Faculty of Physics and
Earth Sciences

Terdiurnal Components of Tidal Forcing Terms in a Middle Atmosphere Model

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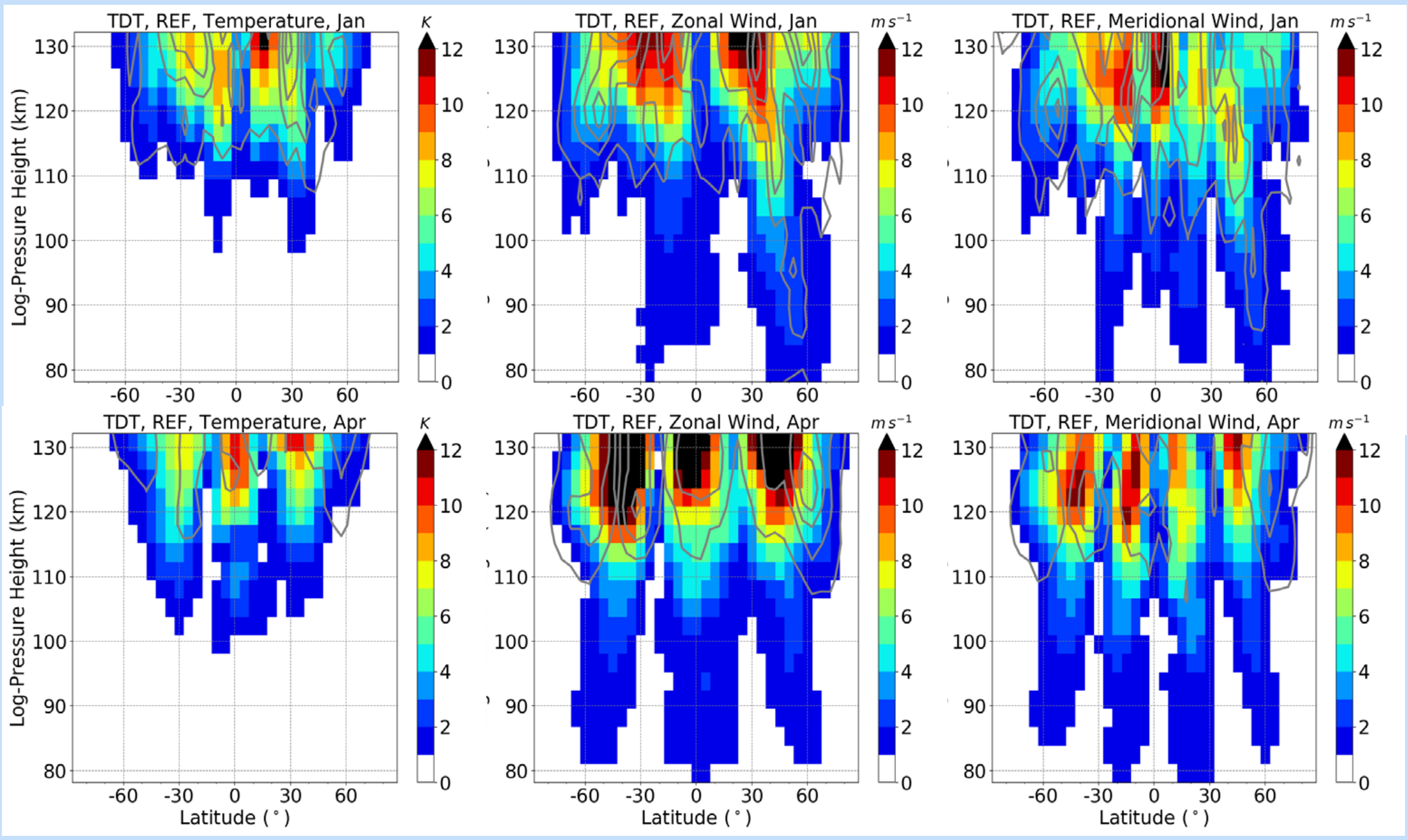
Summary: Atmospheric solar tides play a crucial role for vertical coupling between the troposphere and the mesosphere/lower thermosphere region. Their existence is mainly owing to the daily variation of solar heating. Here, we concentrate on the terdiurnal tide (TDT) with a period of 8h and wavenumber 3. The TDT is, on a long-term scale, smaller than the diurnal tide (DT) or semidiurnal tide (SDT), but occasionally it may reach comparable amplitudes. Its forcing mechanisms are more complex because for higher harmonics like the TDT, nonlinear tidal interactions between DTs and SDTs come into play. Further possible excitation can arise from GW-tide interactions. To investigate the nature of TDT forcing we use a model of the middle atmosphere and analyze the terdiurnal terms of direct solar forcing, nonlinear tidal interactions and GW-tide interactions.

