Past Changes in the Vertical Distribution of Ozone Geneva, January 25th–27th 2011

Ground-based NDACC Microwave Observations of Ozone Profiles at Mauna Loa: The Version 6 Dataset

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INTRODUCTION

- We retrieve ozone profiles from measurements of the spectra of a rotational ozone transition at 110.8 GHz. Measurements at MLO began in July 1995, and are ongoing, with a few minor gaps

- We present here Version 6 (v6) of our data

  1 hour time resolution (> 80 K profiles)

  Attempt to account for measurement errors more accurately

- Review of the measurement characteristics

- Diurnal variations that can be seen with hourly resolution

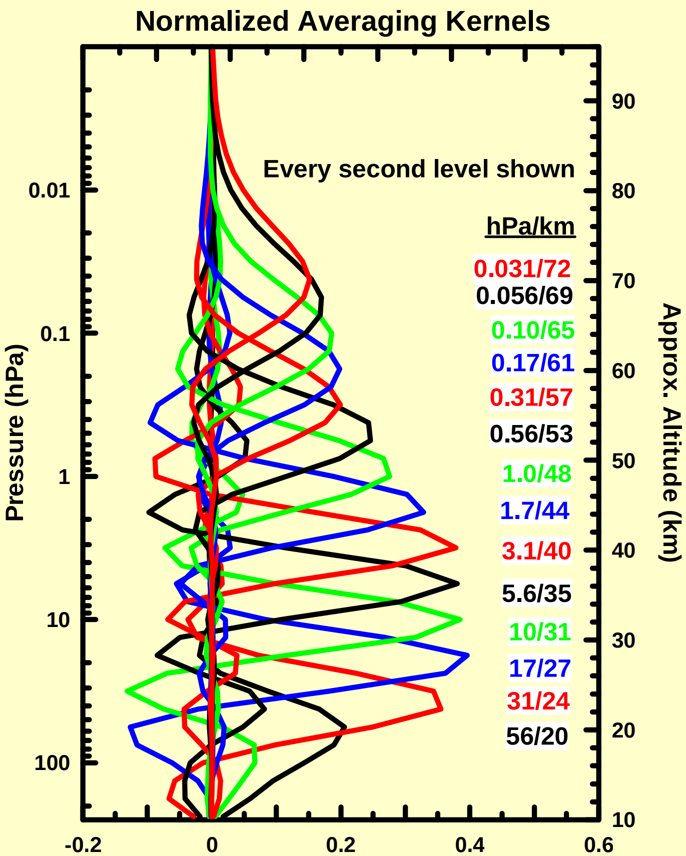
- Internal consistency and validation of the new version, and how it improves on the previous version, considering:

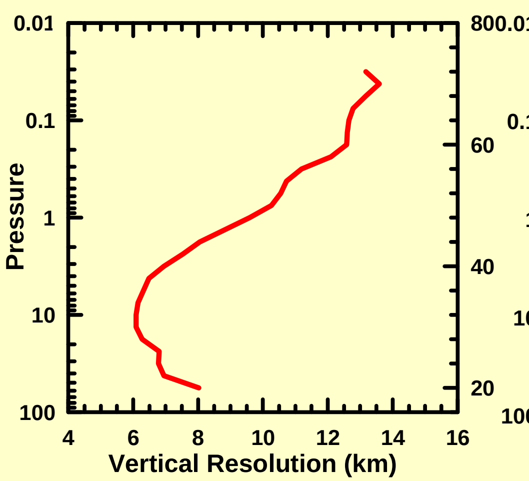
  Average differences when compared to other profiles

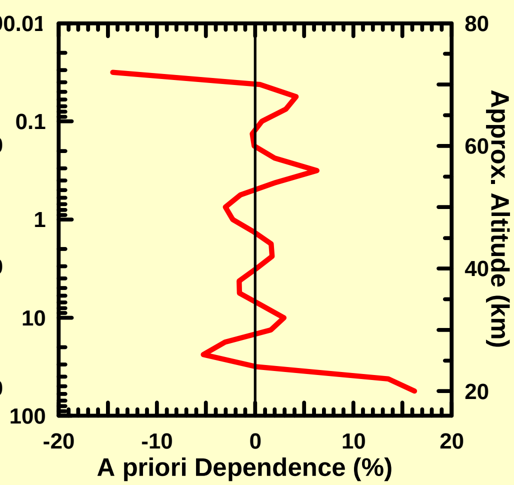
  Offsets that may occur when repairs have been made to the instrument

  Relative trends derived from comparisons of our measurements with those from other instruments

