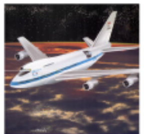
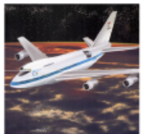


SOFIA Stratospheric Observatory for Infrared Astronomy

The SOFIA Water Vapor Monitor

Thomas Roellig

Agenda



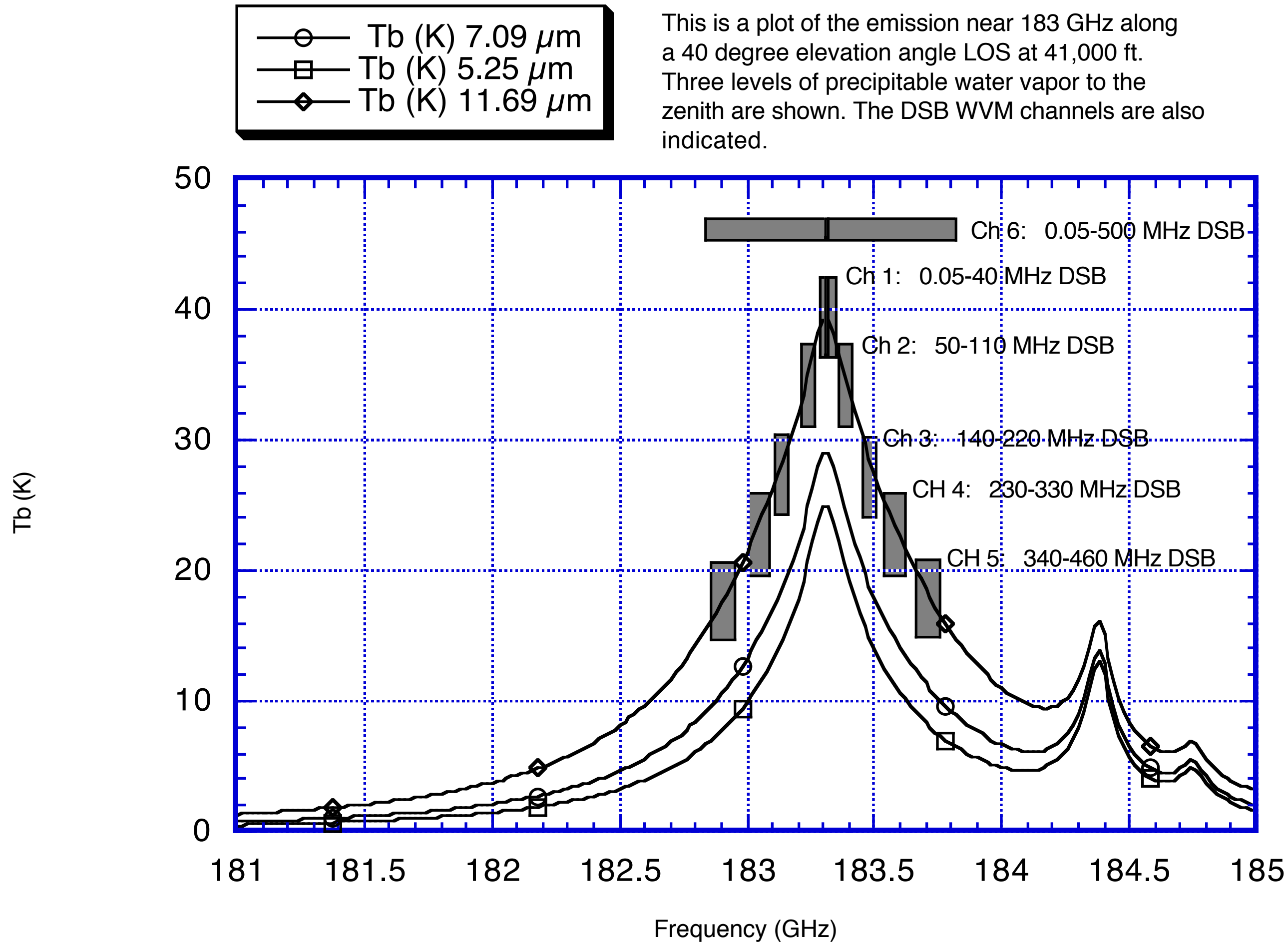
- Introduction to the WVM
- Current status of the WVM
- WVM Calibration
- Atmospheric Model Issues

