Month to Month Changes of Thermospheric Neutral Winds Obtained from a Data Assimilation Model

L. Pedersen[1], L. Scherliess[1] ,and L. Lomidze[2] |[1]*Center for Atmospheric and Space Sciences, Utah State University* [2]*University of Calgary*

I. Introduction

Thermospheric neutral winds are responsible for the transport of energy and momentum in the upper atmosphere. They also affect the composition, dynamics, and morphology of ionospheric plasma. However, direct observations of these winds are limited both spatially and temporally making global studies challenging. In contrast, global ionospheric measurements are abundant and easily obtained from a variety of sources (GNSS, ionosondes, in-situ measurements of electron density by satellites, radio occultation, etc.). Data assimilation is a technique that combines observations with a physical model. The measurements are assimilated as constraints to the equations that describe the dynamics of the system allowing for the estimation of unobserved driving forces; e.g., the thermospheric neutral wind. This poster presents the month-to-month progression of TWAM thermospheric wind estimates for the year 2009 as well as an analysis of the intra-annual variation of the zonal wind reversal near dawn and dusk in the thermosphere.

II. Methodology

This process is defined as follows:

1) **Ionospheric data is assimilated into GAIM-FP** (Global Assimilation of Ionospheric Measurements – Full Physics). GAIM-FP is an ionospheric data assimilation model that is based on an ensemble Kalman filter. The ionosphere and plasmasphere electron density and its associated errors are evolved using a physics-based Ionosphere-Plasmasphere Model which numerically solves the ion and electron continuity and momentum equations. In this study, monthly averaged N_mF_2 and H_mF_2 data obtained from COSMIC radio occultations are assimilated into GAIM-FP to obtain magnetic meridional wind estimates.

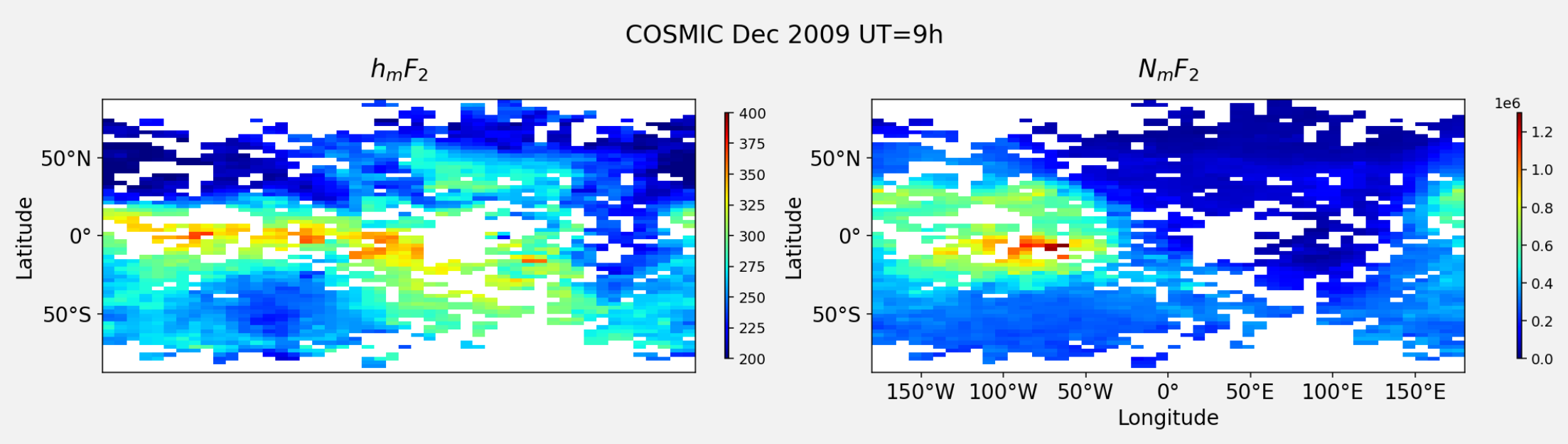
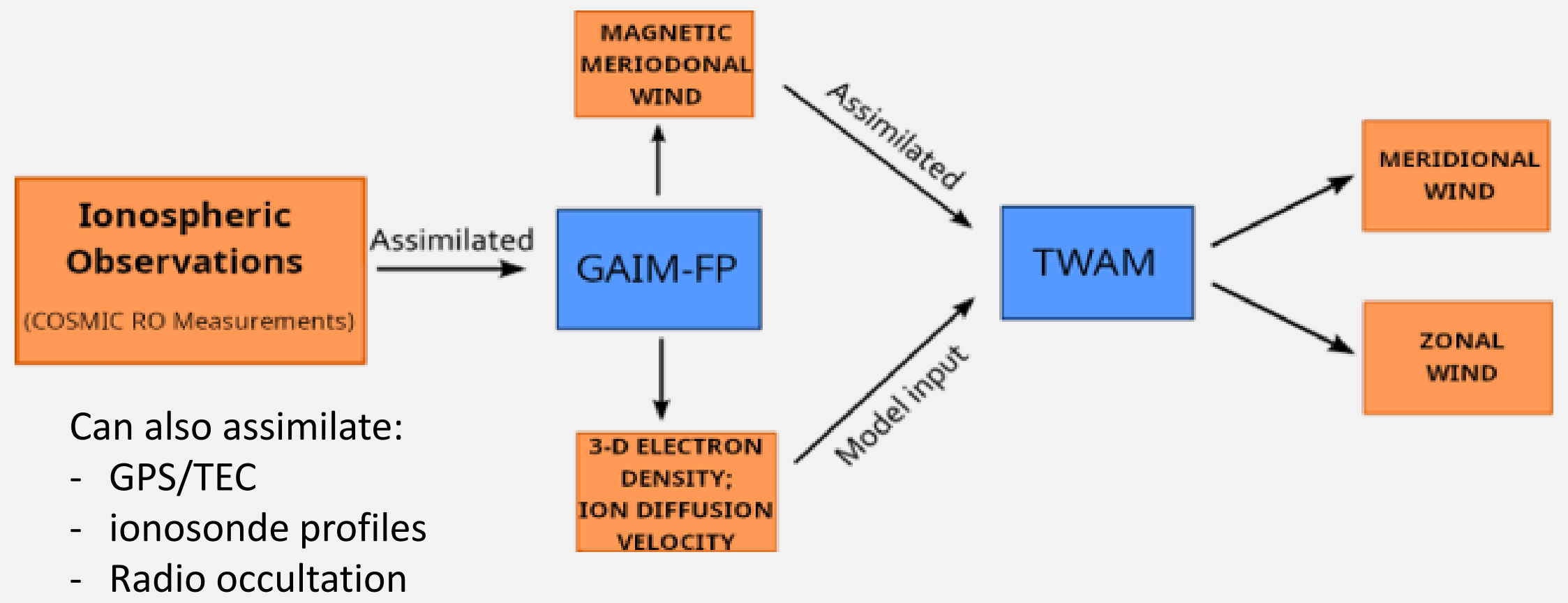