Middle and Upper Atmosphere Model (MUAM)

- Primitive equation 3D grid point model
- Horizontal resolution: 5°x5.625°; upper boundary: 160km (log-p); Δz=2.842 km
- Time step 225s (Matsuno integration scheme)
- Nudging of ERA-Interim monthly mean zonal mean temperature below 30km

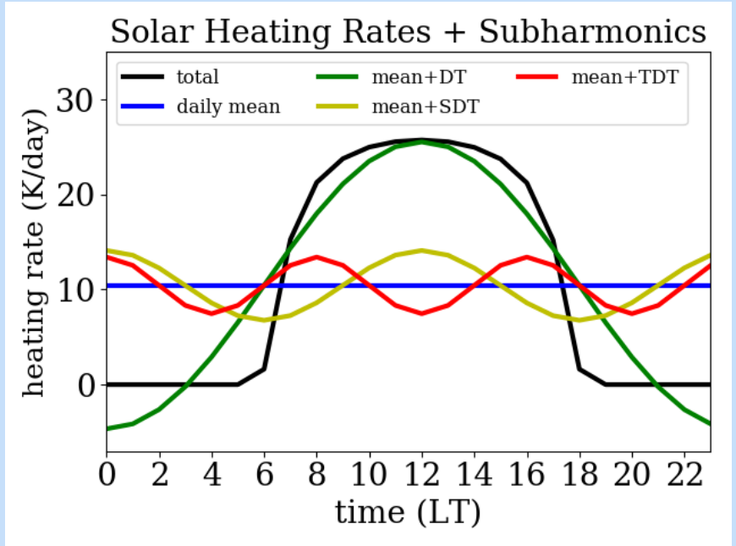
  → ensemble simulation with 11 members (2000-2010)
- Lindzen-type parameterization of gravity waves (GWs) in the middle atmosphere
- Parameterization of solar and IR radiation
- Parameterization of ionospheric effects
- **Tidal sources:**
  - daily solar heating (from solar heating parameterization)
  - nonlinear tidal interations (from the tendency equations)
  - GW-tide interactions (from GW parameterization)
- No sources for non-migrating tides (no orography, no latent heat release, zonal mean distribution of radiative active gases)
- For further details see Lilienthal et al. (2018)



Right:
TDT amplitudes for January (top) and April (bottom). Gray contour lines indicate standard deviations with respect to an 11-year ensemble simulation (Δσ=0.2). From left to right: Temperature, zonal wind, meridional wind amplitudes.

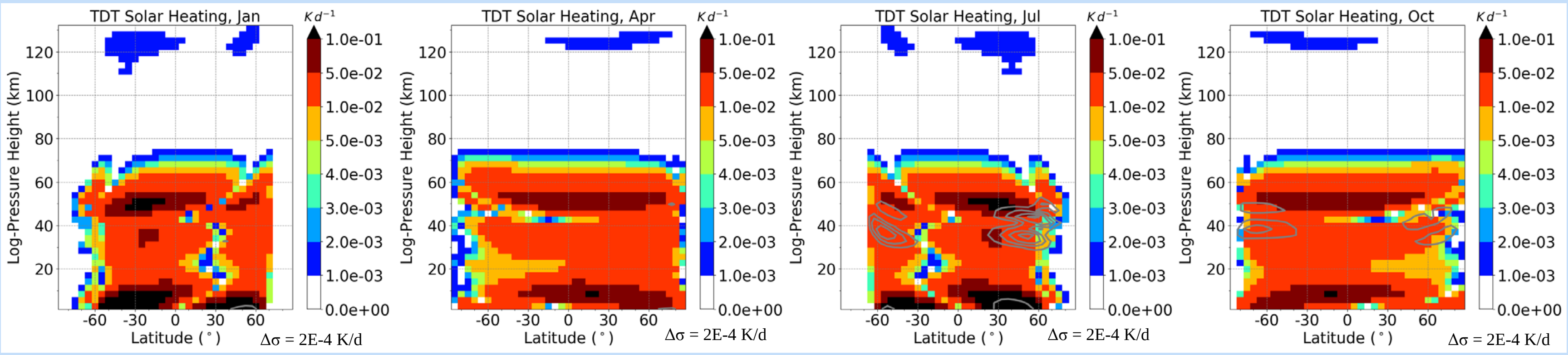
Direct Excitation by Daily Solar Heating

The terdiurnal component of solar heating can be as large as the diurnal or semidiurnal component.



Left: Daily solar heating rates (black) at 50km altitude (2.5°N, 0°E) and its daily mean (blue). Subharmonics of the total heating: DT (green), SDT (yellow), TDT (blue).

Direct solar heating is the strongest excitation source of TDTs below the mesopause. Absorption of solar radiation in the water vapour (troposphere) and ozone region (stratosphere) are the main drivers.



