Using WACCM to drive a Global Ionosphere Thermosphere Model

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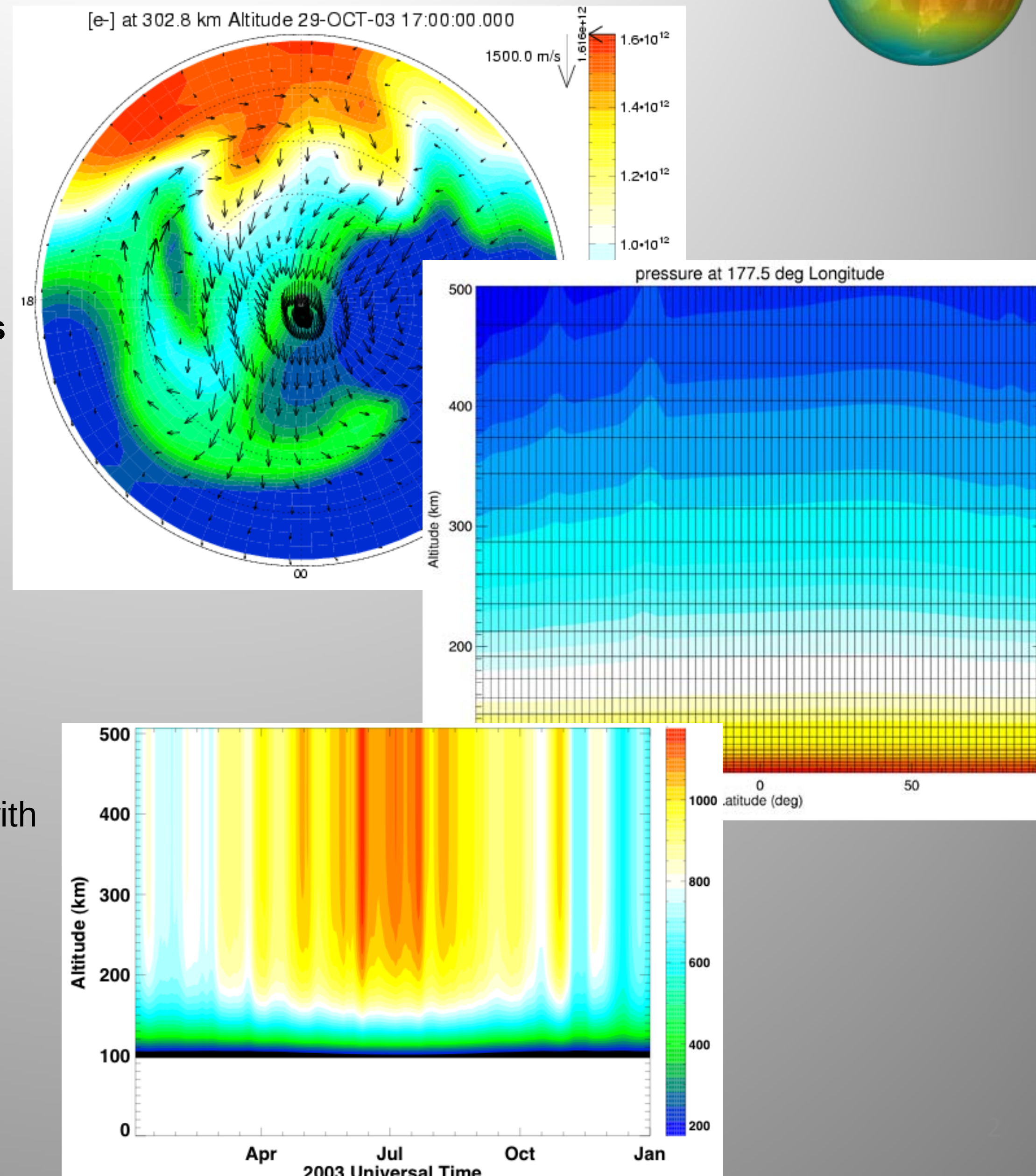
Global Ionosphere-Thermosphere Model

GITM solves for:

- **6 Neutral & 5 Ion Species**
- **Neutral winds**
- **Ion and Electron Velocities**
- **Neutral, Ion and Electron Temperatures**



GITM Features:

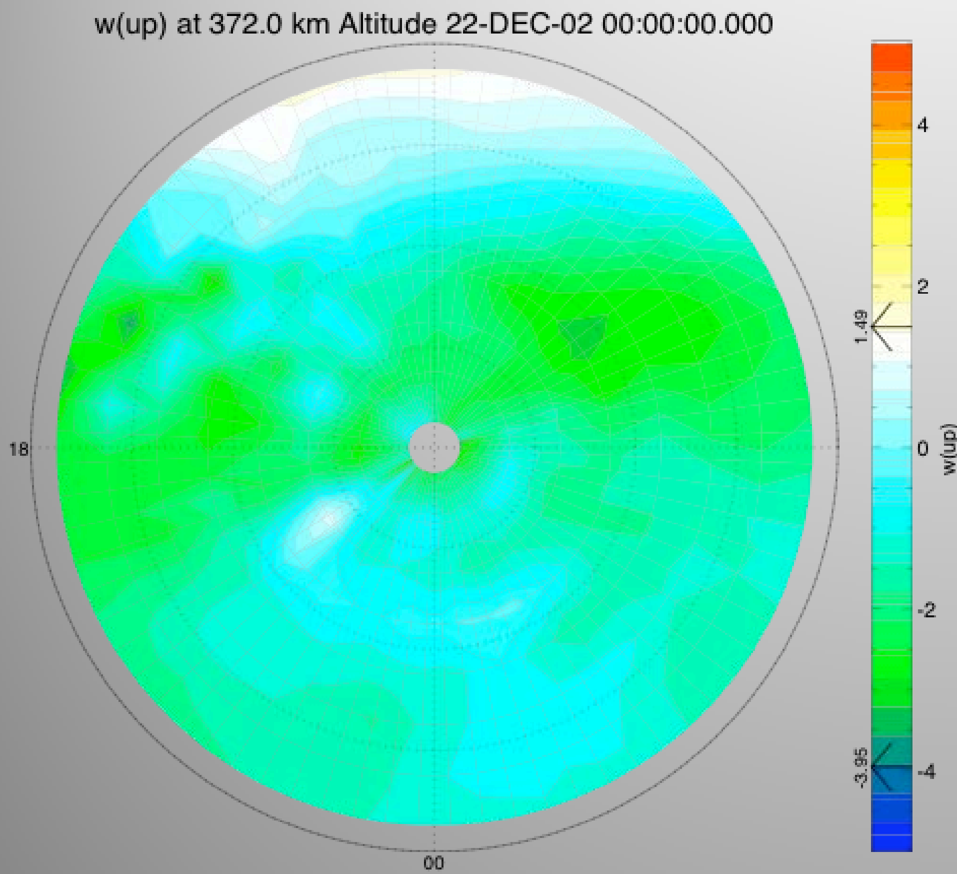
- ✓ Solves in Altitude coordinates
- ✓ Can have non-hydrostatic solution
  - ✓Coriolis
  - ✓Vertical Ion Drag
  - ✓Non-constant Gravity
  - ✓Massive heating in auroral zone
- ✓ Runs in 1D and 3D
- ✓ Vertical winds for each major species with friction coefficients
- ✓ Non-steady state explicit chemistry
- ✓ Flexible grid resolution - fully parallel
- ✓ Variety of high-latitude and Solar EUV drivers
- ✓ Fly satellites through model

