N_2O

the downer in the upper atmosphere

Patrick Sheese[1], **Kaley Walker[1,2]**, Chris Boone[2], Peter Bernath[3], and Bernd Funke[4]

1. University of Toronto, Department of Physics, Toronto, Canada
2. University of Waterloo, Department of Chemistry, Waterloo, Canada
3. Old Dominion University, Department of Chemistry & Biochemistry, Norfolk, USA
4. Instituto de Astrofisica de Andalucia, Granada, Spain

ATMOS 2015, Advances in Atmospheric Science and Applications, 8-12 June, Heraklion, Greece

Outline

- ACE-FTS instrument
- N_2O production
- ACE-FTS N_2O data and climatology
  - Correlation with energetic particle precipitation
- Conclusions

ACE-FTS

Atmospheric Chemistry Experiment – Fourier Transform Spectrometer

- Canadian satellite SciSat was launched into a circular, high-inclination orbit in August 2003
  - ACE-FTS and MAESTRO instruments on board
  - Both instruments are still in operation
- ACE-FTS is a solar occultation instrument
  - High spectral resolution (0.02 cm^{-1}) FTS in the 2.2 to 13.3 µm (750-4400 cm^{-1}) spectral range
  - 30+ trace species are retrieved, as well as 20+ subsidiary isotopologues
  - Vertical resolution of 3-4 km
- ACE-FTS level 2 version 3.5 data were used in this study
  - Processed data set currently spans 2004-2013
  - Filtered using relevant ACE-FTS data quality flags

Stratospheric N_2O

- Surface sources:
  - Ocean and soil emissions
  - Agriculture
  - Biomass burning and fossil fuel combustion

- Injected into the stratosphere via Brewer-Dobson circulation
  - Used as dynamical tracer in stratosphere

- Sinks:
  - $\mathrm{N_2O} + h\nu(\lambda < 200\ \mathrm{nm}) \rightarrow \mathrm{N_2} + \mathrm{O}(^1\mathrm{D})$
  - $\mathrm{N_2O} + \mathrm{O}(^1\mathrm{D}) \rightarrow 2\mathrm{NO}, or\ \mathrm{N_2} + \mathrm{O_2}$

Possible upper atmospheric sources of N_2O

$$N_2(A^3\Sigma_u^+) + O_2 \rightarrow N_2O + O$$

(~95 km, descent)

- Zipf and Prasad [1982], Nature
  - Predicted ~10^9 cm^{-3} (~1-10 ppm) in lower thermosphere during strong magnetic storms

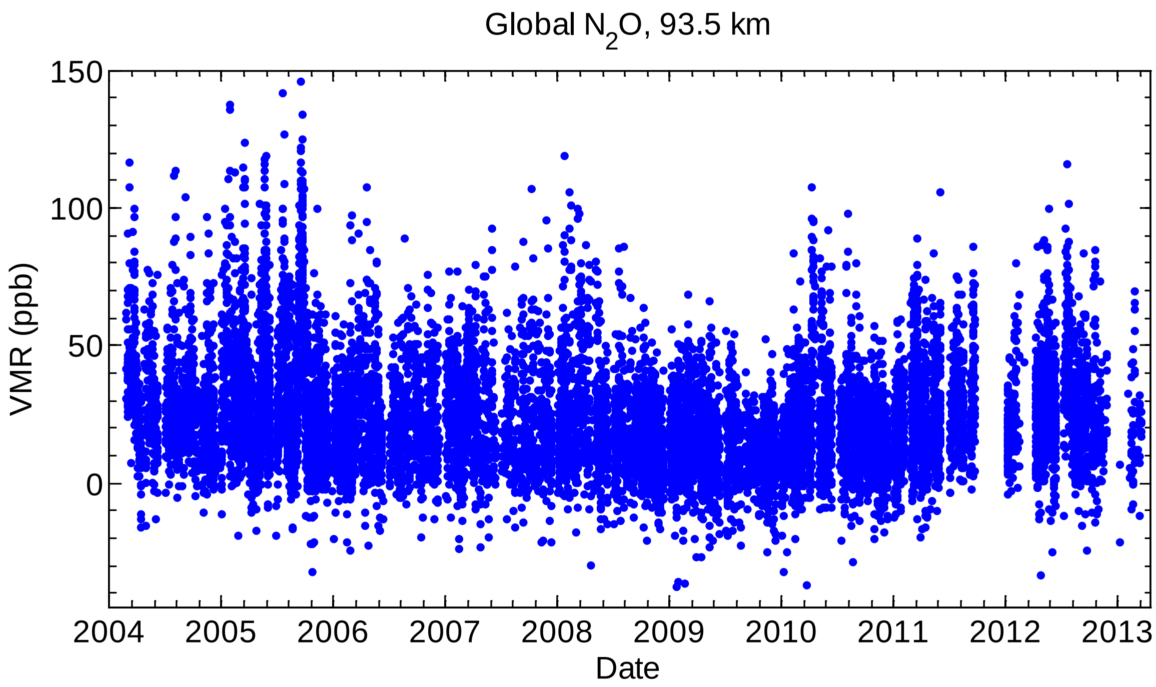
$$NO_2 + N(^4S) \rightarrow N_2O + O$$

(~75 km, descent)

