Forcing mechanisms of the terdiurnal and quarterdiurnal tide

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1 Summary

Model experiments: removing tidal forcings

- Mechanistic global circulation model of the middle atmosphere, including self-excitation of tides.
- Experiments with removing wavenumber 3 (terdiurnal tide, TDT) and 4 (quarterdiurnal tide, QDT) from different sources.
- Remaining tides analyzed.

Main conclusion

The main source of TDT and QDT in the middle atmosphere are the wavenumber 3 and 4 components of diurnal solar heating. Nonlinear interaction of tides and tide-gravity wave interaction play a minor, although non-negligible role.

2 Model and experimental setup

MUAM numerical circulation model

- 3D grid point mechanistic model (Pogoreltsev et al., 2007).
- Extending from surface to lower thermosphere.
- Primitive equations.
- Parameterized gravity waves, solar and thermal infrared radiation.

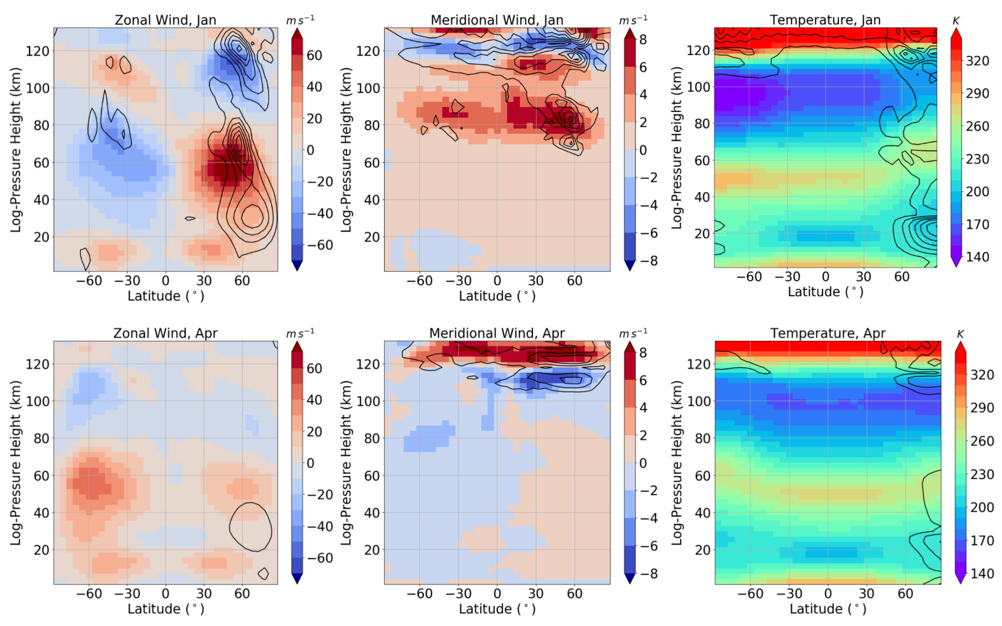

Fig. 1: Modelled background zonal wind (left), meridional wind (middle), and temperature (right) in January (top) and April (bottom) .

