Tidal Effects in the Thermosphere

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Tides

- We know that there are tides that are caused by solar illumination and orographic features on the Earth.
- These tides propagate up from the troposphere and break somewhere in the low thermosphere.
- The question is what effect do these tides have on the thermosphere and ionosphere?
- Recent papers have shown that they can significantly affect the structure of the ionosphere at 350+ km altitude.
- What is the effect on the thermosphere?

Tests

- Run an ionosphere/thermosphere model to examine the thermospheric temperature and wind structure at 120 and 400 km.
- Conduct simulations with:
  - No tides at all
  - MSIS tides (empirically derived tides)
  - GSWM tides (also empirically derived)
    - Diurnal (migrating and non-migrating)
    - Semidiurnal (migrating and non-migrating)
  - Only Diurnal Migrating GSWM tides
- Compare results

Model

- For these simulations, we use the Global Ionosphere Thermosphere Model (GITM)
- Developed at the University of Michigan.
- Non-hydrostatic model, altitude grid, approximately 1/3 scale height resolution in the vertical. Lower boundary at 100 km.
- Block-based domain decomposition in the horizontal direction. Fully parallel. Flexible grid resolution – has been with resolutions from 20^ox10^o (lon x lat) to 2.5^ox1.25^o. Runs on a laptop and a supercomputer. Uses MPI. Written in Fortran-90. Ghostcells are used for vertical boundary conditions and message passing.
- Can run in 1D by turning nLons and nLats to 1.
- Runs on many different computers / operating systems.
- Uses a 4^{th} order Rusanov scheme with an MC limiter for advective solver.

Details

- GITM solves the Navier-Stokes equations on a sphere for the neutrals. Can modify the number of primary constituents in the main module (ModEarth, ModMars, ModTitan -> ModPlanet). For Earth, these are N_2, O_2, O, N and NO.

- Each primary constituent has an individual vertical velocity, but a bulk horizontal velocity. Bulk vertical velocity is the mass density weighted average of the individual vertical velocities. Friction terms affect the individual velocities.
  - Gradient in partial pressure, gravity (varying), ion drag, Corriolis, geometry, and friction all affect the vertical wind.

- Bulk temperature driven by solar EUV, conduction, NO and O2 radiative cooling, Joule heating, and particle heating.

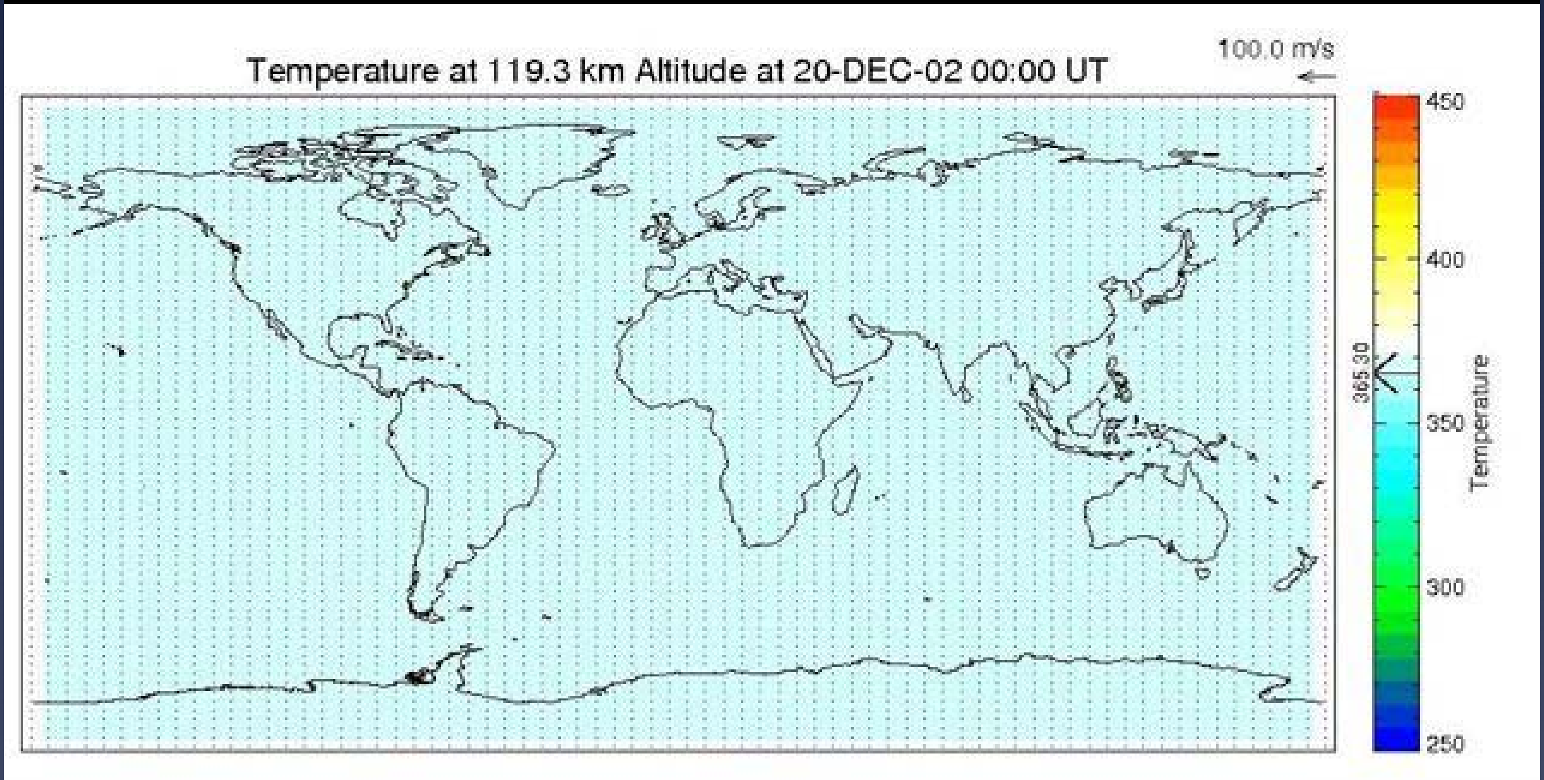
- Chemistry is done explicitly.

- Molecular and Eddy diffusion treated specifically in the vertical momentum equation instead of the continuity equation.

