An Overview of GMD's Water Vapor Research

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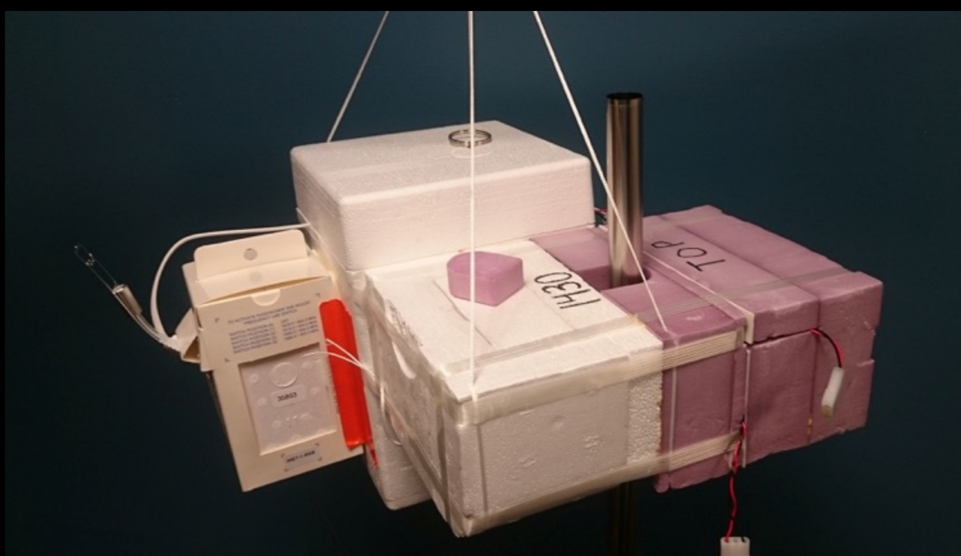
NOAA CPO



GMAC and GMD Review May 23, 2018

Scientific Goal

Monitor and understand the inter-annual and longer-term variability of water vapor in the upper troposphere and stratosphere

Why?

Water vapor is a very powerful greenhouse gas, especially in the very cold region near the tropopause

SWV influences stratospheric O_3 - polar (PSCs) and global (HO_x)

How?

Balloon-borne NOAA Frost Point Hygrometers (FPHs)

Where?

Boulder, Colorado; Hilo, Hawaii; Lauder, New Zealand

When?

1-2 soundings per month at each site

Water Vapor in the Stratosphere

How does it get there?

- Slow vertical transport (Brewer-Dobson Circulation)
- Fast cross-tropopause transport (Deep Convective Ice Lofting)
- Isentropic transport through tropopause breaks
- In situ oxidation of CH_4 and H_2 in the stratosphere

How is it removed?

- Recirculation (Brewer-Dobson Circulation)
- Photo-dissociation by Lyman-α radiation (Mesosphere)
- Dehydration within Antarctic vortex during winter/spring

What controls its distribution?

- Strengths and Phases of BDC, QBO, ENSO (Seasonal, Inter-annual)
  - -> influences on tropical coldpoint (minimum) temperatures
- Amounts of CH_4 and H_2 that have been oxidized (Height-dependent)
- Strengths of deep convection, Antarctic dehydration, Asian monsoon

Water Vapor–Climate Feedback

Tropospheric Water Vapor (>99.9% of atmospheric burden)

- Strong IR absorber of outgoing long-wave radiation (OLR)
- Increased surface and tropospheric temperatures adds WV
- Additional WV absorbs more OLR

Stratospheric Water Vapor (<0.1% of atmospheric burden)

- Strong IR absorber of OLR, weak thermal emission to space
- Climate change to warm the tropical tropopause and increase SWV
- Additional SWV absorbs more OLR

Changes in SWV have a significant impact on surface temperatures

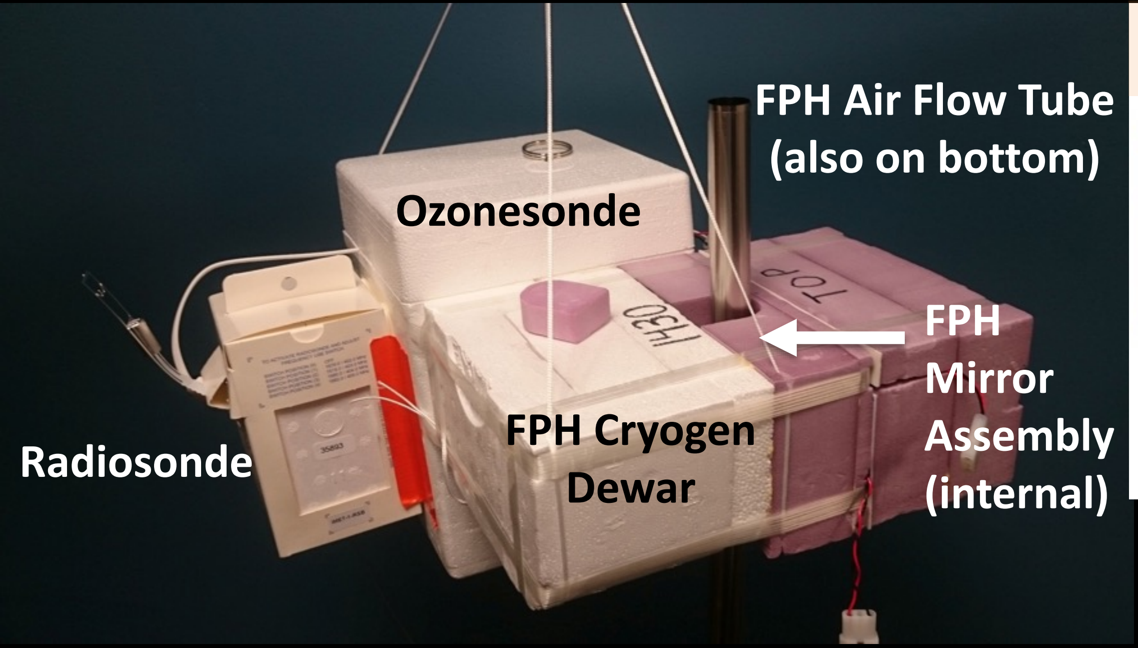
The ~1 ppm (~25%) increase in SWV between 1980 and 2000 would have enhanced the rate of surface warming in the 1990s by ~30%

