U.S. NAVAL RESEARCH LABORATORY

Midnight temperature maximum winds and equatorial spread-F

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Abstract

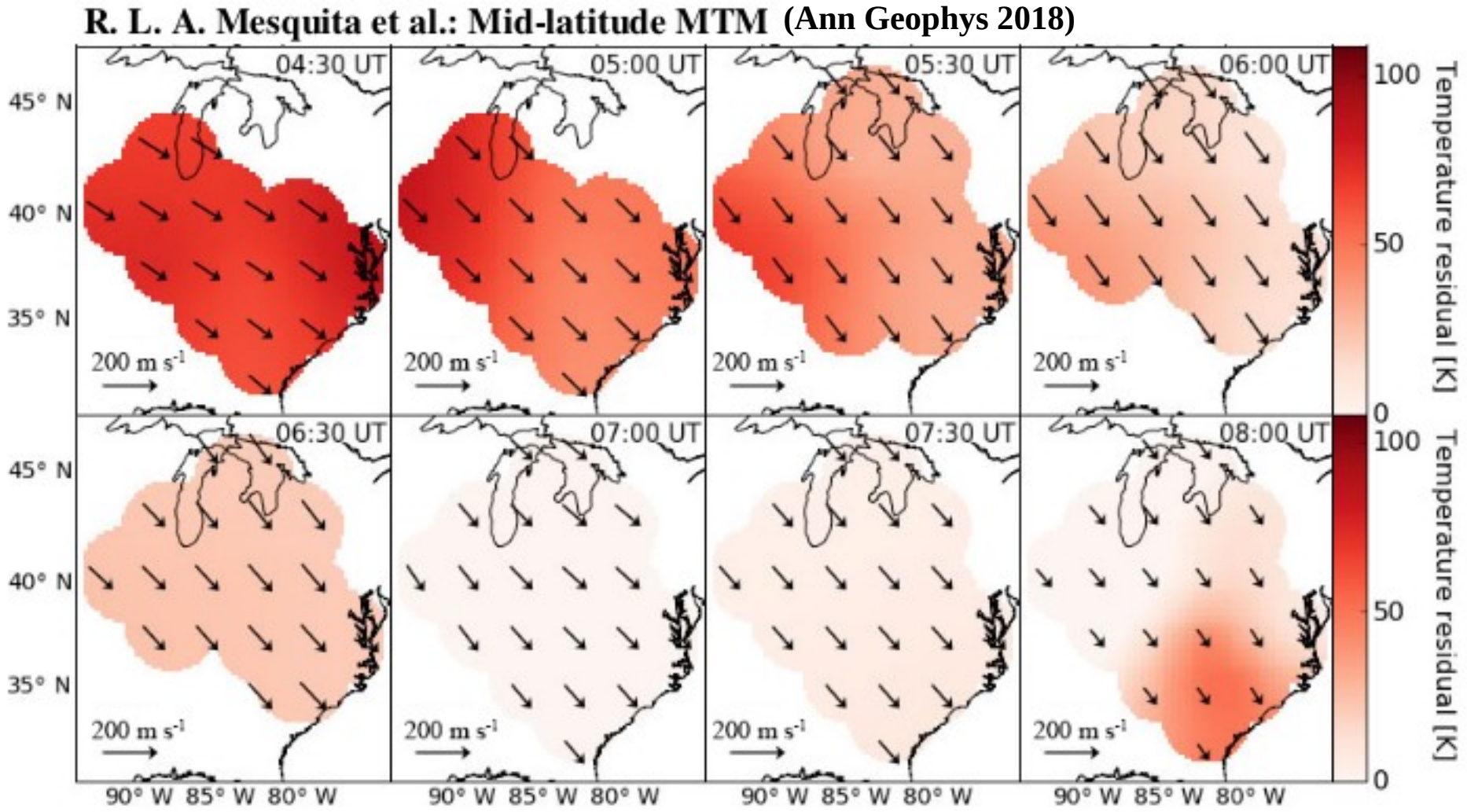
The SAMI3/ESF ionosphere “wedge”code is used to simulate the growth of equatorial plasma bubbles in the presence on a background wind field based on observed “midnight temperature maximum” (MTM) winds[1]. Cases where MTM winds are symmetric across the equator are considered; here the southern meridional wind is the reverse of the (observed) northern meridional wind. Two mechanisms associated with MTM winds are shown to support the growth of the equatorial spread F (ESF) instability:
1. a converging meridional wind, which sometimes precedes an MTM, is known to be destabilizing.
2. Cessation of zonal winds, a well-known MTM feature, is destabilizing.
We argue that regional winds measurements north and south of the magnetic equator would greatly aid the understanding of ESF.