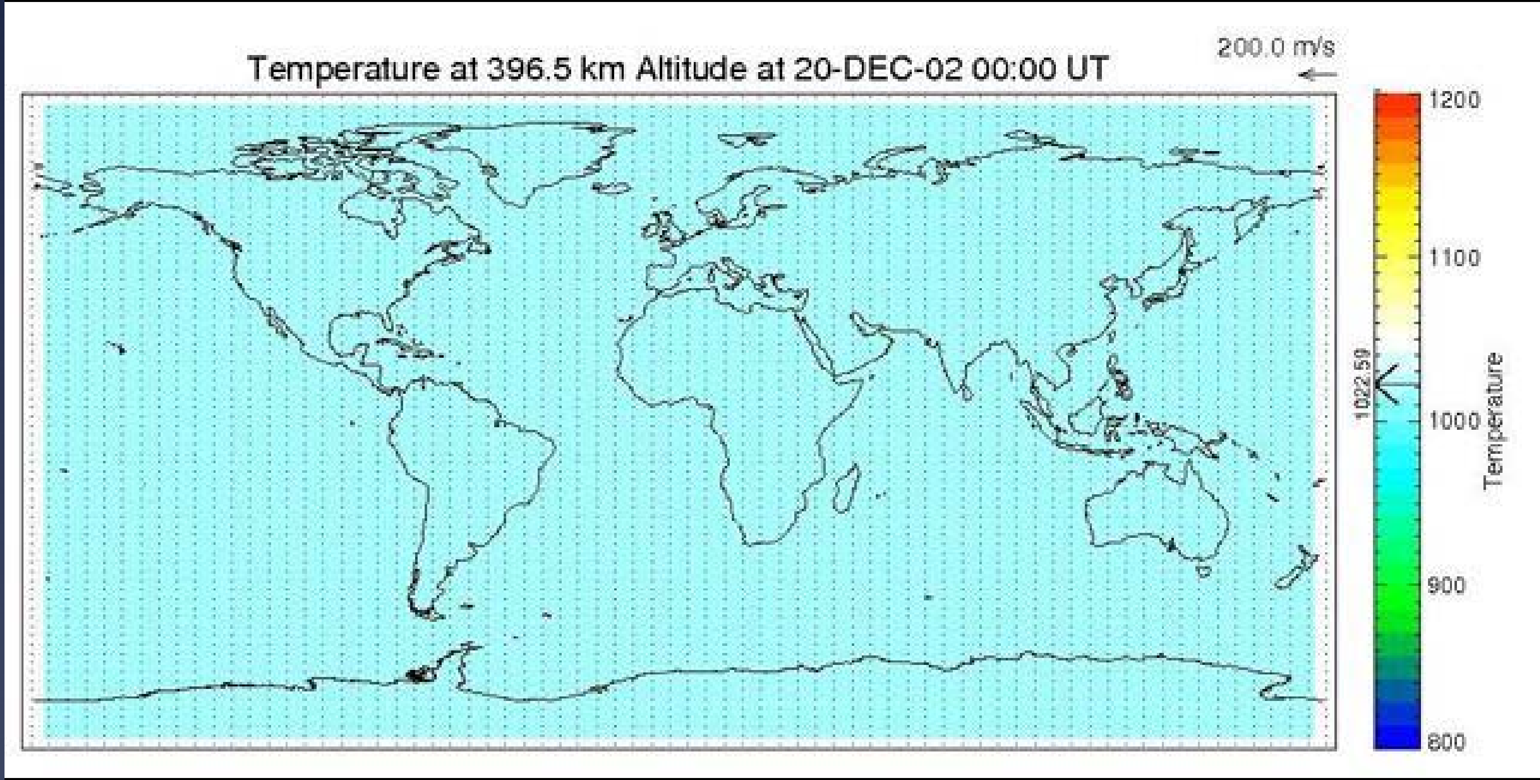
More

- Ionospheric velocities are assumed to be in stead-state.
  - Equations are different across field-lines and along field-lines.
- Electron and ion temperatures solved for.
  - Ion temperature is a combination of electron and neutral temperatures.
- Magnetic field is from IGRF of the start date.
- Electric field is from a wide variety of sources. As is the auroral precipitation pattern.
- Code is initialized with MSIS and IRI, and allowed to evolve.
- MSIS typically drives lower boundary condition on neutrals, while the ions have a continuous gradient boundary condition.

