The Middle and Upper Atmosphere as Observed by MIPAS/Envisat

M. López-Puertas, B. Funke, M. García-Comas, A. Gardini, A. Jurado-Navarro
IAA-CSIC, Granada, Spain

T. Clarmann, G.P. Stiller, M. Kiefer
KIT, IMK, Karlsruhe, Germany

Martin Kaufmann
Forschungszentrum Jülich, Jülich, Germany

Anne Smith, Rolando García
NCAR, Boulder, USA

Chris Boone
University of Waterloo, Ontario, Canada

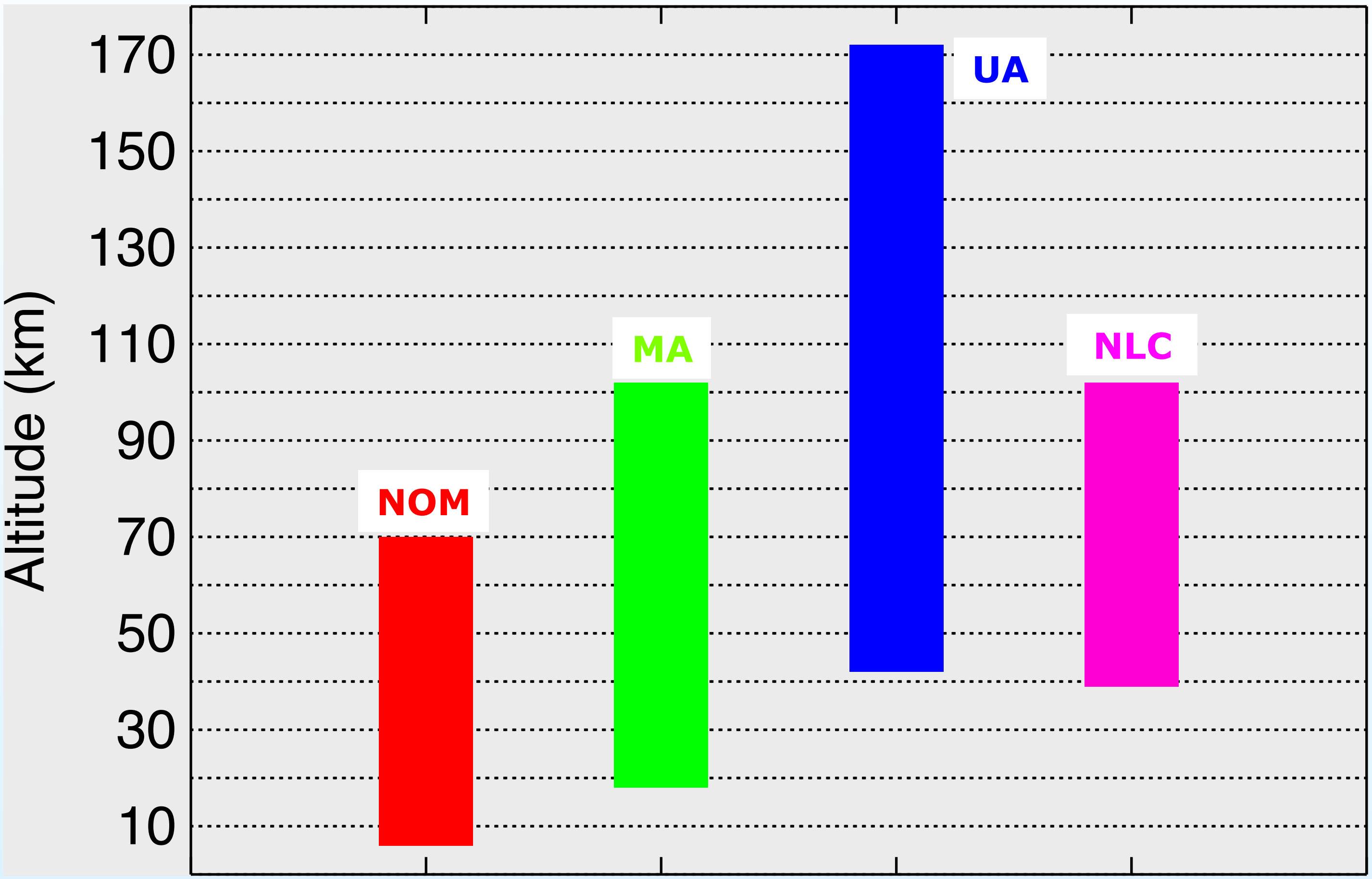
→ ATMOS 2015
Advances in Atmospheric Science and Applications
8–12 June 2015, University of Crete, Heraklion, Greece

Contents

- Overview of MIPAS Middle & Upper atmosphere data

- Ozone variability in the polar winter mesosphere
- Solar cycle effects in mesospheric temperatures
- Solar cycle and trends in COx (CO+CO2) in the MLT