TECHNIQUE AND MEASUREMENT CHARACTERISTICS





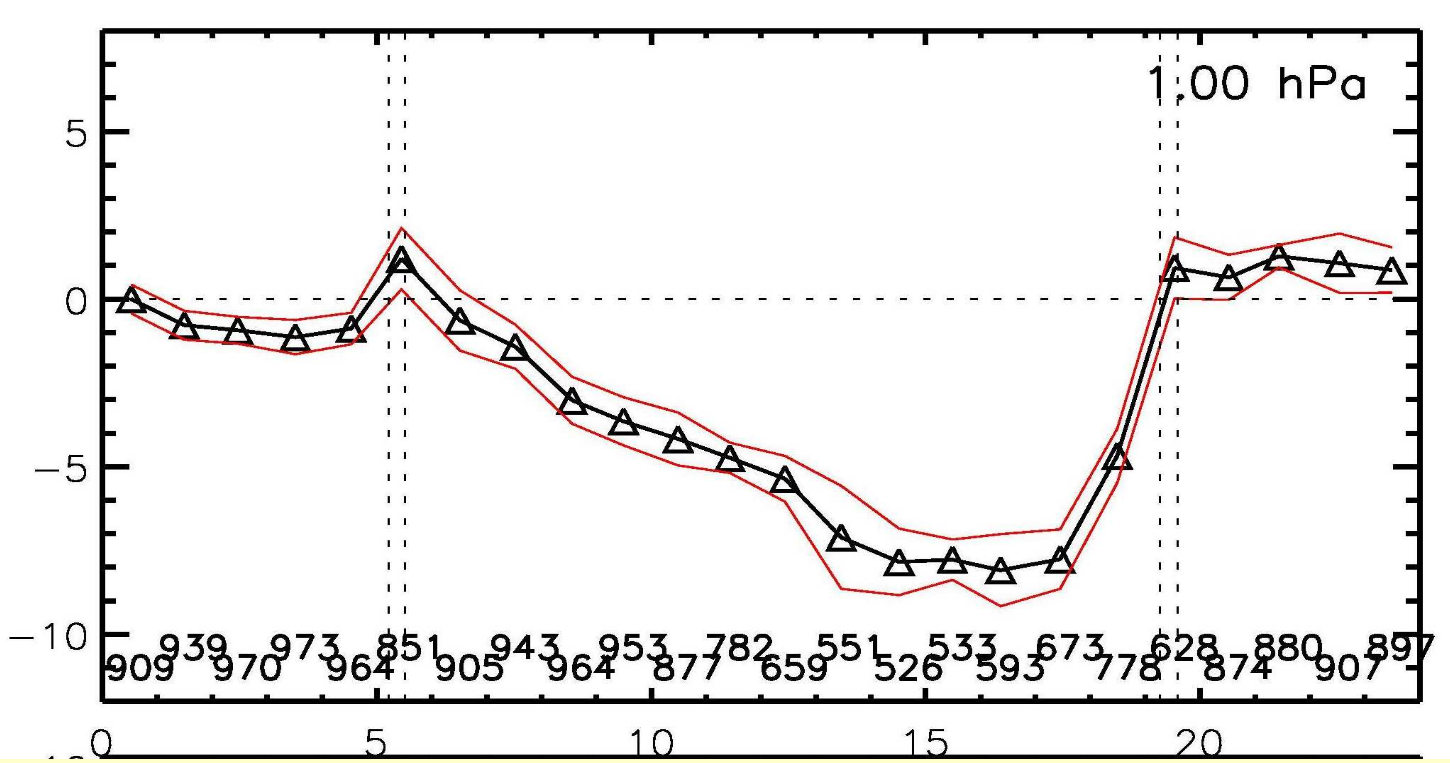


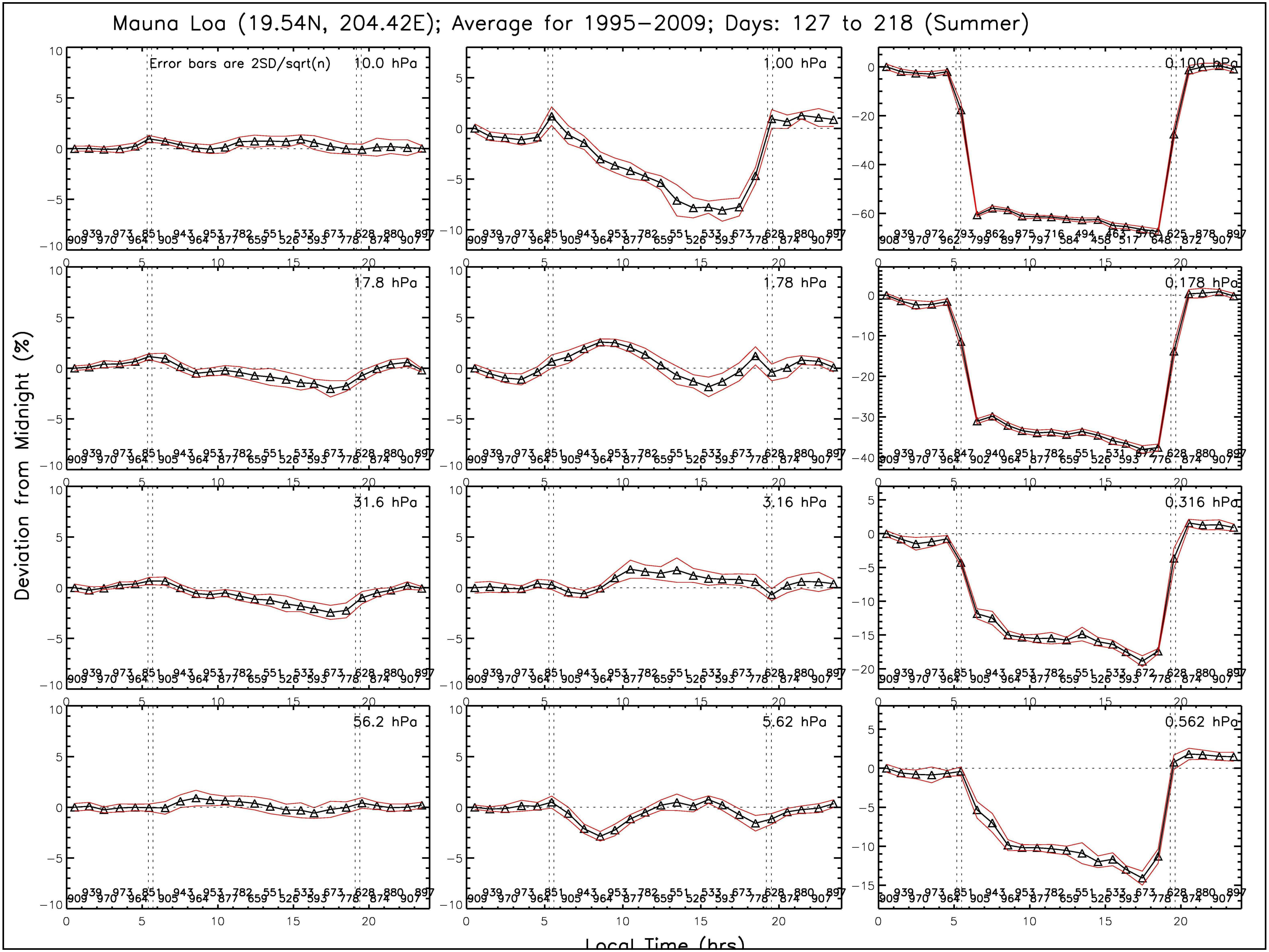
Profiles retrieved from the pressure-broadened ozone line shape using the Rodgers Optimal Estimation technique