WVM Overview

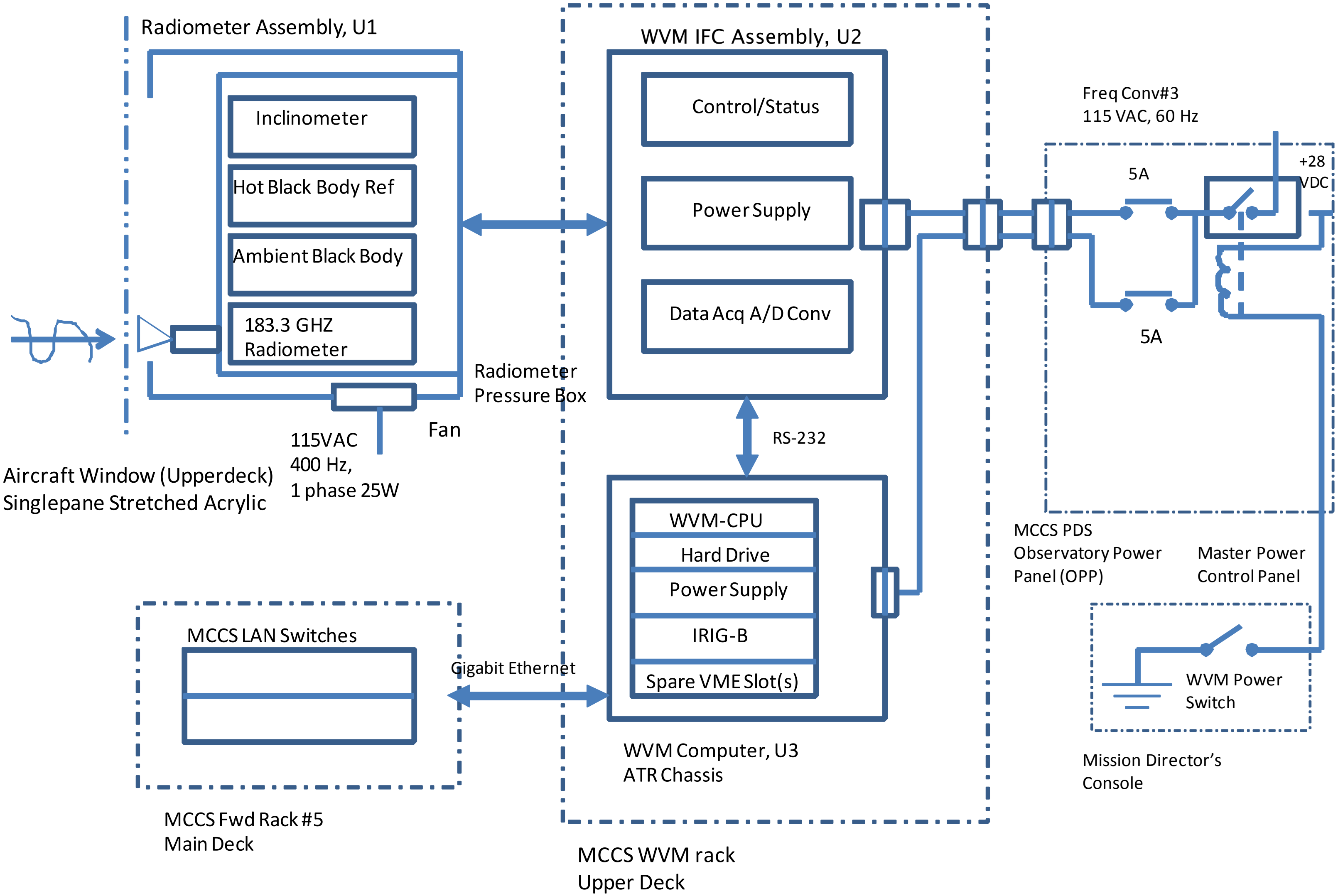
- The SOFIA Water Vapor Monitor (WVM) measures the water vapor overburden above the SOFIA aircraft in flight by measuring the shape of the 183.3 GHz atmospheric water emission line.
- Baseline performance requirement: The Water Vapor Monitor subsystem shall provide a readout of microns of precipitable water vapor in the TA line of sight, with an accuracy of ±2 microns (3-sigma) for each independent measurement. This requirement shall only apply when the integrated water vapor level to the zenith is between 4 and 20 microns (corresponding to flight altitudes of 35,500 to 46,000 feet in the US Standard Atmosphere).
- WVM takes and records data in flight every 15 seconds

The 183.3 GHz Water Line

This is a plot of the emission near 183 GHz along a 40 degree elevation angle LOS at 41,000 ft. Three levels of precipitable water vapor to the zenith are shown. The DSB WVM channels are also indicated.



