

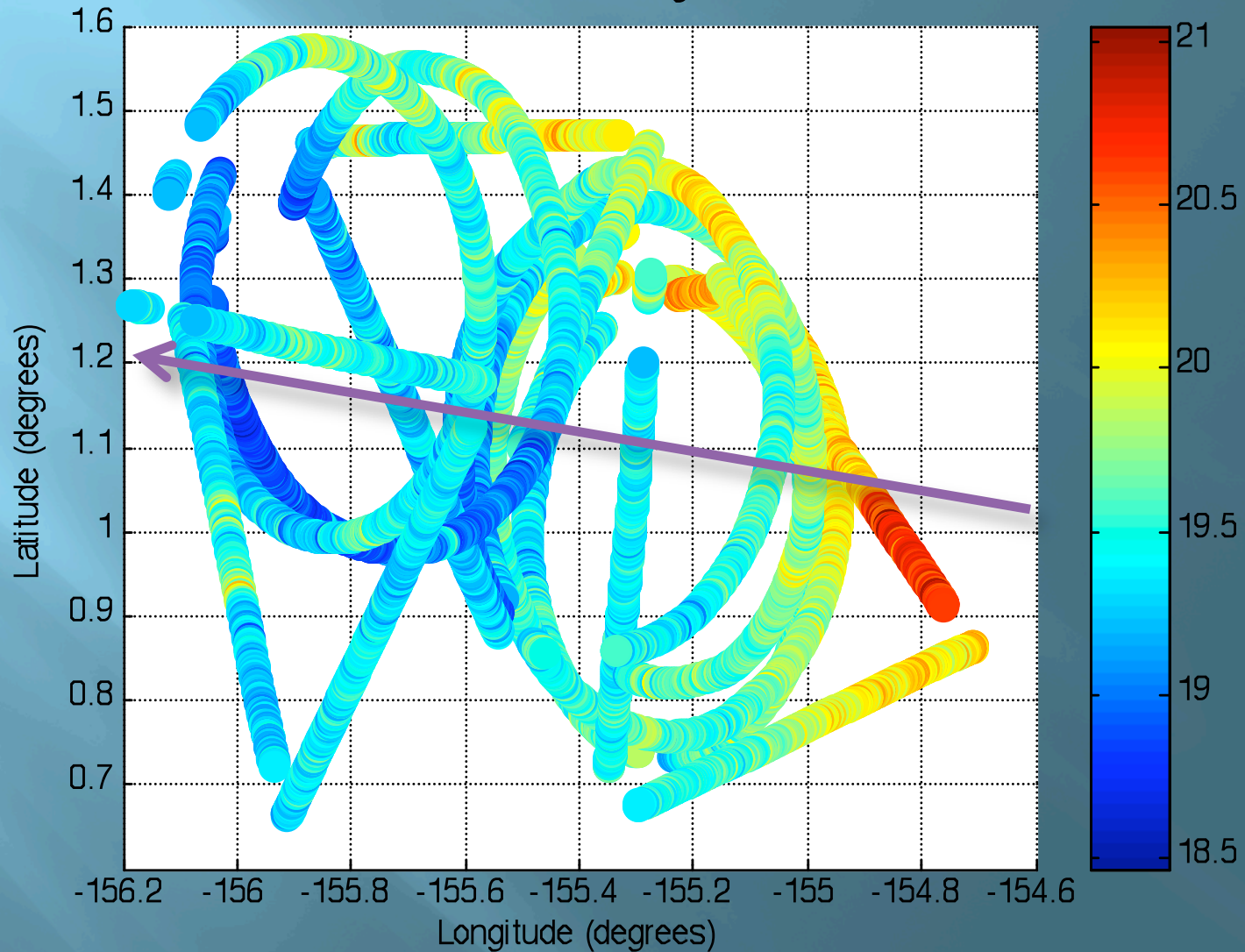
OZONE & WATER VAPOR

3RD PASE WORKSHOP
December 2, 2009

Stephen Conley, Ian Faloon
UC Davis

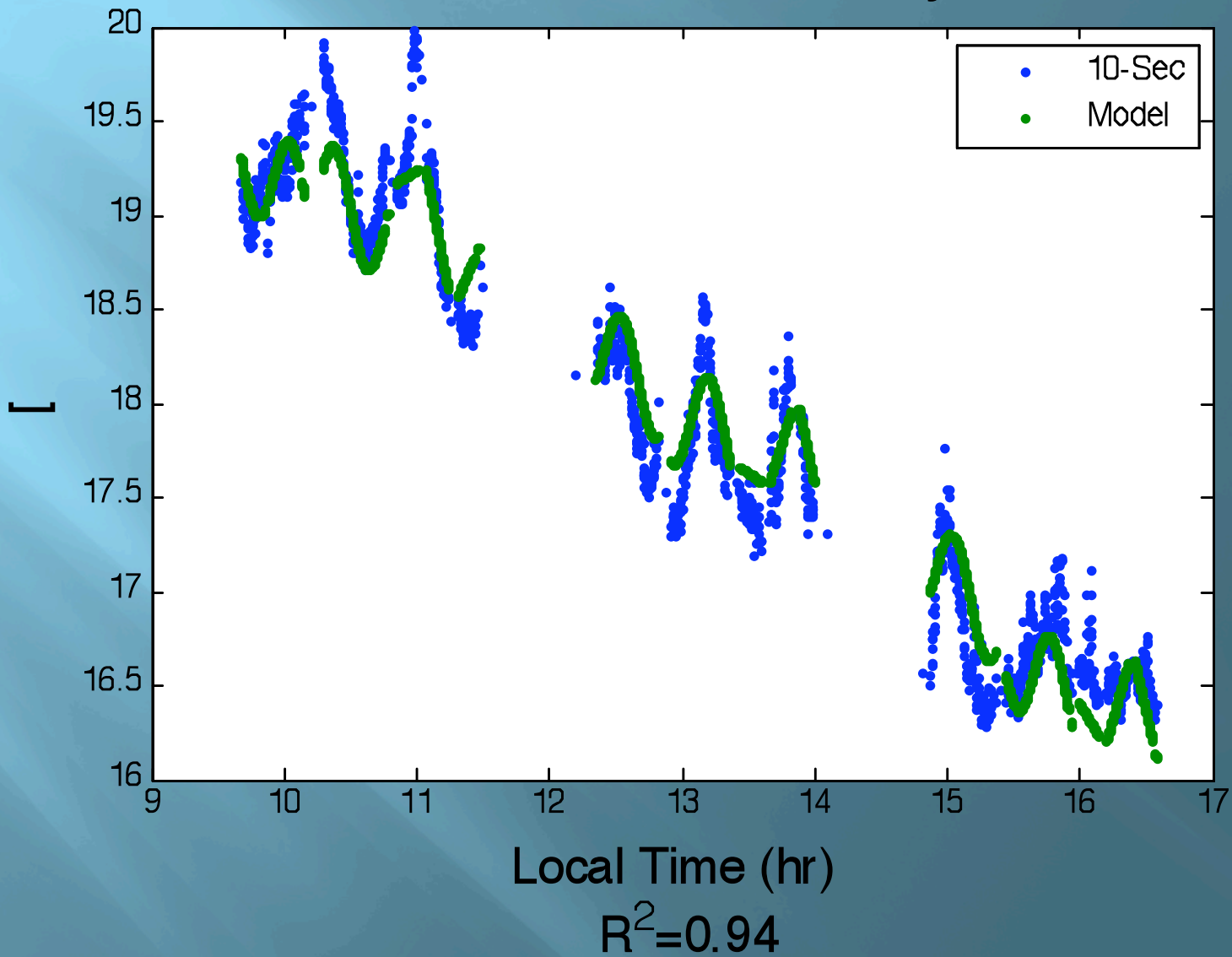
Horizontal Gradient

RF02 - C3 Corrected Flight Tracks

