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Ozone Radiometry at Lauder, New Zealand and Mauna Loa, Hawaii

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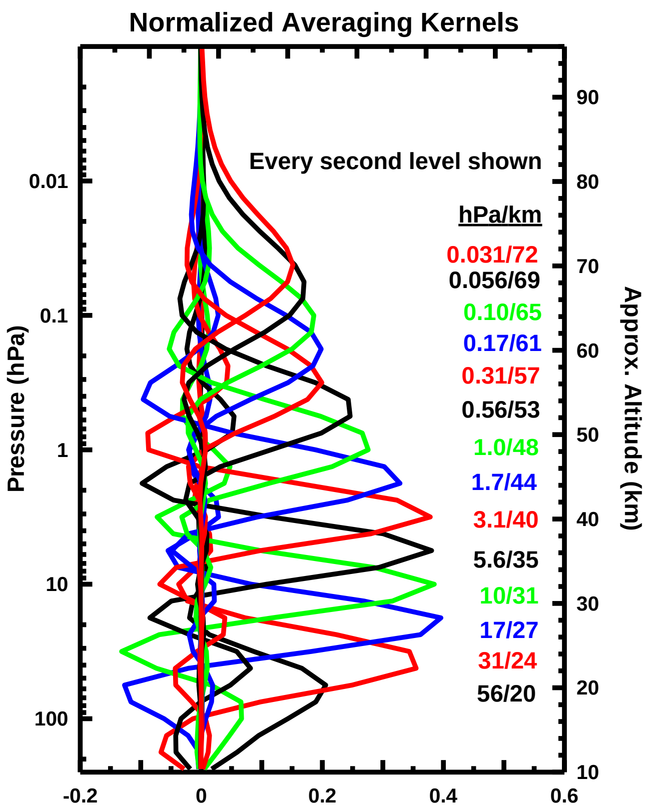
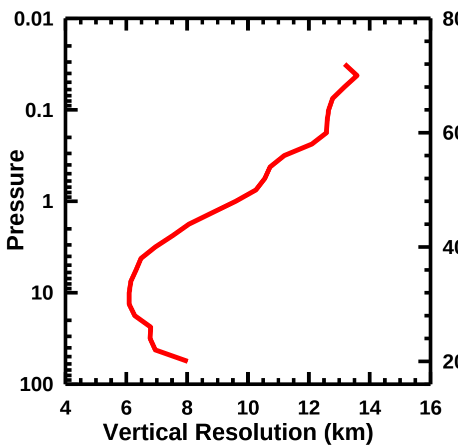
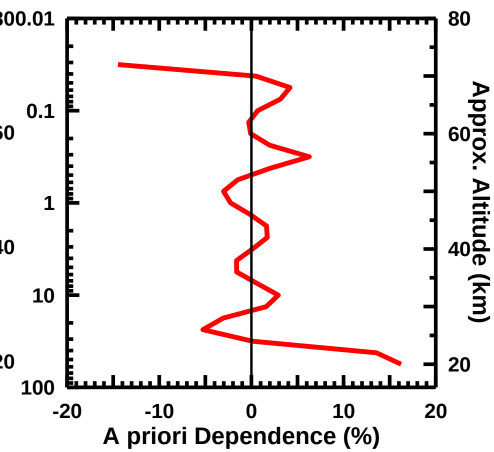
TECHNIQUE AND MEASUREMENT CHARACTERISTICS