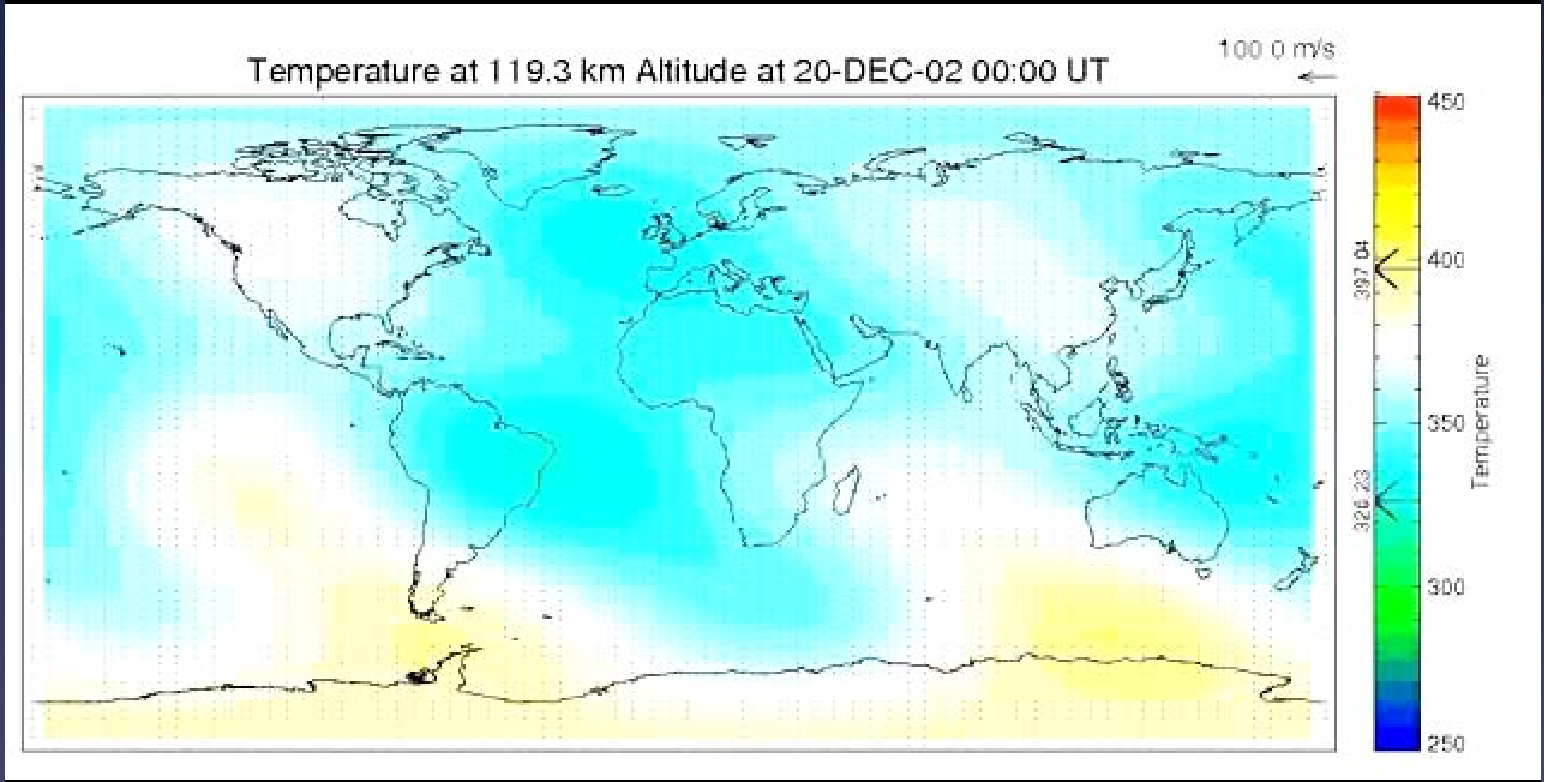
No Tides -120 km



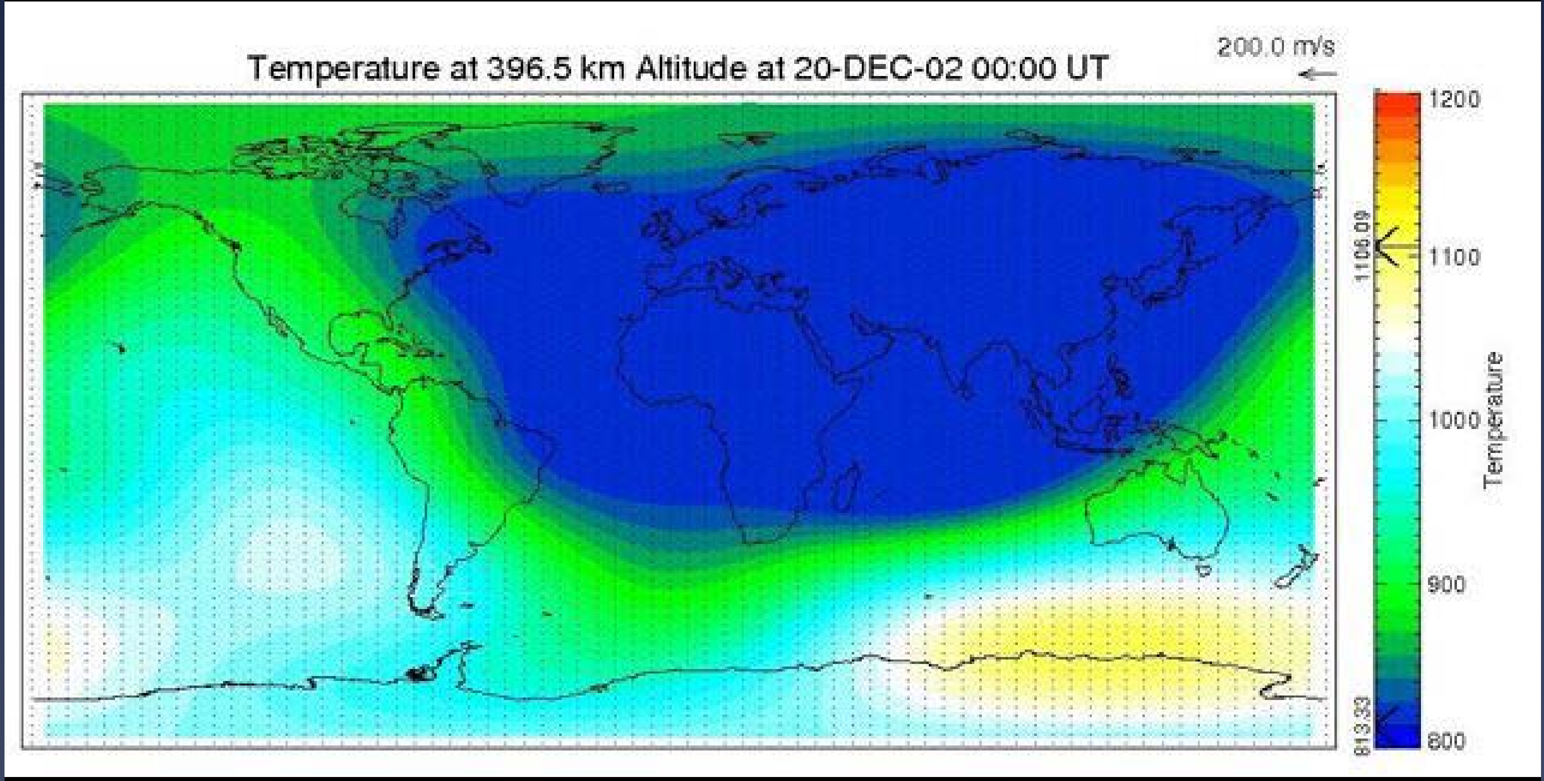
No Tides – 400 km



MSIS Tides – 120 km

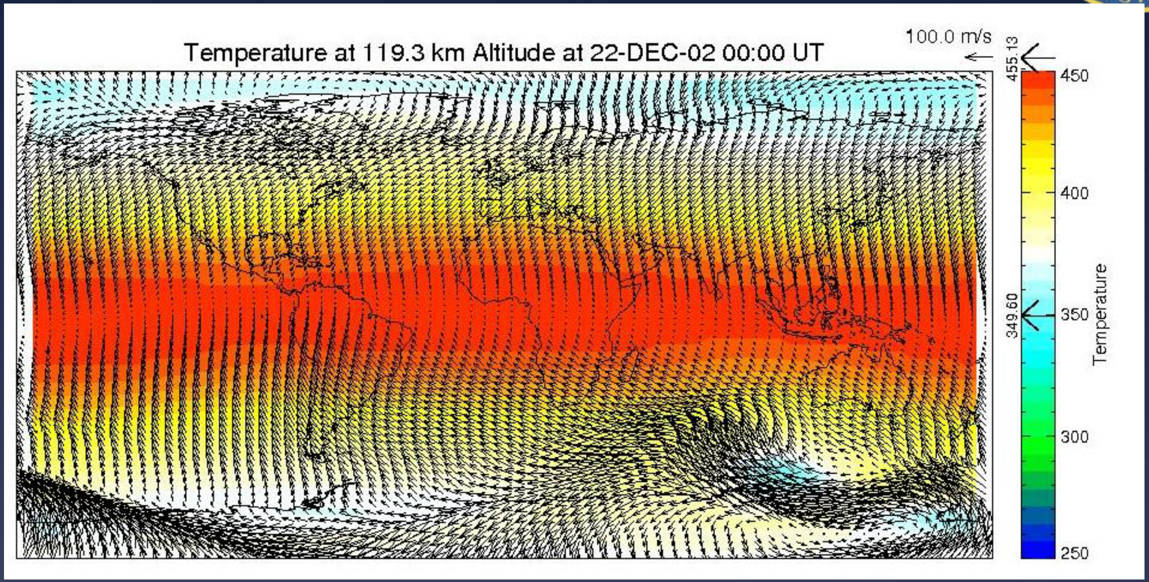