- **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**
- **v5.0 – currently on NDACC and AVDC; v6.0 (MIO) to be uploaded shortly**

DIURNAL OZONE VARIATIONS AT MLO

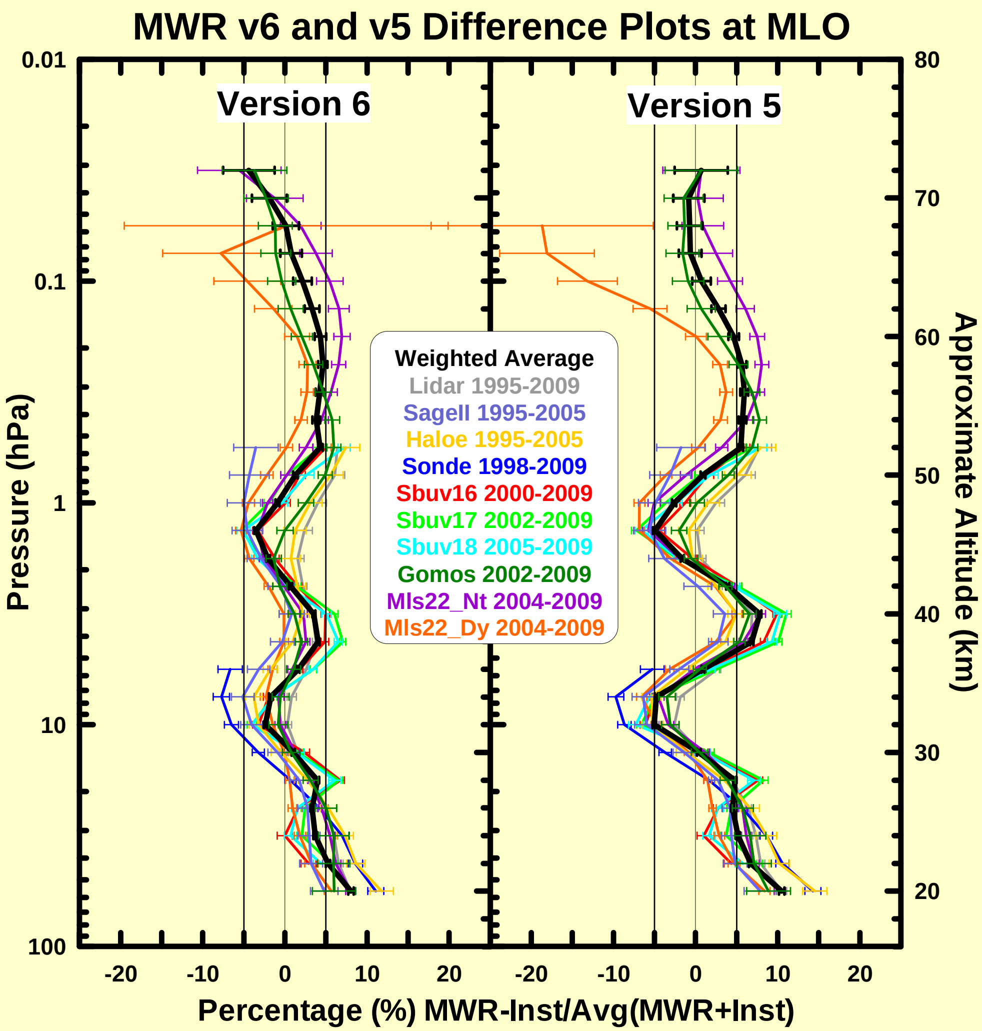
- New v6 hourly retrievals are useful for accounting for *e.g.* orbit drift in satellite measurements
- Data binned hourly and averaged from 1995-2009
- y-axis: Percentage deviation from midnight value; x-axis: Local time
- Vertical lines show ranges of sunrise and sunset times
- Red lines show uncertainties defined as $2\sigma/\sqrt{n}$
- Further details are in the Boyd, *et al.* poster presented at this meeting





Mauna Loa (19.54N, 204.42E); Average for 1995–2009; Days: 127 to 218 (Summer)
Error bars are 2SD/sqrt(n)
10.0 hPa
17.8 hPa
31.6 hPa
56.2 hPa
1.00 hPa
1.78 hPa
3.16 hPa
5.62 hPa
0.100 hPa
0.178 hPa
0.316 hPa
0.562 hPa
Deviation from Midnight (%)
Local Time (hrs)

ESTIMATE OF ABSOLUTE ERRORS IN MLO MICROWAVE OZONE PROFILES



- Thick black line is a weighted average of difference profiles from 10 comparisons
- Contribution of each comparison to the average is weighted in inverse proportion to its variance
- x-axis is % difference; y-axes are pressure and approximate altitude
- Vertical lines are at ±5% for reference
- Oscillatory nature of the difference profiles is reduced in v6
- Peak-to-peak variations in v6 mostly ~30% smaller than in v5
- Average differences less than 5% above 42 hPa in v6
- Plots shown later will be in this form

