Progress in the NASA GOZCARDS Project (with a focus on ozone)

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+ credit/thanks to various PIs/contributors of ozonesonde correlative data

including GEOMS/GECA data harmonization (avdc.gsfc.nasa.gov/GEOMS) participants for AVDC, EVDC / Nilu, NDACC, and Environment Canada

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SPARC/IOC/WMO-IGACO Workshop on
Past Changes in the Vertical Distribution of Ozone
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The NASA MEaSUREs GOZCARDS project: progress and plans

- GOZCARDS: Global OZone Chemistry And Related trace gas Data records for the Stratosphere

- MEaSUREs: Making Earth Science data records for Use in Research Environments

- NASA HQ officials: Martha Maiden, Ken Jucks

- **GOZCARDS focus:** <u>long-term satellite stratospheric data record</u> (1979 to present)
  > to compile and characterize the changing stratospheric state (binned time series)
  > to merge datasets from different instruments
  → ESDRs (Earth System Data Records - or Earth Science Data Records)

- **Philosophy/Goals:** (behind MEaSUREs - this is one of several such projects)
  > Use well-validated datasets
  > Not a "research project" (different NASA funding source) [focus on data]
  > Community feedback is important → needs public availability; "common formats"
  > Similar/parallel efforts for "Climate Data Records" (NASA and NOAA)

- **Notes:**
  > In reality… some issues/subtleties arise
  - Some "data research" needed to "optimize" ESDRs (for robust atmospheric research)
  - We keep learning → more clean-up, validation (+ output file "details")

  > Further improvement / iteration of ESDRs (e.g., via community feedback) may occur
  - also, how to deal with ending data versions (and new versions)

Long-term data records: MEaSUREs GOZCARDS products (& investigators)

Stratospheric Products	Planned Satellite Datasets / Main investigators
O_3 (zonal mean time series)	SAGE I, SAGE II, SAGE III, HALOE, UARS MLS, ACE-FTS, Aura MLS (+ POAM as a check) [RW, JA, LF]
HCl (zonal mean series)	HALOE,ACE-FTS, Aura MLS [LF, RF,JA]
ClO (zonal mean series)	UARS & Aura MLS [MSa, LF, RF]
ClO_x (emphasize polar regions)	UARS MLS, Aura MLS [RS/TC + LF, MSa, RF]
HNO_3 (zonal mean series)	UARS MLS,ACE-FTS,Aura MLS (Odin/SMR as check) [LF/MSa, Fiorucci/Muscari]
H_2O (zonal mean series)	SAGE II, HALOE, ACE-FTS, Aura MLS [JA, RW, LF, RF] (+ POAM data as a check)
N_2O (zonal mean series)	ACE-FTS, Aura MLS [**LF**]
NO_2 (zonal mean series)	SAGE II, HALOE, POAM III, ACE-FTS [RW, JA, LF]
NO (zonal mean series)	HALOE, ACE-FTS [JA, LF]
NO_x (zonal mean series)	SAGE II, HALOE, POAM III, ACE-FTS [RS/TC, RW, JA, LF]
CH_4 (zonal mean series)	HALOE, ACE-FTS [JA, **LF**]
HF (zonal mean series)	HALOE, ACE-FTS [JA, LF, …]
T (zonal mean series)	GMAO MERRA reanalysis [MSc, VP, GM, LF]
EqL/θ binned products	Hoping for most of the above

MEaSUREs GOZCARDS Team

Co-investigators

- M. Santee (JPL)
- M. Schwartz (JPL)
- J. Anderson (Hampton Univ.)
- R. Wang (GATech)
- R. Salawitch(UMCP)

Collaborators

- P. Bernath
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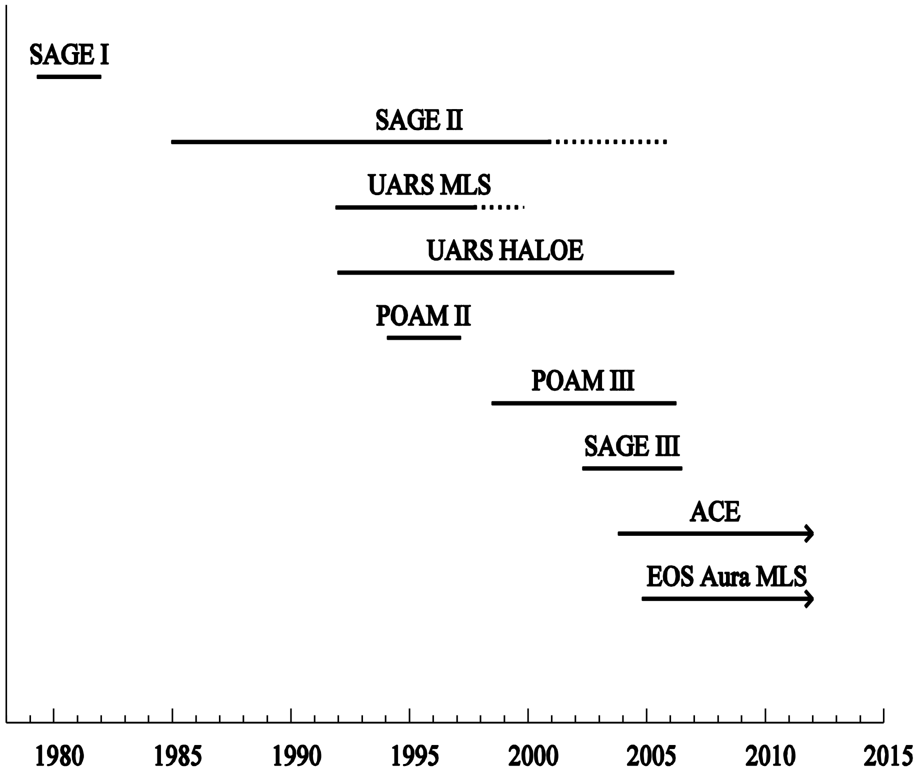
- T. Canty

[- *D. Cunnold]*

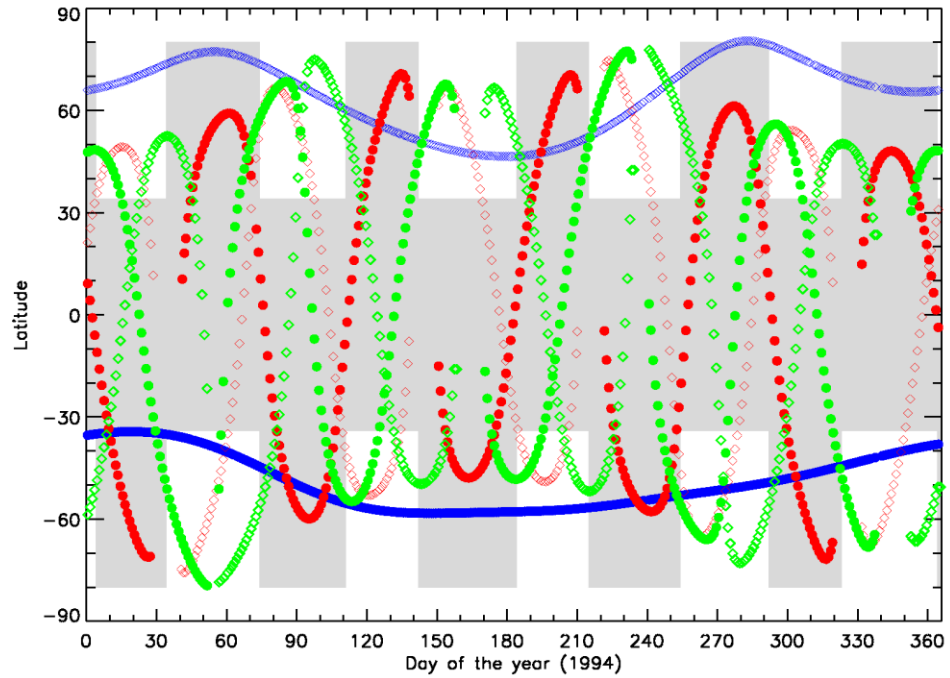
- K. Hoppel
- N. Livesey
- G. Manney
- S. Pawson
- J. Russell
- I. Fiorucci, G. Muscari,
- B. Connor,G. Nedoluha

+ others at JPL
(R. Fuller, B. Knosp,…)

Satellite/Instrument Timelines and coverage



Timeline of satellite missions and instruments considered for the GOZCARDS project and the creation of a stratospheric composition ESDR. Dotted lines indicate some degradation in coverage during the ending phase of some missions (SAGE II, UARS MLS); note that HALOE also suffered from poorer coverage in the 2nd half of the UARS mission.



Yearly coverage provided by some of the satellite sensors. **Shading** shows the **UARS MLS** coverage for 1994, **green open circles** are the **HALOE** (1994) coverage, **red dots** represent the (1994) **SAGE II** occultation locations, while **blue symbols** in polar regions represent **SAGE III** occultation locations (2003).

Reminder:

MLS observes in emission

Others shown here are solar occultation

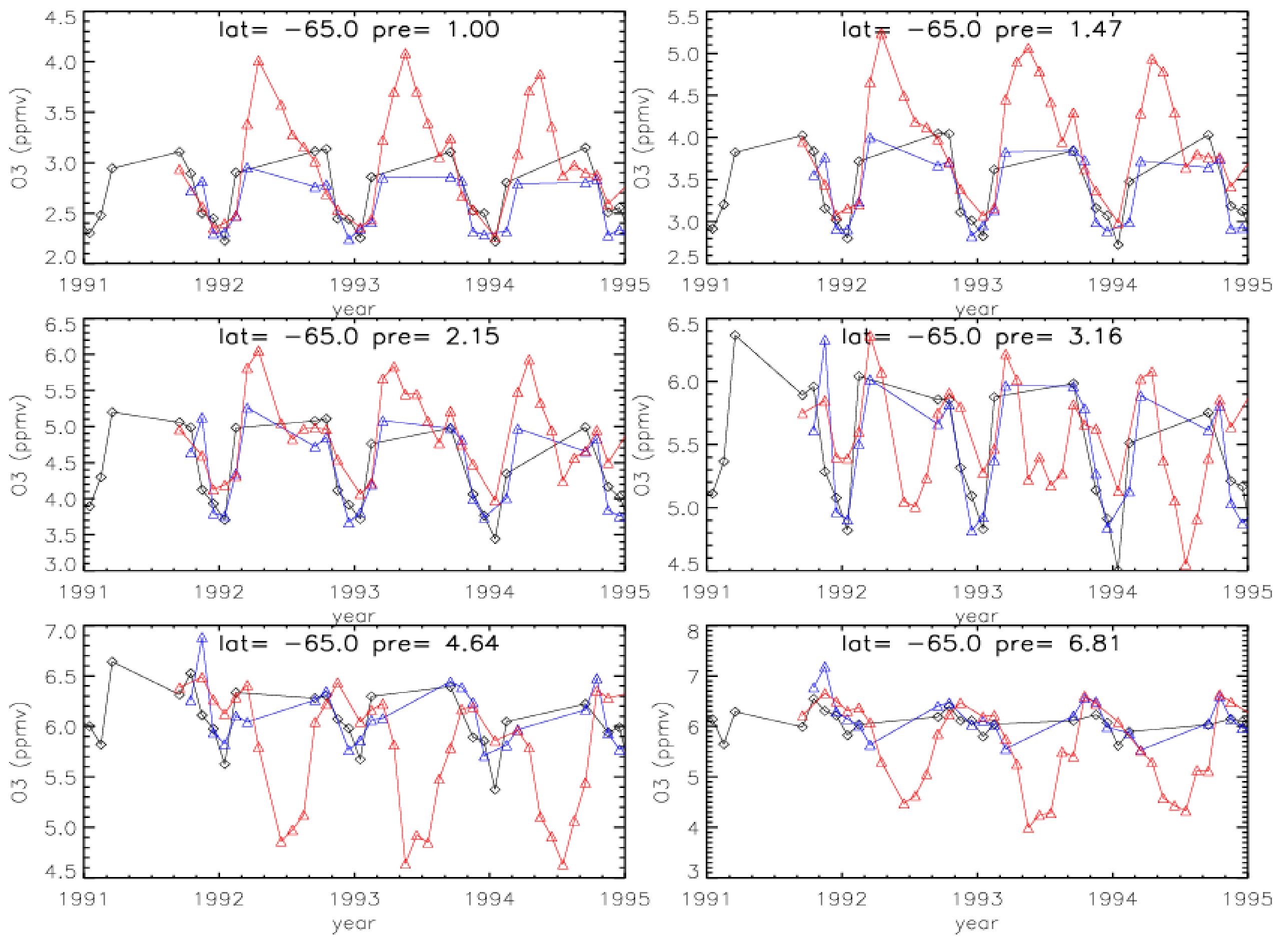
Satellite data sampling issues

- One needs to be aware of significant sampling differences between occultation and emission data [latitude/time-dependent] (e.g., when viewing strong seasonal variations – for any species)