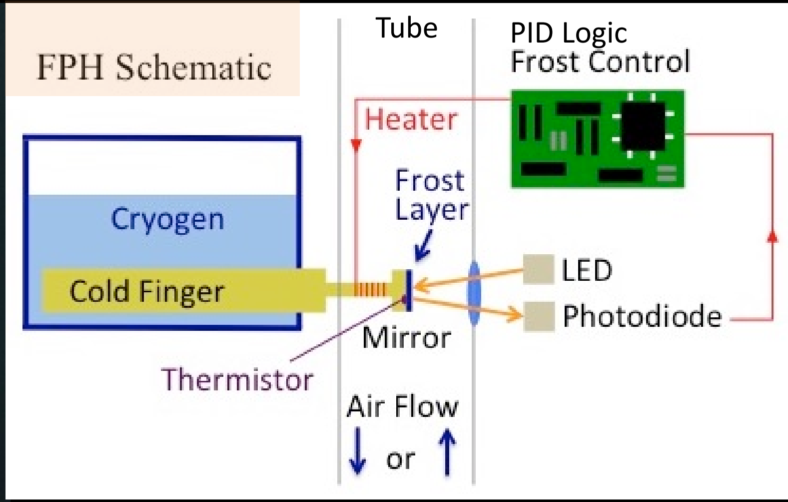
Solomon et al. (2010)

How GMD Measures Water Vapor

Balloon-Borne Frost Point Hygrometers (FPH)

- 1854: First dew point hygrometer developed in Germany
- 1947: First FPH capable of measuring SWV (<10 ppm)
- 1960-70s: Mastenbrook and Oltmans developed balloon-borne FPH at NRL
- 1980: Oltmans begins routine FPH soundings in Boulder
- 1989->: FPH performance improved: digital logic, stable frost control
- Every NOAA FPH is built and bench-tested at GMD. 40-50 per year





Where GMD Measures Water Vapor

NOAA FPH sites	Boulder	40°N	since 1980
(~monthly profiles)	Hilo	20°N	since 2010
	Lauder	45°S	since 2004
Other sites (using CFH)	Sodankylä	67°N	since 2002
(with >5 years of monthly profiles)	Lindenberg	52°N	since 2008
	San José	10°N	since 2005

