Long term stratospheric ozone record obtained by merging O_3 profiles from different satellites

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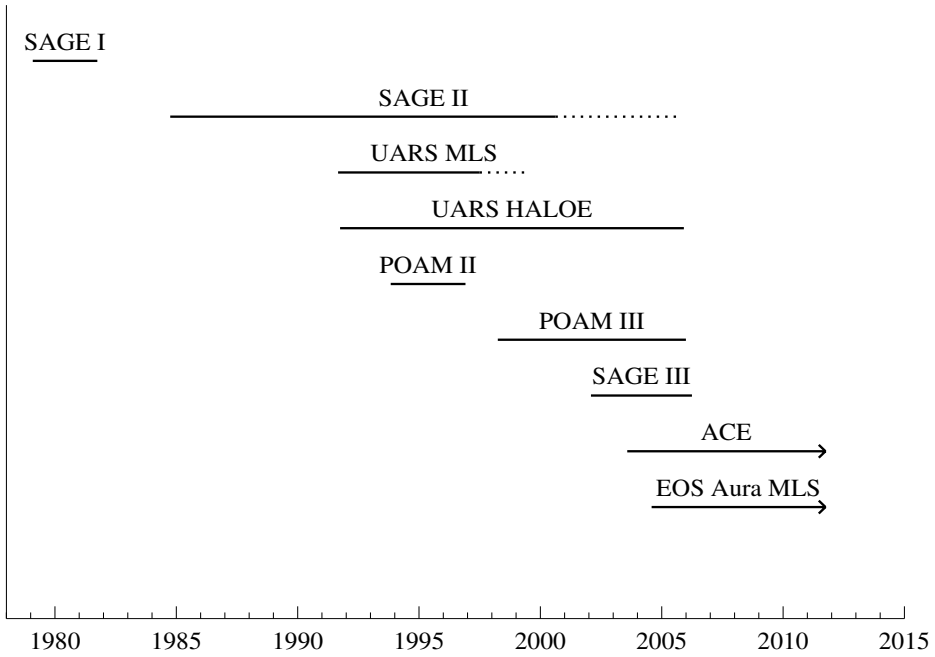
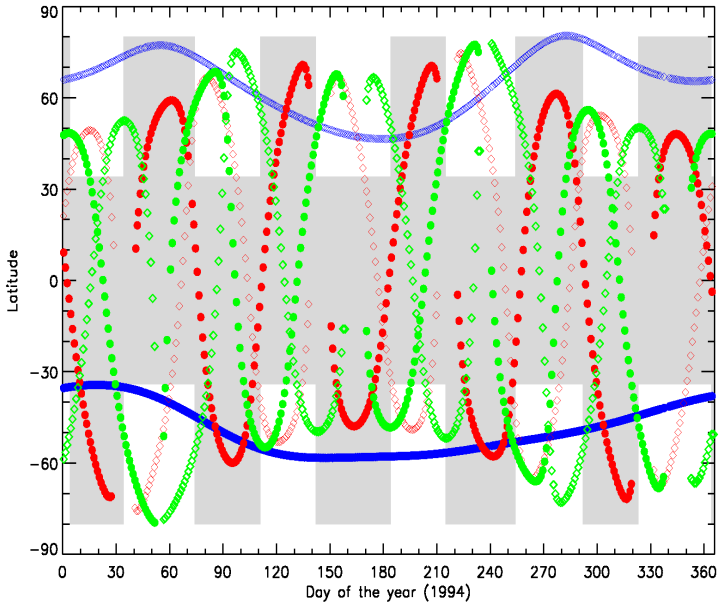
Outlines

- Introduction
- Methodology (how to merge ozone data)
- Results
- Verification (validation)
- Conclusions
- Future work

Satellite/Instrument Timelines and coverage



Timeline of satellite missions and instruments considered for the GOZCARDS project and the creation of a stratospheric composition Earth System Data Record (ESDR).



Yearly coverage plot for some of the sensors

Shading: UARS MLS (1994)
Green circles: HALOE (1994)
Red dots: SAGE II (1994)
Blue symbols (high lat): SAGE III (2003)

Methodology

- Used Data
  - SAGE-I (V5.9) with altitude correction (Wang et al., 1996), new version?
  - SAGE-II (V6.2)
  - SAGE-III (V3)
  - HALOE (V19)
  - UARS-MLS (V5)
  - Aura-MLS (V2.2)
  - ACE-FTS (V2.2 Update)

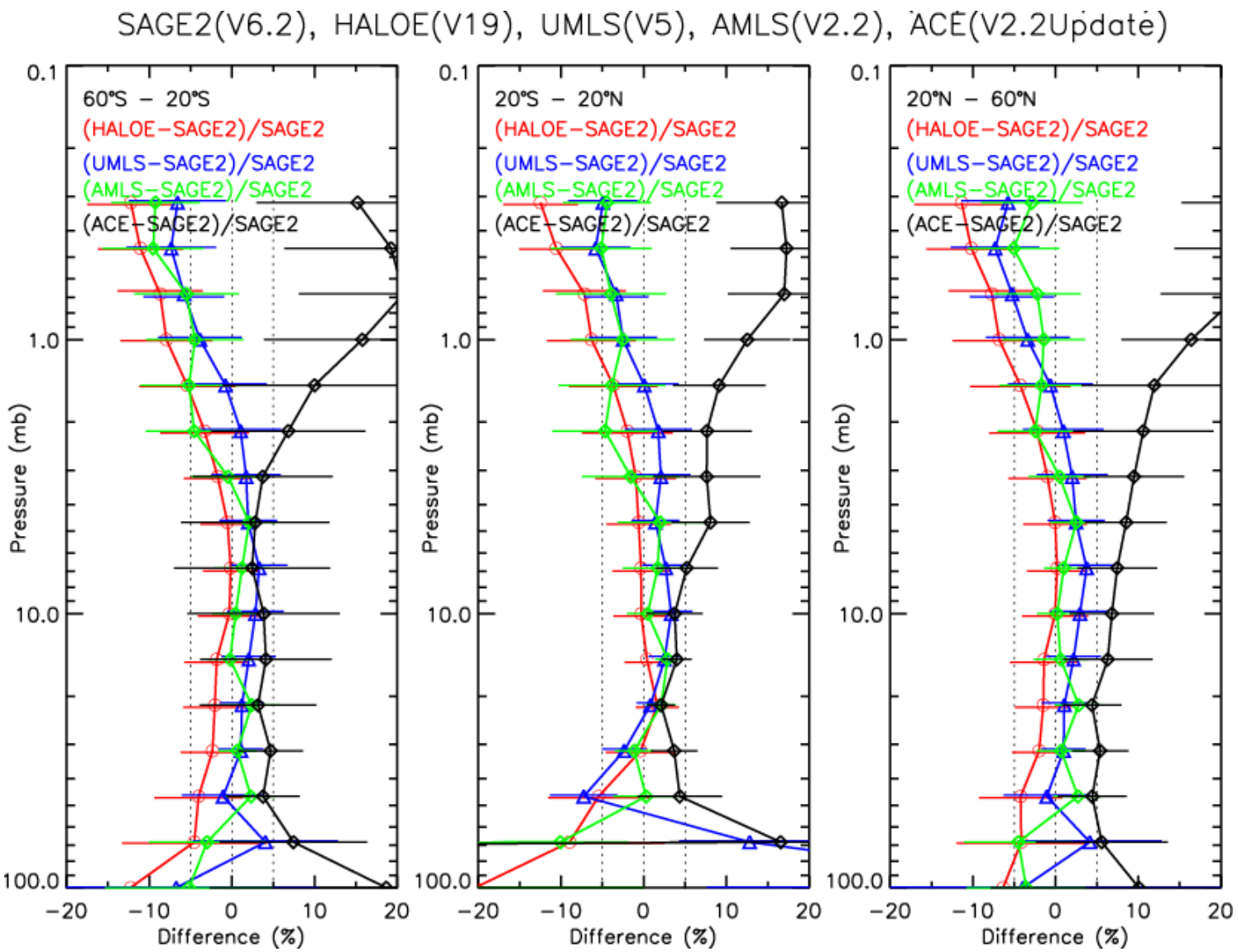
- Common grids
  - Ozone mixing ratios (time, latitude, pressure)
    - (month, 10 degree, UARS pressure) , $P(i)= 1000/10^{(-i/6)}$ i=0, 1, 2, ..

