Comparing interhemispheric differences of mesosphere/lower thermosphere dynamics from ground-based observations and three general circulation models

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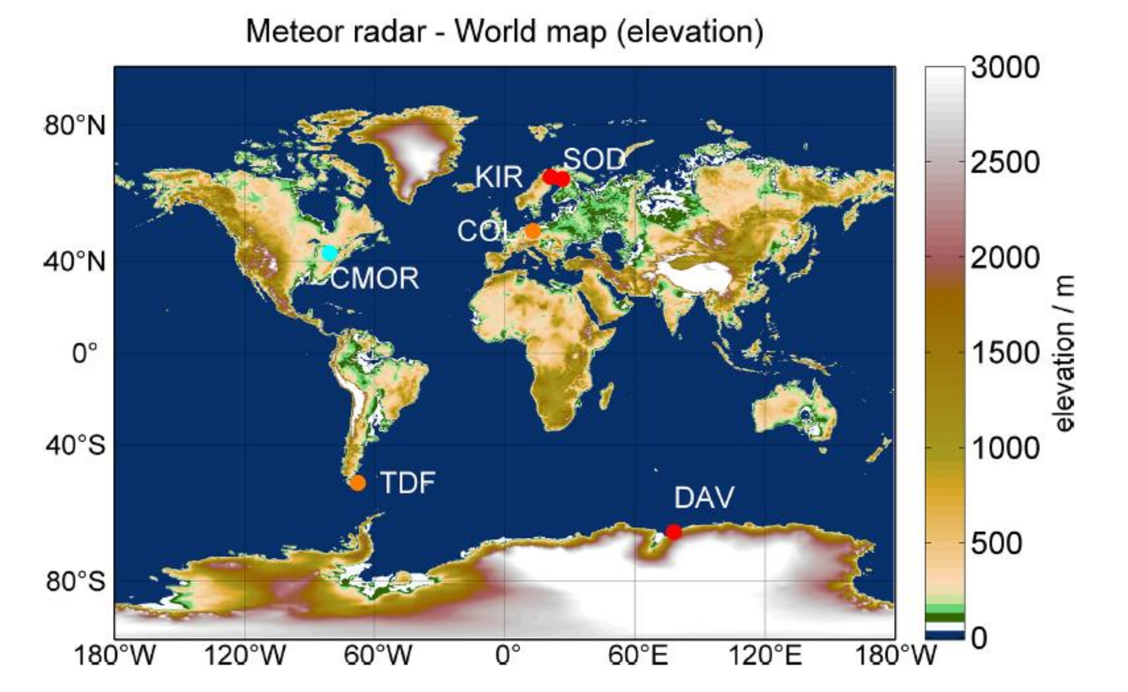
Conjugate Study of Interhemispheric differences



- six meteors radars were used, which collected data between 1999-2017
- climatologies are generated considering the actual observation period for each system
- SOD-Sodankyla, KIR- Kiruna, COL-Collm, CMOR-Canadian Meteor Orbit Radar, TDF- Tierra del Fuego (SAAMER), DAV-Davis

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General Circulation Models used in this study

- Ground-to-Topside Model of Atmosphere and Ionosphere for Aeronomy (GAIA)
  - parameterized gravity waves
  - nudged to reanalysis JRA-25/55 up to 30 km every 6 hours
  - 21 years long run until 2017
- Whole Atmosphere Community Climate Model Extension (Specified Dynamics) (WACCM-X(SD))
  - parameterized gravity waves
  - nudged to reanalysis MERRA up to 50 km every 6 hours
- ICOsahedral Non-hydrostatic (UA-ICON)
  - non-hydrostatic free running model (21 years- first year disregarded)
  - parameterized gravity waves
  - vertical velocity sponge at 120 km altitude