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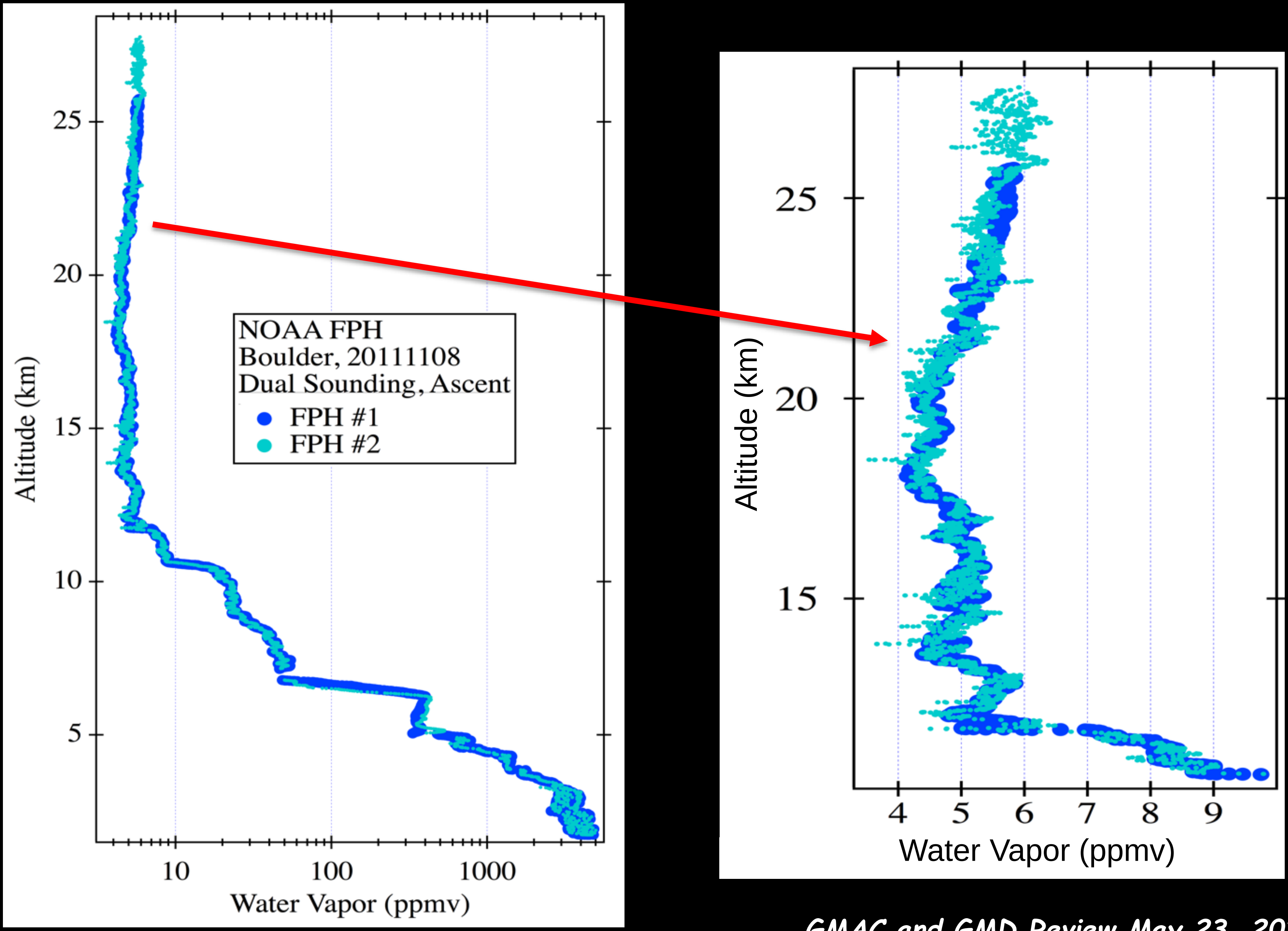
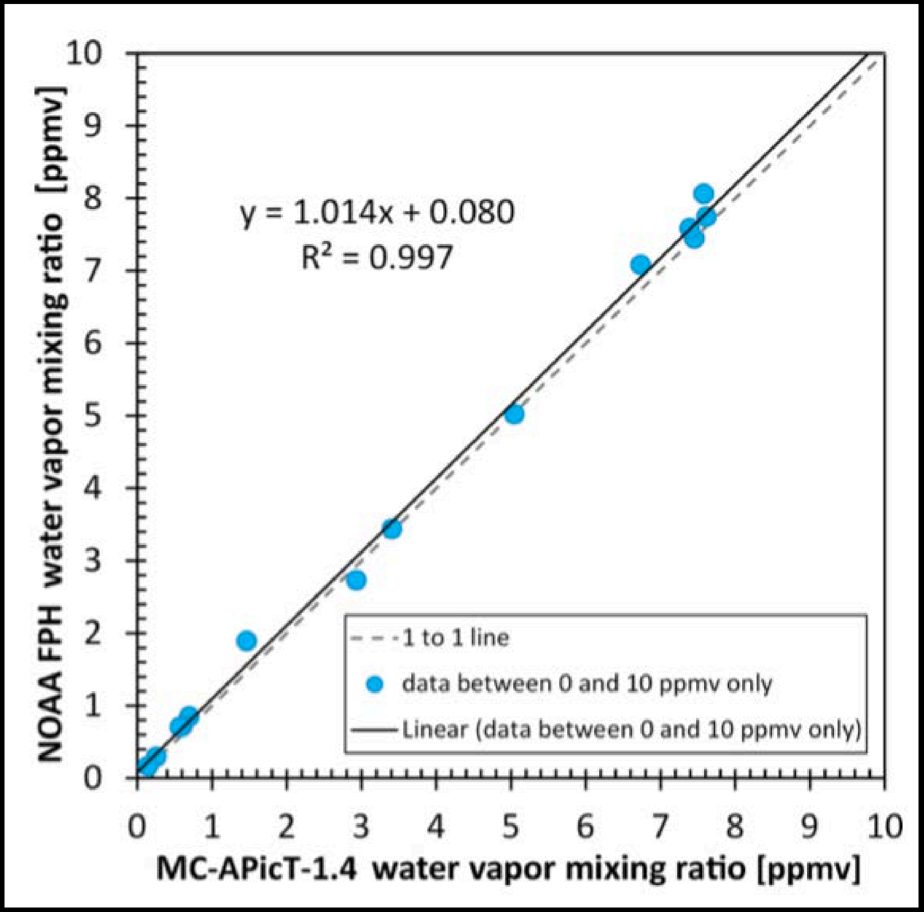
Water Vapor Vertical Profiles