Figure 1 – Example of $H_mF_2$and $N_mF_2$map generated from monthly averaged COSMIC radio occultation data corresponding to Dec 2009 at 0900 UT. These maps are assimilated by GAIM-FP.

2) **Using an implicit Kalman filter, TWAM combines the magnetic meridional winds from GAIM-FP with the equation of motion for the neutral gas (Equation 1).** TWAM also uses the 3-D electron density and ion diffusion velocities from GAIM-FP as input to obtain the distribution of thermospheric meridional and zonal winds at low and mid-latitudes.

Layne Pedersen
Utah State University
Department of Physics
layne.pedersen@usu.edu



Can also assimilate:
- GPS/TEC
- ionosonde profiles
- Radio occultation
- In-situ electron densities
- 1356 Å UV observations

Figure 2 – Schematic view of the methodology.

$$\underbrace{\frac{\partial \boldsymbol{u}}{\partial t} + (\boldsymbol{u}\cdot\nabla)\boldsymbol{u}}_{\text{ADVECTION}} = \underbrace{-2\boldsymbol{\Omega}\times\boldsymbol{u}}_{\text{CORIOLIS}} + \overbrace{\boldsymbol{g}}^{\text{GRAVITY}} \underbrace{-\frac{1}{\rho}\boldsymbol{\nabla}p}_{\text{PRESSURE}} + \overbrace{\frac{\mu}{\rho}\nabla^2\boldsymbol{u}}^{\text{VISCOSITY}} \underbrace{-\nu_{\mathrm{ni}}\,(\mathbf{u}-\mathbf{u_i})}_{\text{COLISIONS}}$$

Equation 1 – Equation of motion for neutral gas. Non-linear advection term is neglected in TWAM.