- Use SAGE-2 ozone as reference
  - Calculate offsets between SAGE2 and other satellites during overlap periods
  - Adjusting offsets to other satellite measurements and then averaging them with SAGE2 to derive final merged ozone product
  - Special case when there are few (or no) overlap data
    - High latitudes
    - ACE-FTS

Number of SAGE II/ACE-FTS Co-located Monthly Means

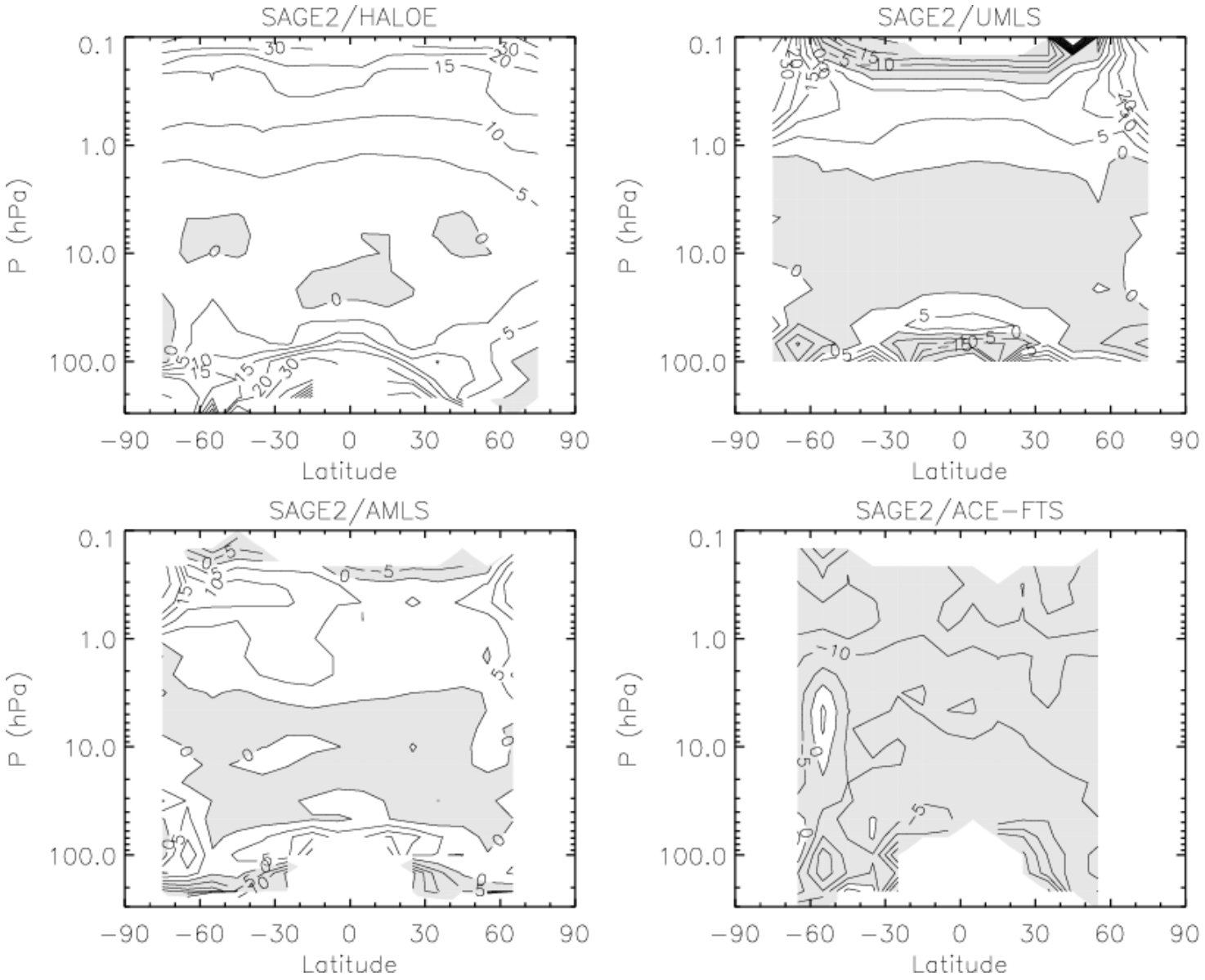
P(hPa)	85S	75S	65S	55S	45S	35S	25S	15S	5S	5N	15N	25N	35N	45N	55N	65N	75N	85N
1.0000	0	0	2	5	4	3	3	4	4	4	3	3	7	5	6	2	0	0
1.4678	0	0	3	6	4	3	3	4	4	4	3	3	7	7	7	2	0	0
2.1544	0	0	3	6	5	3	3	4	4	4	3	3	7	7	7	2	0	0
3.1623	0	0	3	6	4	2	3	4	4	4	3	3	7	7	7	2	0	0
4.6416	0	0	3	6	4	3	3	4	4	4	3	3	7	7	7	2	0	0
6.8129	0	0	3	6	4	3	3	4	4	4	3	3	7	7	7	2	0	0
10.000	0	0	3	6	5	3	3	4	4	4	3	3	7	7	7	2	0	0
14.678	0	0	3	6	5	3	3	4	4	4	3	3	7	7	7	2	0	0
21.544	0	0	3	6	5	3	3	4	4	4	3	3	7	7	7	2	0	0
31.623	0	0	3	6	5	3	3	4	4	4	3	3	7	7	7	2	0	0
46.416	0	0	3	6	6	4	3	4	4	4	3	3	7	8	8	2	0	0
68.129	0	0	3	6	6	4	3	4	4	4	3	3	7	8	8	2	0	0
100.00	0	0	3	6	6	4	3	4	4	3	3	3	7	8	8	2	0	0
146.78	0	0	3	6	6	4	3	4	3	2	3	3	7	8	8	2	0	0
215.44	0	0	3	6	6	4	3	4	3	1	2	2	4	6	6	2	0	0
316.23	0	0	3	6	5	3	3	4	3	0	2	2	3	3	1	1	0	0

Zonal mean ozone differences and standard deviations between SAGE-2 and **HALOE**, **UARS MLS**, **Aura MLS** and **ACE-FTS**

