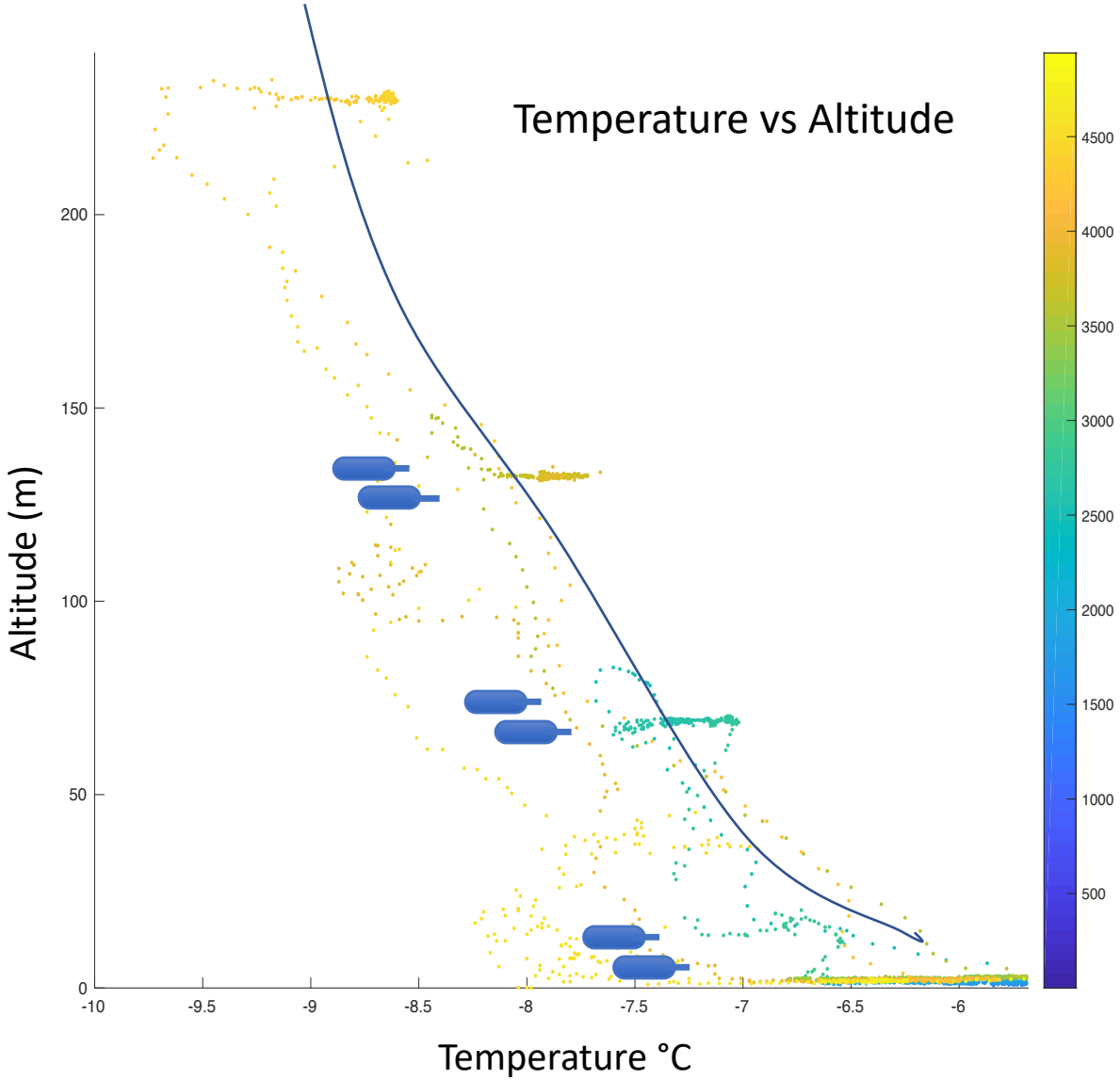


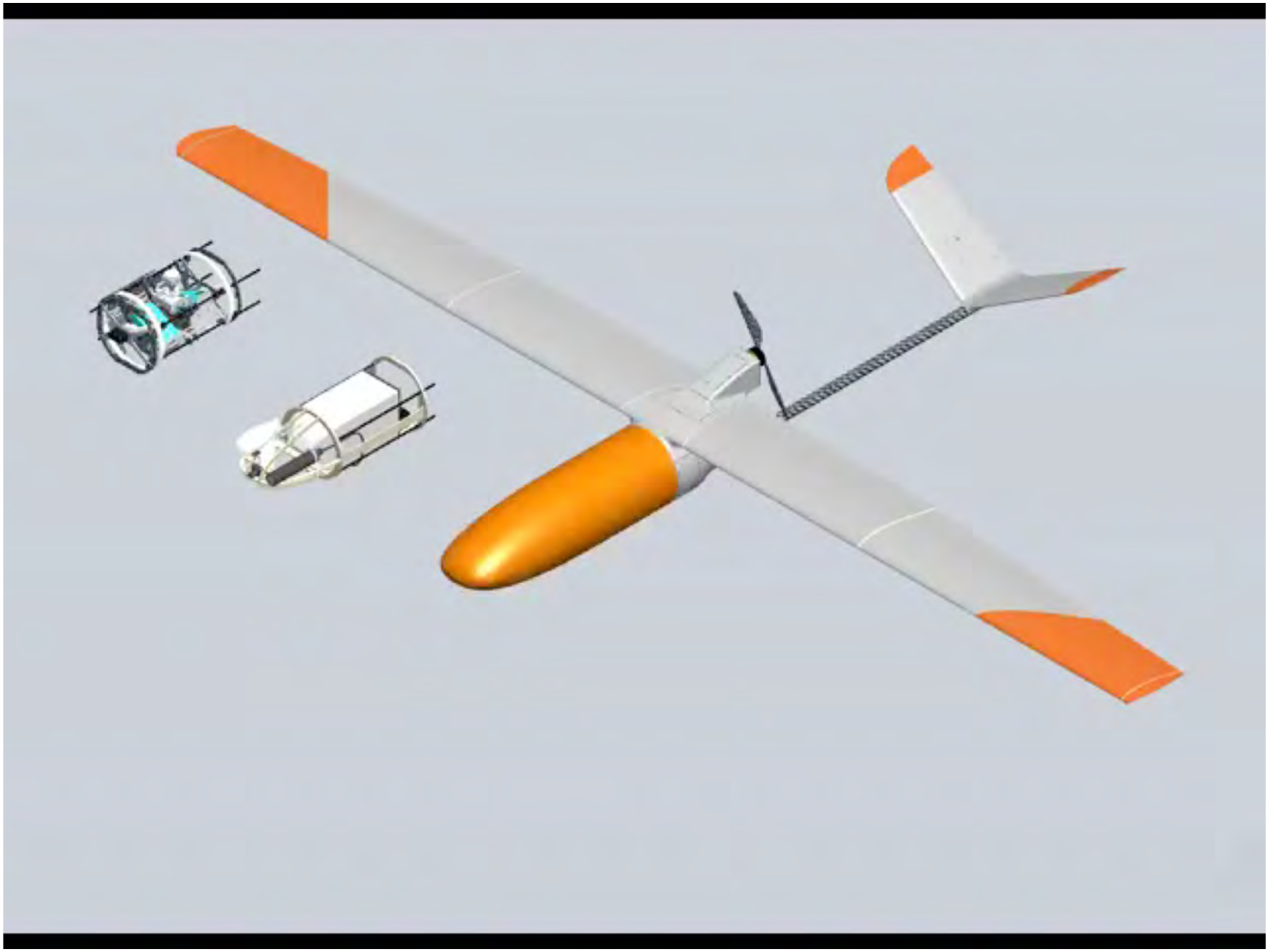
Estimates of loss due to sublimation range from 6% to 18% of (39 to 120 gigatonnes/year (*Boisvert et al. 2016: 6%;* Lenarts et al. 2012: 12%; Box and Steffen, 2001:18%).



