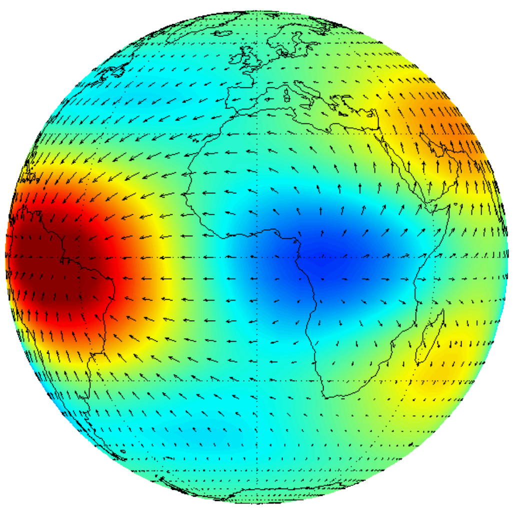
Nonmigrating tidal impacts on the NO 5.3 μm infrared cooling of the low-latitude thermosphere



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Objectives

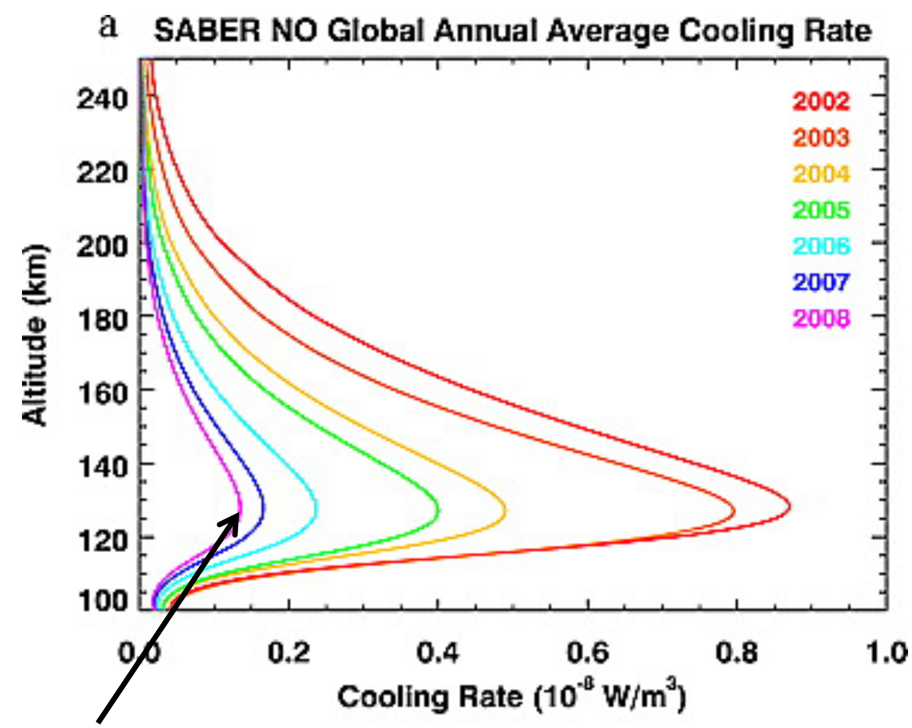
- What is the impact of nonmigrating tides from the troposphere on Earth's upper atmosphere energy budget?
- What is the main tidal coupling mechanism: temperature, density, or advection?

Approach

- Tidal diagnostics of NO 5.3 μm data from SABER
  - → Equator, 2008, 100-160 km
  - → largest tides, less geomagnetic contamination
- Photochemical modeling
  - → MIPAS, TIME-GCM, MSIS: [NO], [O], T, density; background
  - → CTMT (empirical tidal model): T, density, vertical winds; tides

NO 5.3 μm Volume Emission Rates (VER)

- NO at 5.3 μm is key infrared emission
- optically thin, energy escapes thermosphere completely
- upper atmosphere' natural thermostat: major cooling from 100 – 200 km



~1 nW/m^3

Mlynczak et al., JGR 2010

Changes in NO 5.3 μm VER reflect changes in
- → NO abundance
- → O abundance
- → temperature
- → exothermic production of vibrational levels

} tidal impacts: density, advection, T (NO abundance, O abundance, temperature)

} storm time, excluded here (exothermic production of vibrational levels)