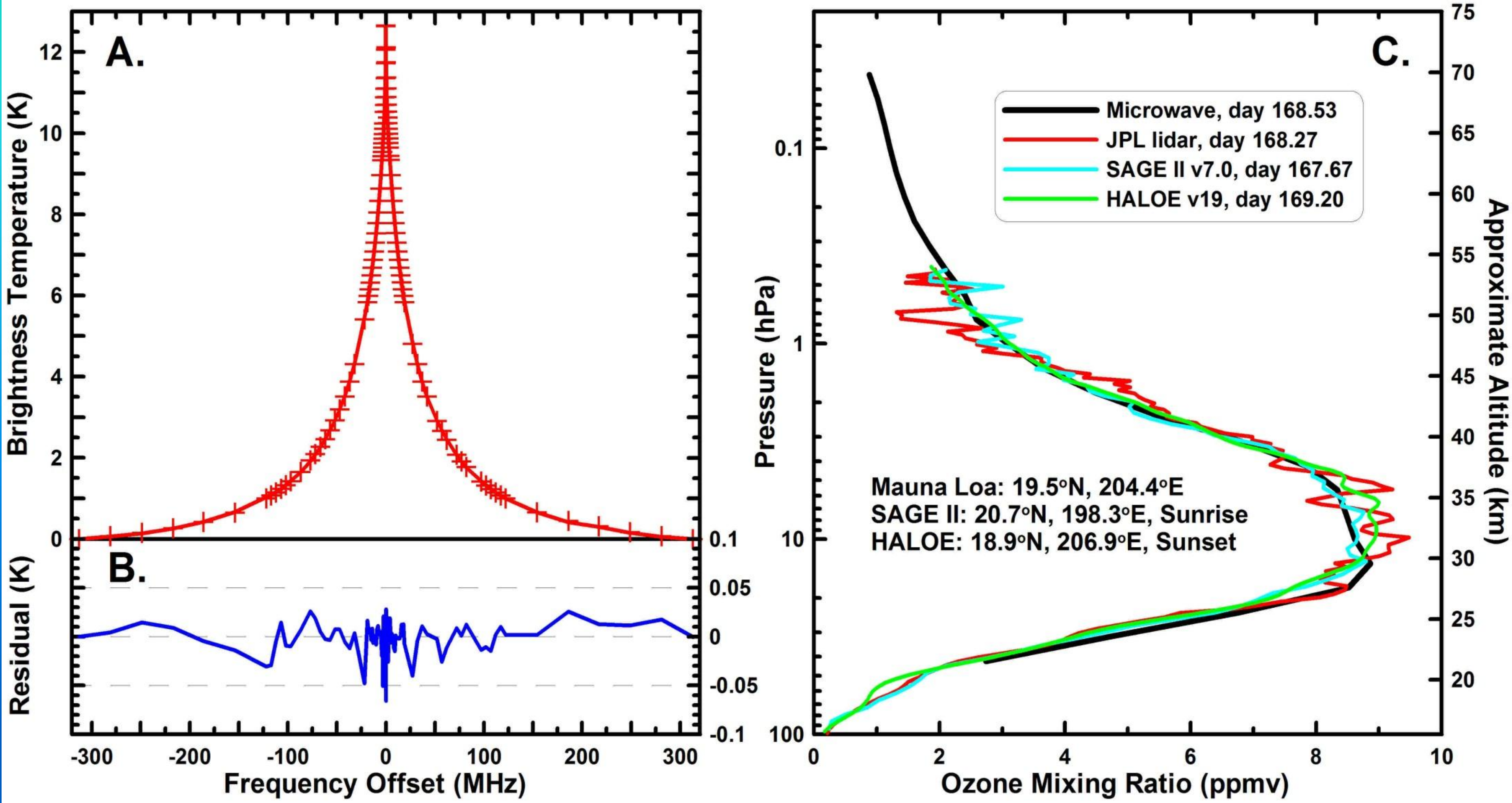




Profiles retrieved from the pressure-broadened ozone line shape using the Rodgers Optimal Estimation technique

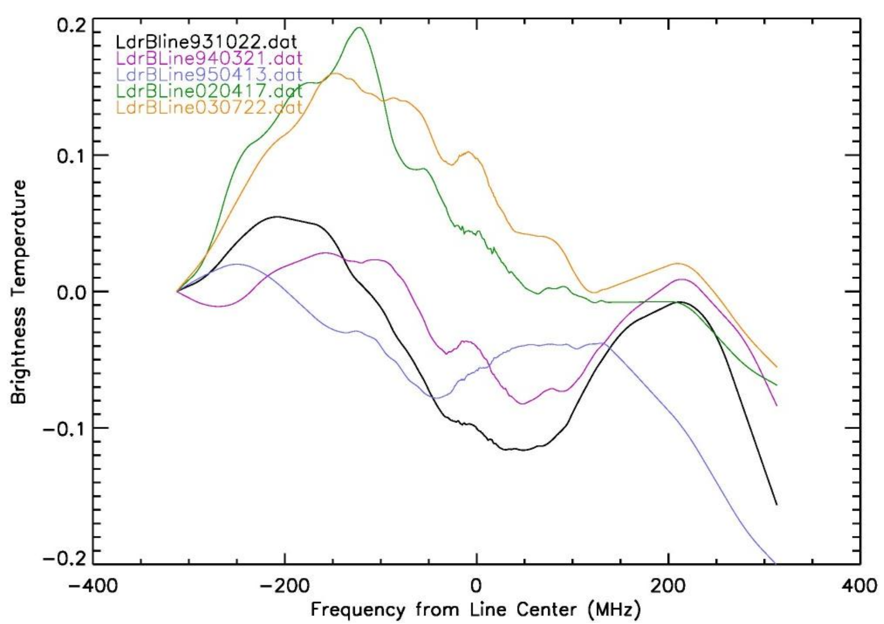
- **Measuring the ozone emission line at 110.836 GHz**
- **Vertical Resolution: 6-10 km, 56-0.8 hPa, (~20-50 km), 13 km at 0.1 hPa**
- **A priori Dependence: < 6%, 32-0.04 hPa (~24-70 km), up to 16% at top and bottom of usable profile**
- **Expected Precision: 4-5% 56-0.3 hPa (~20-57 km), 7% at 0.1 hPa (~64 km)**
- **Expected Accuracy: 6-9% 56-0.3 hPa (~20-57 km), 11% at 0.1 hPa**
- **Usable Range: 56-0.07 hPa (~20-66 km) for day-time; 56-0.03 hPa (~20-72 km) for night-time**
- **Lauder: October 1992 to current day**
- **Mauna Loa: July 1995 to current day**