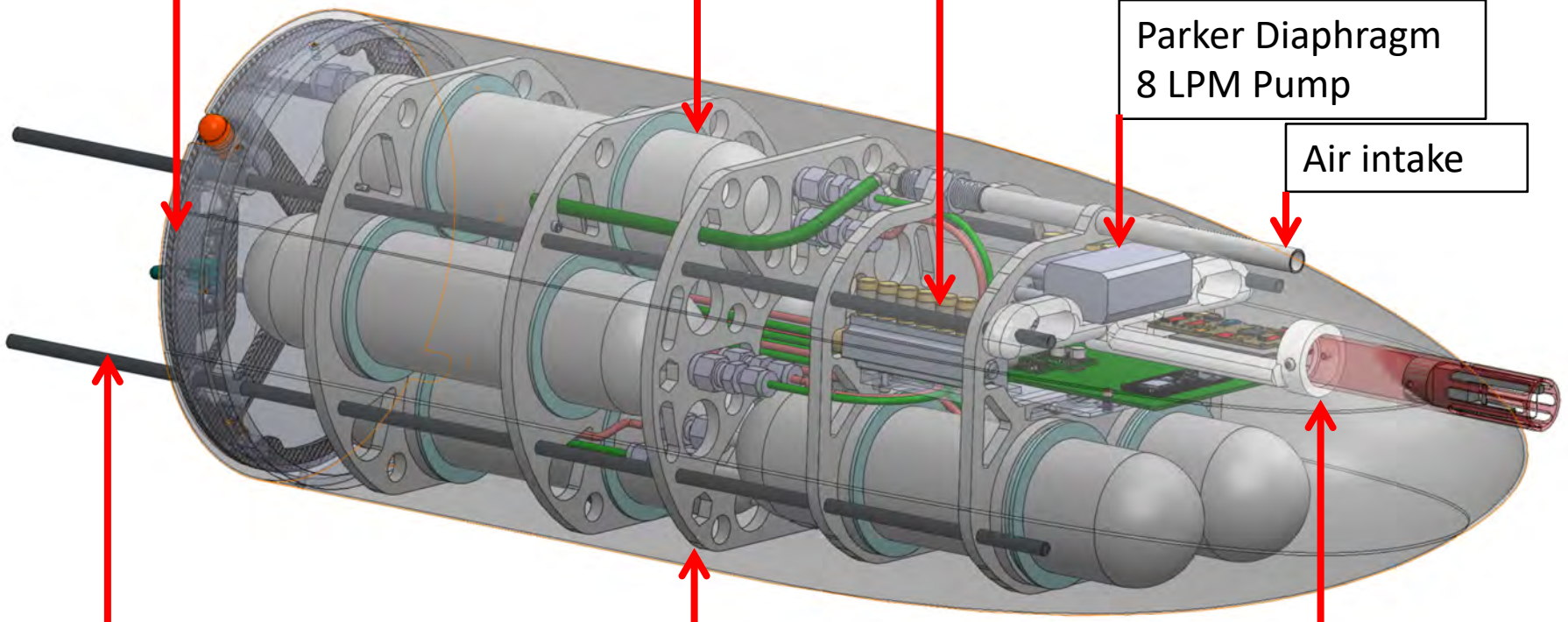
						Pair Differences		
Flask #	Location/Alt	PPm	dD ‰	d18O ‰	± ‰	PPm	dD ‰	d18O ‰
1	68	4861	-276.6	-35.65	0.16			
2	68	4847	-276.2	-35.62	0.11	14	-0.40	0.03
3	131	4954	-269.2	-34.57	0.1			
4	131	4989	-268.9	-34.37	0.1	-35	-0.30	0.20
5	0	4377	-287.4	-37.25	0.19			
Outside Prior	0	4496	-291.1	-37.41	0.15	-119	3.70	0.16
(~ 30 minutes before behind the tent - so different conditions?)								