- Funke et al. [2008a], ACP
  - MIPAS N_2O enhancement after 2003 solar proton event
- Semeniuk et al. [2008], JGR
  - CMAM reproduces 2004 ACE-FTS v2.2 N_2O enhancement in upper stratosphere

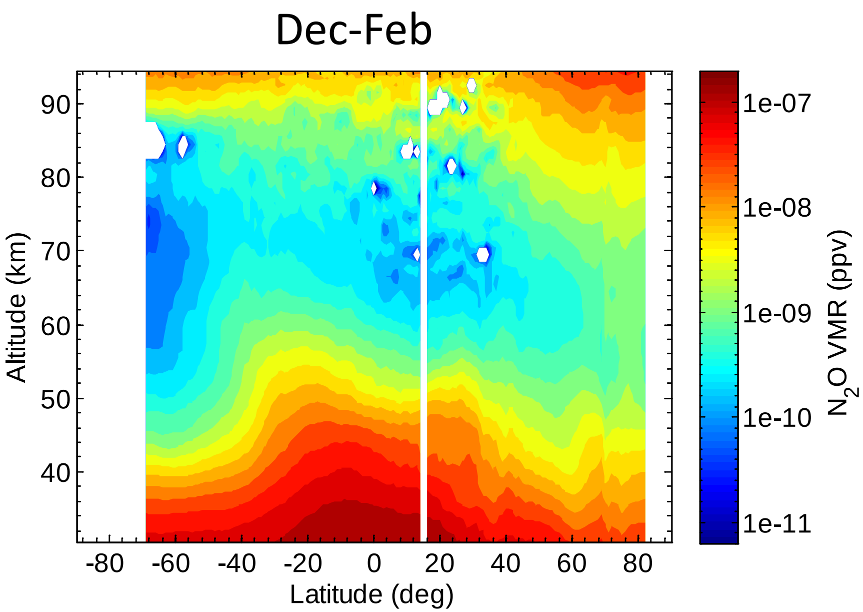
- Funke et al. [2008b], ACP
  - MIPAS mesospheric N_2O enhancements during polar winter
    - Predicted N_2O VMRs of ~100 ppb in lower thermosphere

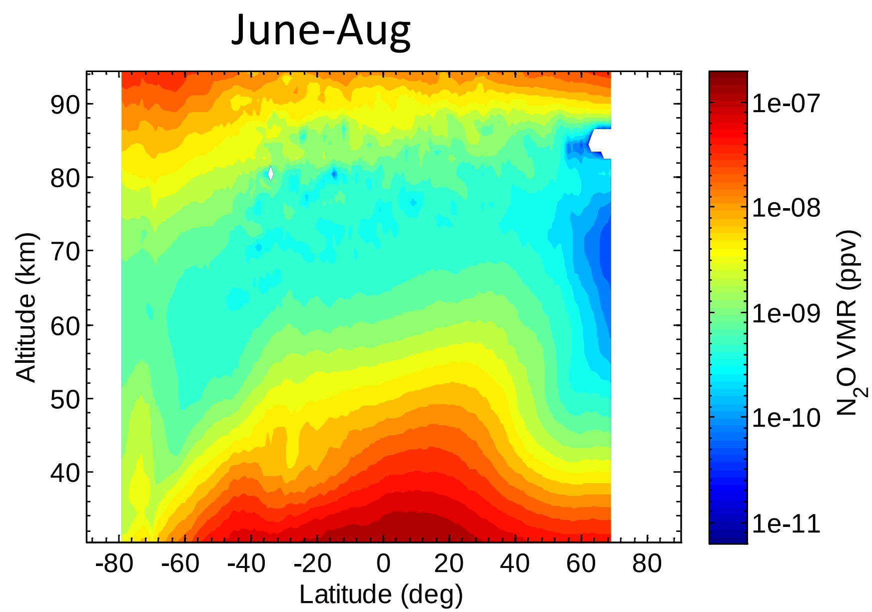
ACE-FTS N_2O data in thermosphere



- Typically in the 10's of ppb
- Reaches over 100 ppb during times of strong solar activity