DE2 and DE3 in SABER NO 5.3 μm VER

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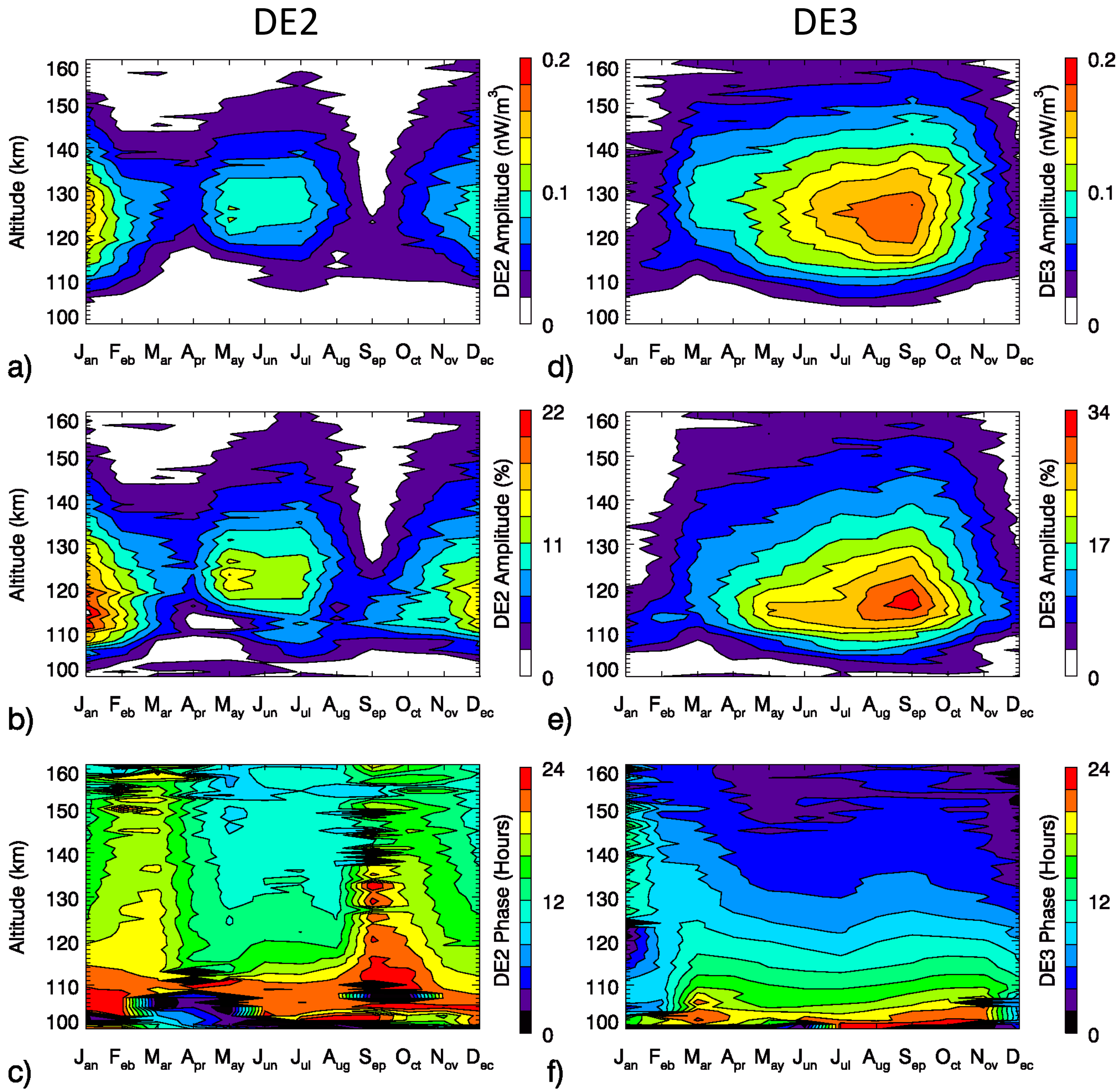