TDT forcing terms / QDT forcing terms

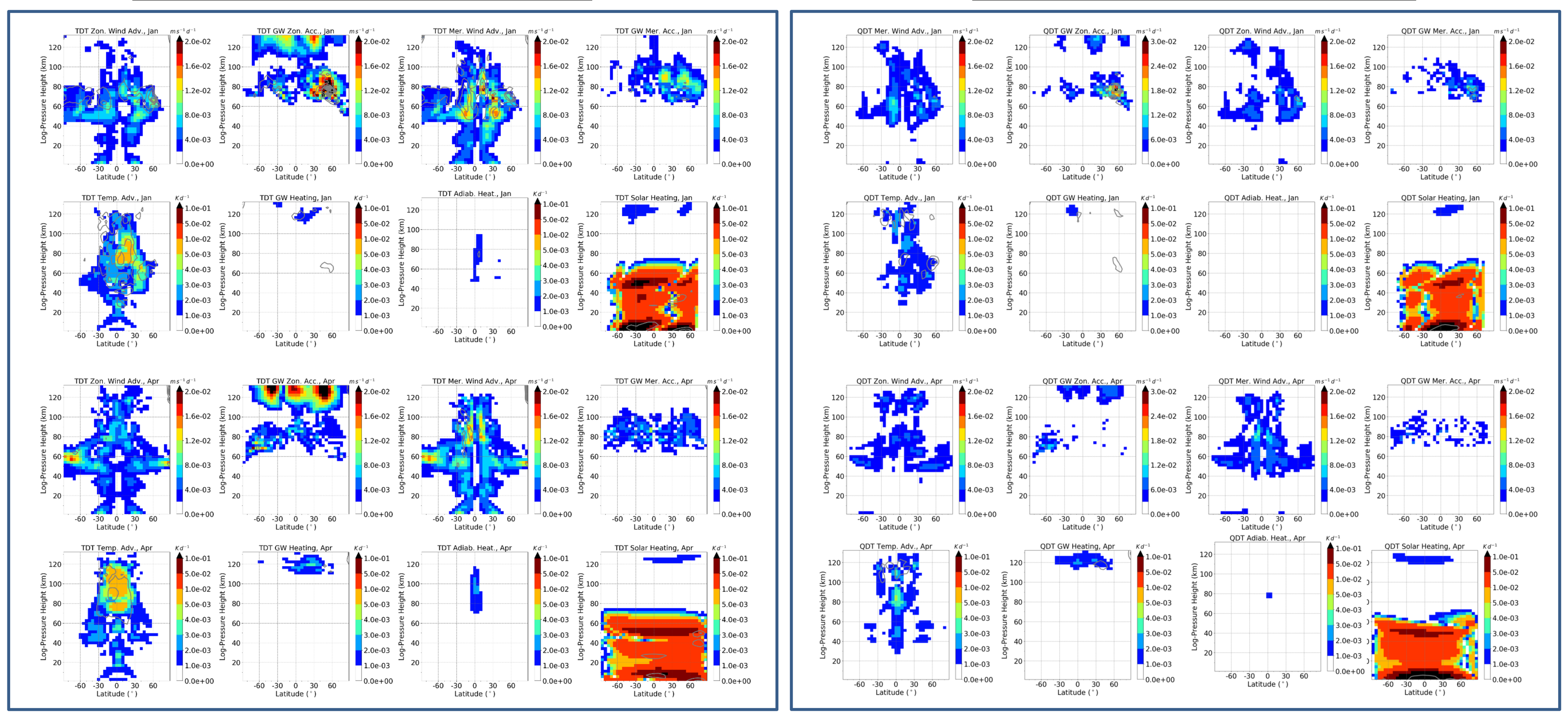

Fig. 2: Terdiurnal wavenumber 3 (left panels) and quarterdiurnal wavenumber 4 (right panels) component of forcing terms scaled by density (from left to right) from the REF run: 1st row: a) nonlinear zonal wind advection, b) zonal GW acceleration, c) nonlinear meridional wind advection d) meridional GW acceleration. 2nd row: a) nonlinear temperature advection, b) GW heating c) nonlinear adiabatic heating, d) direct solar heating. Results for January. 3rd and 4th rows: Same as in 1st and 2nd row, but for April.

Experimental setup

Separately removed TDT/QDT forcing terms:

REF : reference run with all forcings
NO_SOL: solar heating removed
NO_NLIN: nonlinear interaction (between tides) removed
NO_GW: gravity wave (GW) forcing removed

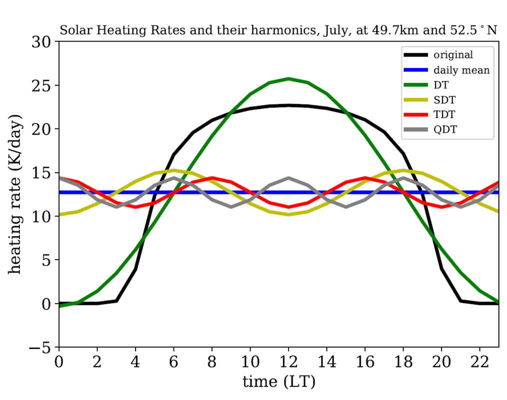

Fig. 3: Example of solar heating rates and their harmonics.

3 Results

TDT zonal wind

- Reference TDT amplitudes show a 2-3 peak meridional distribution.
- Amplitudes during equinoxes are stronger than during solstice.
- Strongly reduced amplitudes with removed solar forcing.
- Amplitudes partly increase when nonlinear or gravity wave forcing is removed, especially below 110 km.
- This can be due to destructive interference between waves owing to different forcing (see Fig. 6).

