The SBUV Ozone Record: The Good, the Bad, and the Ugly

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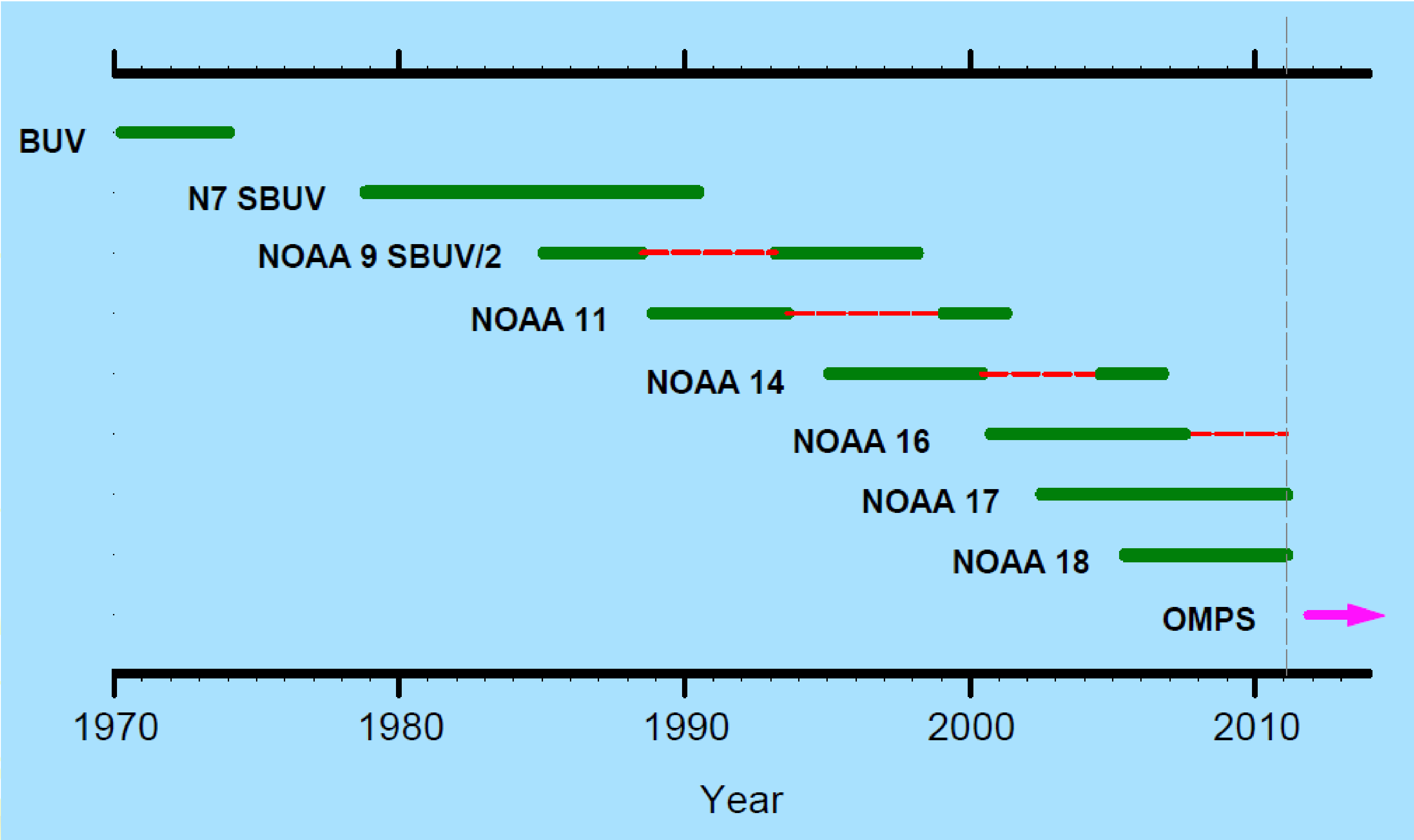


A series of BUV instruments have been measuring the ozone vertical distribution since 1970. *(The red dashed segments indicate periods when instruments are near the terminator as a result of orbit drift.)*

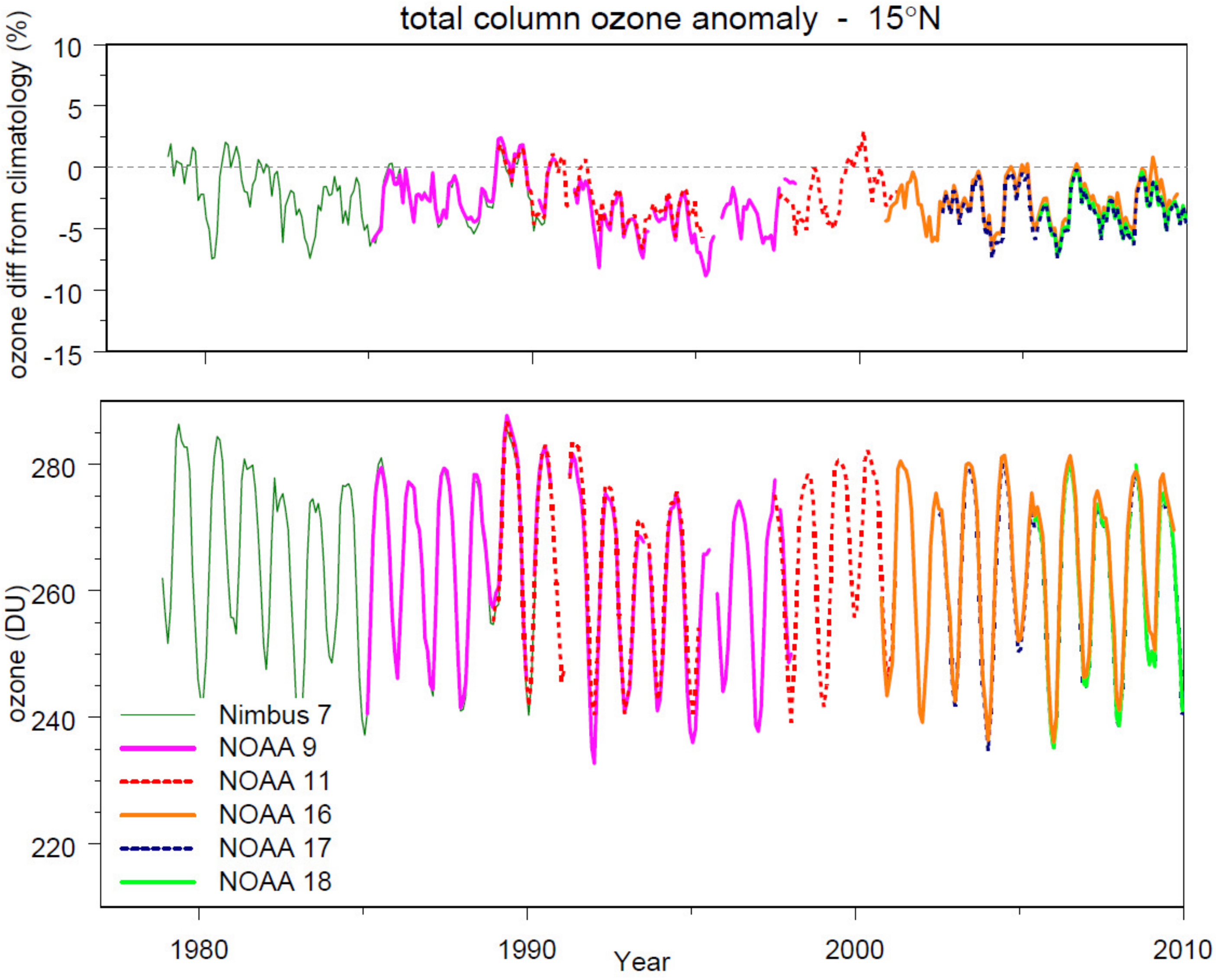
Recent Changes to Algorithm (Version 8.6)

- Brion-Daumont-Malicet ozone cross sections
  - Better spectral resolution (0.01 nm vs 0.1 nm for B&P)
  - Extended wavelength range (195 nm – 345 nm)
  - More accurate temperature dependence
- Cloud height climatology based on OMI
- Instrument-to-instrument calibrations adjusted using observations co-located in LT.

Nimbus-7 SBUV and all NOAA SBUV/2 data have been reprocessed. Data are available for evaluation. Public release is expected in few months. Nimbus-4 BUV reprocessing is planned. Same algorithm would be applied to NPP/OMPS profiler, scheduled for launch in October.