III. Results

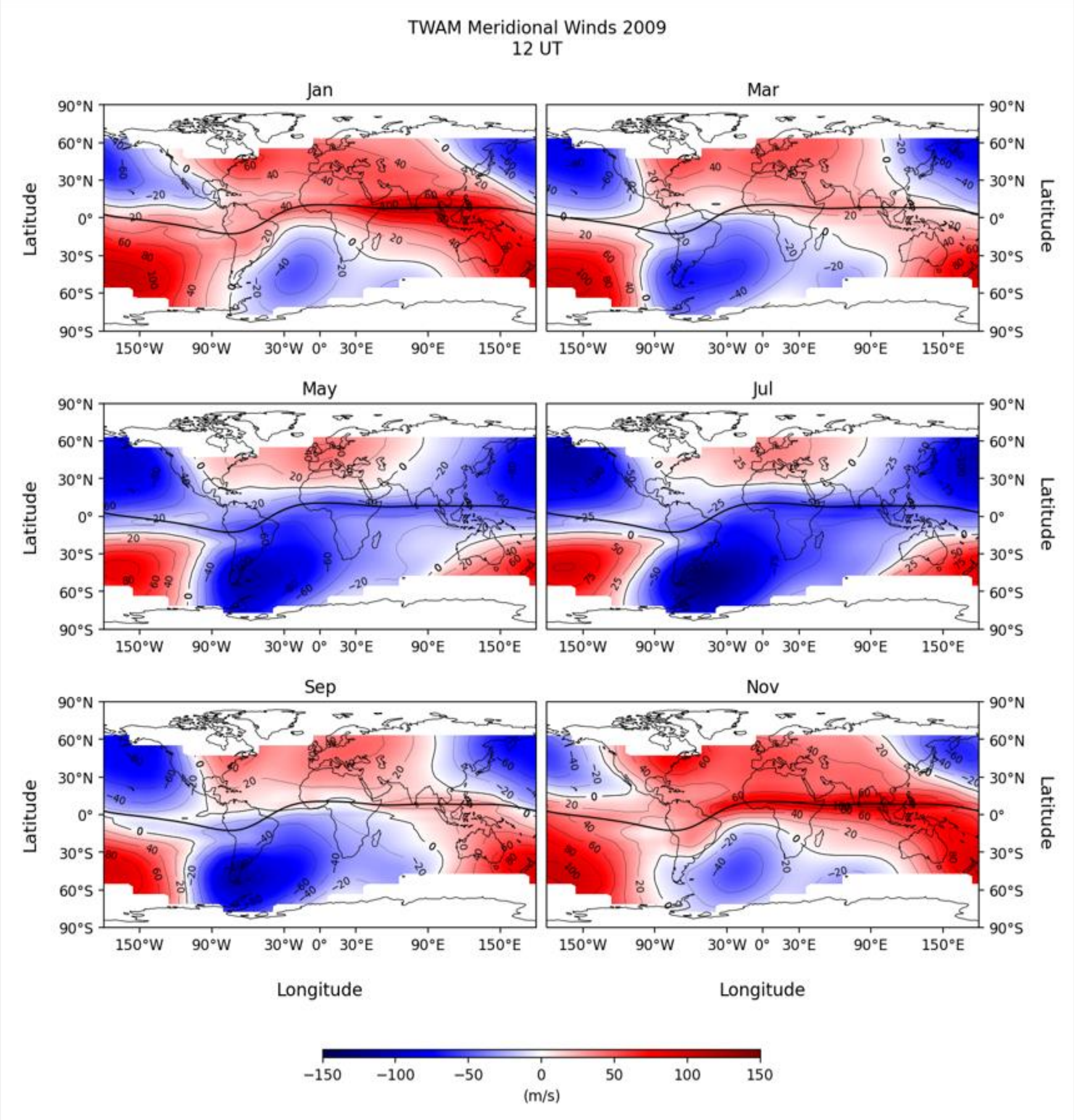


Figure 3 – Example of thermospheric meridional winds (positive northward) obtained from TWAM using monthly averaged NmF2 and HmF2 data obtained from COSMIC radio occultations. Results correspond to 1200 UT and are shown for every other month of 2009.

Figures 3 and 4 show examples of **low and mid-latitude meridional and zonal neutral wind** estimates obtained from TWAM for every other month of 2009. Meridional winds trend poleward during the day and equatorward during the night, symmetric at equinoxes. During solstice, the winter hemisphere has the strongest winds. Zonal winds trend eastward at night and westward during the day. During solstice, nighttime winds are largest in the winter hemisphere and are symmetric at equinoxes.