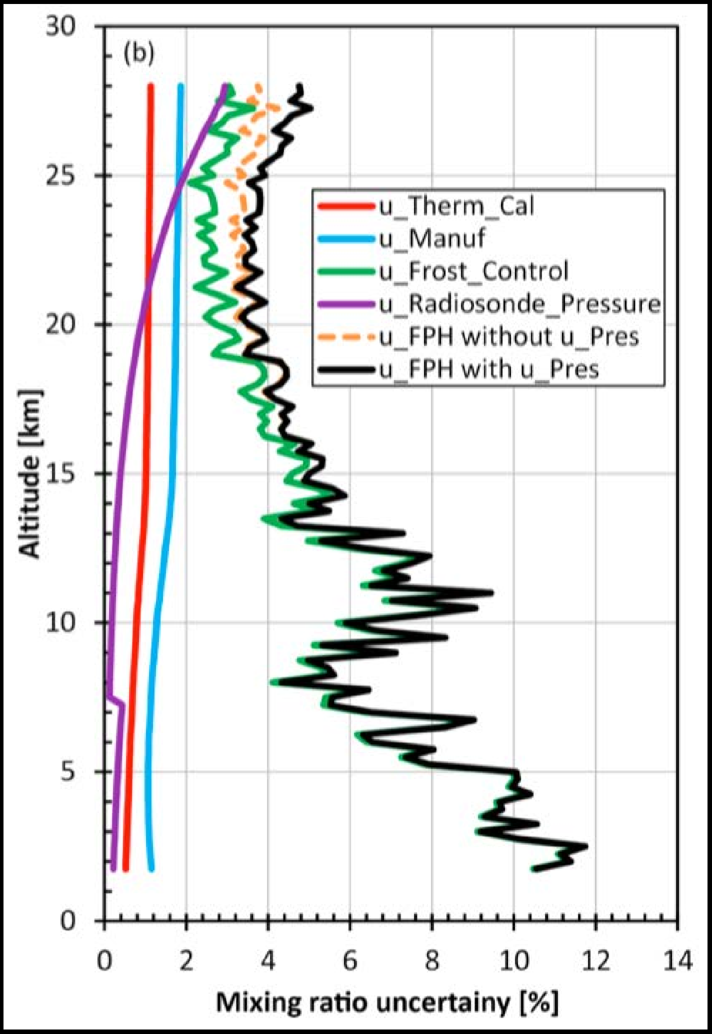


FPH Measurement Accuracy and Uncertainties

Laboratory Comparison
AQUAVIT-2 (2013)