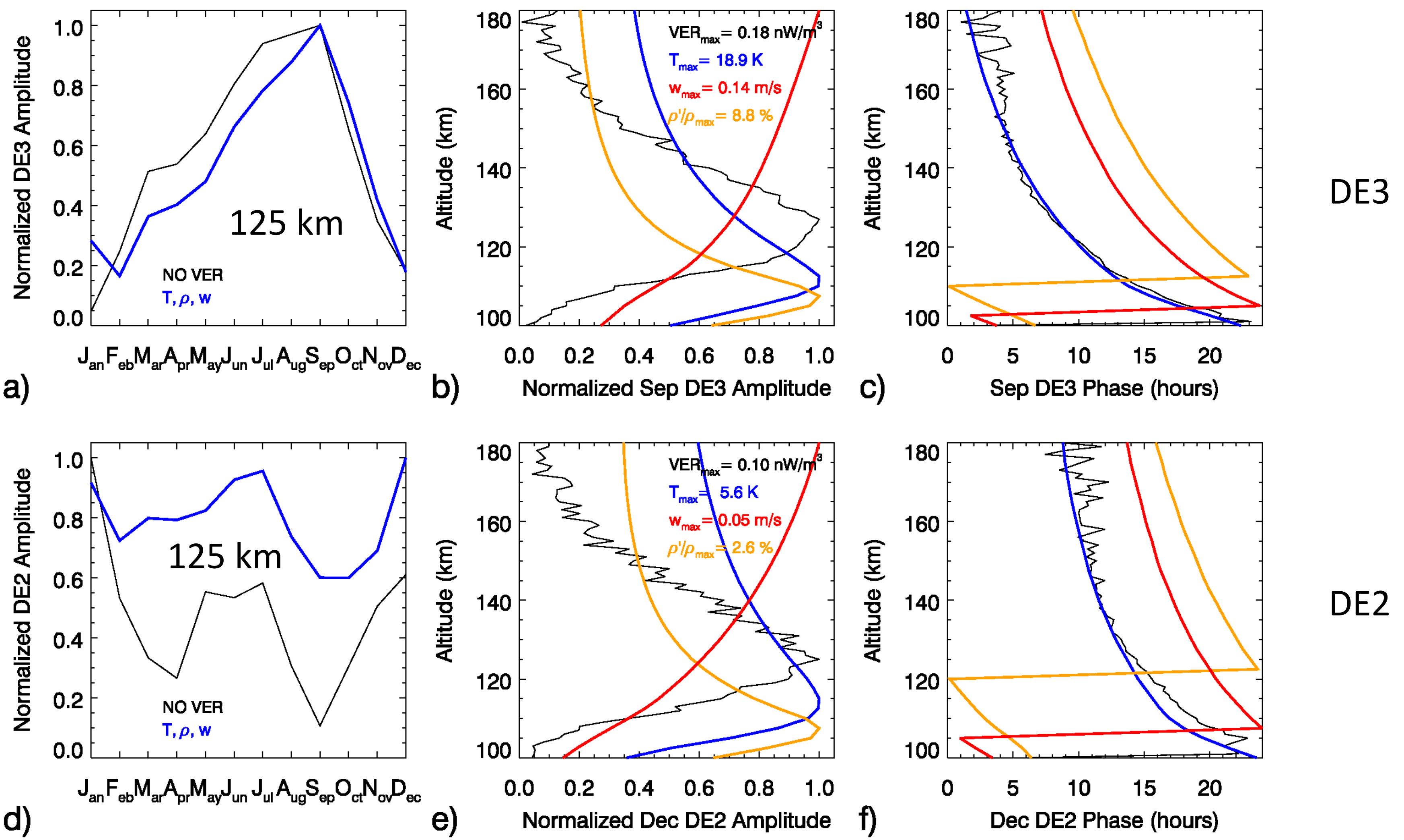
Amplitude in nW/m^3

Amplitude in %
of monthly mean

Phase in LT of max

2 days after $K_p > 4$
excluded from analysis

DE2 and DE3 from CTMT, 2008 @ equator



CTMT: empirical tidal model based on Hough Mode Extensions constrained with SABER and TIDI tidal diagnostics; pole-to-pole; 0-400 km; T, density, u, v, w; *Oberheide et al., JGR 2011*