The "Good"

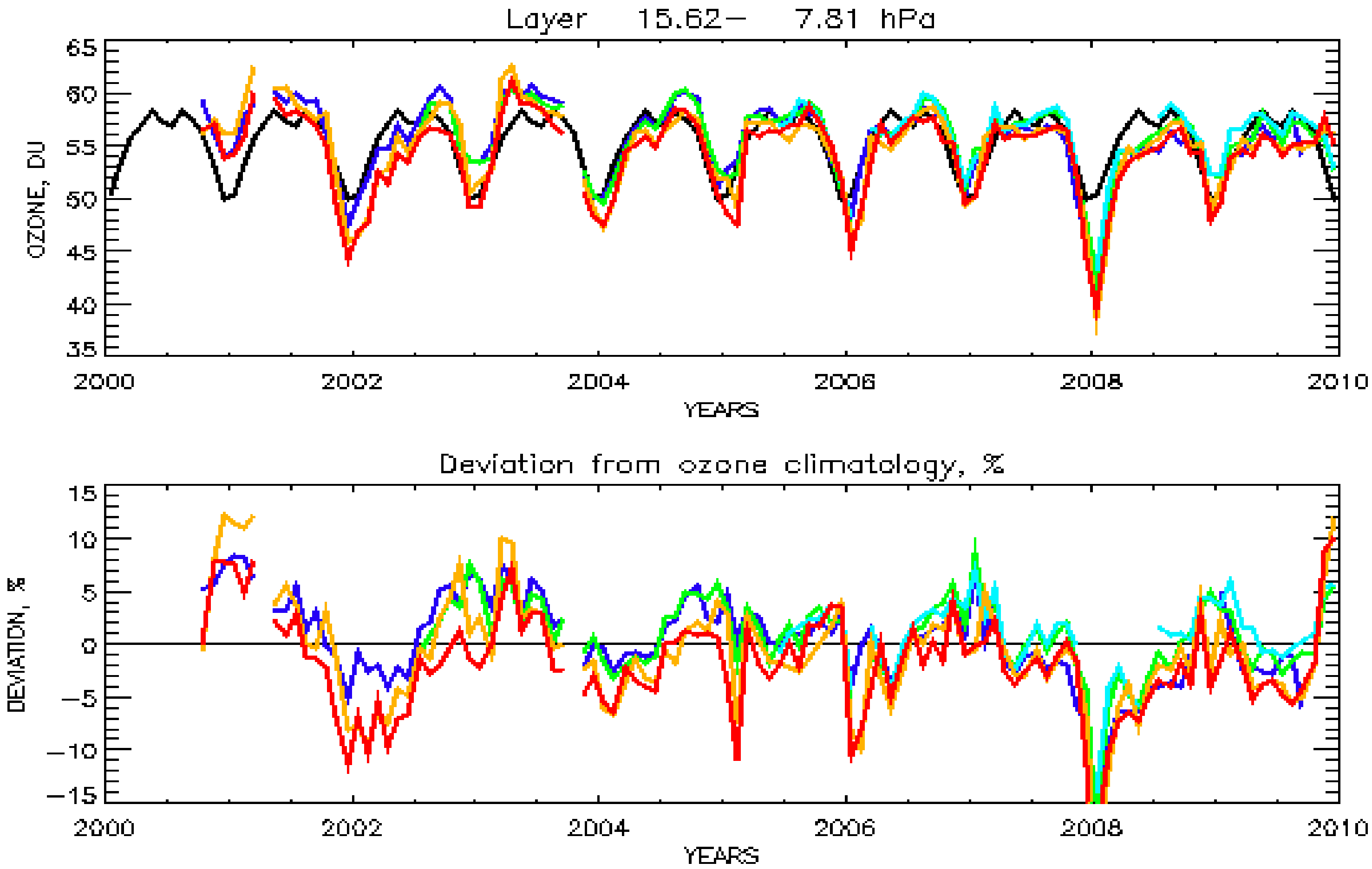
- Record spans 40 years (1970-present)
  - Longer than any satellite record
  - Expected to continue for another 10+ years
  - Full daily coverage of sunlit earth
- Instrument optimized for measurement <310 nm
  - Low straylight, high S/N, optimum spectral sampling
- Very high quality total O_3 record
  - Accuracy: <2 DU up to 70˚ sza, 2% at 80˚, 3% at 88˚ (more accurate than TOMS/OMI, better SZA range than Dobson/Brewer)
- Adequate vert. resolution above O_3 density peak (20-25 km) to study inter-annual variability and trend
- Changes in UTLS (trop-5 to trop+10 km) column O_3 can be monitored with 1-3 DU precision to constrain model-predicted changes in UTLS O_3.



Time series of total column ozone from series of SBUV instruments
(Anomaly is difference from the McPeters-Labow climatology)

Comparison of SBUVs with microwave and lidar instruments at Mauna Loa obs.

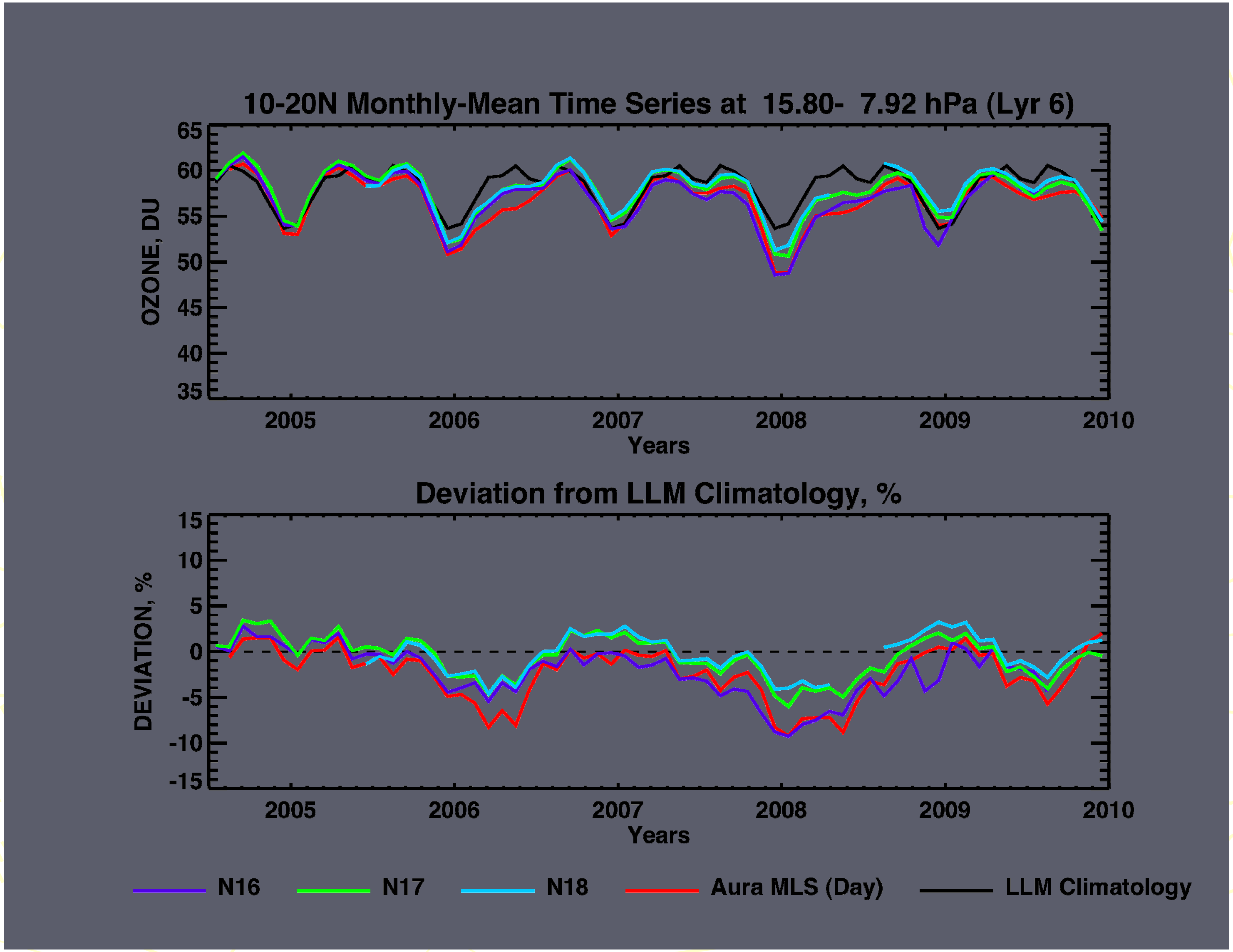
__ Ozone climatology; __ Microwave; __Lidar; SBUV: __NOAA16, __NOAA17, __NOAA18



Top: Time series of monthly averaged coincident measurements for layer 6. Microwave measurements were averaged from 10 am to 4 pm.

