VCSEL Hygrometer in HIPPO: Performance, calibrations, first results

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Photo by Minghui Diao

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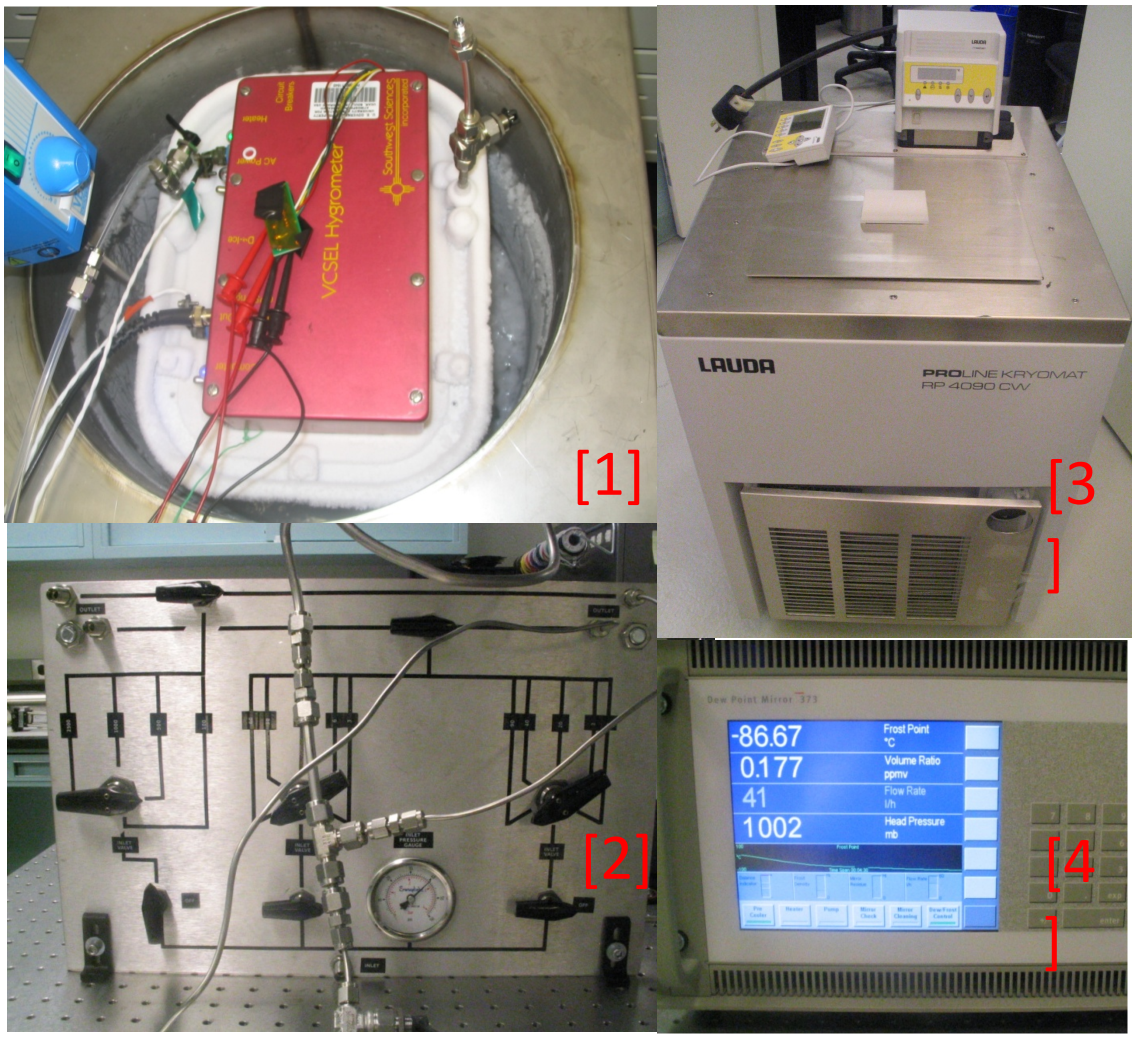
Water vapor calibration methods

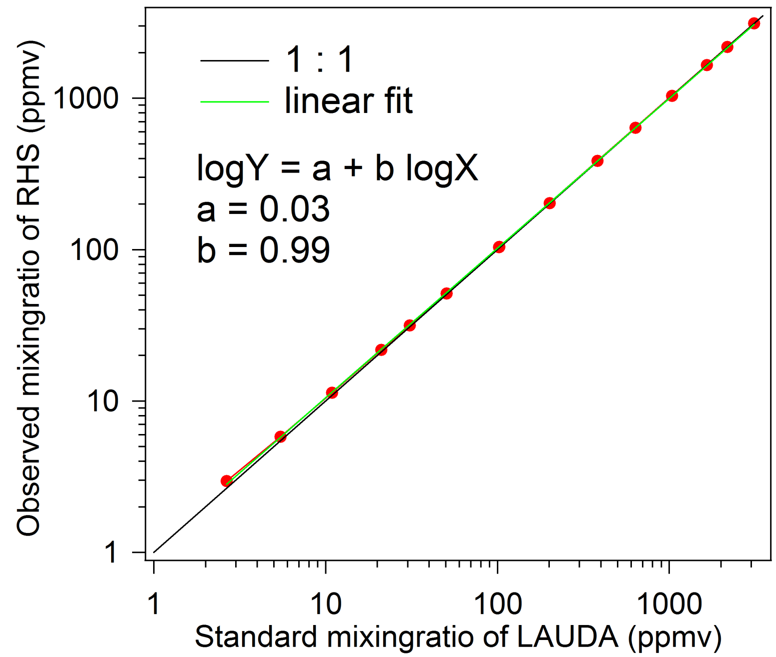


1. Organic slash bath system
   -80 to -10 °C dewpoint
2. Critical orfice dilution flow
   3 to 3000 ppmv
3. LAUDA temperature controller
   -90 to 30 °C dewpoint
4. MBW-373 LX chilled mirror
   -90 to 30 °C dew point

Using multiple, orthogonal methods to calibrate water vapor concentrations at representative temperature, pressure, and mixing ratio conditions

Intercomparisons between chilled mirror and temperature-bath systems

(flow dry nitrogen over packed ice column in bath, then directly into the MBW-373LX chilled mirror hygrometer)



Two independent measures of frost point, in excellent agreement

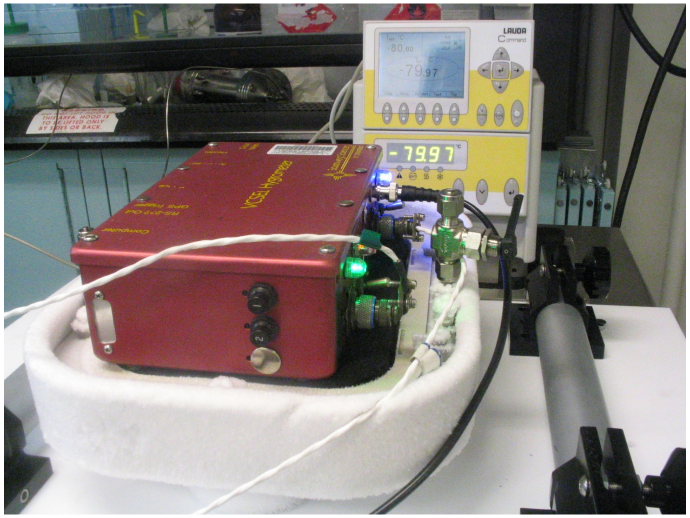
e.g. recent results:

temp. controlled bath is at -80.00 C (0.63 ppmv)

chilled mirror is at -79.5 C (0.54 ppmv)