GITM - 2

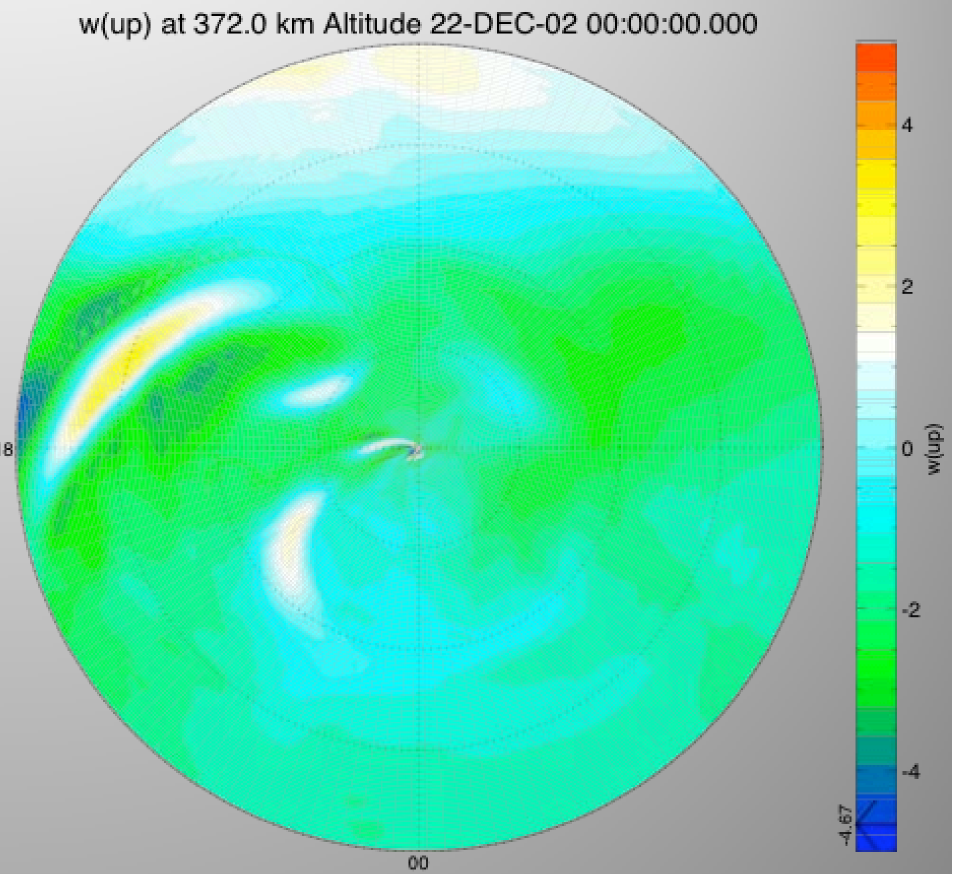
- Developed at the University of Michigan.
- First paper published 2006 (Ridley, Deng and Toth - JASTP).
- Non-hydrostatic model, altitude grid, approximately 1/3 scale height resolution in the vertical. Lower boundary at 100 km.
- Block-based domain decomposition in the horizontal direction. Fully parallel. Flexible grid resolution – has been with resolutions from 20^{o}x10^{o} (lon x lat) to 2.5^{o}x0.3125^{o}. Runs on a laptop and a supercomputer (Have run on up to 256 PEs). 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.
  - Anything that the SWMF can run on.
- Uses a 4^{th} order Rusanov scheme with an MC limiter for advective solver. Does vertical advection, then horizontal, then add sources.

Resolution

5 x 5 degree resolution



2.5 x 0.3125 degree resolution

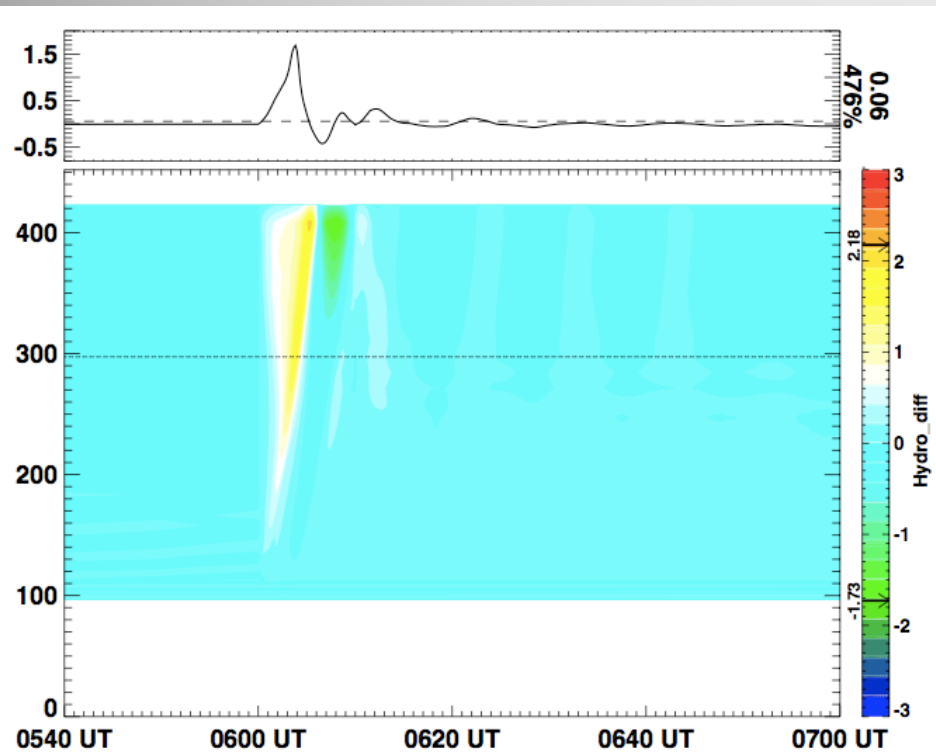


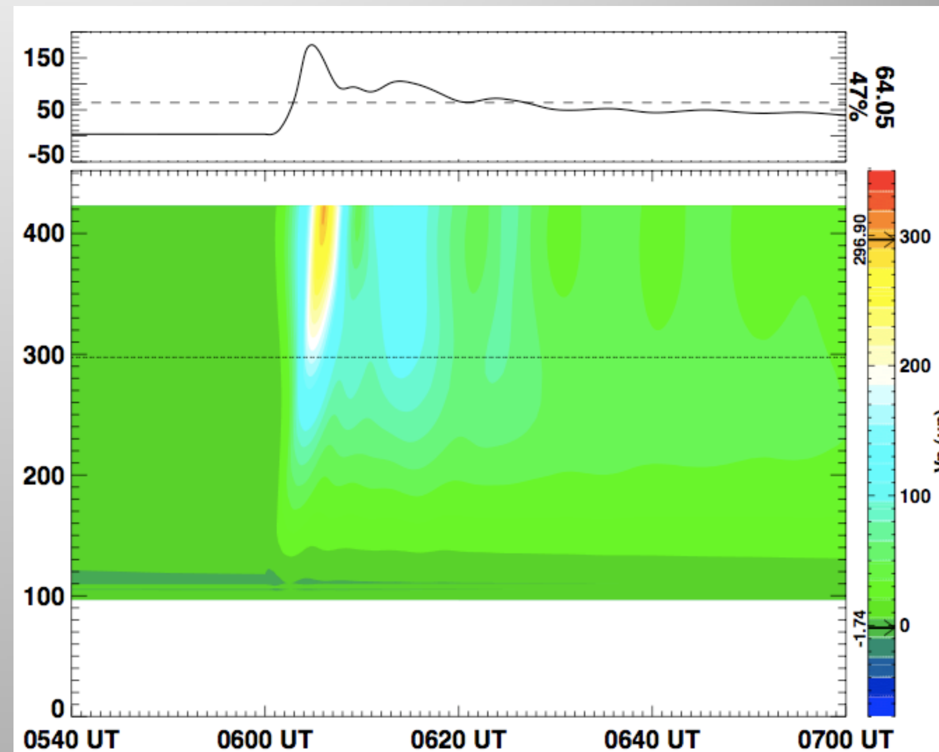
2 x 16 times the resolution!

GITM - 3

- GITM solves the Navier-Stokes equations on a sphere (with lots of source terms) 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. There are no assumptions on steady-state. Subcyling is used to capture time-scales down to about 0.01 seconds.
- Molecular and Eddy diffusion treated specifically in the vertical momentum equation instead of the continuity equation.