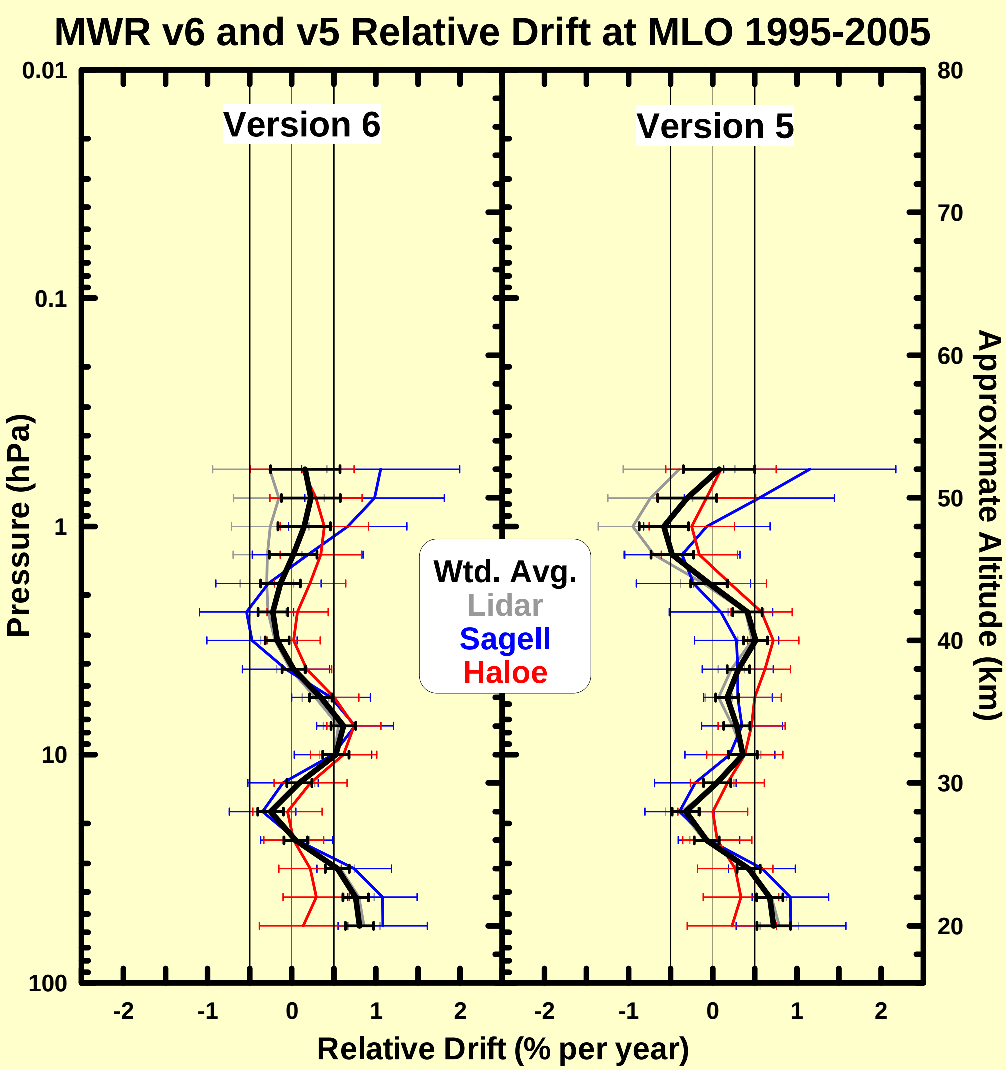
INTERNAL SELF-CONSISTENCY OF THE DATA

- **The same instrument has been used essentially unchanged throughout this series of measurements, except for necessary repairs**
- **We are confident of the basic intensity calibration of our measurements:**
  - Tropospheric attenuation and receiver noise measurements are referenced to black body sources with well-calibrated temperatures
  - Calibration measurements are made automatically each hour, and checked against measurements made manually several times each week
  - Observing geometry has been measured two different ways and is well understood
- **Processing protocols are uniform throughout each individual version of the data**
- **Comparisons with JPL lidar temperature measurements show that composite temperature profiles used in v6 processing are improved**
- **Trend errors, caused by spectral errors that change slowly or when the instrument is repaired, are an issue:**
  - We attempt to account for this using an instrument model supported by physical measurements
  - We believe we've done a better job of this in version 6 than in version 5

EVALUATION OF DRIFT IN MICROWAVE MEASUREMENTS

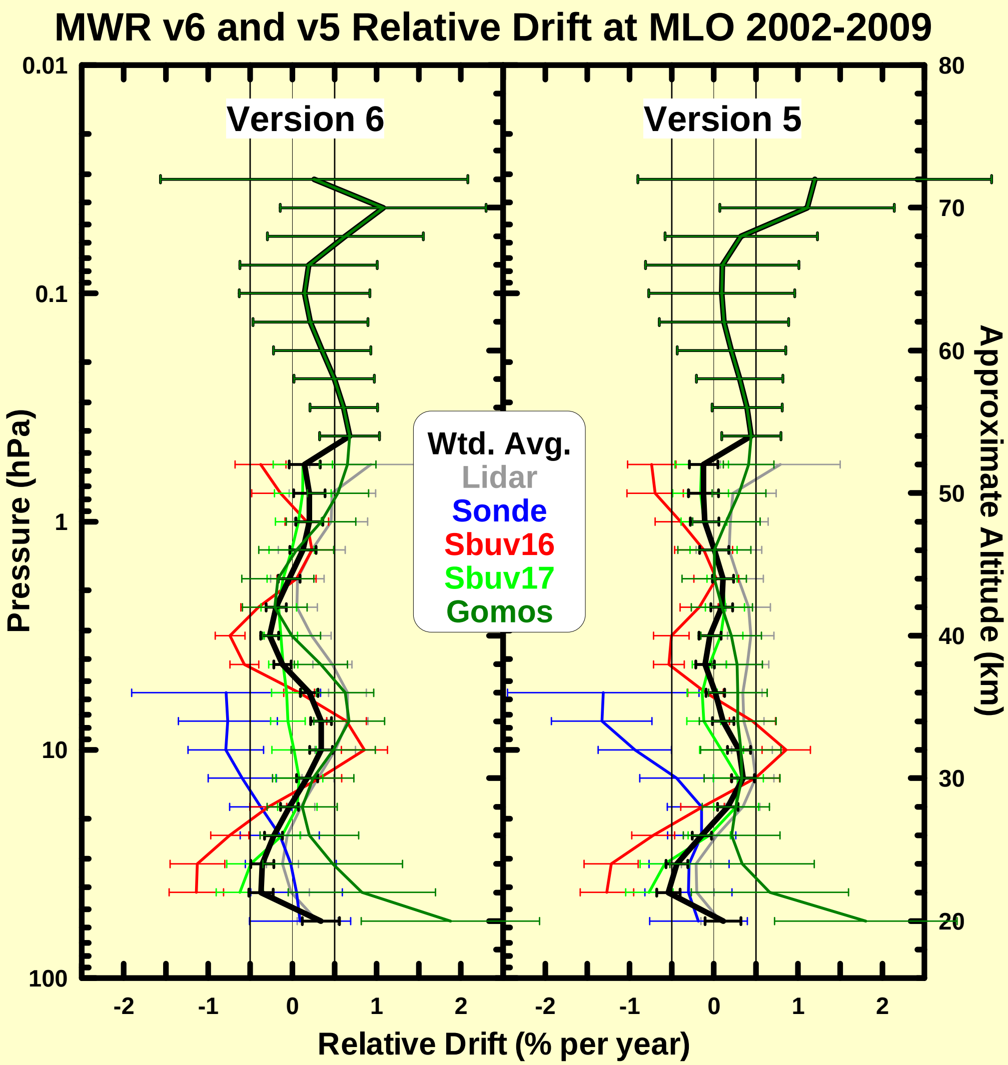
- Technique:
  - Fit linear trends to time series of differences between MWR and other long-term measurements
  - Select instruments that have been operating throughout a period
  - Calculate error-weighted averages from results of several comparisons
- Period from 1995 to 2005: JPL Lidar, SAGE-II, HALOE
  - Ozonesondes not homogenized before 1998 (manufacturer/cathode solution). No single SBUV instrument covering that entire period
- Period from 2002 to 2009: JPL Lidar, NOAA sonde, SBUV16 and 17, GOMOS
  - Can add Aura-MLS by going forward to 2004
  - Can go back to 2000 by dropping SBUV17 and GOMOS