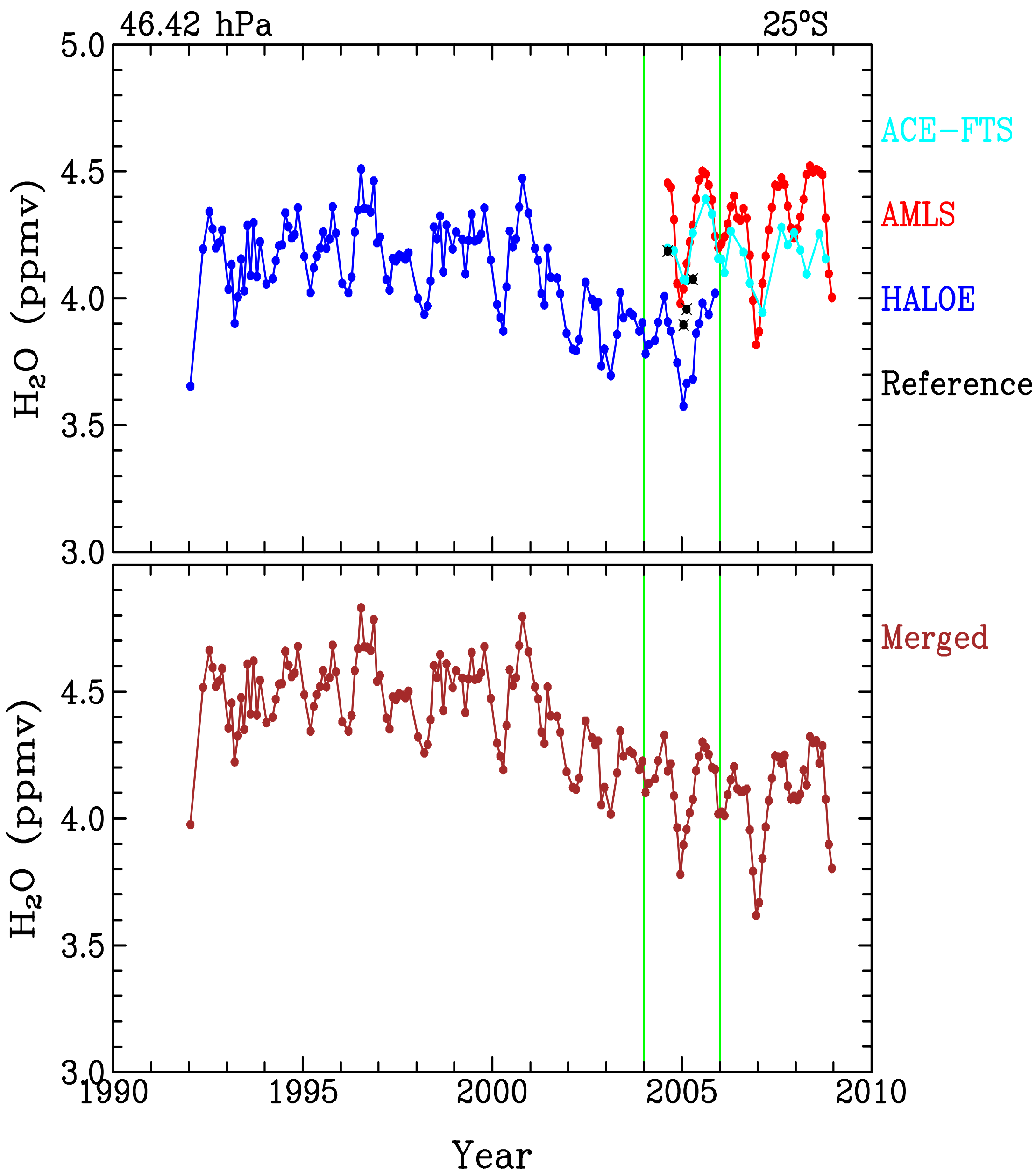
- This is <u>sampling</u>, typically <u>not an inaccurate data issue</u>
- Fits to the datasets would be a recommended method for investigators wishing to use these (e.g. vs models)

[**No** fits are to be provided in the (first) GOZCARDS data files]

Monthly zonal mean ozone from SAGE-II, UARS-MLS, and HALOE



H_2O



- **Merging Datasets: Simple case (use H_2O as an example)**

1) Get averages of overlapping datasets

2) Constant offsets from each individual dataset are obtained with respect to the reference (here chosen as the average of the overlapping zonal averages). [but for O_3, choose SAGE II as ref.]

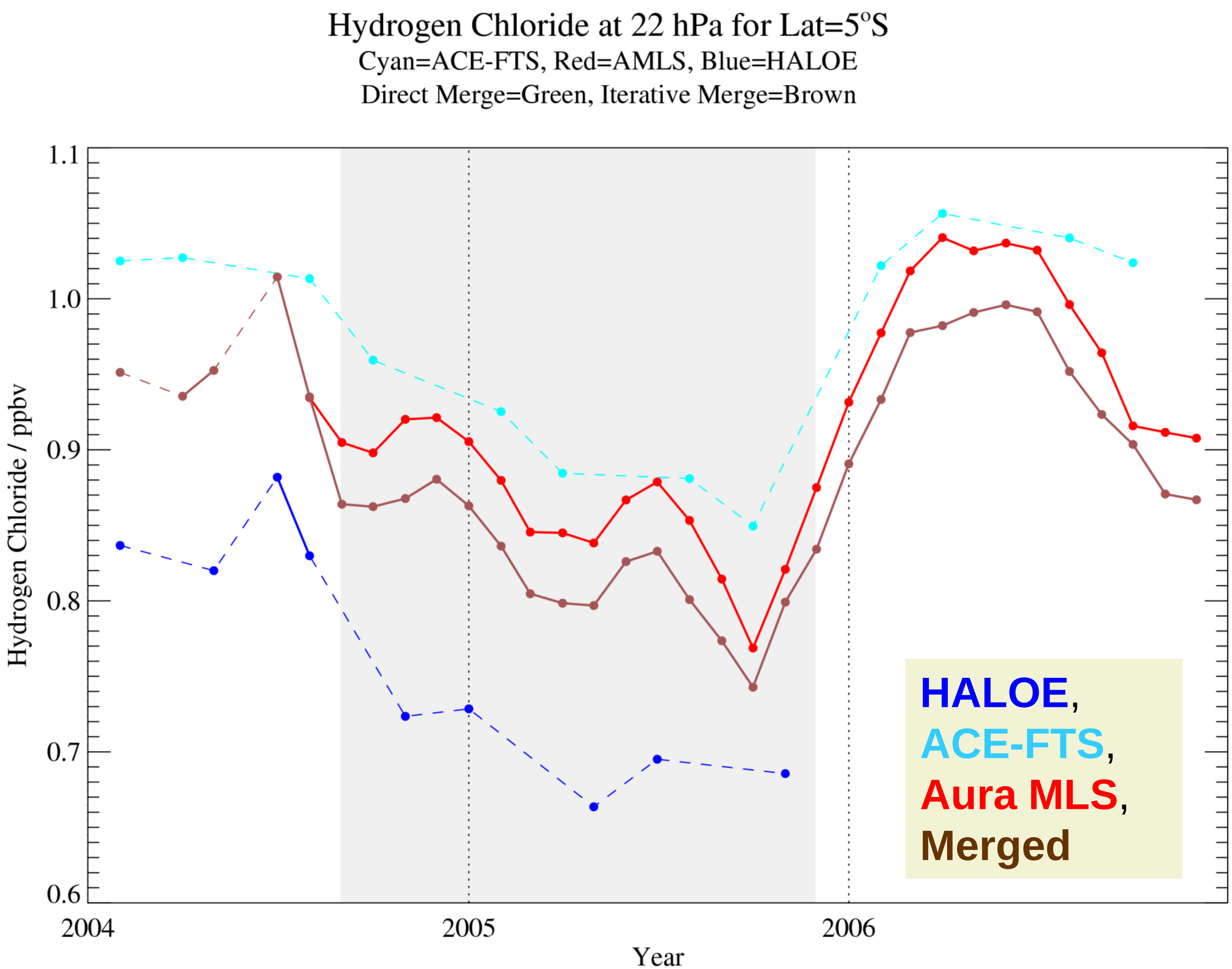
3) Each time-series is then adjusted by the appropriate offset.

4) Obtain a merged time-series by averaging available adjusted data sets.

- **We have been refining the approach**

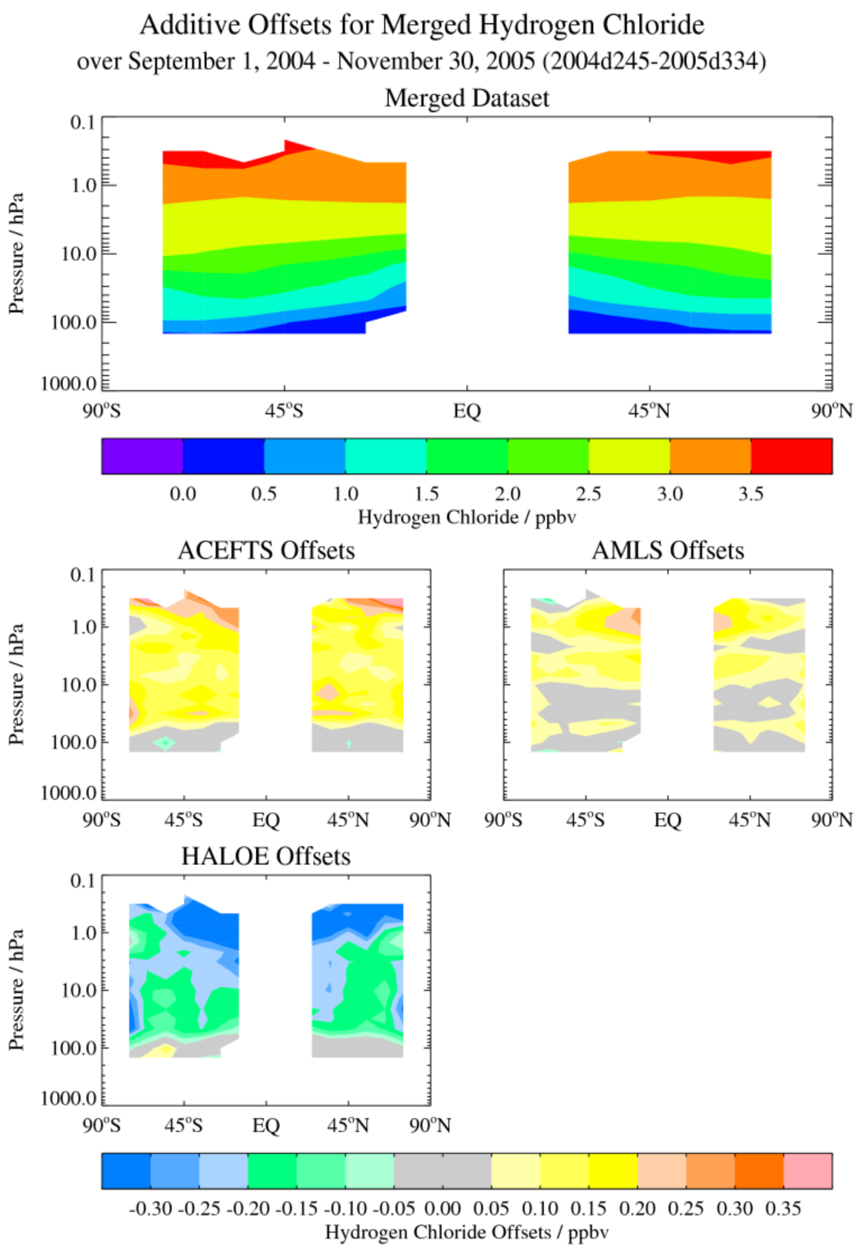
> basically, use MLS as a "transfer standard",
- merge MLS and ACE-FTS (say) first
- then, add HALOE (but keep equal weighting for each of the 3 datasets)
→ increases overlap possibilities for adjusting datasets
[probably less of an issue for ENVISAT and SAGE II or HALOE]