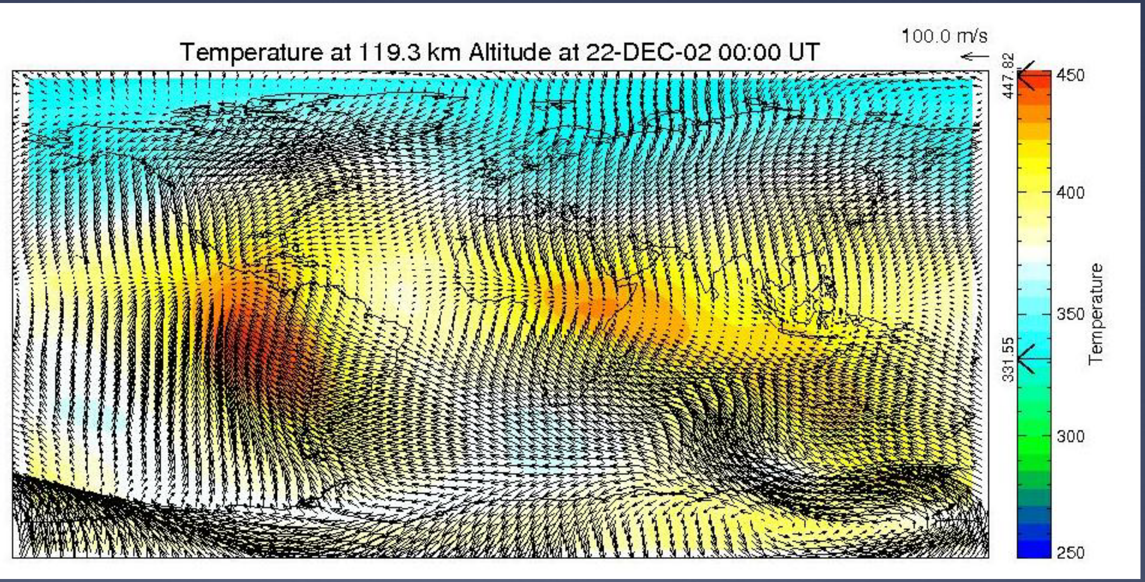
MSIS Tides – 400 km



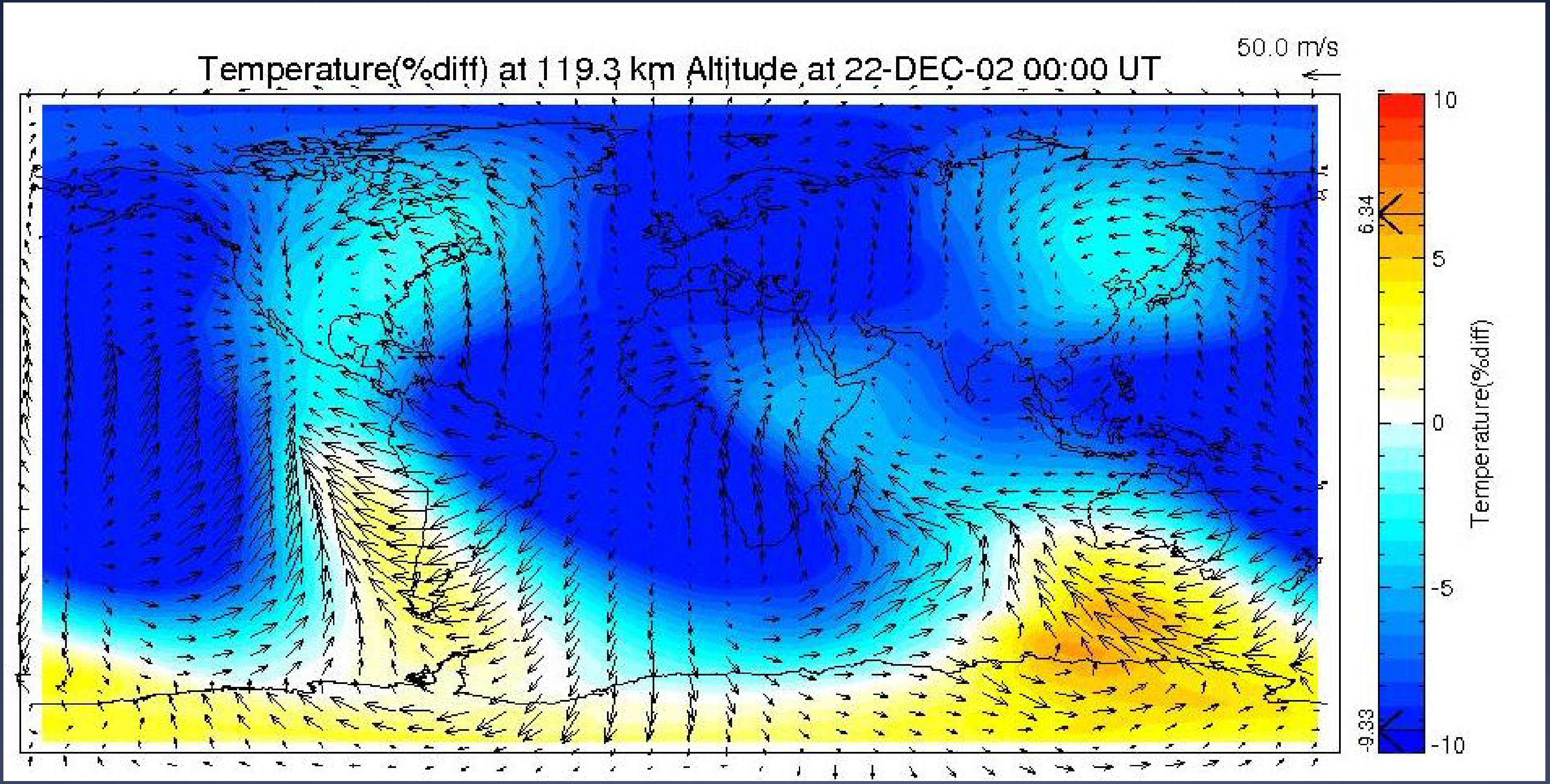
Compare 120 km

- Significant differences in both temperature structure and wind pattern