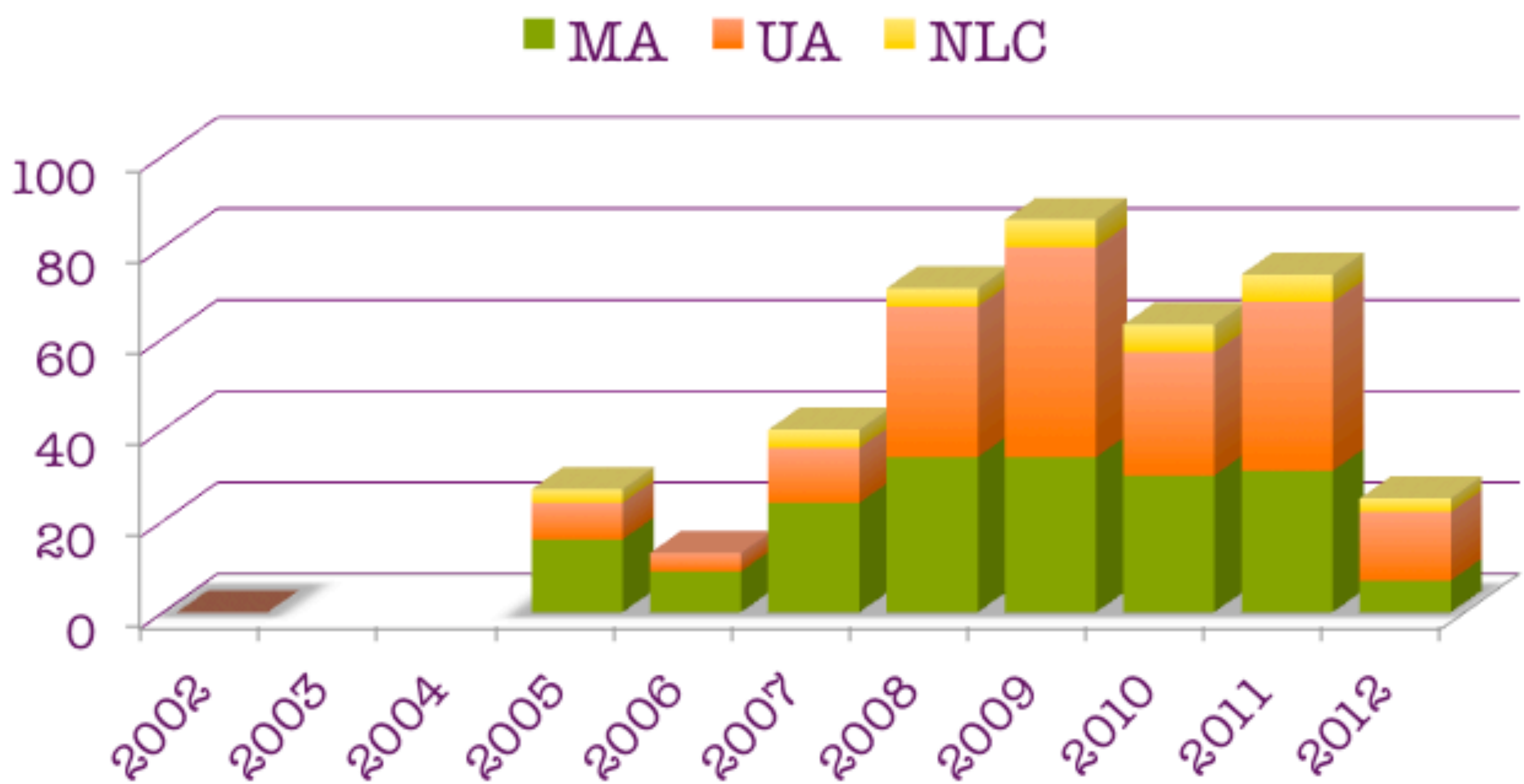
Middle & Upper modes coverage (OR)



Altitude sampling:

- NOM: 27 sweeps (1.5-4 km)
- **MA: 29 sweeps (3km)**
- **UA: 35 sweeps (3 and 5 km)**
- **NLC: 25 sweeps (1.5 and 3 km)**

MIPAS Middle & Upper Atmosphere Obs.



- 1 day before 2005
- A few days from 2005 until mid-2007.
- Regular 1 MA+1 UA every 10 days + 3 NLC days/season, ~20%, thereof.