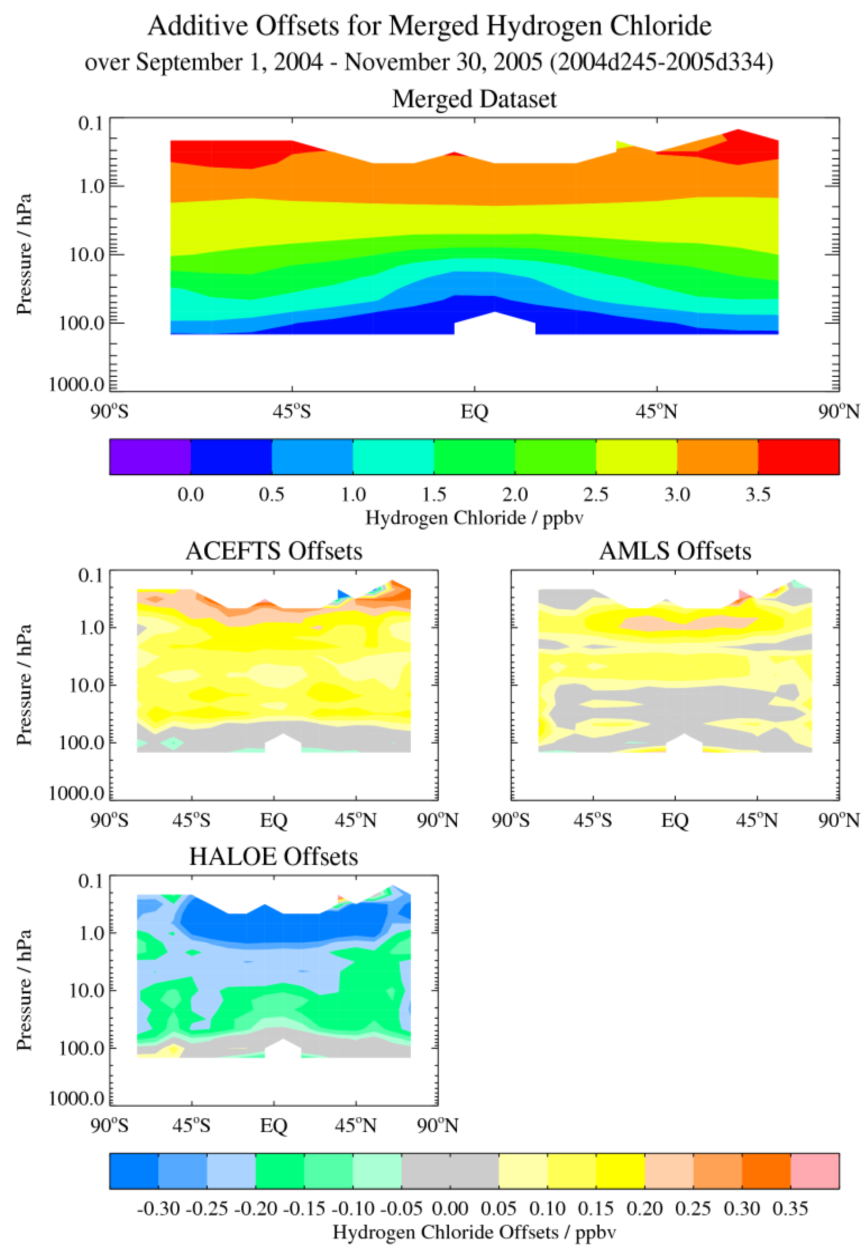
Illustration of poor monthly coverage overlap (tropics mainly) between some stratospheric sounders (for HCl)



HCl: merging datasets, offset values

We go from no tropical overlap (left set of plots) with "direct" merge to "global" coverage / no gaps (right set of plots) with "iterative" merge

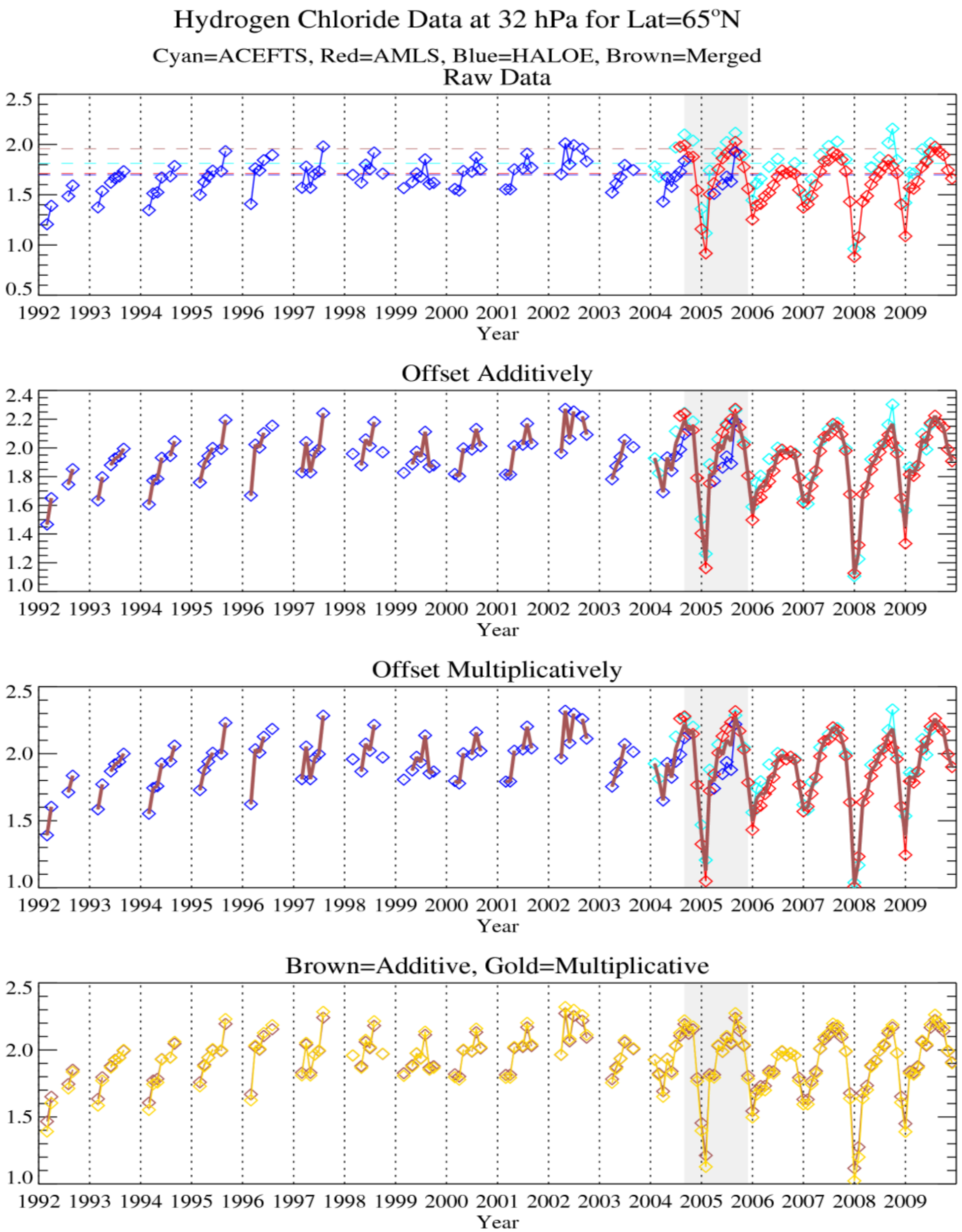




HCl: merging datasets

HALOE, ACE-FTS, Aura MLS, Merged

32 hPa, 65˚N



We have investigated both additive and multiplicative offsets

- generally, only small differences
  > multiplicative case can lead to undesirable results when VMRs are close to zero
  > for additive case, need to ensure that no negative merged values occur (e.g., place a limit on the max. offset value)

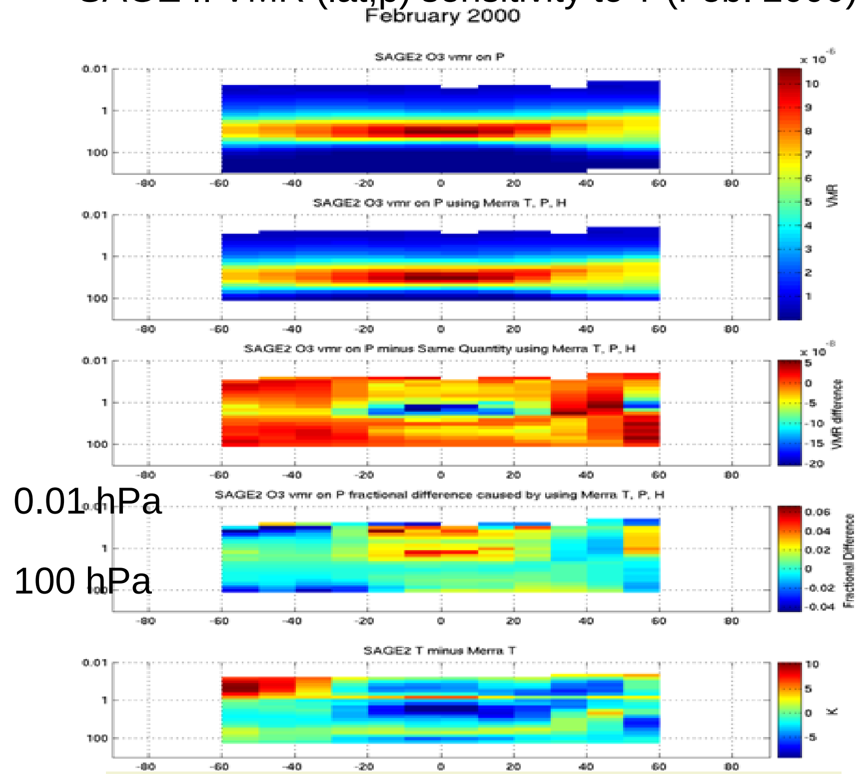
Besides the issue of what "reference" to use, averaging datasets (before or after an overlap period) will blend the trends from each dataset [e.g., an MLS trend problem (HCl upper strat.) should not be averaged with the ACE-FTS trend…]

GOZCARDS Ozone

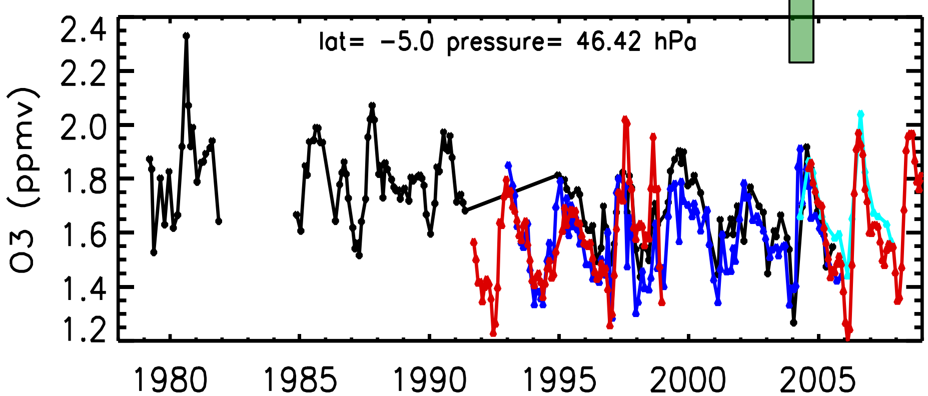
For our merged ozone data record:

- Adjust and merge Aura MLS (AMLS), UARS-MLS (UMLS), HALOE, and SAGE III <u>using SAGE II as reference</u>
- Then, for increased coverage at high lats., bring in ACE-FTS data versus this reference (check avg. offsets and adjust/merge)
- Some issues can arise when converting SAGE II from density/z grid to VMR/p grid
  > Temperature sensitivity (e.g., anomalous T trend)
  [*McLinden et al.*, 2009]
- See Ray Wang's presentation (Wed. afternoon) for more details (results/plans)

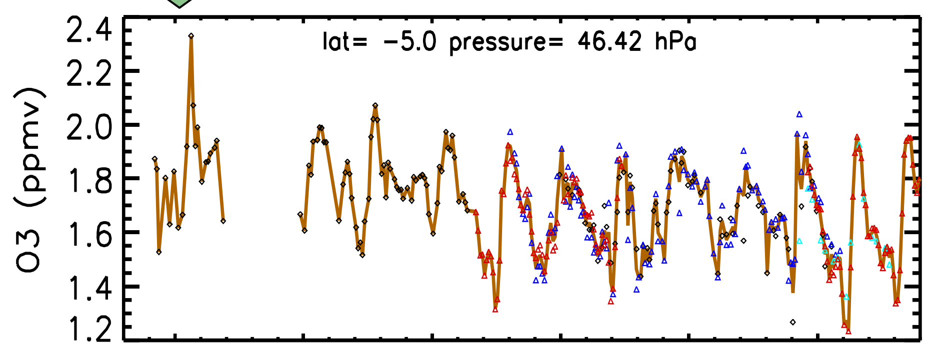
SAGE II VMR (lat,p) sensitivity to T (Feb. 2000)



T sensitivity example for SAGE II O_3 (if use SAGE/NCEP or MERRA T)



Monthly zonal average ozone from **SAGE-I/II**, **HALOE**, **UMLS/AMLS**, and **ACE-FTS** between 0 and 10° S at 46 hPa.