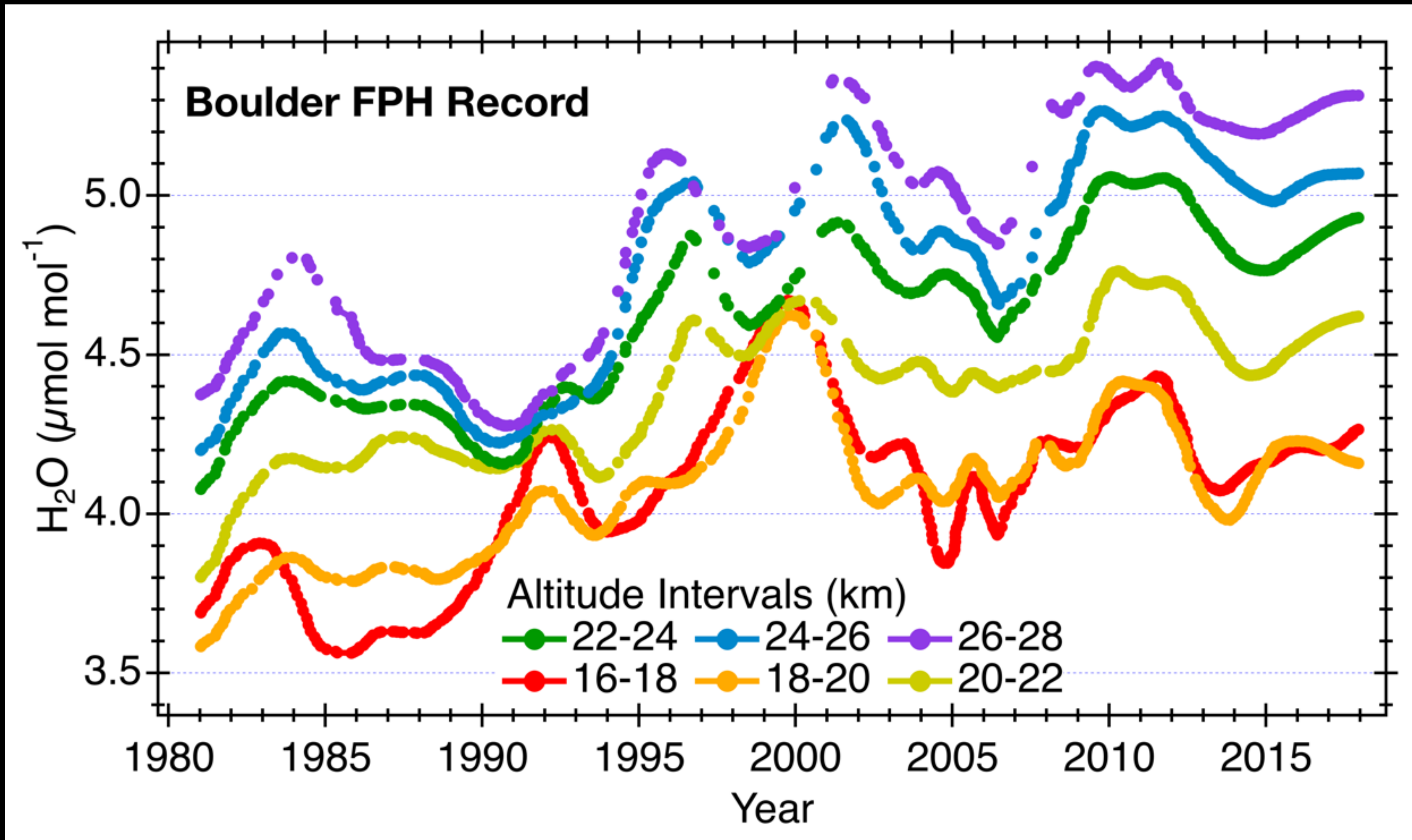


from Hall et al. (2016)



from Hall et al. (2016)

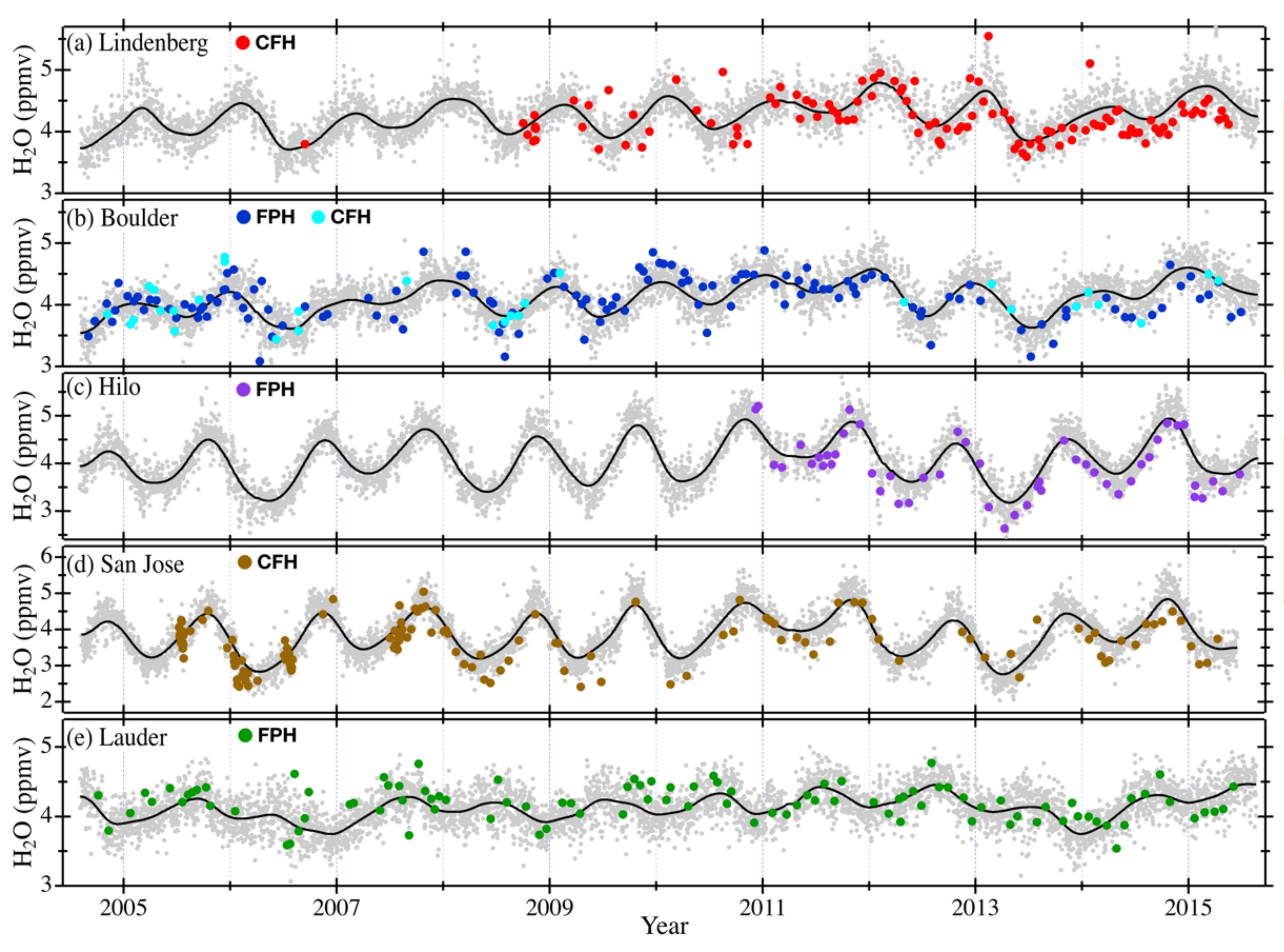
Scientific Findings



updated from Hurst et al. (2011)