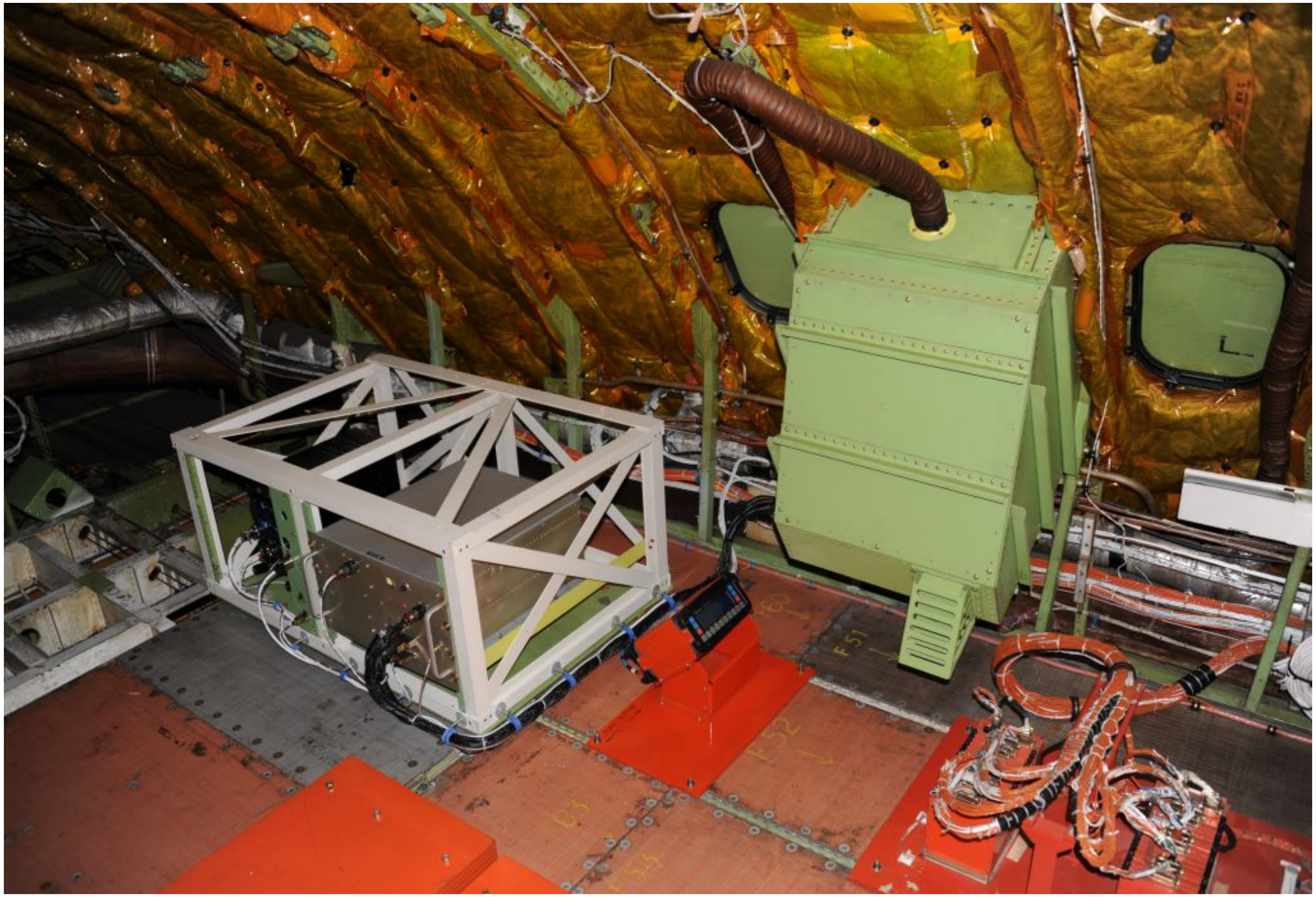
WVM Sub-System Block Diagram



National Aeronautics and Space Administration

WVM Subsystem Installed Hardware

SOFIA Stratospheric Observatory for Infrared Astronomy



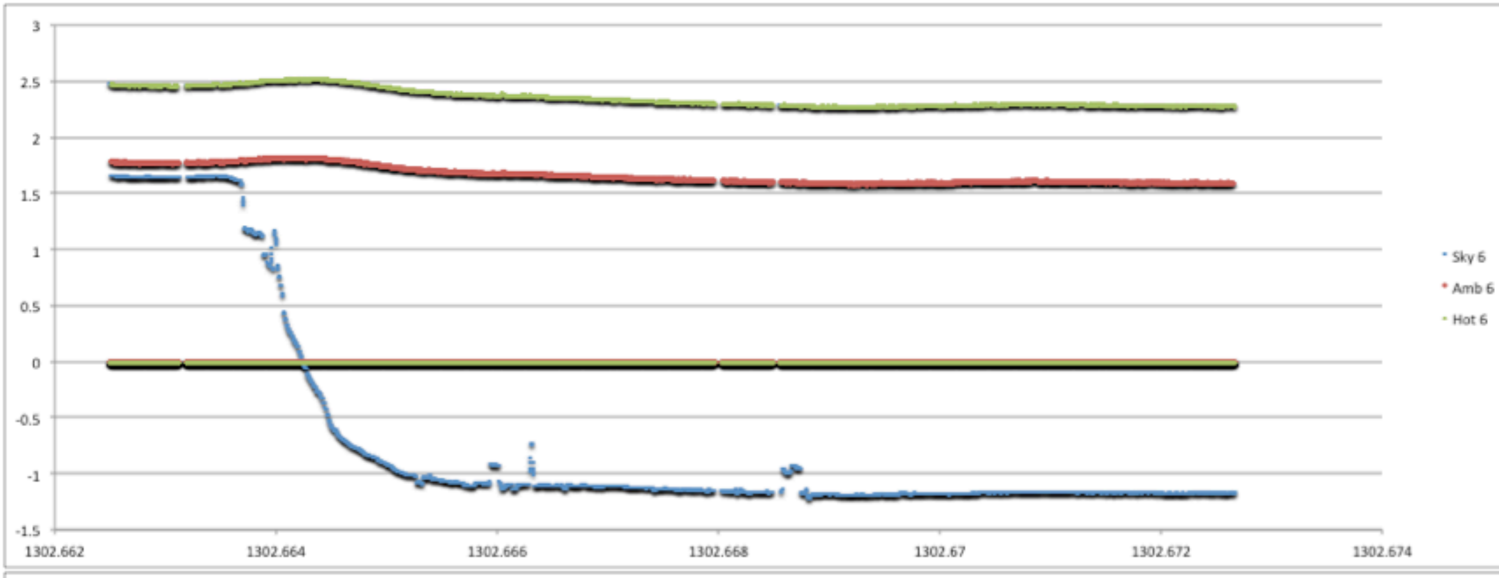
Current WVM Status

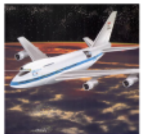
- WVM hardware was installed in aircraft for Early Science and has been operational - at least up until Flight 100 (4/13)
  - Malfunctioned after MCCS reboots during that flight
  - Should note that this hardware was used for qualification testing and underwent severe shake-and-bakes
- Two built-to-print flight sets of hardware have been developed, the first is ready to be installed in the aircraft
  - Delivered to the DAOF
  - Ruggedized in the DFRC labs
  - Passed its post-ruggedization functional testing