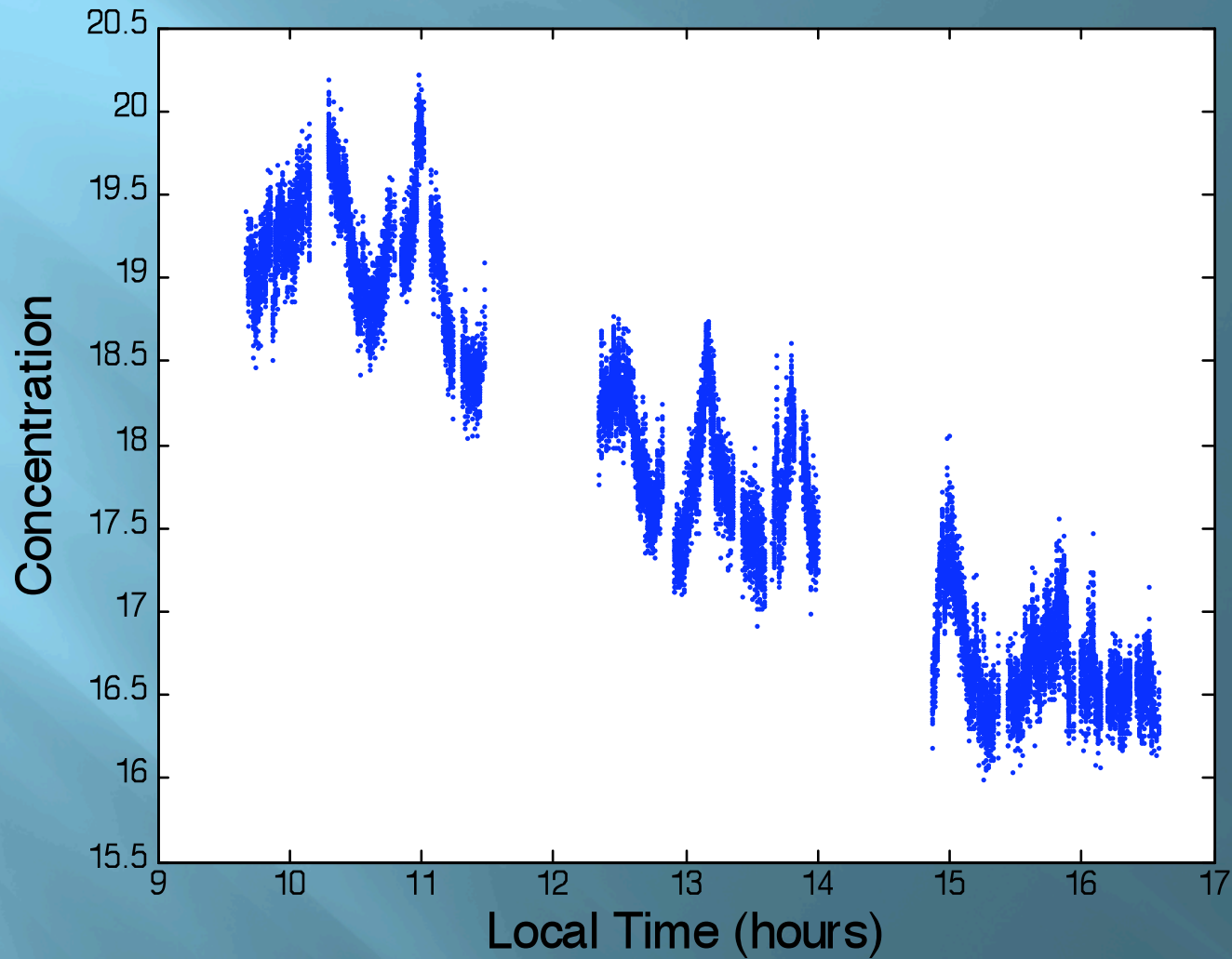


Ozone Fit Accuracy

RF02 - O3 Model Quality

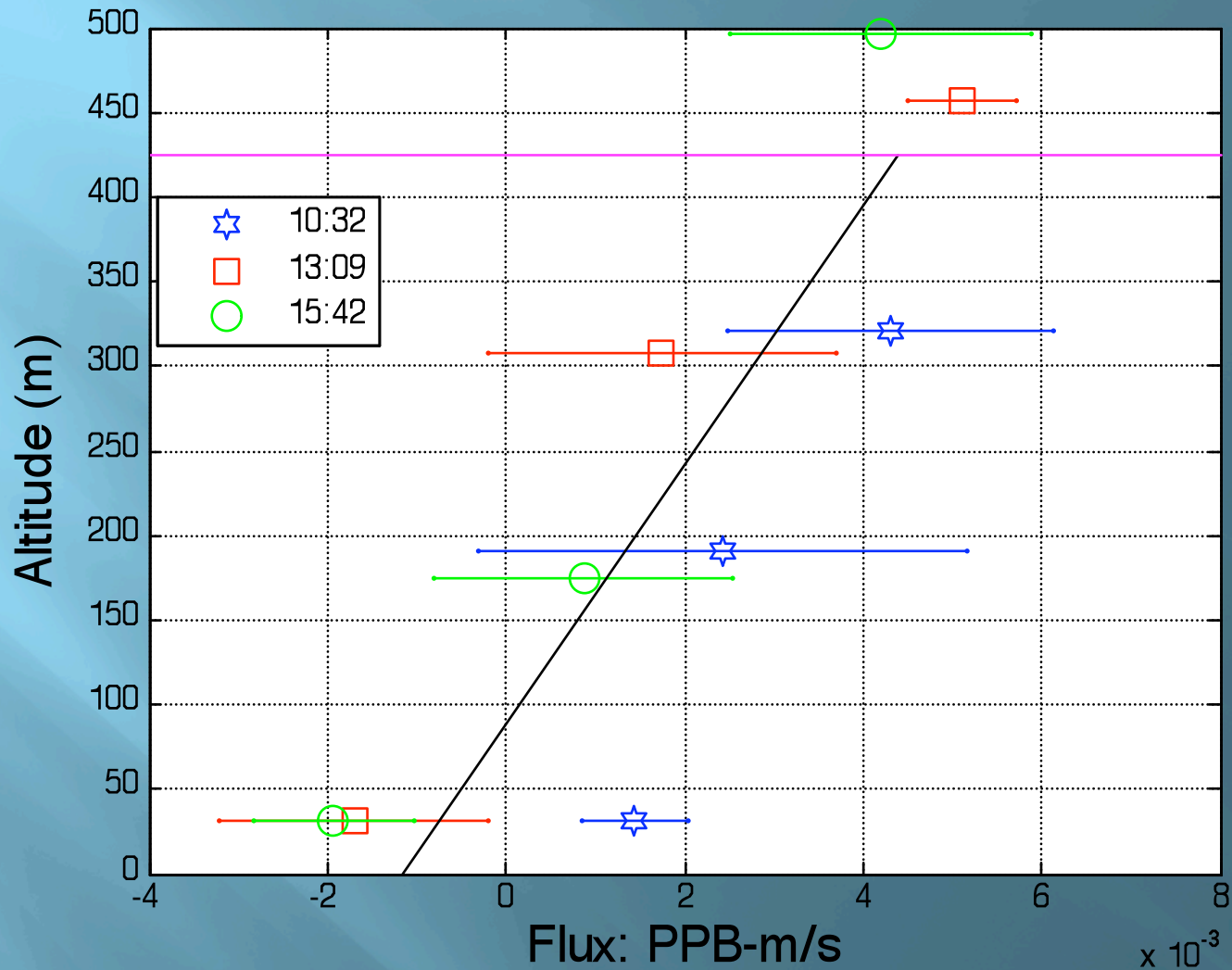


RF02 O₃ Time Series



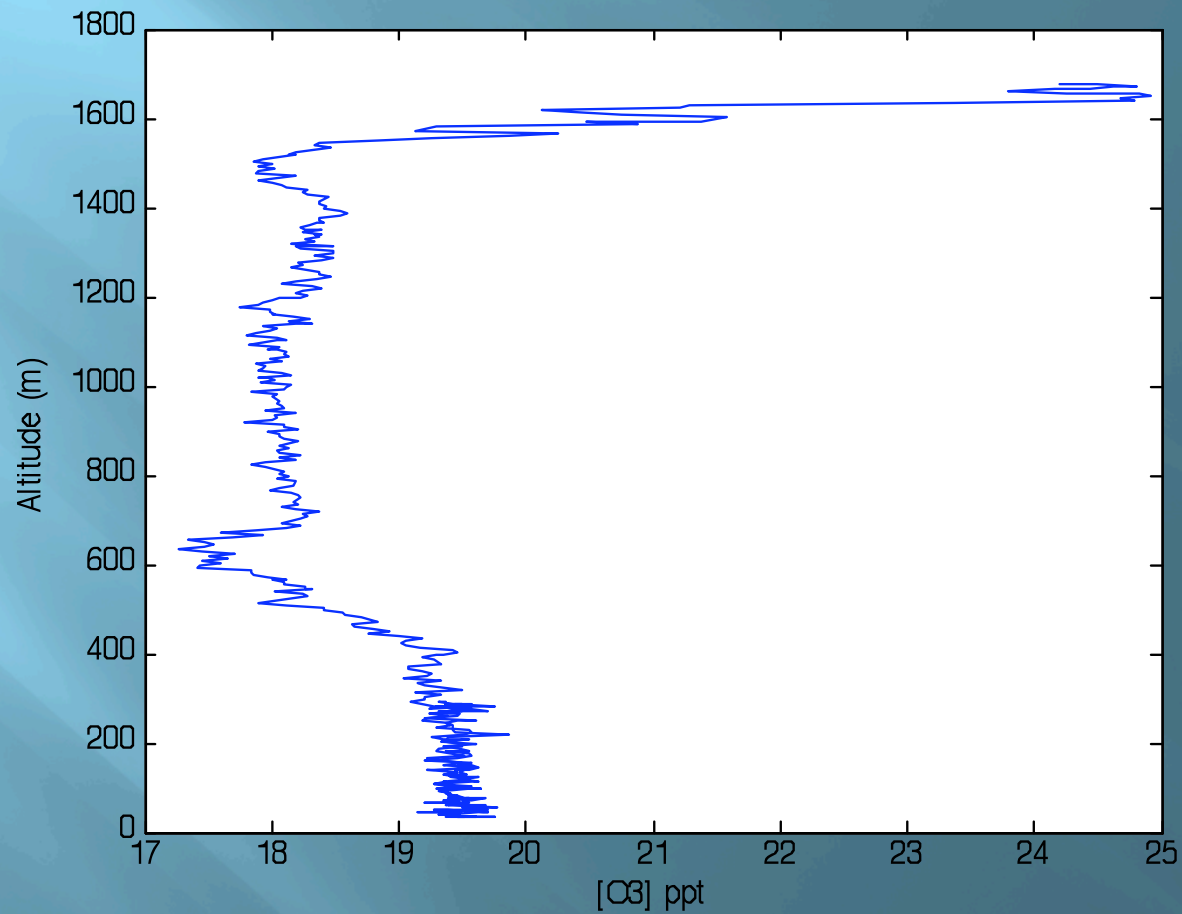
Ozone loses ~15% During the 7 hour flight