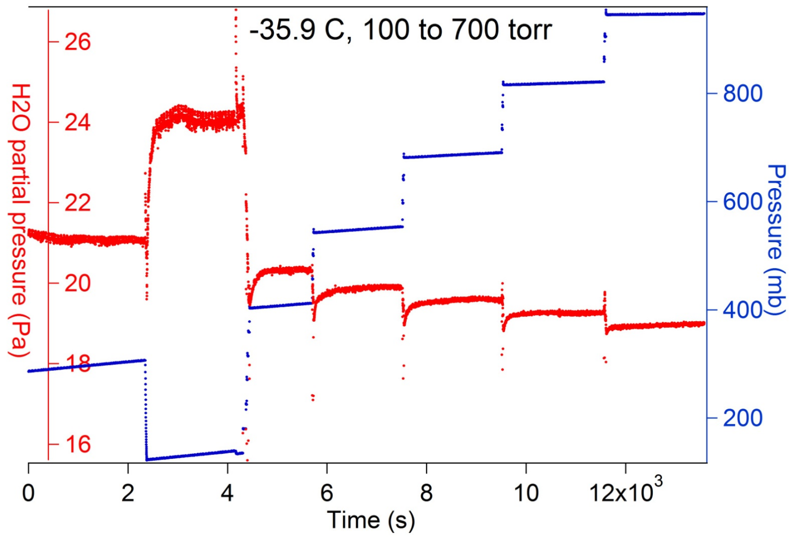
....but this takes more than a day to remove outgassing

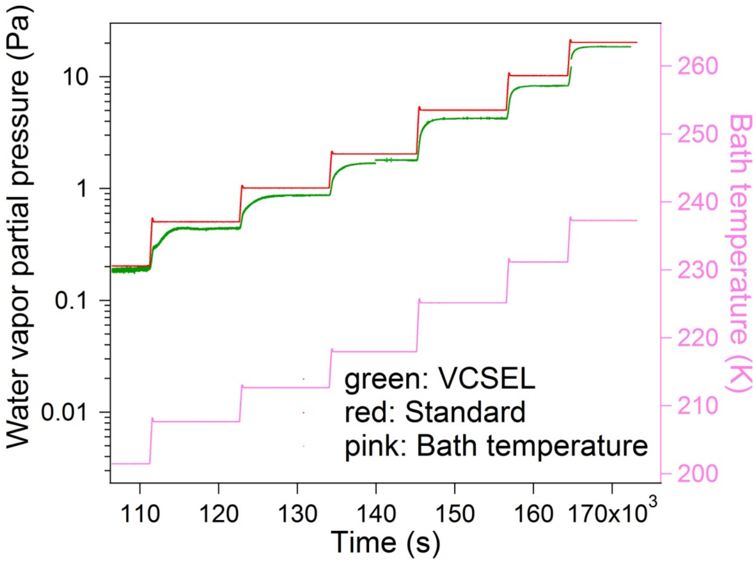
Calibrations of VCSEL hygrometer in temp. bath



@pressure from 100 to 700 torr

@ Temperature from -80 to 30°C



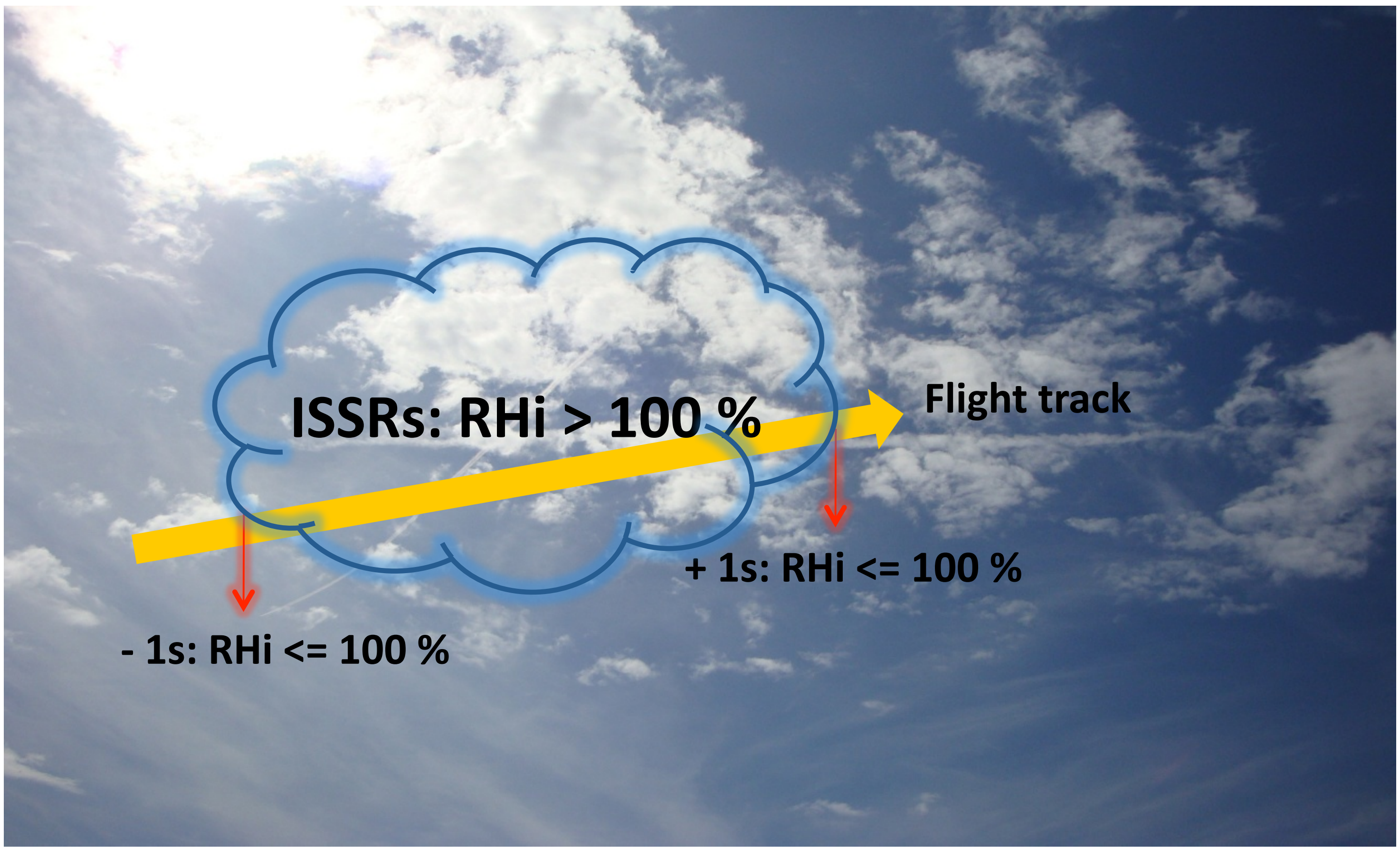


Climatologies of ISSRs

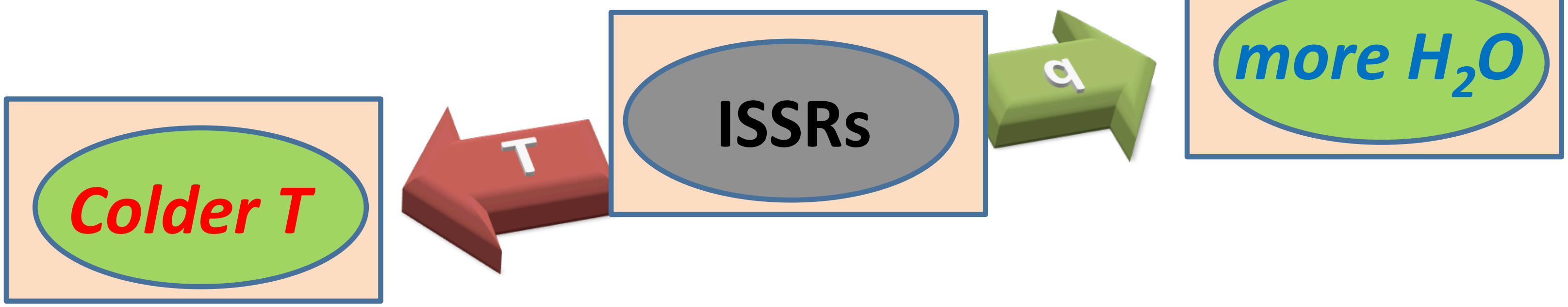
Ice supersaturations (ISS): 1s; RHi > 100 %.