Current WVM Status - 2

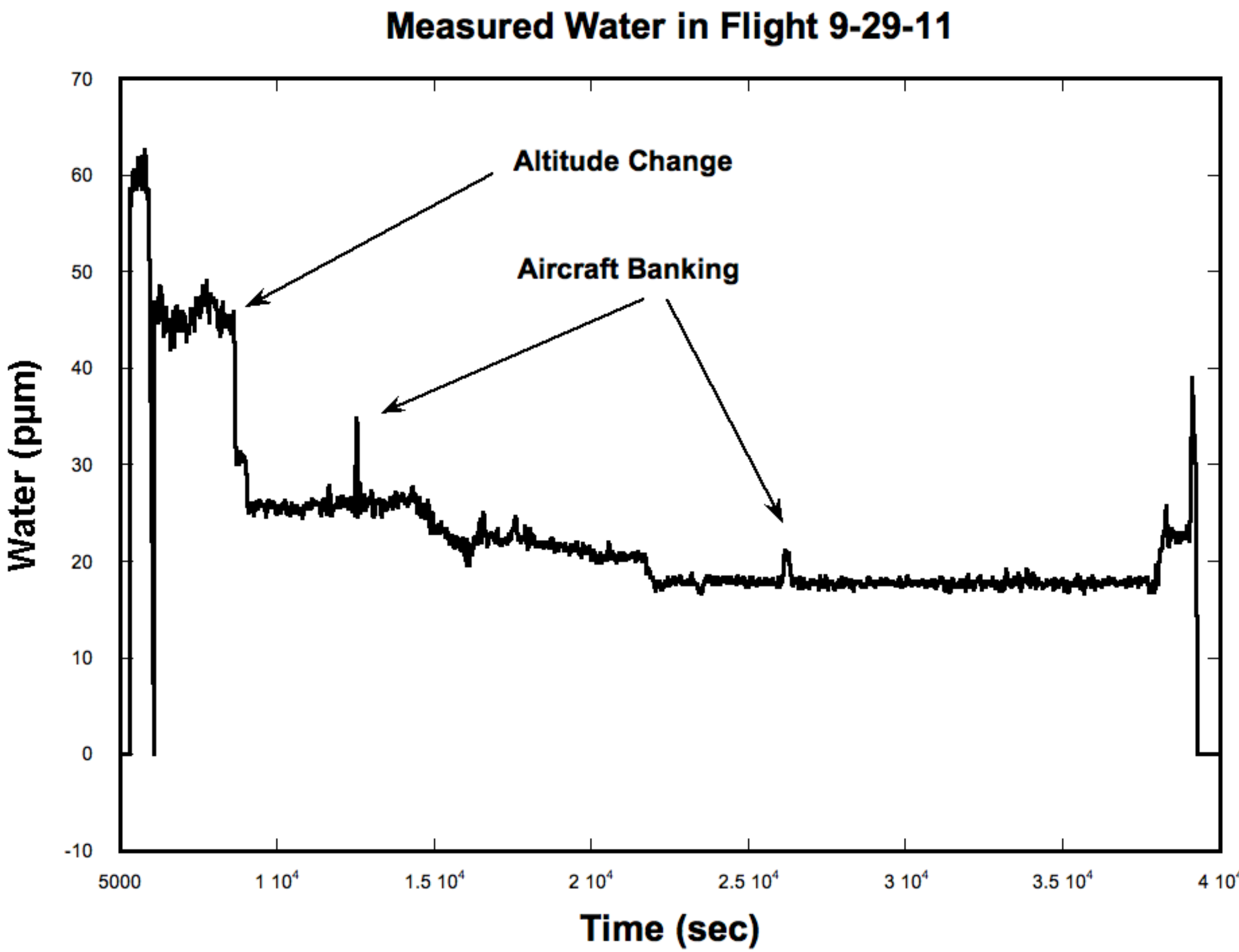
- Clearly detected the 183 GHz water line, saw line strength go down as aircraft gained altitude as expected
- Saw changes in line strength due to aircraft banking, stratospheric "weather"