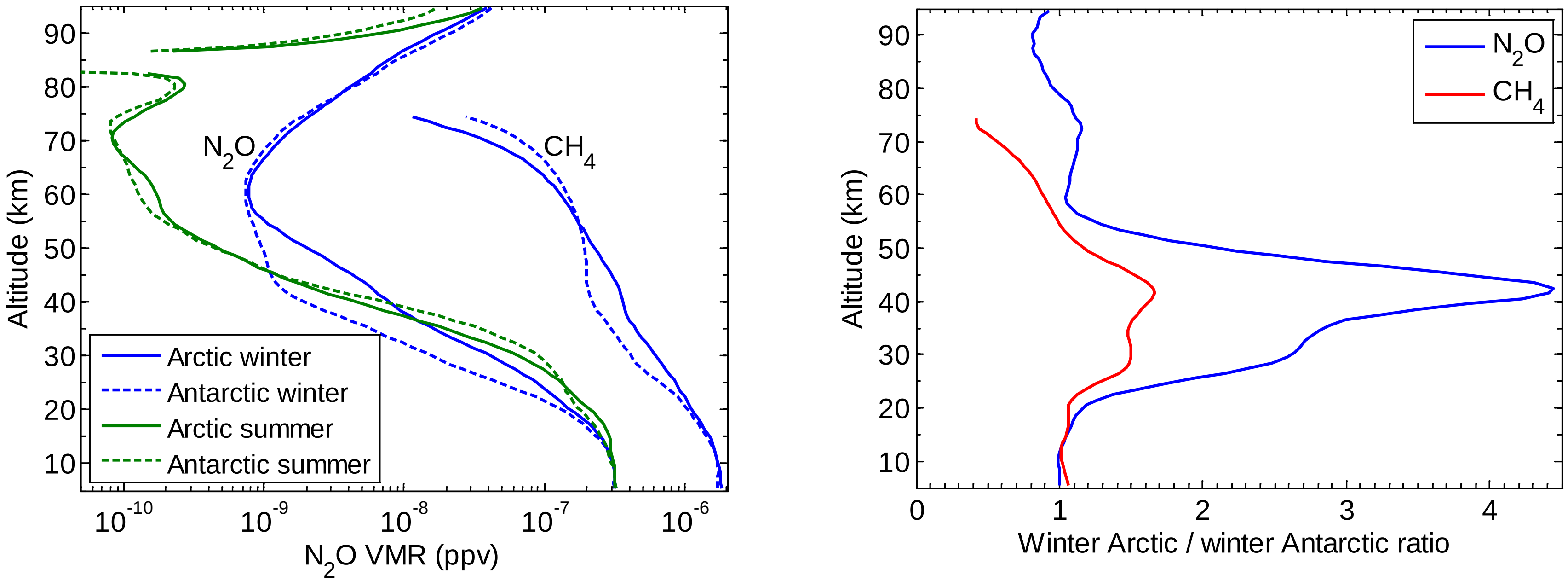
ACE-FTS N_2O climatology (2004-2013)