RF02 O₃ Flux Profile



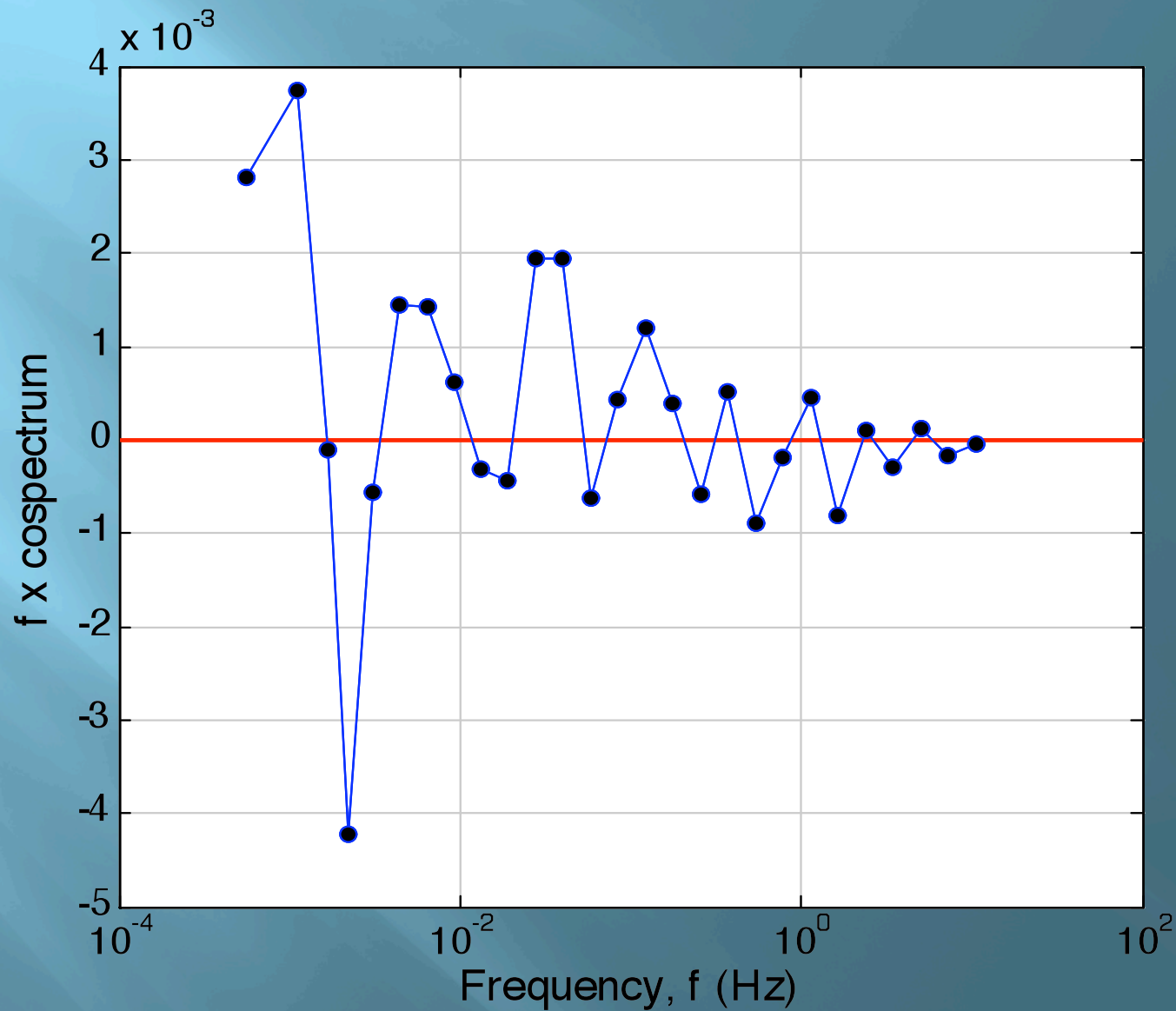
Upward flux of ozone into BuL?

RF02 Ozone Profile (1st)

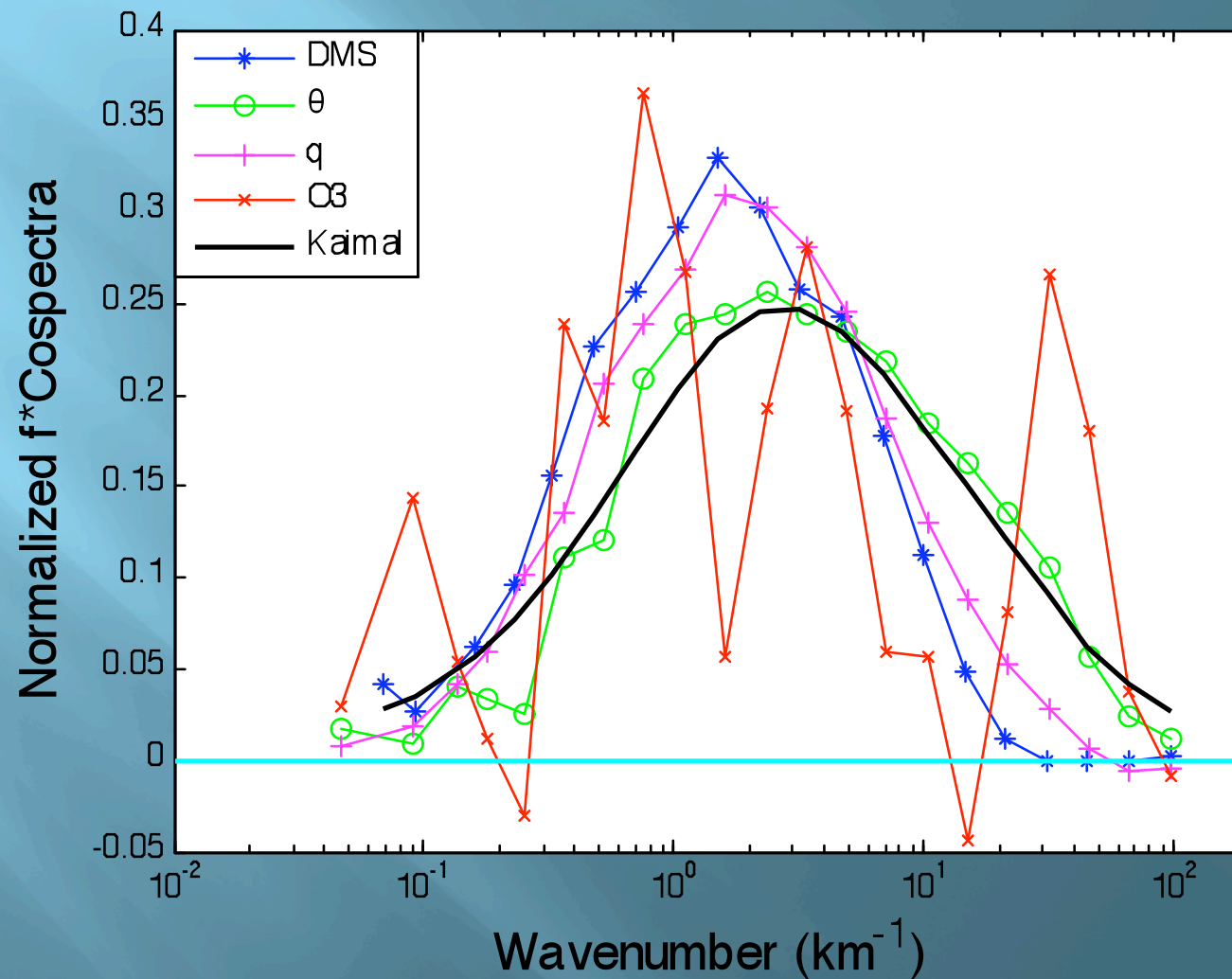


Positive flux at z_i not surprising in light of lower BuL concentration

RF02 TBL2 O₃/w Cospectrum



Normalized Cospectra



Ozone Budget

RF	Obs ppb/hr	Div ppb/hr	Adv ppb/hr	Residual ppb/hr	HO2 ppb/hr	OH ppb/hr	Photo ppb/hr	Net ppb/hr
1	-0.31	0.06	-0.10	-0.27	-0.03	-0.03	-0.28	0.06
2	-0.21	-0.05	0.18	-0.34	-0.04	-0.03	-0.30	0.03
3	-0.37	0.06	0.07	-0.50	-0.04	-0.02	-0.30	-0.13
5	-0.24	0.03	0.00	-0.27	-0.04	-0.03	-0.30	0.10
8	0.06	0.15	0.13	-0.22	-0.04	-0.02	-0.25	0.08
11	-0.02	-0.03	0.49	-0.48	-0.03	-0.02	-0.23	-0.20
12	-0.09	0.09	0.12	-0.31	-0.04	-0.03	-0.34	0.11
14	-0.41	0.04	-0.28	-0.17	-0.04	-0.02	-0.27	0.16
	-0.20	0.05	0.08	-0.32	-0.04	-0.02	-0.28	0.03
6	0.24	0.08	0.13	0.03			-0.06	
13	0.58	0.19	0.31	0.08	-0.03	-0.01	-0.11	0.23
	0.41	0.14	0.22	0.05	-0.03	-0.01	-0.09	0.23

NO Estimate

$$P \approx [NO] \cdot [k_1 \cdot [HO_2] + k_2 \cdot [RO_2]]$$

Average HO₂ ~ 3.4x10⁸ mlc/cm³

Average RO₂ ~ 7.6x10⁸ mlc/cm³

$k_{HO_2+NO} = 8.1 \times 10^{-12}$

$k_{CH_3O_2+NO} = 7.7 \times 10^{-12}$

$$[NO] = \frac{P}{k_1[HO_2] + k_2[RO_2]} = \frac{(30/3600) ppt/sec}{8.1 \times 10^{-12} \cdot 3.4 \times 10^8 + 7.7 \times 10^{-12} \cdot 7.6 \times 10^8}$$

Assuming the average NET in the ozone budget of .03 ppb/hr,
the NO concentration is ~ 1 ppt.