Photochemical modeling

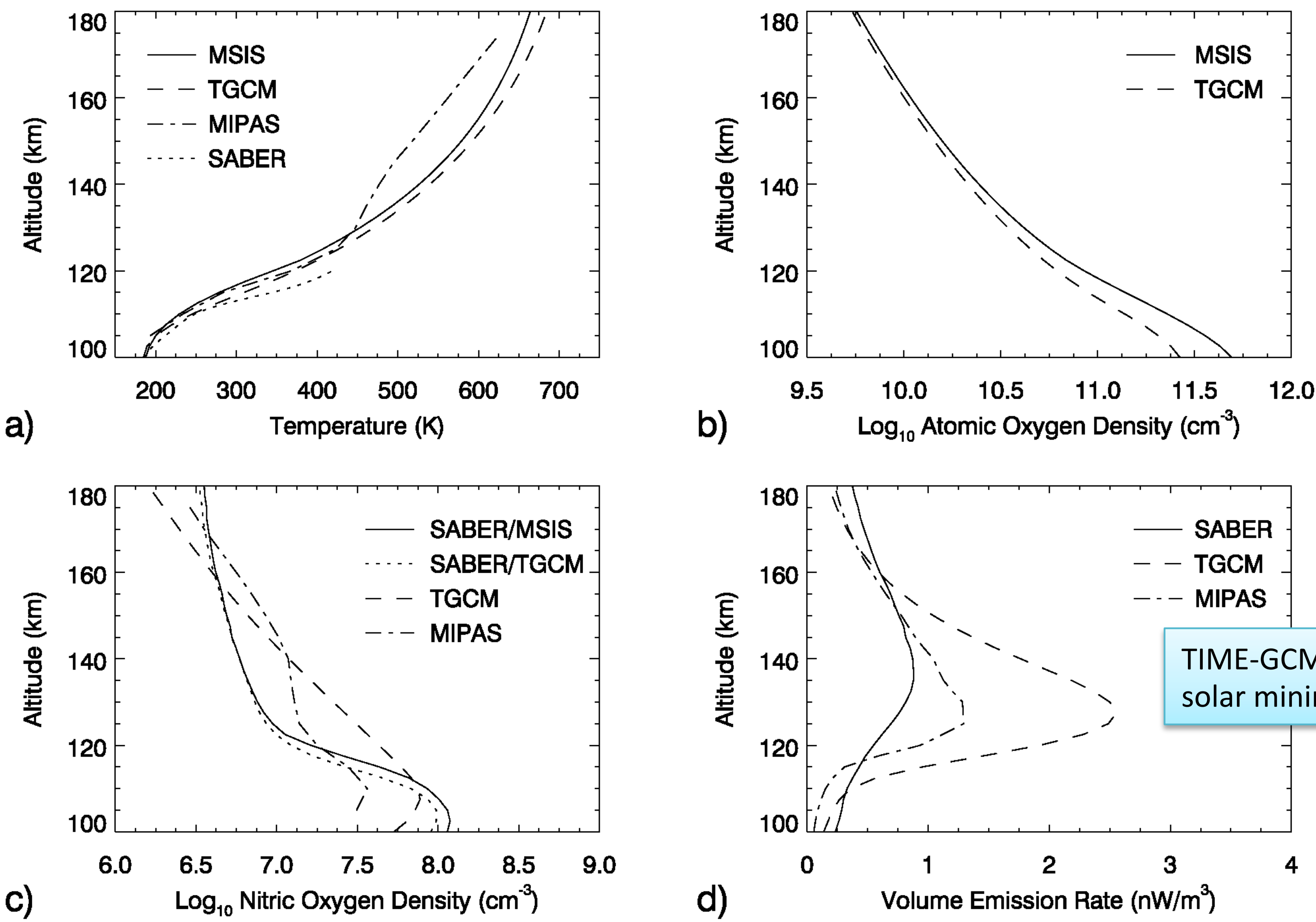
$$VER = h\nu A[NO]_{\nu=1}$$

$$[NO]_{\nu=1} = \frac{S_E + k_{NO-O}e^{-2700/T}[O]}{A + k_{NO-O}[O]}[NO]_{\nu=0}$$

NO at 5.3 µm governed by NO-O collisions exciting the v=1 vib. state, *Winick et al., 1987*

- Need background [NO], [O], T
  - → MIPAS, TIME-GCM, MSIS
  - → different data sets for sensitivity study (large T dependence, vertical gradients, uncertainty in [O], …)
- Need tidal perturbations in [NO], [O], T
  - → T from CTMT
  - → [NO], [O] from CTMT tidal density and vertical wind (advection)