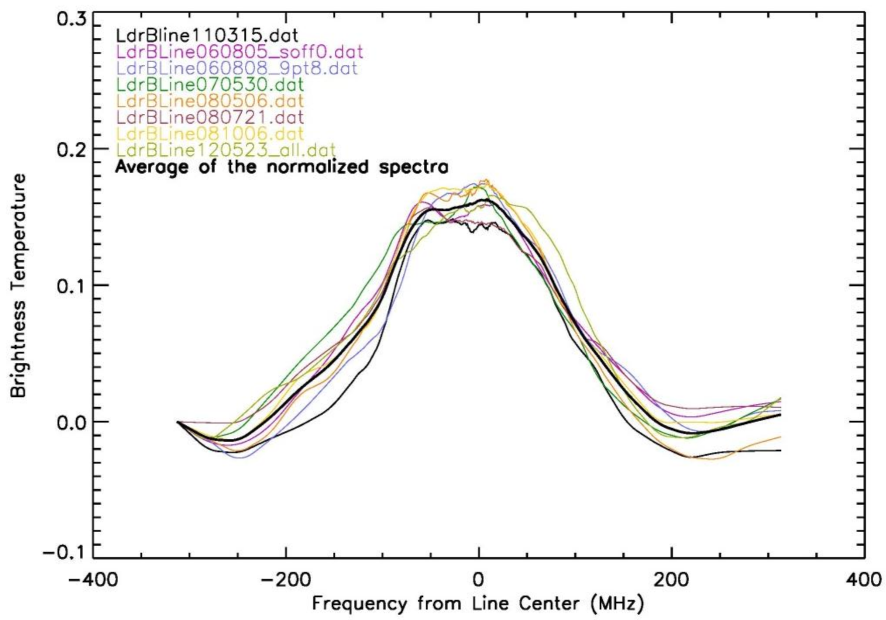
EXAMPLE SPECTRUM AND PROFILE FROM MAUNA LOA



Panel A: Night-time spectrum recorded June 18, 1999 at Mauna Loa using the microwave instrument (+ signs) superimposed on a spectrum calculated from the retrieved ozone profile. Panel B: Difference between measured and model spectra. Panel C: Ozone profile retrieved from the spectrum. Profiles from the co-located JPL lidar, a SAGE II overpass and a HALOE overpass all made within 24 hours of the microwave measurement are also shown.