Nonhydrostatic





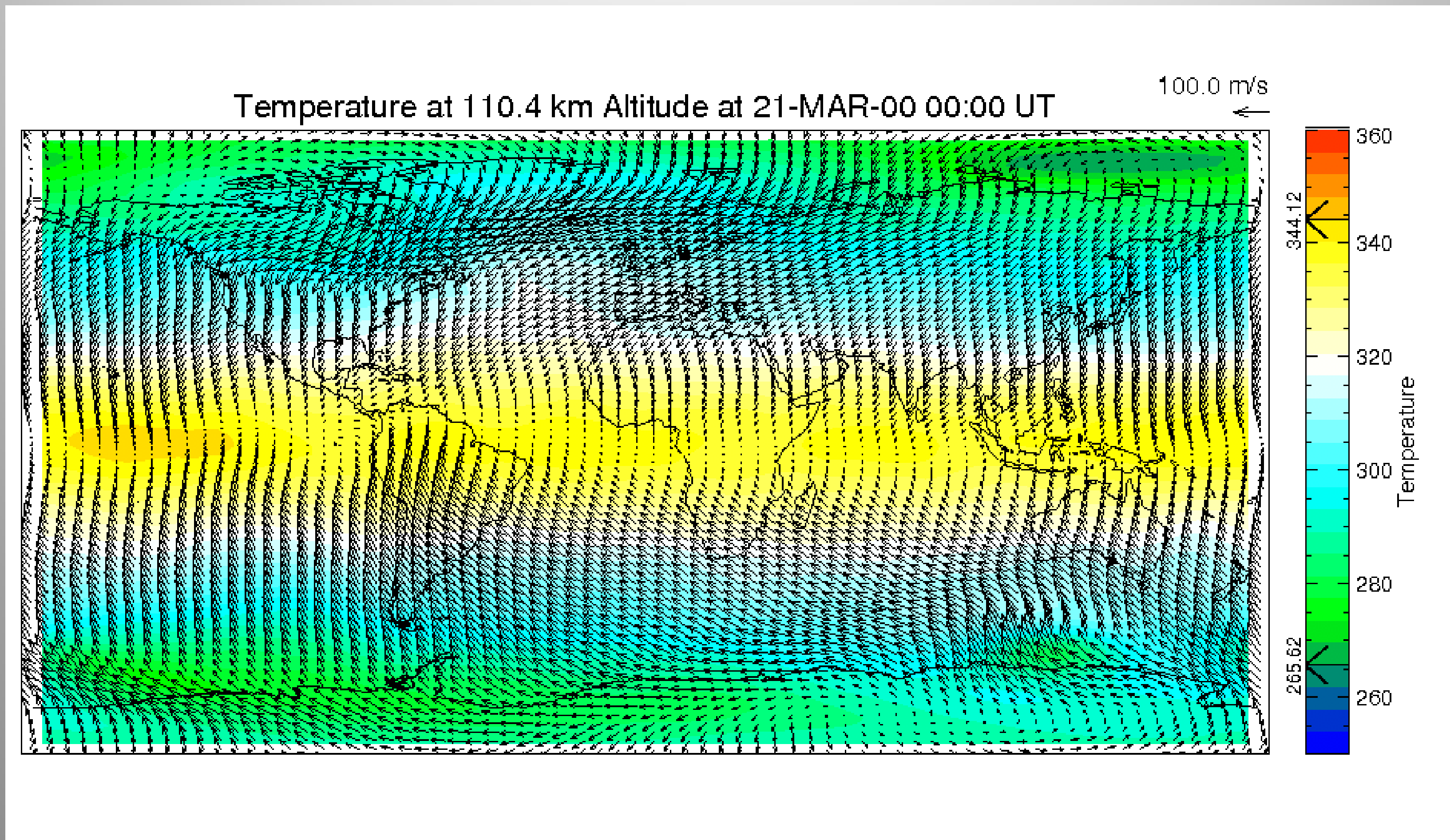
Coupling from WACCM

- Dan Marsh provided monthly tide file
  - Mean, Diurnal and Semi-Diurnal components
  - Temperature, Zonal and Meridianal Flows
  - Other components included, but not coupled yet.
  - March 2000
  - Mean heights of the pressure levels

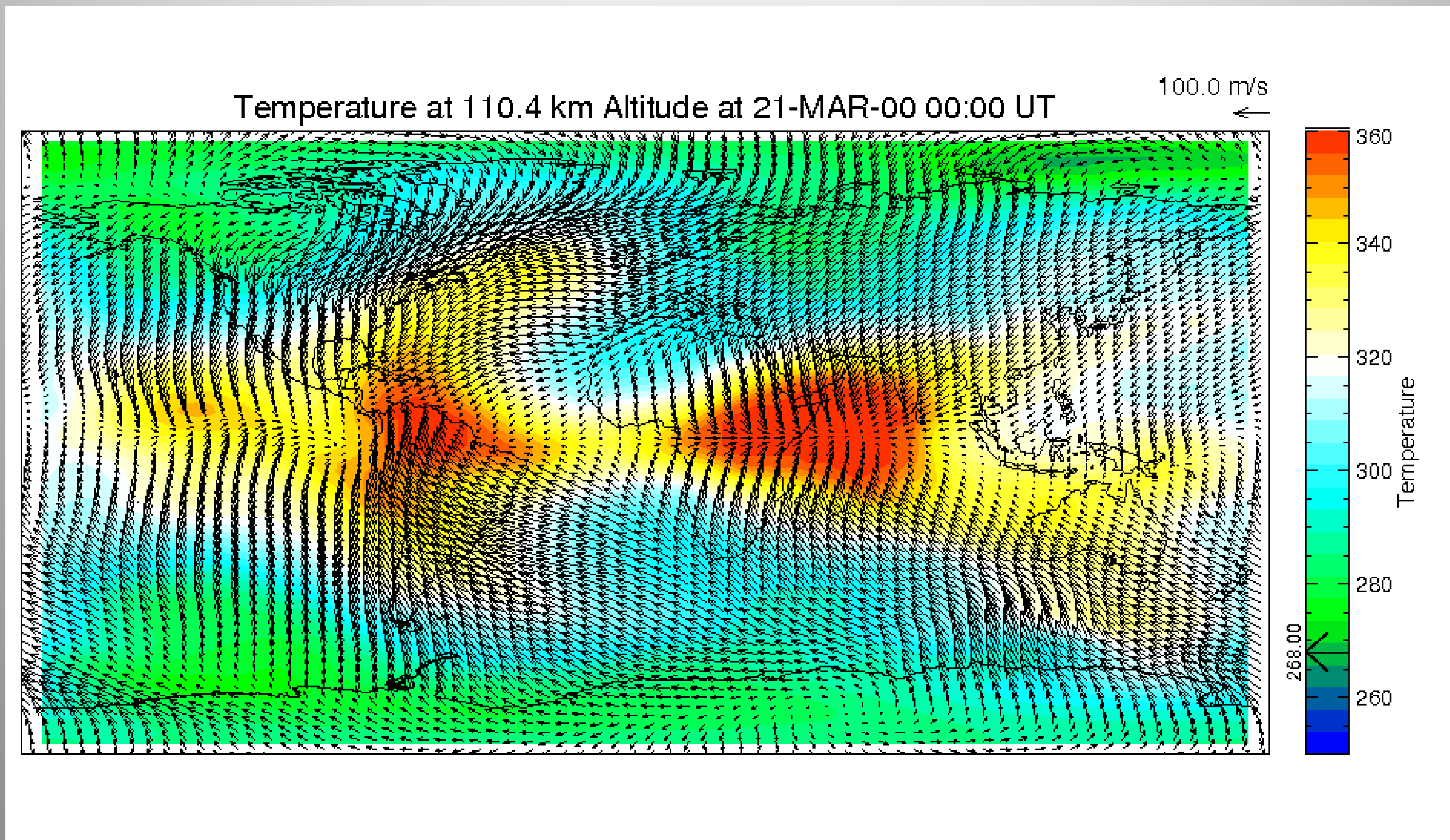
Coupling from WACCM - 2

- Take netCDF file and extract important fields at altitudes close to GITM's lower boundary.
- Read file into GITM, linearly interpolate in latitude, longitude and altitude to GITM ghostcells (about 96 and 98 km altitude).
- GITM uses ghostcells to drive GITM simulation.
- First simulation uses ONLY mean fields.
- Second simulation uses means and tidal components.