Ice supersaturated regions (ISSRs):

-/+ 1s RHi < 100 %; Inside RHi > 100 % for many seconds.



Formation of ISSRs



- $\boldsymbol{d}$**RHi =** $RHi_{inside} - RHi_{outside}$
- $\boldsymbol{d}$**RHi** $= d(e*1/e_s) = \underbrace{(1/e_s)\, de}_{\text{Part 1.}} + \underbrace{e\, d(1/e_s)}_{\text{Part 2.}}$

Part 1. **Part 2.**

Explanations:

- **Part 1**: ***de*** is from **water vapor partial pressure**

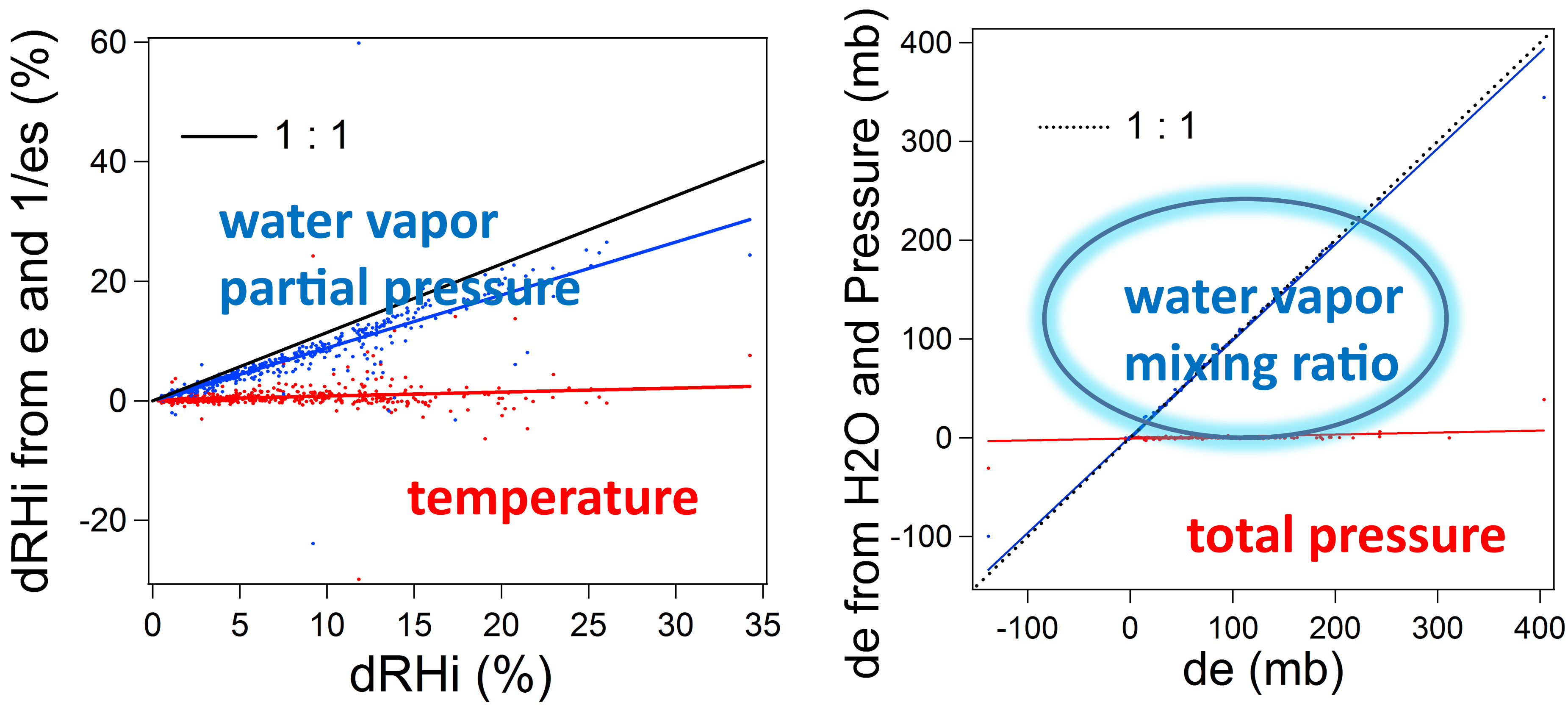
  $e = H_2OMR\ (ppmv) * Pressure(Pa) * 1e\text{-}6$

- **Part2** : ***d*(1/e$_s$)** is from **temperature**

  $1/e_s = 1/(\exp(9.550426-5723.265/T+3.53068*\ln(T)-0.00728332*T))$

  (Murphy and Koop)

START08: Formation of ISSRs



dRHi $= d(e/e_s) = 1/e_s * de + e * d(1/e_s)$

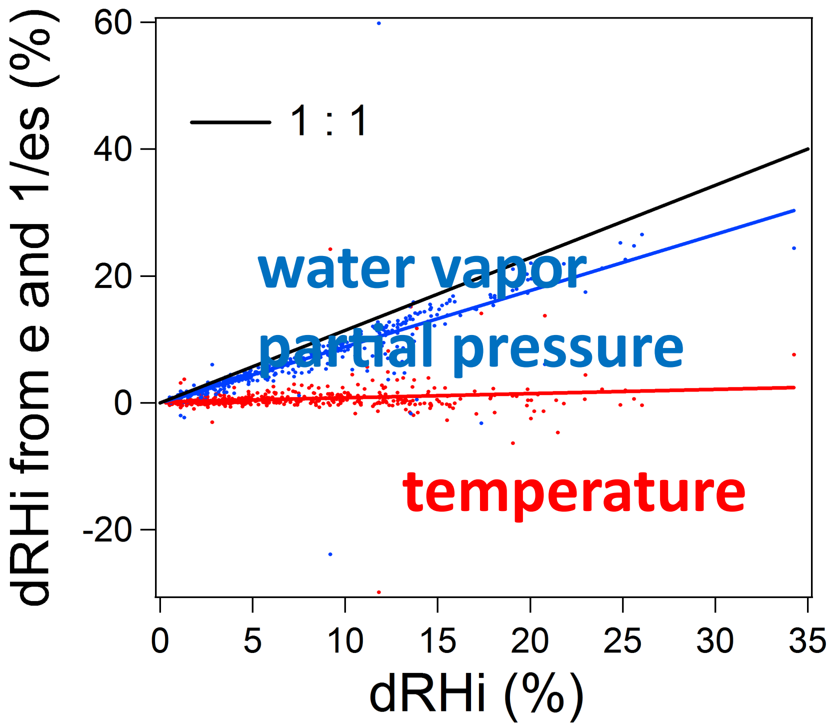
Part 1. Part 2.

de $= d(\text{H2OMR} * \text{Pressure})$

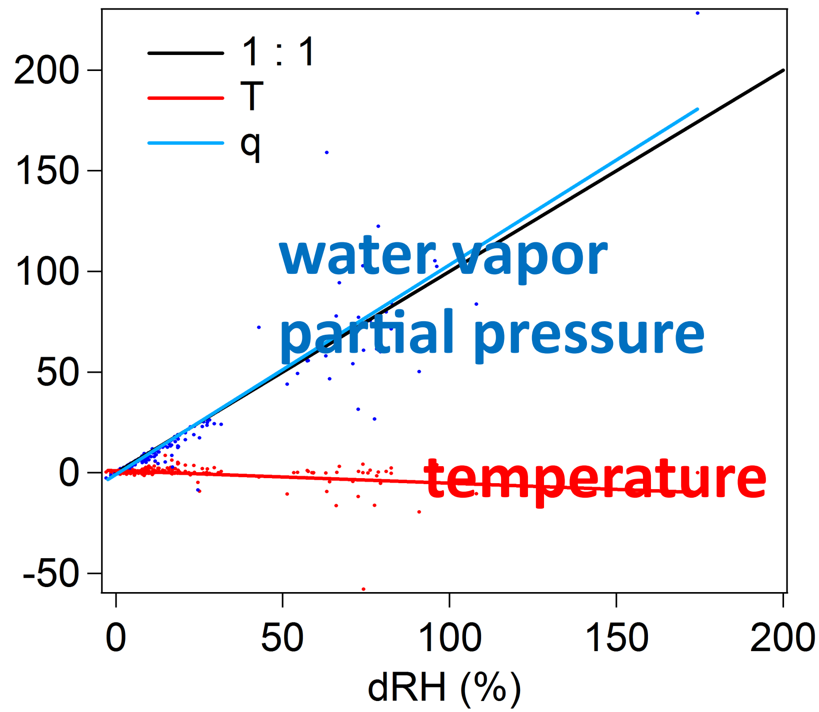
$= \text{Pressure} * d\text{H2OMR} + \text{H2OMR} * d\text{Pressure}$

Part A. Part B.