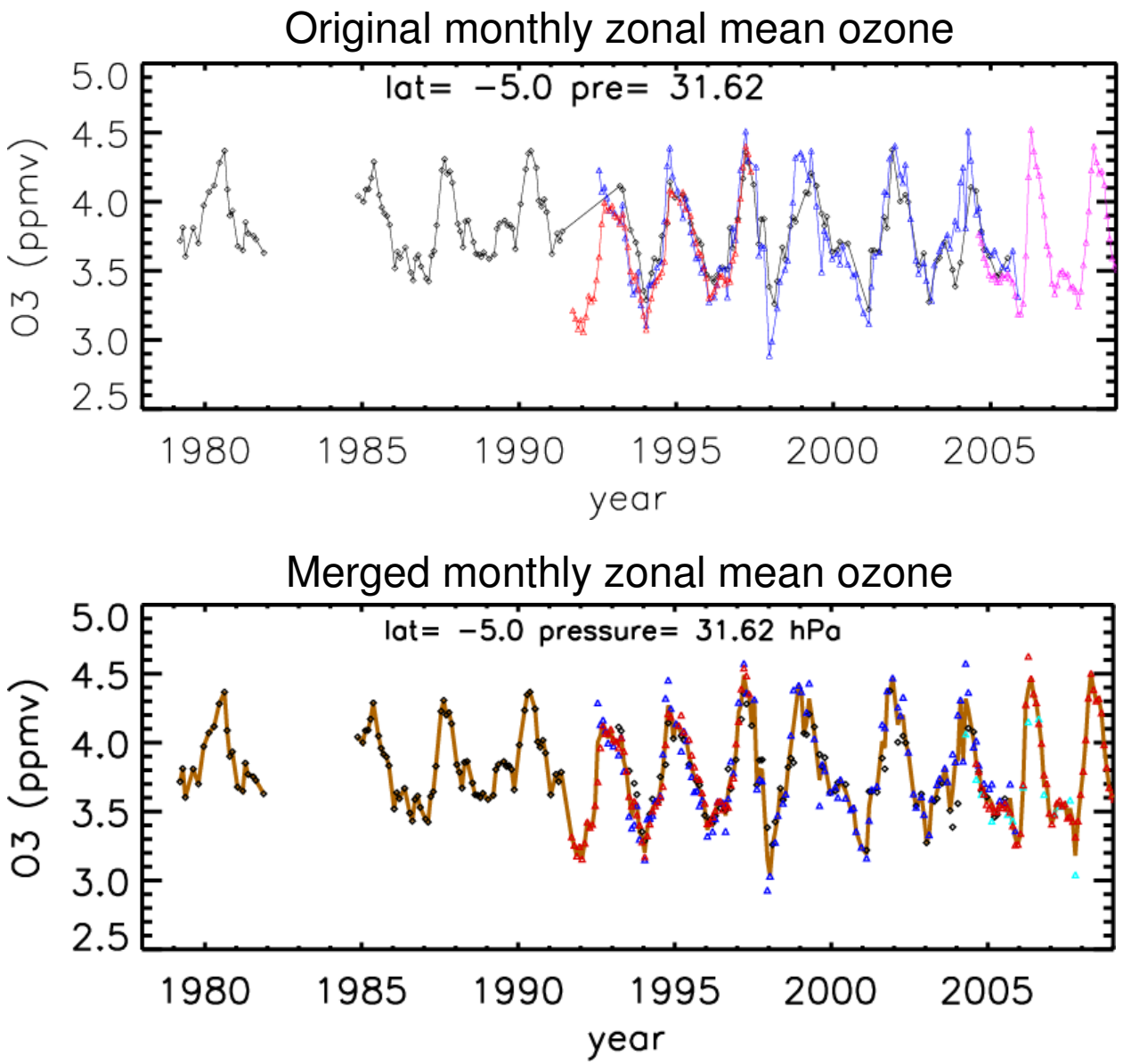


Based on monthly zonal means

Mean differences (%) in zonal mean ozone between SAGE-II and other satellites
(sage2-other)/other *100%, shaded areas indicate negative values



Example of combining/merging satellite monthly zonal mean O3 data



SAGE-I/II (black),
HALOE (blue),
UMLS/AMLS (red),
ACE-FTS (cyan).
merged O3 (brown**)**

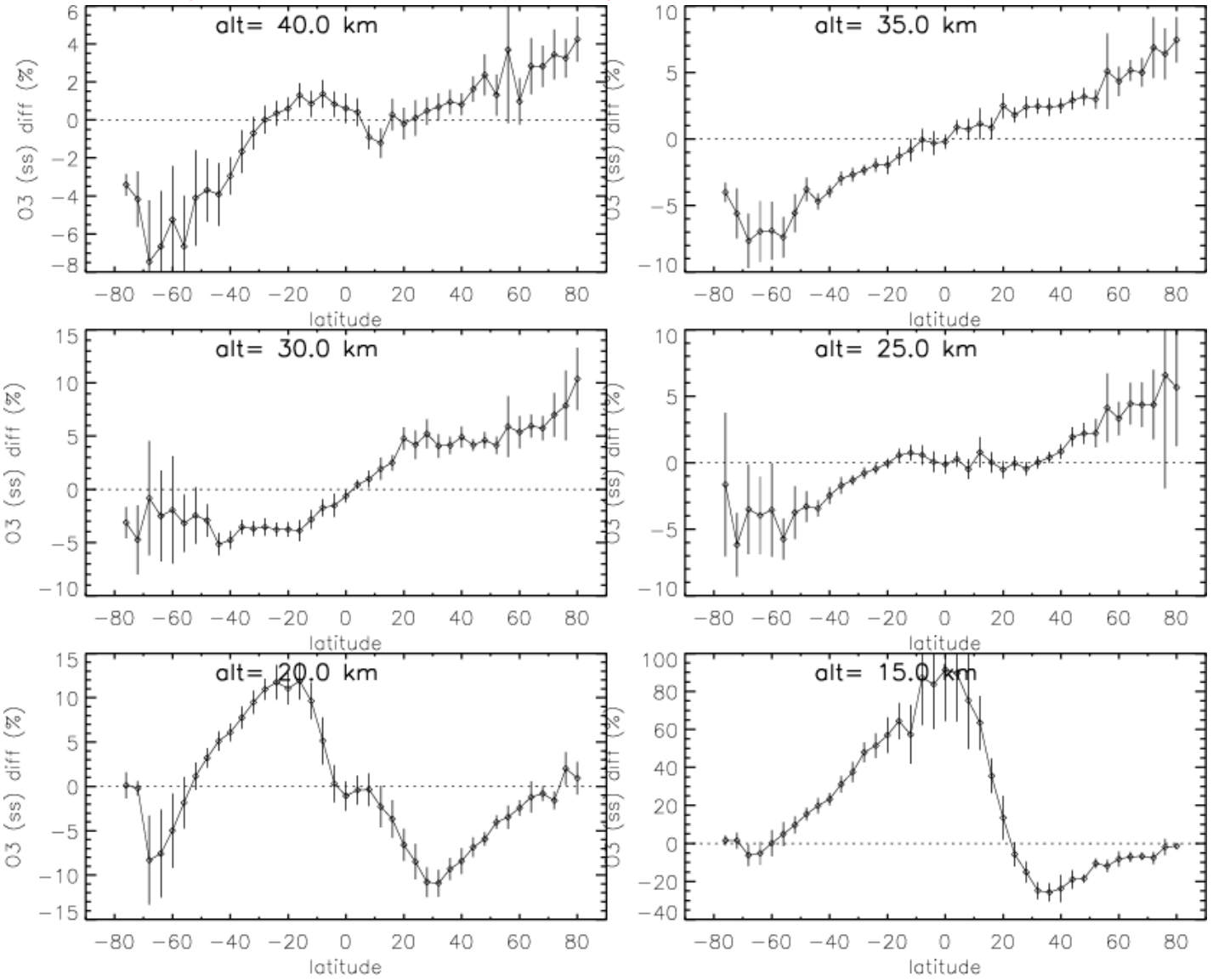
Verification (validation)