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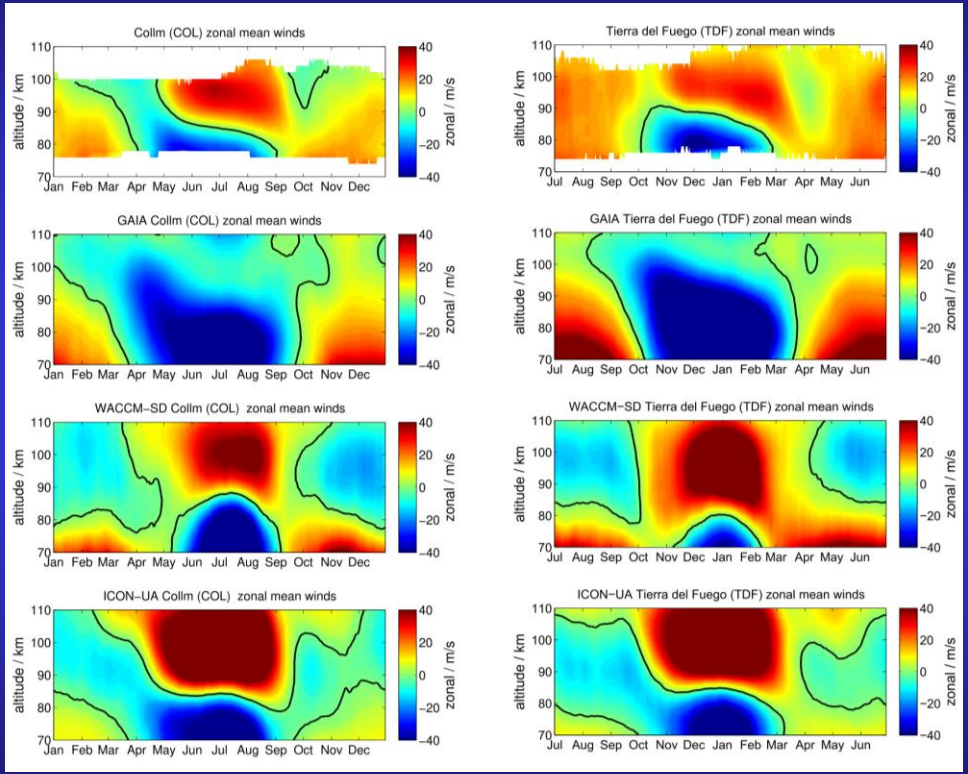
Interhemispheric differences (mean winds)

Mid-latitude Collm vs. Tierra del Fuego



- during winter eastward zonal winds indicate stronger magnitude in SH
- spring transition is less asymmetric compared to northern hemisphere
- GAIA captures in general interhemispheric differences, but doesn't reproduce summer zonal wind reversal
- WACCM-X and ICON show pronounced summer time wind reversal, but the winter eastward wind reverses at an too low altitude

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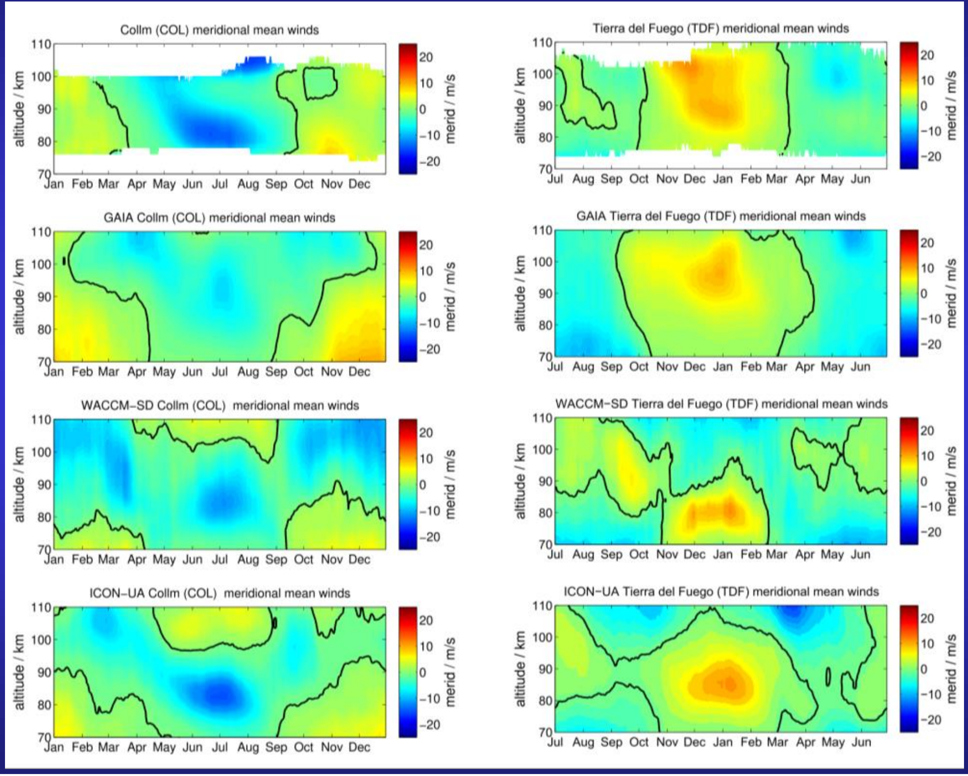
Interhemispheric differences (mean winds)