Formation mechanism of ISSRs in START08



Formation mechanism of ISSRs in HIPPO Global #3 (Quicklook data)



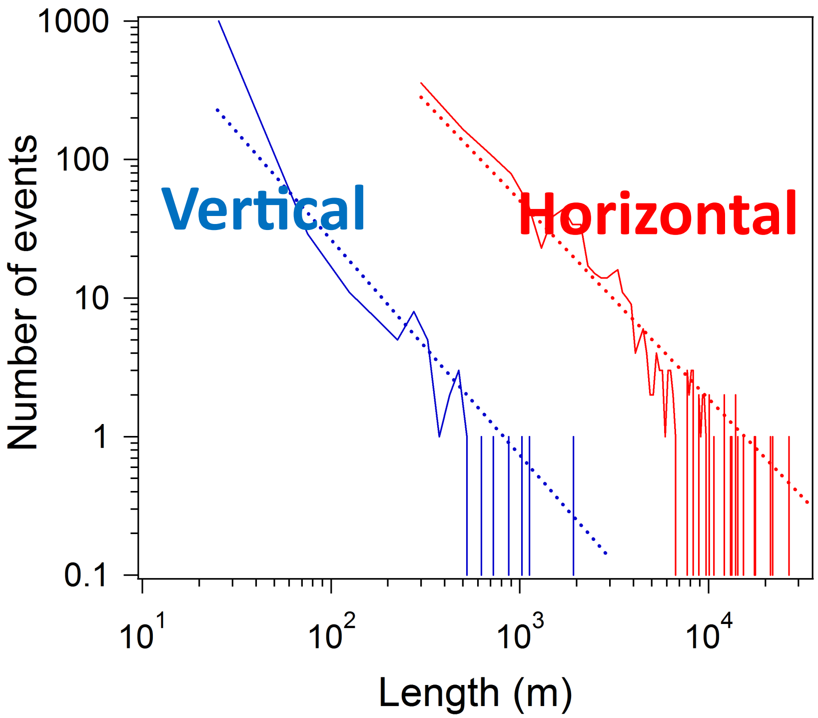
moisture dominates over temperature effects when comparing neighboring areas

Comparison of START08 and HIPPO-3 data for ice supersaturation

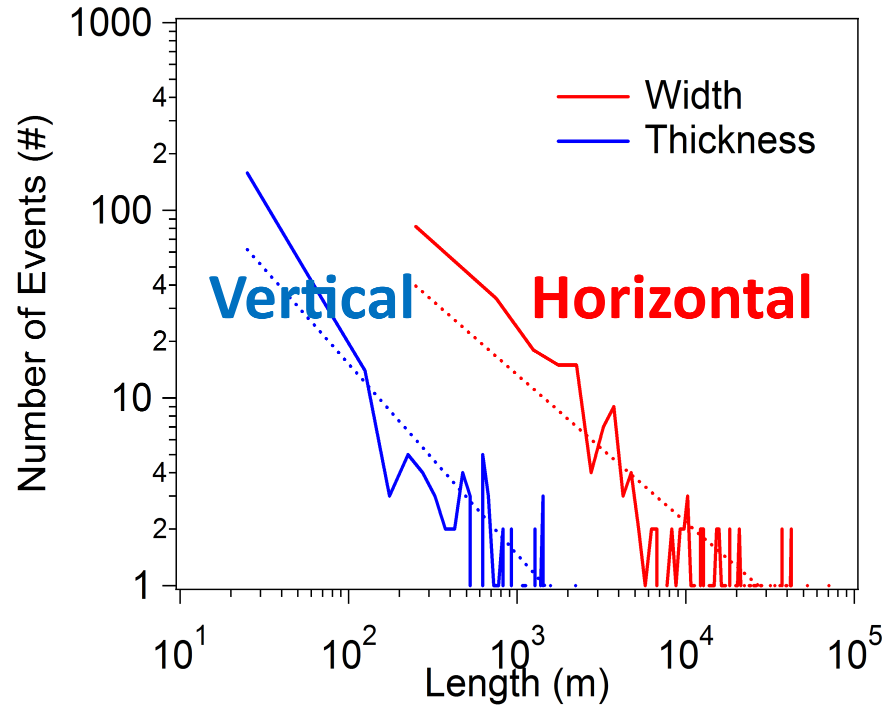
Size distribution of ISSRs in START08

Size distribution of ISSRs in HIPPO Global #3 (Quicklook data)

log(Number of events) = $a+b$ log(Length)



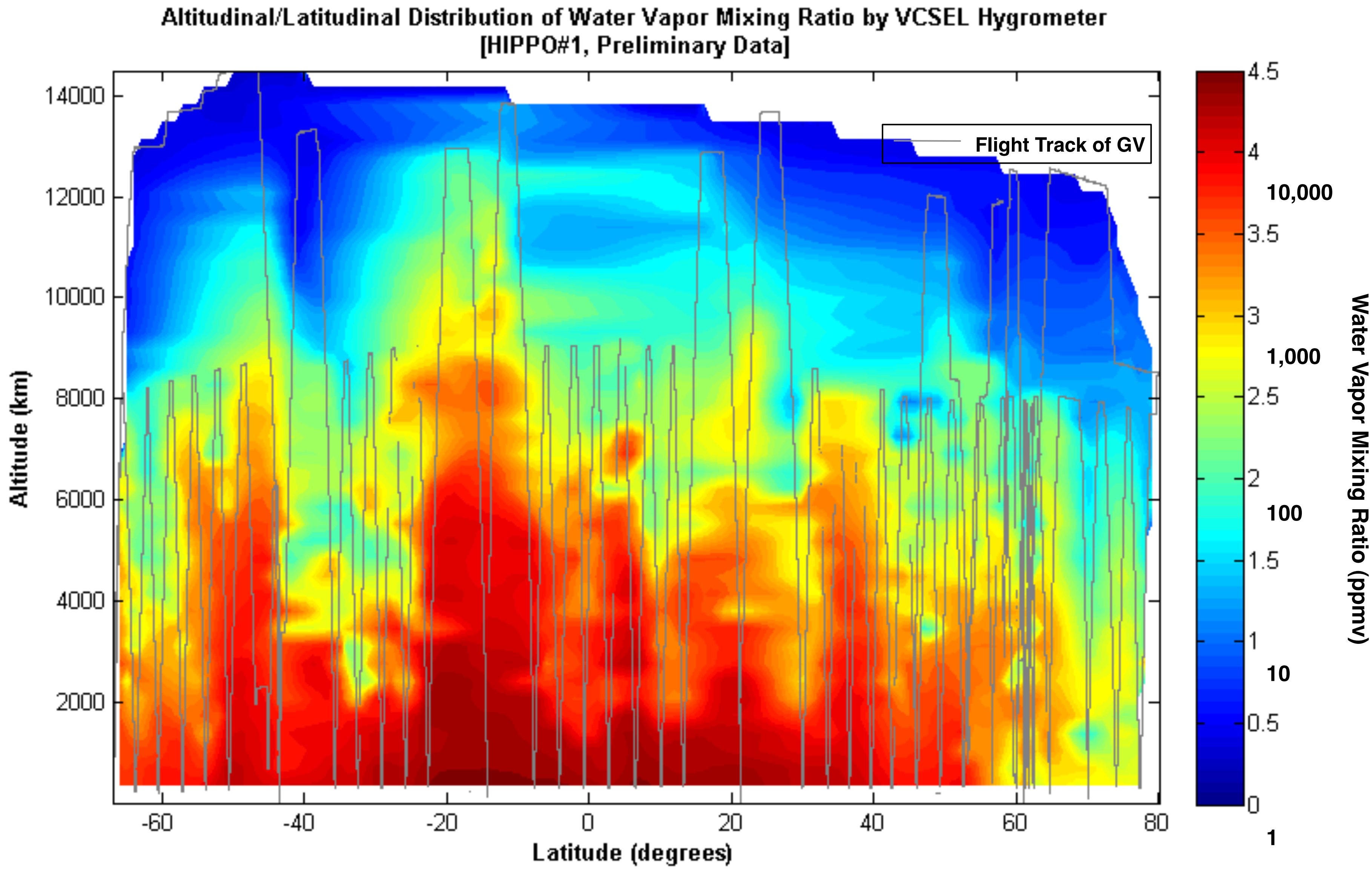
START08: exponents are -1.6 (thickness), -1.4 (width)