Example of merged O_3 data (brown color) between 0 and 10° S at 46 hPa. Individual data (after adjusting for offsets) are indicated by different colors (as in Figure at left).

Data validation and robustness for trend detection?

- "Ignoring" (for now / for brevity) the "past" datasets…
  what about the newer ones, Aura MLS and ACE-FTS?

Past Validation: "well-validated" (mostly "snapshots" in time and space)
but…requires longer-term validation (ongoing)
+ new data versions require further scrutiny

MLS

- *Froidevaux et al*. (2006, 2008) [vs other satellites, large balloon, aircraft lidar]
- *Jiang et al*. (2007) [vs sondes, lidars]
- *Livesey et al.* (2008) [UT focus, in situ aircraft]
- Other ground-based work for upper strat. / mesosphere
  (e.g., *Boyd et al*, 2007; *Hocke et al.*)
  + other refs. (e.g., *Stajner et al.*, etc.. assimilation work)
  → Typically < 5 to 10% agreement,
  with some larger diffs. for p > 100-150 hPa (MLS high bias)

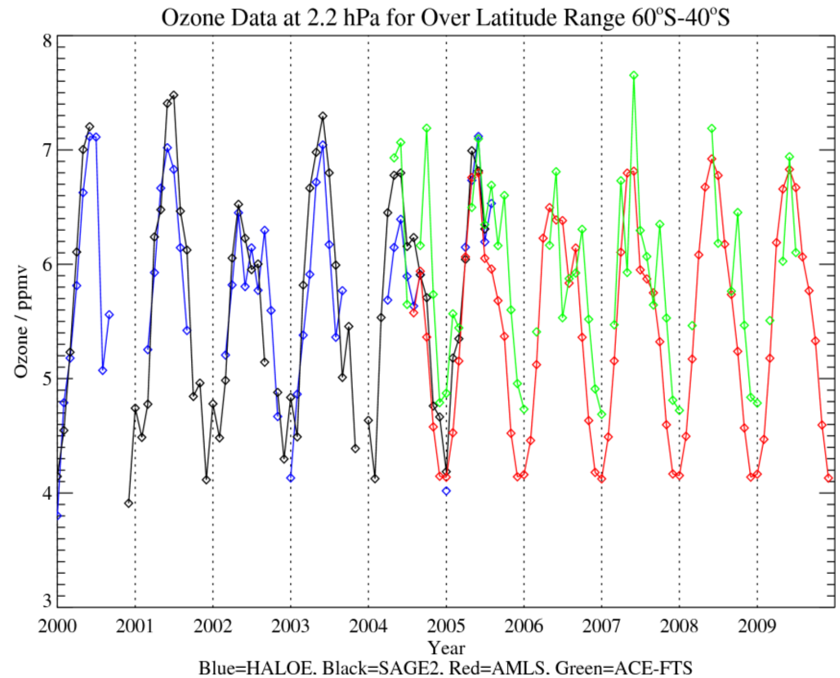
ACE-FTS

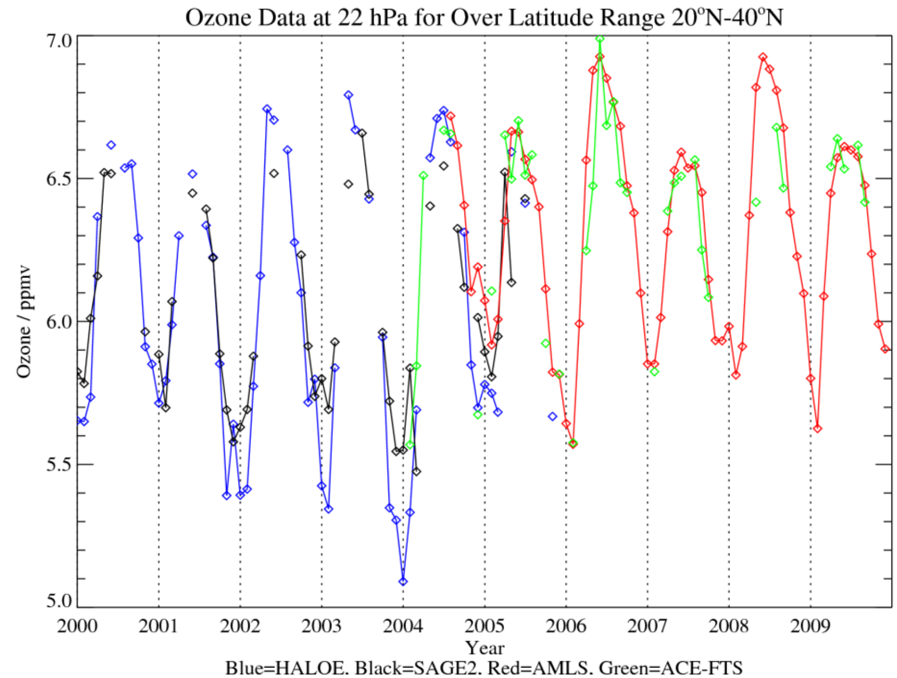
- *Dupuy et al.*, 2009
  For 16-44km, 1-8% agreement
  For z > ~ 45 km high ACE-FTS bias (~20% on average)

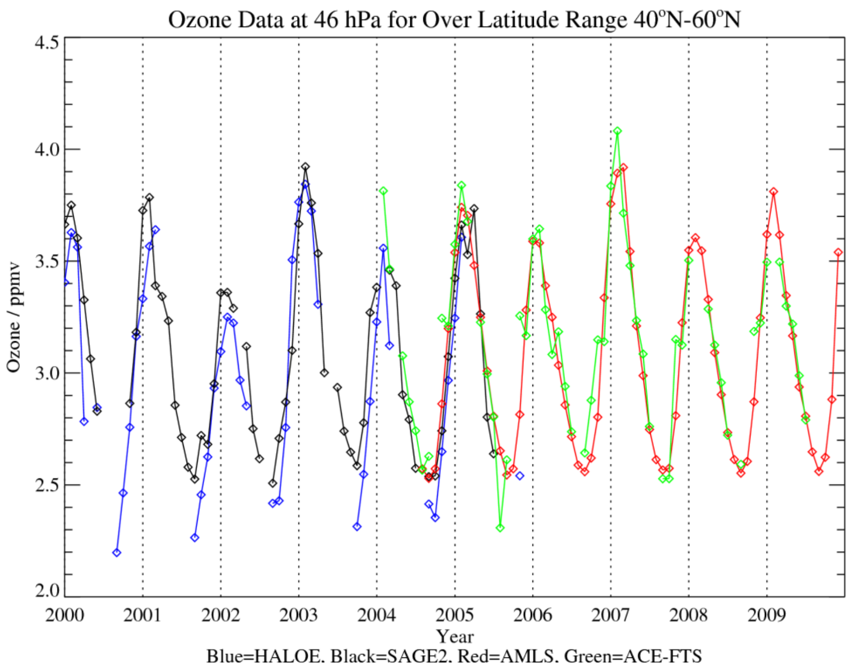
"Longer-term" validation work is emerging (recent or unpublished + see this workshop…)

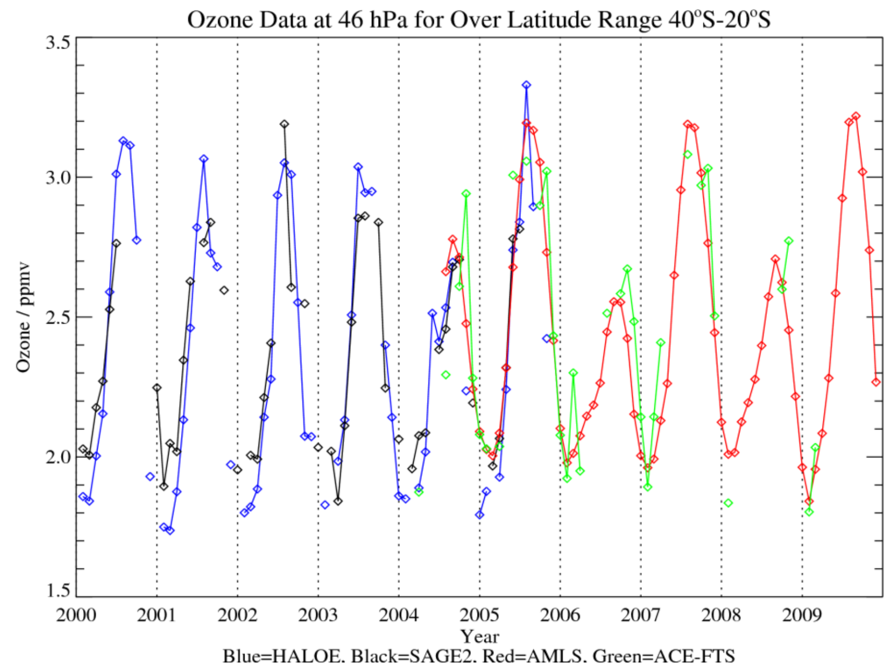
- **Some examples** of interannual change from MLS (and ACE-FTS) **follow**
  [needs more detailed study – preliminary data/results]