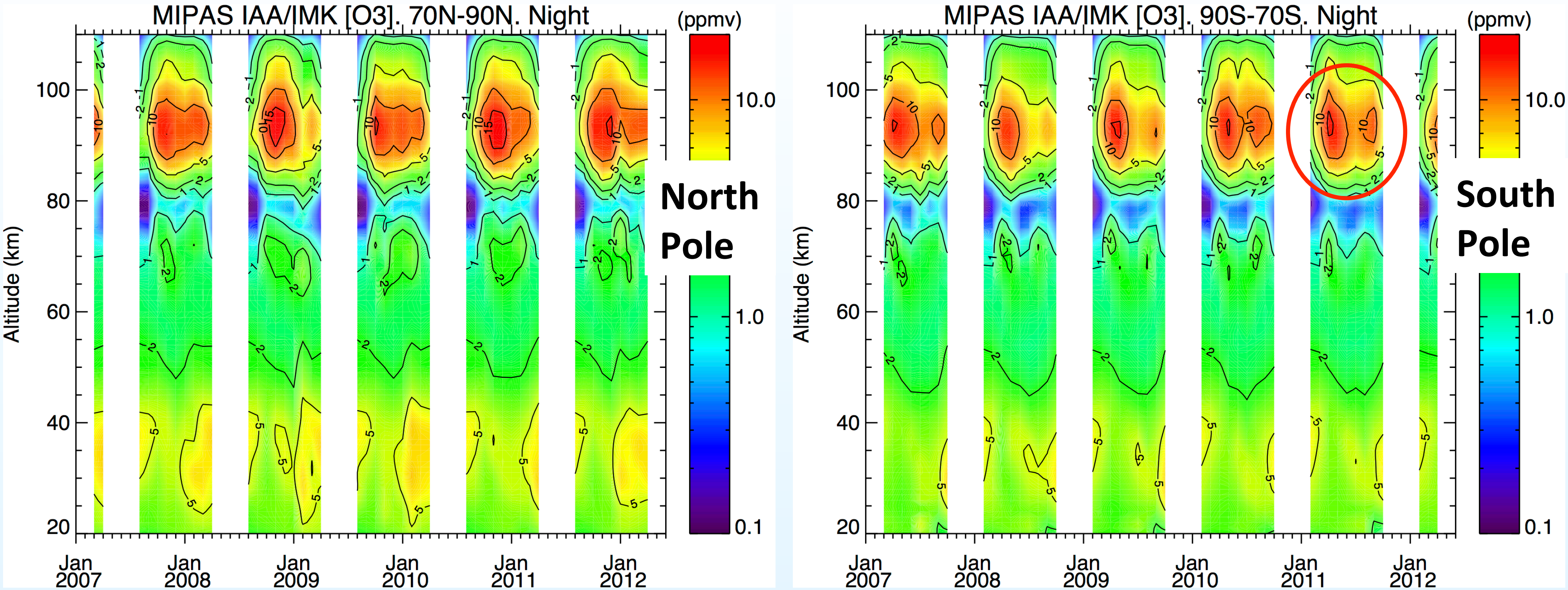
Species retrieved from MA, UA & NLC modes

SPECIES	Spectral Range [μm]	Altitudes [km]	Reference/Comment
Temperature	15	20-100	García-Comas et al. ACP, 2012, 2 P. 96
O_3 [vmr]	12.8, 9.6	20-100	Gil-López et al., 2005; Smith et al., 2013
H_2O [vmr]	12.5, 6.3	20-90	García-Comas et al. (in prep.) P. 114
PMC Ice vol. dens.	11-13	78-90	López-Puertas et al., 2009; in prep.
NO [vmr]	5.3	20-100	Funke et al. (2005a,b; 2014) P. 44
NO_2 [vmr]	6.3	20-60	Funke et al. (2005a,b; 2014)
CH_4 [vmr]	7.8	20-75	
N_2O [vmr]	7.8	20-55	Funke et al. ACP, 2008.
Temp. & NO [vmr] Therm.	5.3	105-170	Bermejo-P. et al., 2011.
CO [vmr]	4.7	20-150	Funke et al. (2007; 2009) P. 114
CO_2 [vmr]	10, 4.3	70-140	Jurado-Navarro et al., in review, 2 P. 119