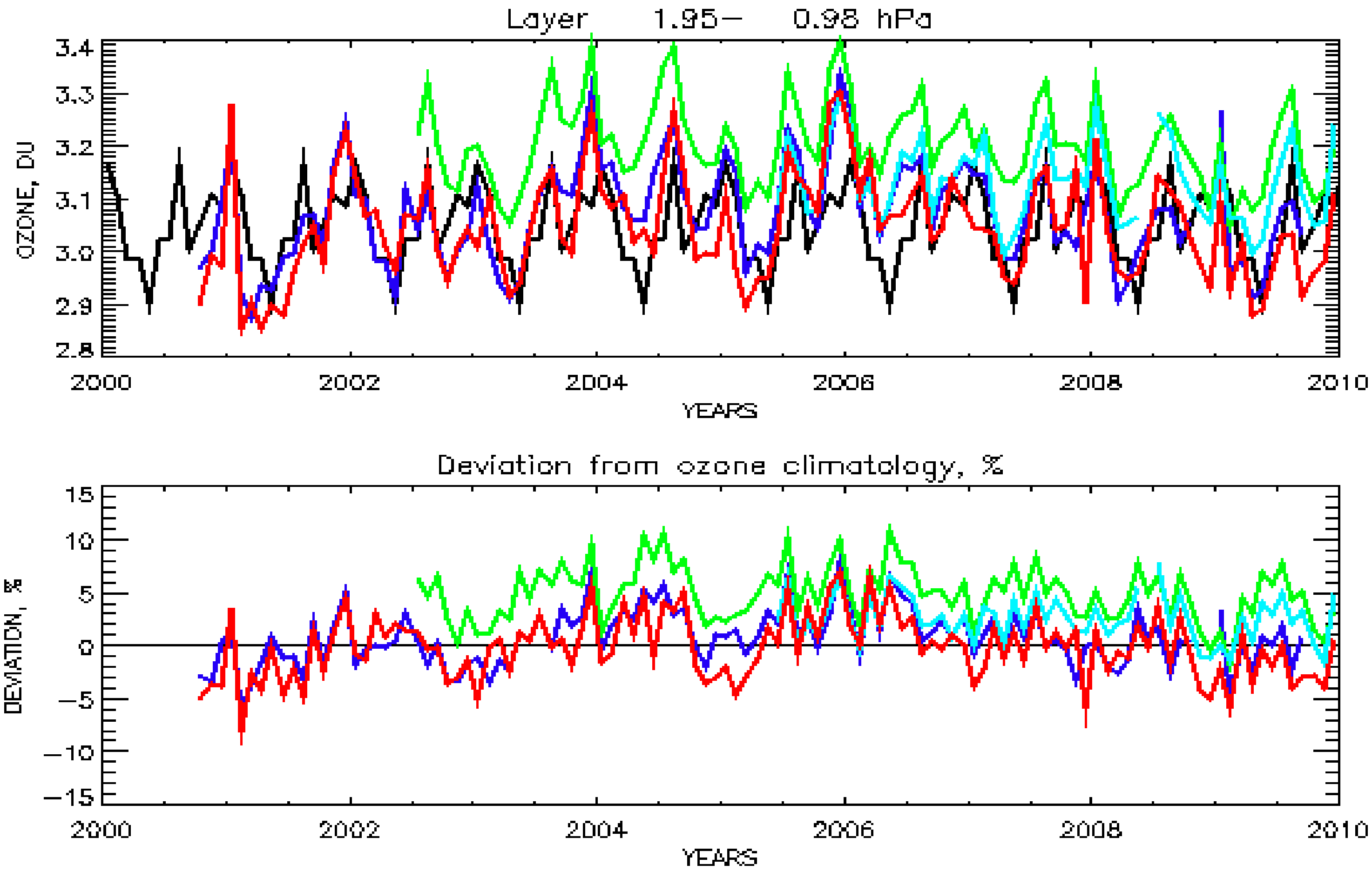
Bottom: deviations in % from ozone climatology (data-clim).

Comparison with Aura MLS observations in Mauna Loa lat band

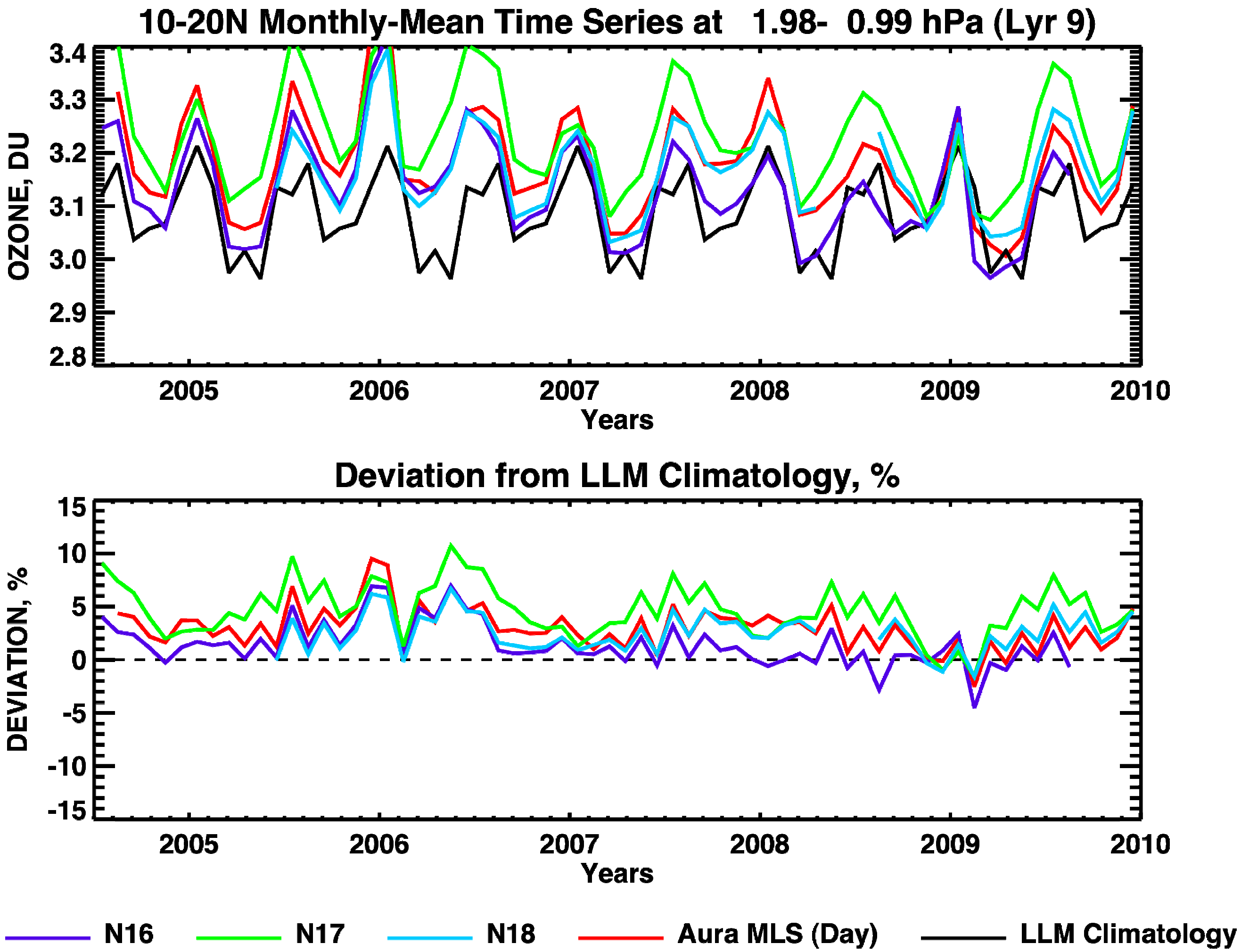


Comparison of with ground based data in layer 9

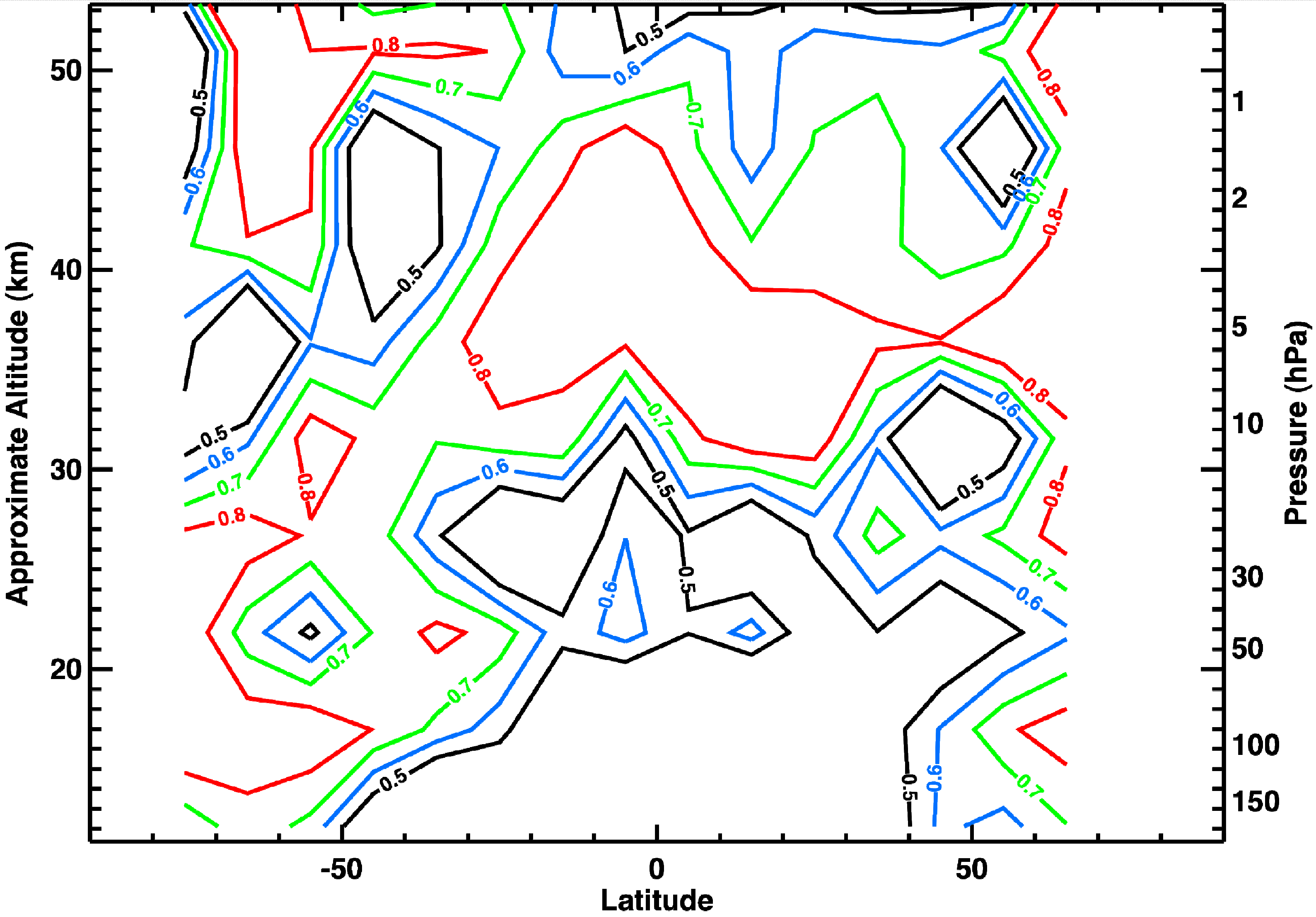
__ Ozone climatology; __ Microwave; SBUV: __NOAA16, __NOAA17, __NOAA18