Mid-latitude Collm vs. Tierra del Fuego



- Meridional winds show some differences of the seasonal summer mesospheric winds
- there is a reasonable agreement between GAIA and the meteor radars in both hemispheres
- WACCM-X and ICON-UA capture the summer winds between 80-90 km, but show some differences in the vertical seasonal morphology

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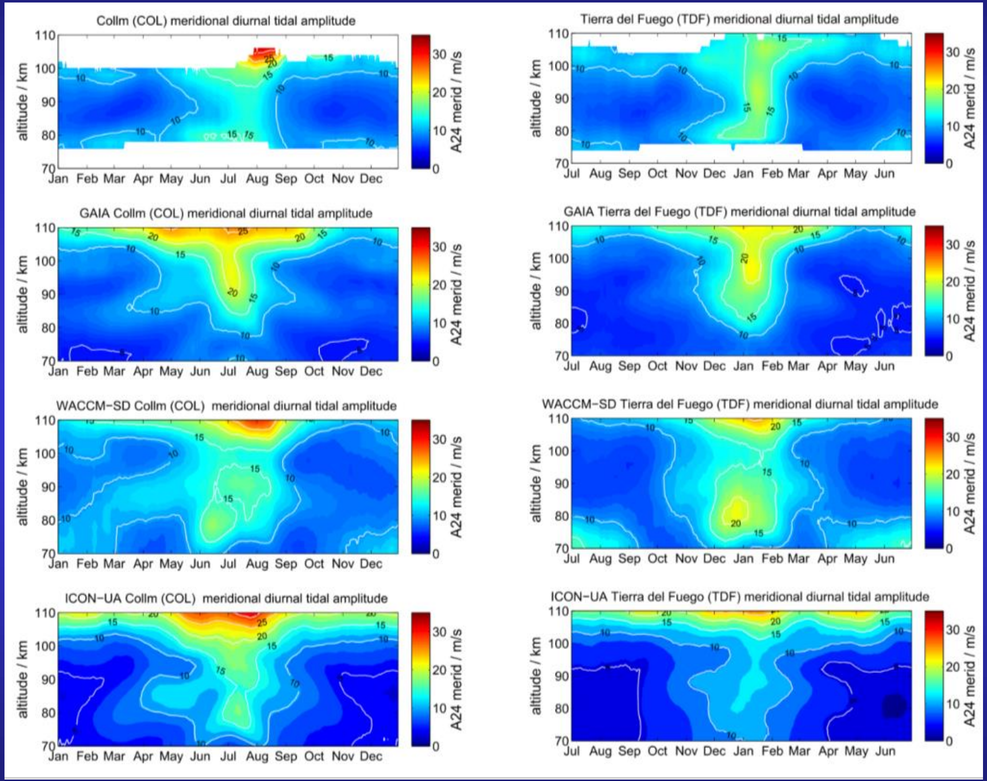
Diurnal tides and interhemispheric differences

Mid-latitude Collm vs. Tierra del Fuego



- diurnal tides maximize during hemispheric summer
- the seasonal behaviour appears to be very similar in both hemispheres
- reasonable agreement of diurnal amplitudes between GCM's and observations