HIPPO#3: exponents are -1.0 (thickness), -0.79 (width)

N ~ 1000 ice supersaturated areas in HIPPO-3 alone

- vertical thicknesses (10s m); horizontal thicknesses (100-1000 km)
- need to distinguish tropics, mid-lat., polar
- different mechanisms in tropics vs. mid-latitudes?



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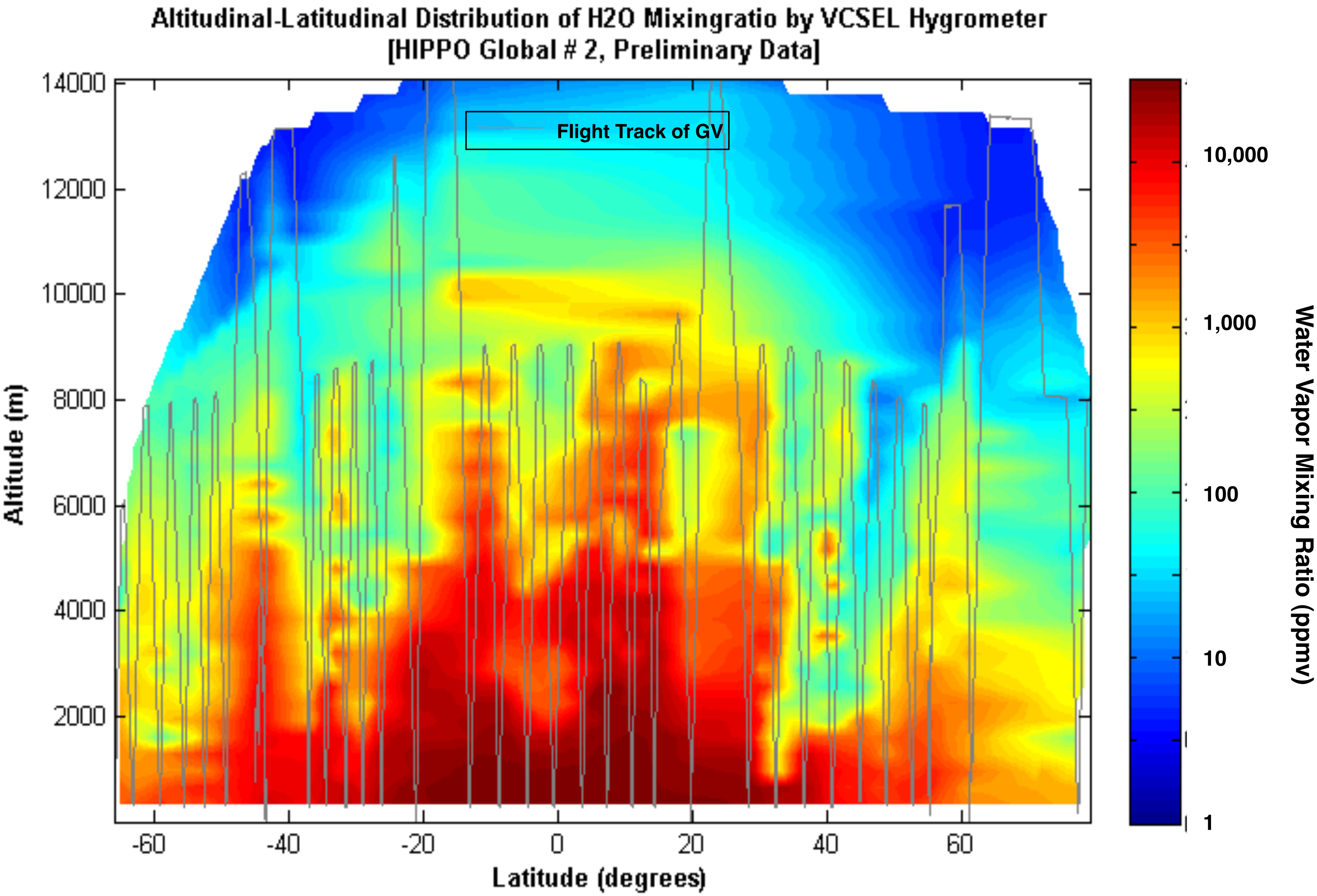