Top: TDT component of solar heating rates in January, April, July and October (from left to right) scaled by density to highlight the excitation region. Gray contour lines indicate standard deviations with respect to an 11-year ensemble simulation. Note that scale is not continous.

References:
Lilienthal, F., Jacobi, C., and Geißler, C.: Forcing Mechanisms of the Terdiurnal Tide, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2018-154, in review, 2018.

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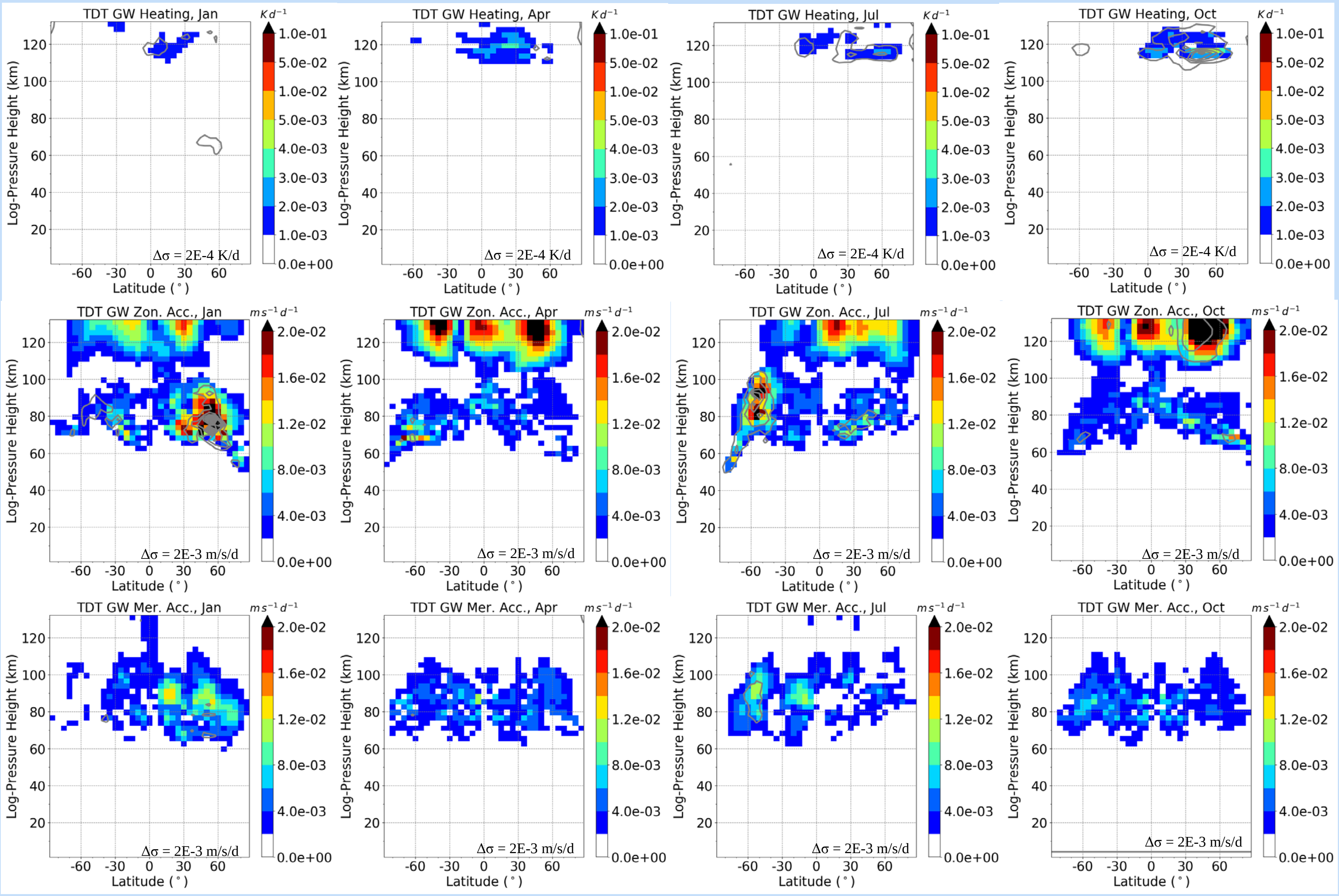
Secondary Forcing: GW-Tide Interactions

In our model, heating of the atmosphere due to GWs is weak and only important in the thermosphere above 110km altitude, being stronger during equinoxes than during solstices.

The same holds for the zonal wind acceleration. Additionally, there is a strong excitation region in midlatitudes of the winter hemisphere during solstice.

The meridional wind acceleration due to GW is generally weak.



TDT component of GW-tide interactions in January, April, July and October (from left to right) scaled by density to highlight the excitation region. Gray contour lines indicate standard deviations with respect to an 11-year ensemble simulation. Top row: Heating from GWs. Middle row: Zonal wind acceleration. Bottom row: Meridional wind acceleration.