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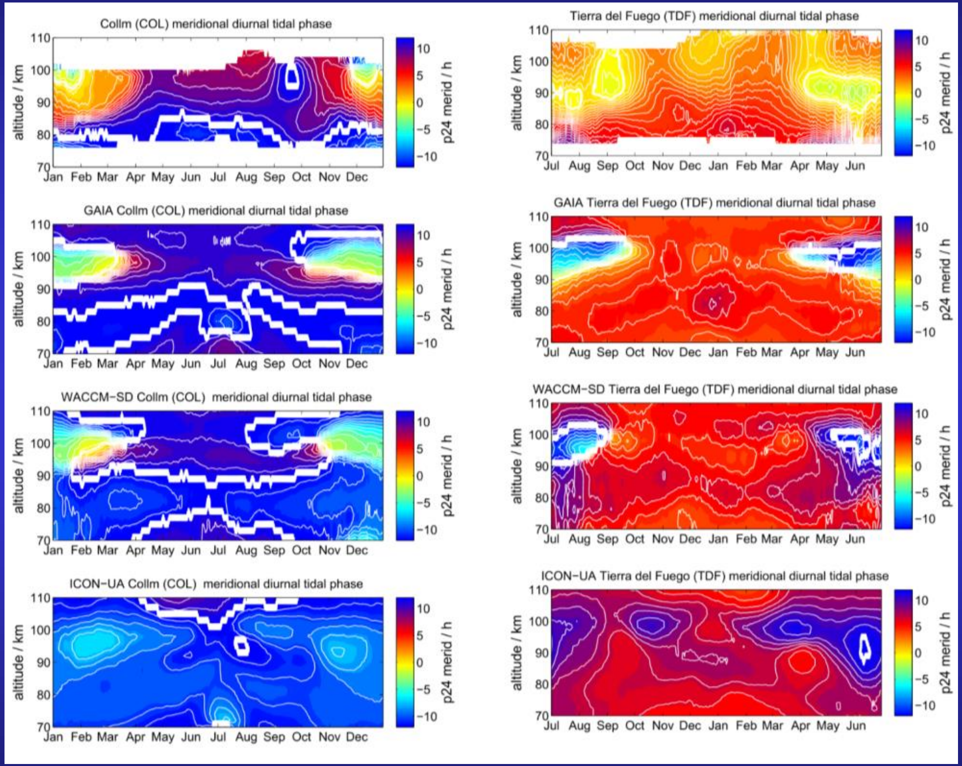
Diurnal tide phase interhemispheric differences

Mid-latitude Collm vs. Tierra del Fuego



- diurnal tidal phases exhibit only small interhemispheric differences
- GAIA and WACCM show reasonable agreement for the northern hemisphere, but some systematic phase offset in the southern hemisphere
- ICON-UA reveals an even increased phases offset
- zonal and meridional components

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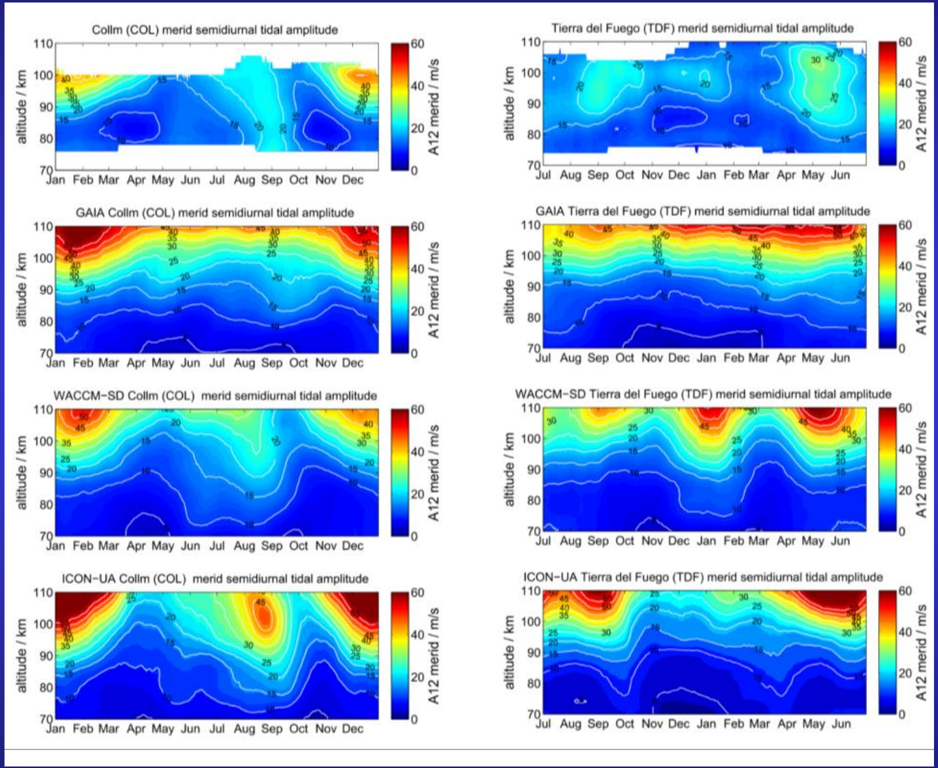
Semidiurnal tides interhemispheric differences

Mid-latitude Collm vs. Tierra del Fuego



- semidiurnal tides show characteristic interhemispheric differences
- amplitudes are larger during the northern hemispheric winter
- the northern hemisphere reveals seasonal asymmetry with a maximum at the end of summer, which is missing in southern hemisphere
- GAIA and WACCM-X reproduce partially the seasonal pattern at the northern hemisphere, but exhibit larger differences in the southern hemisphere
- ICON-UA captures the seasonal behaviour of the amplitudes in both hemispheres