NO₂ Estimate

$$\frac{NO}{NO_2} \approx \frac{j_{NO_2}}{k_{NO+O_3}[O_3] + k_{RO_2+NO}[RO_2] + k_{HO_2+NO}[HO_2]}$$

$$k_{HO_2+NO} = 8.1 \times 10^{-12} \text{ cm}^3 \text{ mlc}^{-1} \text{ s}^{-1}; k_{CH_3O_2+NO} = 7.7 \times 10^{-12} \text{ cm}^3 \text{ mlc}^{-1} \text{ s}^{-1}$$

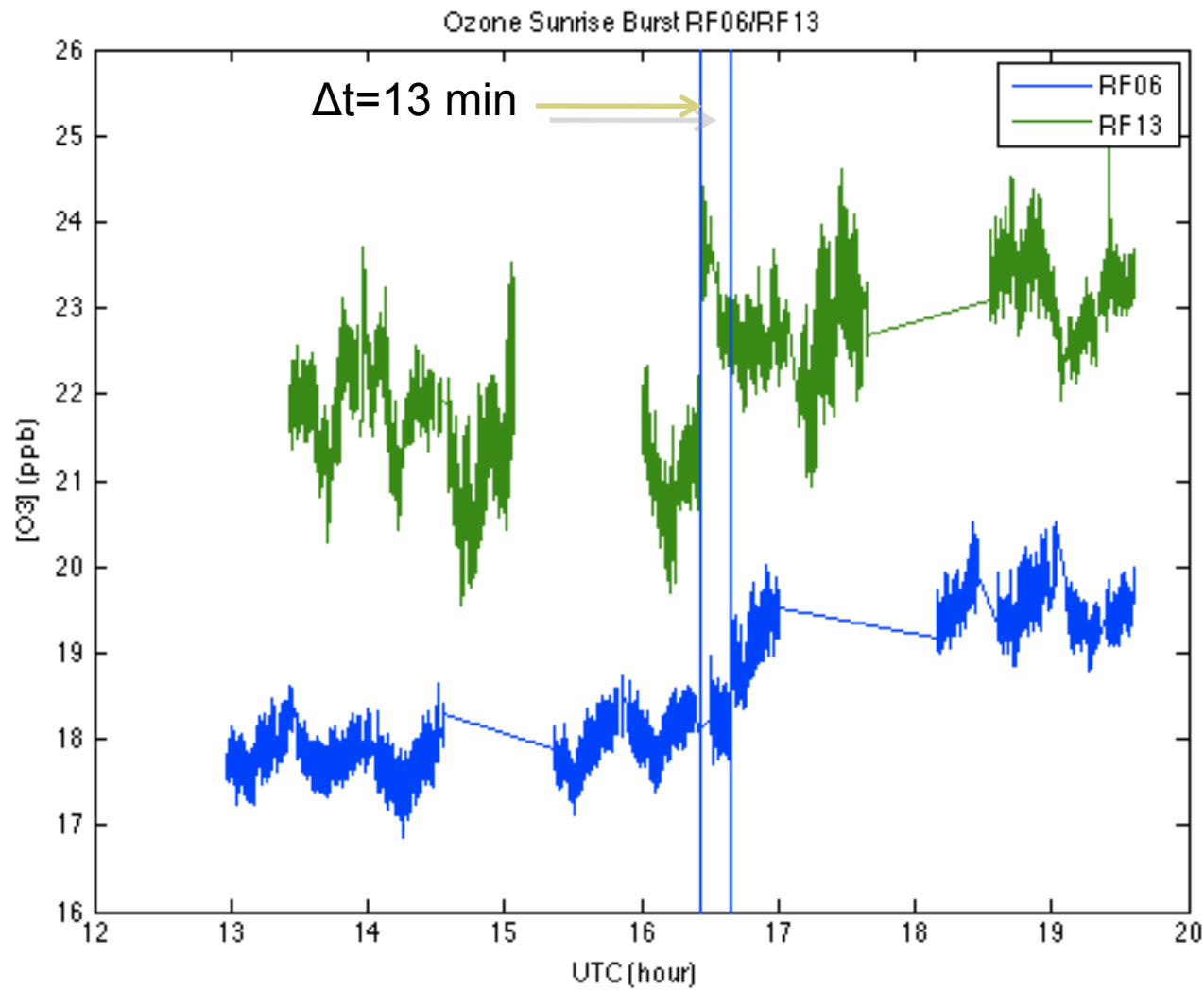
$$j_{NO_2} \approx .0066 \text{ s}^{-1}; k_{NO+O_3} = 1.9 \times 10^{-14} \text{ cm}^3 \text{ mlc}^{-1} \text{ s}^{-1}; [O_3] = 17 \text{ ppb}$$

$$\frac{NO}{NO_2} \approx \frac{.0066 \text{ s}^{-1}}{1.9 \times 10^{-14} [4.2 \times 10^{11}] + 7.7 \times 10^{-12} [7.6 \times 10^8] + 8.1 \times 10^{-12} [3.4 \times 10^8]}$$

$$\frac{NO}{NO_2} \approx .4 \Rightarrow NO_2 \approx 2.5 \text{ ppt}$$

$$NO_x \approx 3.5 \text{ ppt}$$

Sunrise Ozone Burst

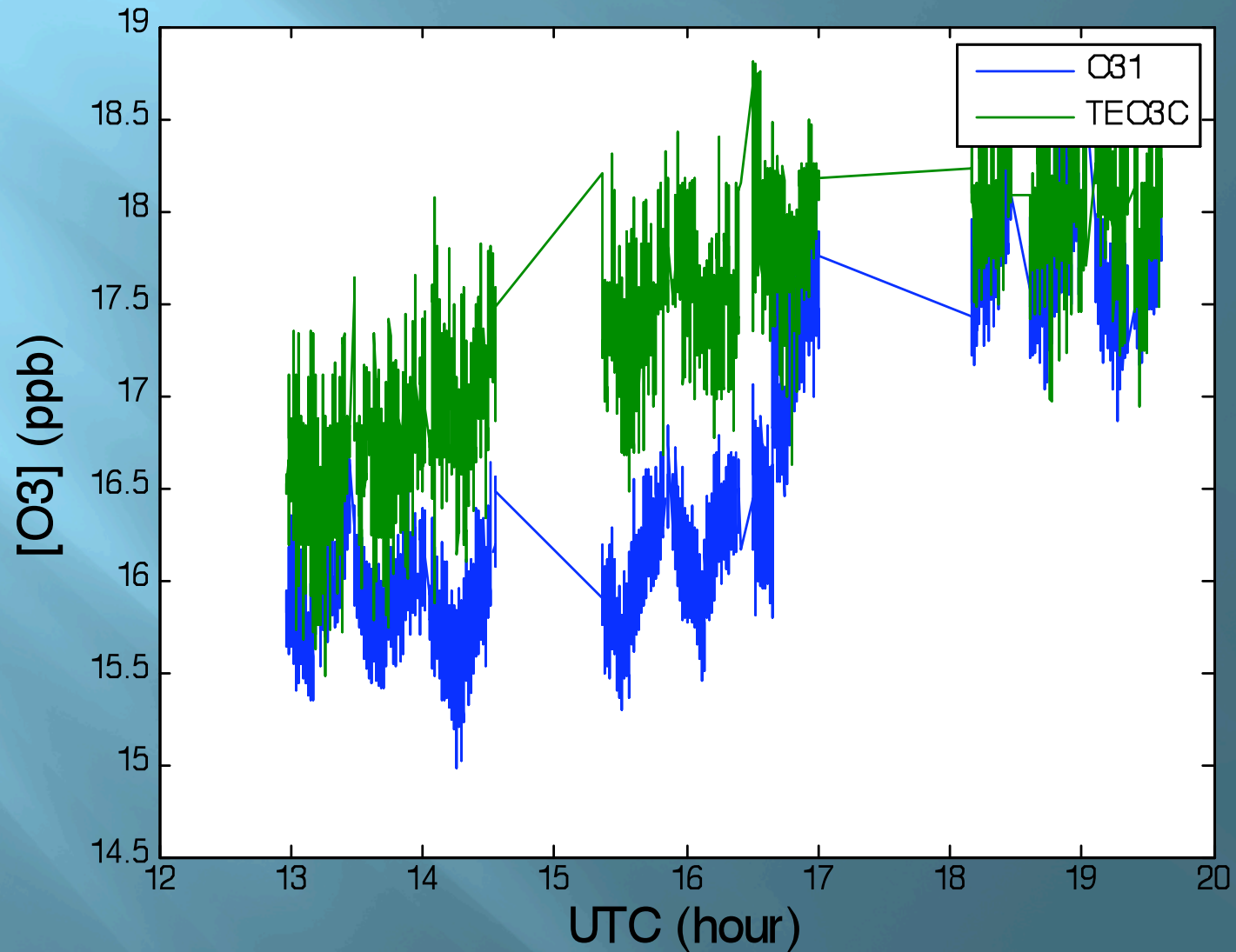


Sunrise Data

- According to the US Naval Observatory sunrise calculator, sunrise at the location of the bursts was:
 - RF06 (-0.29,-155.89): 16:24 UTC
 - RF13(+3.26,-154.43): 16:12 UTC
- The time of the bursts differed by 13 minutes and sunrise differed by 12 minutes!