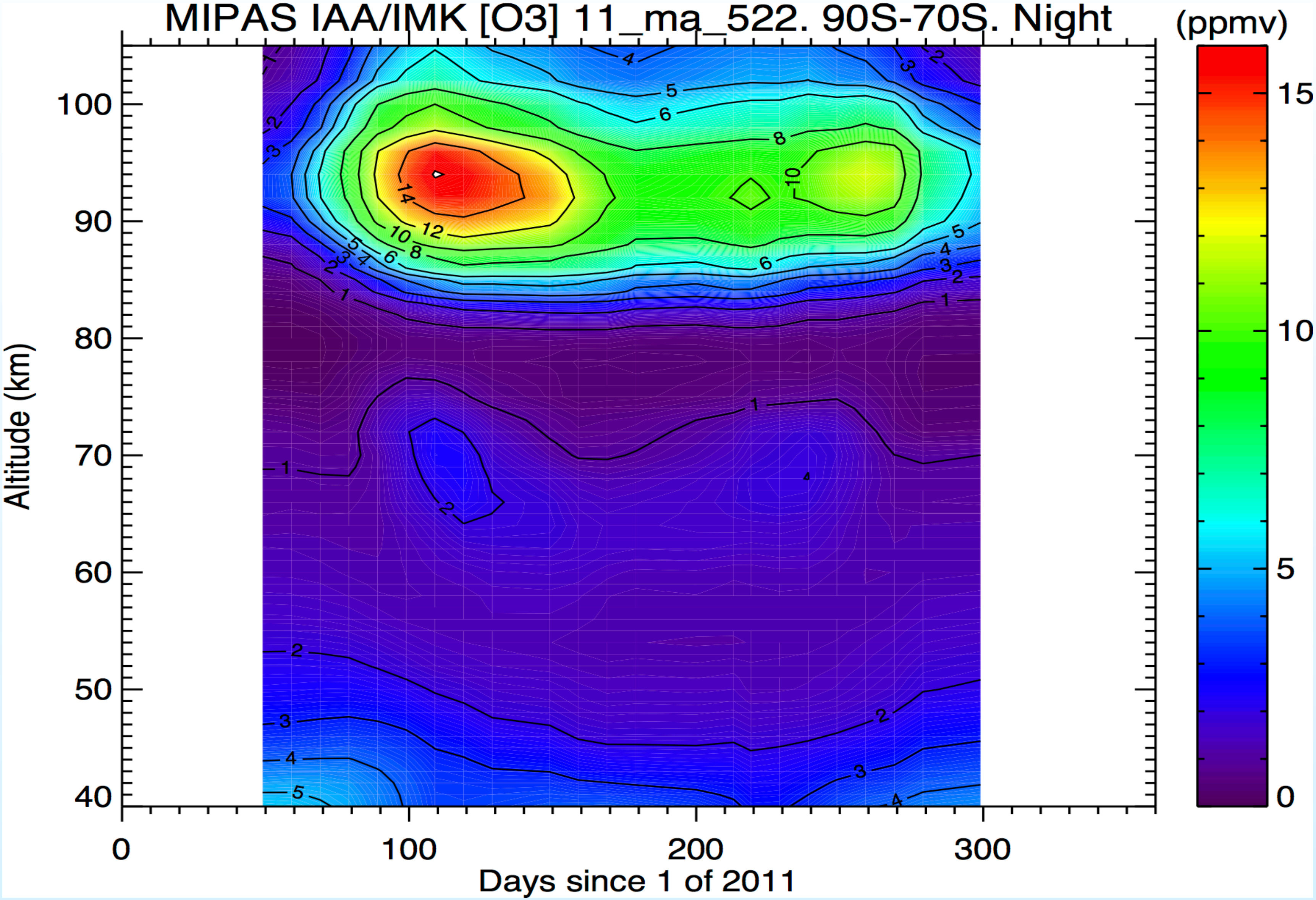
O3 in polar winter mesosphere

Smith, López-Puertas et al., JGR, 2014

MIPAS O3 Time series. Night (10pm)



MIPAS O3 2011 SH. Night (10pm)



What controls O3 in the MLT?

Production:

k_1: $O+O_2+M \Rightarrow O_3$

Loss:

J: $O_3+h\nu \Rightarrow O+O_2$

k_2: $O_3+H \Rightarrow OH+O_2$

k_3: $O_3+O \Rightarrow O_2+O_2$

Timescales are short (<1 hour)

Day equilibrium

$$O_3 \approx \frac{k_1 \cdot O \cdot O_2 \cdot N}{J}$$

Night equilibrium

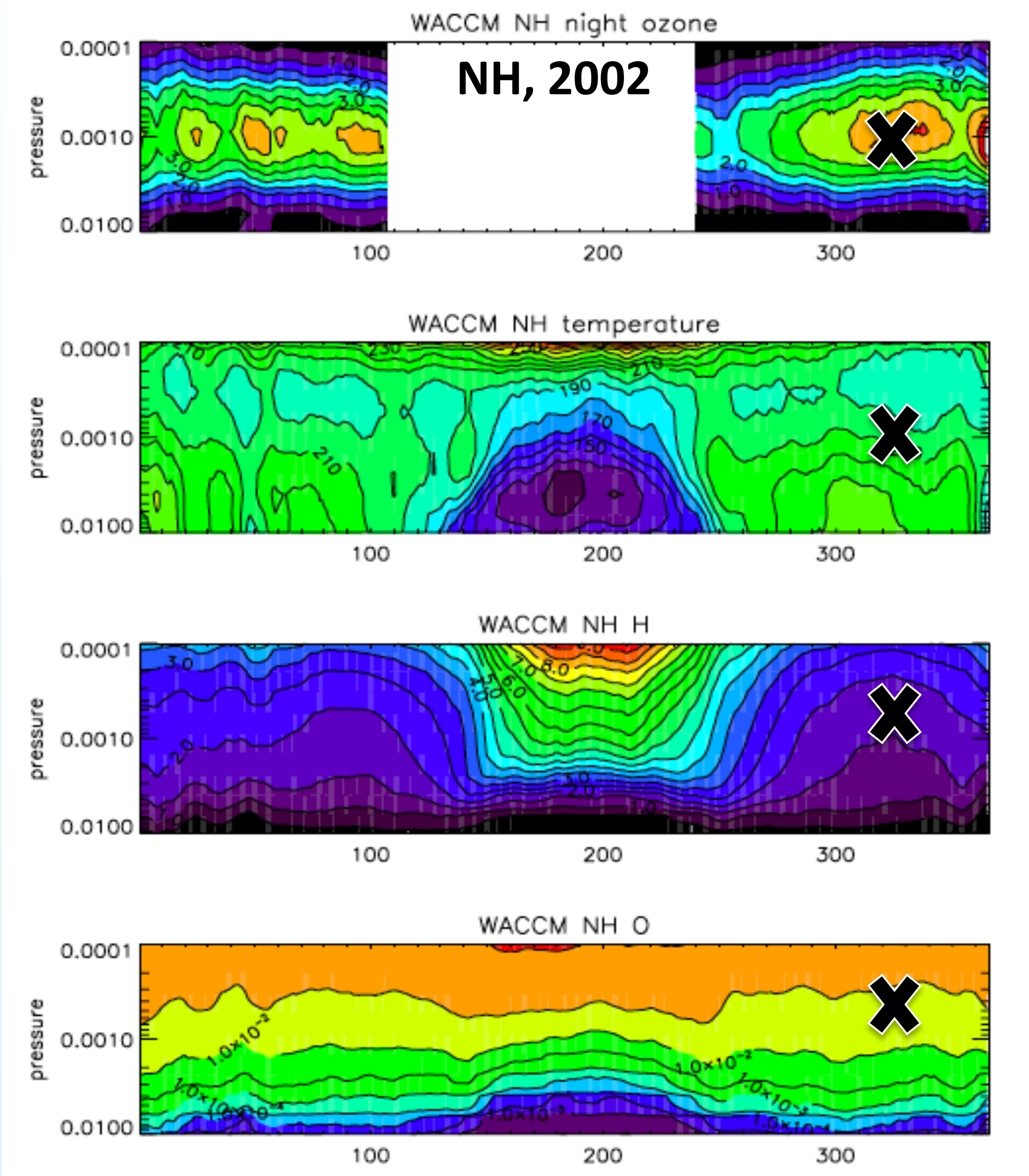
$$O_3 \approx \frac{k_1 \cdot O \cdot O_2 \cdot N}{k_2 \cdot H + k_3 \cdot O}$$