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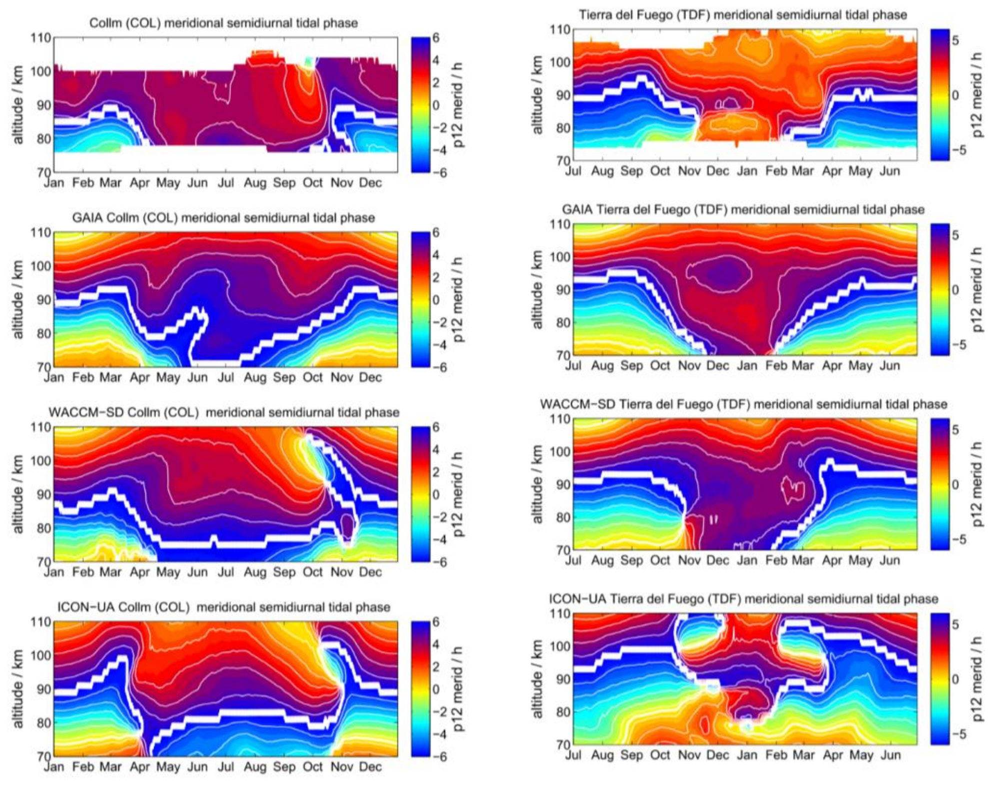
Semidiurnal tidal phases interhemispheric differences

Mid-latitude Collm vs. Tierra del Fuego



- semidiurnal tidal phase show characteristic hemispheric differences
- in the southern hemisphere tidal phases exhibit a more smooth seasonal variability and symmetric seasonal behaviour
- in the northern a pronounced and rapid phase change before the fall transition is visible, which is entirely missing in the southern hemisphere
- GAIA shows better agreement for the southern hemisphere
- ICON-UA and WACCM-X(SD) seem to reproduce the hemispheric seasonal asymmetry