Comparison with MLS in Layer 9

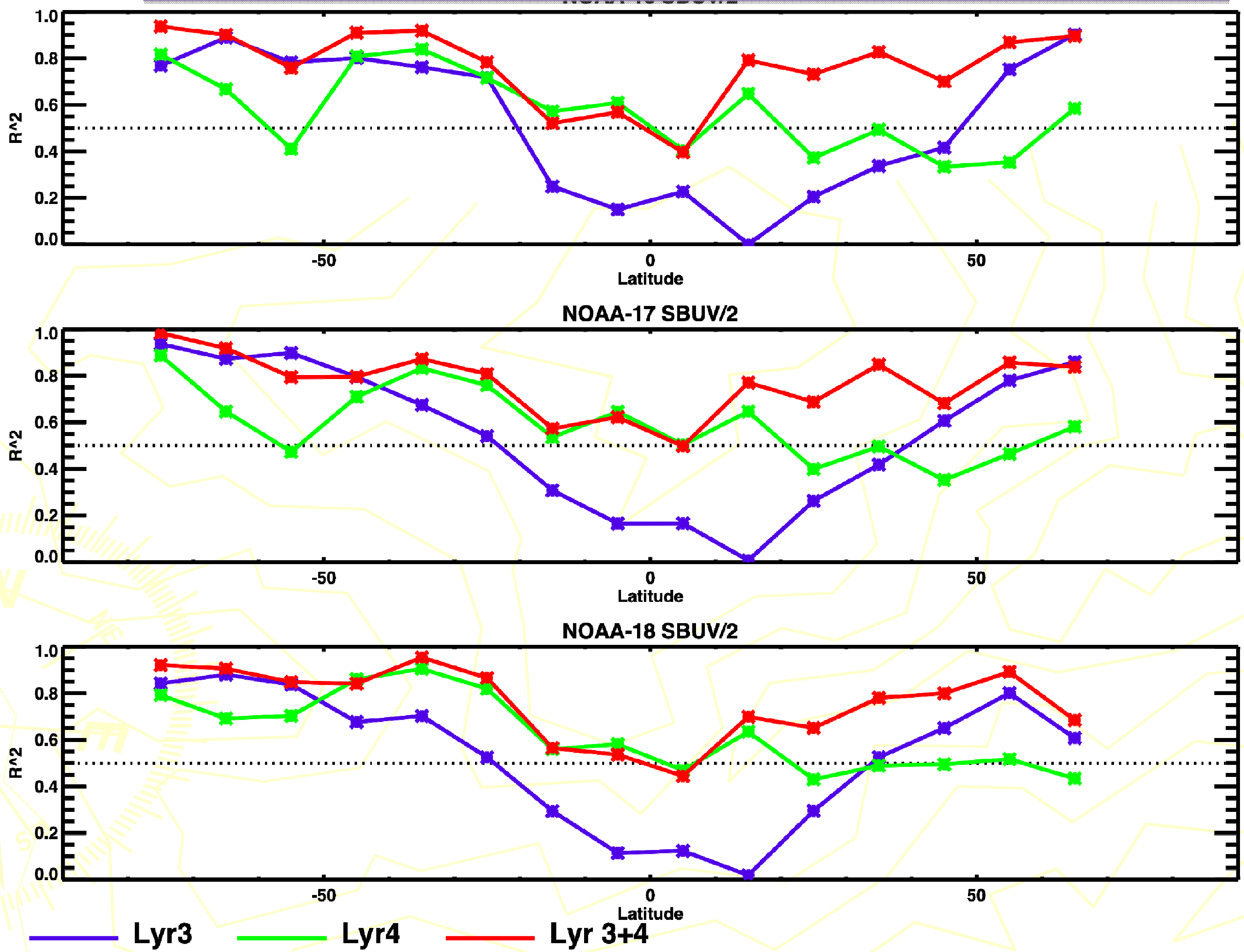


NOAA 17 SBUV/2 & Aura/MLS MZM Anomaly Correlation



Contours show r-squared values

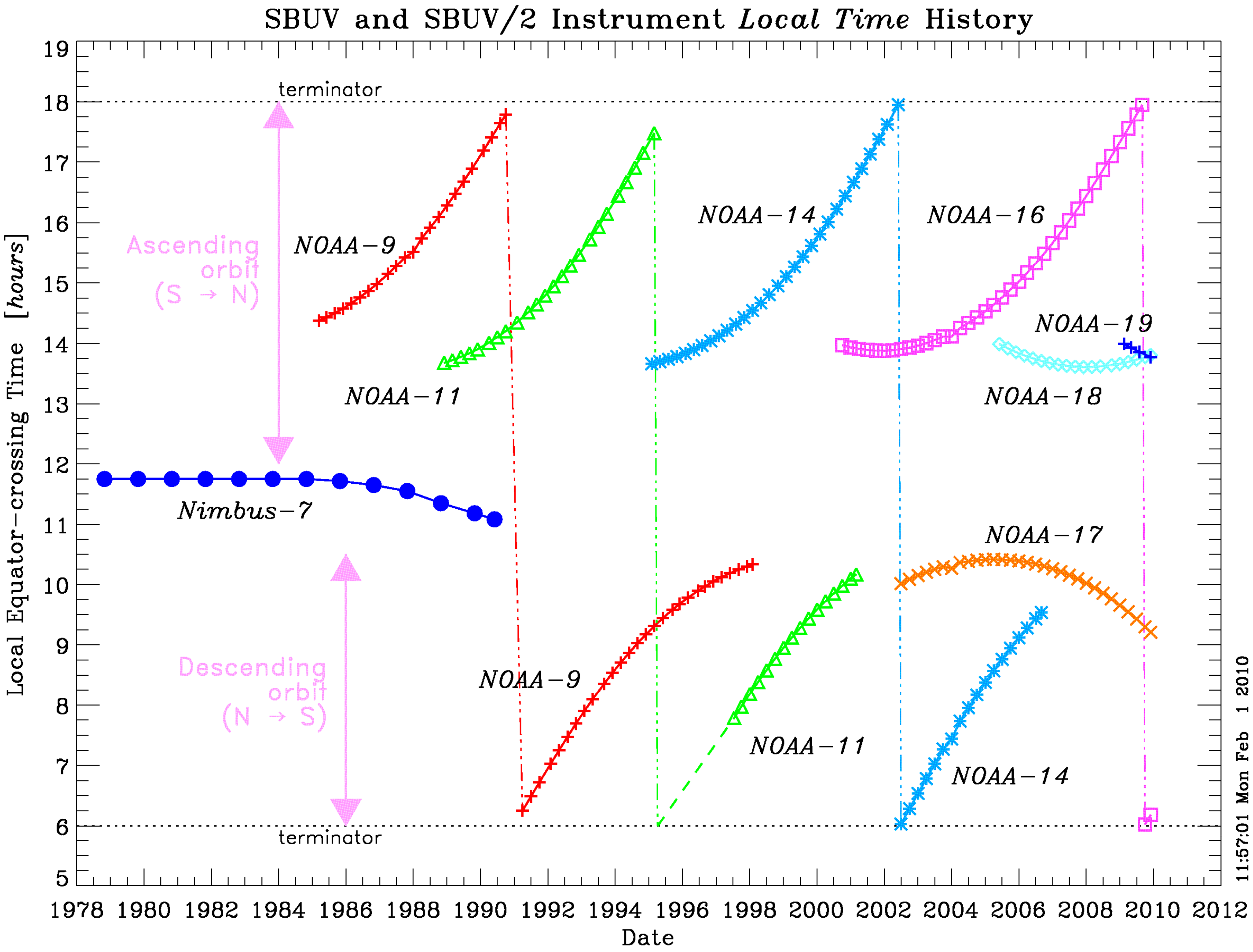
R-squared for lower strat layers and layer combinations



The "Bad"