June 7, 2018 flight with samples taken in pairs





Sample Pod Nose Cone



6 x ~500 cc glass flasks with 2 ports, dip tube

Electrical-coms connection to S2 flight computer

Valve manifolds and control board

Parker Diaphragm 8 LPM Pump

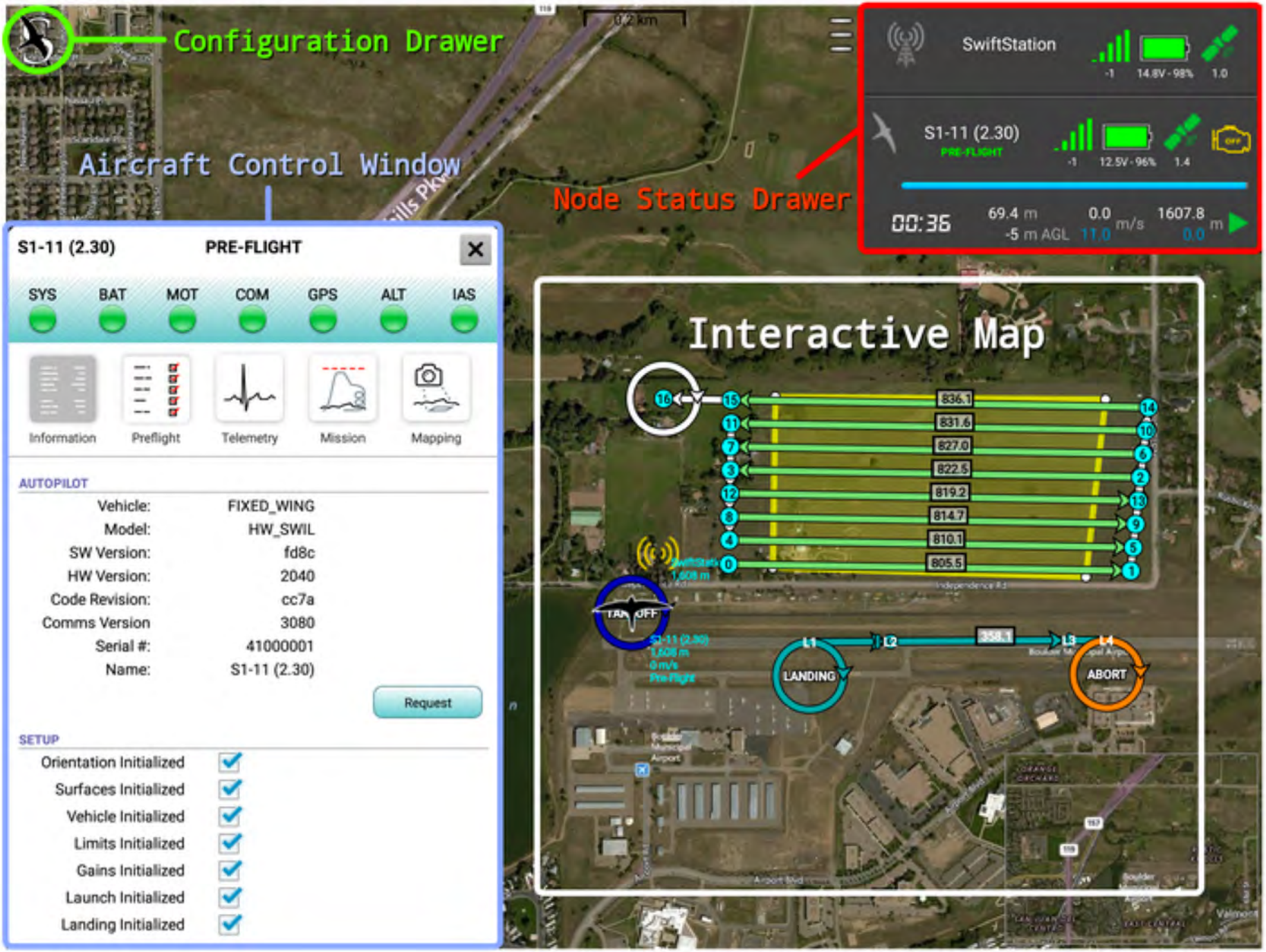
Air intake

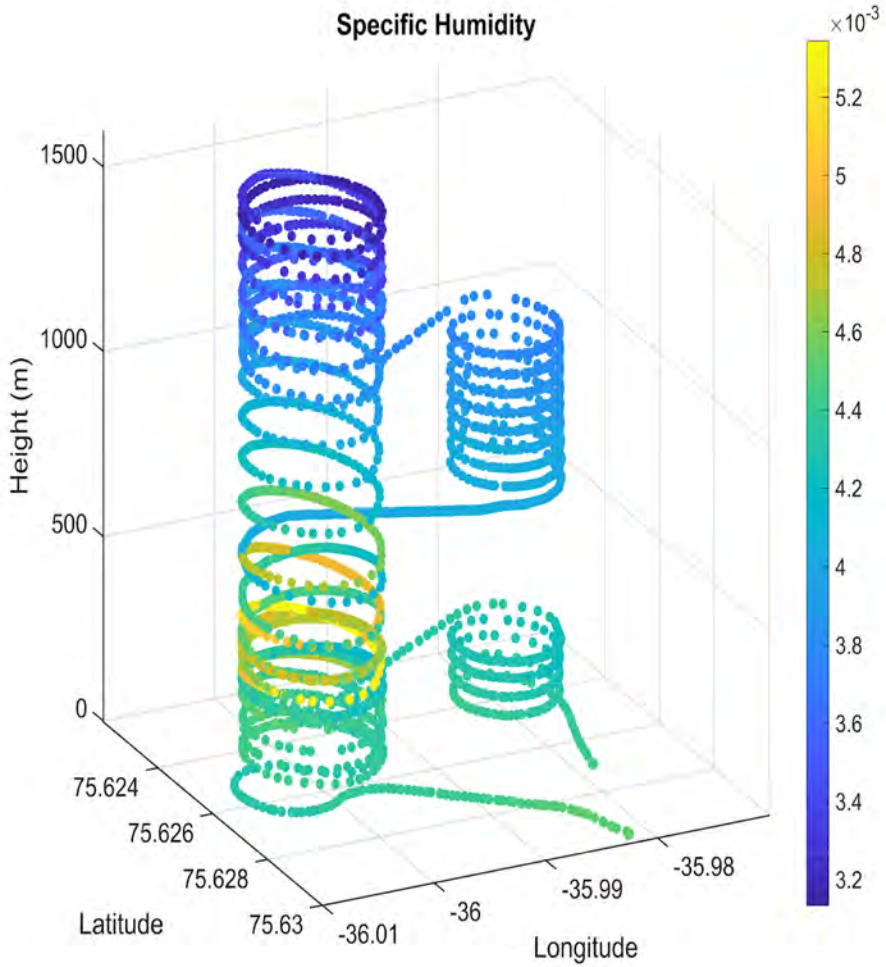
Carbon fiber rods connecting pod to S2 fuselage