Measured Sky Brightness During Climb and Banking

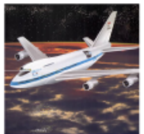




Example Measured Water Vapor in Flight



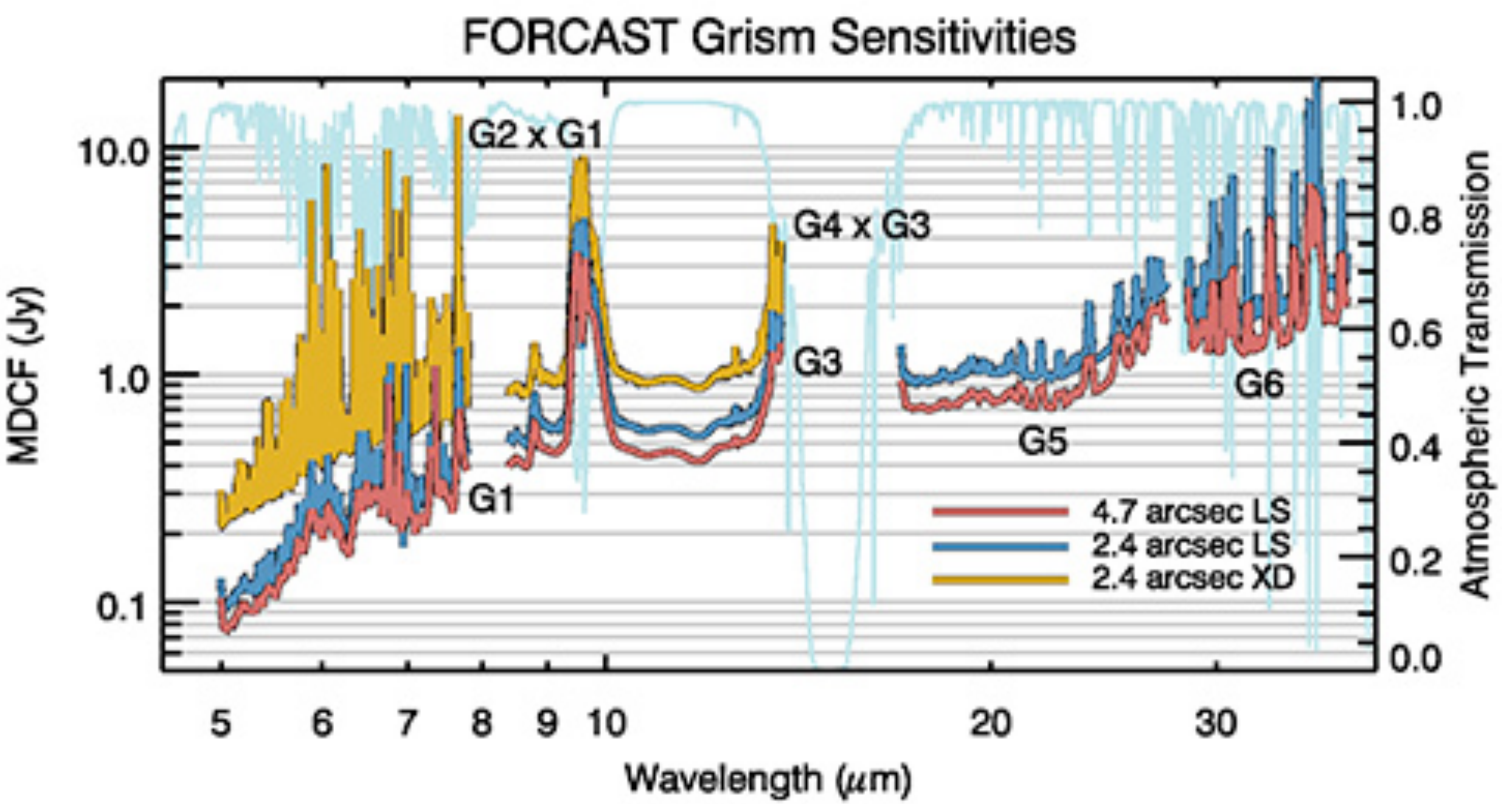
WVM Calibration Plans



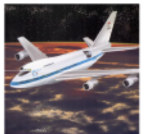
- WVM flight data is/will be calibrated by three methods
  - Comparison with GEOS-V satellite date
  - Comparison with balloon radiosonde date
  - Cross comparison with SOFIA Science Instruments
    - Spectrographic instruments
    - GREAT, FliteCAM grism, FORCAST grism
- Much data already taken, but has been taken with the qualification unit hardware
- Is still TBD how much the calibration differs between the different hardware

FORCAST Grisms

- Plan is to collect data with FORCAST and WVM Flight Unit #1 hardware in upcoming flight in early December
  - Flight plans will use grisms with many suitable water calibration lines