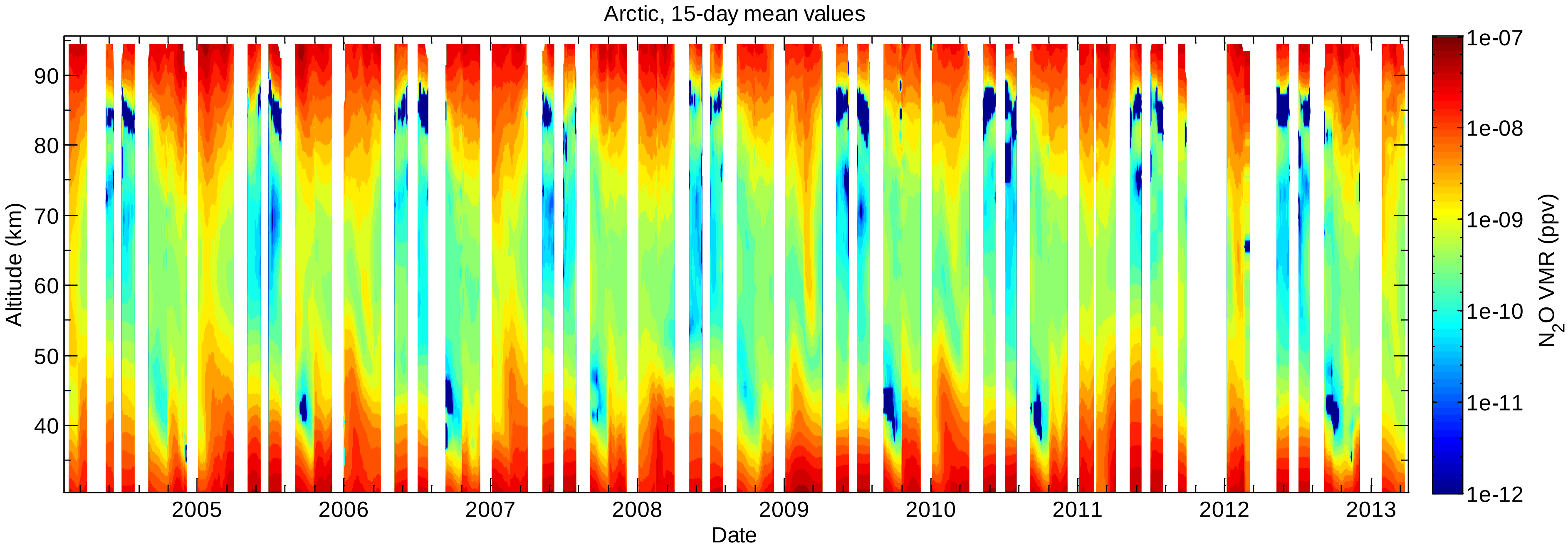
- Stratospheric region exhibits Brewer-Dobson circulation
- Clear thermospheric N_2O source

Mean ACE-FTS profiles



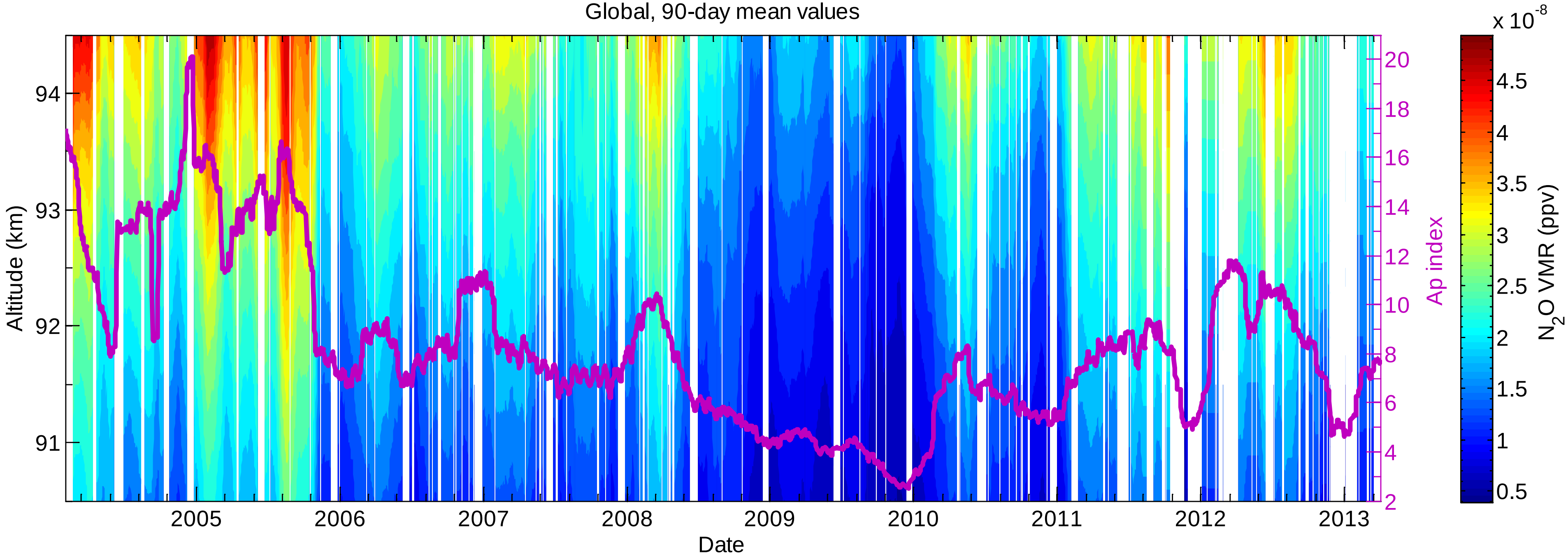
- Arctic winter and Antarctic summer – Dec-Feb
- Arctic summer and Antarctic winter – June-Aug