Trends of 0.20 – 0.25 ppm decade^{-1}

FPH and CFH vs MLS, 68 hPa



Spatial Coincidence Criteria

Δlat < 2°

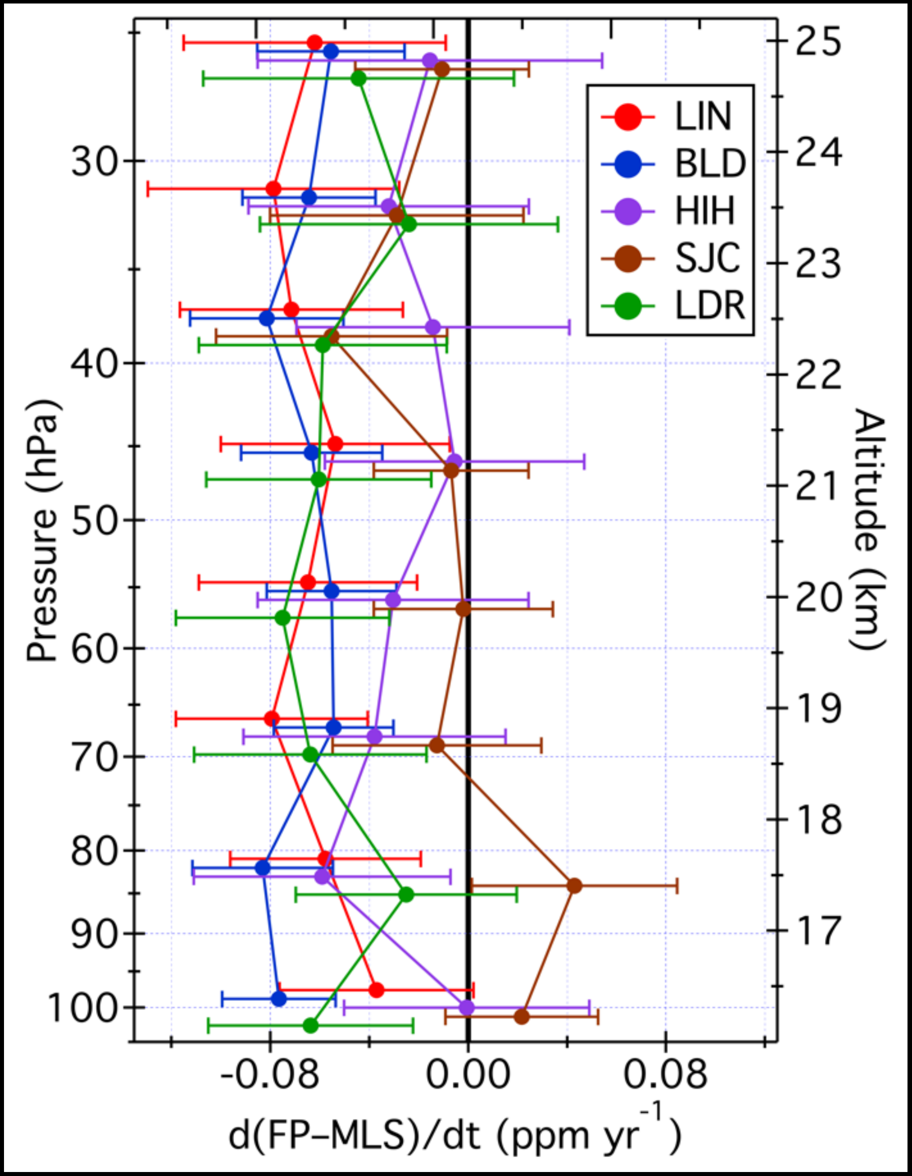
Δlon < 8°

Temporal Matching

Δt < 18h

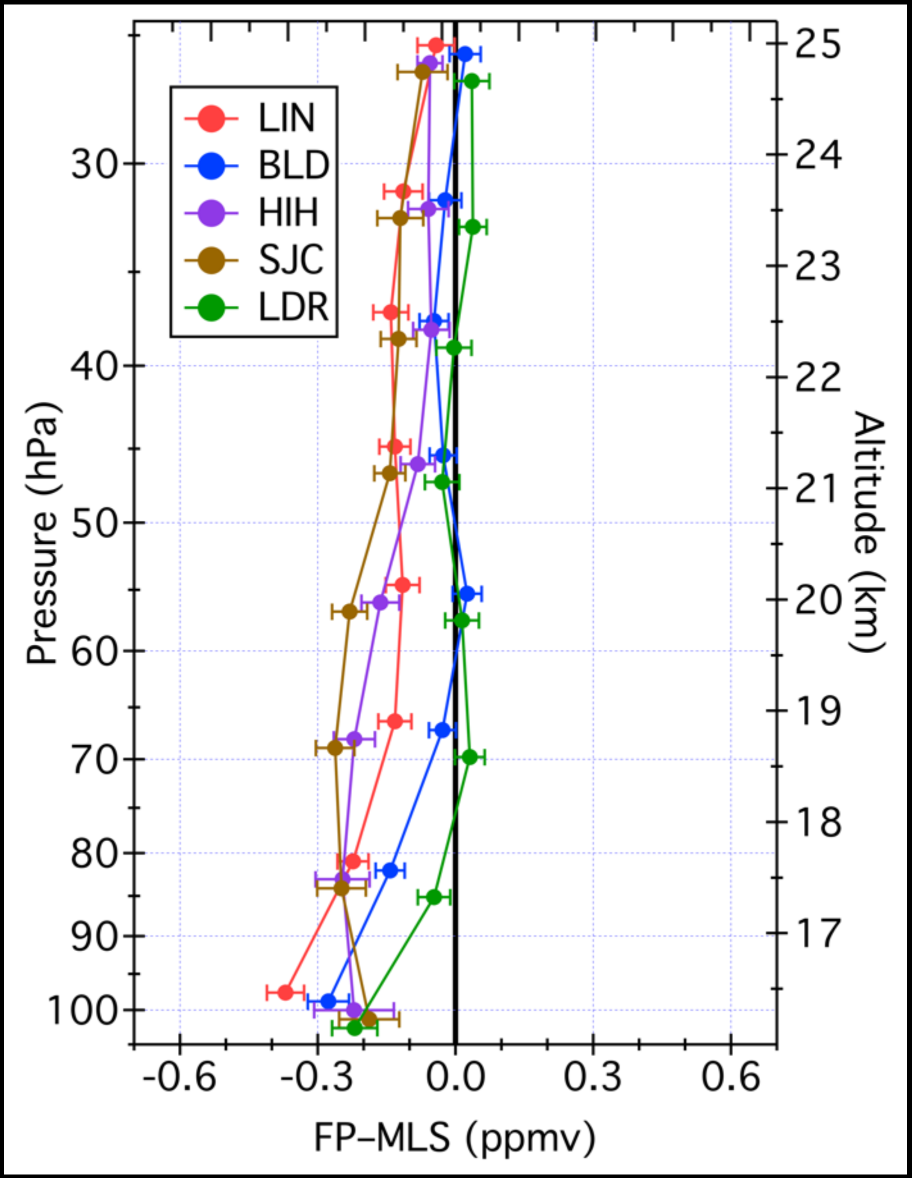
from Hurst et al. (2016)