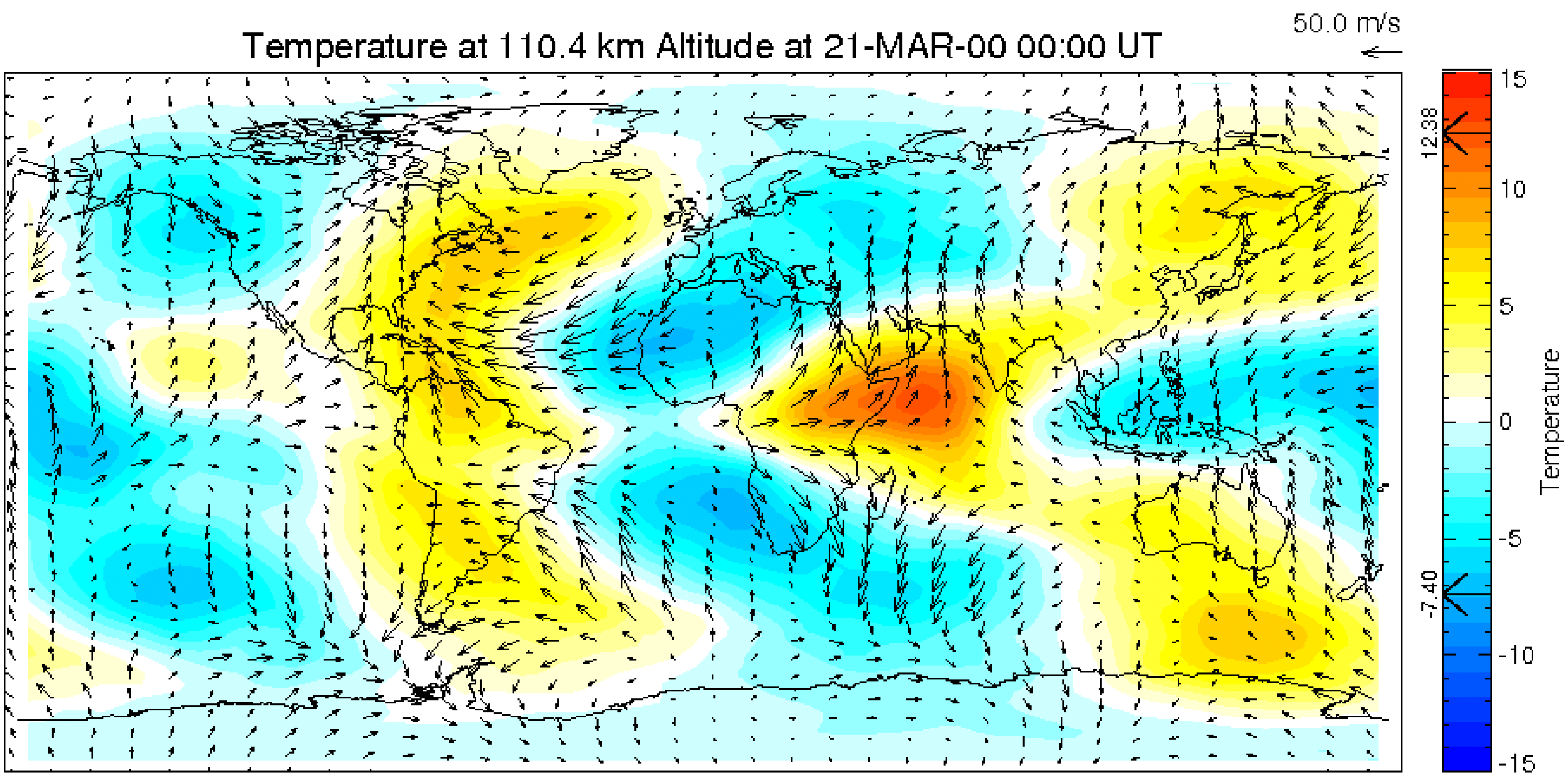
No Tides (Temperature @ 110 km)



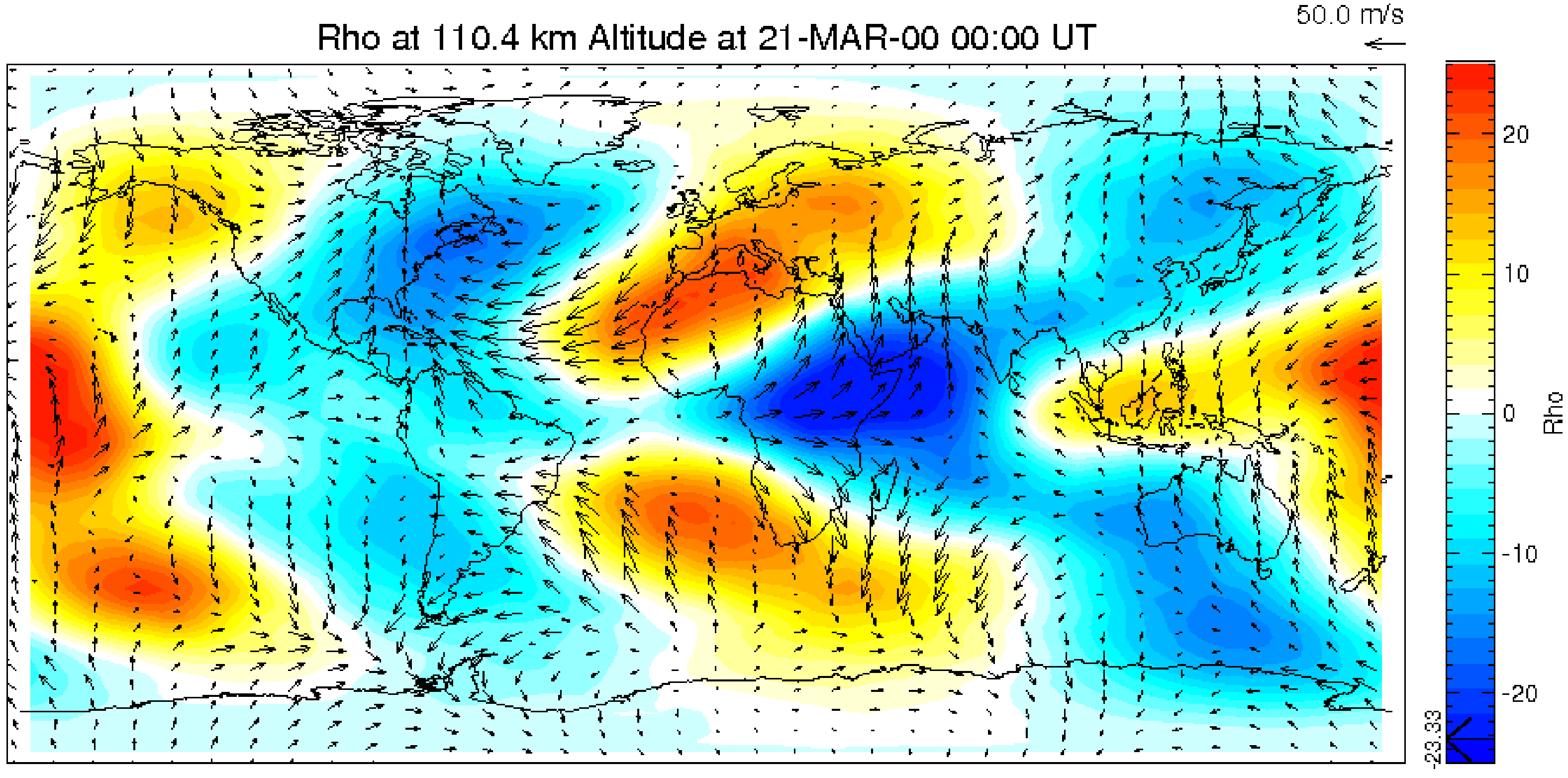
Tides (Temperature @ 110 km)