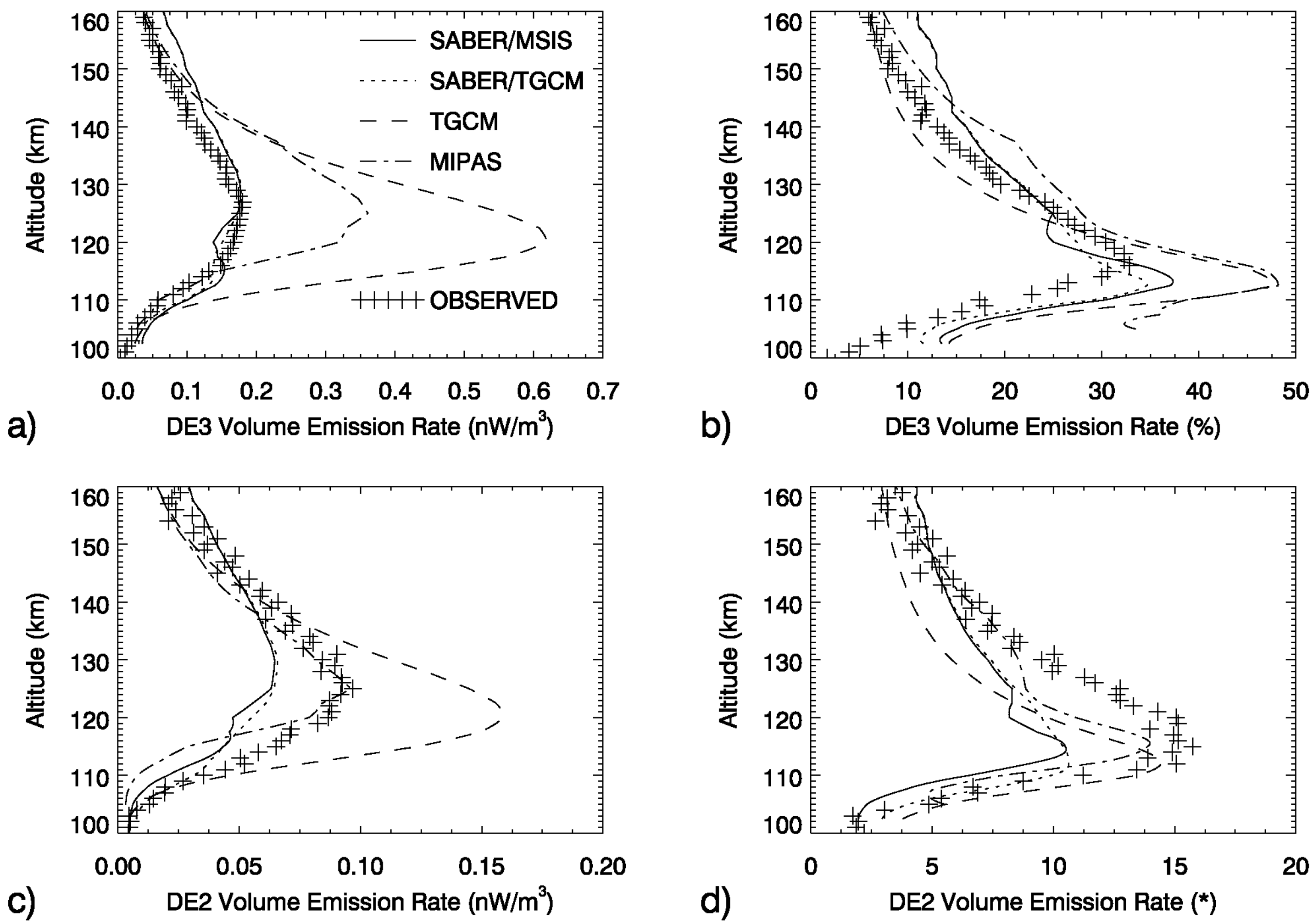
September 2008 zonal means @ equator



TIME-GCM from generic solar minimum run

SABER/MSIS; SABER/TGCM computed from observed SABER NO 5.3 µm VER

Obs. vs. modeled DE3 and DE2 @ equator



DE3
September

DE2
December

→ Systematic biases due to the different backgrounds largely vanish in relative amps.

→ Overall good agreement between obs and modeled amps given the uncertainties.