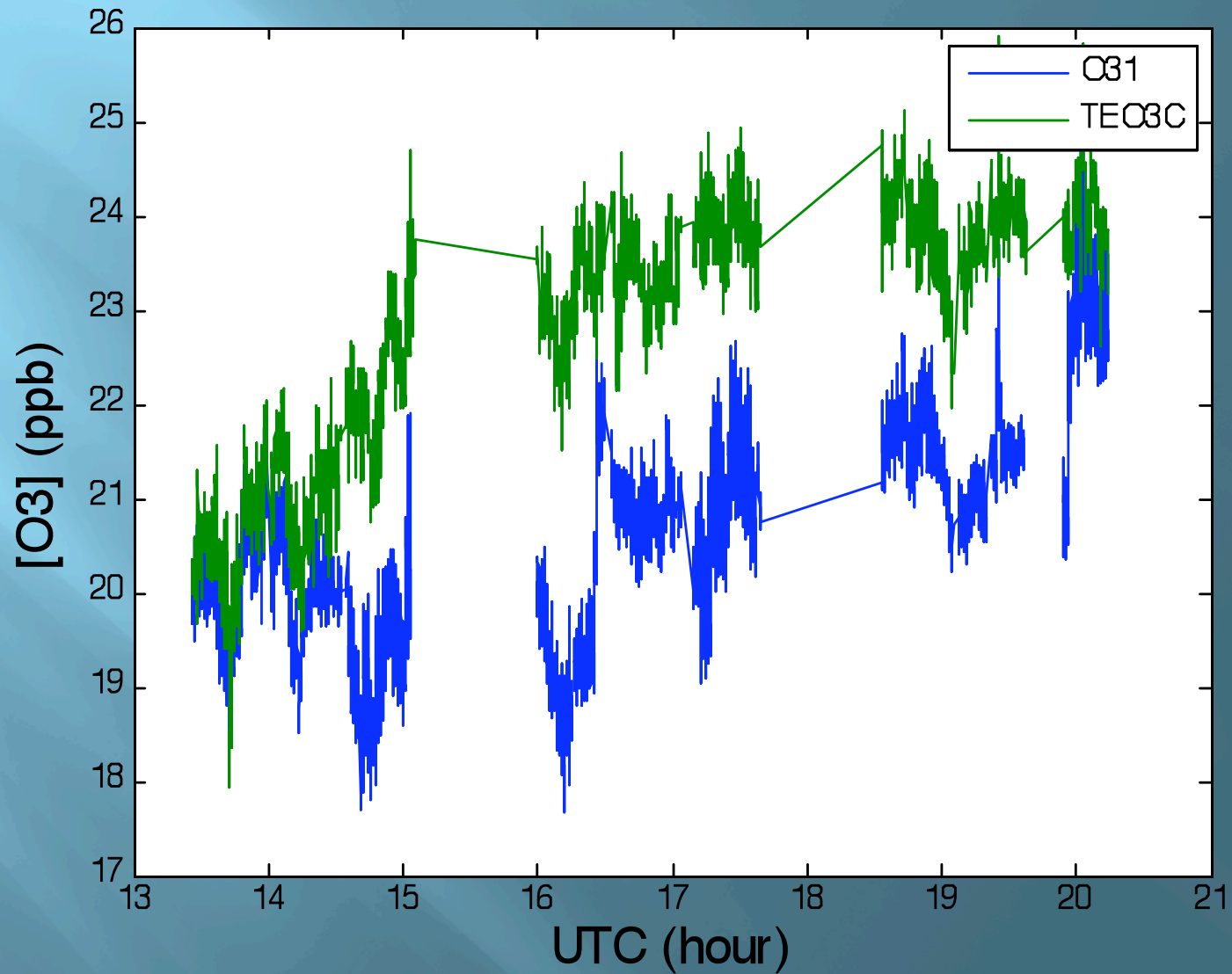
Sunrise Ozone Discrepancy

RF06 O3 Instruments



Sunrise Ozone Discrepancy

RF13 O3 Instruments



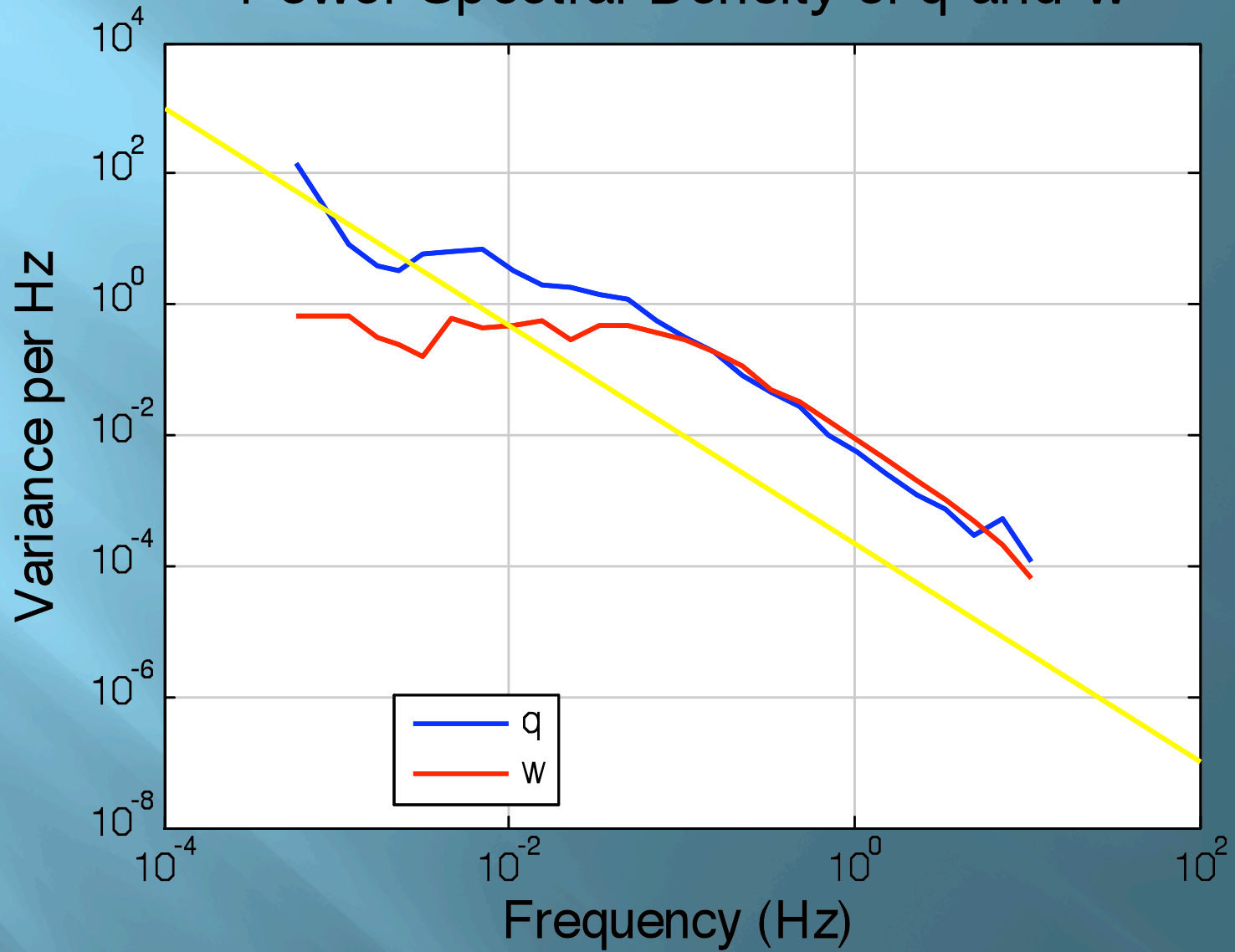
Ozone Conclusions

- ▣ Sunrise burst remains a mystery – but is likely instrumental rather than physical.
- ▣ Assuming no significant halogen chemistry, the NO_x concentration is around 3.5 ppt.
- ▣ High rate O_3 measurement dubious for time and space fit.