- Internal cross checks

- Coordinate conversion (T) issues

SAGE-2 zonal mean O3 (SS) differences and 2 standard deviations

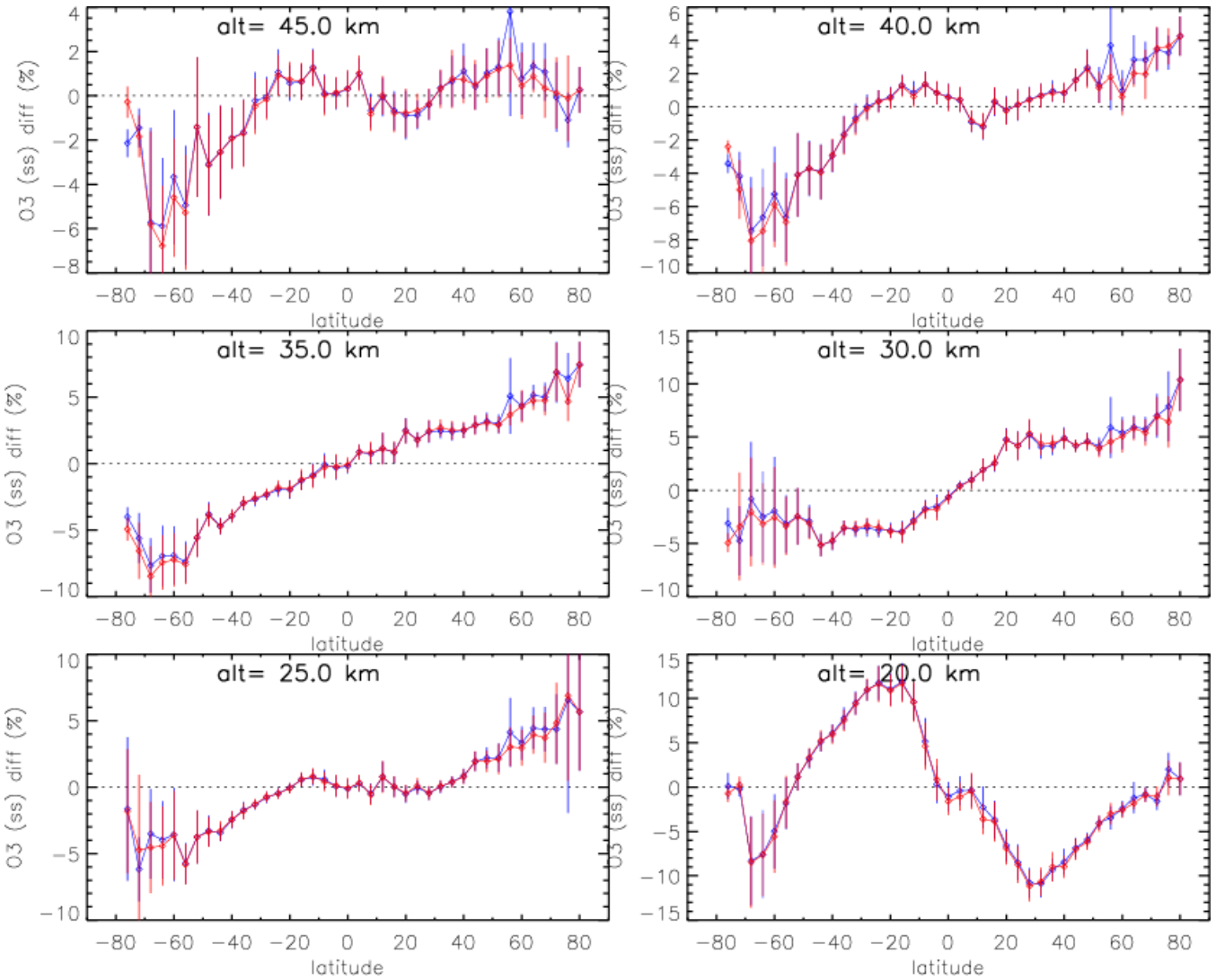
(1984-1990, 1995-2005), (BRFW – RW) / RW * 100%



Based on monthly zonal mean O3 number density at 4 degree bin

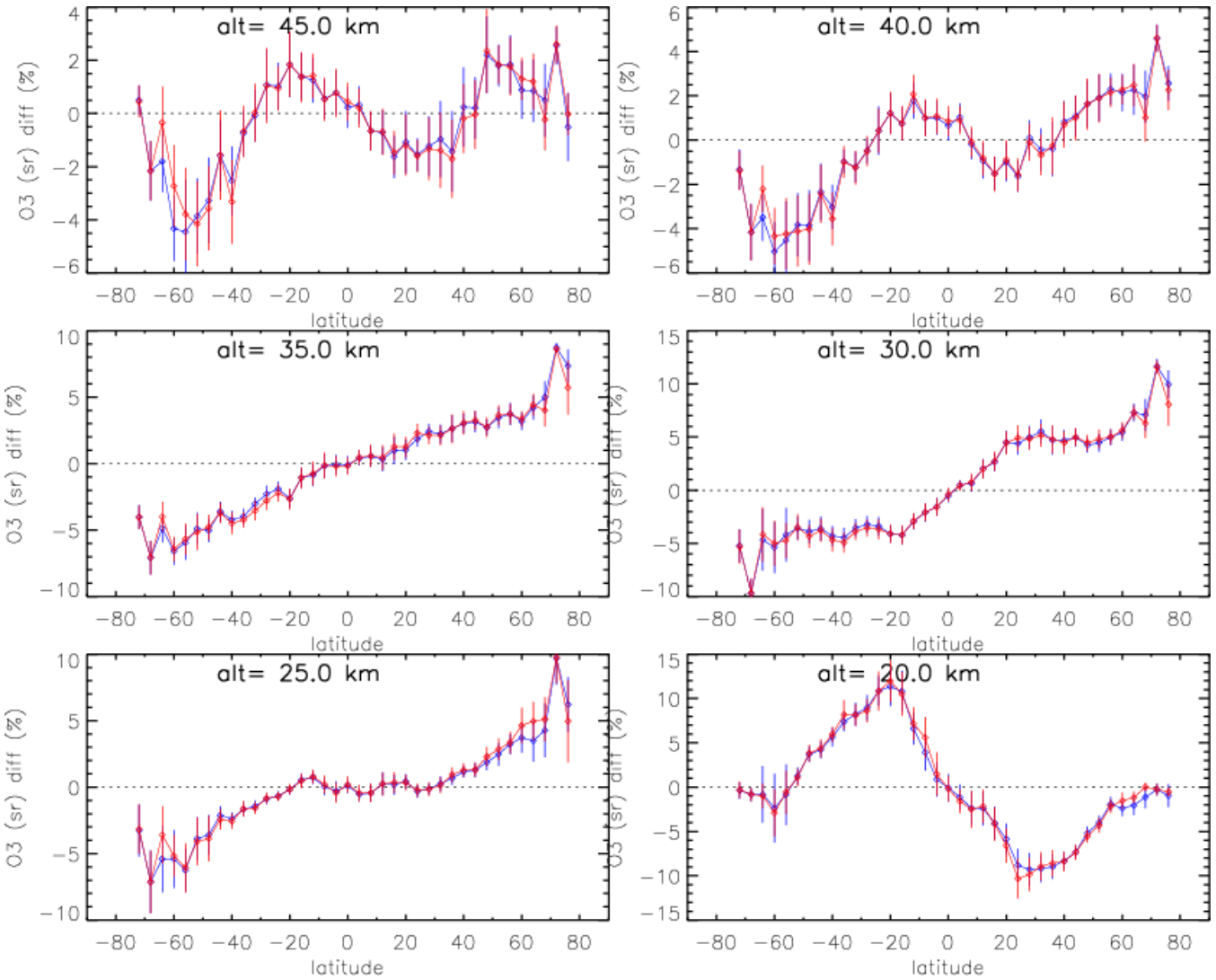
SAGE II zonal mean O3 (SS) differences and 2 standard deviations