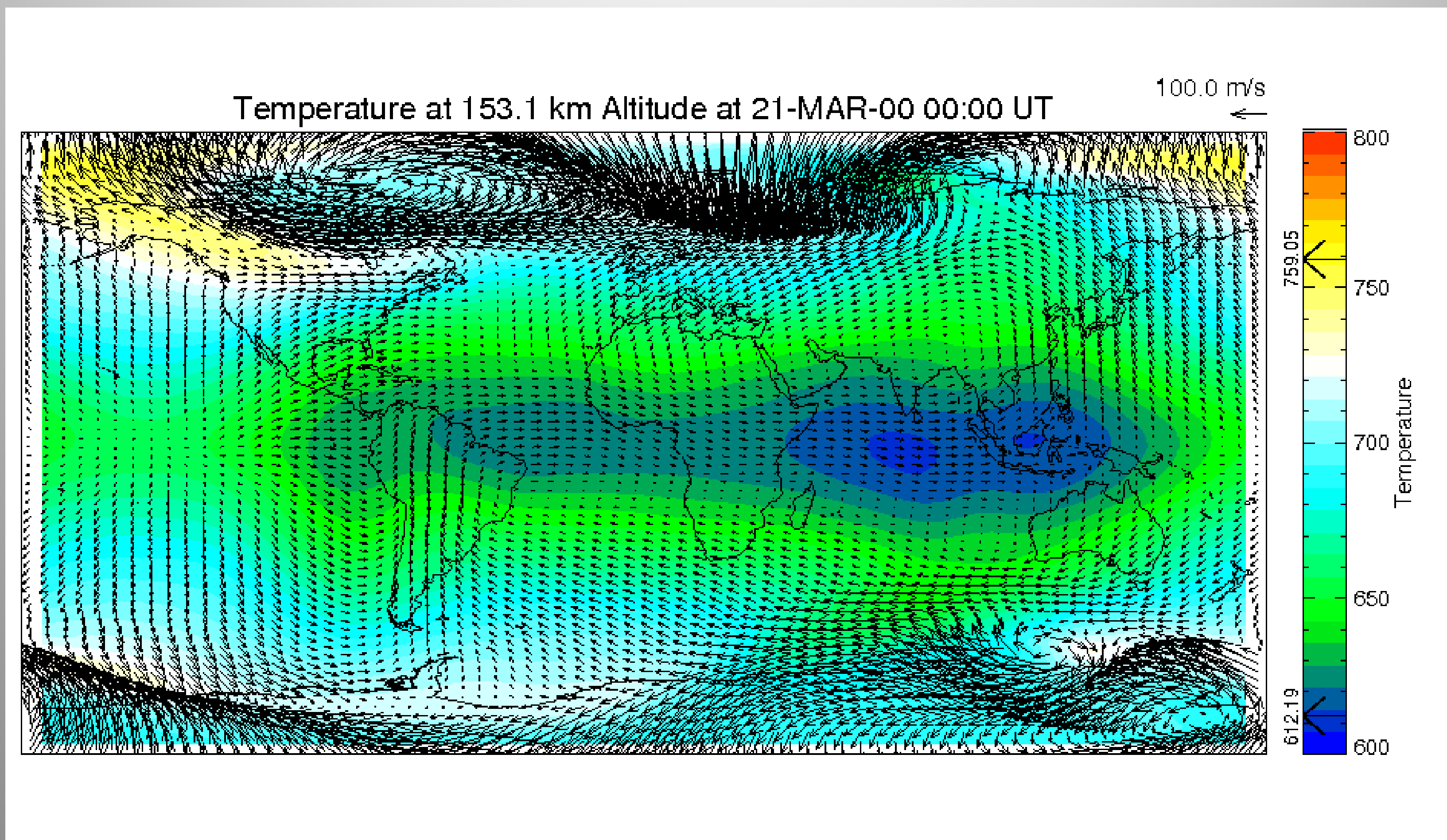
Difference in Temperature @ 110 km



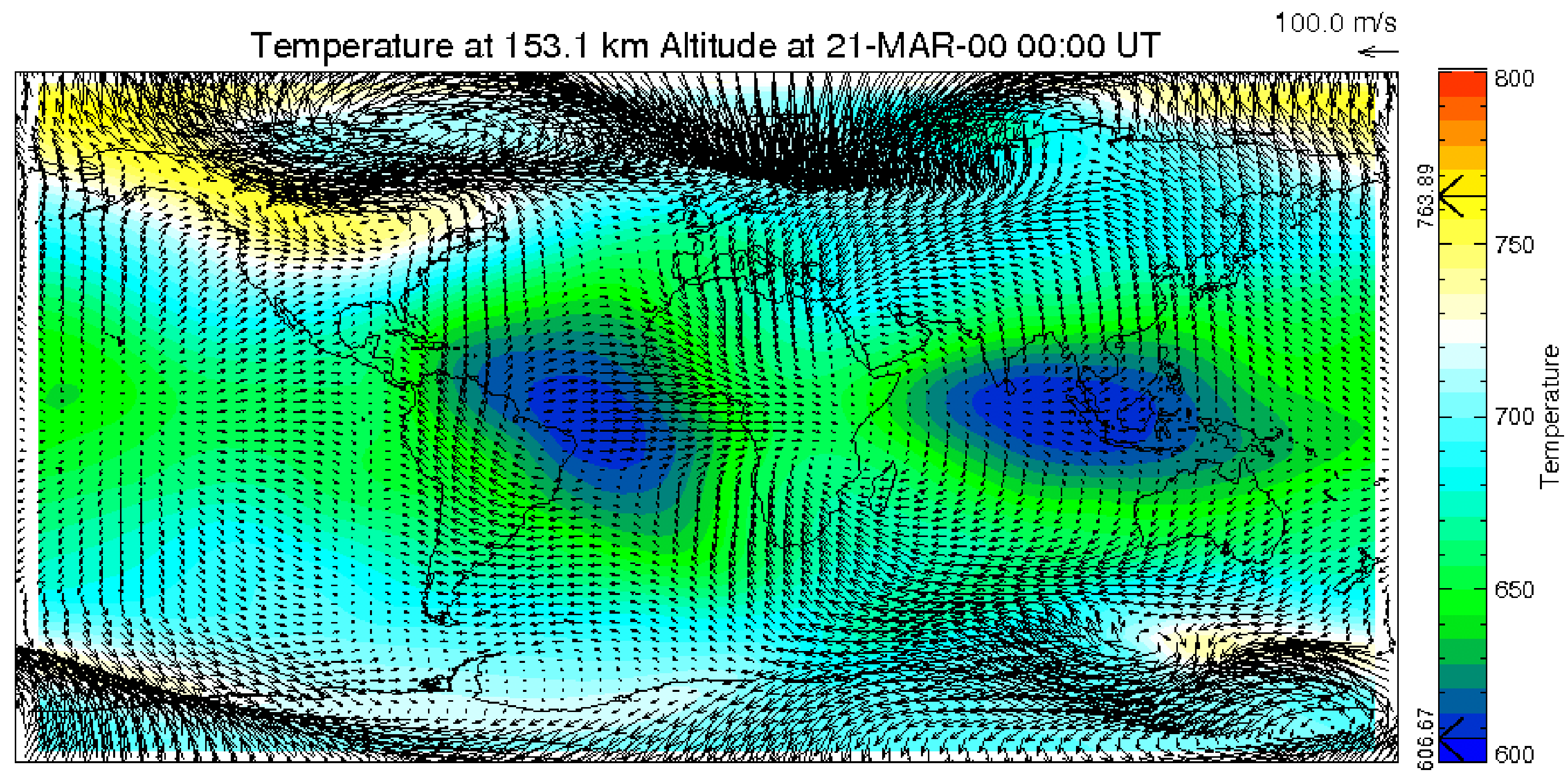
Difference in Rho at 110 km



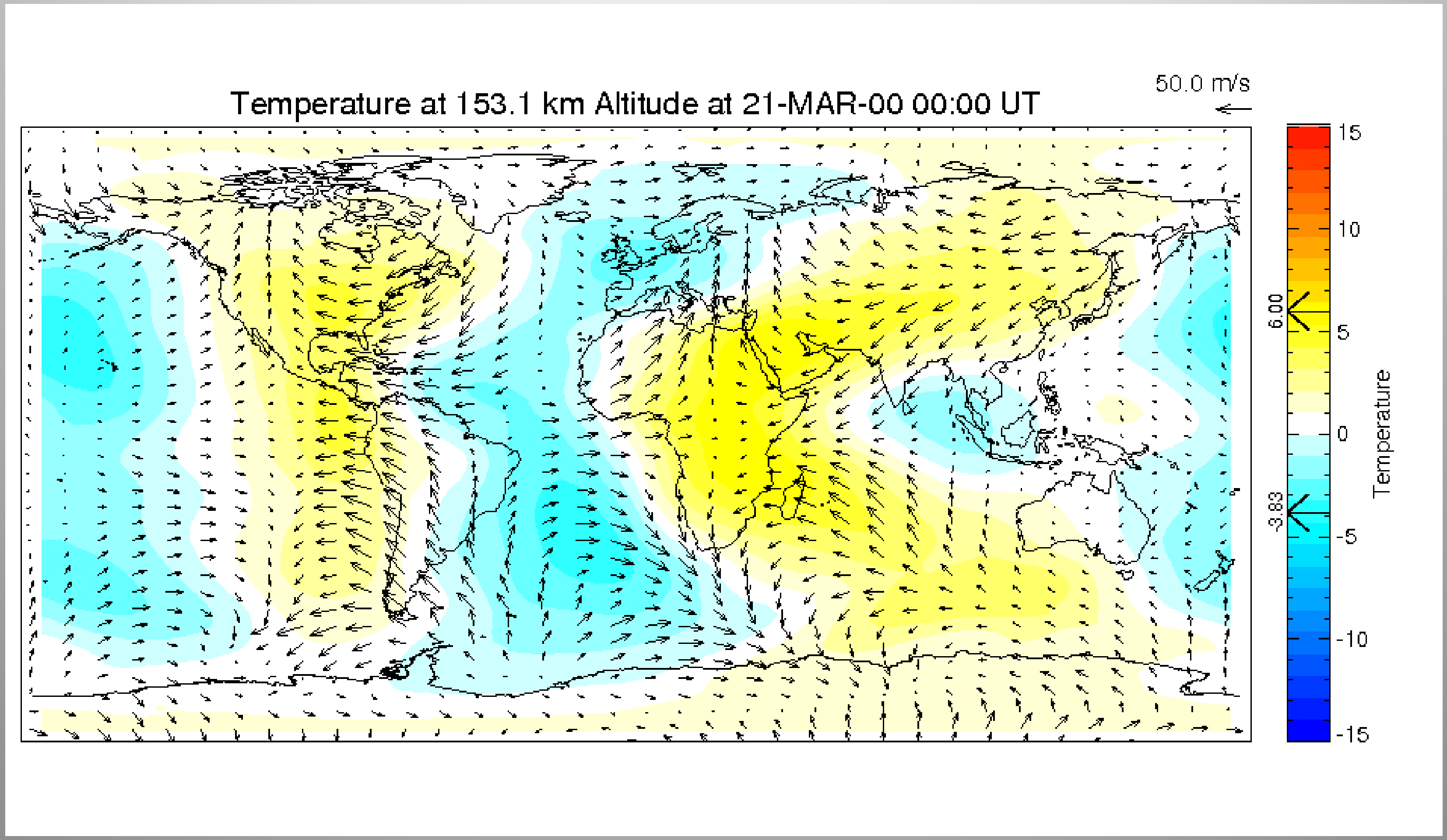
No Tides (Temperature @ 150 km)