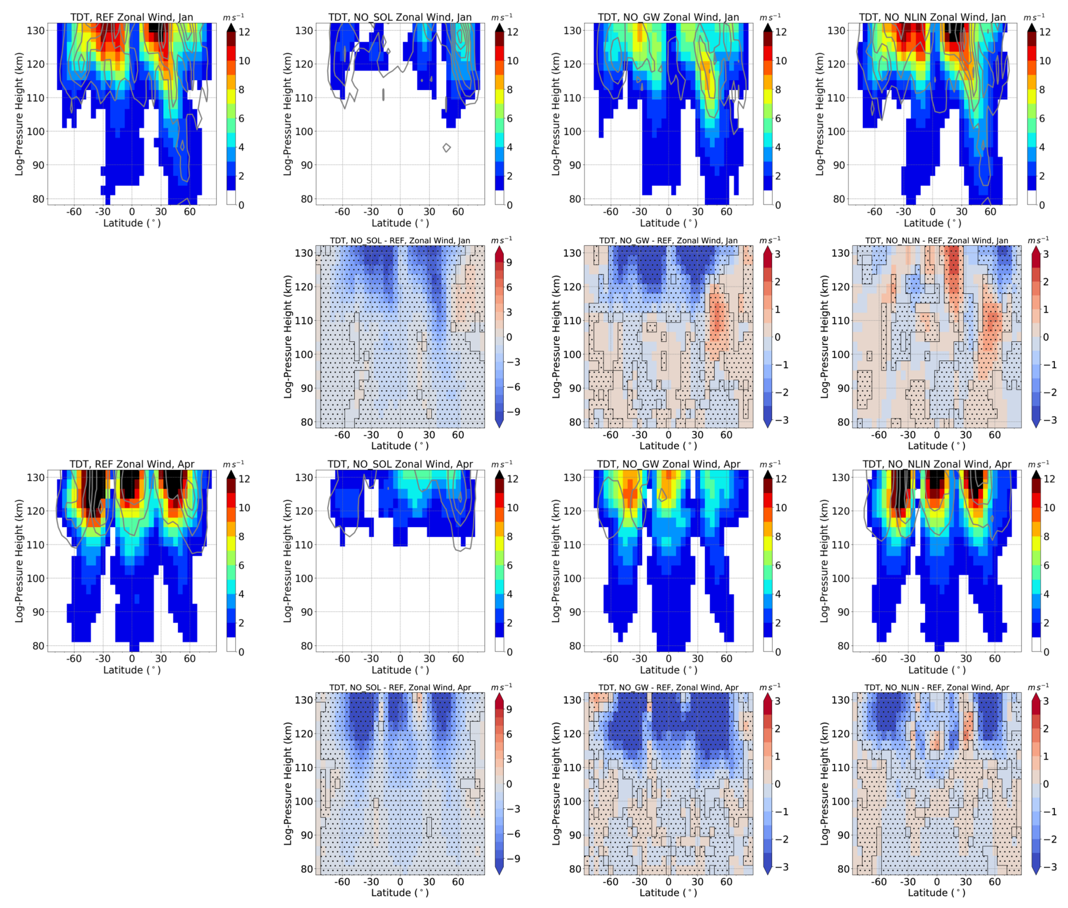

Fig. 4: TDT zonal wind amplitudes. Upper row, from left to right: 1) REF, 2) NO_SOL, 3) NO_GW, 4) NO_NLIN, 2nd row: 1) REF-NO_SOL, 2) REF-NO_GW, 3) REF-NO_NLIN. Note the different scaling for 1) in 2nd row. 3th and 4th row: as in 1st and 2nd row, but for April.

QDT zonal wind

- QDT amplitudes are smaller than TDT ones.
- Strongly reduced amplitudes with removed solar forcing.
- Amplitudes increase due to destructive interference especially of the solar and nonlinearily forced QDT components.