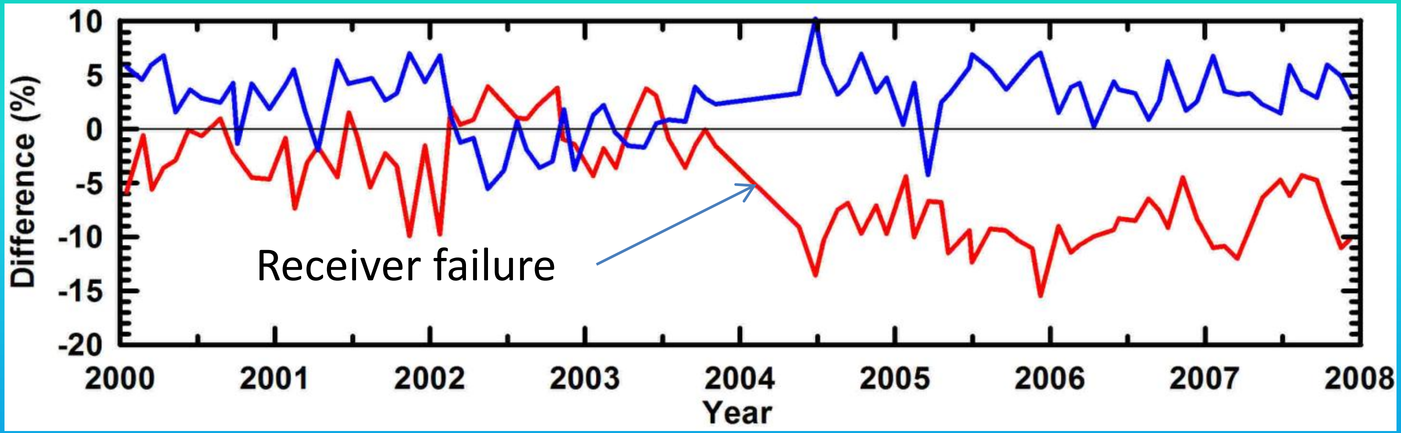
FRONT-END: CORRECTIONS FOR BASELINE





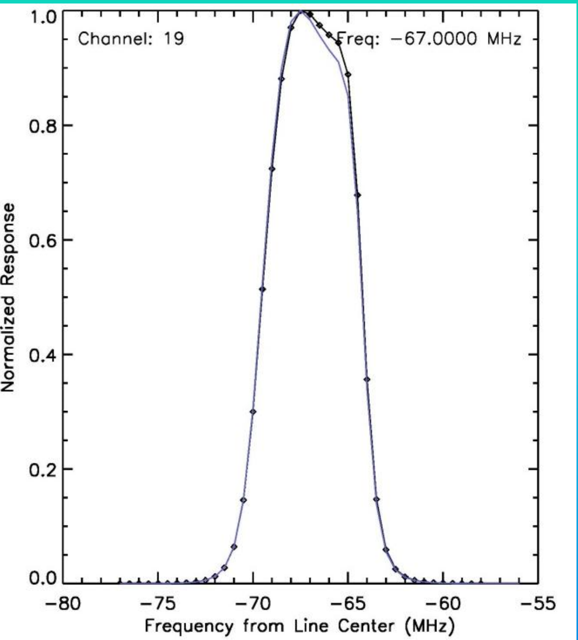
- *Standing waves in the receiver dewar make the antenna pattern frequency dependent*
- *The tropospheric thermal emission is ~[(1/sin(elevation angle)]*
- *The convolution of the frequency-dependent antenna pattern with the angle-dependent tropospheric emission produces artifacts in the measured spectrum*
- *By reconfiguring the instrument, we can measure the spectrum of the baseline artifact*
- *Plots show baseline measurements made with the Lauder MWR since 1993*
- *Some variability in early period. Large gap between 1995 and 2002 – need to estimate baseline transition during this period*
- *Consistent baseline characteristics since 2004. Change between 2003 and 2004 due to receiver repair*

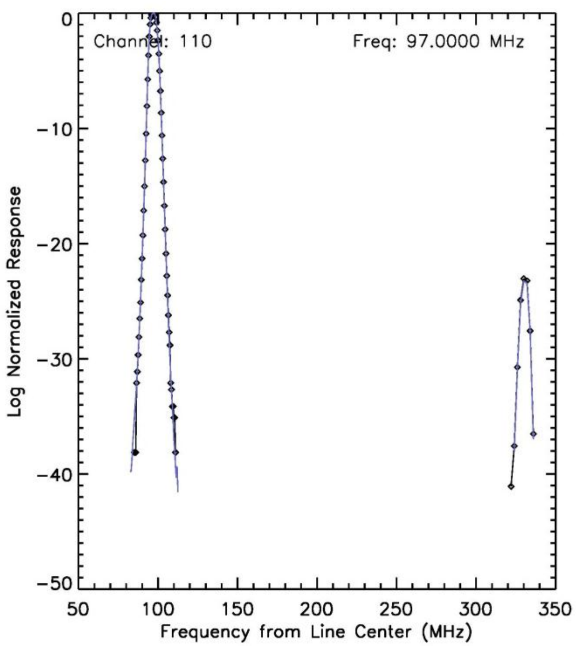
EFFECT OF APPLYING BASELINE CORRECTIONS ON RETRIEVALS BEFORE AND AFTER RECEIVER REPAIR



- ***Plot shows time-series of RIVM Lidar – MWR monthly averaged ozone profile differences at 32 hPa (~26 km) between 2000 and 2008***
- ***Blue – with baseline corrections applied to the MWR spectra***
- ***Red – No baseline corrections applied; 7-8% step in the time-series after repair of receiver in 2004!***
- ***Blue line shows dip between 2002 and 2003, not related to baseline (possibly due to change in the filter response characteristics that have not been correctly accounted for)***

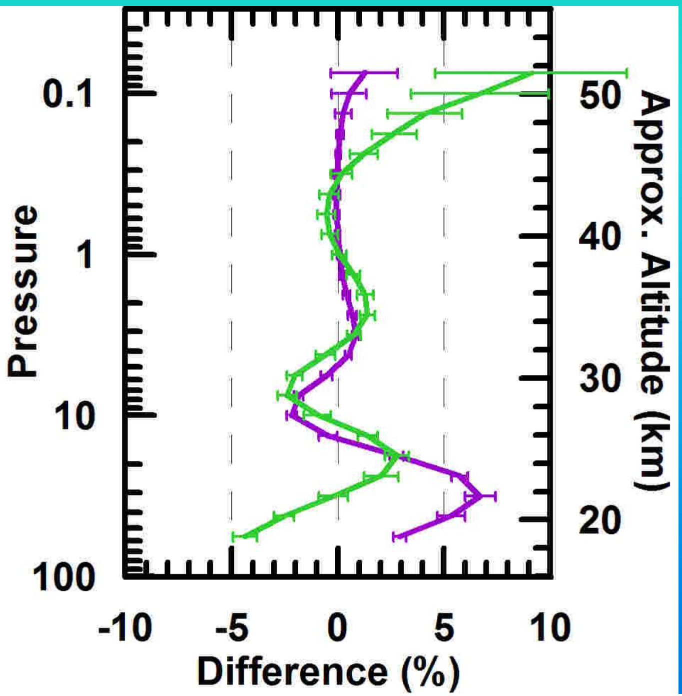
BACK-END: MEASUREMENT OF FILTER FUNCTIONS