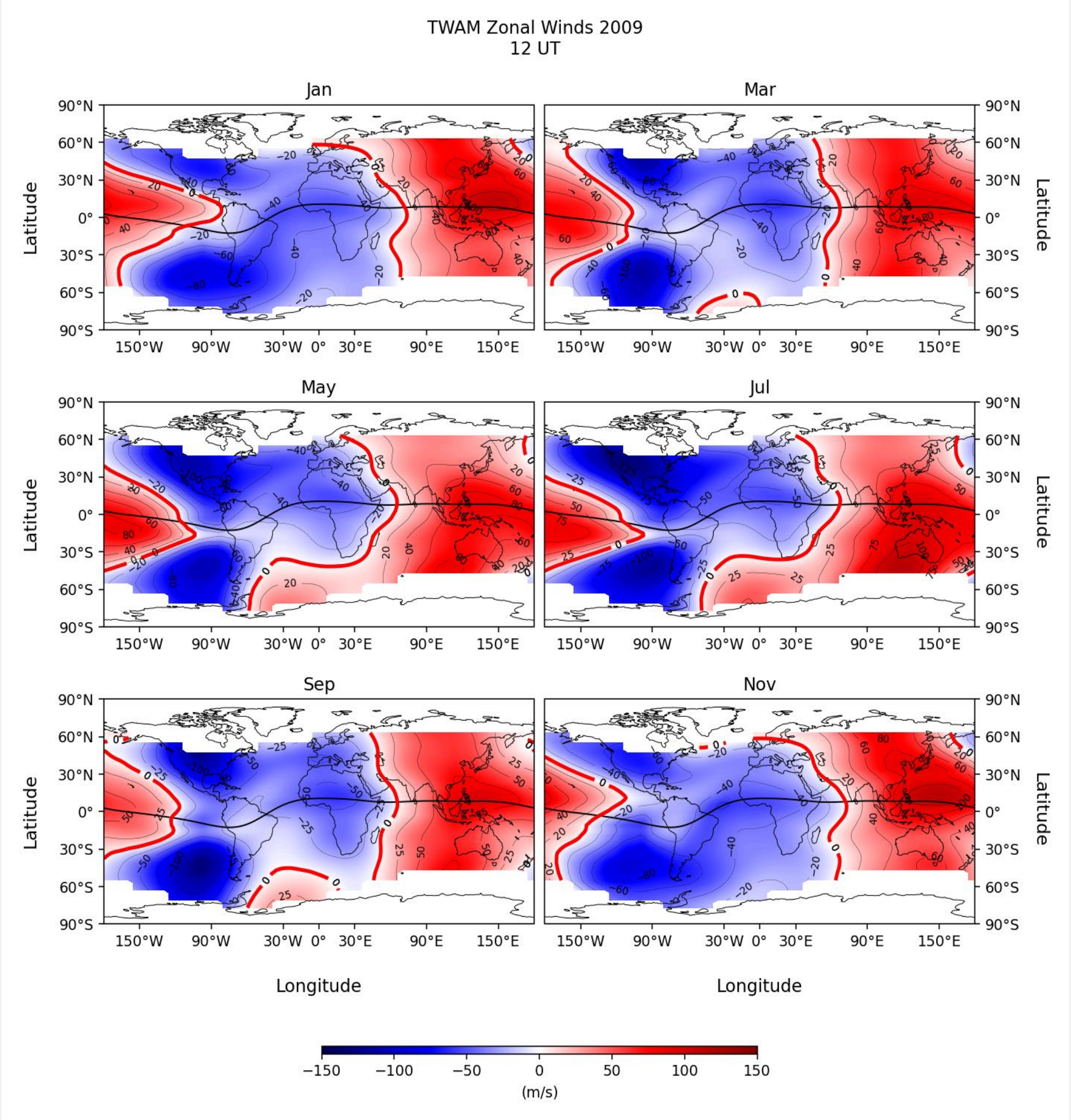


Figure 4 – Same as Figure 3 but for thermospheric zonal winds (positive eastward). Dawn and dusk reversal line are marked in red.

IV. HWM Comparison

Figure 5 shows a comparison with the Horizontal Wind Model (HWM14). The top panels show are TWAM meridional (left) and zonal (right) winds corresponding to March, 2009, at 1200 UT derived from ionospheric observations. The middle panels show HWM winds for the same time period derived from decades of wind observations. The bottom panels show the difference between TWAM and HWM and demonstrate a generally good agreement between the two models. The difference between these models are reminiscent of semidiurnal variations.