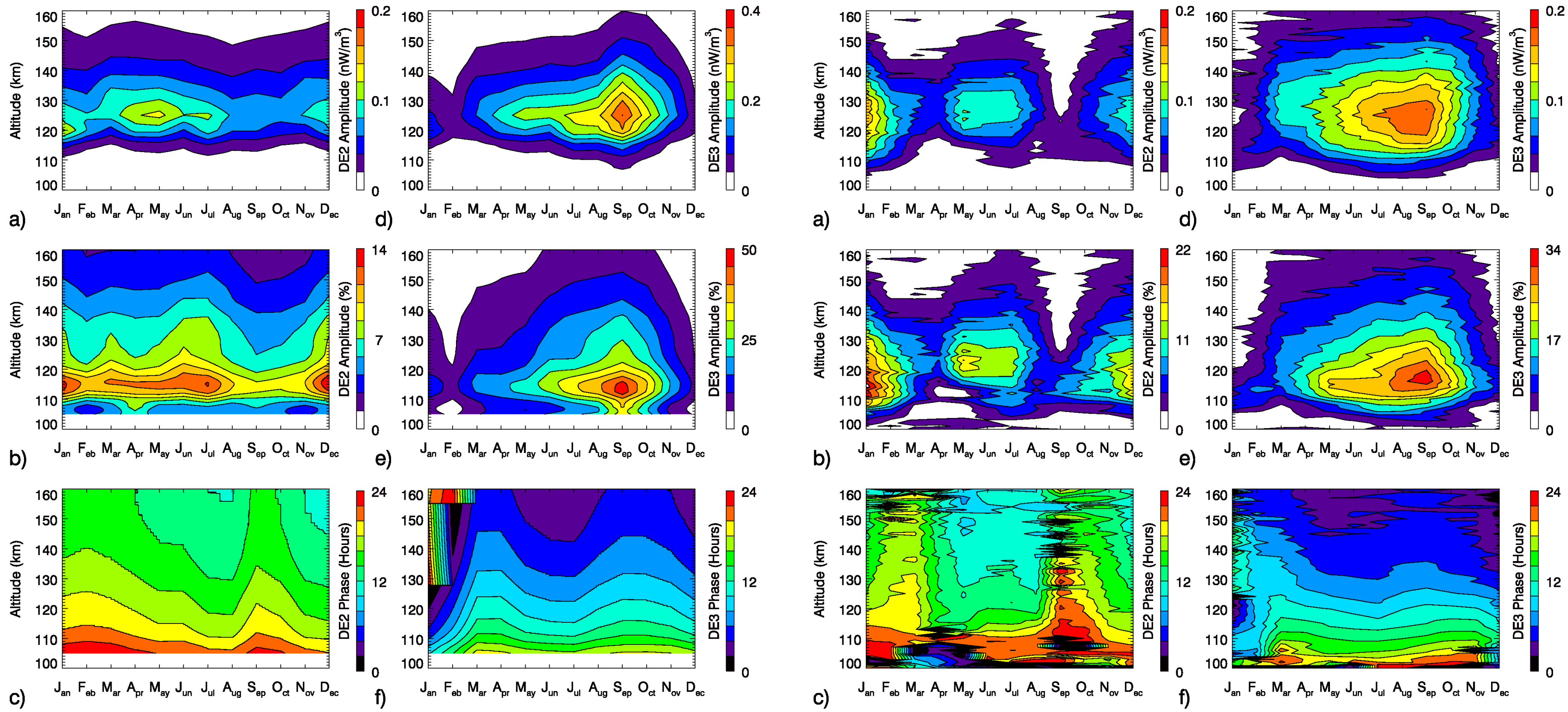
Obs. vs. modeled DE3 and DE2 @ equator

Modeled, MIPAS background

DE2 DE3

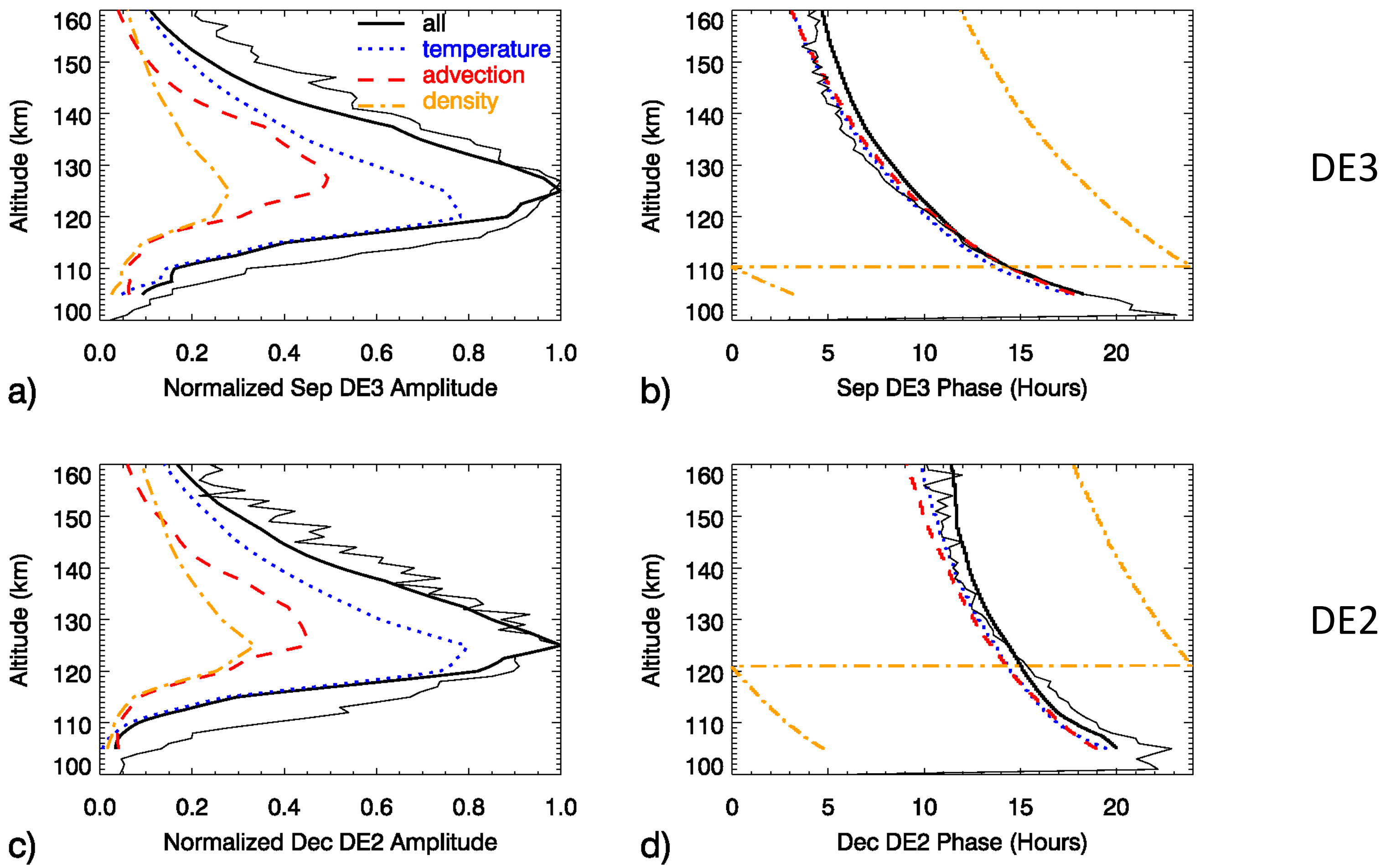
Observed, SABER

DE2 DE3



- → Note the different scales. Modeled amps using MIPAS generally larger.
- → General structure well reproduced.

Tidal coupling



- → Temperature major tidal coupling mechanism; due to T dep. of reaction rate
- → Advection and density largely compensate each other below 120 km
- → Advection contributes above 120 km, same direction as T effect

Summary and conclusions

- DE2 and DE3 tides from tropospheric convection strongly impact the NO 5.3 μm infrared emission during solar min
  - → Relative amplitudes on the order of 20% (DE2) and 30% (DE3) around 115 km
  - → Absolute amplitudes on the order of 0.1 nW/m^3 (DE2) and 0.2 nW/m^3 (DE3) around 125 km
  - → Significant longitude and local time modulation of Earth's upper atmosphere "natural thermostat"
- Tidal coupling mainly imposed by temperature dependence of NO-O reaction rate
  - → Density and advection mainly compensate below 120 km
  - → Advection adds to T effect above 120 km

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