ESTIMATED RELATIVE DRIFT 1995 TO 2005



- Vertical reference lines at ±0.5%/yr
- Attribution of apparent drifts is uncertain for this period
  - Only 3 comparison sources
  - Relatively small number of SAGE-II and HALOE overpass measurements available
- Apparent drift magnitudes are <0.5%/yr above 30 hPa
- Magnitude of estimated drift smaller for v6 than v5 in the 1-3 hPa region
- Signs of drift are opposite for the 2 versions in the 1-3 hPa range
- Both versions appear to drift upward at ~10 and ~56 hPa

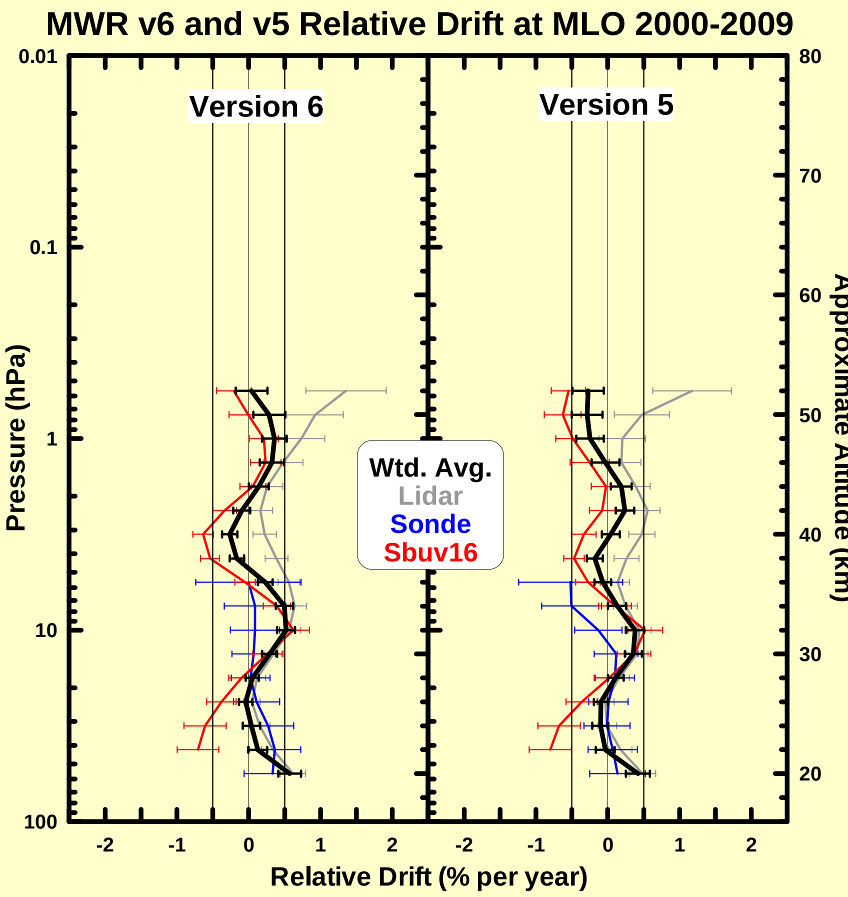
ESTIMATED RELATIVE DRIFT 2002 TO 2009

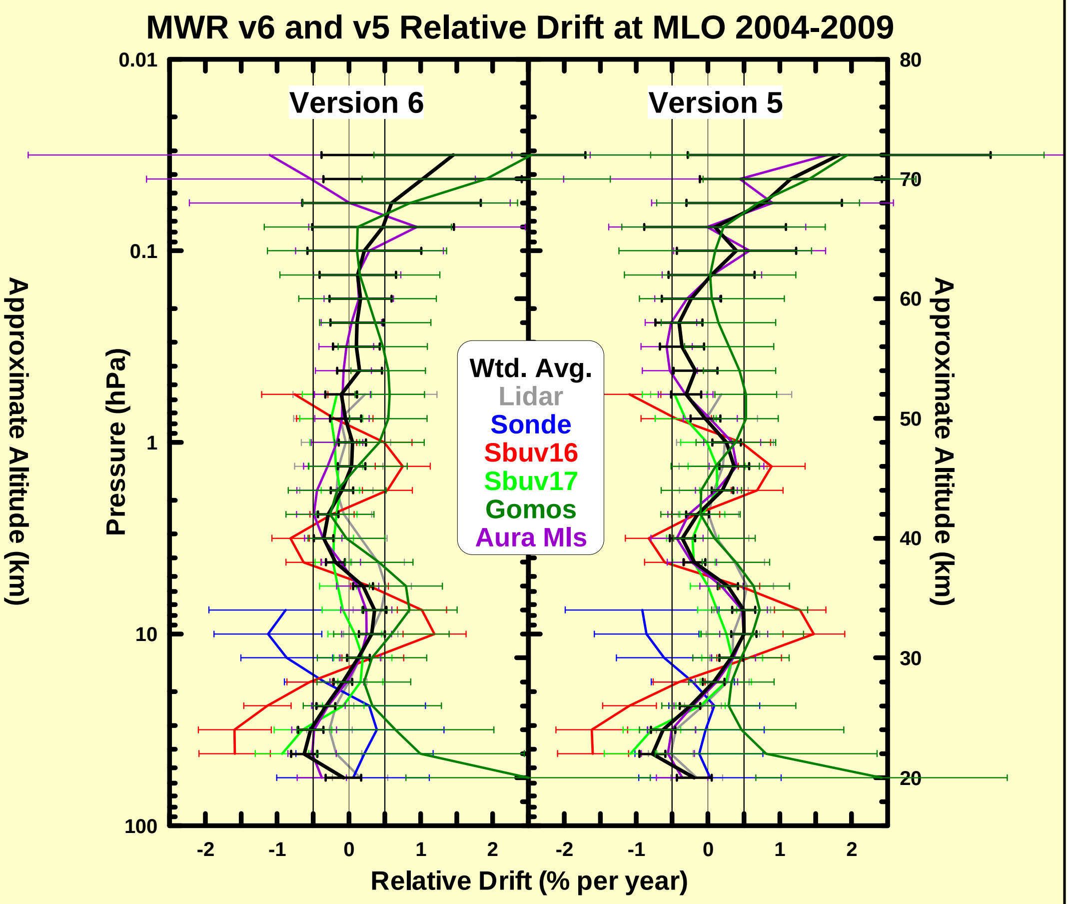


- Drift estimates <~0.2%/yr from ~0.8 to ~8 hPa for both versions, <0.5%/yr from 0.8 to 56 hPa
- SBUV comparisons are not consistent:
  - Excellent agreement with SBUV17 (light green)
  - Poor agreement with SBUV16 (red)
  - We note that agreement is better when using SBUV16 v8.6 data (shown) than when using v8 data (not shown)

ESTIMATED RELATIVE DRIFTS 2000 TO 2009 AND 2004 TO 2009

- Drift patterns are similar if comparison periods are:
  - Lengthened, dropping SBUV17 and GOMOS (2000-2009)
  - Shortened, adding MLS (2004-2009)
- Microwave v6 agrees better than v5 with MLS and GOMOS above 2 hPa (2004-2009):
  - However, drift estimates in this region are not significant for either version