ACE-FTS Arctic time series



- Regular Arctic winter N_2O intrusions in stratopause region
  - Especially during sudden stratospheric warmings

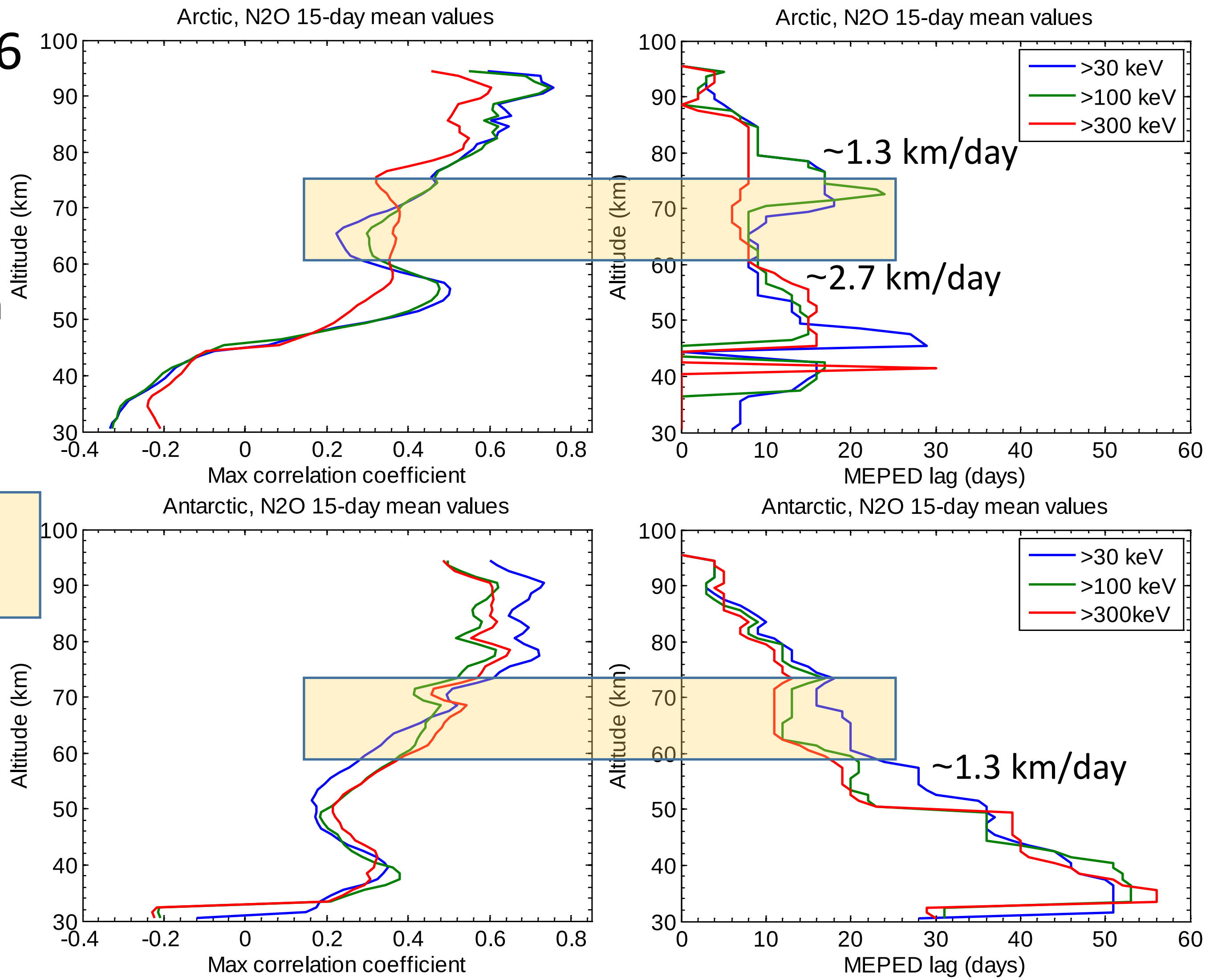
11-year solar cycle



- A_p index is a measure of geomagnetic activity used as a proxy for energetic particle precipitation

Winter correlation with MEPED

- MEPED (on NOAA-16 POES) measures electron fluxes at top of atmosphere
  - Ionization/dissociation due to precipitating electrons peak near
    - ~90 km for > 30 keV
    - ~75 km for > 100 keV
    - ~60 km for > 300 keV
- 0-60 day lag introduced in MEPED data