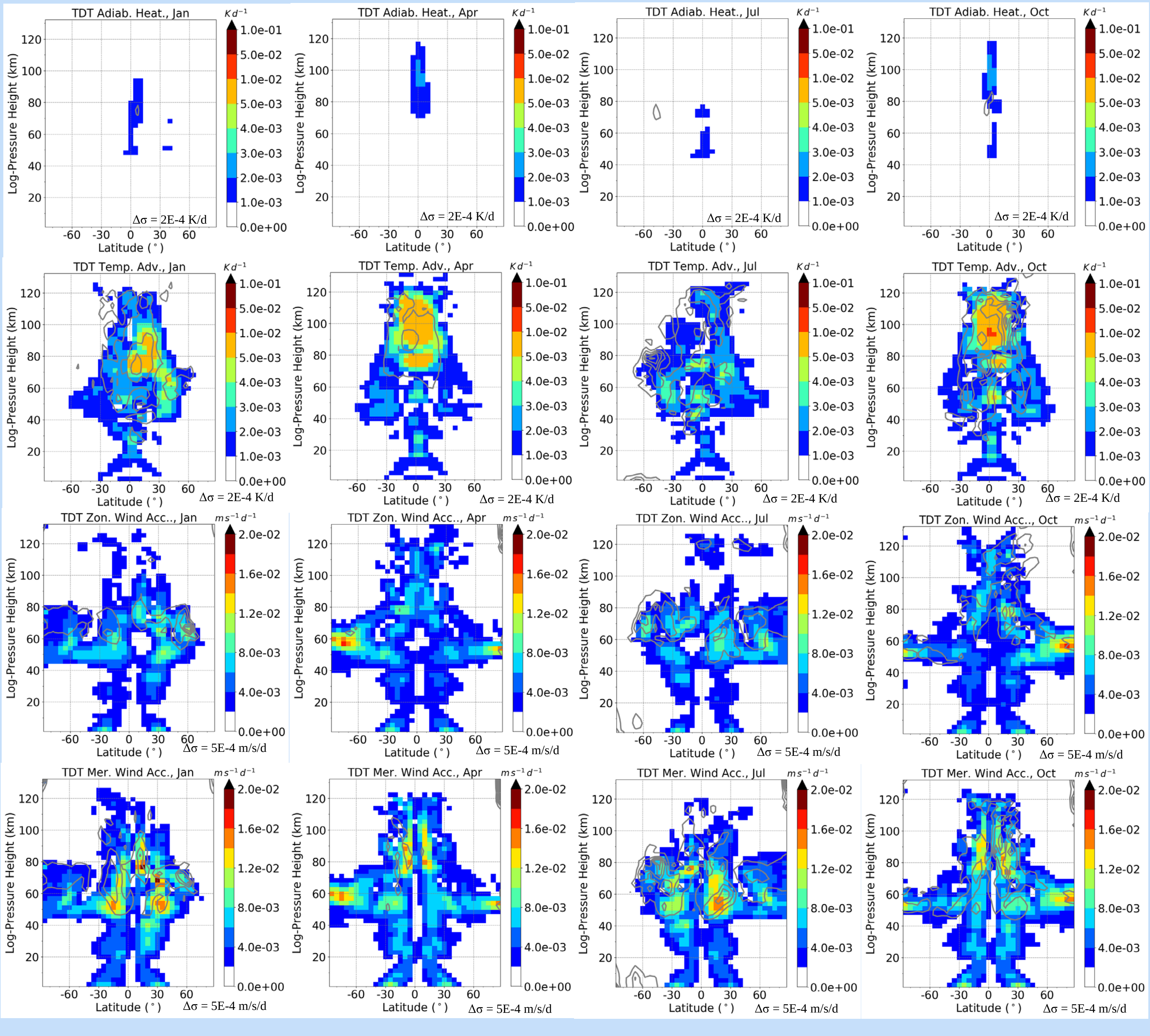
Secondary Forcing: Nonlinear Tidal Interactions

Nonlinear TDT forcing from adiabatic heating is negligible.

Heating due to temperature advection is strongest during equinoxes in the mesosphere near the equator and exceeds the solar forcing there.

Nonlinear zonal wind acceleration mainly excites TDT in the stratosphere at low latitudes (solstices) and near the poles (equinoxes).

This is similar for the nonlinear meridional wind acceleration.



TDT component of nonlinear tidal interactions in January, April, July and October (from left to right) scaled by density to highlight the excitation region. Gray contour lines indicate standard deviations with respect to an 11-year ensemble simulation. 1st row: Adiabatic heating. 2nd row: Heating due to temperature advection. 3rd row: Zonal wind acceleration. 4th row: Meridional wind acceleration.

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