Calibration Issues

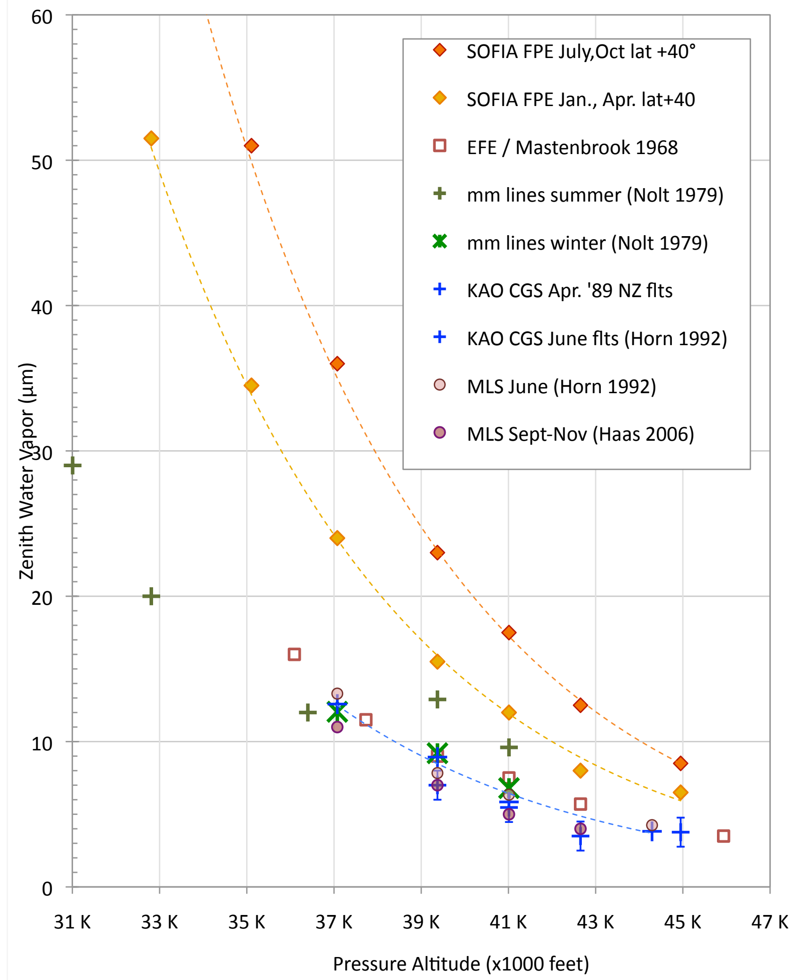


- What is truth?
  - Radiosonde instrument payloads measure dew point, but technology doesn’t work particularly well above the tropopause
  - Other truth data falls into two camps, with a difference of a factor of two-three between them
- Can calibrate empirically by comparing WVM readings with measurements of standard objects
  - Needs to be done separately for each instrument and each filter
  - Very time consuming, but good data will be built up over time

SOFIA Stratospheric Observatory for Infrared Astronomy

Blue dashed curve is fit to the collection of past measurements:

- Mastenbrook (1968): 10-yr. balloon campaign, mixing ratios integrated upward (EFE98)
- Nolt (1979): zenith interferometer, 30K – 45K, H_2O sub-mm emission lines
- KAO CGS: FIR telluric absorption line profiles, ATRAN fits, U.S. and NZ flights, 37K – 45K
- J. Horn (1992); M. Haas (2006): Microwave Limb Sounder (MLS) synoptic soundings from orbit (Sun at Earth limb)

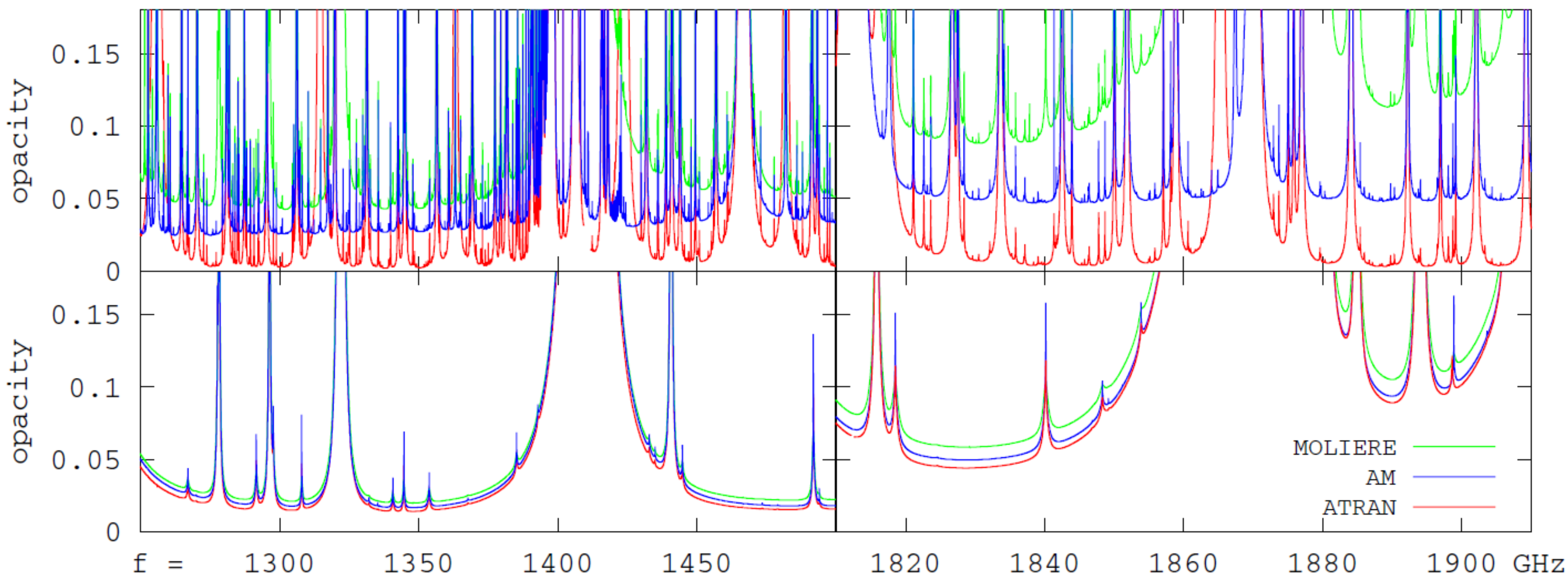


Much higher curves (orange, red dots) are from SOFIA FPE output for summer & winter, a factor of 2 to 3 greater (for any season and all altitudes of interest) than the envelope of published data from four different methods.