FPs vs MLS: Post-2010 Drifts

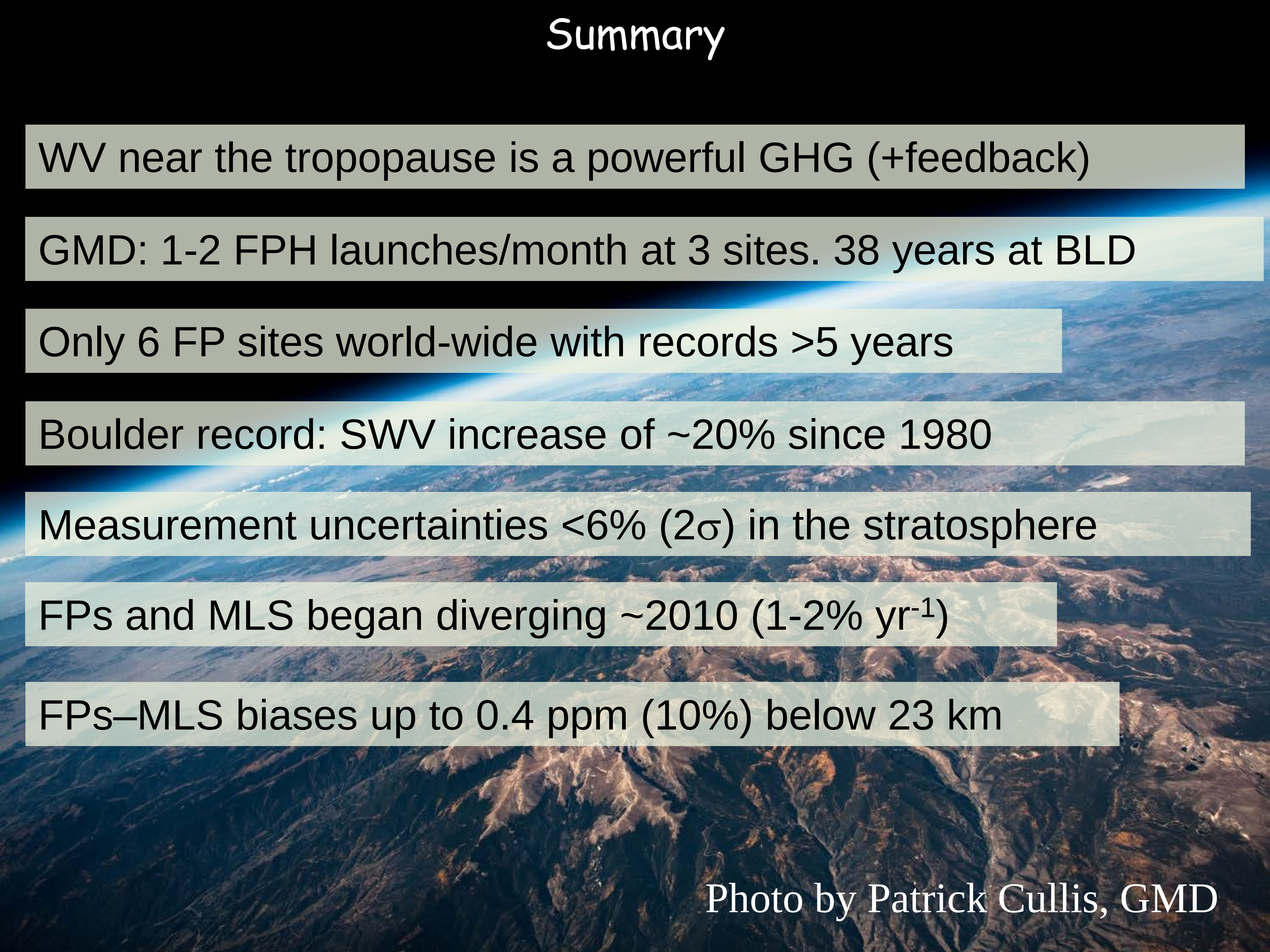


adapted from Hurst et al. (2016)