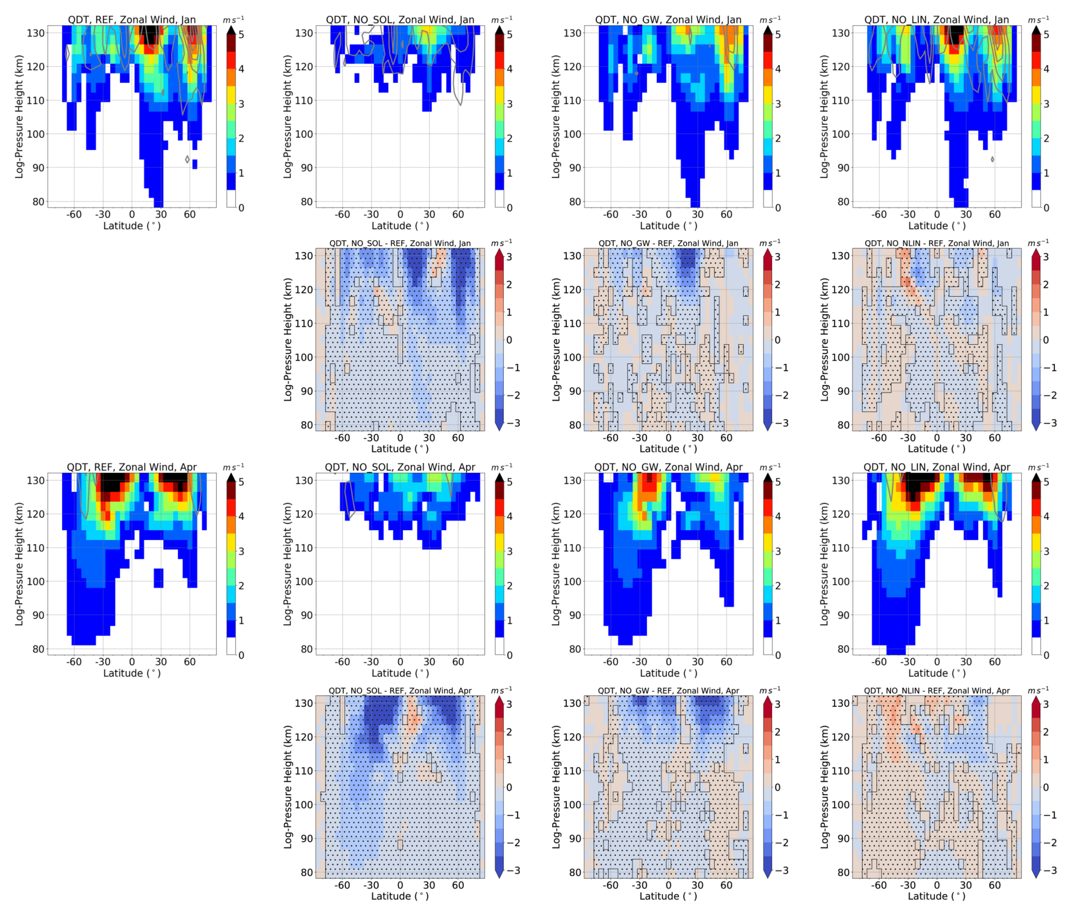

Fig. 5: As in Fig 4, but for the QDT.

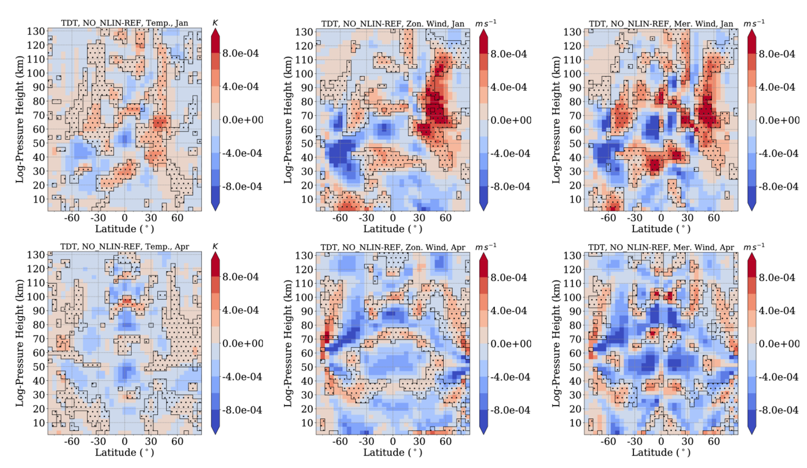

Fig. 6: Example for destructive interference between TDT waves from different forcings. Color code: Scaled NO_NLIN-REF amplitudes. Hatched: 120° < NO_NLIN-NO_SOL phase difference < 240° (destructive interference between solar and nonlinear wave). Left: temperature, middle: zonal wind, right: meridional wind. 1st row: January, 2nd row: April.

4 Conclusions and final remarks

Conclusions

- Removing wavenumber 3 or 4 from different acceleration and heating terms gives insight into forcing mechanisms of the TDT and QDT.
- Solar terdiurnal and quarterdiurnal forcing is the strongest source of TDT and QDT.
- Nonlinear interaction of tides is effective in the mesosphere.
- GW acceleration of tides is mainly effective in the lower thermosphere.
- Waves from different sources partly interfere destructively, so tides without GW or nonlinear sources are stronger at some latitudes.

Perspectives

- Additional experiments with more than one forcing removed.
- Analyse nonlinear terms from reanalyses for validation.

References

- Pogoreltsev, A.I., Vlasov, A.A., Fröhlich, K., Jacobi, Ch., 2007: J. Atmos. Sol.-Terr. Phys., 69, 2083–2101, doi:10.1016/j.jastp.2007.05.014.

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