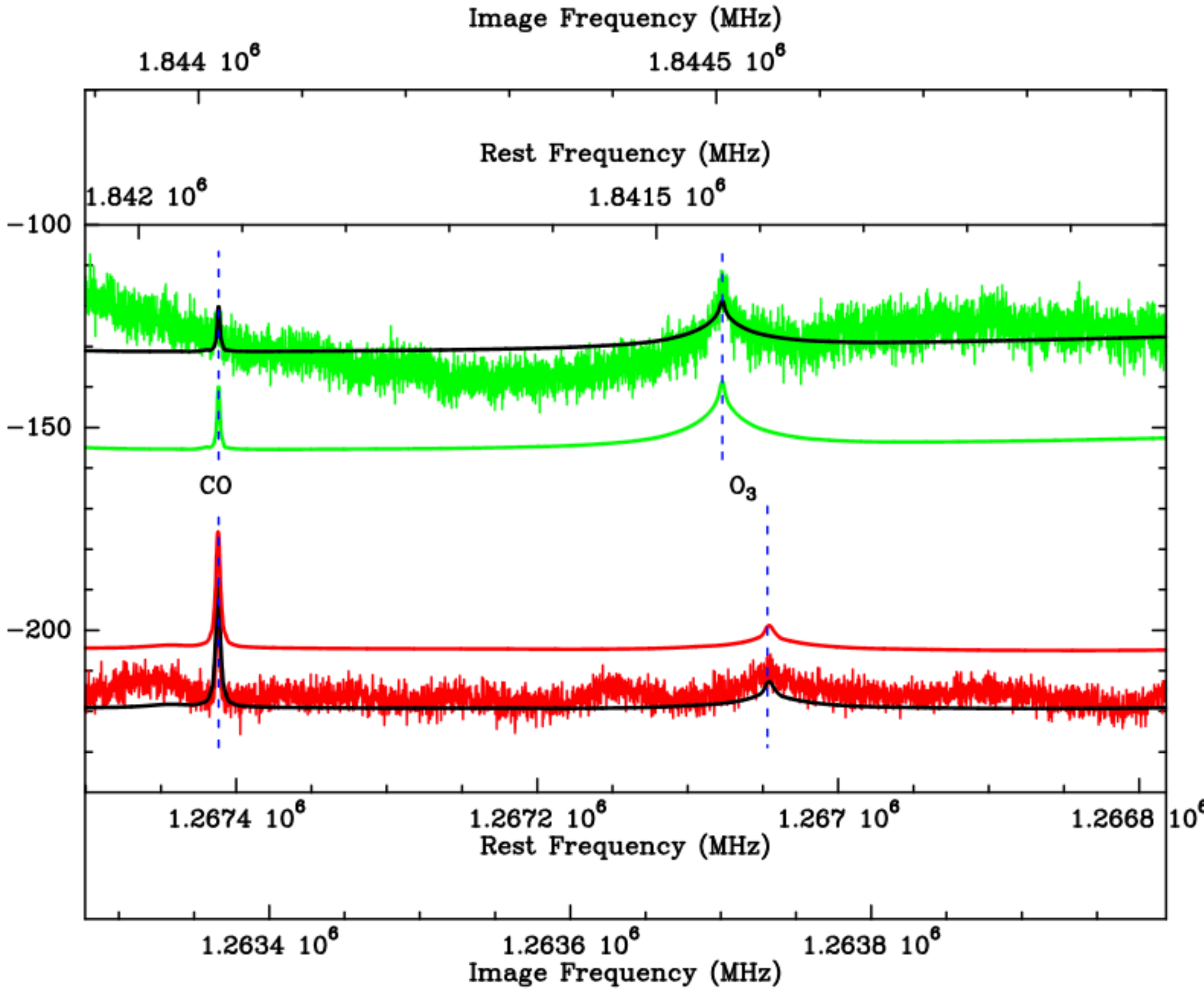
Once WVM is Calibrated – Then What?

- Even once the water vapor is known, the atmospheric models do a very poor job of predicting the effects on the SOFIA instruments
- May need to adopt the slow painful empirical technique after all

Different Model Predictions



GREAT – L1 and L2 Channels



Pwv = 12.3 μm for L1

Pwv = 35 μm for L2