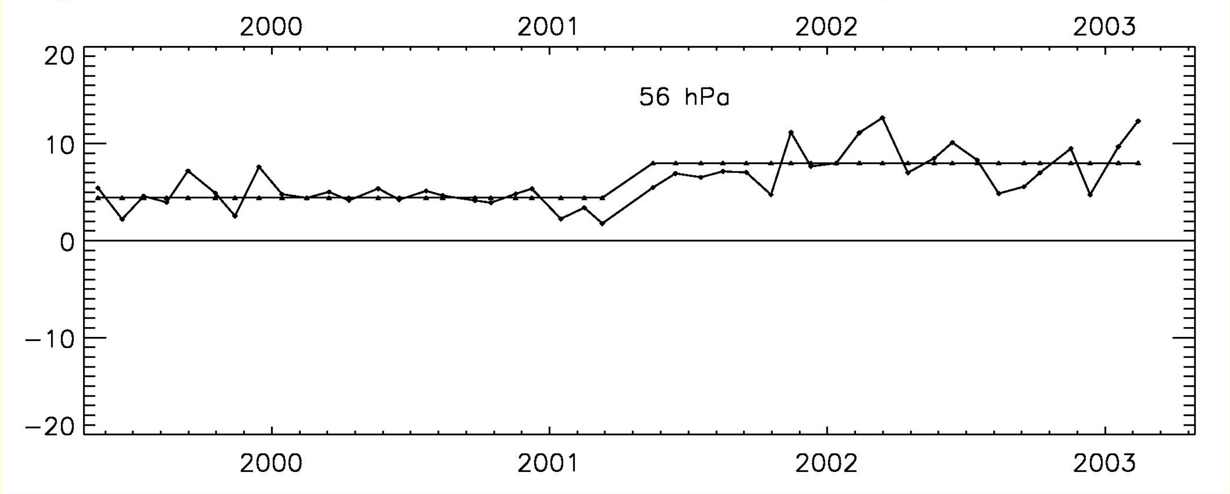




USING OTHER OZONE MEASUREMENTS TO TEST FOR STEPS IN MICROWAVE DATA AFTER REPAIRS

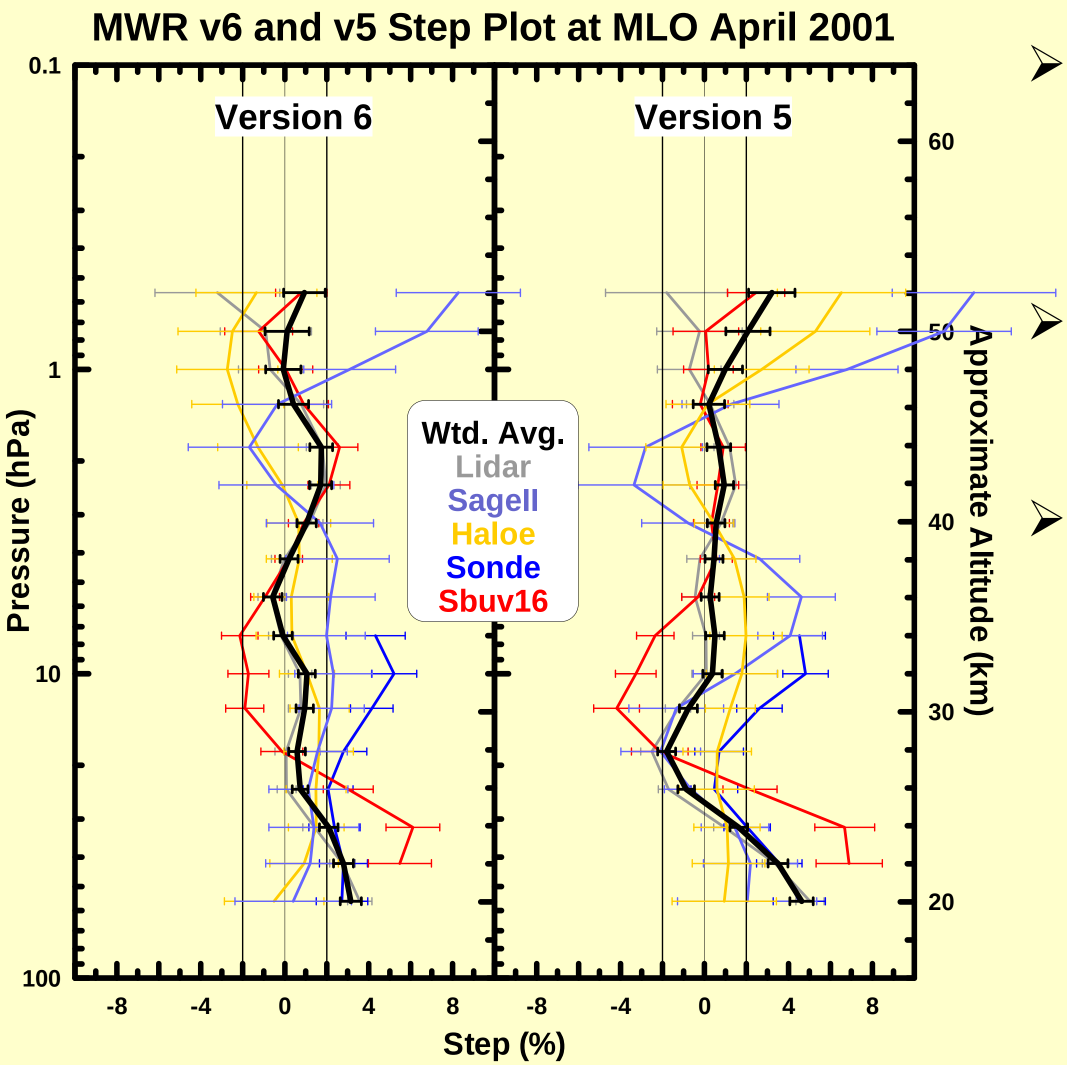
- Determine if a repair introduced a step in the data – if so, how big?
- Technique: Fit step functions to time-series of differences between MWR and another set of measurements, with fits made two years either side of the time of the repair

Example: Step fitted to MWR-Lidar time-series at 56 hPa in April 2001