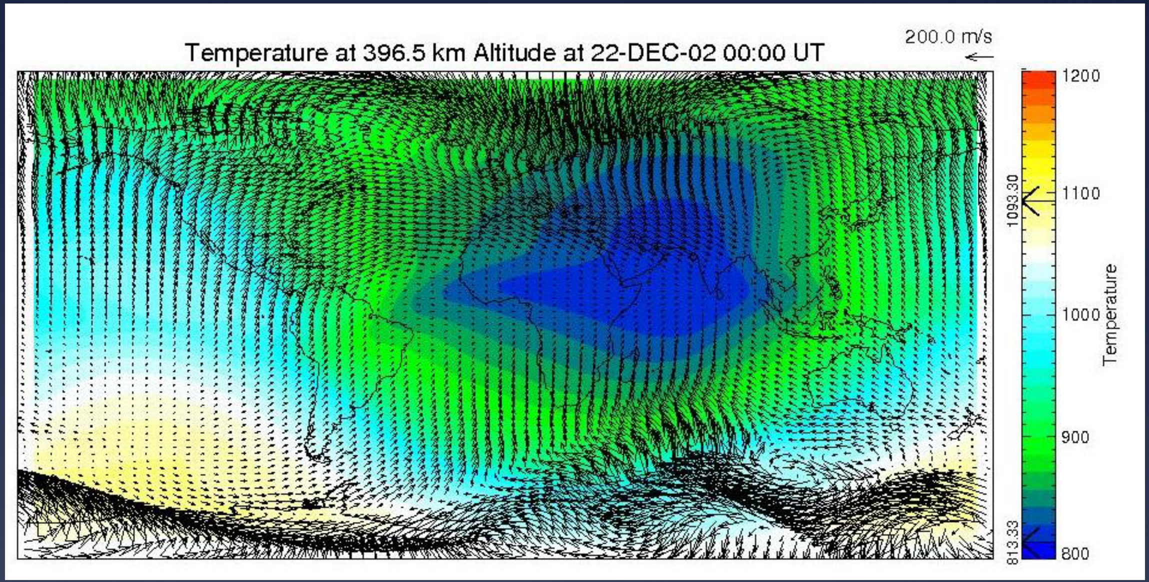


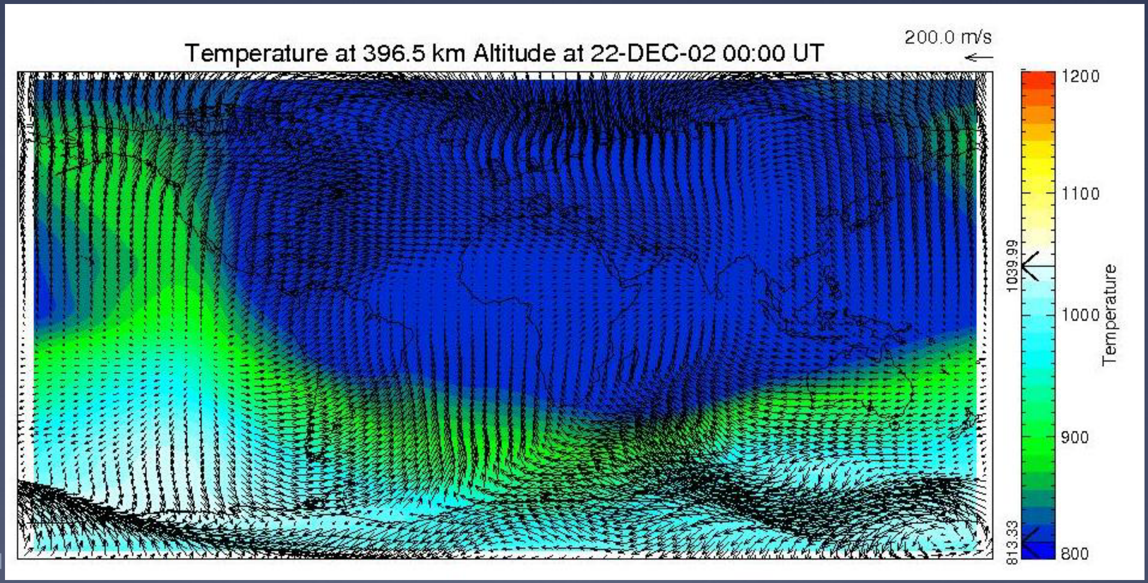
Compare 120 km



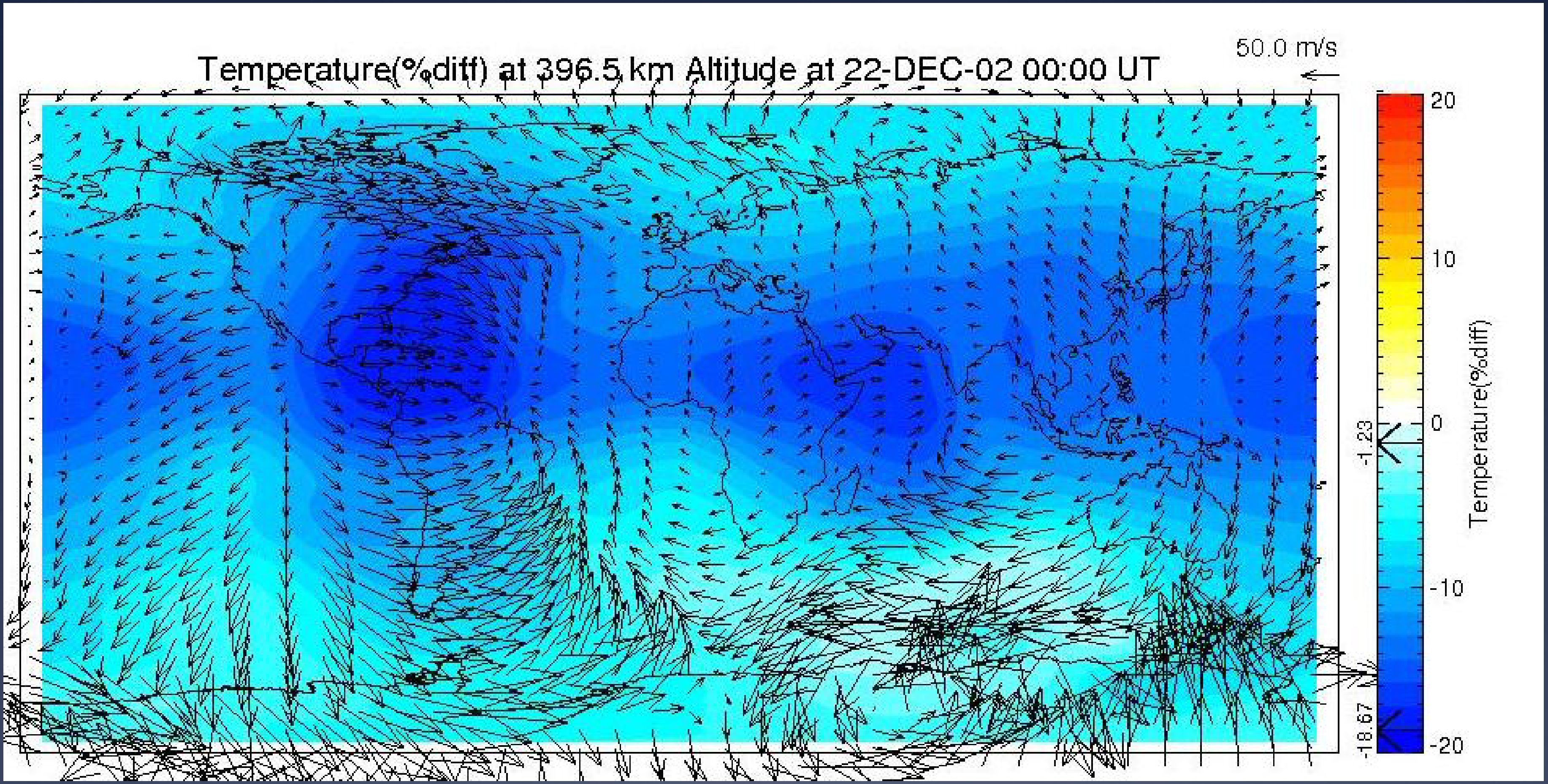
Compare at 400 km

- Very different temperature structure.