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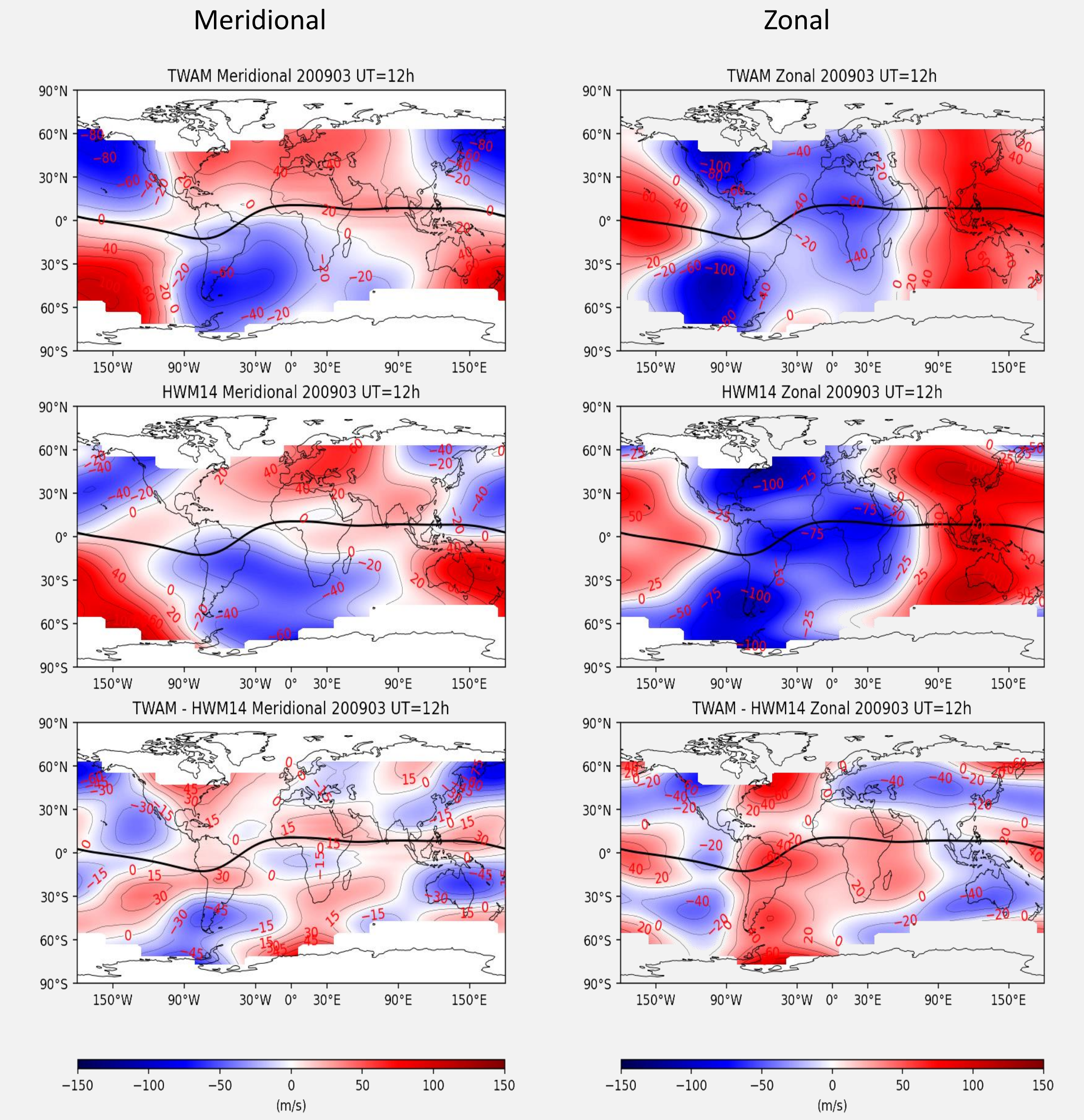

Figure 5 – Example of thermospheric meridional (left) and zonal (right) winds obtained from TWAM (top) and HWM14 (middle) showing very good agreement between the two models. Results correspond to March,2009, at 1200 UT. Bottom panel shows the difference between the two model results.