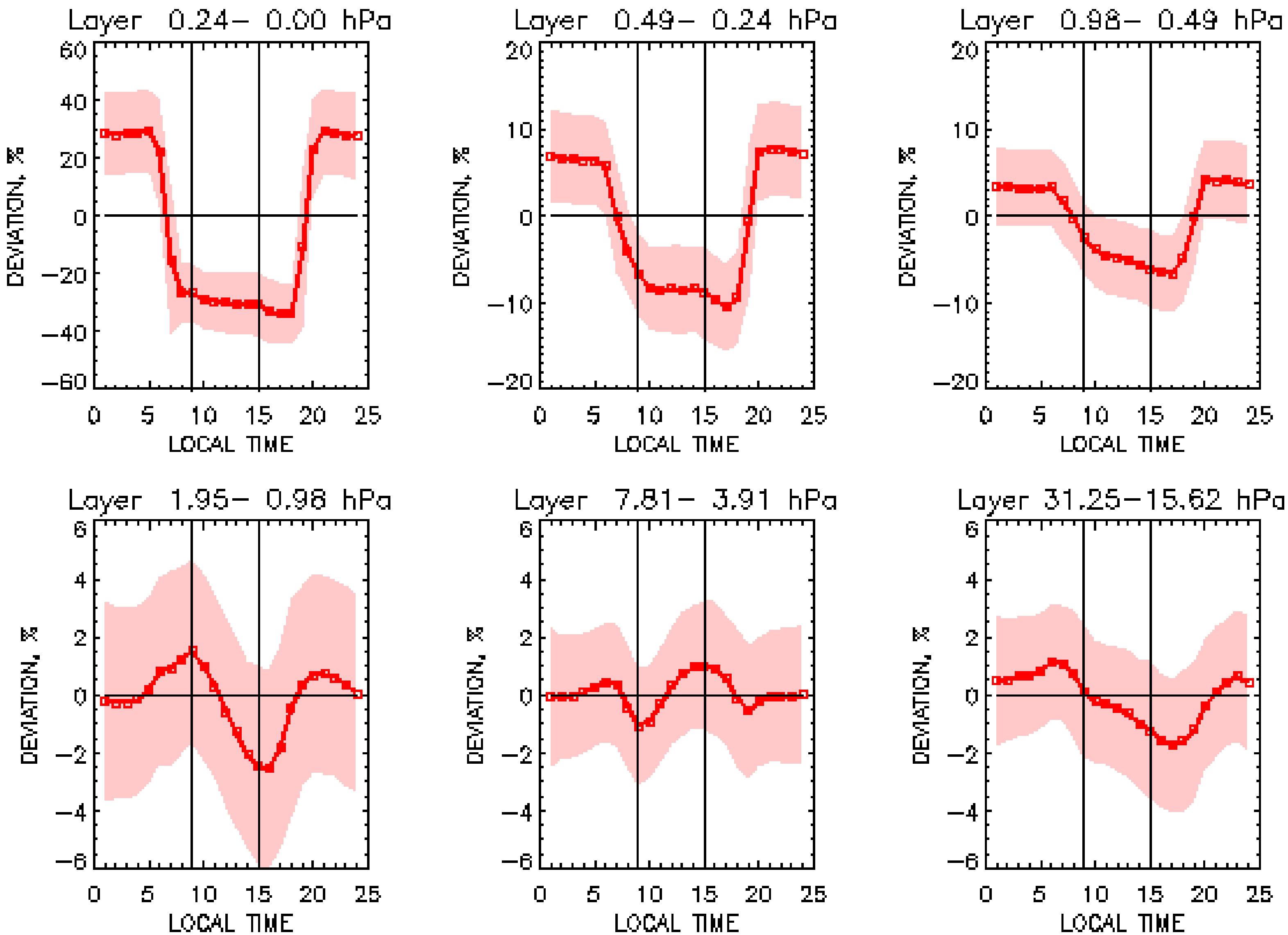
- Only 20 years of high quality data (1979-1988, 2001-2010)
  - Rest has variety of problems (typically, only at the ~5% level). Nimbus-4 BUV was not well calibrated, data record is sparse in later years. Drifts in NOAA 9,11,14 satellite orbits caused several year gaps in solar calibration. NOAA-14 SBUV/2 grating drive had jitter causing errors in wavelength.
- 5 year data gap (1974-1978)
- Poor vert. resolution below the O_3 density peak (20-25 km)
- Calibration errors propagate non-linearly to O_3 profile
  - The relationship varies with sza. Hence, a fixed calibration error produces O_3 MR error that varies with season, latitude and local time of measurement. Therefore, corrections to the SBUV record should be made at the radiance level. This problem is particularly serious for instruments in drifting orbits.

The orbit drift problem

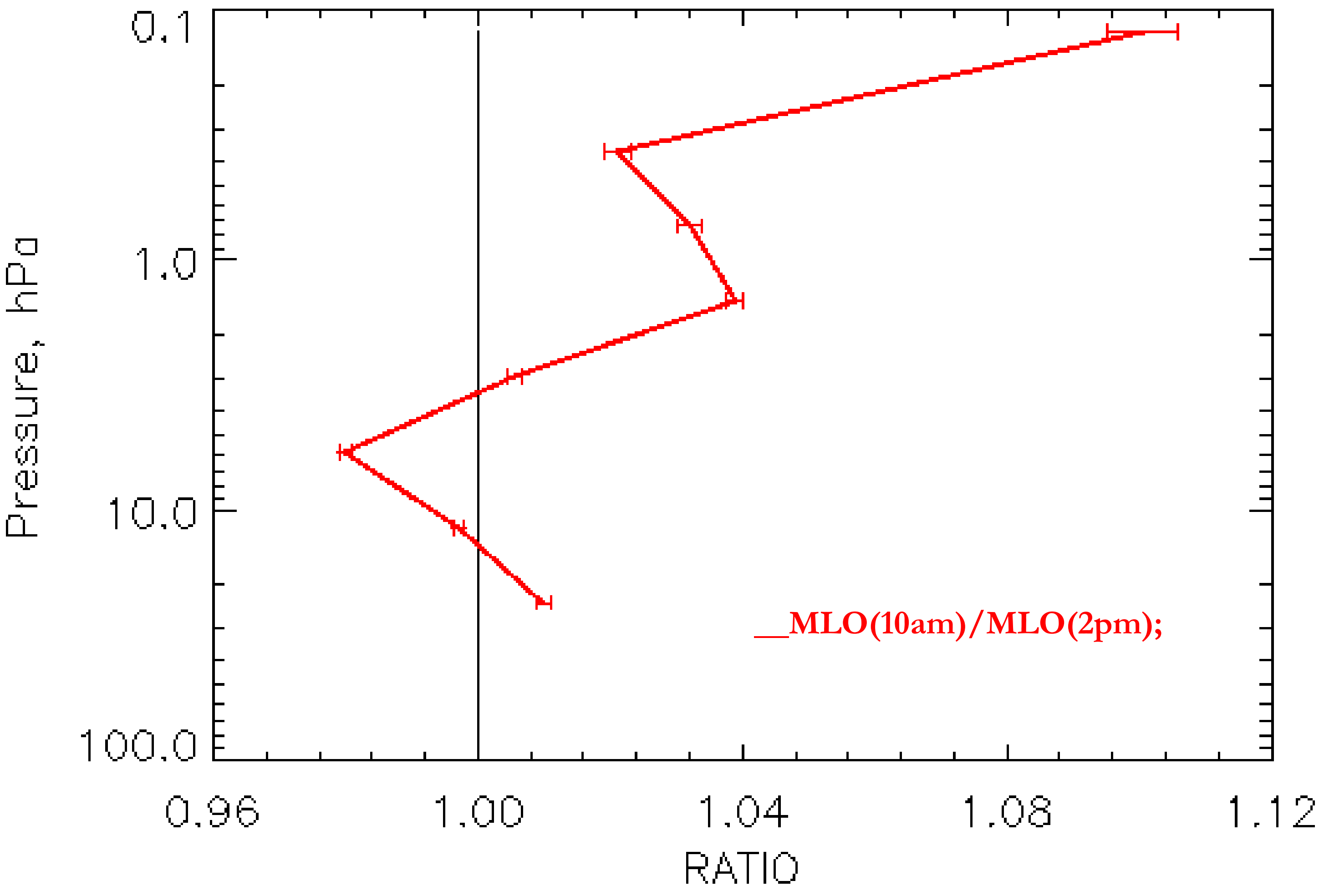


Local equator crossing time of BUV series

Diurnal variation of O_3 at MLO (ref: Parrish et al.)



Ground-based microwave at MLO: Ratio of 9-10am measurements to 2-3 pm measurements



The "Ugly"

- Ground-based microwave instruments show significant local time variation in O_3 MR during the day, down to at least 10 hPa.
  - These variations are caused by some combination of tidal and chemical effects.
  - The variations are season and latitude dependent and may vary from year to year.
  - Currently, there are no good models to account for them. Ground-based microwave data are sparse and have very uneven data quality.

Problems in Using SAGE to Correct SBUV Record

- SAGE measures on altitude scale while SBUV measures on pressure scale
  - Accurate temperature record required for conversion
- NOAA SSU temperature record is of poor quality
  - coarse vertical resolution, not corrected for LT variations from atmospheric tides, no ground-truth to monitor calibration drifts
- Part of SAGE/SBUV differences are caused by LT effects. Microwave data also show systematic differences between sunrise/sunset values.
- BUV radiances calculated from SAGE O_3 profiles produce noisy/inconsistent corrections to SBUV measurements.