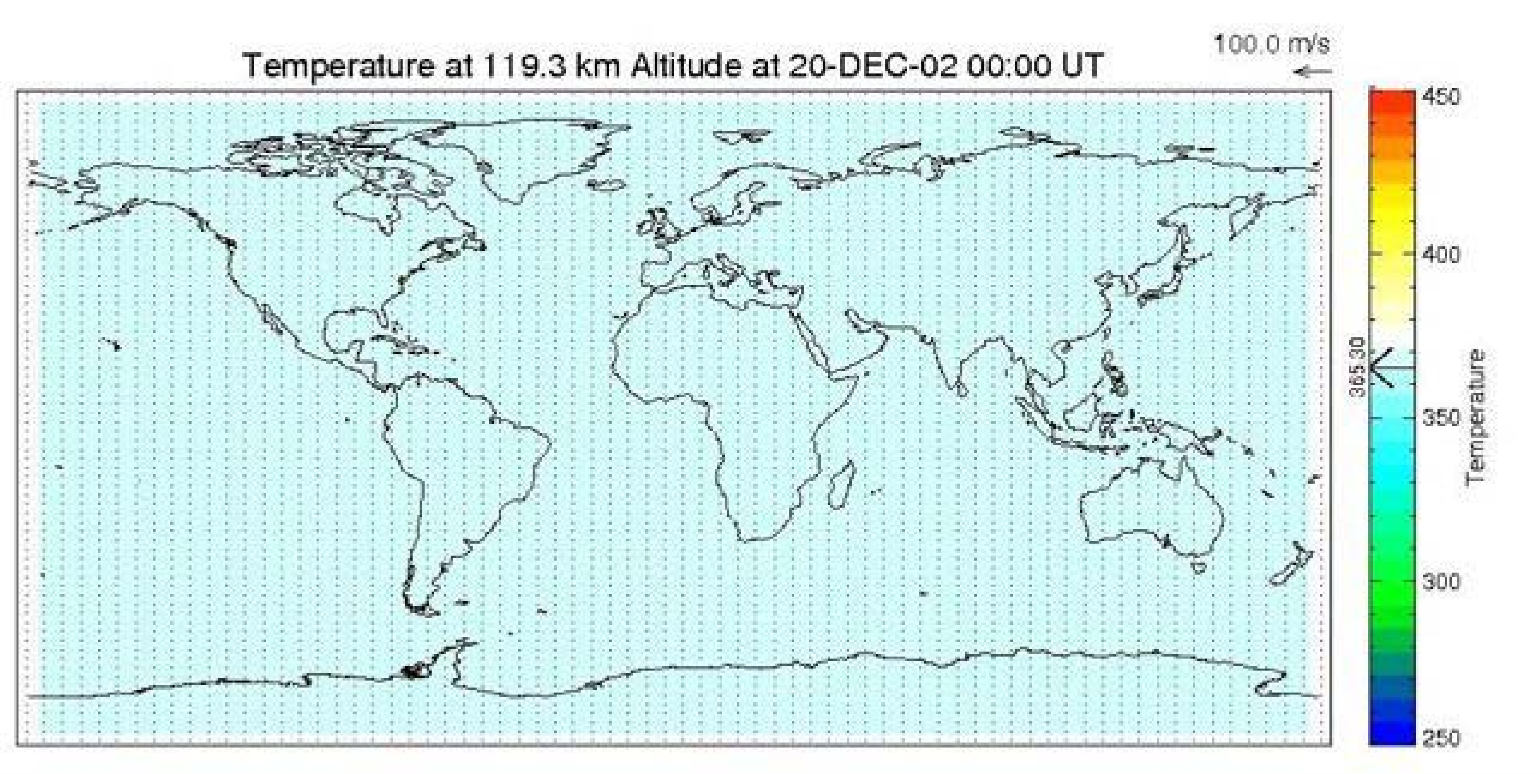




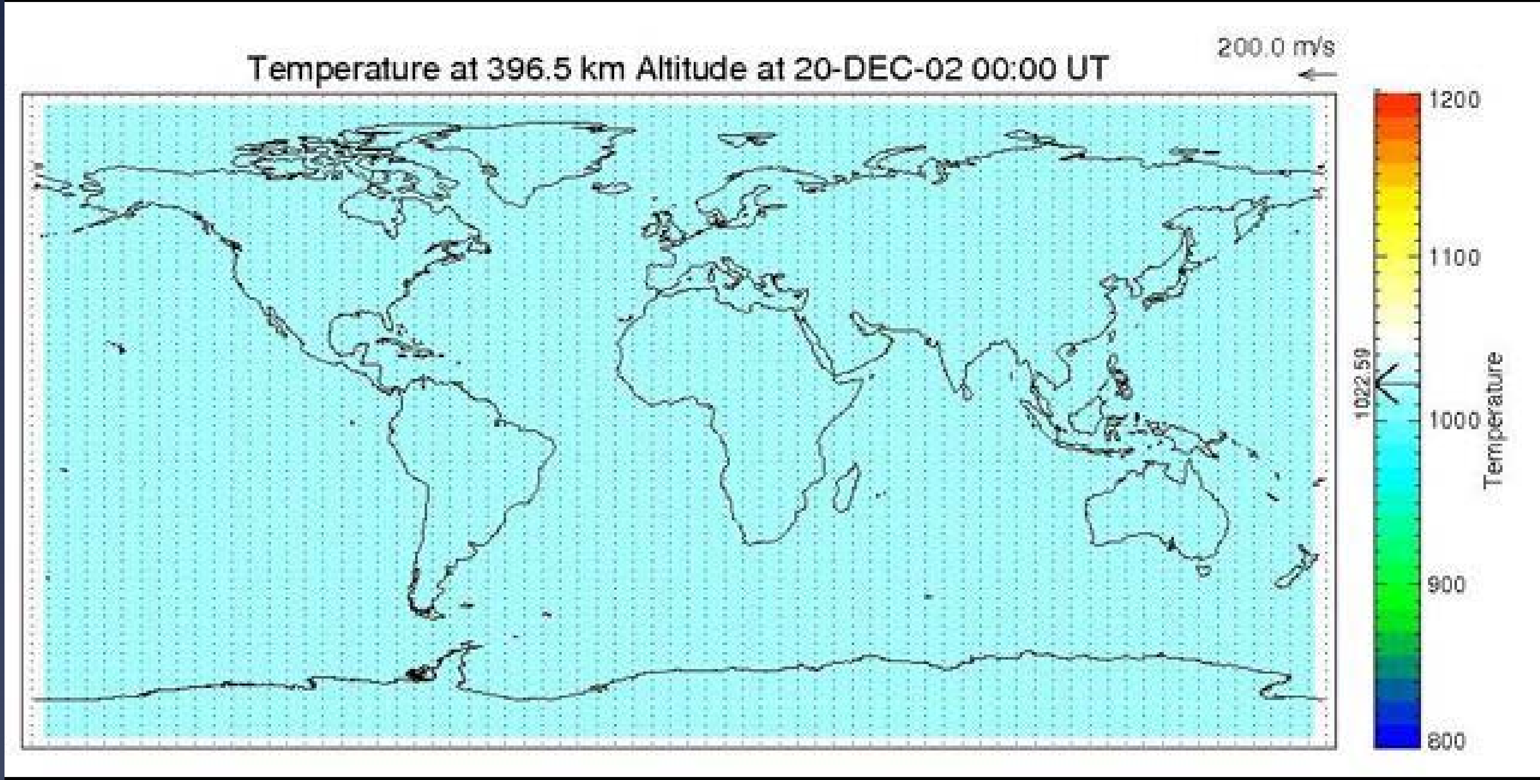
Compare at 400



GSWM – 120 km


Temperature at 119.3 km Altitude at 20-DEC-02 00:00 UT
100.0 m/s
450
400
350
300
250
365.30
Temperature