Tides (Temperature @ 150 km)



Difference in Temperature @ 150 km



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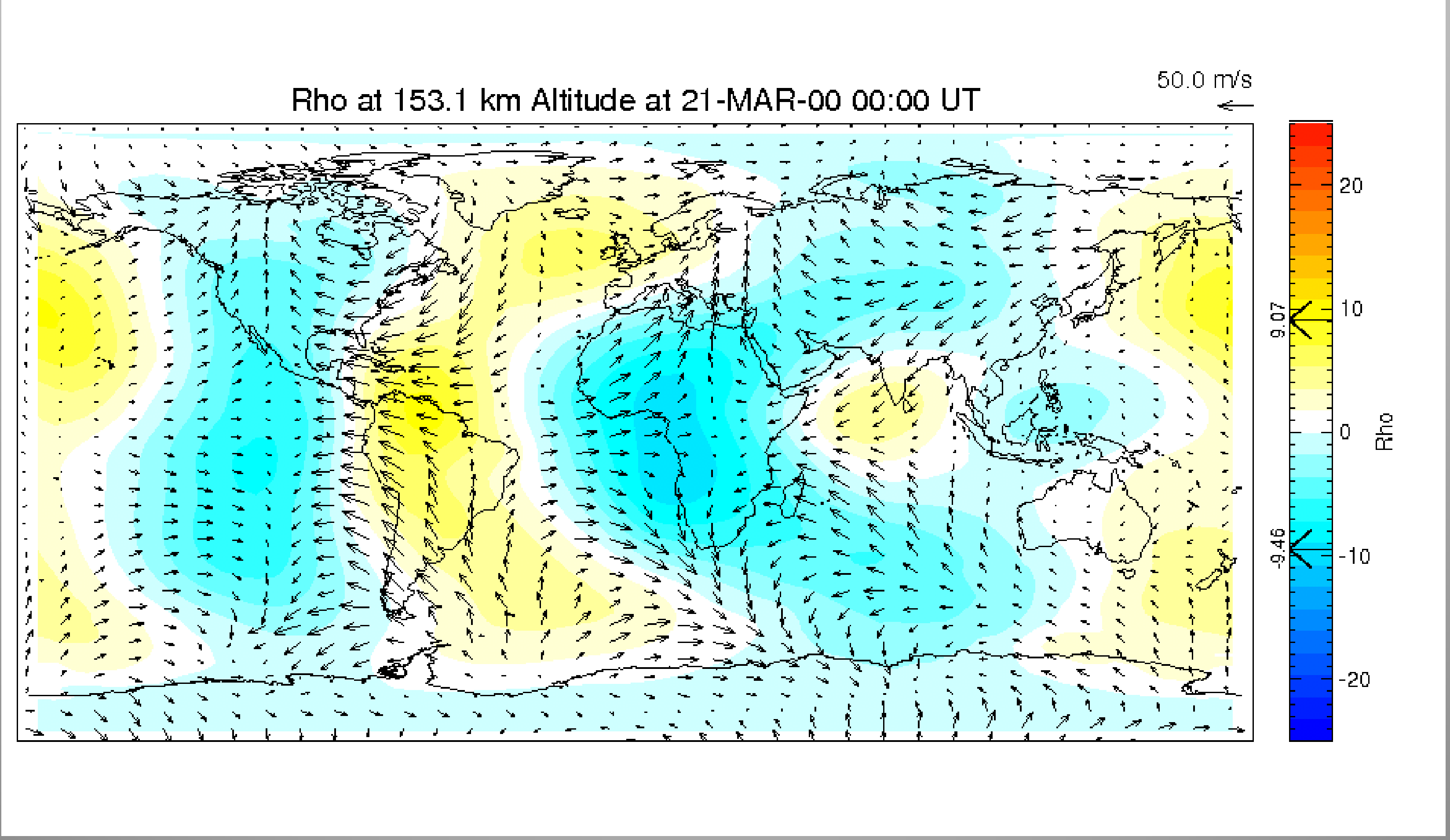
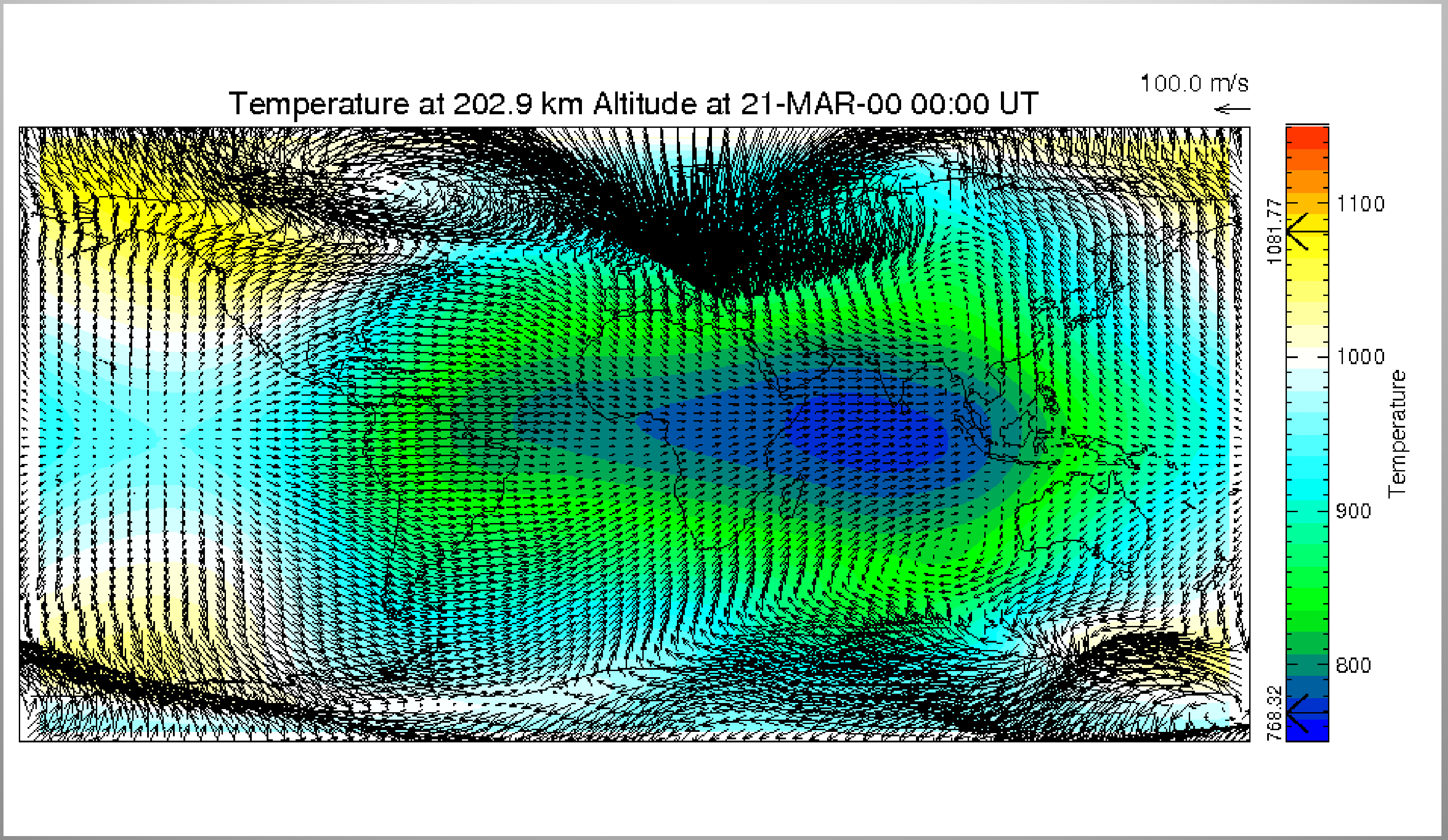
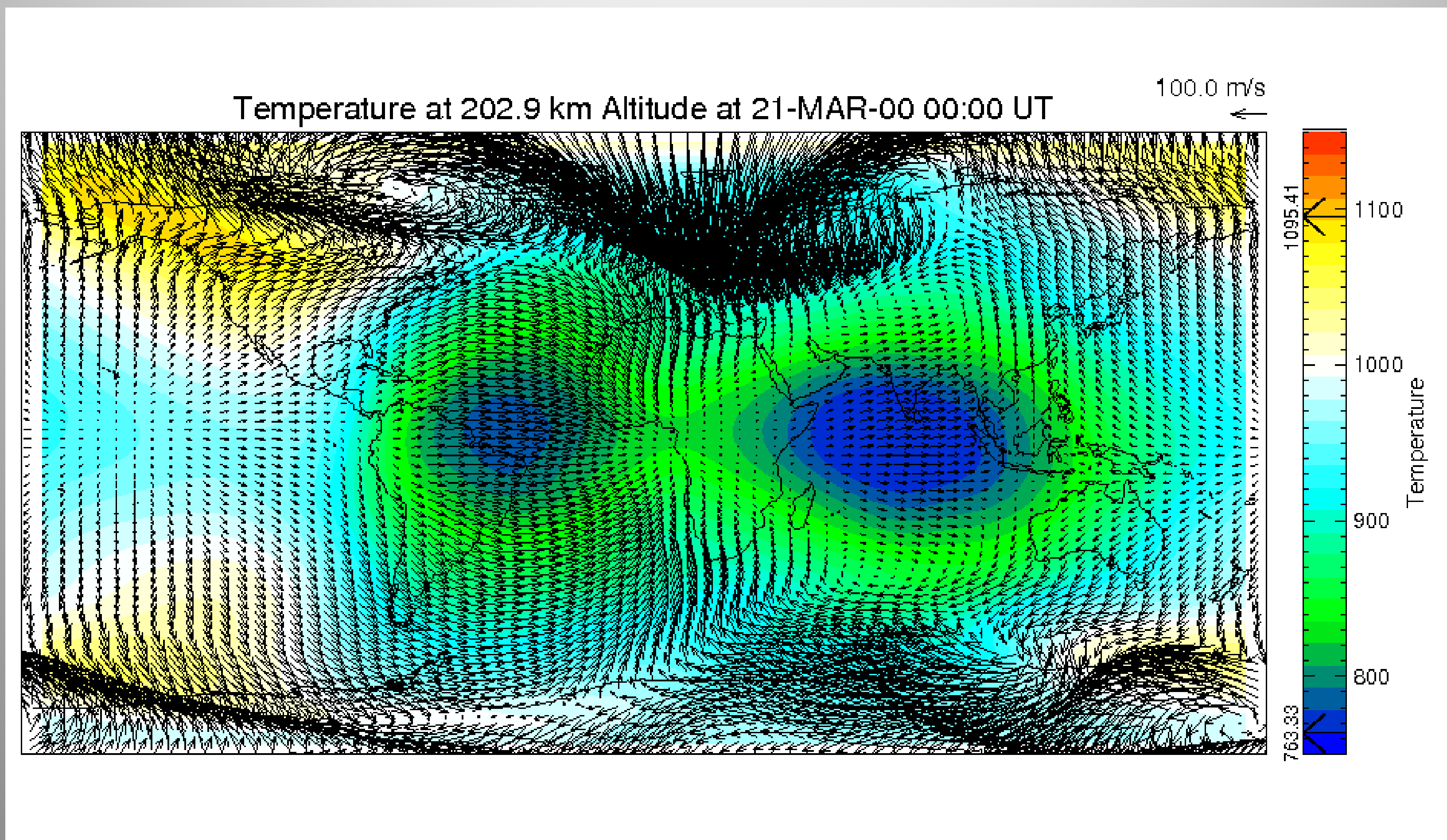