Examples of temporal correlation between MLS and ACE-FTS



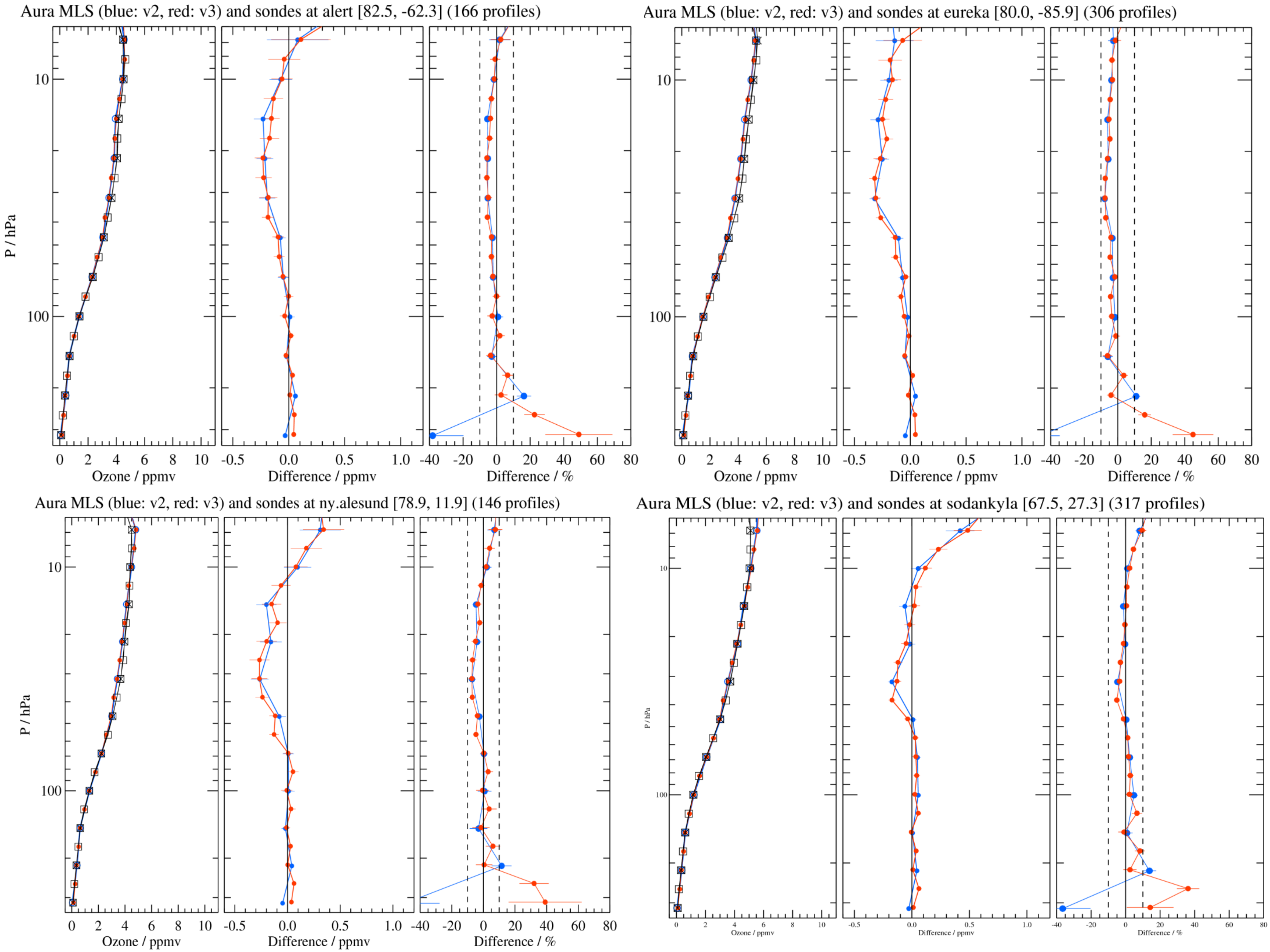




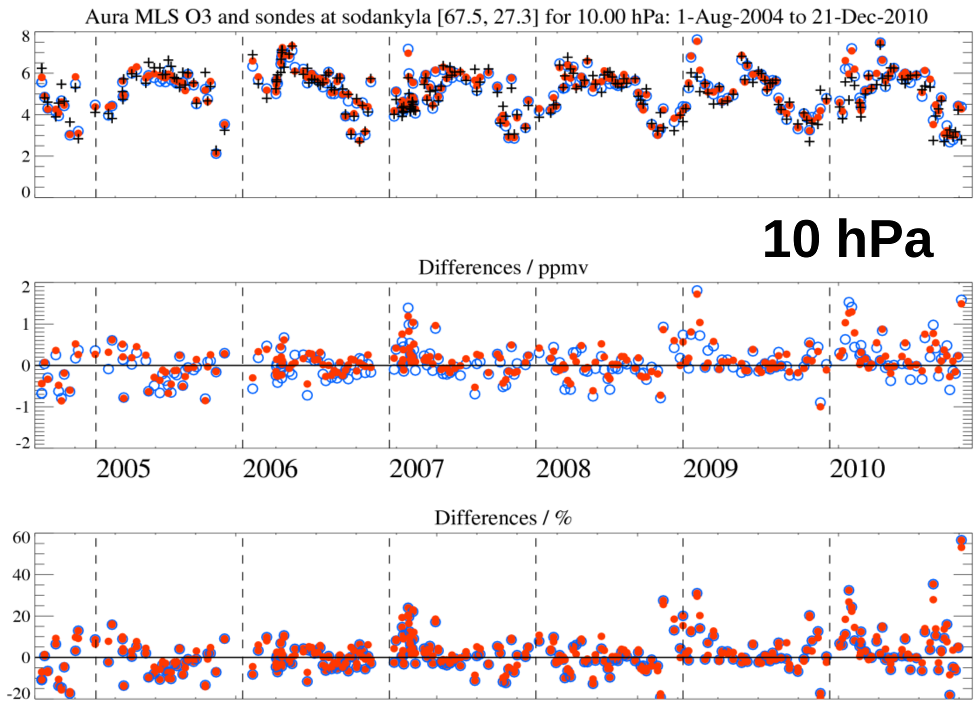


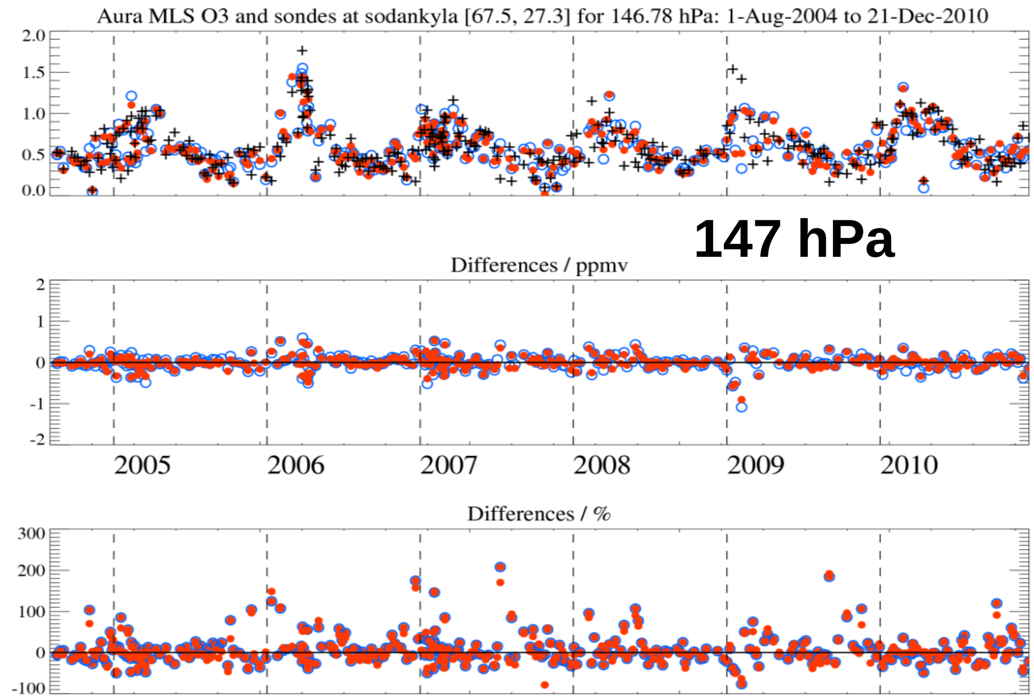
Improved results are being sought (some ACE-FTS data de-spiking and clean-up needed)

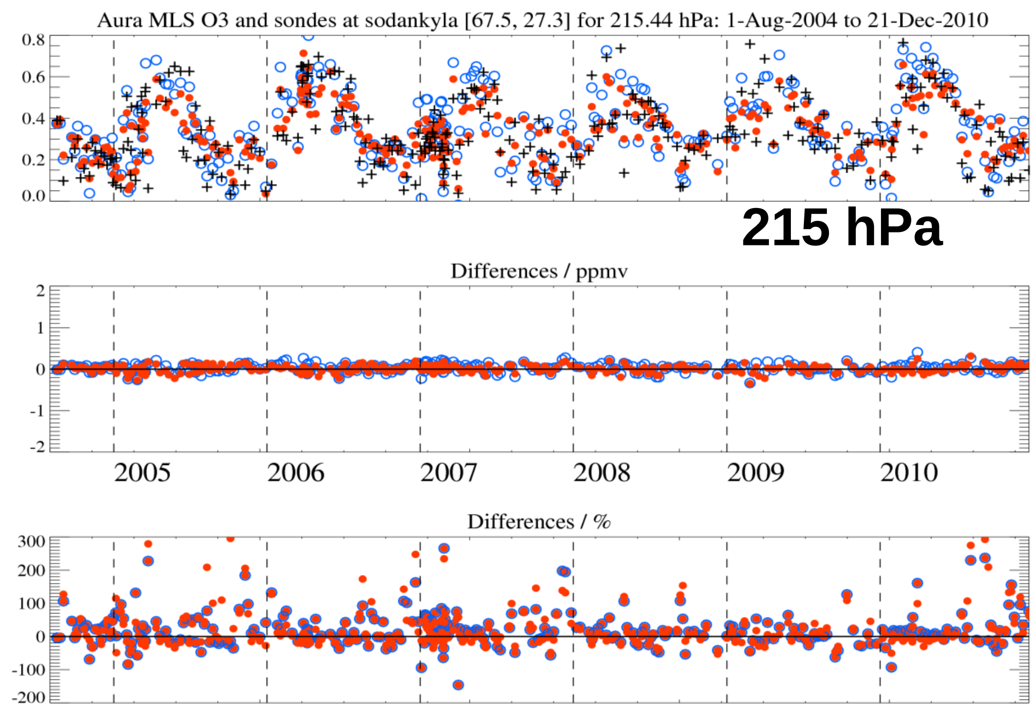
MLS (v2.2 and v3.3) vs sondes at high N. lats: Alert, Eureka, Ny Alesund, Sodankyla



MLS and sonde ozone time series for Sodankyla (68N)



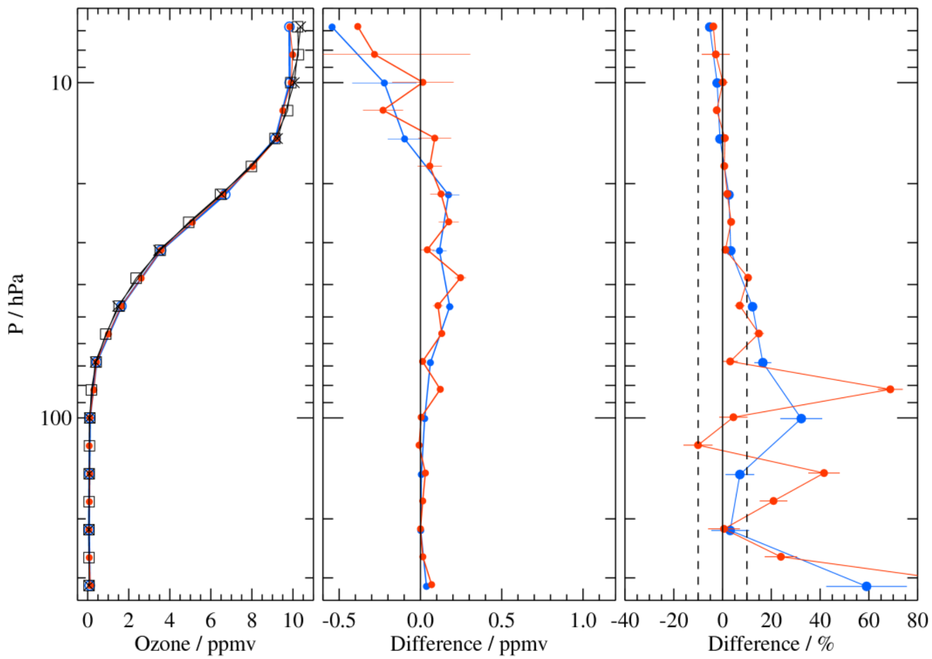




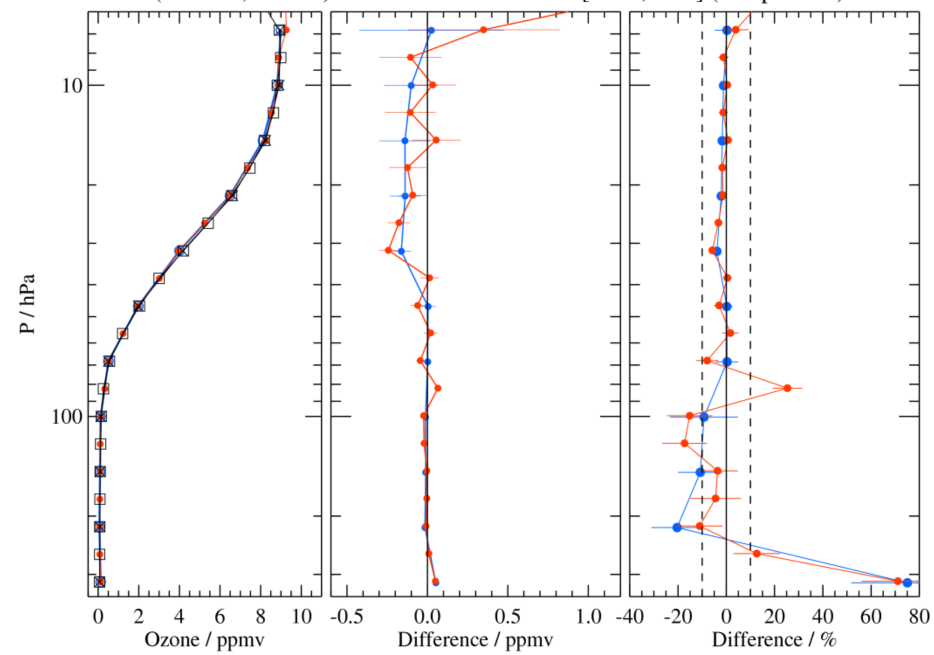
Tropical sites/data: more difficult for UTLS [and for (small) trends…]

MLS vs sondes: v3.3 "misbehaves" more in UTLS (syst. error amplification?)