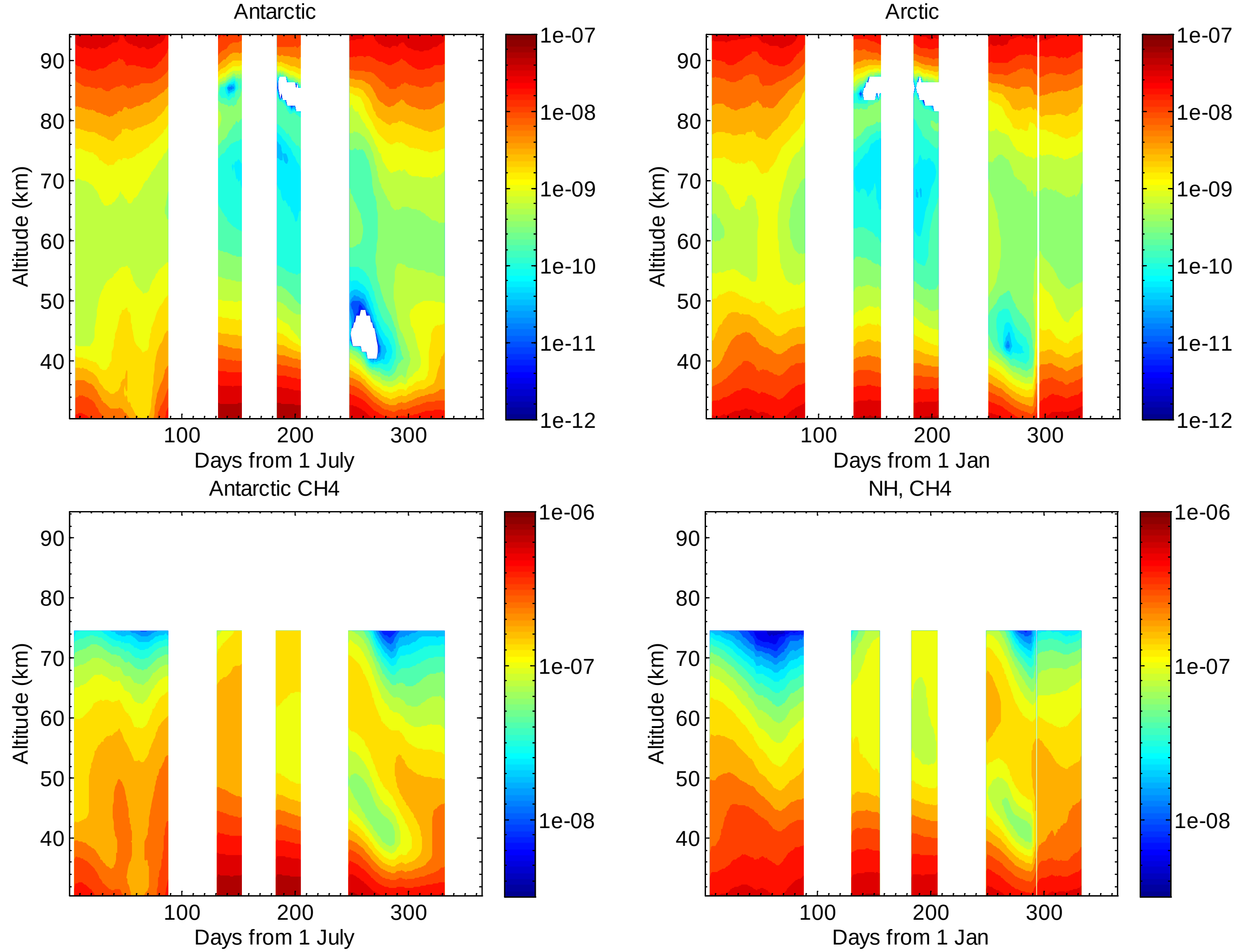
Conclusions

- ACE-FTS has the only measurements of N_2O in the upper mesosphere – lower thermosphere
  - Clear EPP source in lower thermosphere
    - Continual source throughout all seasons
      - ~10 ppb near equator
      - ~30 ppb near poles
  - ACE-FTS and MEPED correlations are consistent with an upper mesospheric N_2O source near 70 km (from EPP NO_2 enhancements)
- N_2O Transported down into upper stratosphere in winter
  - In Arctic winter 40-50 km region, N_2O can be predominantly thermospheric
    - In summer, purely tropospheric
  - ~100x less N_2O than NO_x, which can be responsible for up to 10% of O_3 destruction
    - N_2O intrusions likely insignificant contributor to stratospheric O_3 loss
    - Need to model fraction of NO produced in MLT via N_2O destruction
  - ACE-FTS N_2O should not be used as dynamical tracer in this region (polar winter upper stratosphere)