(1984-1990, 1995-2005), (BRFW – JA) /JA * 100%, (BRFW-RW)/RW*100%



SAGE II zonal mean O3 (SR) differences and 2 standard deviations

(1984-1990, 1995-2005), (BRFW – JA) /JA * 100%, (BRFW-RW)/RW*100%



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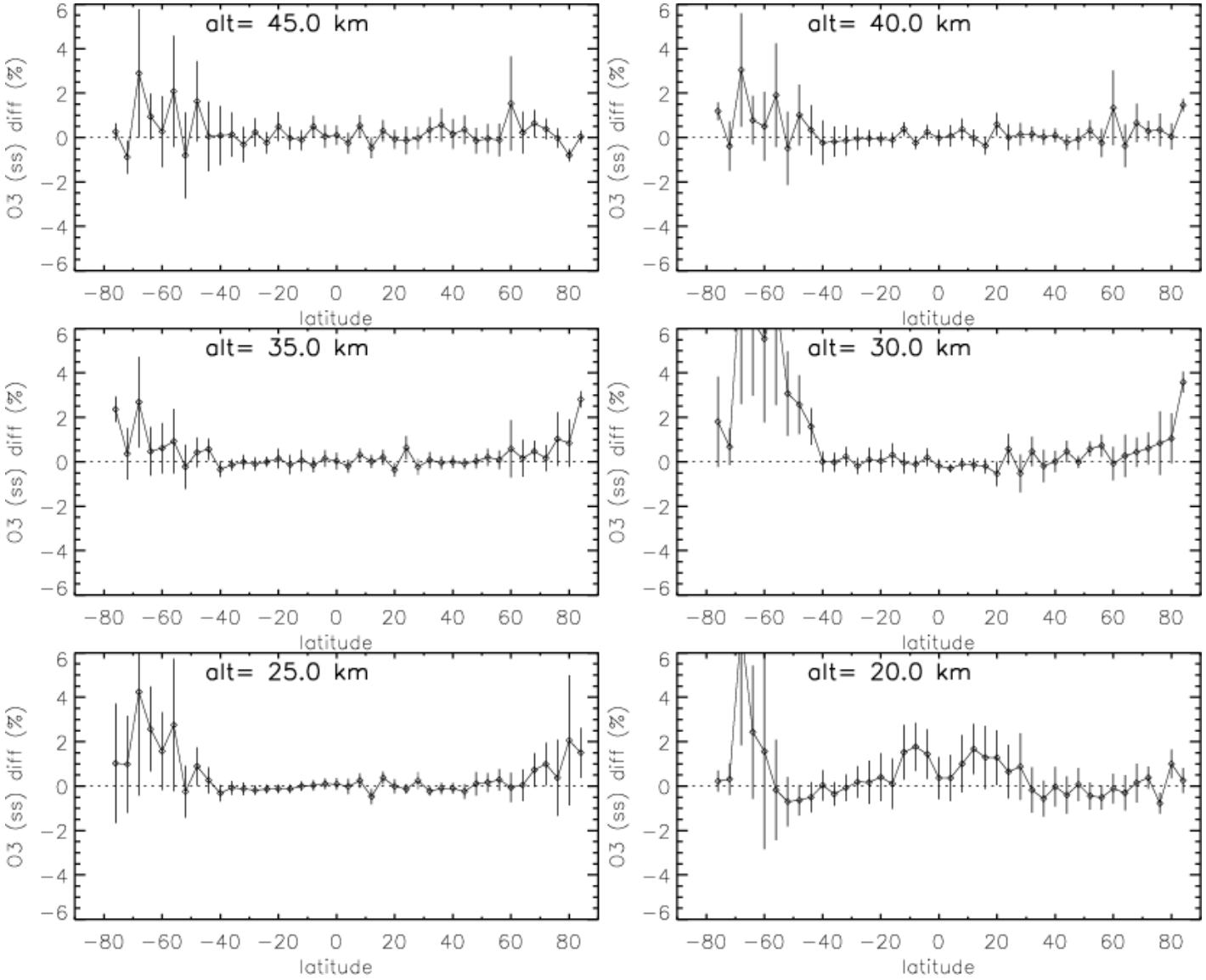

SAGE2 data from Ray Wang are shifted 4 degrees North

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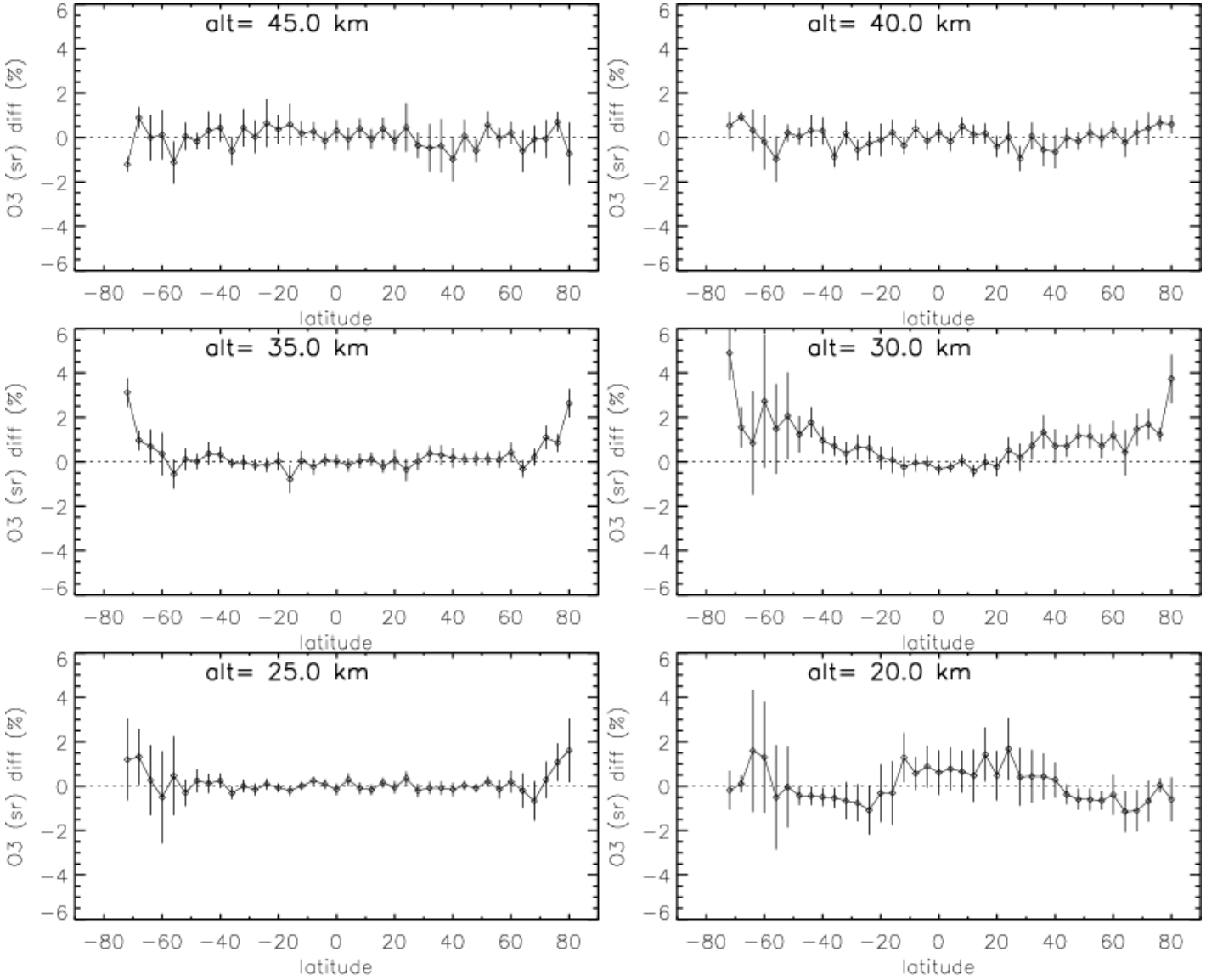

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Coordinate conversion (T) issues