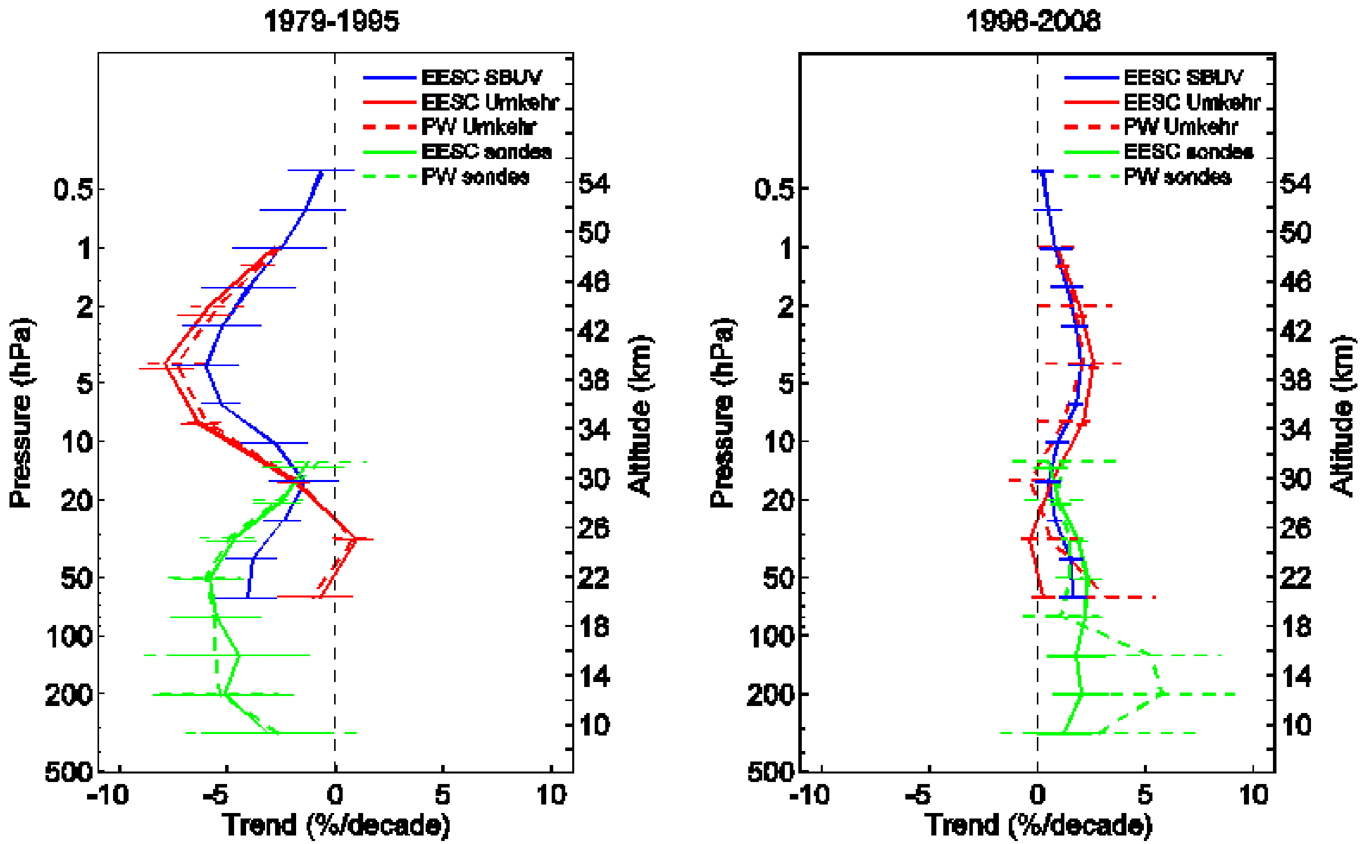
We do not recommend using SAGE to correct SBUV

Next Steps

- Use available Umkekr/sonde data to correct Nimbus-4 BUV (1970-1974) radiances and then reprocess.
- Continue to evaluate calibration errors in NOAA SBUV/2 instruments - considering the fact that some of the observed differences between these instruments are not due to calibration error but due to LT effects.
  - For deriving trends one needs additional terms in the fit to account for LT variations.
- A new algorithm version (V9) is planned. The goal is to improve retrieval accuracy in the UTLS region for climate studies.