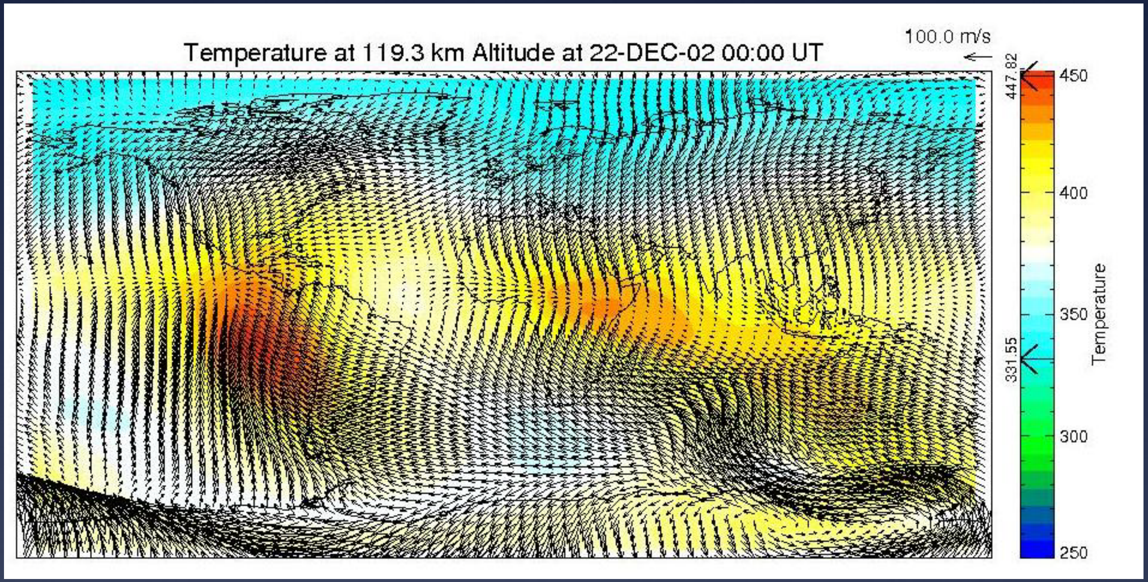
GSWM – 400 km

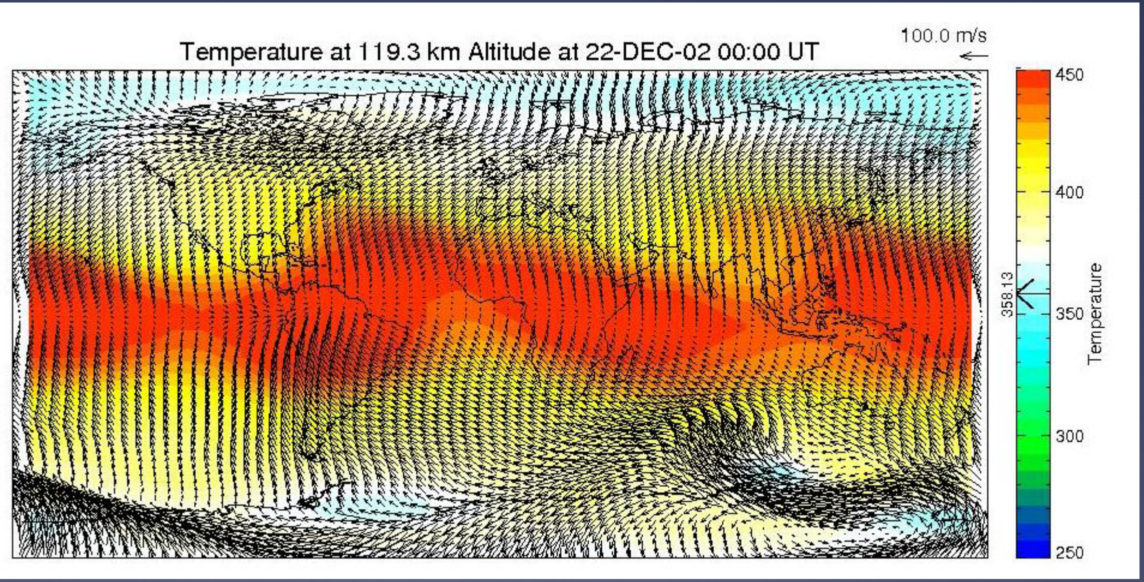


Temperature at 396.5 km Altitude at 20-DEC-02 00:00 UT
200.0 m/s
1022.59
1200
1100
1000
900
800
Temperature

MSIS – GSWM Compare 120km

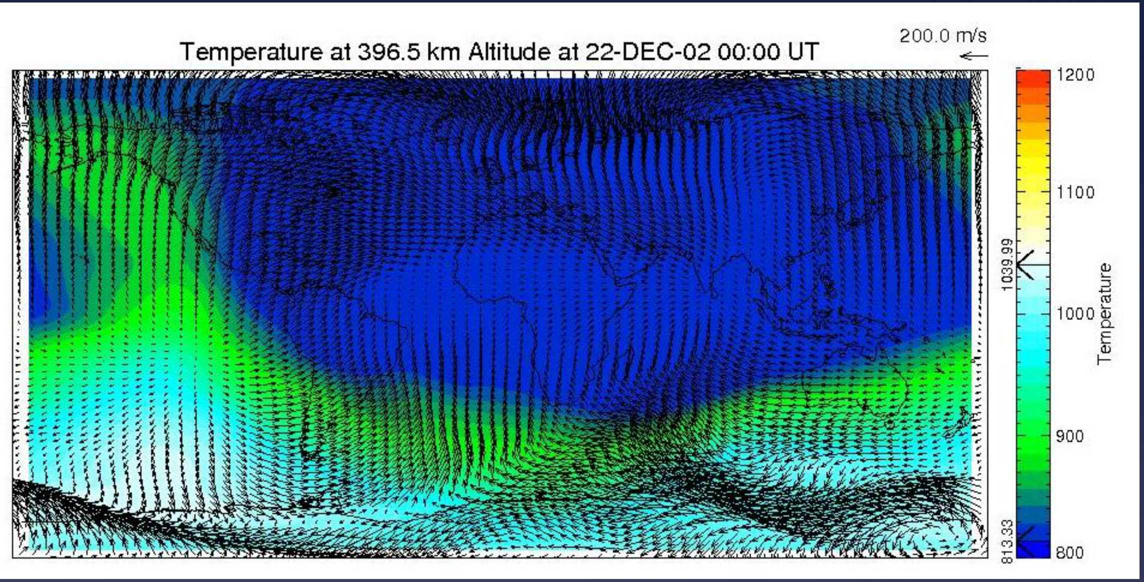
- MSIS on top.
- Significant differences here.