Water Vapor

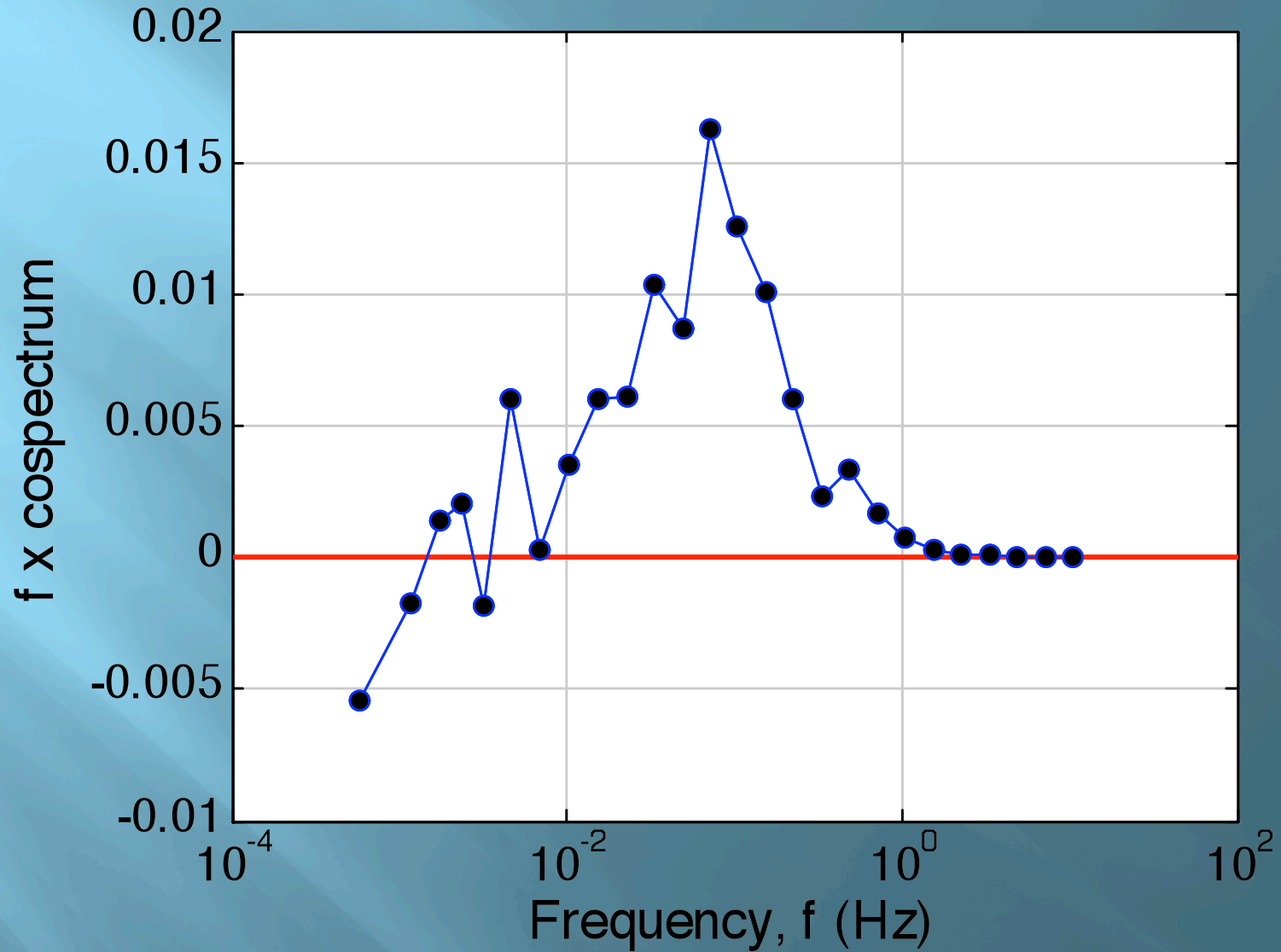
- ▣ Two water vapor measurements, Lyman-Alpha and TDL.
- ▣ Uncertain if Lyman-Alpha measurement is suitable for flux calculation.
- ▣ TDL data not yet available.

Power Spectral Density of q and w



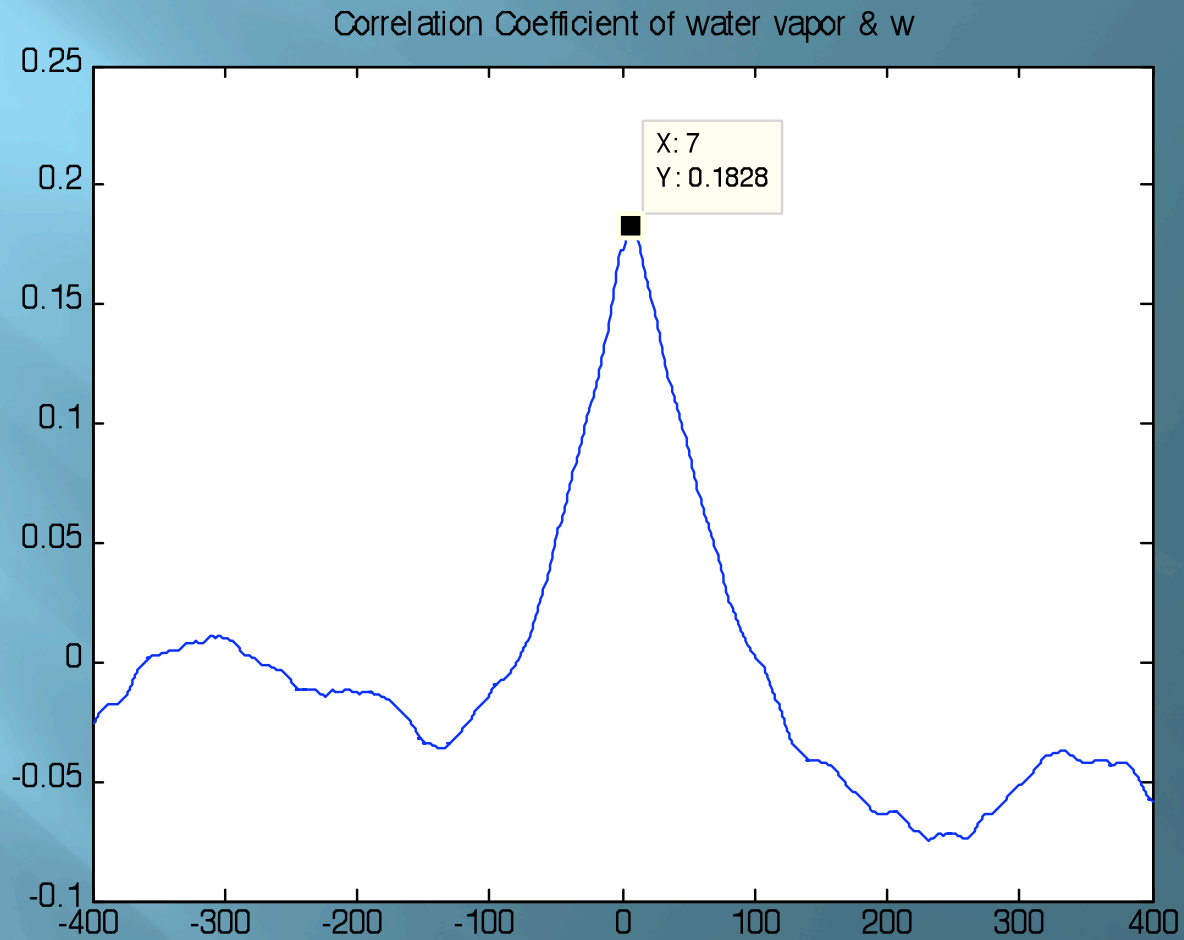
Water vapor spectrum shows 6 hz spike discovered by RAF team