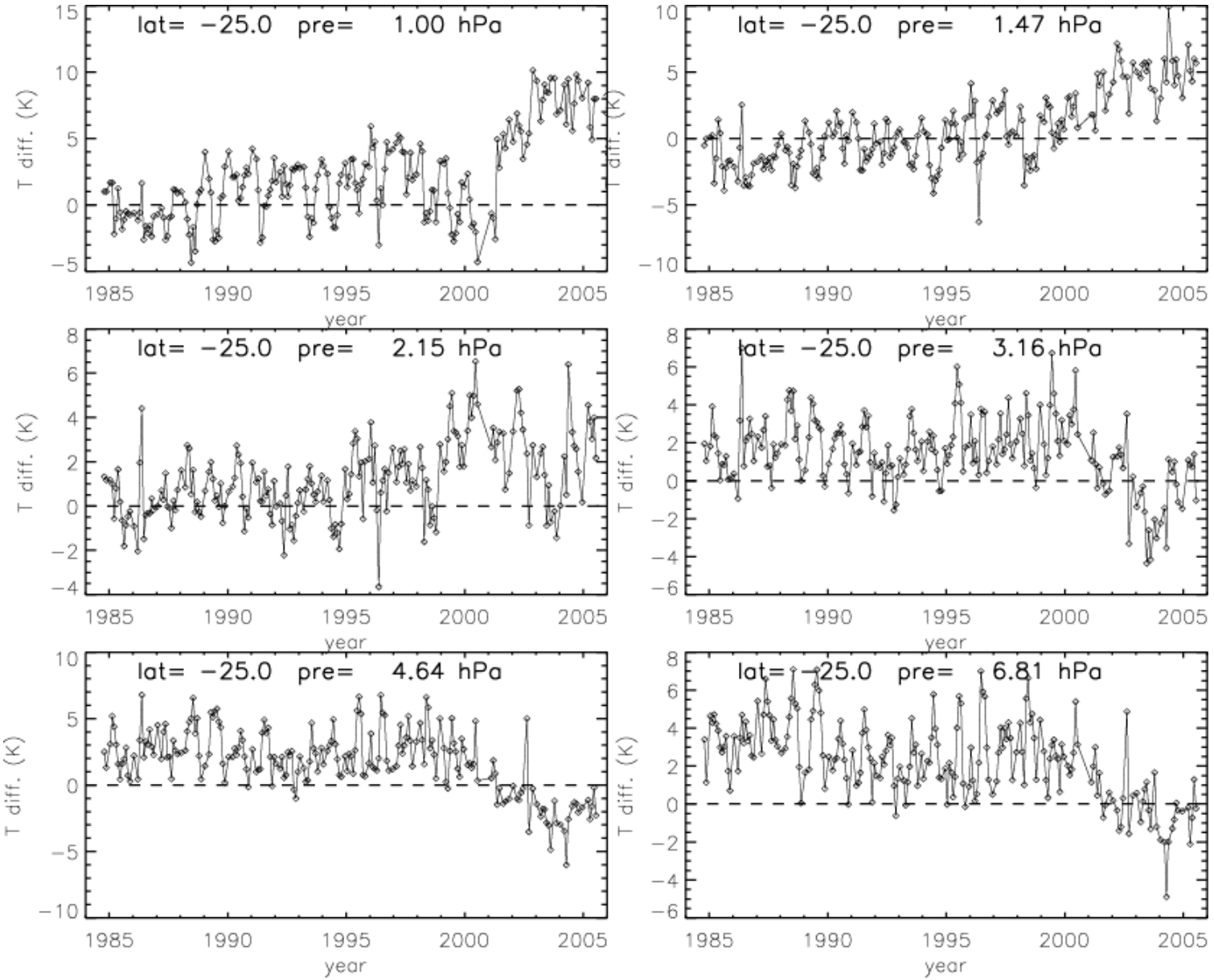
- Nazaryan et al. (2005) shows good consistency between SAGE-II and HALOE trends
  - Compare ozone VMR (1991-2000, 20 to 55 km)

- McLinden et al. (2009) indicates there are anomalous positive temperature trends in SAGE-II reported T in the tropical upper stratosphere for 1991-2005.
  - Consistency of SAGE-II temperature data?
    - Check time series of differences in monthly zonal means (10^0 bin) between SAGE-II (NCEP reanalysis) and MERRA