Variability due to:

- Day versus night
- T (since k_1, k_2, k_3 and N are temperature dependent)
- O (long lifetime above 80-85 km)
- H (long lifetime above 80-85 km)

$$\frac{\Delta O_3}{O_3} \sim -5.8\frac{\Delta T}{T} + \frac{\Delta O}{O} - \frac{\Delta H}{H}$$

NH high latitude ozone in WACCM



O3

T

H

O

Early winter:
Model shows low H coincident with high O_3

What controls H at the polar winter mesopause?

$$\frac{\partial \mathrm{H}}{\partial t} + \overline{v} * \frac{\partial \mathrm{H}}{\partial y} + \overline{w} * \frac{\partial \mathrm{H}}{\partial z} = P - L \cdot \mathrm{H} + X_E + X_M$$

Advection by the transformed Eulerian mean circulation **IS VARIABLE**

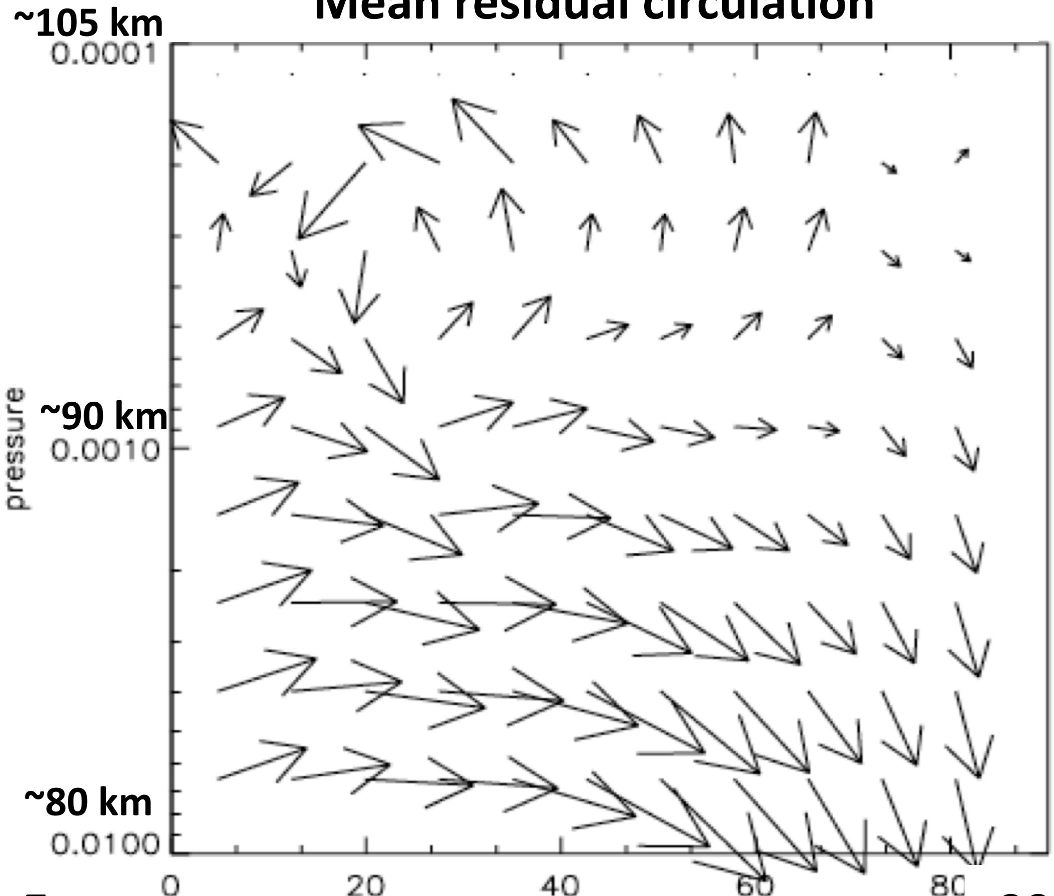
Chemical production stops => **Negligible chem. production**