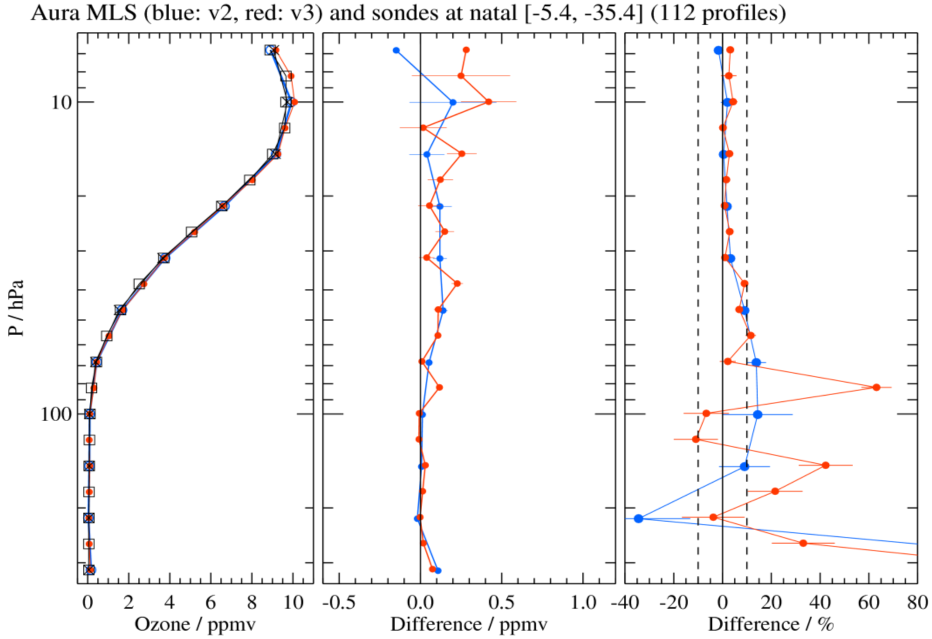
Aura MLS (blue: v2, red: v3) and sondes at ascension.island [-8.0, -14.4] (176 profiles)



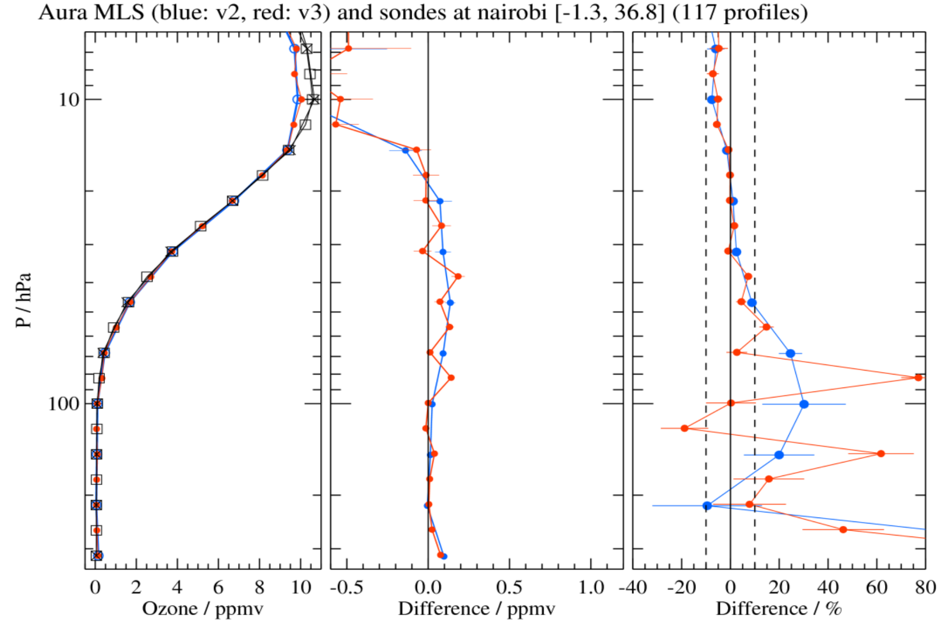
Aura MLS (blue: v2, red: v3) and sondes at la.reunion [-21.1, 55.5] (124 profiles)



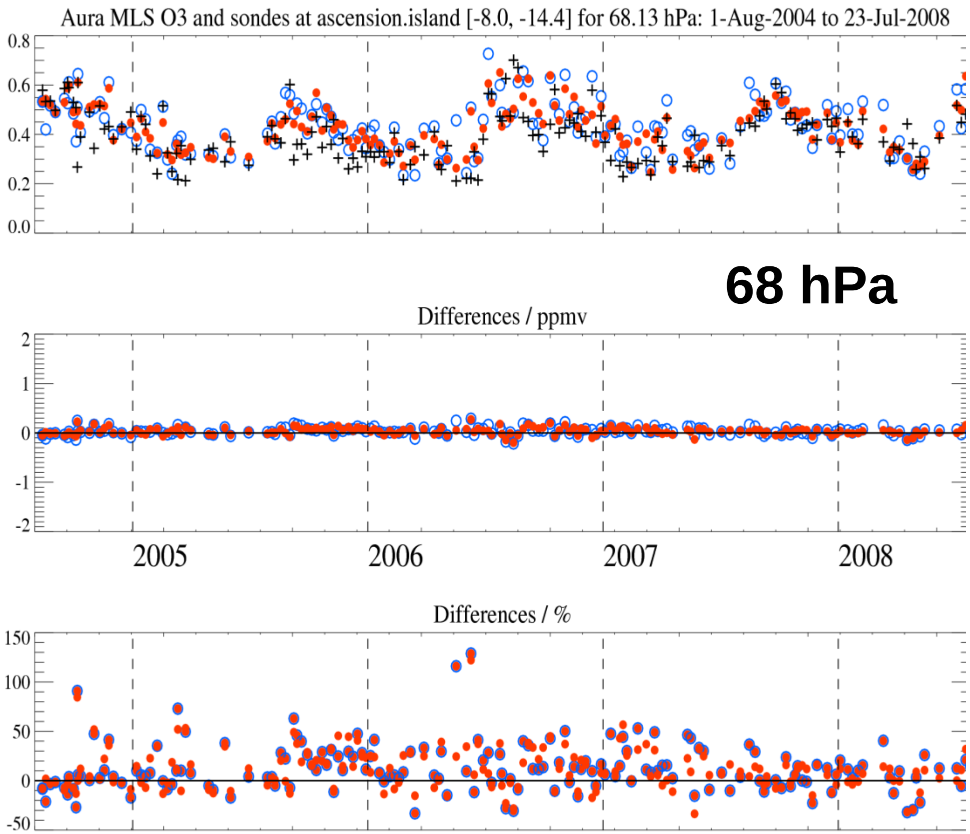
Aura MLS (blue: v2, red: v3) and sondes at natal [-5.4, -35.4] (112 profiles)

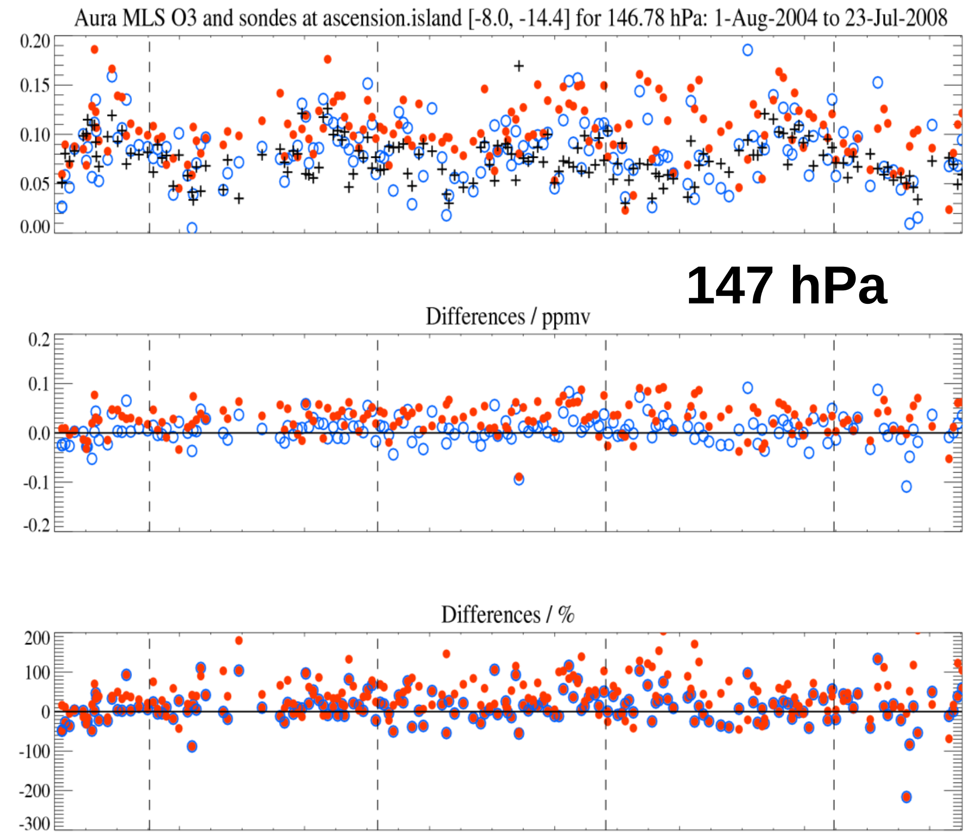


Aura MLS (blue: v2, red: v3) and sondes at nairobi [-1.3, 36.8] (117 profiles)



MLS & sonde series for Ascension Island (8S)



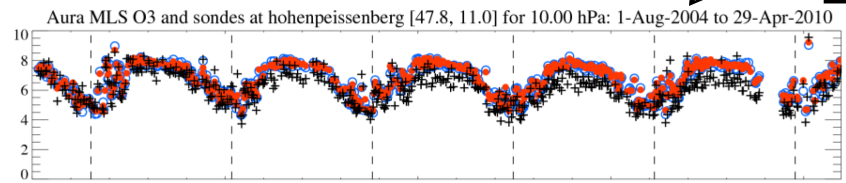


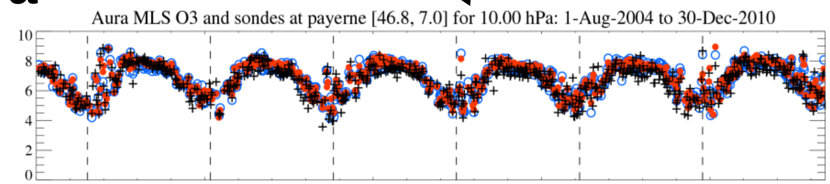
In summary, there is useful MLS "tracking" of O_3 variations (seen in sonde data) appears down to 147 hPa (even in tropics; ~13 km)
[and down to 215 hPa at higher latitudes – ~10 km]
> "nice", but will need more quantification for "accurate trends"
See similar (MLS vs sonde) material from *J. Logan et al.* at this workshop...