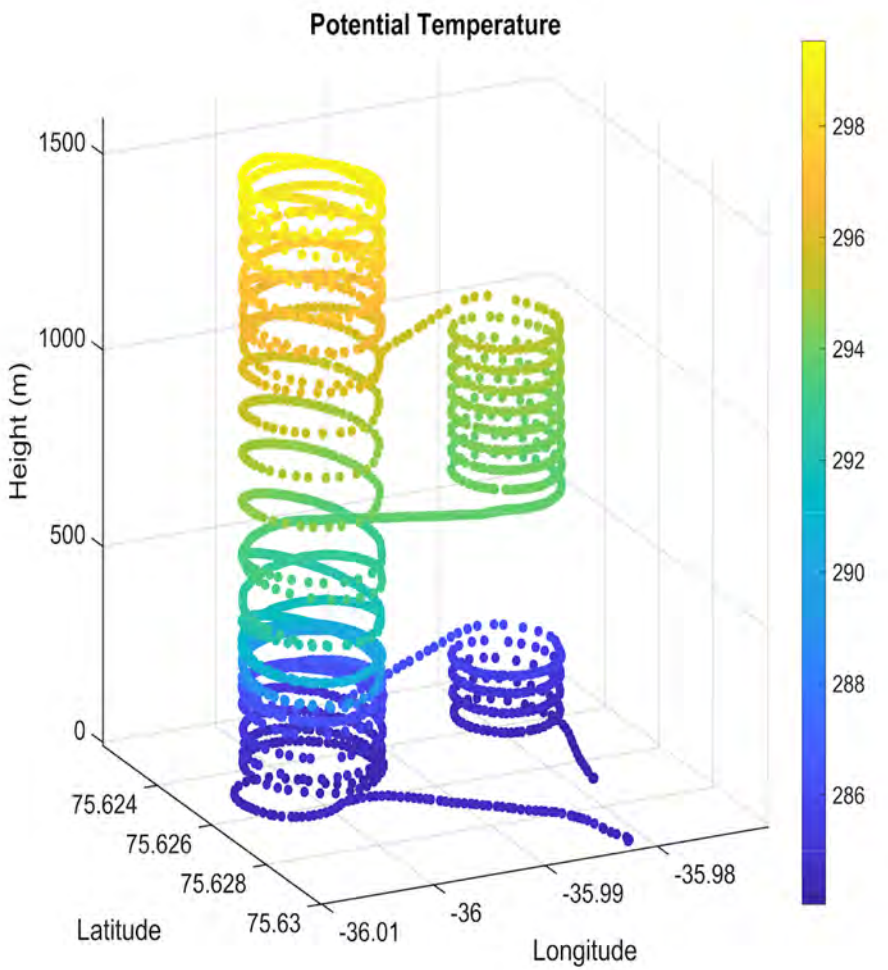
Nylon 3D printed frames

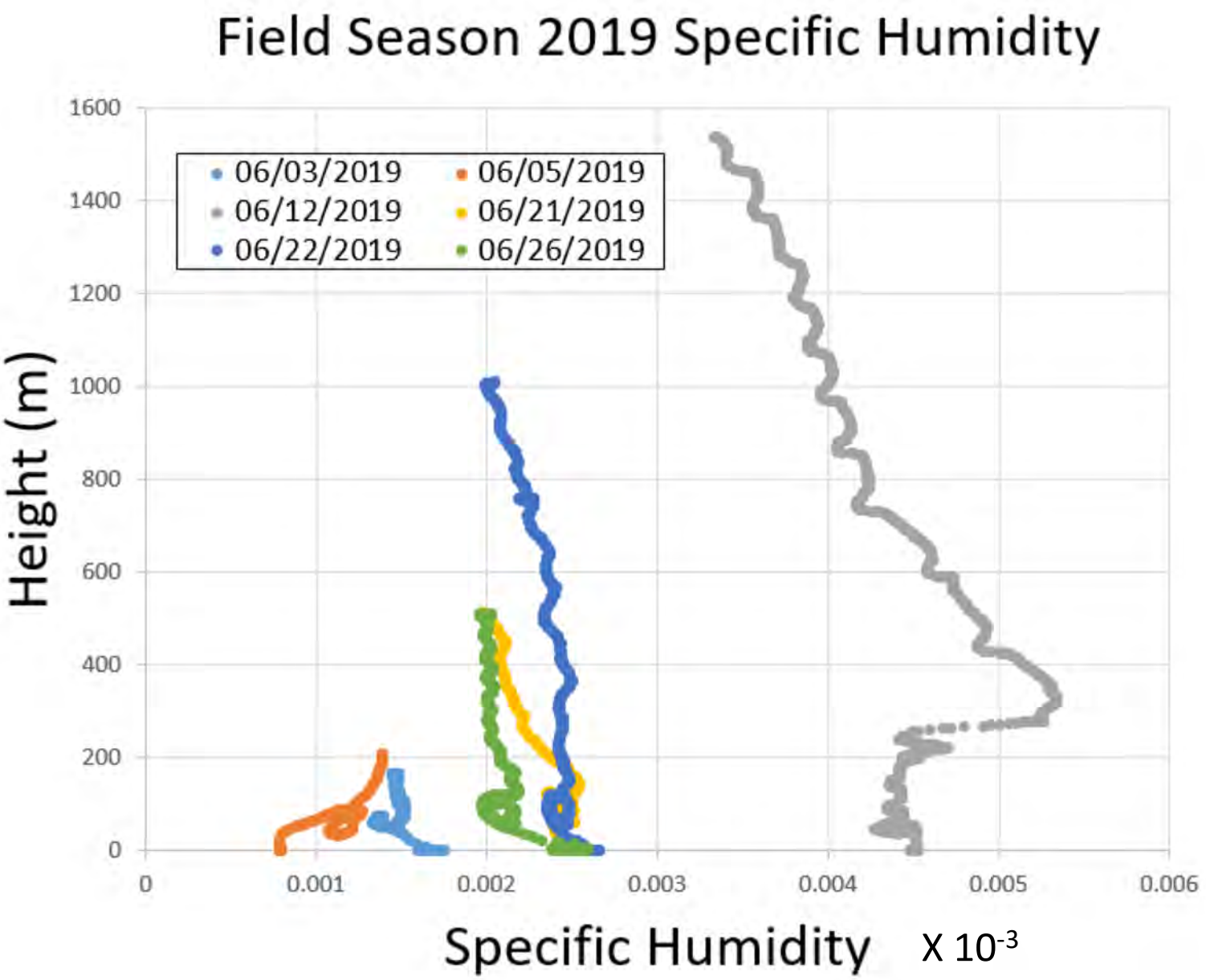
Vaisala RSS421 R/H & Temp. Probe


Black Swift

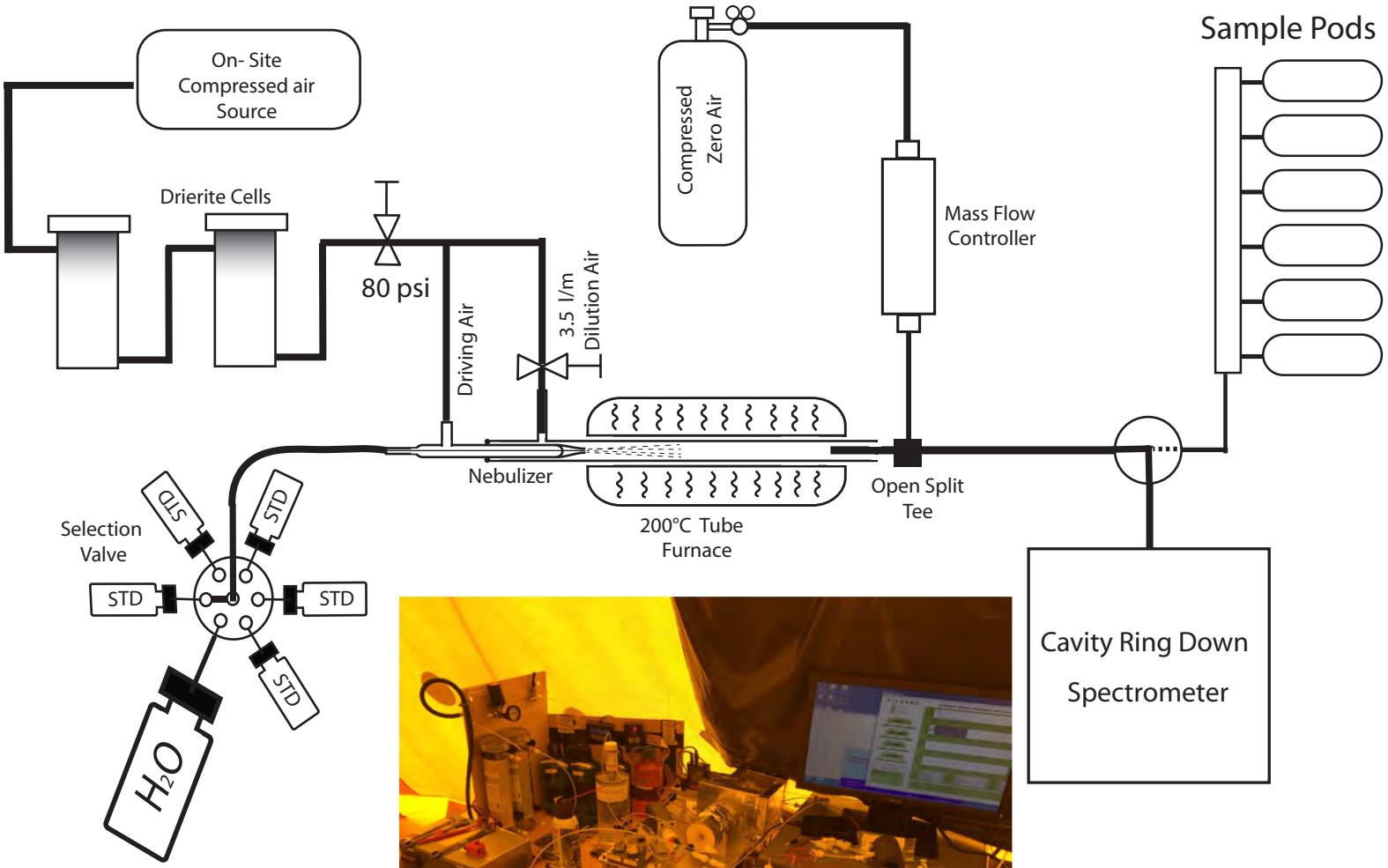

Configuration Drawer
Aircraft Control Window
Node Status Drawer
Interactive Map
SwiftStation
S1-11 (2.30)
PRE-FLIGHT
00:36
69.4 m
-5 m AGL
0.0 m/s
1607.8 m
S1-11 (2.30)
PRE-FLIGHT
SYS
BAT
MOT
COM
GPS
ALT
IAS
Information
Preflight
Telemetry
Mission
Mapping
AUTOPILOT
Vehicle: FIXED_WING
Model: HW_SWIL
SW Version: fd8c
HW Version: 2040
Code Revision: cc7a
Comms Version 3080
Serial #: 41000001
Name: S1-11 (2.30)
Request
SETUP
Orientation Initialized
Surfaces Initialized
Vehicle Initialized
Limits Initialized
Gains Initialized
Launch Initialized
Landing Initialized
836.1
831.6
827.0
822.5
819.2
814.7
810.1
805.5
TAKEOFF
LANDING
ABORT
L1
L2
L3
L4
358.1