Co-spectrum of q and w



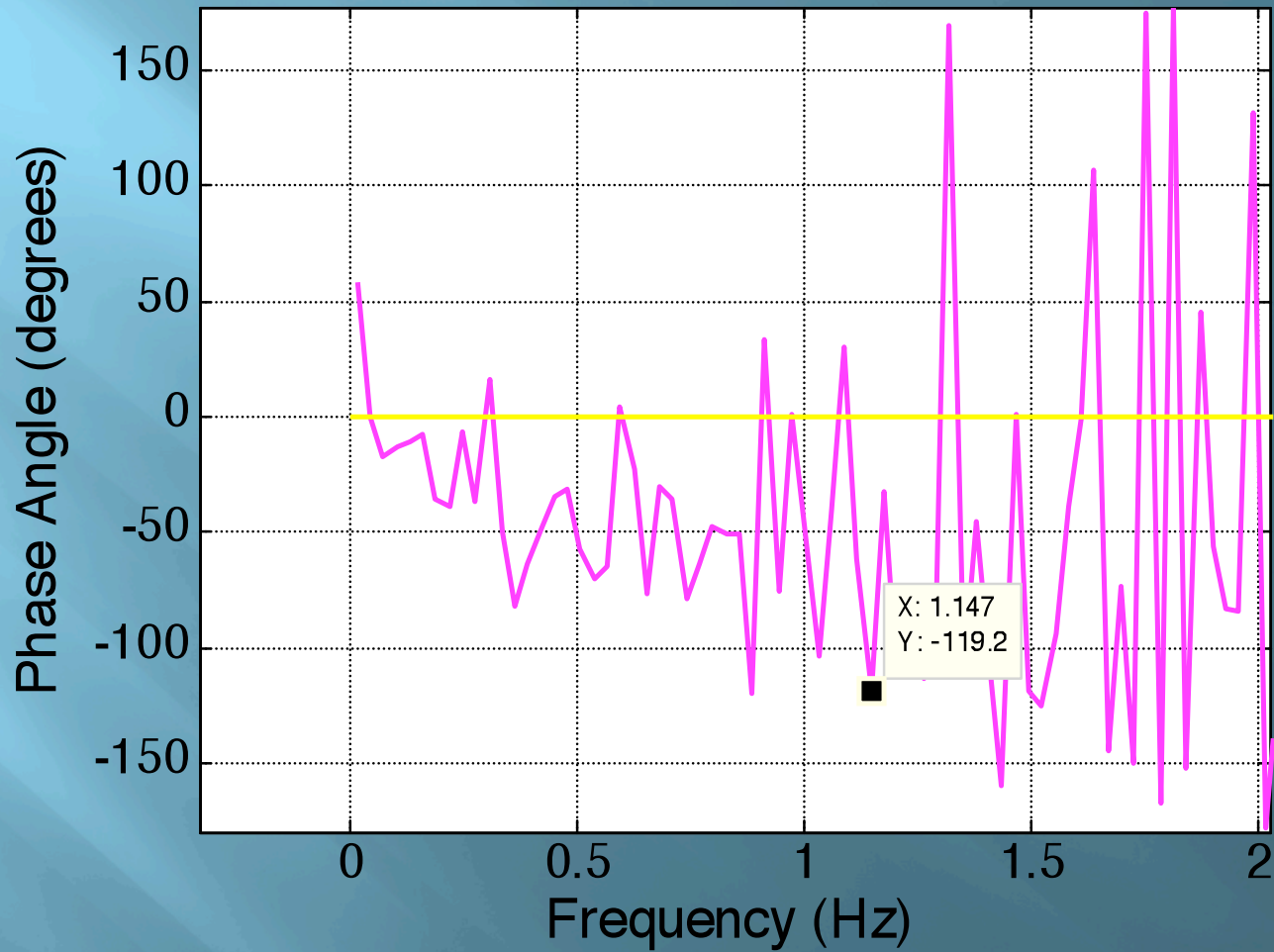
Area under curve (proportional to flux) drops to near zero by 2 hz