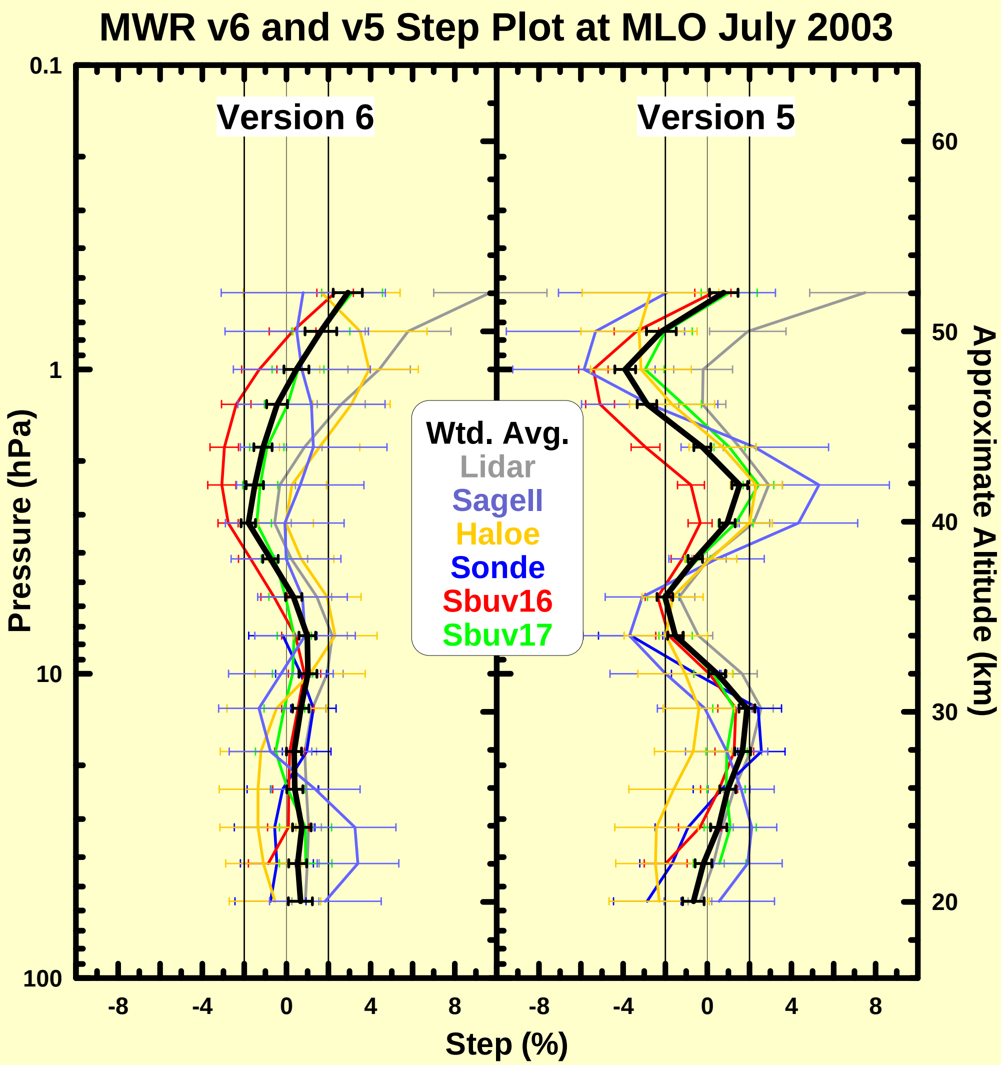
- Do for all reasonable comparison datasets available at the time of the repair
- Calculate the variance-weighted average of step sizes from the comparison set
- Caveats:
  - We have assumed that a step is the appropriate function
  - A relative drift between the compared datasets will alias into a step
  - Time-series having the best precision will dominate the variance-weighted average