Time series of monthly zonal mean temperature differences

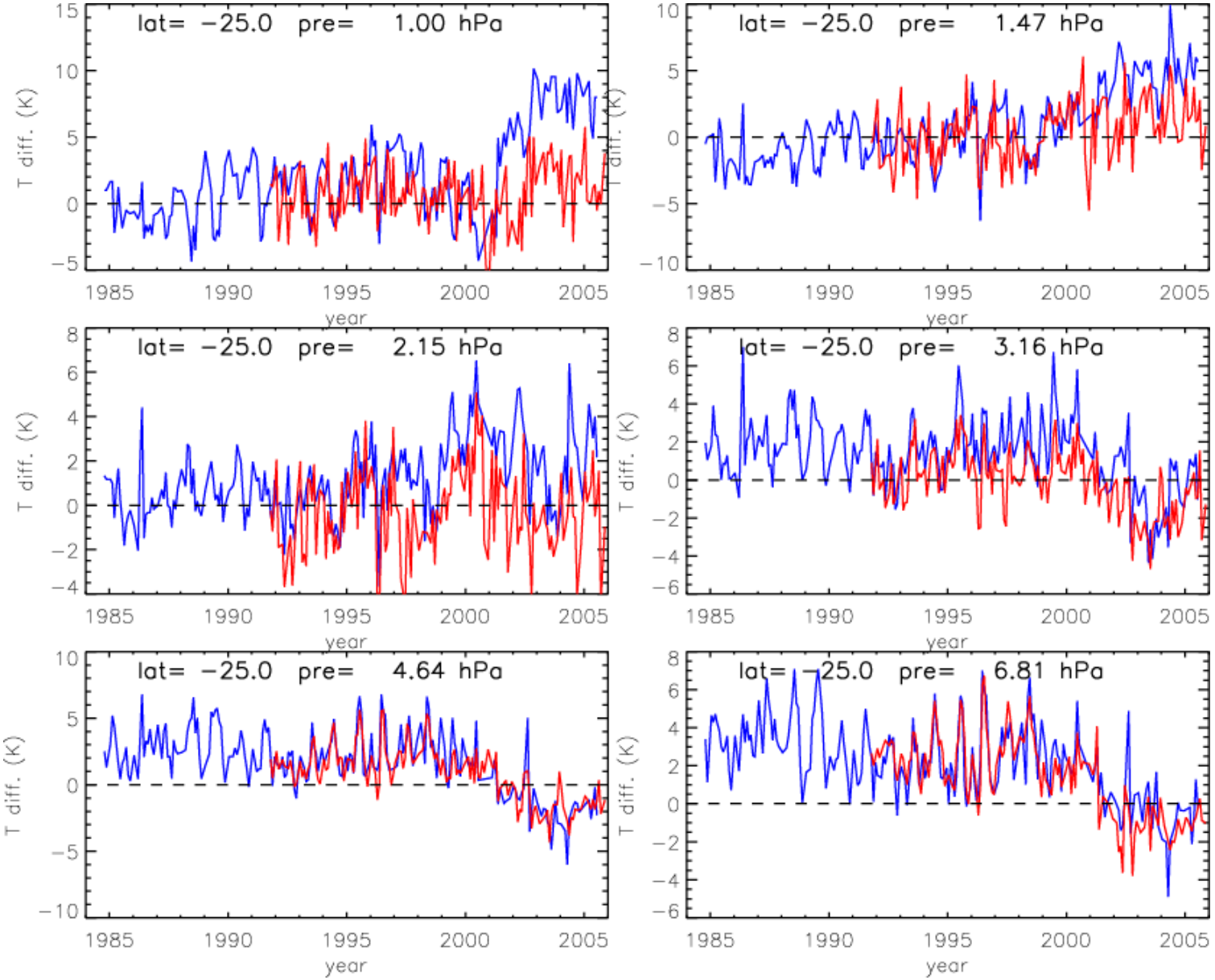
20^0-30^0S

SAGE-2(NCEP) minus MERRA



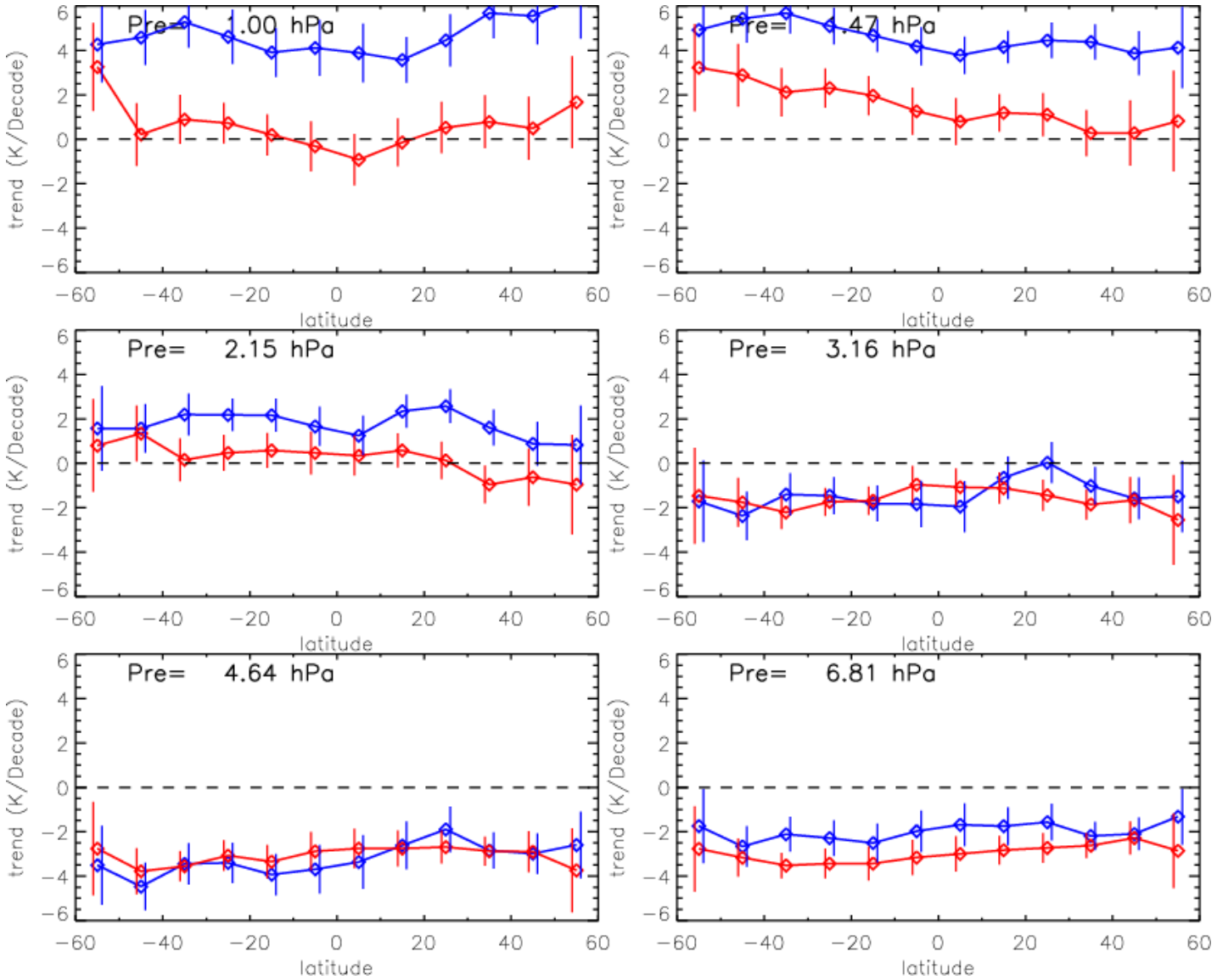
Time series of monthly zonal mean temperature differences

SAGE-2(NCEP) – MERRA: HALOE - MERRA



Relative temperature trends between SAGE2/HALOE and MERRA (1991-2005)

(SAGE2 – MERRA) (HALOE – MERRA)



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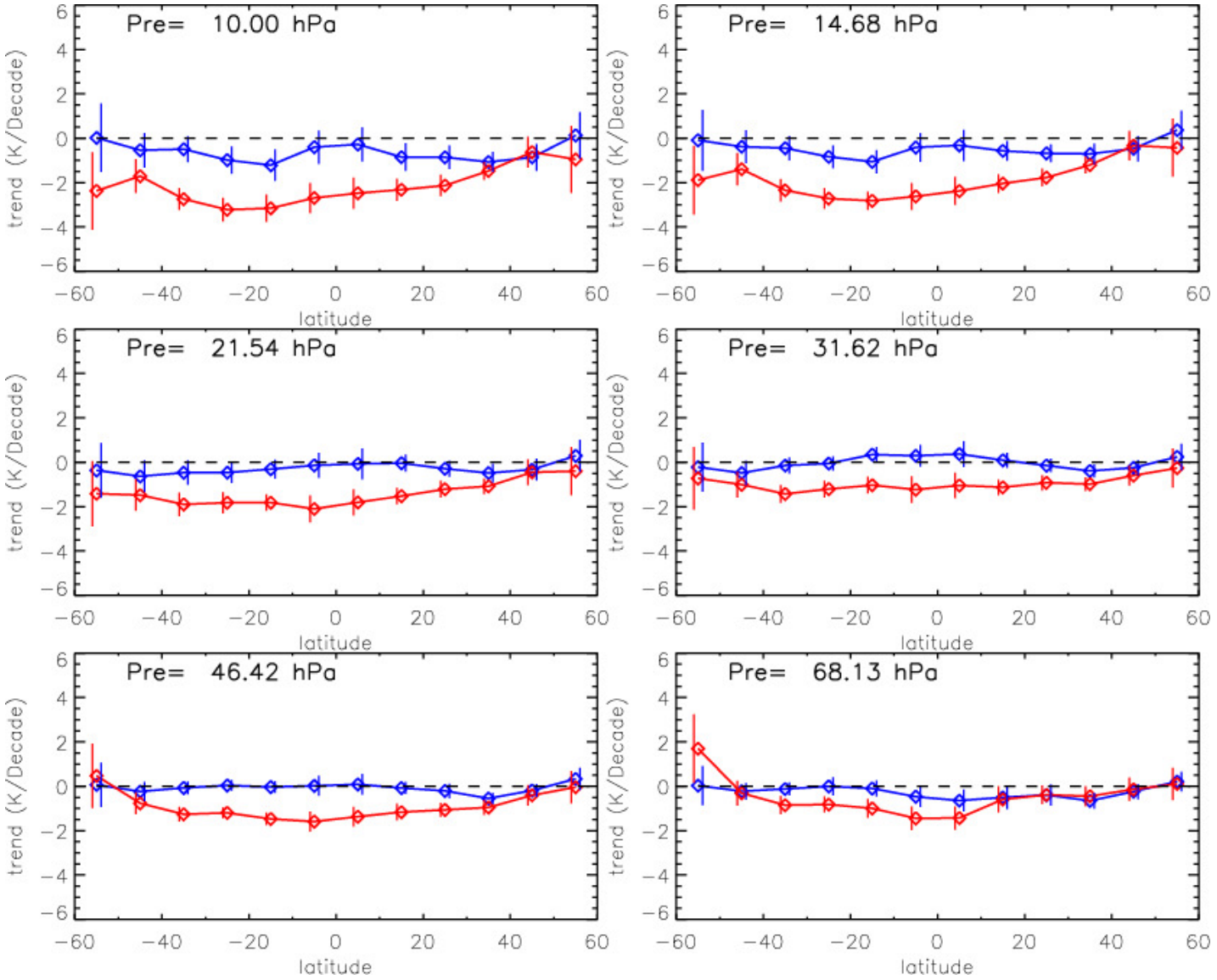
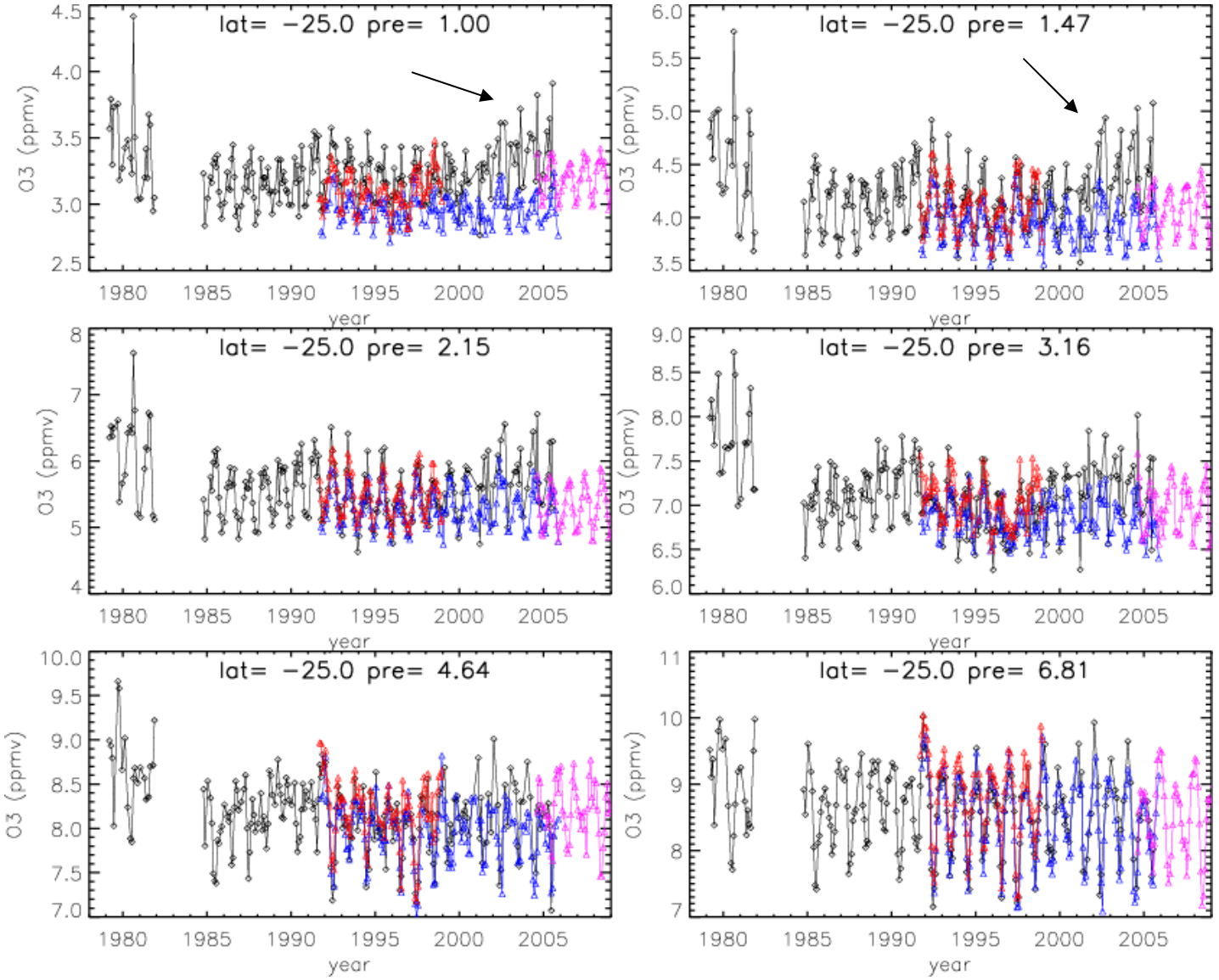