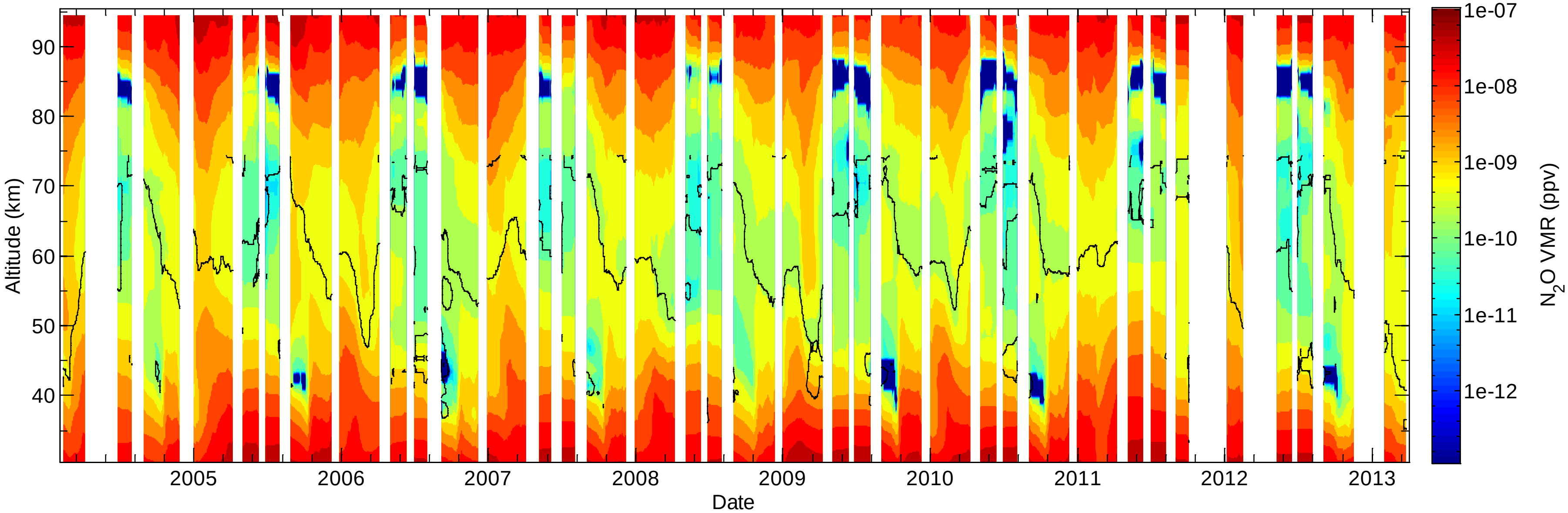
Acknowledgement

- This project and the ACE mission are primarily funded by the Canadian Space Agency