BACKUP SLIDES

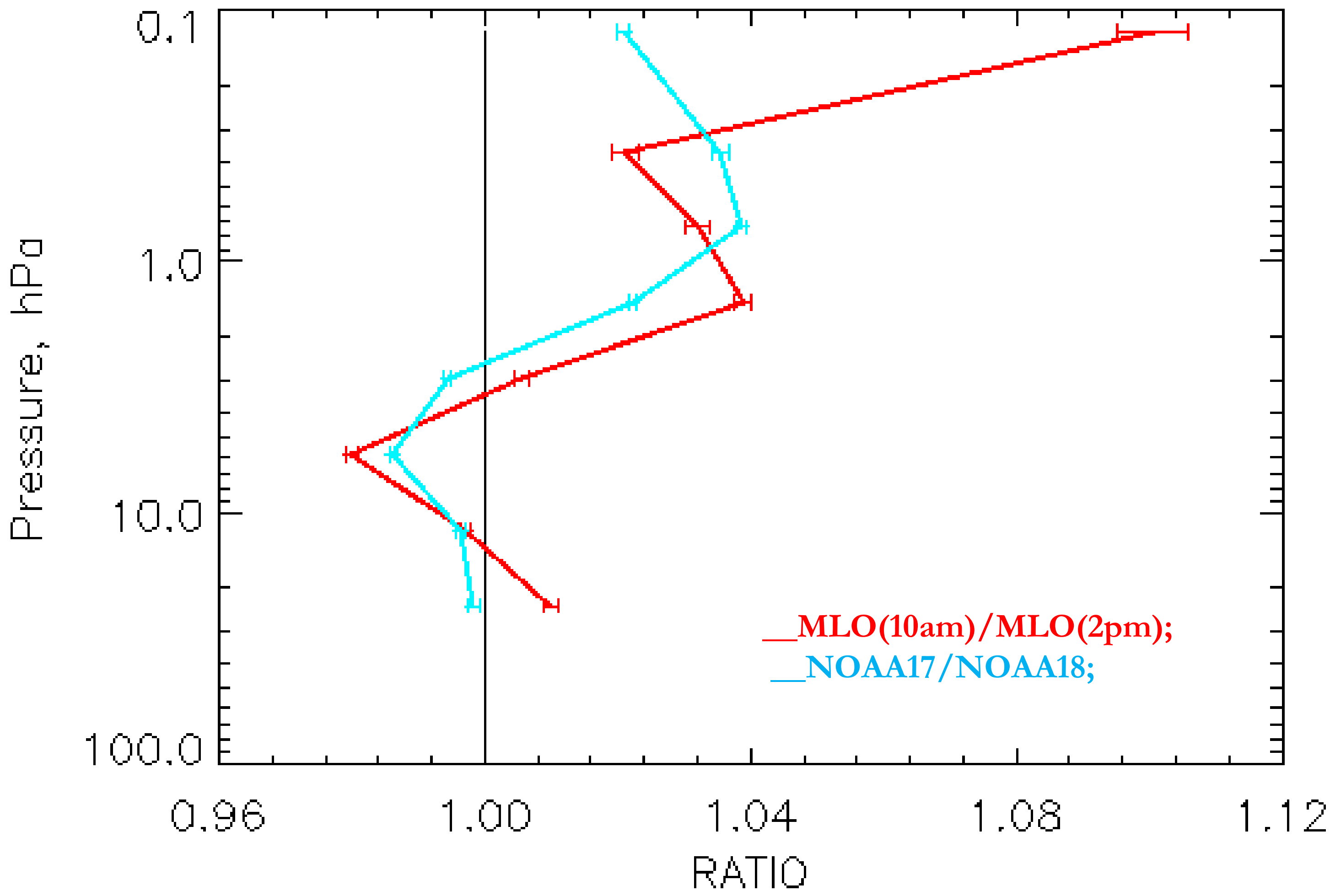
Trends from SBUV



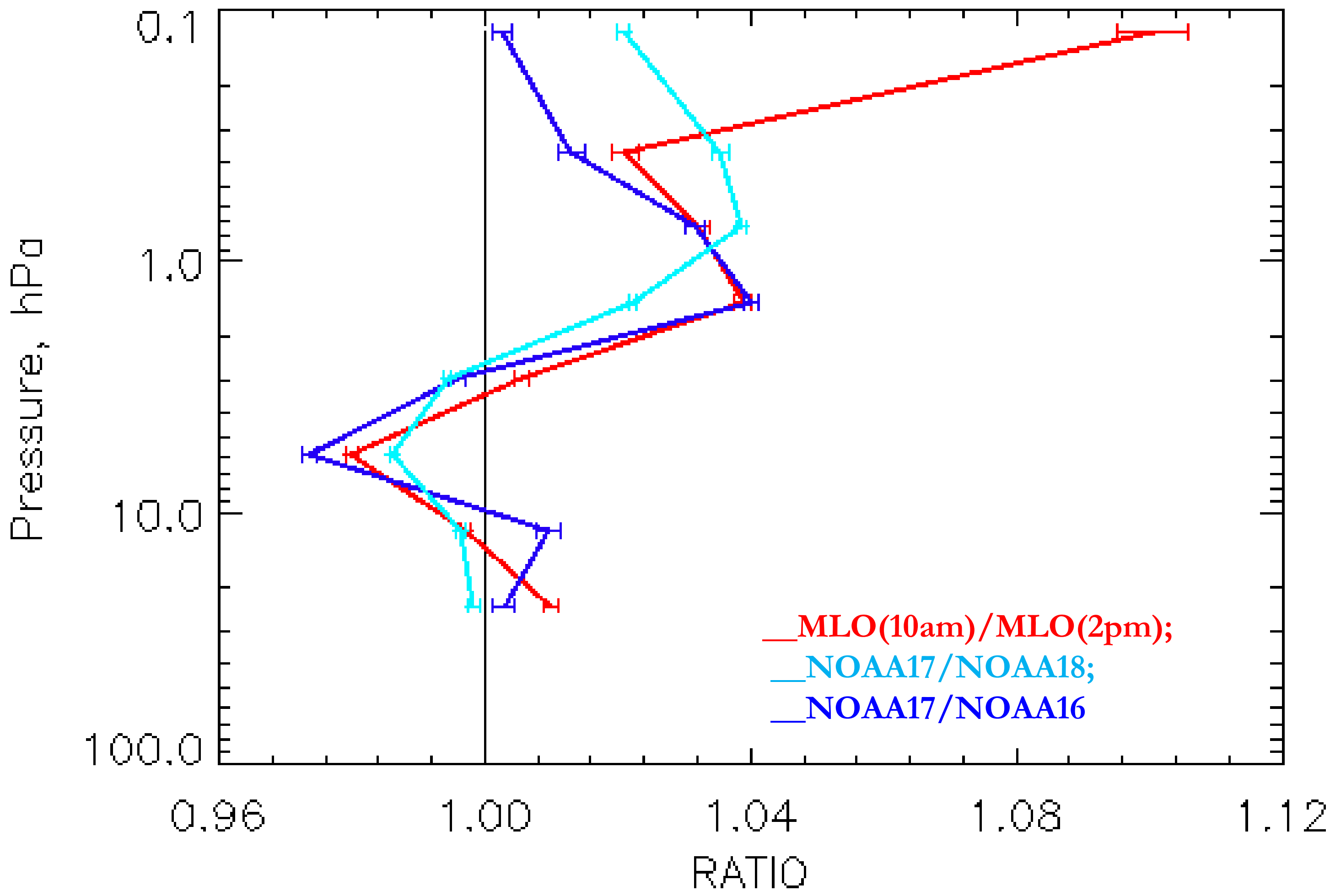
Vertical profile of ozone trends over northern midlatitudes estimated from ozonesondes, from Umkehr, and from SBUV(/2) retrievals. The %/decade trends for two periods are shown: 1979 to 1995 in panel (a) and from 1996 to 2008 in panel (b). Piecewise linear trends with inflexion point in January 1996 derived from ozone sonde and Umkehr data are also shown.

(From Chapter 2, 2010 WMO Ozone Assessment)

Ratio of NOAA 17 (morning orbit) to NOAA 18 (afternoon orbit) (observations near MLO)



Ratio of NOAA 17 (morning orbit) to NOAA 16 (afternoon orbit) (observations near MLO)



Comparison of SBUV (version 8.6) measurements (NOAA16, NOAA17 and NOAA18) with ground based microwave observations at Mauna Loa, 2000-2010.