Eddy Diffusion. Not very important

H is very light. Molecular diffusion and diffusive sep. **decreases H**

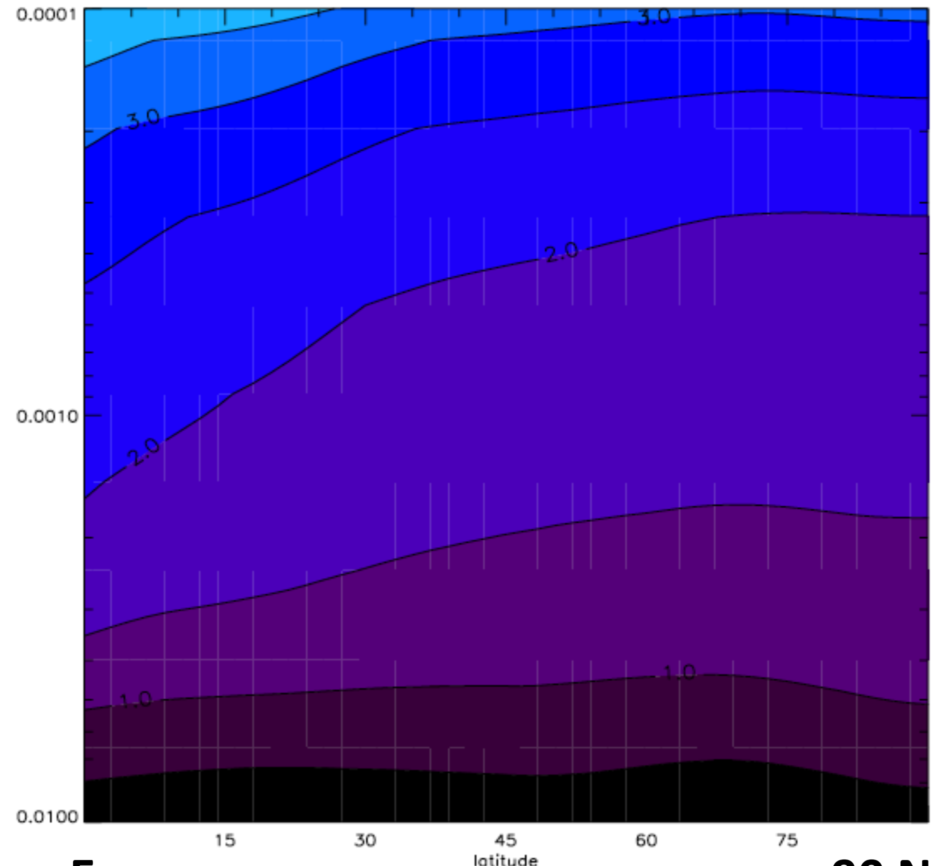
Mean circulation in NH winter, WACCM

Mean residual circulation



Eq. 90 N

H



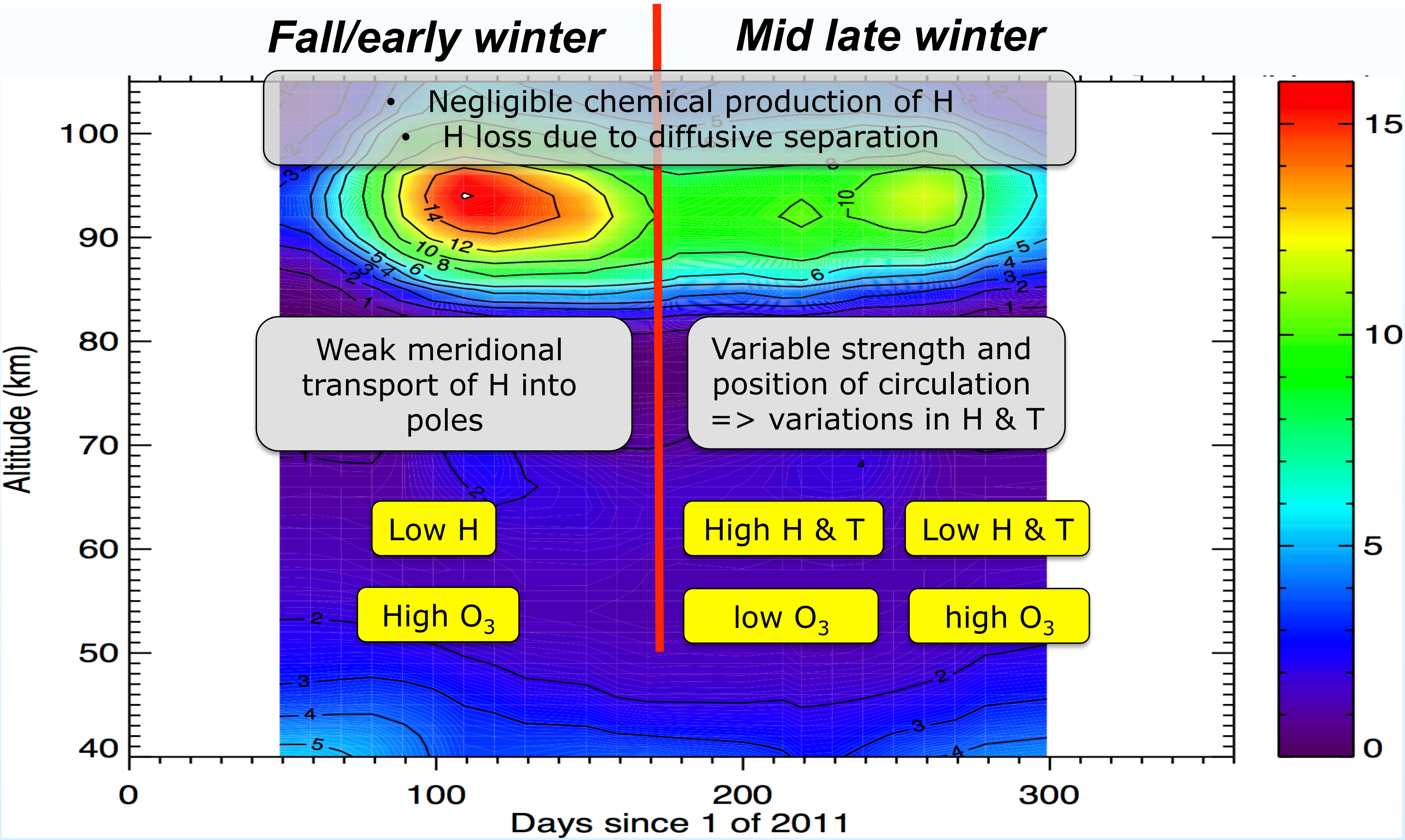
Eq. 90 N