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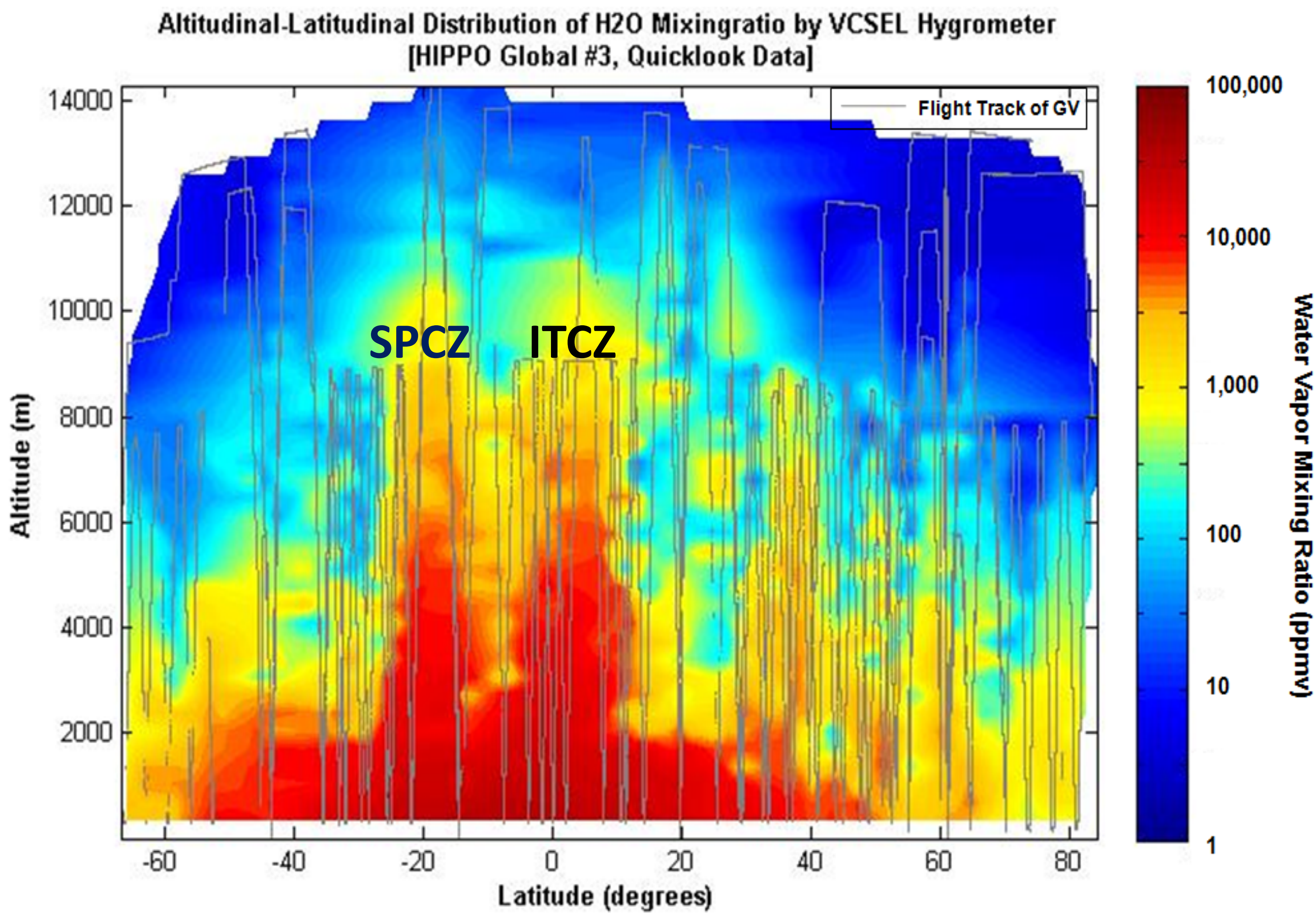
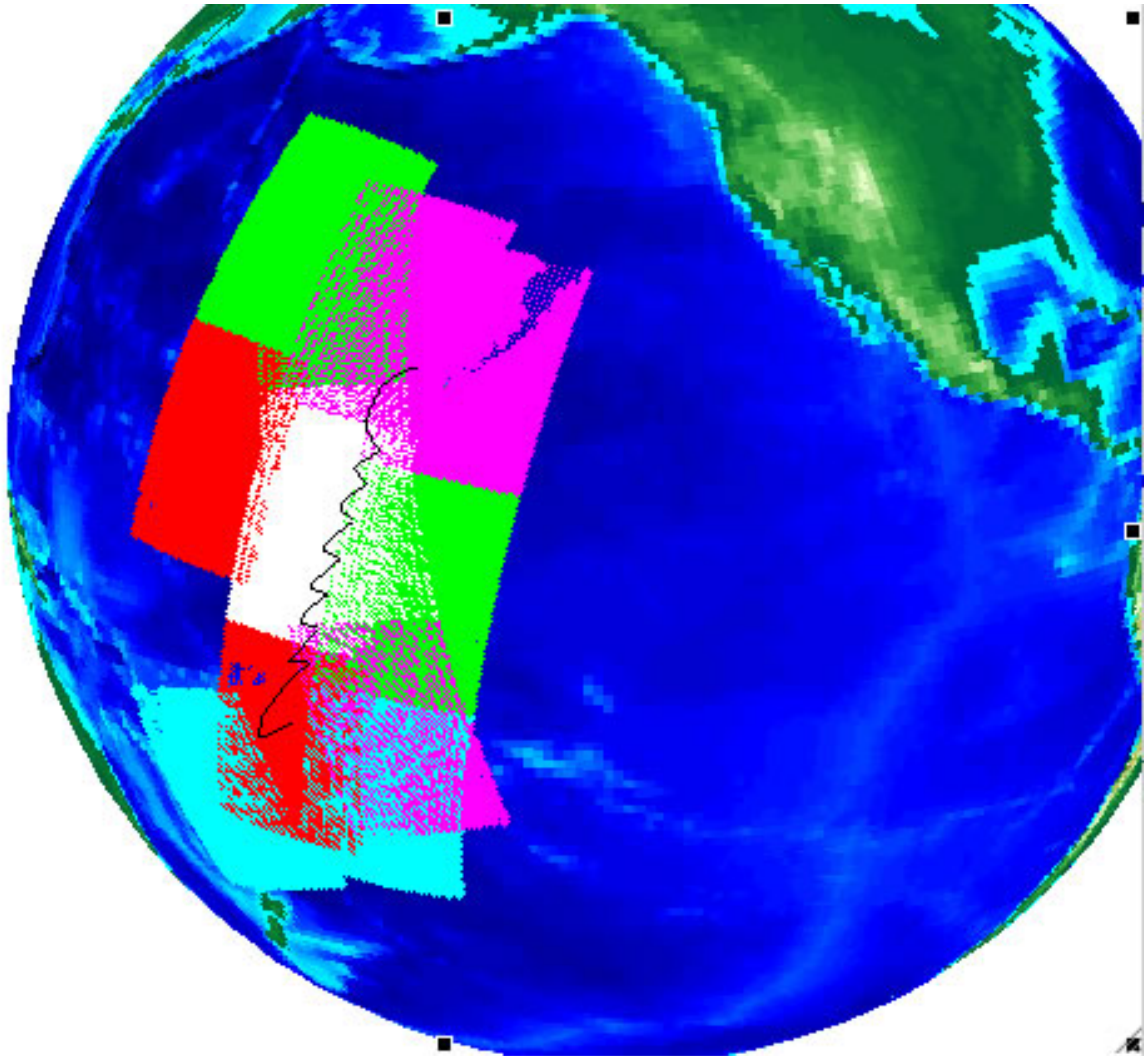
HIPPO Global Campaign # 3

water vapor distribution, March, 2010

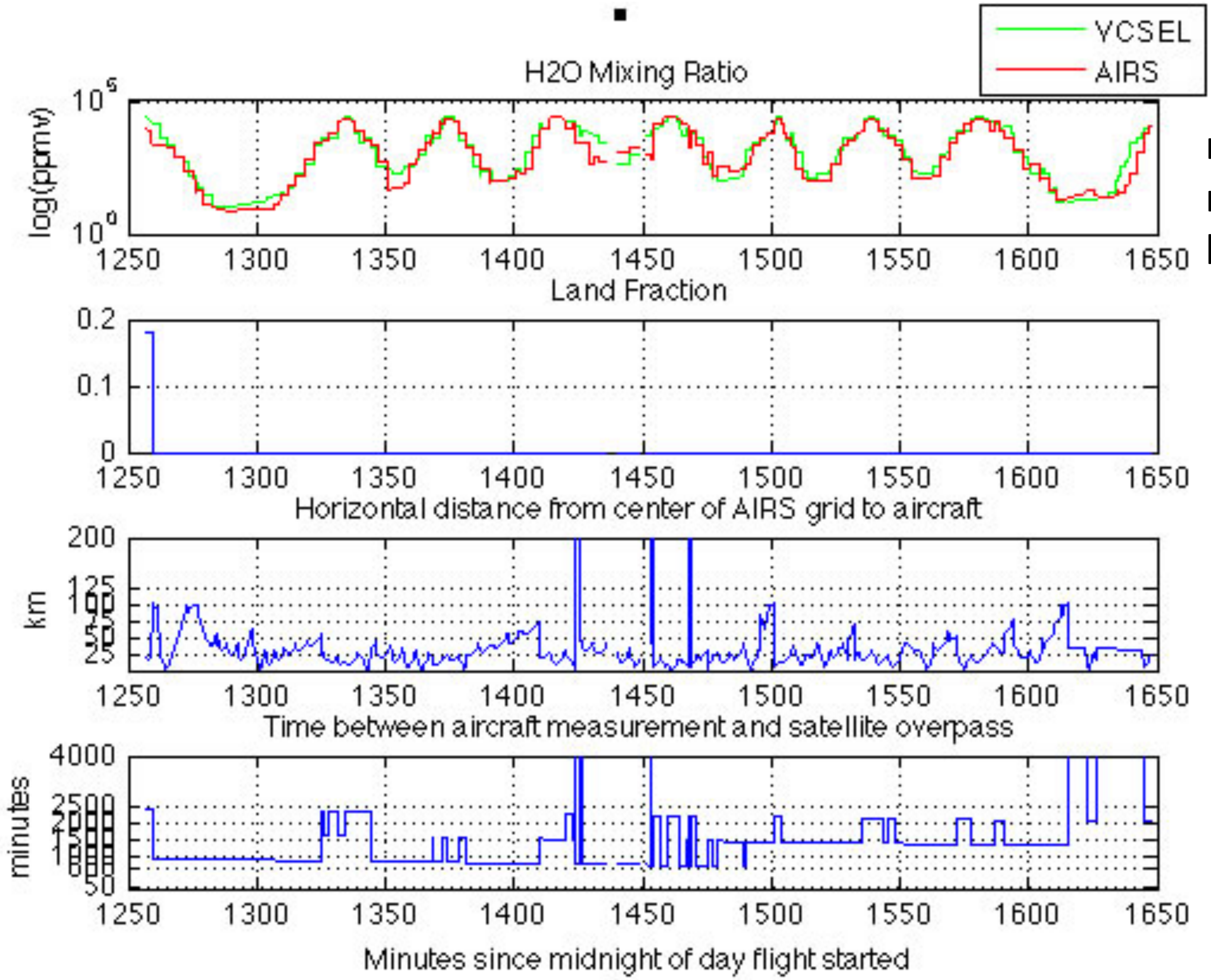


Can we generalize this zonally and in time? Look at AIRS... *M. Zondlo and M. Diao*