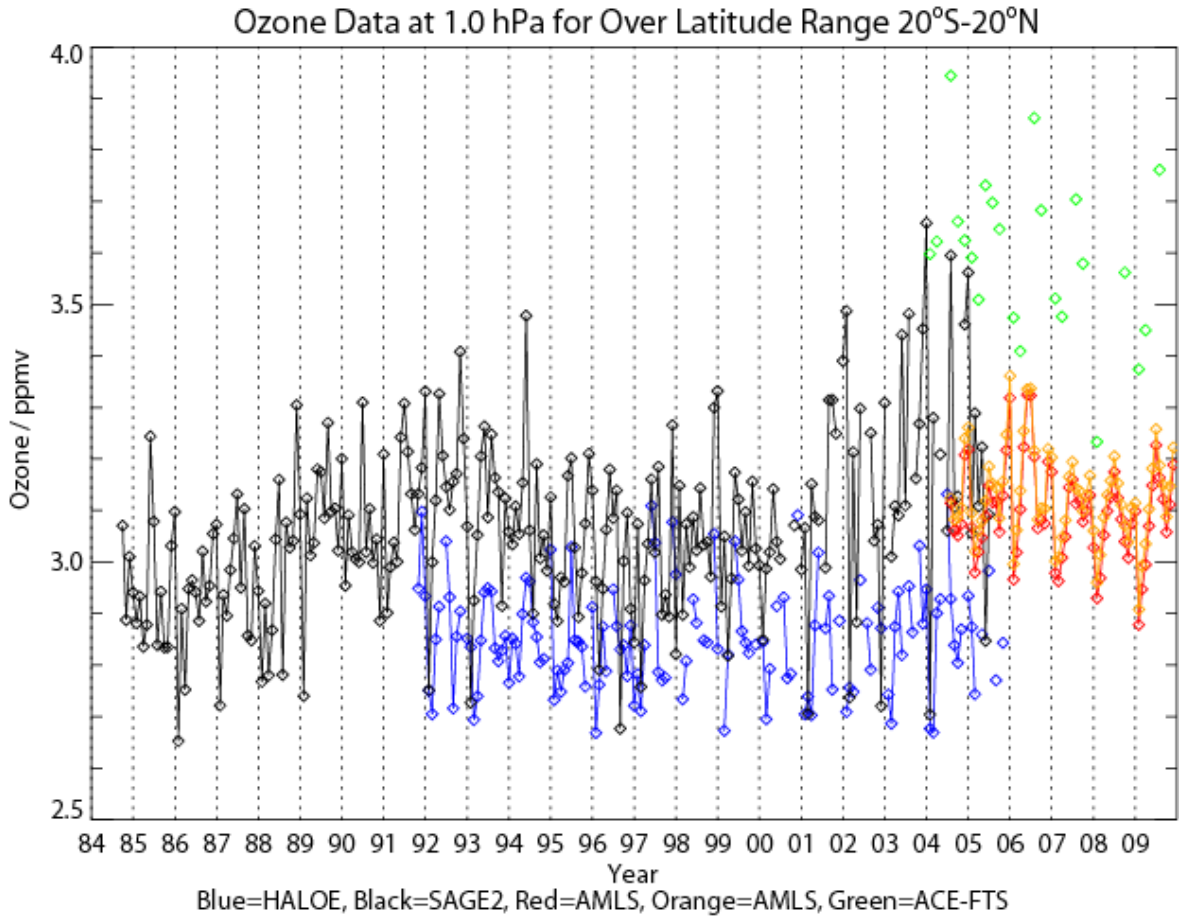
Ozone monthly zonal means at 25^{0}S

SAGE-I/II UMLS HALOE AMLS



SAGE-II ozone values are elevated after mid-2000/2001

Ozone Data at 1.0 hPa for latitude 20^0S to 20^0N



SAGE-I/II, HALOE, Aura MLS, ACE-FTS

Conclusions

- Monthly zonal mean O3 files from SAGE-I, SAGE-II, SAGE-III, HALOE, UARS-MLS, Aura-MLS and ACE-FTS have been created. A preliminary merged O3 time series by using SAGE-II as reference standard has been produced.

- Based on comparisons of NCEP reanalysis temperature data (reported along with each SAGE-II O3 profile) against HALOE and MERRA temperatures
  - **For P <3 hPa**, there are anomalous positive trends in SAGE-II reported temperatures **mainly after mid-2000/2001**. This would result in anomalous positive SAGE-II ozone trends reported on mixing ratio and pressure coordinates.
  - **Between 3.1 and 6.8 hPa**, SAGE-II temperature shows significant negative trends compared to MERRA for 2000-2005, but HALOE shows similar trends as SAGE-II. Both SAGE-II & HALOE suggest that MERRA has anomalous positive trend (2000-2005).
  - **For p > 10 hPa**, SAGE-II reported T (NCEP) shows no relative drift versus MERRA

- For p > 3 hPa, anomalous ozone trends will not arise from conversion of SAGE-II ozone from native number density/altitude to mixing ratio/pressure coordinates
  - Based on no significant temperature trends versus HALOE (and MERRA for p > 10 hPa)
  - Nazaryan et al. (2005) show no long term drift between SAGE-II and HALOE ozone (mixing ratios) between 1991 and 2000 (from slopes of time series of differences)

Future work

- Investigate anomalous SAGE-II reported temperatures (NCEP) in the upper stratosphere ($p < 3$ hPa) after mid-2000/2001
  - NCEP reanalysis data problem?
    - Option 1: Discard SAGE-II VMRs for this range/period
    - Option 2: Correct SAGE-II VMRs by using other temperature data (e.g. MERRA, SSU)

- Generate GOZCARDS merged ozone profiles
  - Finalize data screening (mainly, ACE-FTS data outliers)
  - Finalize latitude and pressure ranges

- Verification (validation) of merged O3 profiles
  - compare with SBUV (McPeters et al.)
  - welcome other collaborations (e.g., SPARC Data Initiative)