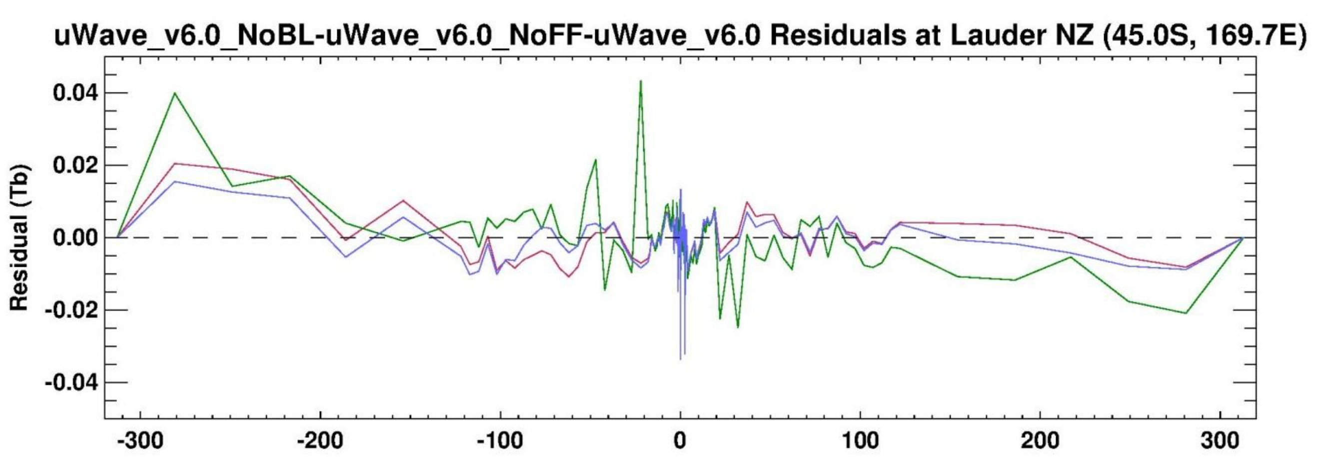
- ***Spectrometer consists of 120 discrete, non-ideal filters. We convolve measured responses of the filters with a typical ozone spectrum to derive filter function corrections, which are the order of 1%***
- ***Mostly responses do not change significantly with time, however during the lifetime of the instruments we have repaired or replaced filters. In the process of disturbing the spectrometer responses can also change***
- ***Bottom plot shows the presence of image responses in some channels, which must also be accounted for***