HIPPO #1: RF05, Hawaii to Samoa



HIPPO #1, RF05 tropics

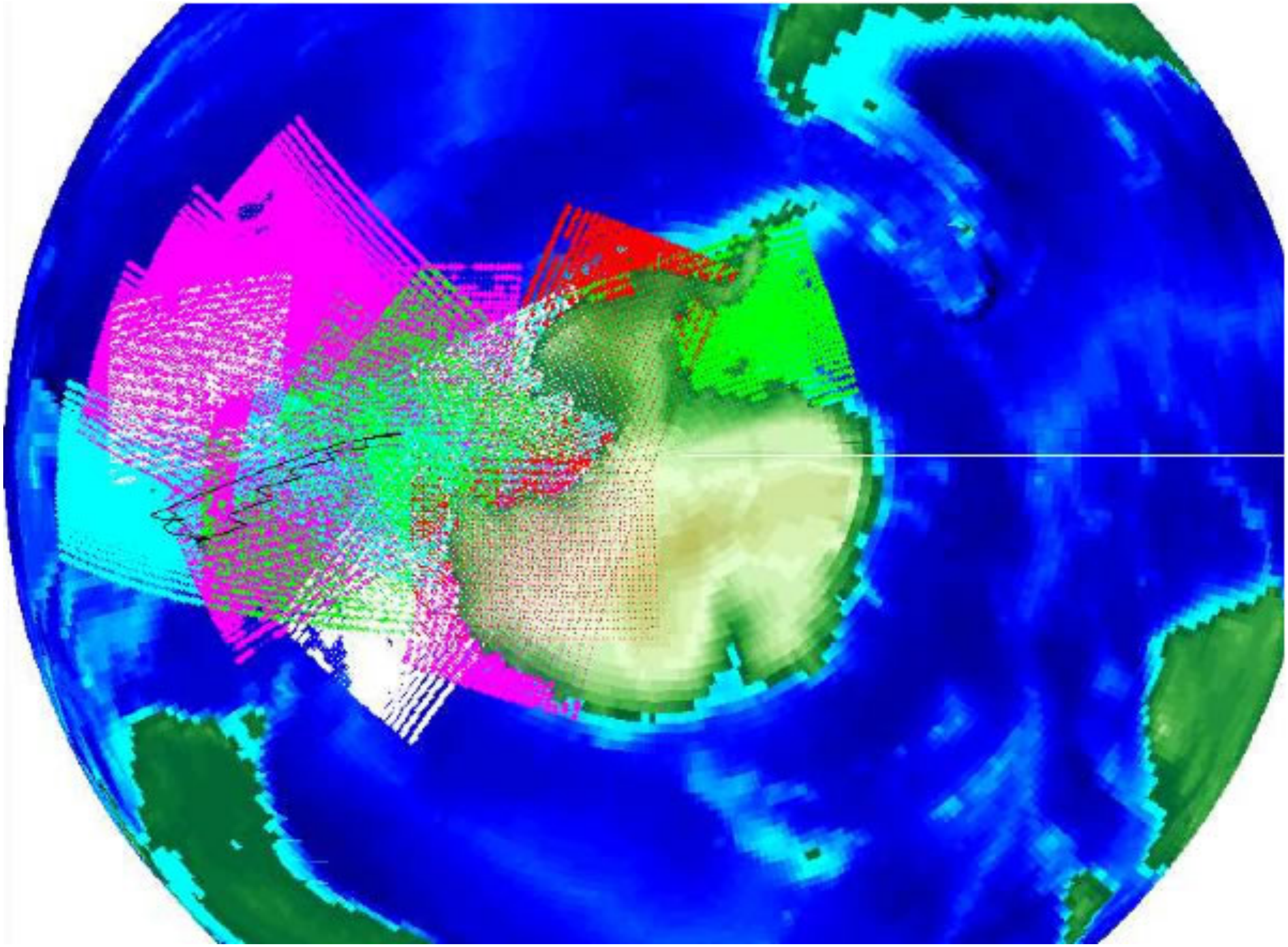


$r^2 = 0.96$

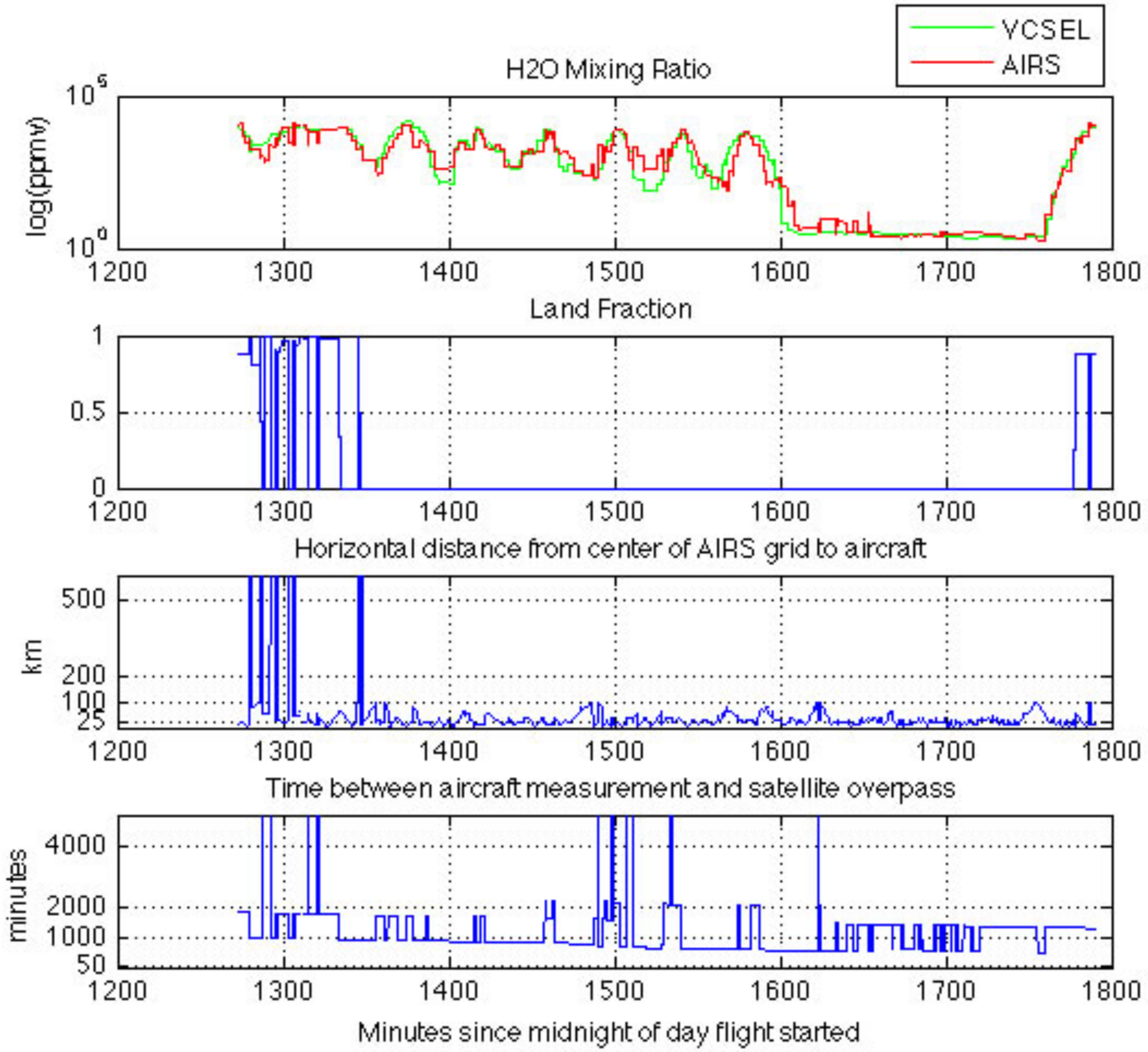
m=1.03

b=518 ppmv

HIPPO #1, RF07: Christchurch to 67 S and back



HIPPO #1, RF07: Christchurch to 67 S and back



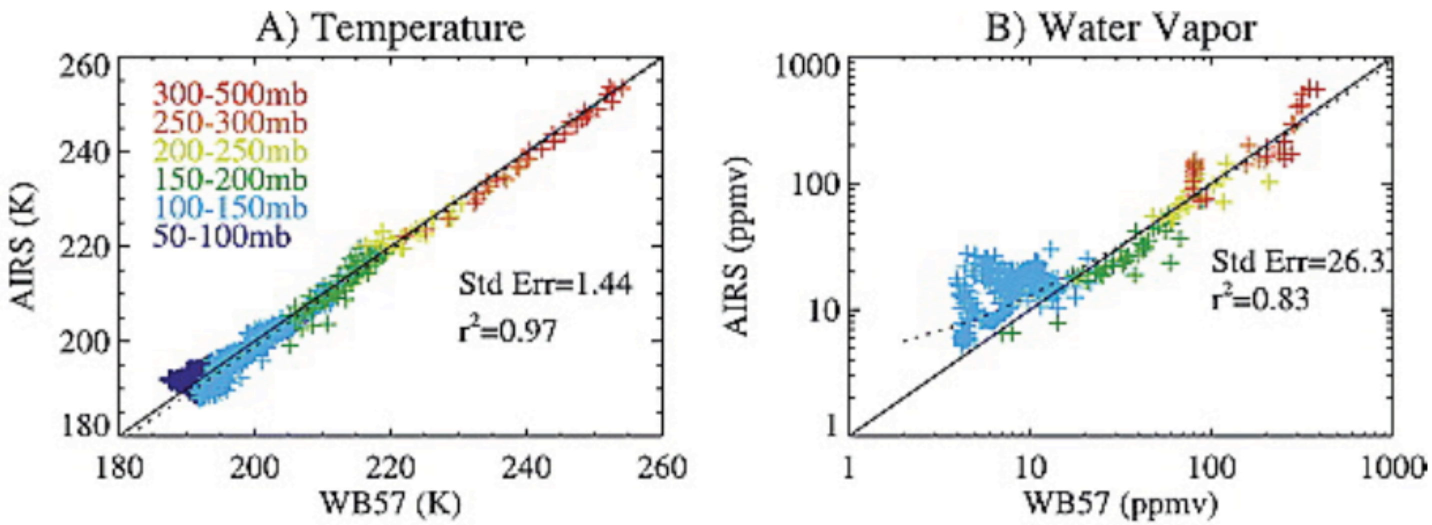
r^2=0.92

m=0.86

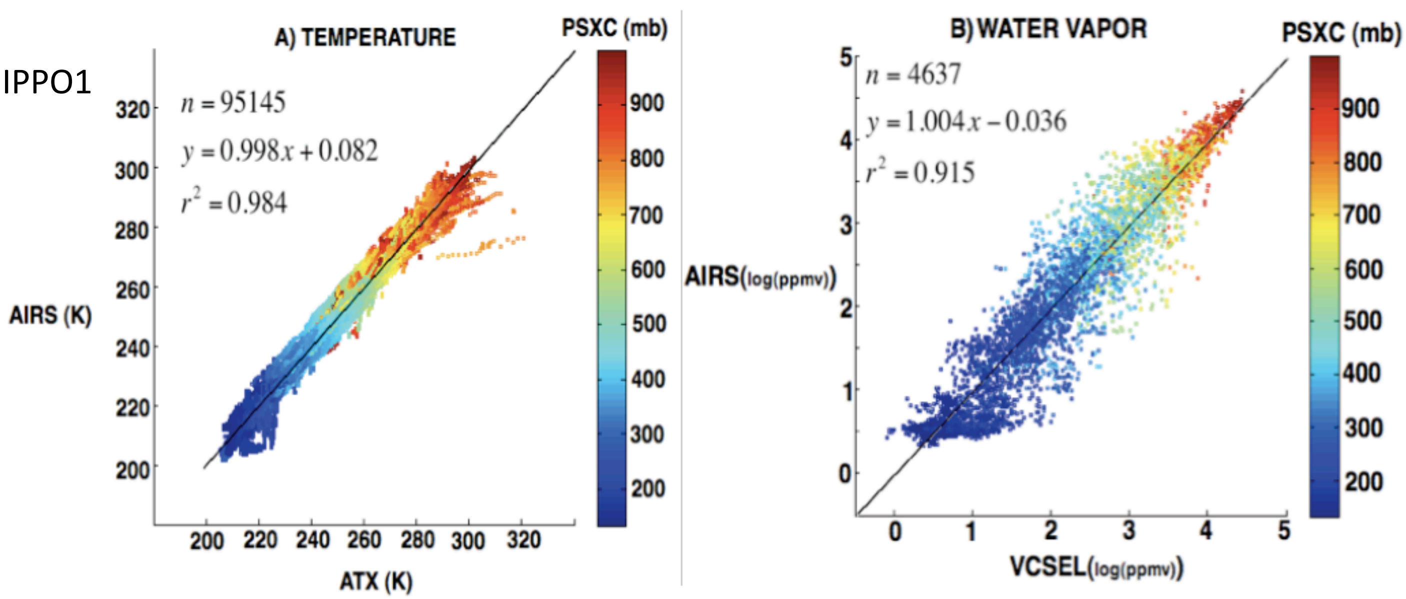
b=21 ppmv

All data: Comparison of VCSEL with AIRS for HIPPO-1/START08

Gettelman et al., 2004:
PreAVE
+/- 12 hr
co-located



Jumbam et al., 2010:
START08/HIPPO1
+/- 3 hours
co-located



VCSEL and AIRS show better correlation with tighter space/time constraints

HIPPO summary for H_2O/VCSEL:

1. Performance
   - HIPPO-1 looks good
   - HIPPO-2 had intermittent bias in 5 C to -20 C range (long period etalon); need to remove some data
   - HIPPO-3 noisy in 5 C to -20 C (low signal)
     - (improvements: dielectric mirrors, sealed lenses)

2. Calibrations
   - Multiple, orthogonal methods at trop./lower strat. temp. and press.
   - Appears to be very stable between START08, HIPPO 1-3 (when reasonable S/N)
   - Limited amount of time for calibrations in HIPPO (2-3 weeks), so more efforts needed

3. Ice supersaturation (fall submission JGR, Diao et al.)
   - Ice supersaturated areas differ from adjacent regions largely due to more moisture, not colder temperatures
   - Small sizes (generally < 30 m thick, < 1 km length)
   - HIPPO data consistent with START08 results in terms of size, PDF, magnitude
   - Examine ice supersaturation differences between NH/SH

4. VCSEL and AIRS H2O show very good agreement throughout HIPPO
   - Calibration/validation of AIRS in polar, SH regions
     - (Jumbam et al., 2010, JGR, to be submitted summer)
   - RH bimodality in deep tropics excellent agreement with AIRS data

5. Meridional / zonal / vertical extent of SPCZ vs. ITCZ using AIRS to provide larger context