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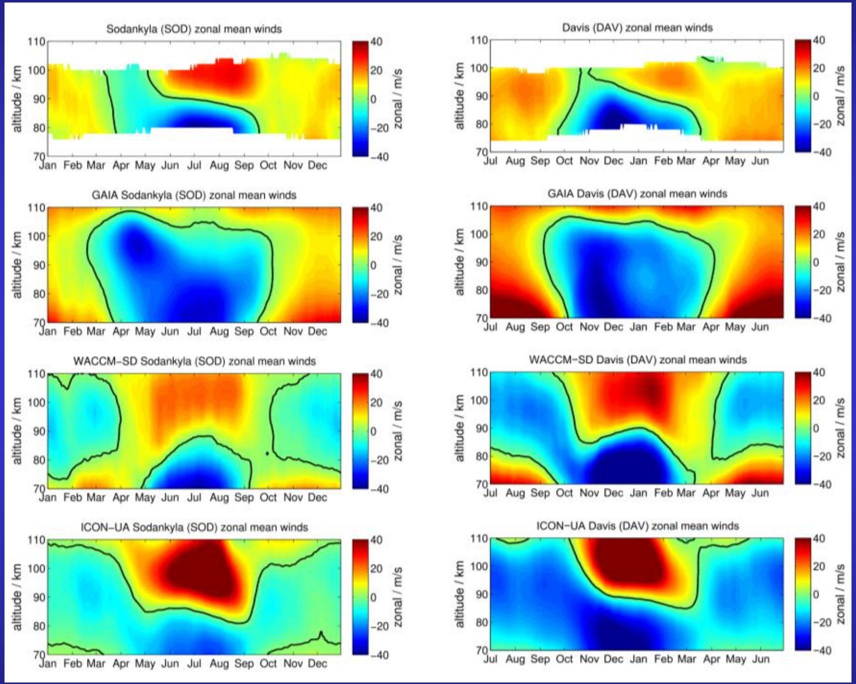
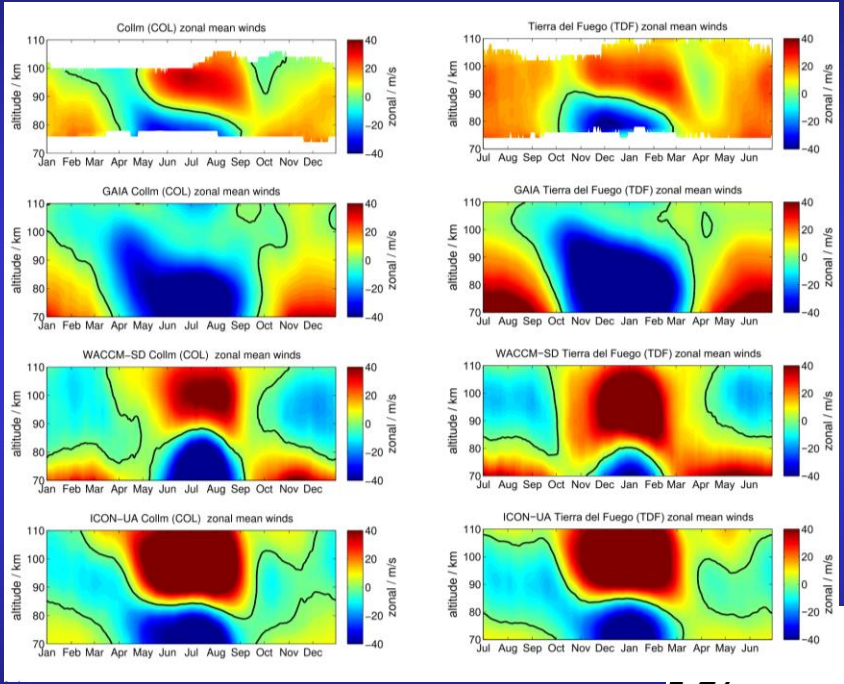
Comparison between mid and polar-latitudes

Polar latitude Sodankylä vs. Davis



Mid-latitude Collm vs. Tierra del Fuego



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Summary – GCM vs. MR

- mean zonal and meridional winds show deviations between meteor radar observations and model climatologies in the seasonal morphology of the MLT winds, which could be reduced by improved gravity wave parameterizations (e.g., including multi-step vertical coupling processes through secondary waves (Becker and Vadas, 2018))
- nudging to reanalysis data seems to have limited improvement on semidiurnal tides as the reanalysis is often updated in 6 hour intervals, which is likely not sufficient to capture the variability
- diurnal tides are well-represented in GCM's and only phases at polar latitudes might be overestimated concerning the meteor radar observations

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Conclusion

- Zonal and meridional winds at the MLT indicate interhemispheric differences
  - hemispheric spring transition
  - winter season eastward zonal wind magnitude
- GCM's partially capture interhemispheric differences in the mean winds
- GAIA indicates reasonable agreement during the hemispheric winter season, but misses summer zonal reversal
- WACCM-X and ICON-UA show pronounced zonal wind summer wind reversal, but present westward winds during winter
- ICON-UA and GAIA capture seasonal asymmetry

Results are published in:

Stober, G., Kuchar, A., Pokhotelov, D., Liu, H., Liu, H.-L., Schmidt, H., Jacobi, C., Baumgarten, K., Brown, P., Janches, D., Murphy, D., Kozlovsky, A., Lester, M., Belova, E., Kero, J., and Mitchell, N.: Interhemispheric differences of mesosphere–lower thermosphere winds and tides investigated from three whole-atmosphere models and meteor radar observations, Atmos. Chem. Phys., 21, 13855–13902, https://doi.org/10.5194/acp-21-13855-2021, 2021.

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