EFFECTS OF APPLYING MEASURED CORRECTIONS ON THE RETRIEVAL – LAUDER, JANUARY 2012

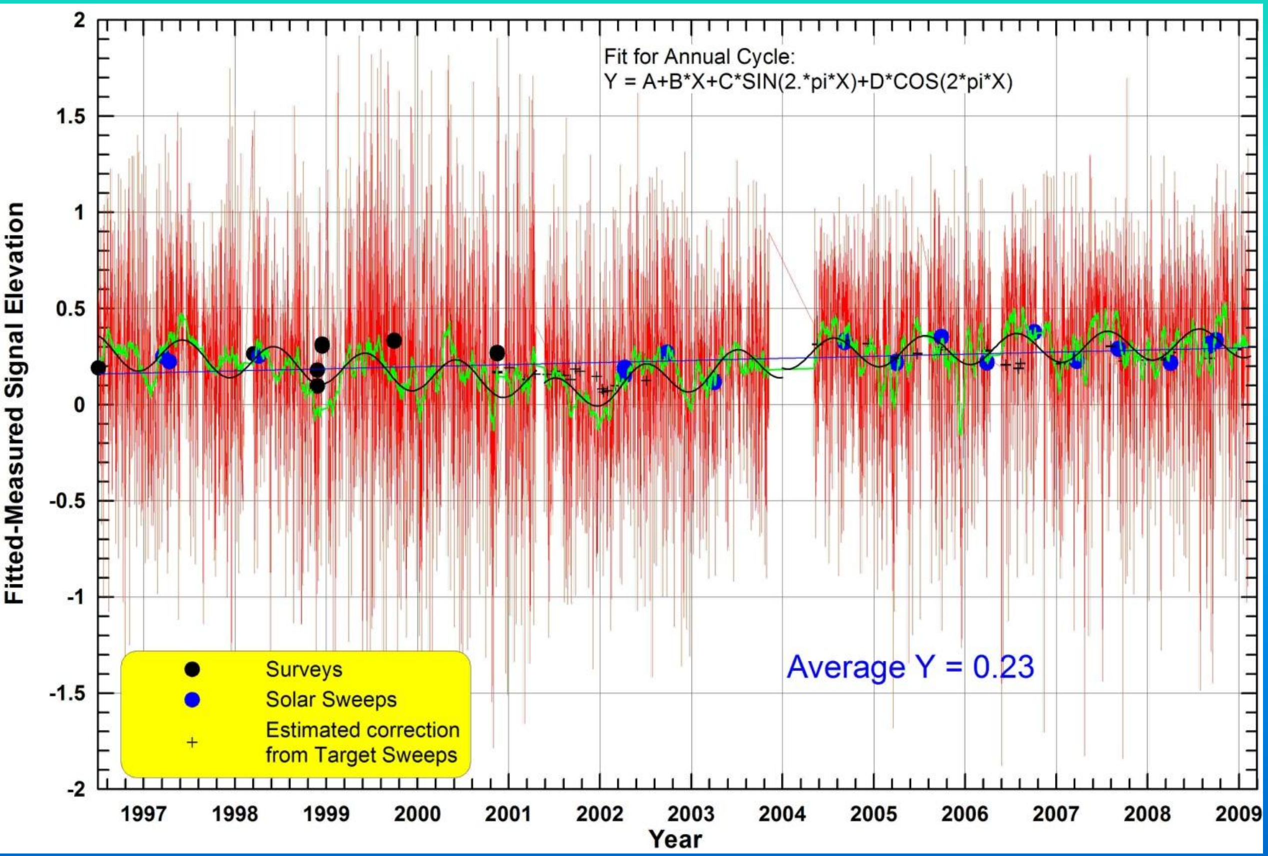


- *Left Panel: Plot shows differences between non-corrected and corrected (standard) MWR ozone retrievals*
- *Purple profile is No Baseline-Standard; Green profile is No Filter Functions-Standard*
- *Baseline error effects lower part of profile*

- *Bottom Panel: Plot shows averaged residuals in each configuration*
- *Purple = NoBL; Green = NoFF; Blue = Standard*



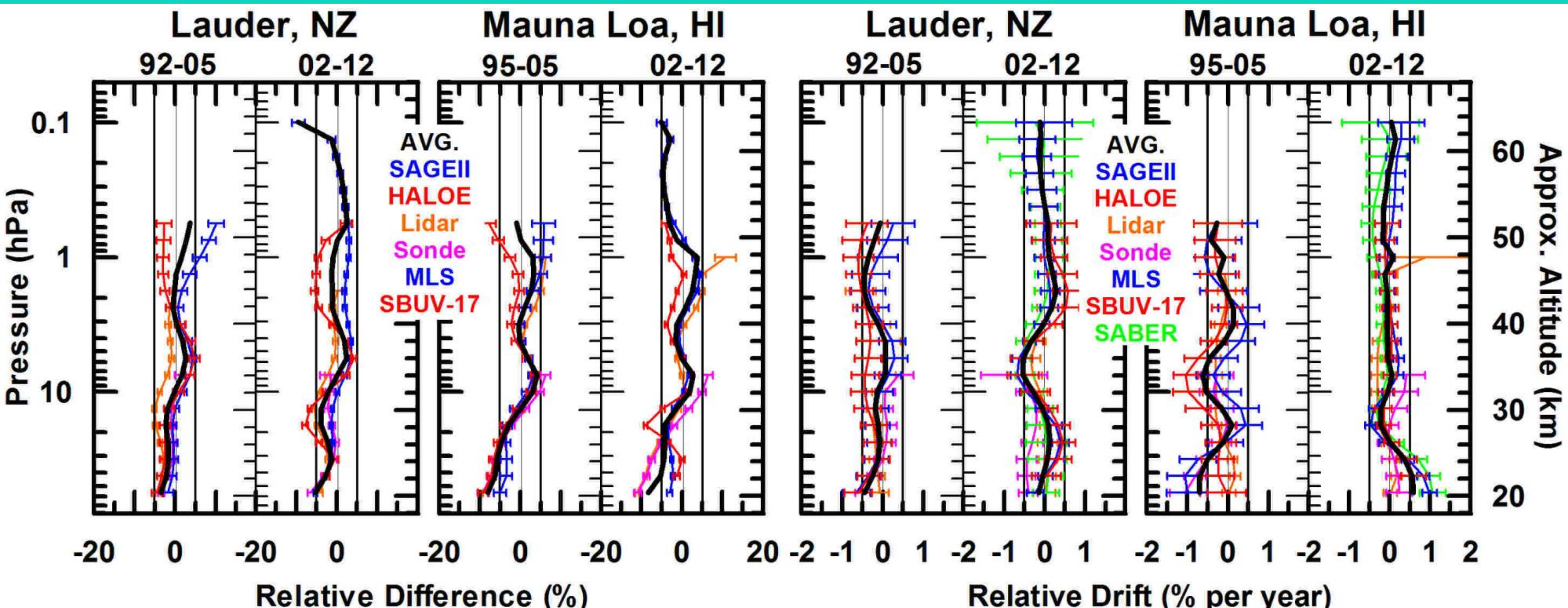
MEASURING ERROR IN SIGNAL ELEVATION



- *Error of 0.1^o in the signal elevation = ~ 1% change to the retrieval*
- *Instrument at Lauder points WNW so we can calibrate on the sun around equinoxes (blue circles)*
- *Can also survey instrument position in relation to target (black circles)*
- *Third method is to use the calibration software to fit for signal elevation (red lines)*