Increase H by:

- Poleward flow in winter upper mesosphere
- Downward flow below 95 km

Decrease H by poleward flow above 95 km

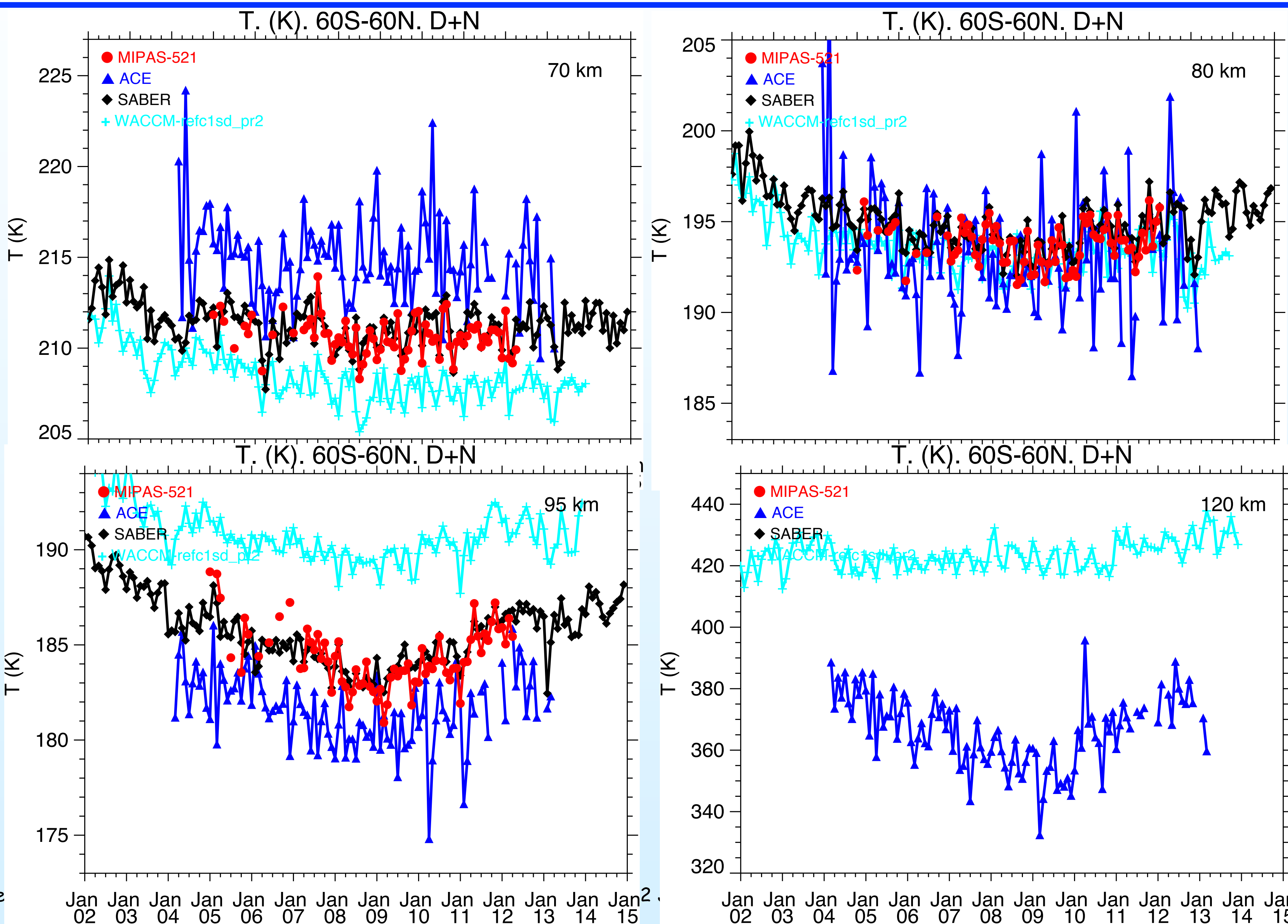
Summary of O3 in the polar night mesopause



Temperature: Comparison of MIPAS, SABER, ACE, and WACCM.