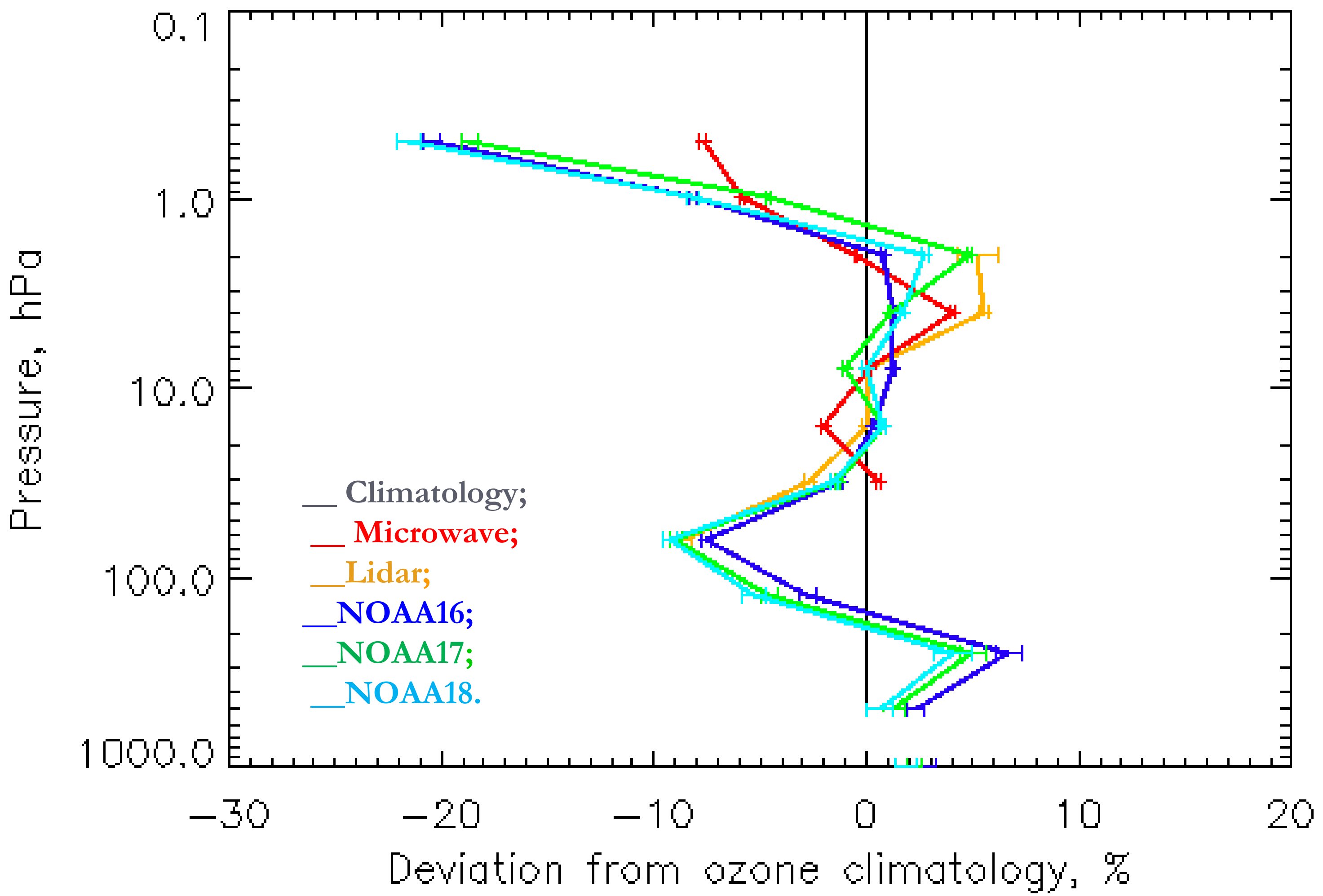


Figure 3. Vertical profiles of the mean deviation from the ozone climatology, %

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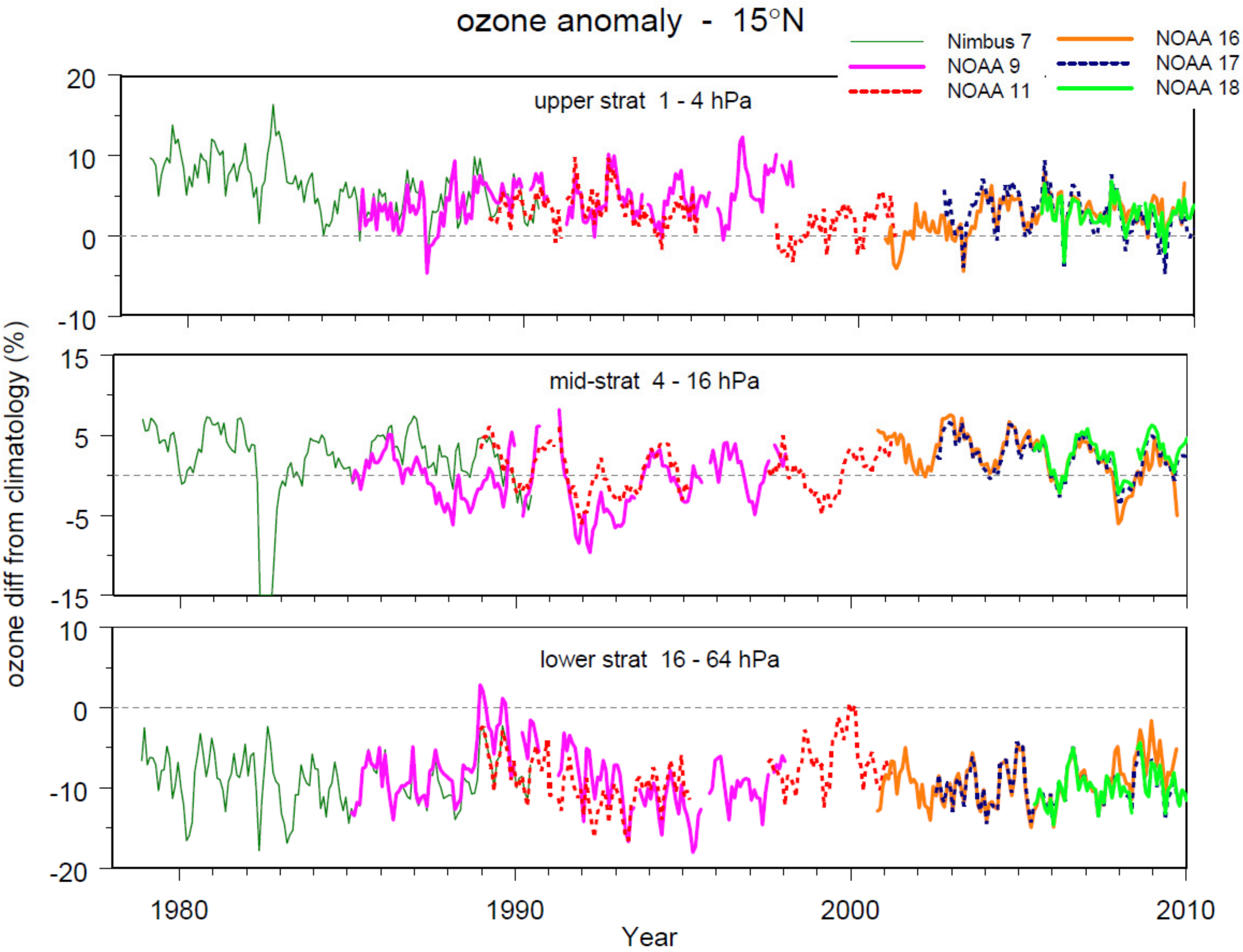
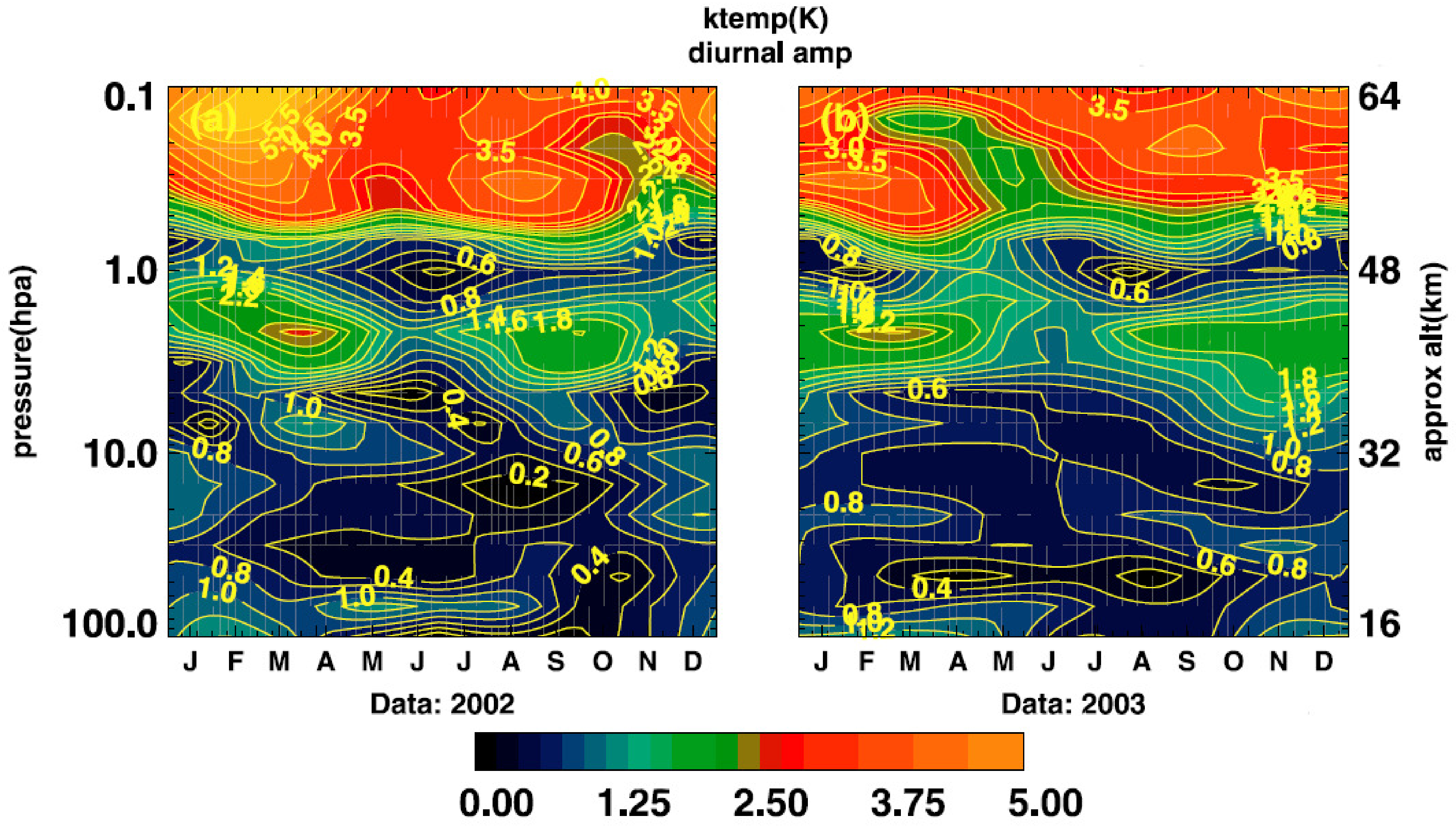
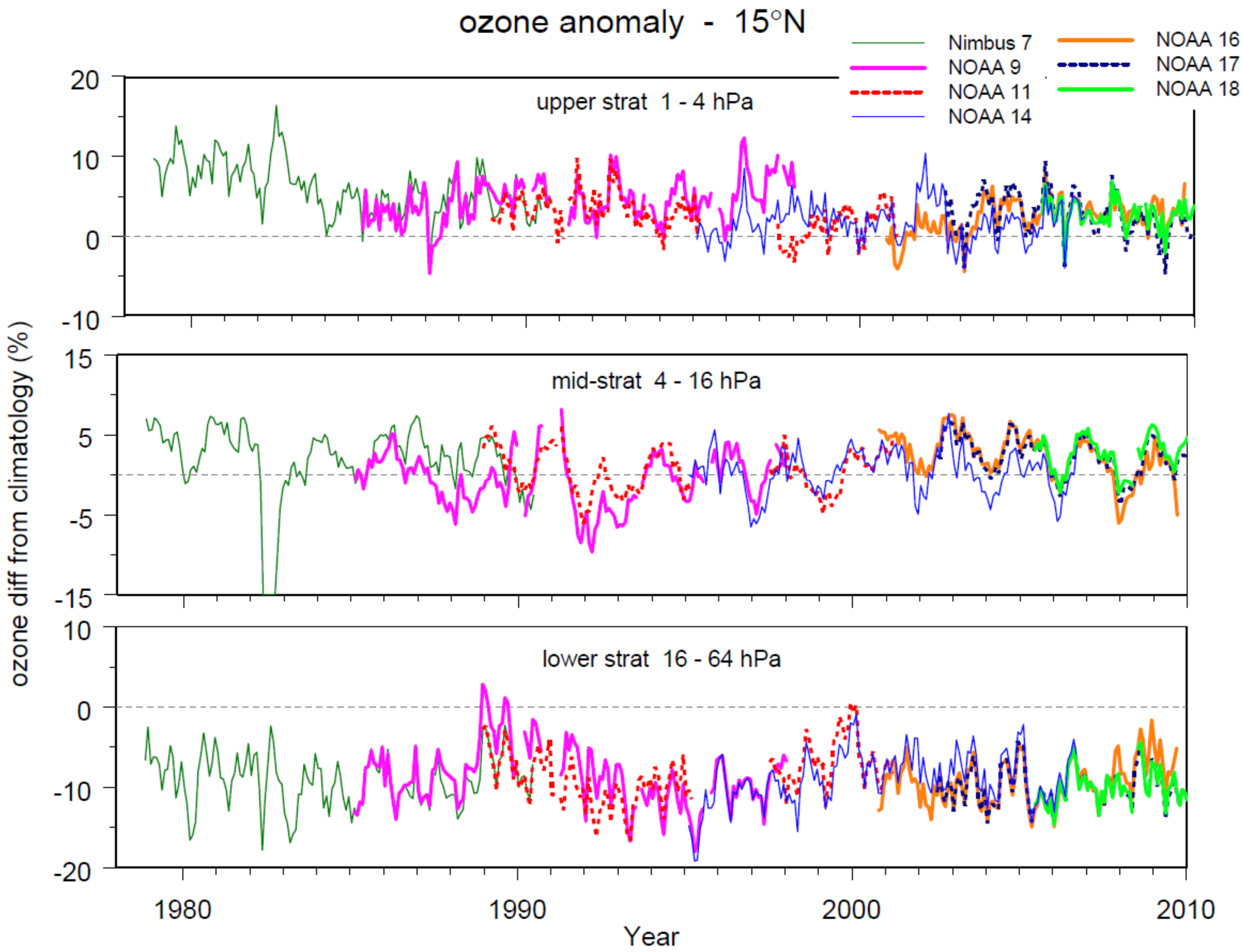


Time series in upper stratosphere, middle stratosphere and lower stratosphere



The amplitude of the diurnal variation of temperature as a function of altitude and month as deduced from SABER measurements at the equator over two years: 2002 & 2003.

From Huang et al., 2010



NOAA-14 fills in missing data in late 1990. Consistency within 5%.