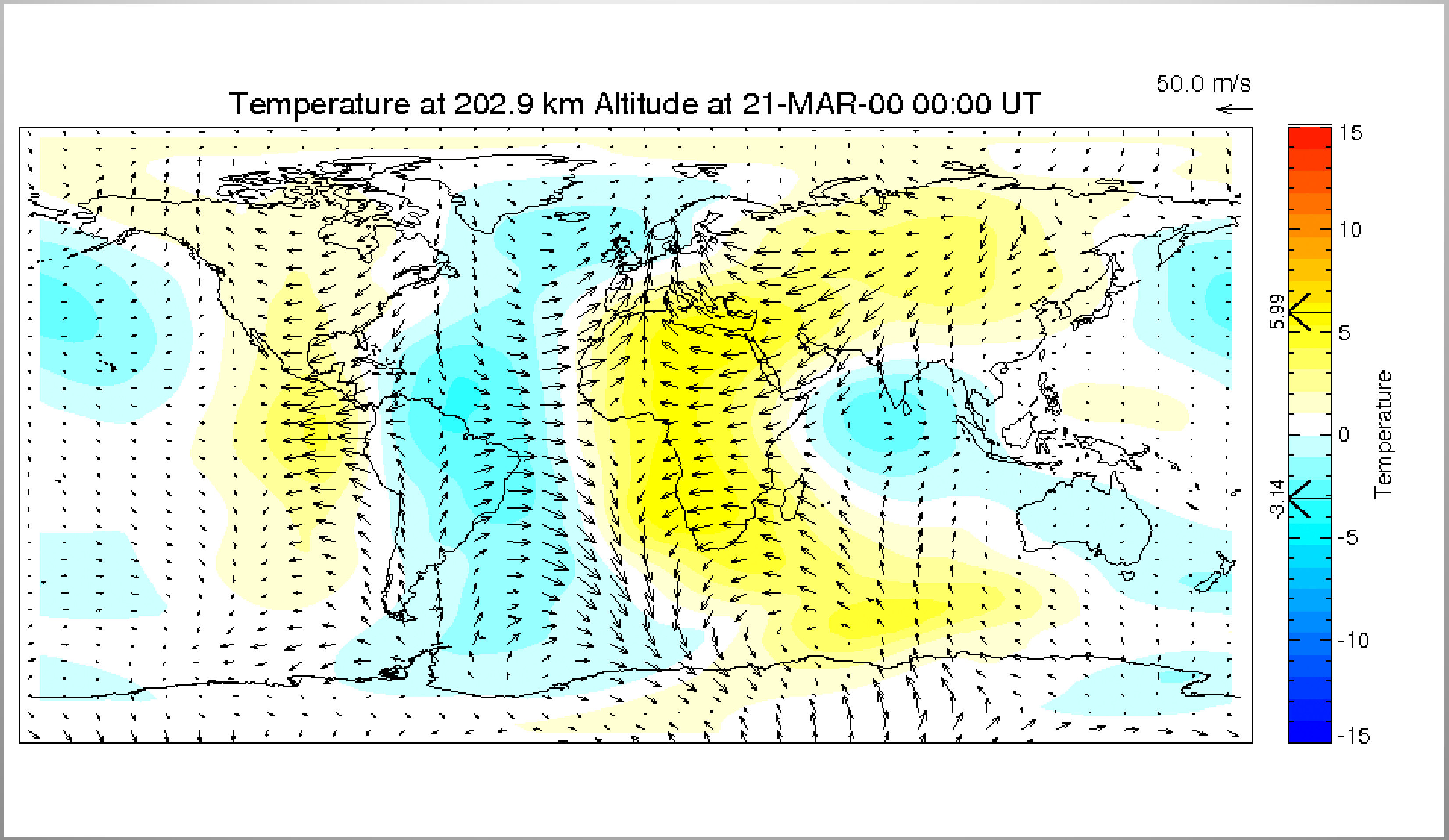
No Tides (Temperature @ 200 km)