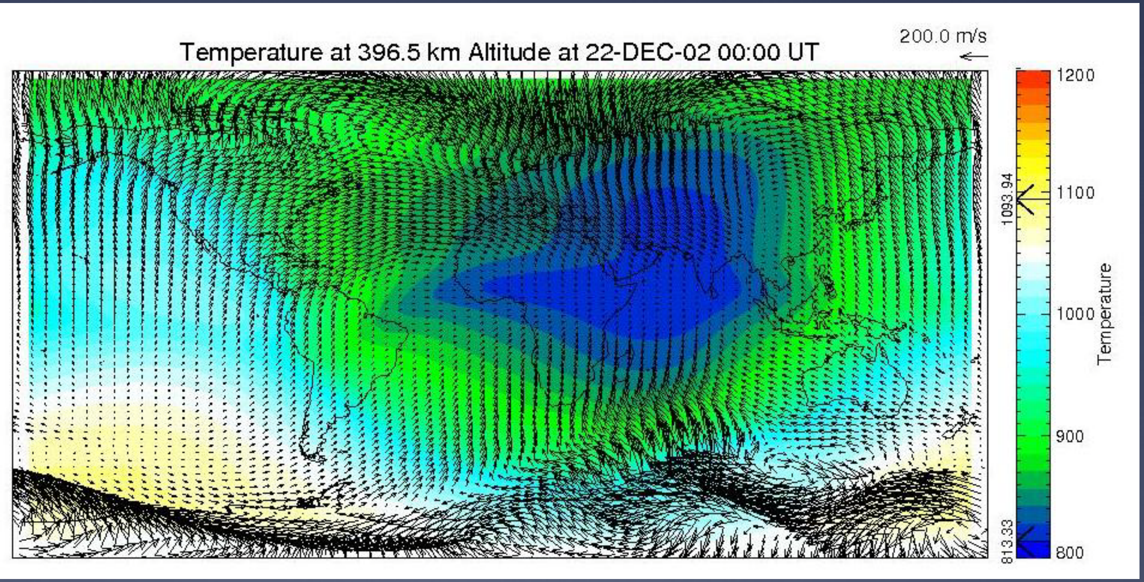




MSIS – GSWM Compare 400km

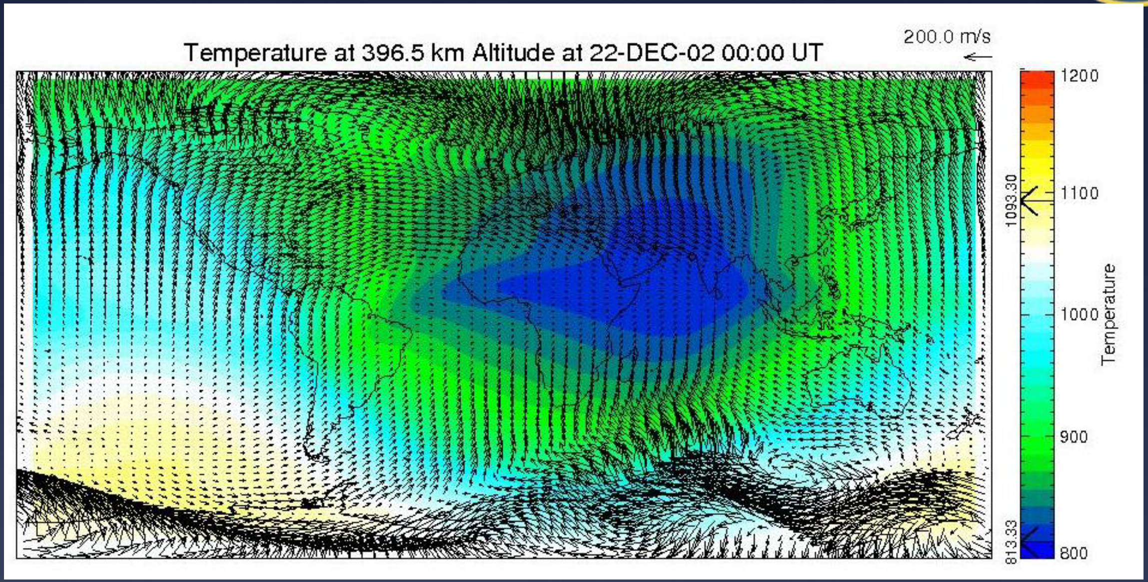
- MSIS on top.
- Once again, significant differences.
- GSWM is definitely hotter.
- GSWM actually seems more like No Tide run than MSIS run!

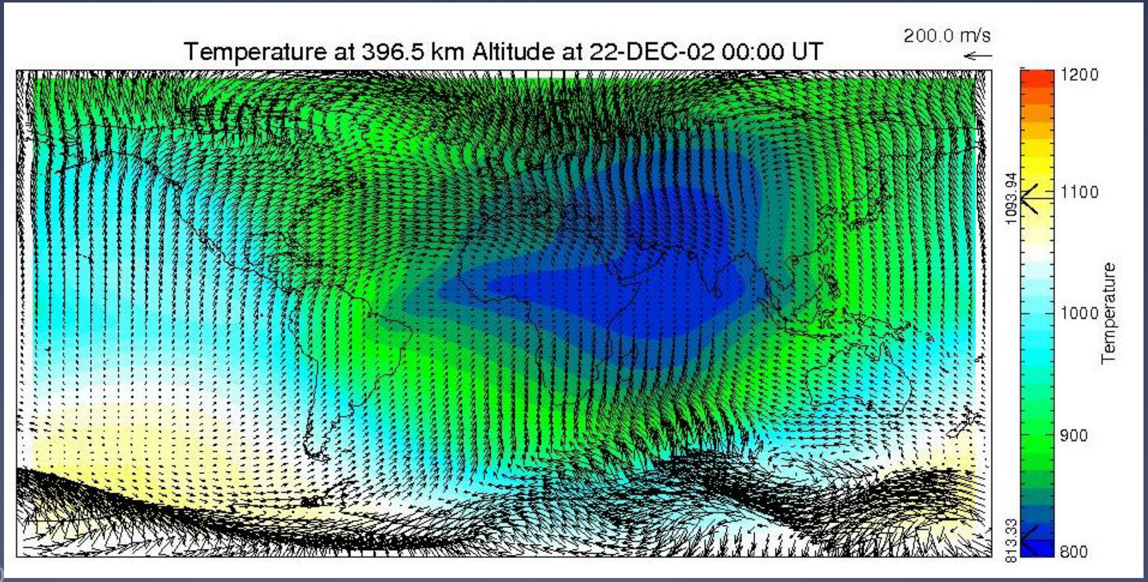




GSWM – No Tides

- No tides on top.
- Similar temperature structure (differences less than 2%, which is ~20K).
- Similar wind pattern (differences of about 20 m/s).
- Difference between MSIS and GSWM has to do with very large-scale temperature structure of the bottom boundary condition.





Summary

- At 120 km altitude, there are very clear differences between the simulations with different tidal structures on the lower boundary.
  - MSIS adds some structure.
  - GSWM adds significantly more structure when all tides are included.
  - Still, at this altitude, there is clear driving by the interaction with the magnetic field. Which is dominant?
- At 400 km altitude, there is less (percentage) influence of the tides on the temperature and wind structure.
  - Mean temperature dominated in the simulations we did.
  - Need to do closer analysis on perturbations.
- Need to study effects on ionosphere.
- Should probably talk to Maura and Astrid…