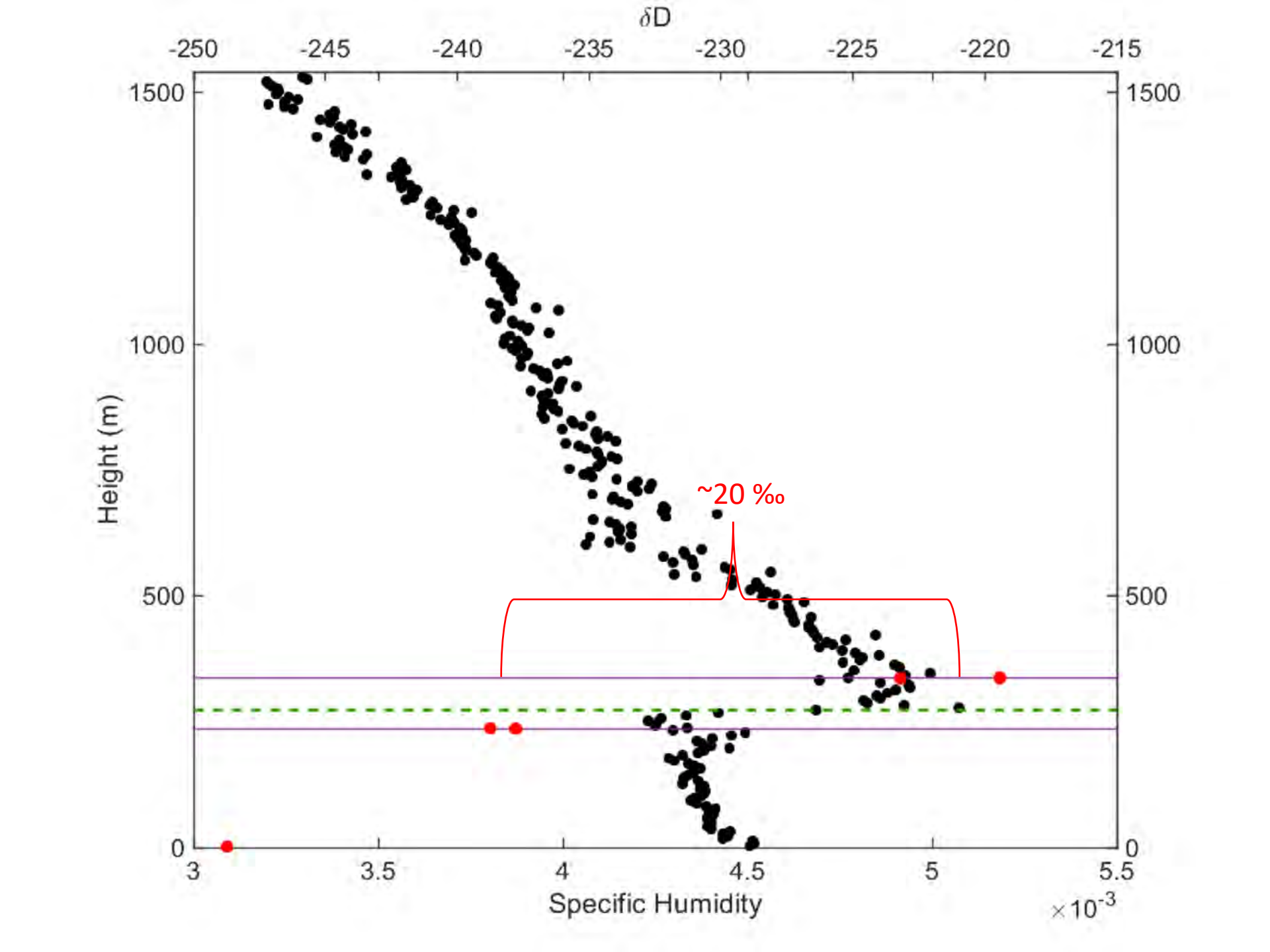

Specific Humidity
×10^-3
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
1500
1000
500
0
Height (m)
75.624
75.626
75.628
75.63
Latitude
-36.01
-36
-35.99
-35.98
Longitude


Potential Temperature
298
296
294
292
290
288
286
1500
1000
500
0
Height (m)
75.624
75.626
75.628
75.63
Latitude
-36.01
-36
-35.99
-35.98
Longitude


Field Season 2019 Specific Humidity
06/03/2019
06/05/2019
06/12/2019
06/21/2019
06/22/2019
06/26/2019
Height (m)
1600
1400
1200
1000
800
600
400
200
0
0
0.001
0.002
0.003
0.004
0.005
0.006
Specific Humidity
X 10-3

Inlet system to introduce water standard and samples to CRDS System




δD
-250
-245
-240
-235
-230
-225
-220
-215
1500
1000
500
0
Height (m)
~20 ‰
3
3.5
4
4.5
5
5.5
Specific Humidity
×10-3

https://doi.org/10.5194/amt-2019-240
Preprint. Discussion started: 19 June 2019

Atmospheric Measurement Techniques Discussions

First data set of H_2O/HDO columns from TROPOMI

Andreas Schneider[1], Tobias Borsdorff[1], Joost aan de Brugh[1], Franziska Aemisegger[2], Dietrich G. Feist[3,4], Rigel Kivi[5], Frank Hase[6], Matthias Schneider[6], and Jochen Landgraf[1]

[1]Earth science group, SRON Netherlands Institute for Space Research, Utrecht, the Netherlands
[2]Atmospheric Dynamics group, Department of Environmental Systems Science, ETH Zürich, Zürich, Switzerland
[3]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany
[4]Max Planck Institute for Biogeochemistry, Jena, Germany
[5]Finnish Meteorological Institute, Sodankylä, Finland
[6]Institute of Meteorology and Climate Research (IMK-ASF), Karlsruhe Institute of Technology, Karlsruhe, Germany

Correspondence: Andreas Schneider (a.schneider@sron.nl)

Atmos. Meas. Tech., 8, 1799–1818, 2015
www.atmos-meas-tech.net/8/1799/2015/
doi:10.5194/amt-8-1799-2015

Atmospheric Measurement Techniques

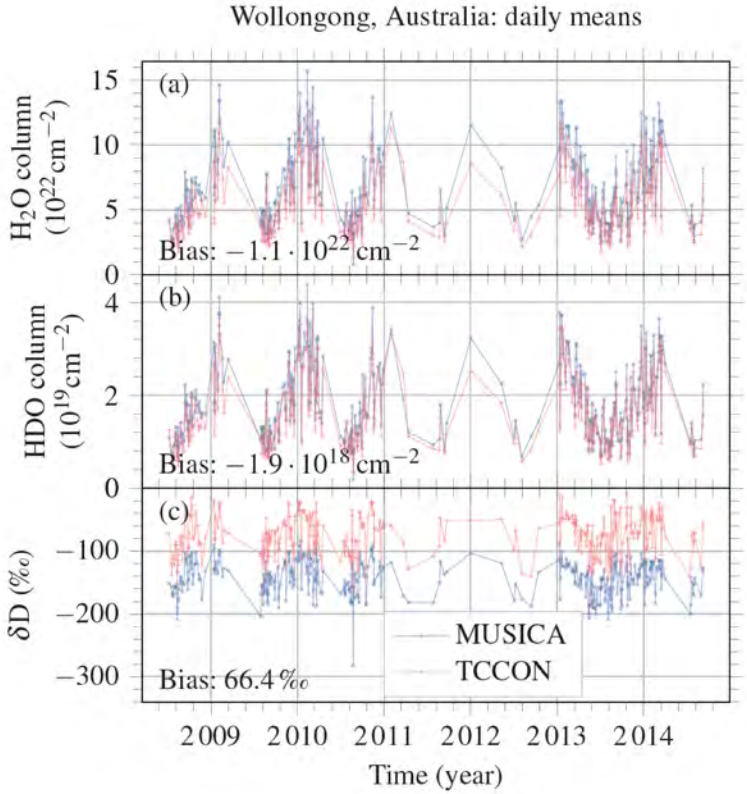
Validation of SCIAMACHY HDO/H_2O measurements using the TCCON and NDACC-MUSICA networks