Full-Record Biases



Summary



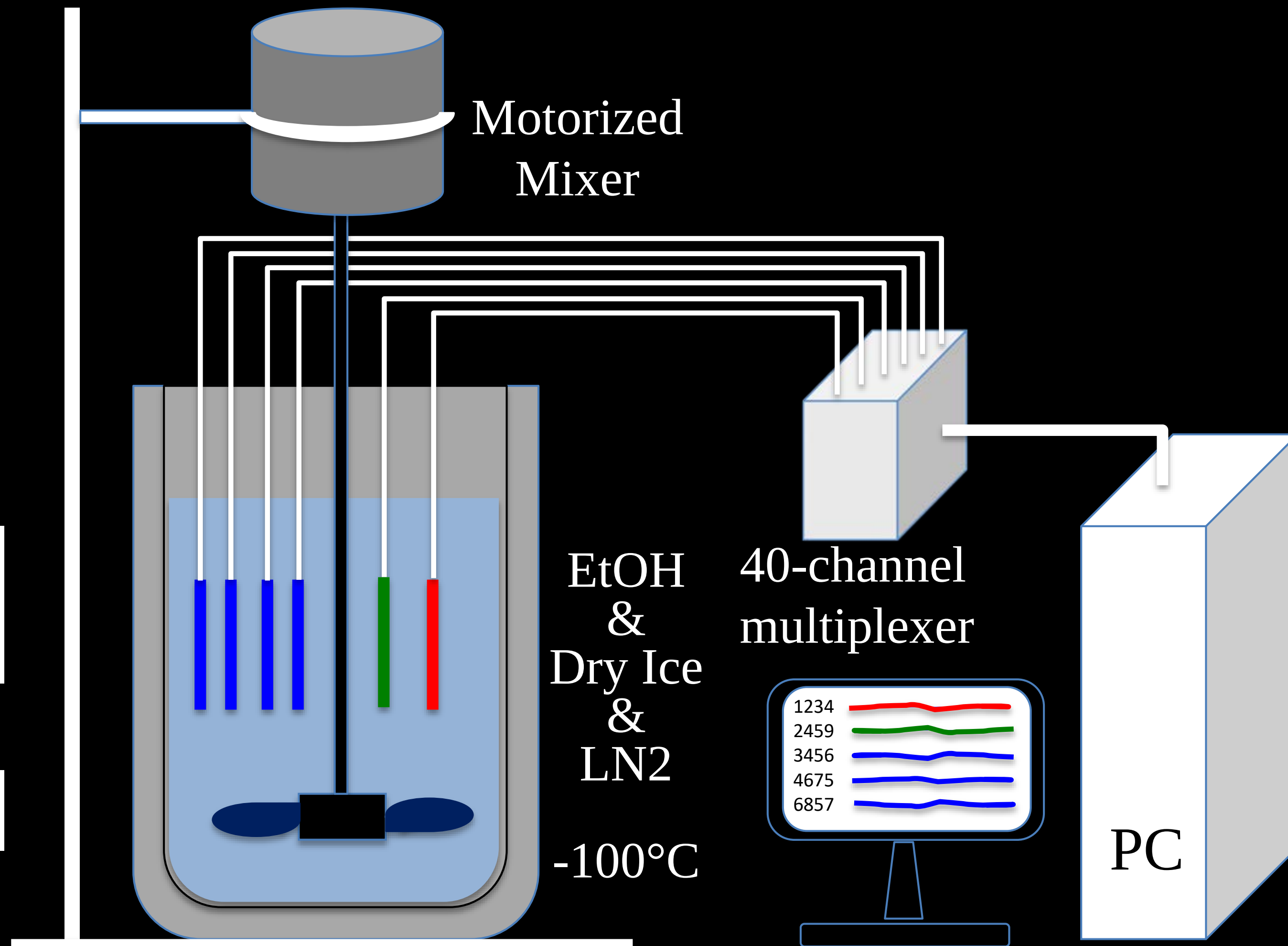
- WV near the tropopause is a powerful GHG (+feedback)
- GMD: 1-2 FPH launches/month at 3 sites. 38 years at BLD
- Only 6 FP sites world-wide with records >5 years
- Boulder record: SWV increase of ~20% since 1980
- Measurement uncertainties <6% (2σ) in the stratosphere
- FPs and MLS began diverging ~2010 (1-2% yr^{-1})
- FPs–MLS biases up to 0.4 ppm (10%) below 23 km

Photo by Patrick Cullis, GMD

Extra Slides

Ensuring Long-Term FPH Measurement Accuracy

Calibration of mirror thermistors



Thermistors

35 New

4 Archived

1 NIST-calibrated

Calibration Range: -100 to +20° C (takes ~36 hours)

FP vs Satellite Drifts

FPH – MLS