V. Variation of zonal wind speed reversal

Figure 6 shows the intra-annual latitudinal variation of the zonal wind reversal at dawn (top) and dusk (bottom) for the year of 2009. The left-most curve corresponds to January and the curve for each successive month is plotted to the right of the previous month on a modified longitude scale with an offset of 30° for each consecutive month at dawn and an offset of 10° for each consecutive month at dusk. The maximum extent in longitude for each month migrates southward from the winter months to the summer months and back up northward from summer to winter.

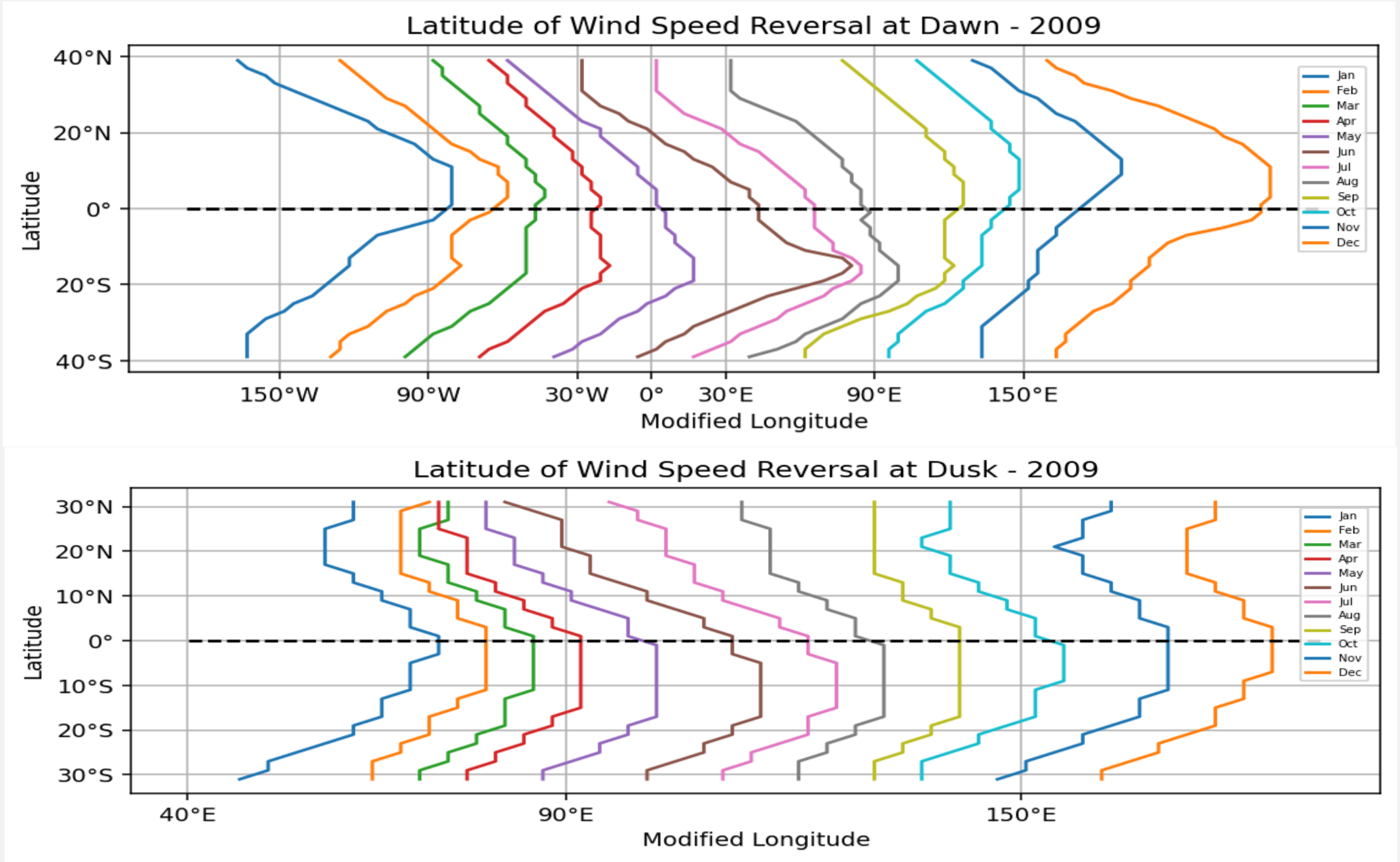

Figure 6 – Latitudinal variation of the zonal wind reversal at dawn (top) and dusk (bottom) for the year of 2009. The maximum longitudinal extent for each month cycles southward from the winter months through the summer months and back northward from the summer months to the winter months.