R. A. Scheepmaker[1], C. Frankenberg[2], N. M. Deutscher[3,4], M. Schneider[5,6], S. Barthlott[5], T. Blumenstock[5], O. E. Garcia[6], F. Hase[5], N. Jones[4], E. Mahieu[7], J. Notholt[3], V. Velazco[4], J. Landgraf[1], and I. Aben[1]

[1]SRON Netherlands Institute for Space Research, Utrecht, the Netherlands
[2]Jet Propulsion Laboratory (JPL), California Institute of Technology, Pasadena, CA, USA
[3]Institute for Environmental Physics, University of Bremen, Bremen, Germany
[4]Centre for Atmospheric Chemistry, University of Wollongong, Wollongong, Australia
[5]Karlsruhe Institute of Technology (KIT), Institute for Meteorology and Climate Research (IMK-ASF), Karlsruhe, Germany
[6]Izaña Atmospheric Research Centre (IARC), Agencia Estatal de Meteorología (AEMET), Santa Cruz de Tenerife, Spain
[7]Institute of Astrophysics and Geophysics, University of Liège, Liège, Belgium

Correspondence to: R. A. Scheepmaker (r.a.scheepmaker@sron.nl)

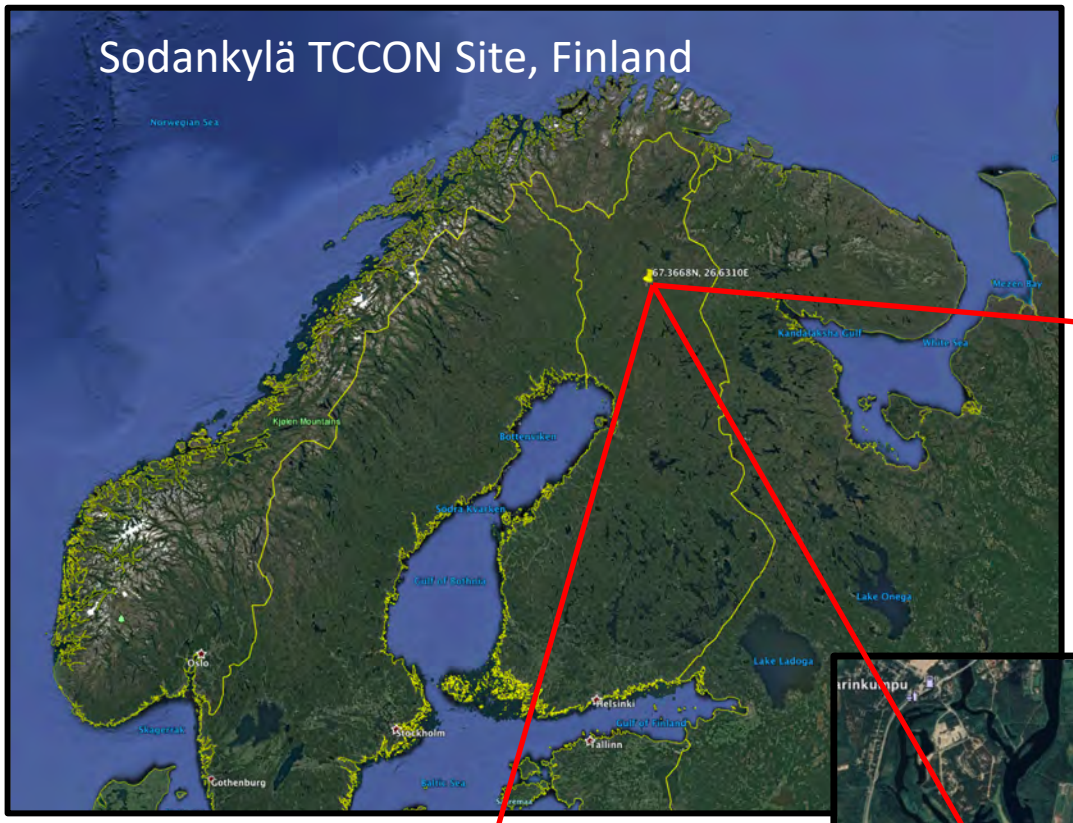
Received: 20 October 2014 – Published in Atmos. Meas. Tech. Discuss.: 27 November 2014
Revised: 26 March 2015 – Accepted: 27 March 2015 – Published: 21 April 2015



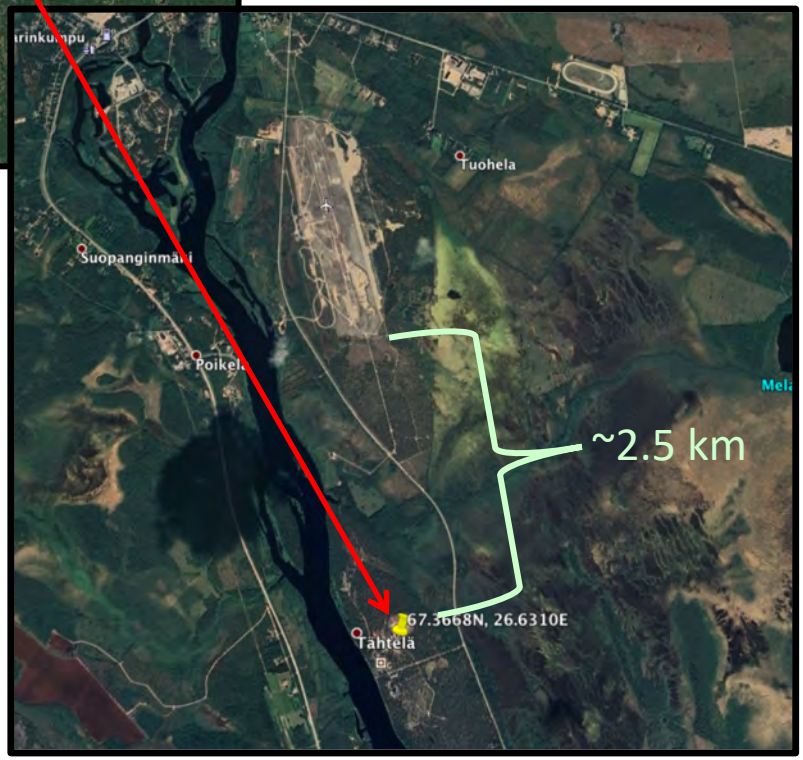
Total Carbon Column Observing Network (TCCON)