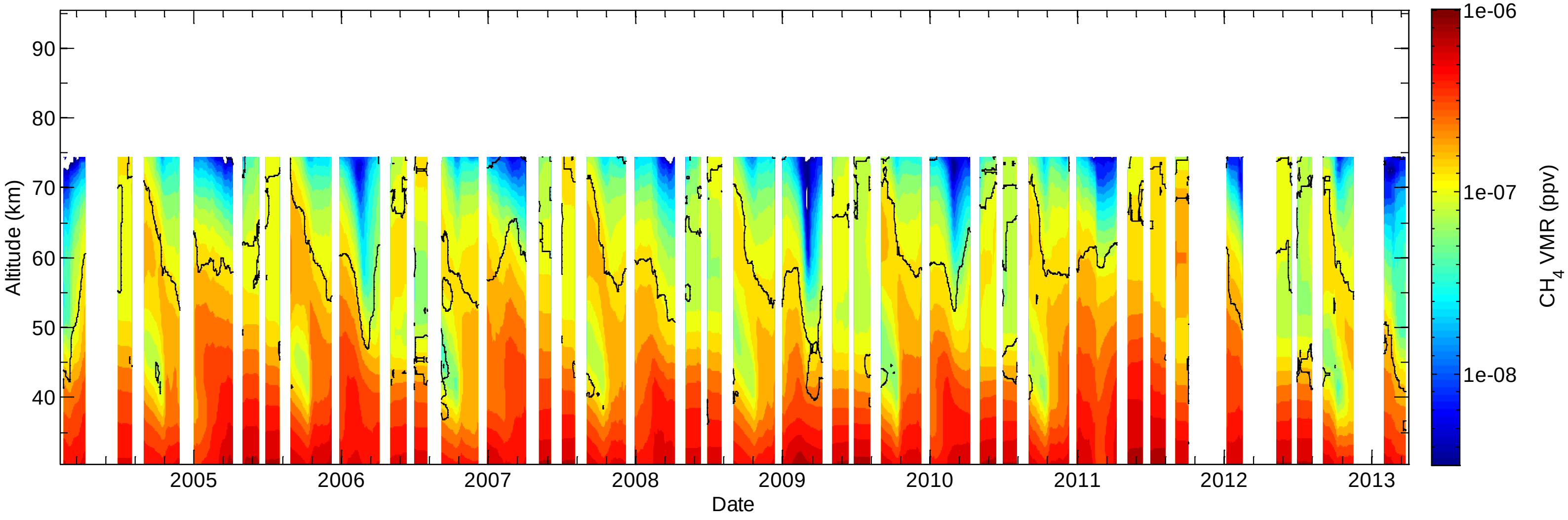
Extra slides


Antarctic
Arctic
Antarctic CH4
NH, CH4
Altitude (km)
Days from 1 July
Days from 1 Jan
1e-07
1e-08
1e-09
1e-10
1e-11
1e-12
1e-06
90
80
70
60
50
40
100
200
300

N2O time series

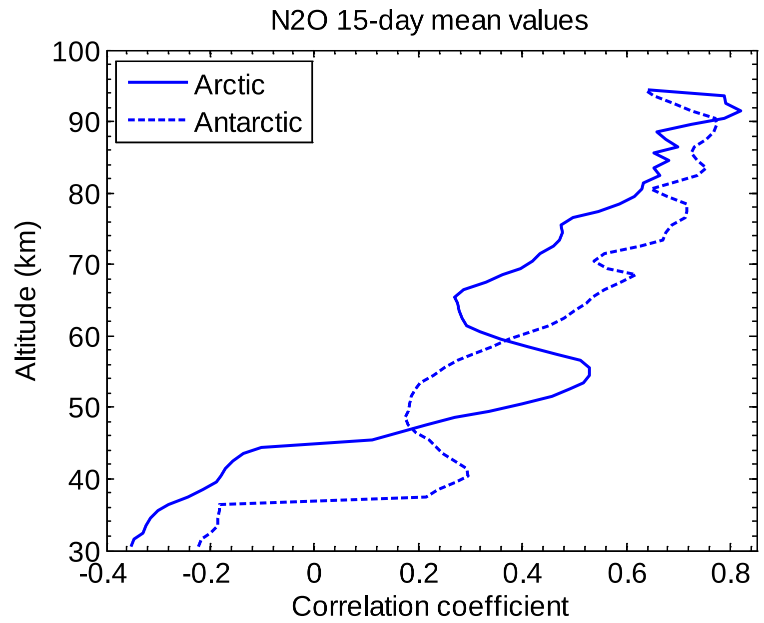


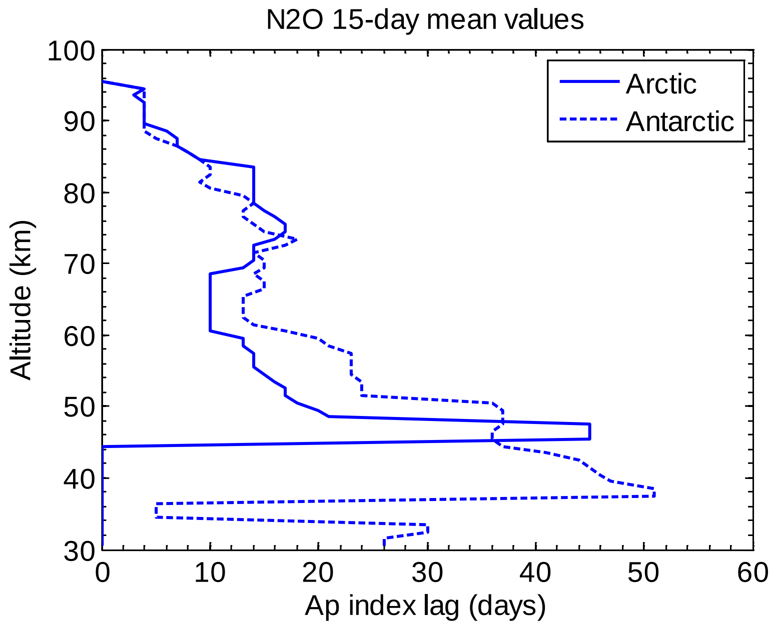
CH4 time series



Winter N_2O correlation with A_p index

0-60 day lags added to Ap index time series





Winter N_2O correlation with A_p index