RF02/TBL1 Correlation Coefficient



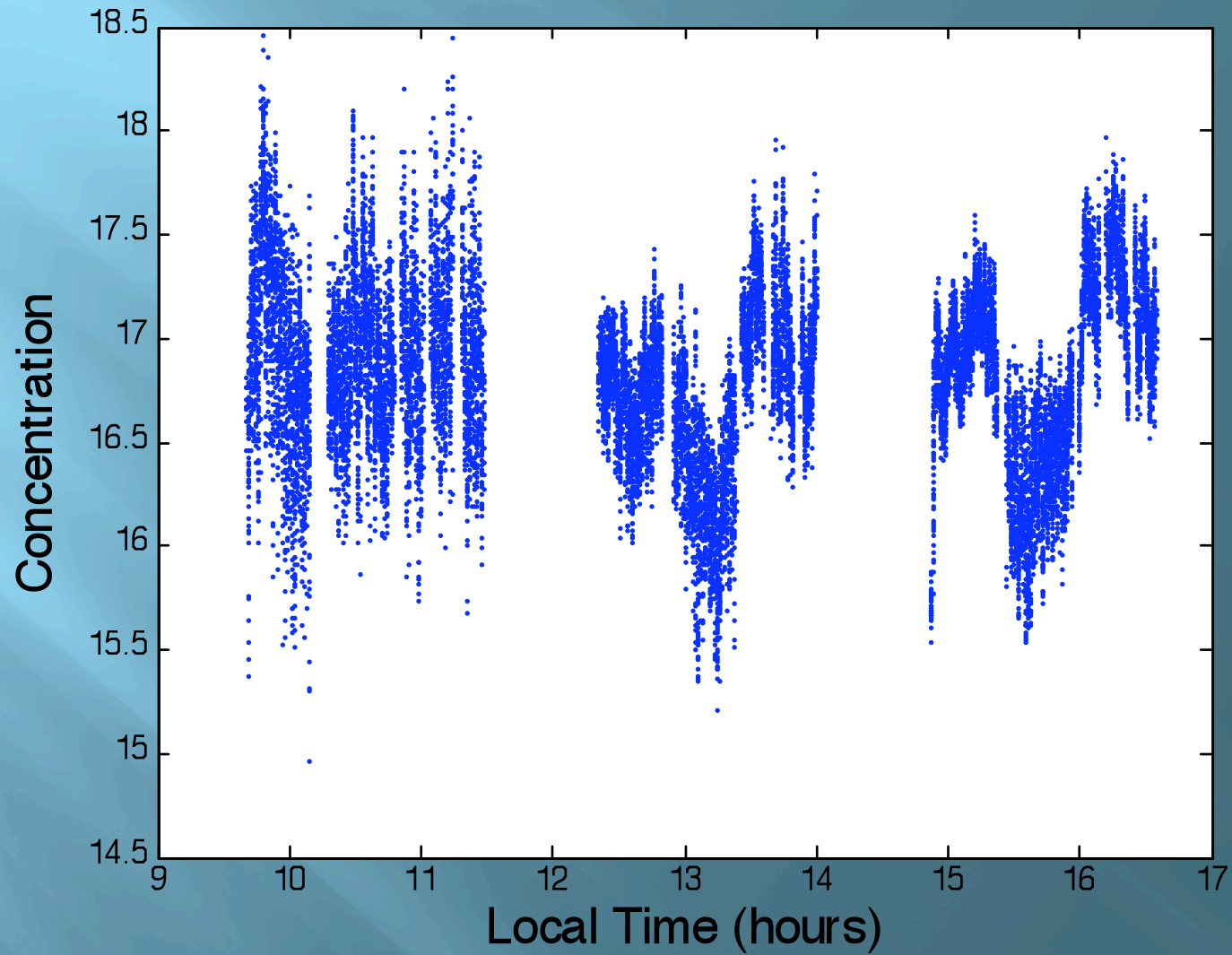
Optimum Lag Value = 7 samples

Phase Angle Spectrum of q and w

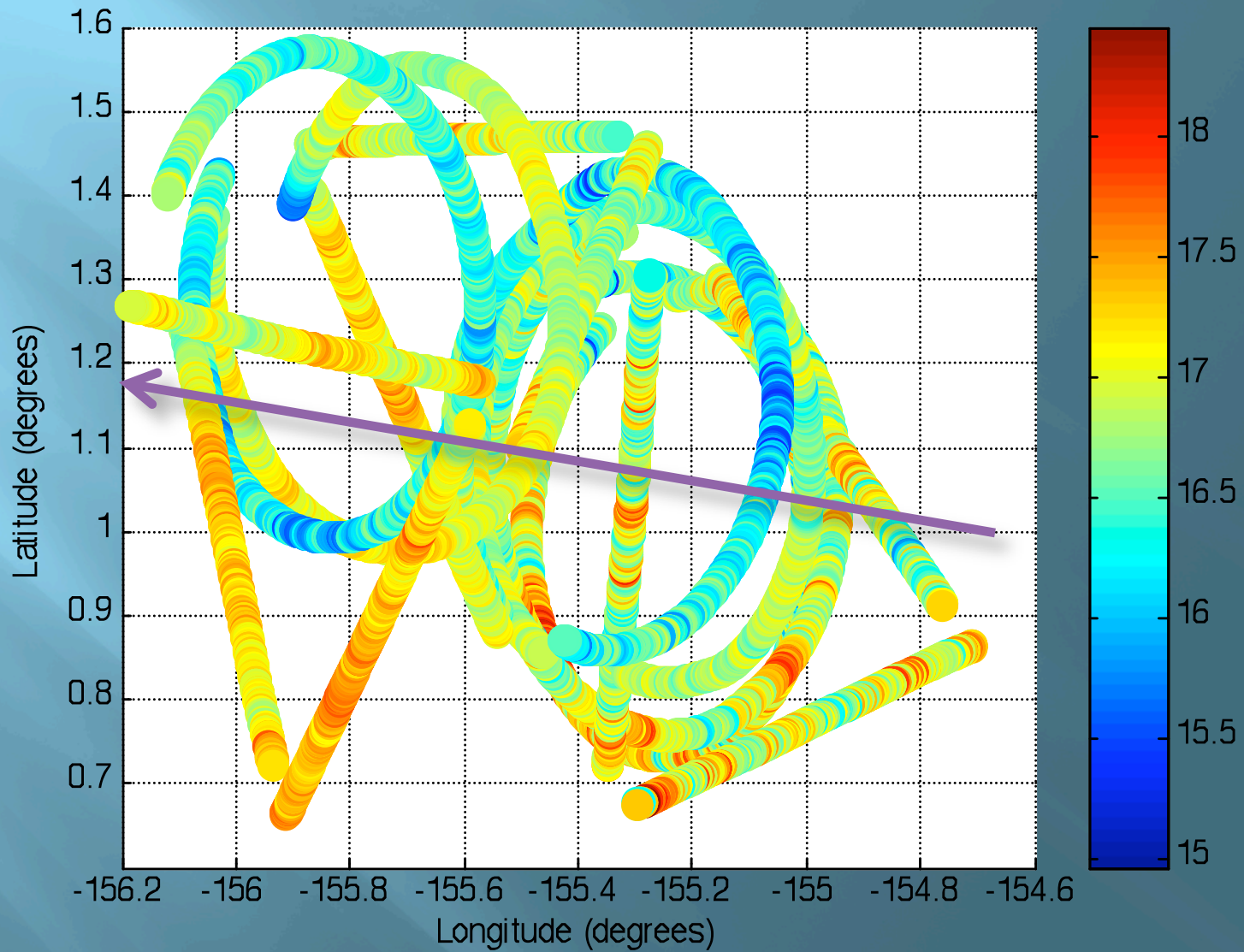


$$\text{Lag} = 119/360/1.147*25=7 \text{ samples}$$

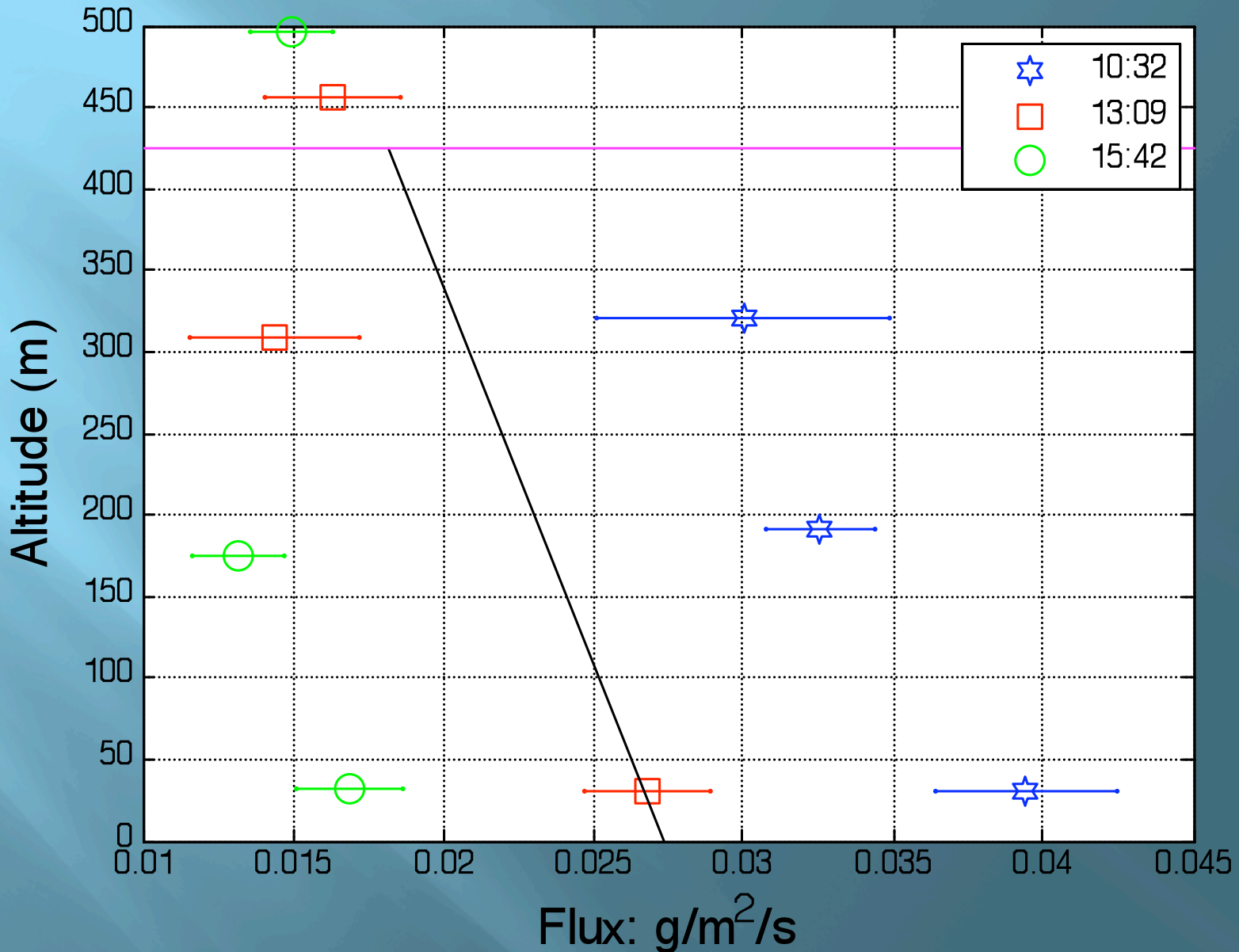
Water Vapor



Horizontal Gradient



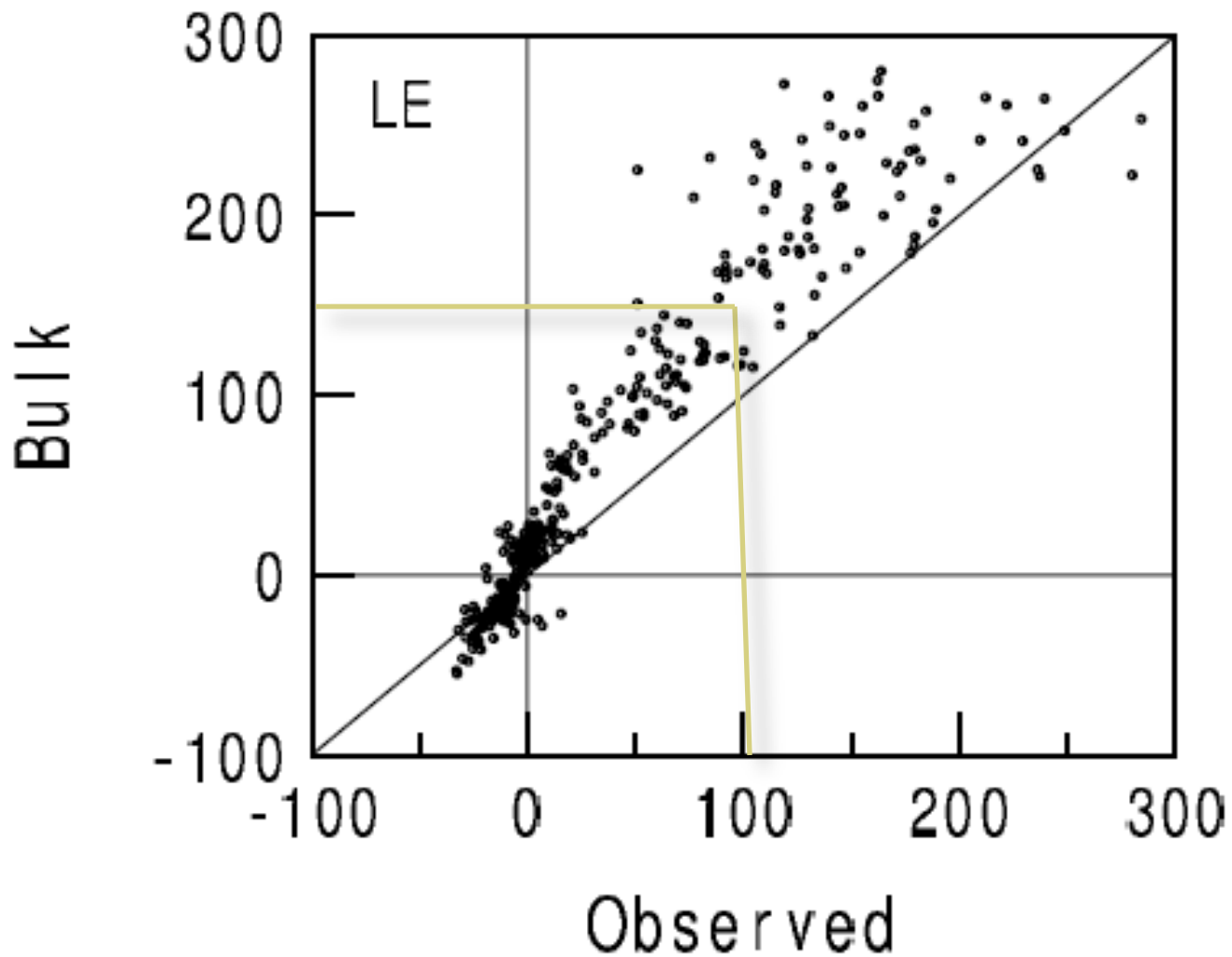
RF02 Water Vapor Flux



Compared to Bulk Estimate

RF	T °C	SST °C	Bulk Moisture Flux w/m ²	Measured Moisture Flux w/m ²
1	26.1	27.6	114.0	49.6
2	26.1	27.8	141.6	78.2
3	25.8	27.5	162.8	106.9
5	25.7	25.3	130.7	135.8
6	25.2	25.5	110.7	71.2
7	26.4	27.5	189.0	176.0
8	26.3	27.6	172.5	76.6
11	26.0	27.2	178.9	168.3
12	25.5	26.3	144.7	72.5
13	25.7	25.7	152.3	105.1
14	25.4	25.2	119.3	81.5
	25.8	26.7	147.0	102.0

Vickers & Mahrt (JGR 2006)



Water Vapor Issues

- ▣ Water vapor flux 30% less than Fairall bulk estimate. Not the first time.
- ▣ Unexplained spike at 6 hz. Appears insignificant to fluxes.
- ▣ TDL data not yet available