Biases remain for independent measurements of water vapor and isotopes

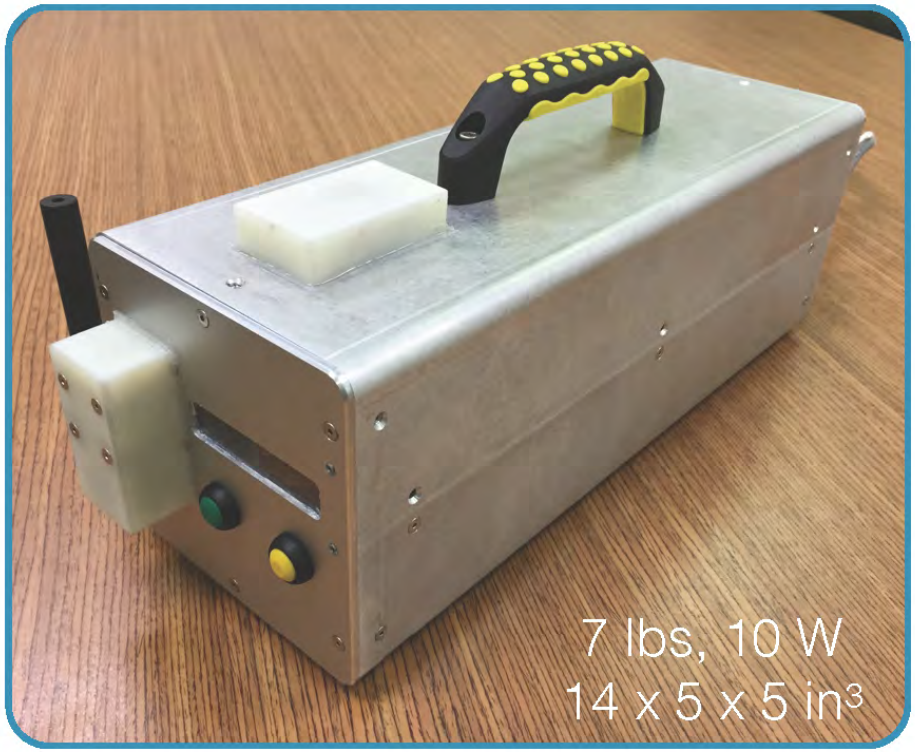
TROPOspheric Monitoring Instrument (TROPOMI) on the Copernicus Sentinel-5 Precursor satellite. launched in 2017, for a nominal lifetime of 7 years

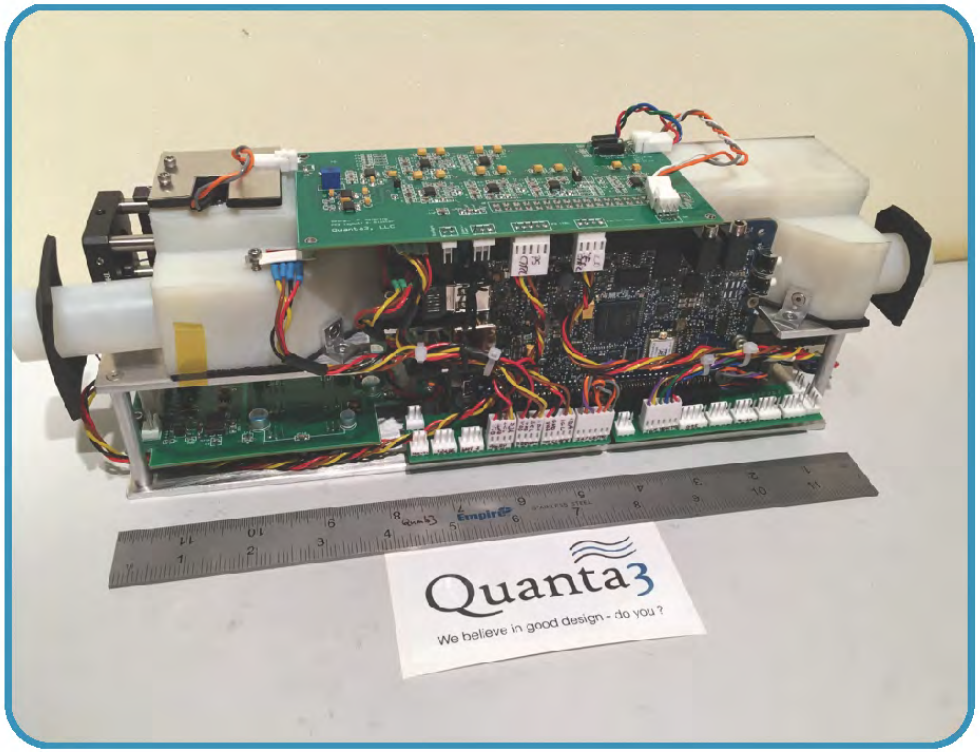

Sodankylä TCCON Site, Finland
67.3668N, 26.6310E
Norwegian Sea
White Sea
Lake Onega
Lake Ladoga
Oslo
Helsinki
Stockholm
Tallinn
Gothenburg


67.3668N, 26.6310E


Tuohela
Poikel
~2.5 km
67.3668N, 26.6310E
Tahtelä

Handheld Prototype





Quanta3

Future Plans

- Maximize data density in space and time
- Develop potential for sampling other gases
- Collaborate with other groups to co-measure and validate other systems

Lessons Learned

- Keep batteries warm
- Avoid dependence on a compass
- Always plan for the unexpected

Case STX 485 Quadtrac pulls the Dome on skis

14 meters tall, 47 tons
Towed ~ 500 km across Greenland

Sharpeye SxV High Performance X-band ground surveillance radar system

- **Up to 80 W radiated power**
- **Weight: 20 Kg**
- **Power: 150 watts 9- 32 volts DC**
- **Range: 5 Km person, 15 km vehicle**


Thanks

https://seec.colorado.edu/act/