> But poorer behavior is observed in MLS v3.3 vertical oscillations (UTLS, tropics)

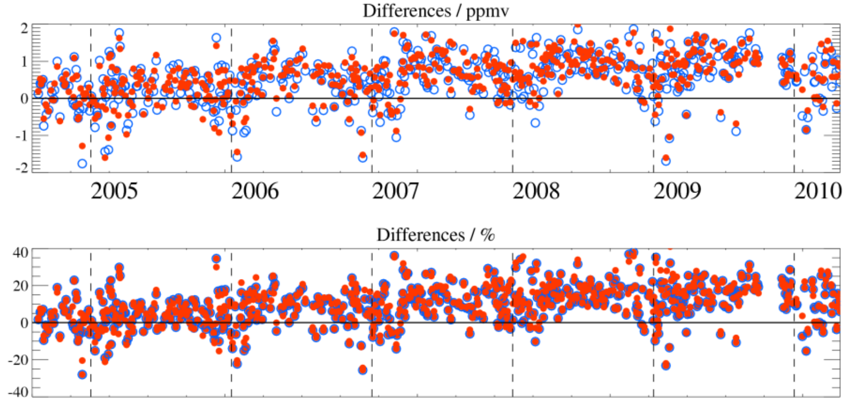
MLS and sonde series for Hohenpeissenberg and Payerne

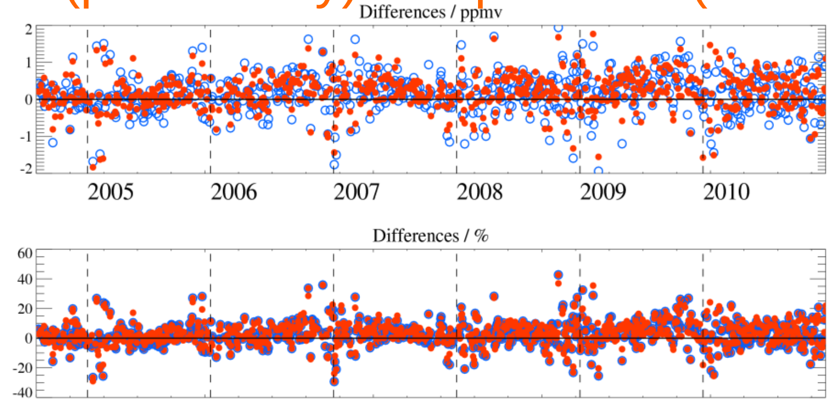
10 hPa



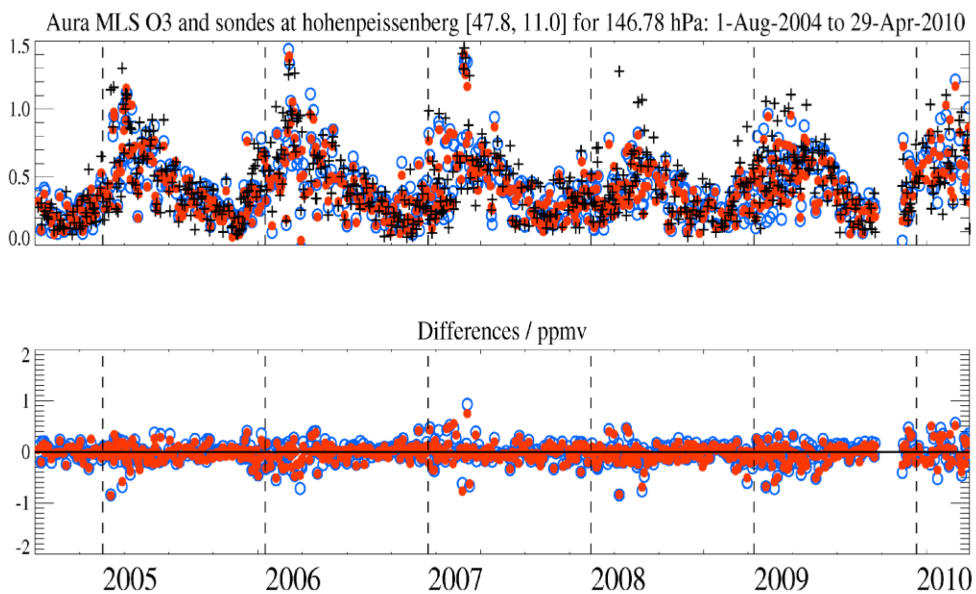


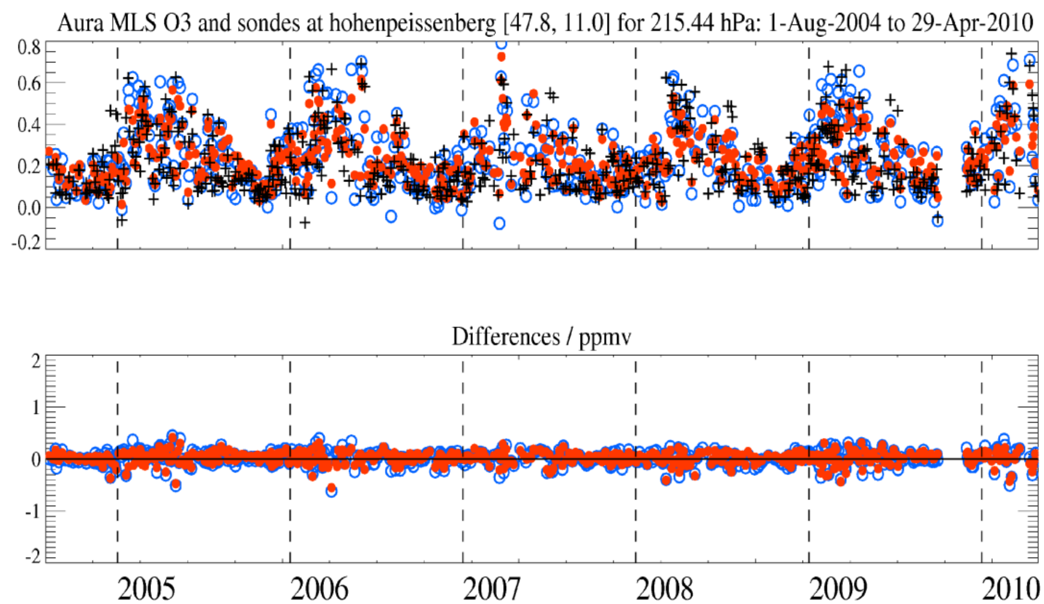
Trend differences between sites are seen in (preliminary) comparisons (at low p)





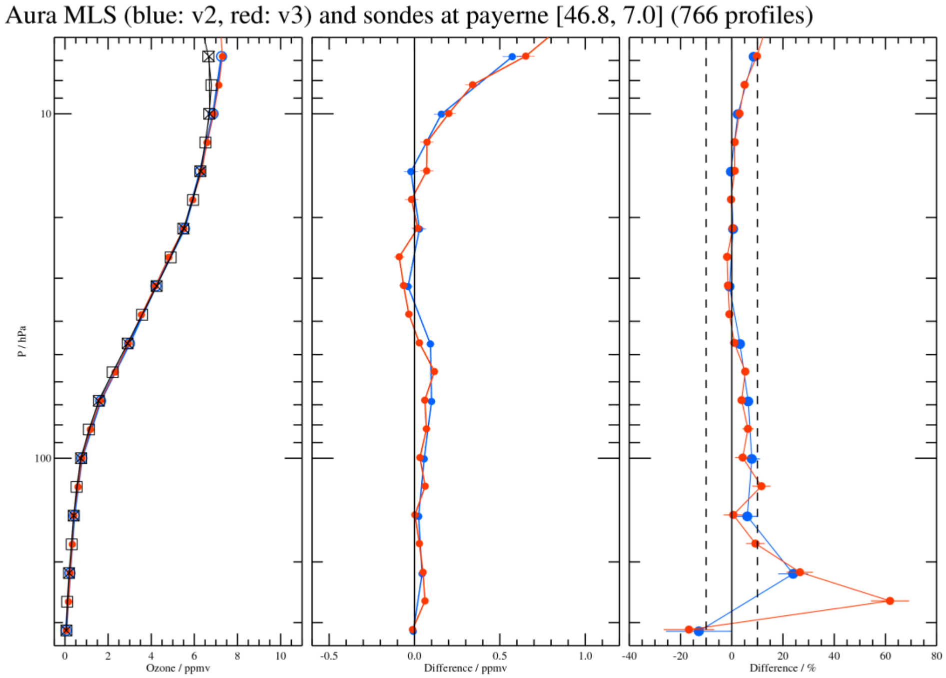
MLS and sonde series: 147 hPa Hohenpeissenberg 215 hPa