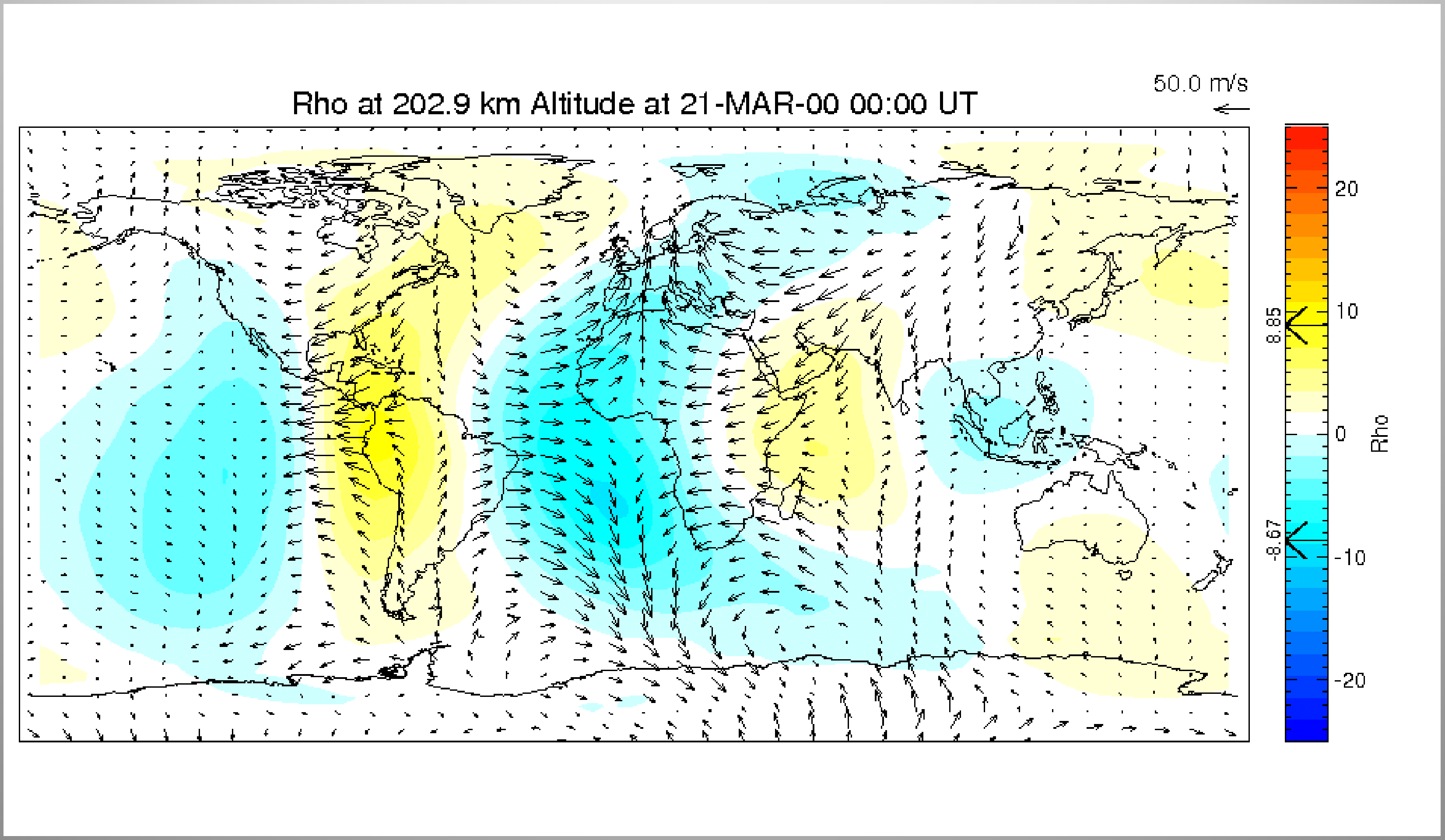
Tides (Temperature @ 200 km)



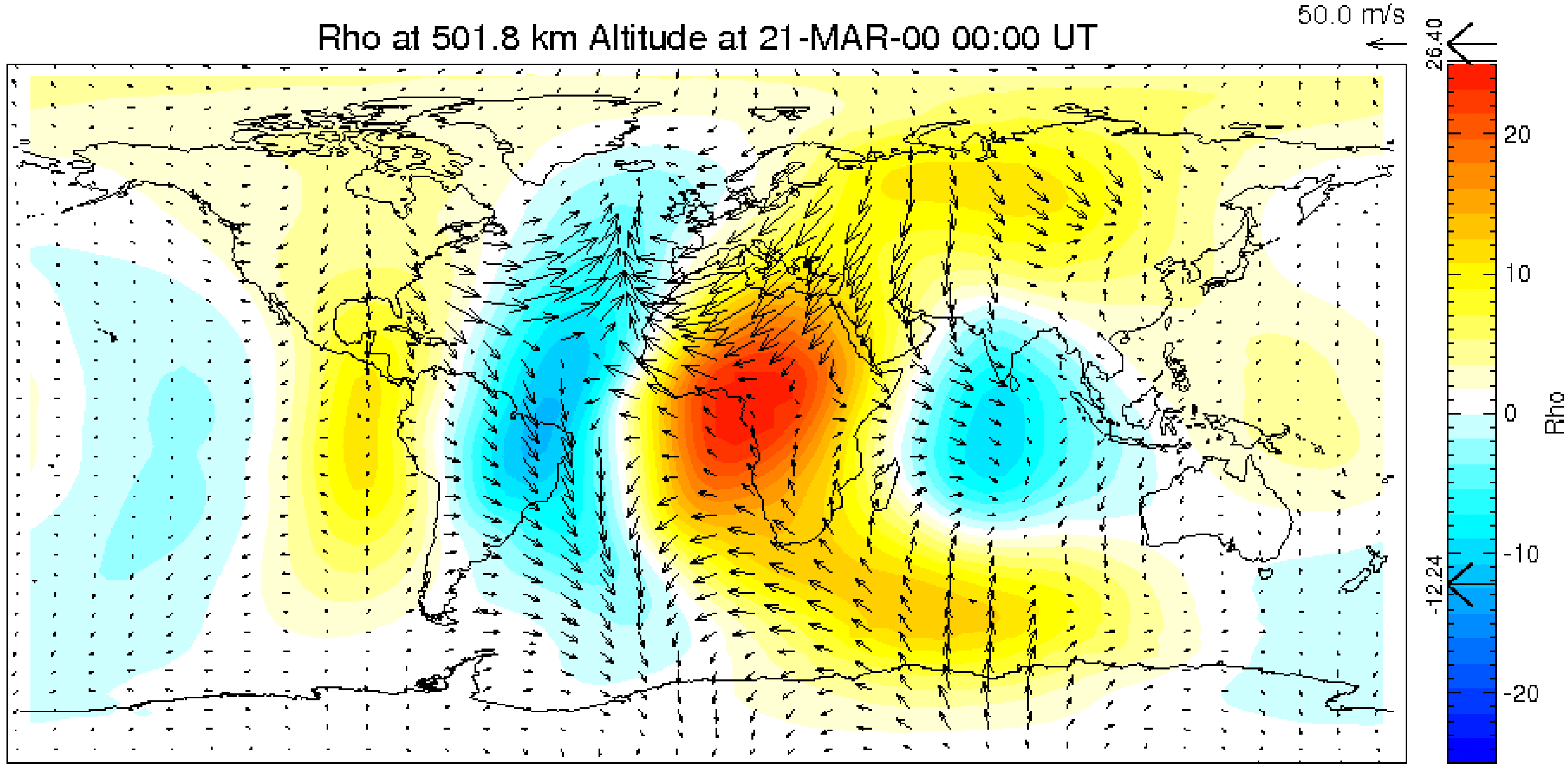
Difference in Temperature @ 200 km



Difference in Rho at 200 km



Difference in Rho at 500 km



Summary

- Successfully have driven GITM with WACCM generated tidal fields
  - Temperature and horizontal winds
  - This is similar to the coupling we have done with GSWM
  - Need to incorporate vertical wind and densities to complete the coupling
- Tidal signatures cause:
  - ~15% perturbation in temperature at 110 km
  - ~25% perturbation in mass density at 110 km
  - Decreasing perturbations until about 5% at 200 km
  - ~50 m/s horizontal wind differences throughout the atmosphere
  - Mass density perturbation starts to rise to 15%-20% by 500 km
- Throughout the lower thermosphere, mass density perturbations are anti-correlated with temperature perturbations