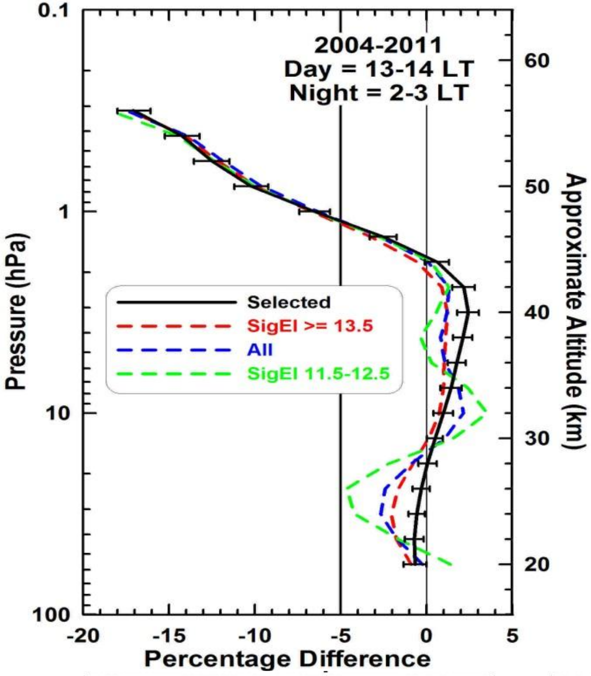
- *Fitted method is noisy, however after smoothing there is good agreement with calibration measurements. Green line is a running average of the fit data; black line shows annual cycle fit*
- *Both the solar sweeps and the fitted data support the premise that there is an annual cycle in the signal elevation offset at Lauder with ~0.2^o amplitude*

PUT IT ALL TOGETHER …



- *Plots show relative differences and drifts between MWRs and other datasets over two periods. Black profiles are averages of the individual instrument profiles*
- *First period (9x-05) compares MWR with Lidar, Sonde, SAGEII, and HALOE. Second period (02-12) compares MWR with Lidar, Sonde, MLS, SBUV-17, and SABER (drift only)*
- *Relative differences mostly within 5%. Averaged profiles are in good agreement over the two periods*
- *Relative drifts mostly within 0.5%/year, and often within 0.2%/year and insignificant. Some features (e.g. Lauder 02-12 at 7 hPa), indicate issue with MWR*

HOWEVER – SOME SYSTEMATIC ISSUES STILL PRESENT: MAUNA LOA

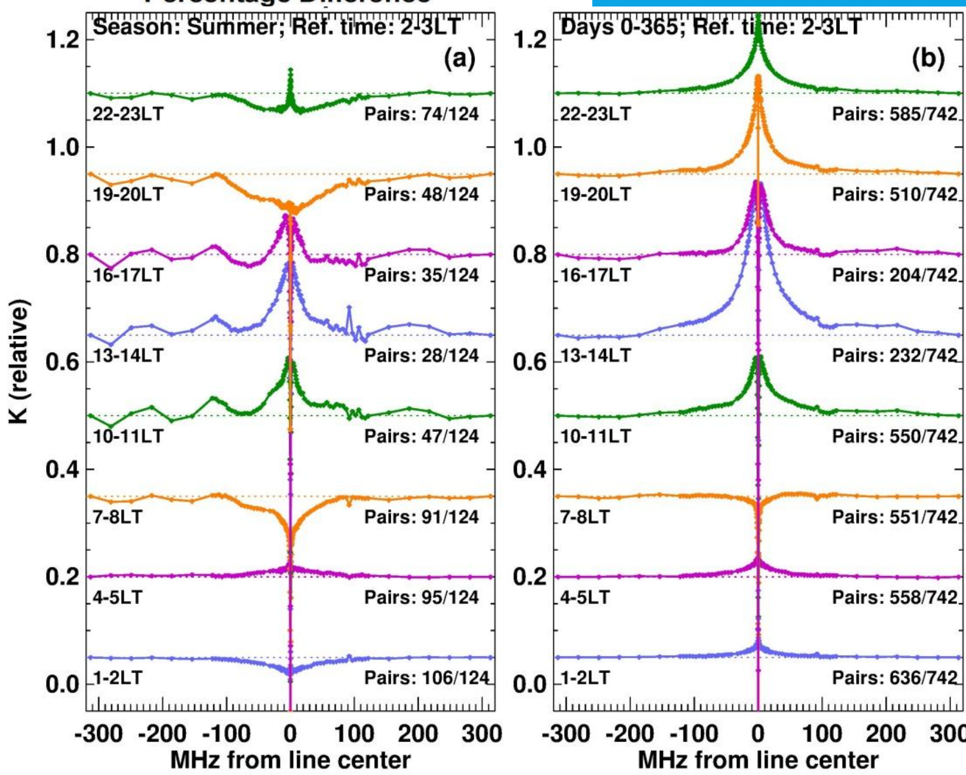


Ripple in the retrieval is a typical effect of systematic measurement errors. We identified two issues:

1. Profile dependence on line-of-sight elevation angle

a) Top Panel: Red and green show results of selecting higher and lower angles

b) Amplitude of systematic errors in difference spectra (bottom left panel) increases at lower angle



2. Diurnal variation In building temperature

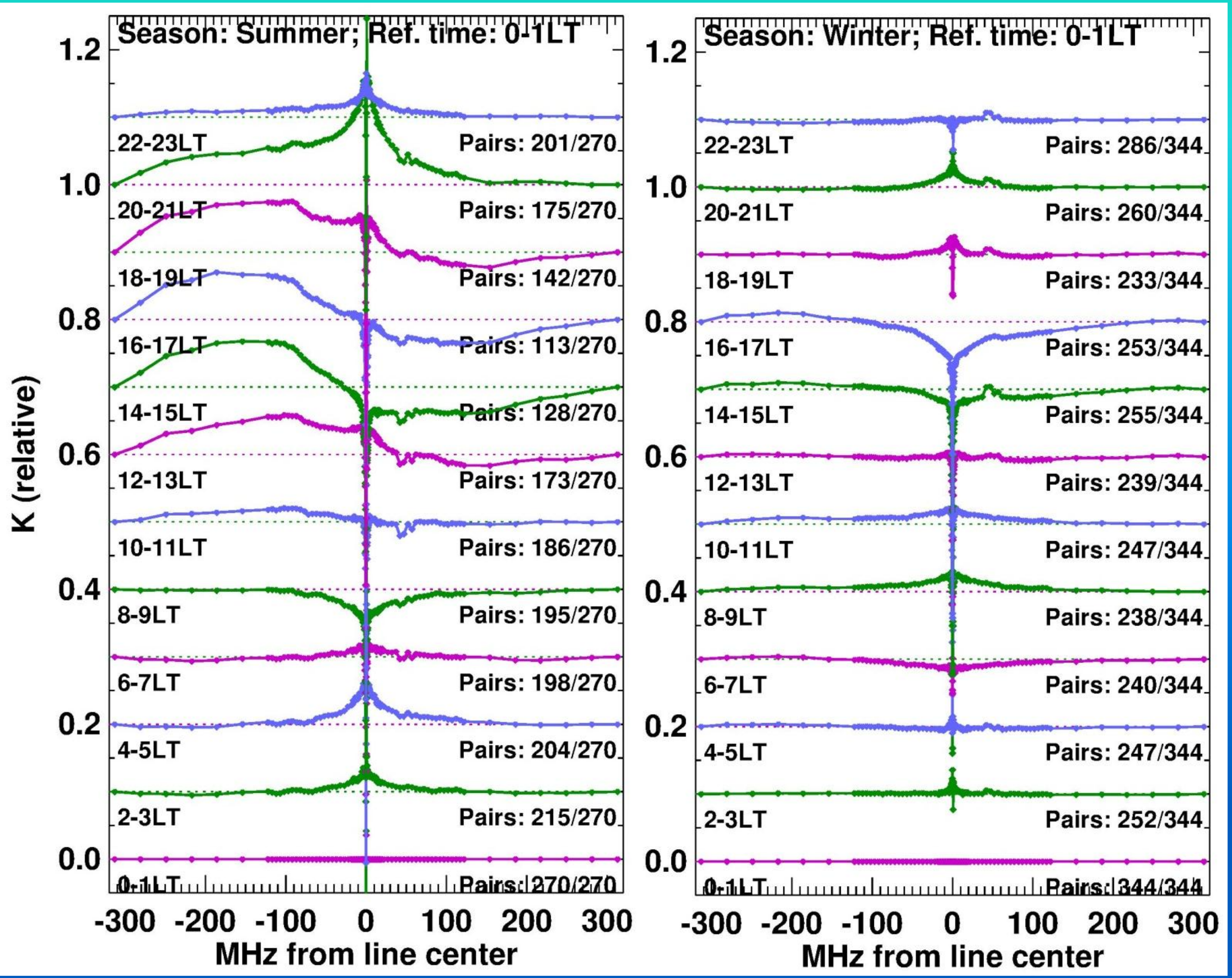
Black profile in top panel and the bottom right spectral plots show result of using only data that meet 2 criteria:

1) Elevation angle ≥ 13.5 deg.

2) Building temp. within ± 2.5 C

Difference between All (Blue) and selected data in the top panel is < 1.3% above 10 hPa and ~2% at 30 hPa

LAUDER



- *Plot shows hourly averaged differences between normalized spectra and spectra taken at a reference time (12-13z = 00-01LT)*
- *Left panel: Summer months, shows systematic spectral effects in the afternoon and evening*
- *Right panel: Winter months, shows only small systematic effects through the day*