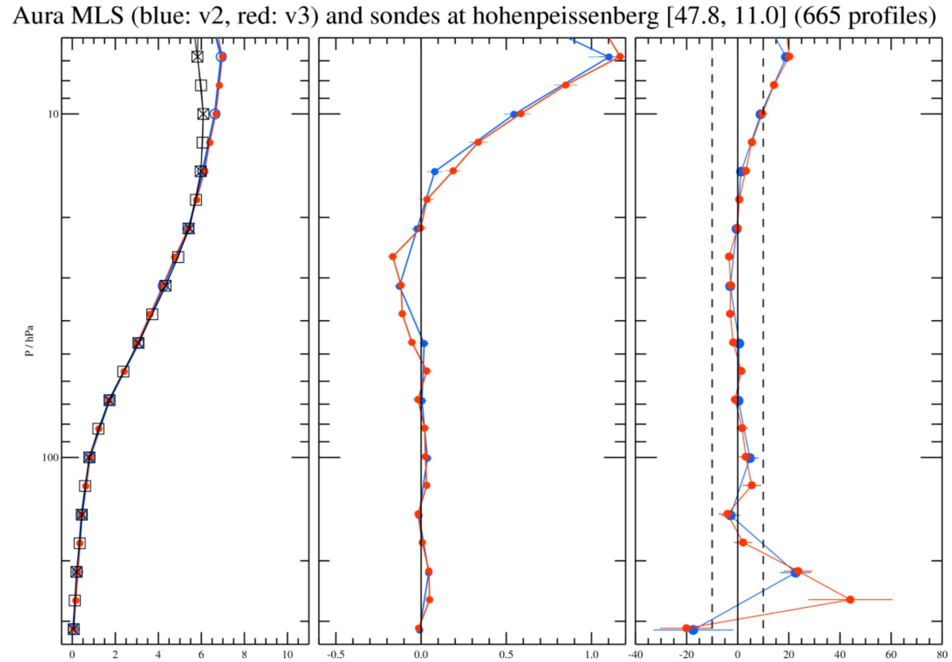


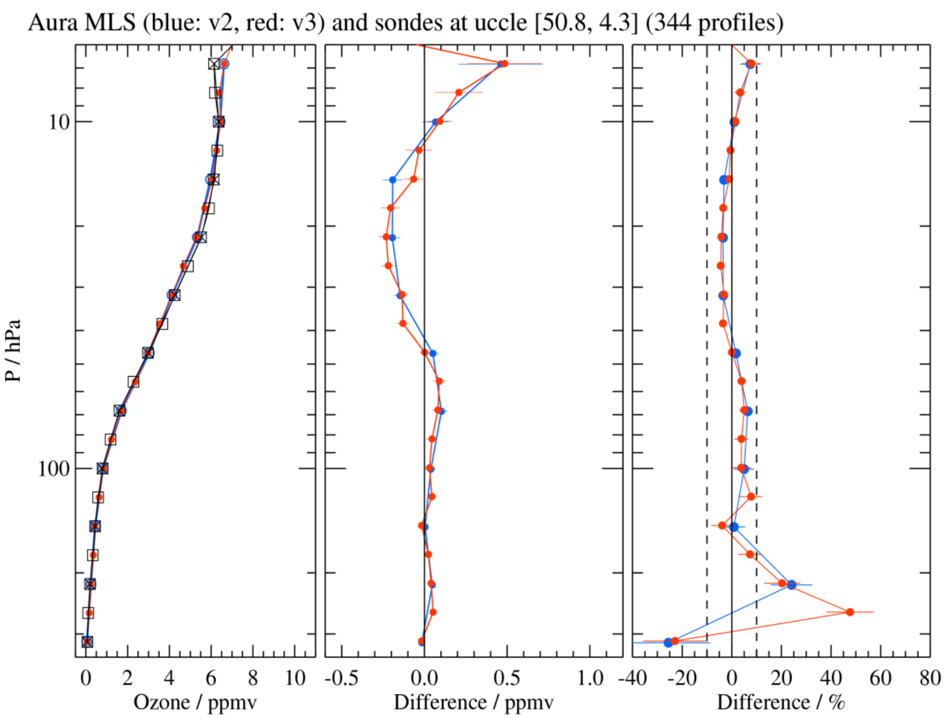


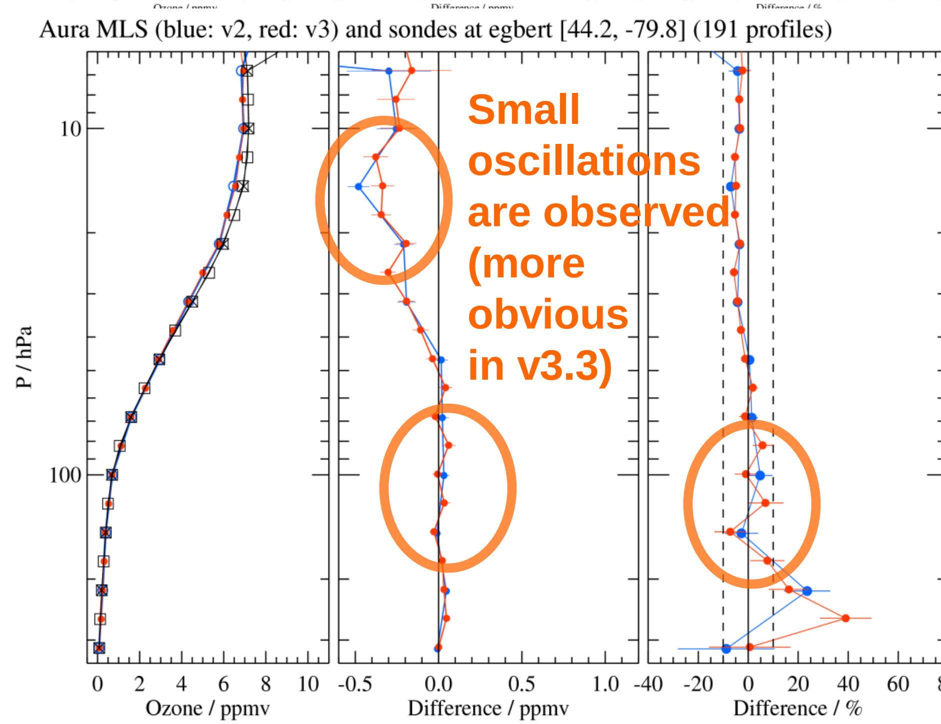
MLS vs sondes at midlatitudes: Payerne, Hohenpeissenberg, Uccle, Egbert

Legionowo (similar lat.) shows very similar results

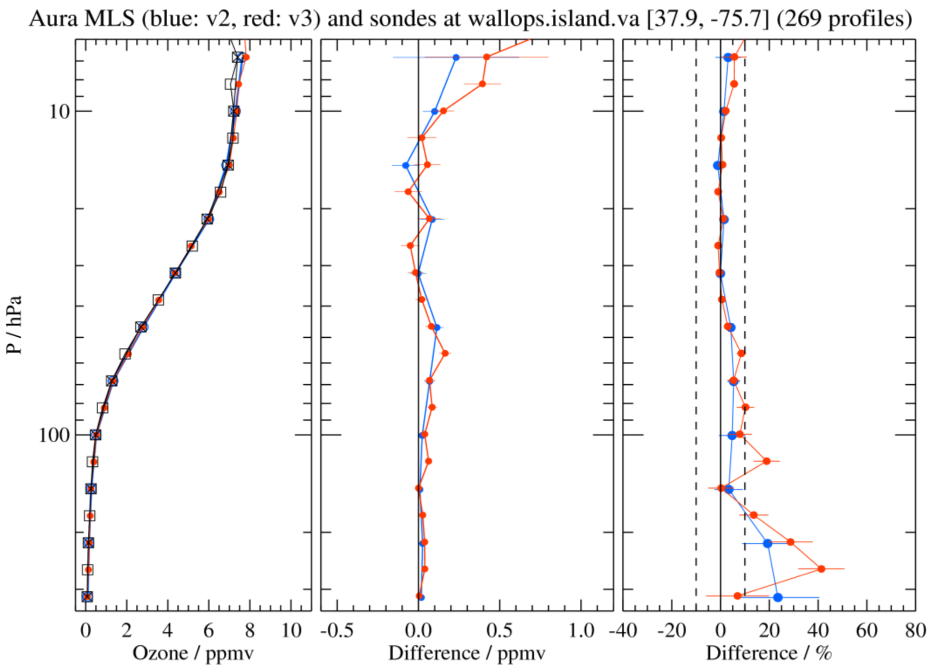


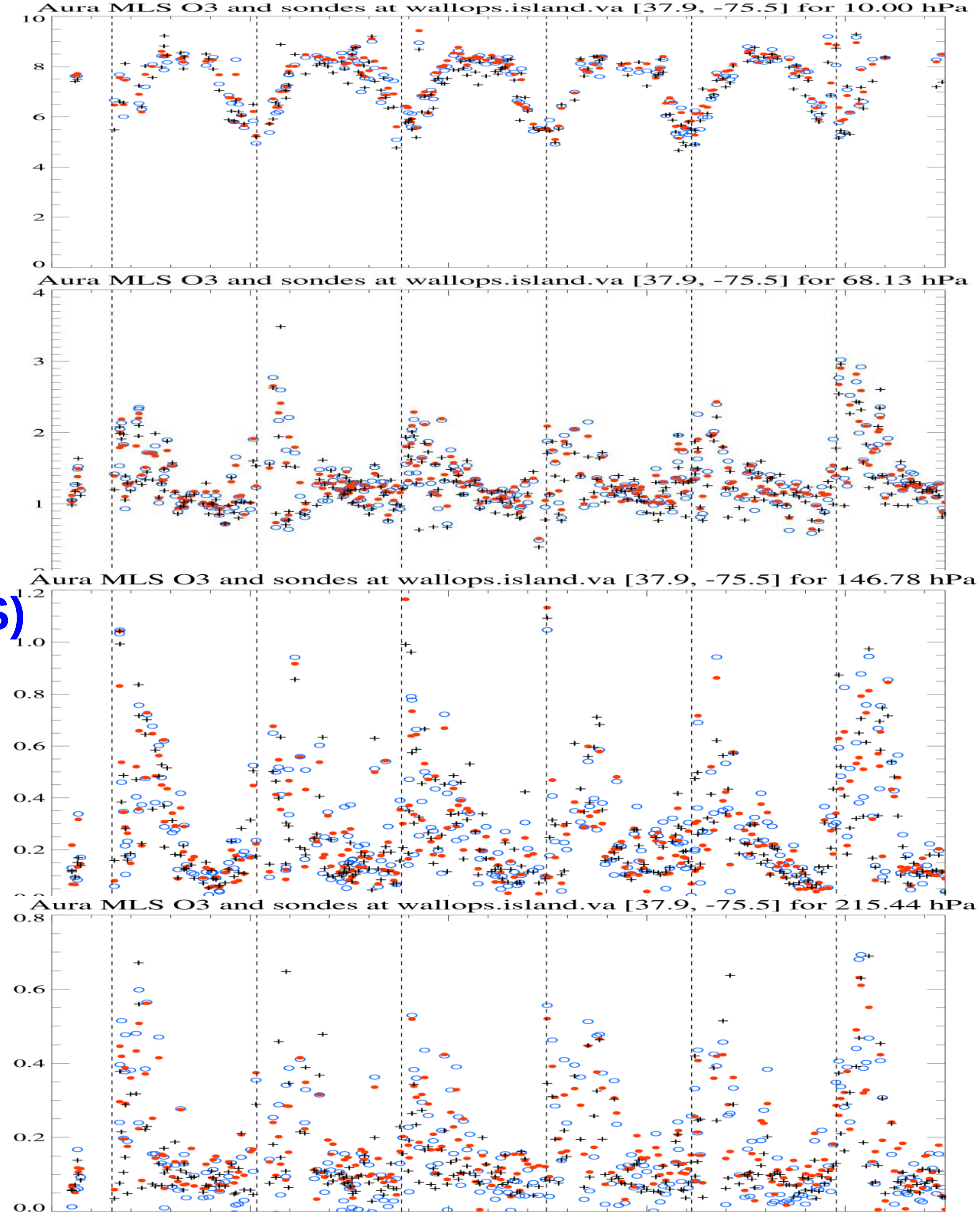




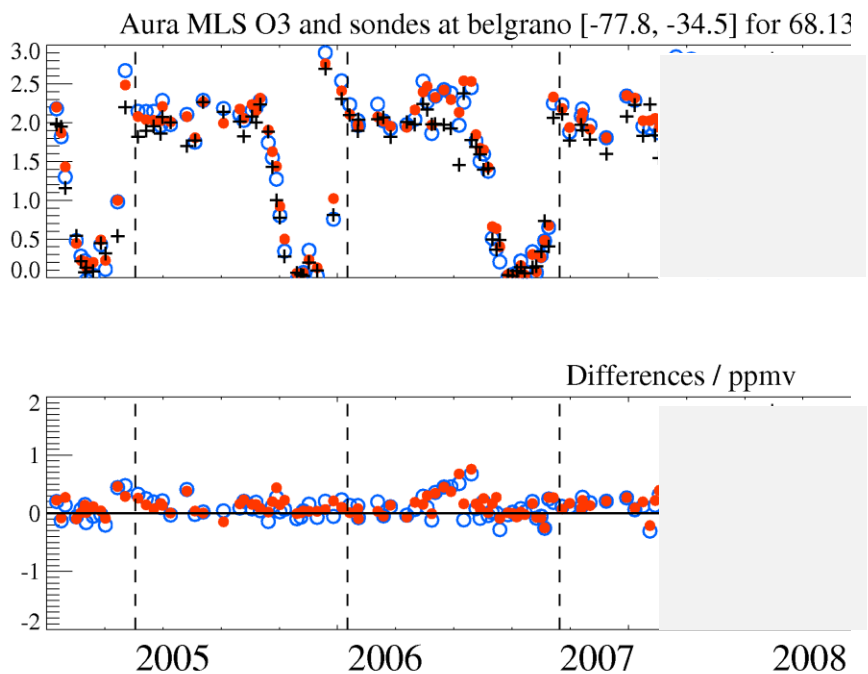


MLS and sonde data for Wallops Island (38N)





MLS & sonde series for Belgrano (78S)



GOZCARDS summary and further work

- **Merging of satellite datasets is proceeding for MEaSUREs GOZCARDS**
  > Exploratory work is (should be) nearing an end
- **See Ray Wang's presentation for more details. We now need to:**
  > Finalize file contents/formats (avg. values, std. devs.,…) [essentially there]
  > Improve data screening (e.g., eliminate outliers from ACE-FTS dataset)
  > Finalize latitude and pressure ranges, and consider special boundary cases
  > Consider using newer data versions
    - For Aura MLS, v2.2 & v3.3 are very similar for most of stratosphere., but low lat. UTLS oscillations in v3.3 are an issue → **will likely use v2.2 (for O_3)**
    - For ACE-FTS, recommendations are to use v2.2 (update) [will stop when?...]
  > Upper strat./lower mes. SAGE II vmr/p data should be reconsidered (post-2000)
  > Double-check the work, look through many plots, etc… for robustness (extra care is needed when delivering for public usage)
- **Cross-validation work is useful** [see also Ray Wang's presentation]
- **Ambitious project with many species/products**
  > scheduled for data deliveries this coming year
    - and **public access**: JPL GOZCARDS website and via GES DISC
  > will look for more intercomparison opportunities – and early user feedback…
- **Also, some overlap with SPARC Data Initiative** (led by M. Hegglin, S. Tegtmeier)
  > happy to see sharing/comparisons versus several European datasets
    → undoubtedly, more to be learned…

The GOZCARDS project work will contribute to O_3 trend detection efforts

- **Suitability for assessing long-term change?**
  - Past datasets (trends depend mainly on SAGE and HALOE) have been scrutinized in the past (trend consistency within ~ 0.5%/decade)
    > but for merging process, some T-related issues & impact on conversion from density to VMR, mainly post-2000 [see Ray Wang's presentation]
  - Regarding Aura MLS and ACE-FTS data
    > Even with 5 or 6 years of data, it's fairly early ["how" suitable?...]; detailed analyses and significance tests needed (e.g., need ~8 yrs of data to detect a trend of 1.5%/decade – *Jones et al.* [2009])
    > For ACE-FTS sparser time/lat coverage: could use MLS validation as a transfer
- **Internal consistency and evidence?**
  - Stability of various MLS subsystems is excellent (apart from a few "end of life" issues affecting HCl main band & OH)
    > We will investigate in more detail: space radiances & moon views
  - As for other datasets, external validation is needed and important
- **Evaluation suitability versus other datasets**
  - MLS data **are** public, being used/studied [see more at this workshop]
- **Useful for long-term data merging?**
  This **is** being worked on, and refined [public availability is the goal, for further community scrutiny – some iteration may occur]
- **What is "best" after SAGE/HALOE?** TBD (workshop goals)