- Validation
- Solar effects + Trends
(López-Puertas et al., JGR, in preparation)

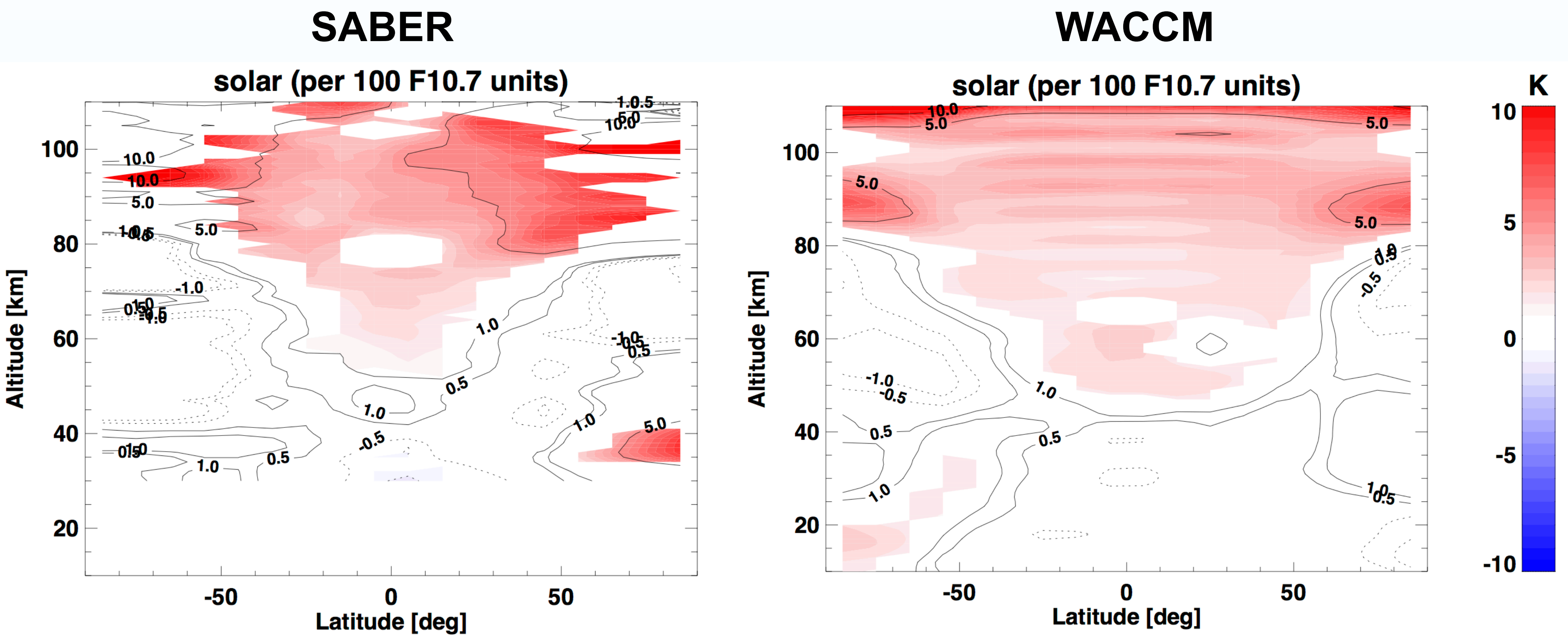
De-seas. time series of Temperature 60S-60N



Solar cycle and trend in Temperature

- Multiple linear regression (MLR) of temperatures in the MLT to obtain the solar signal and trend.
- Average data monthly, over ±60° latitudes, de-seasonalized.
- MLR predictors: Time, 10.7 cm flux, and two QBO indices
- In the MLT, however, only Time(t) and f10.7 yield statistically significant regression coefficients

Solar Cycle in Temperature



- 1-5 K/100 F10.7 units.
- Visible at lower altitudes in the tropics
- Stronger in the polar upper mesosphere/lower thermosphere
- WACCM response is similar to SABER below ~75 km but weaker above & in polar regions

The COx (CO+CO2) solar cycle and trends in the MLT (Garcia et al., JGR, in preparation)

Summary/Conclusions

- MIPAS has provided a very good quality dataset of temperature and many species (O_3, H_2O, CH_4, NO, NO2, CO, CO2, PMCs) in the middle and upper atmosphere.
- O3 in polar night mesopause very variable (max. in early winter). Controlled by H and T, in turn controlled by chemistry, molecular diffusion, and the residual circulation.
- Temperature:
  - Solar and trend signals visible in the data.
  - Solar signal in SABER visible above ~70 km. Stronger in the polar region. WACCM's response is similar to SABER below ~75 km but weaker above & in polar regions.
  - Similar solar signals in MIPAS, SABER and ACE.
- COx (CO+CO2) trend in the MLT is larger than in the troposphere.

Thanks!