STEP ESTIMATES FOR REPAIRS MADE IN APRIL, 2001



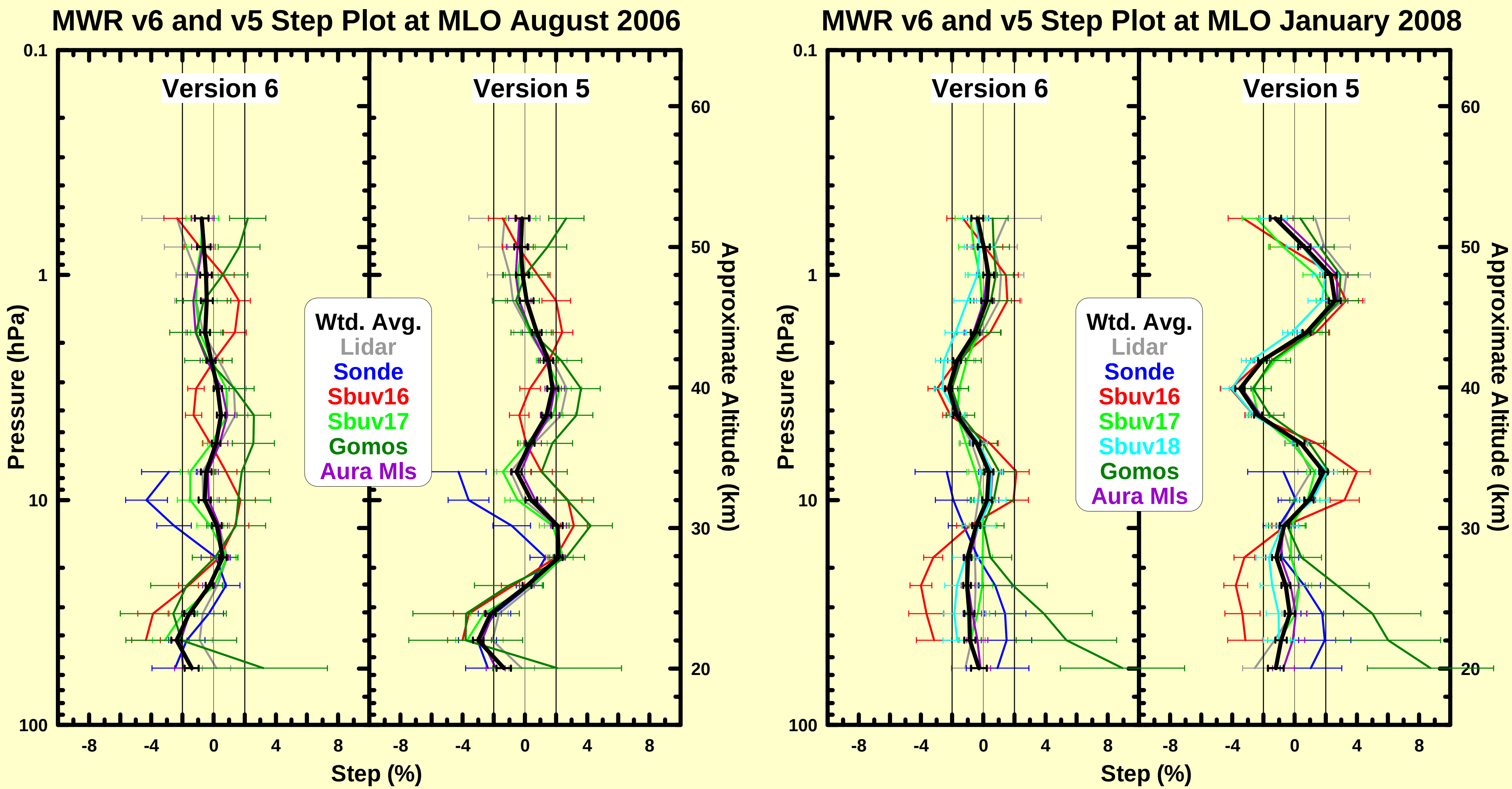
- Step estimates significantly larger for v5 than for v6 at 56, 18, and 0.6 hPa, but smaller at 2 hPa
- Apparent step at 56 hPa is consistent with results from 1995-2005 drift analysis
- Attribution is uncertain in this instance, because:
  - Estimates from JPL lidar influence average quite strongly because their errors are small
  - JPL lidar instrument was moved from temporary facility into NDACC building at the same time

STEP ESTIMATES FOR REPAIRS MADE IN JULY, 2003



- SBUV17 added to the comparisons
- Fitted step function centered on July; repairs made then likely to affect results in middle and upper stratosphere
- v5 plot characteristically oscillates between -3% and +2% with strong consistency between the several comparisons
- v6 estimates are mostly smaller
- signs of the steps are opposite in 2-3 hPa region, and consistent with the 1995-2005 drift plot

STEP ESTIMATES FOR AUGUST 2006 AND JANUARY, 2008



- ➢ GOMOS, Aura MLS, and SBUV18 datasets added
- ➢ Patterns are similar for 2 periods, peak-to-peak reduced by about a factor of 2 in v6

CONCLUSIONS

- v6 absolute profile errors are estimated to be < 5% from 42 hPa and up
  - peak-to-peak variations in profile differences in v6 are generally ~30% smaller than corresponding ones in v5

- For both versions, the apparent drifts are:
  - generally < 0.5%/yr from 1995-2005
  - generally < 0.3%/yr from 2002-2009

- Estimates of repair-induced steps:
  - generally < 2%
  - improvement in the step estimates for v6 vs. v5 is greater in 2006 and 2008 than in 2001 and 2003

- We believe v6 is superior to v5 for trends because:
  - step estimates for v6 are generally smaller, by a factor of ~2 in some cases
  - better temperature profiles are used in v6