[1] Krall et al., Space Weather, 2021

Winds from the NATION dataset

NRL PPD

North American Thermosphere Ionosphere Observing Network:



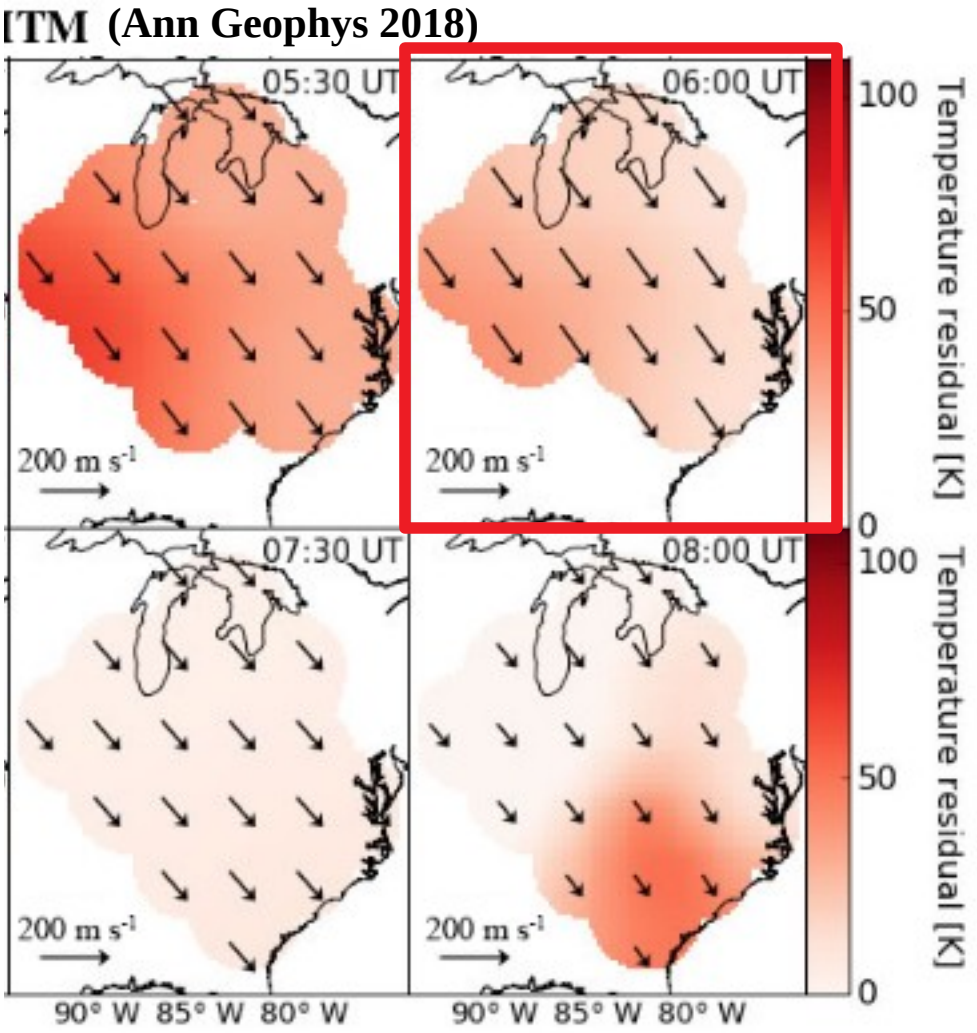
Winds from the NATION dataset

NRL PPD

North American Thermosphere Ionosphere Observing Network:

Peak equatorward wind is at 0600 UT (0030 LT)

This wind, if part of a north-south converging pattern, might enhance the growth of equatorial spread F (ESF).



Winds: Mesquita et al., Ann. Geophys., 2018

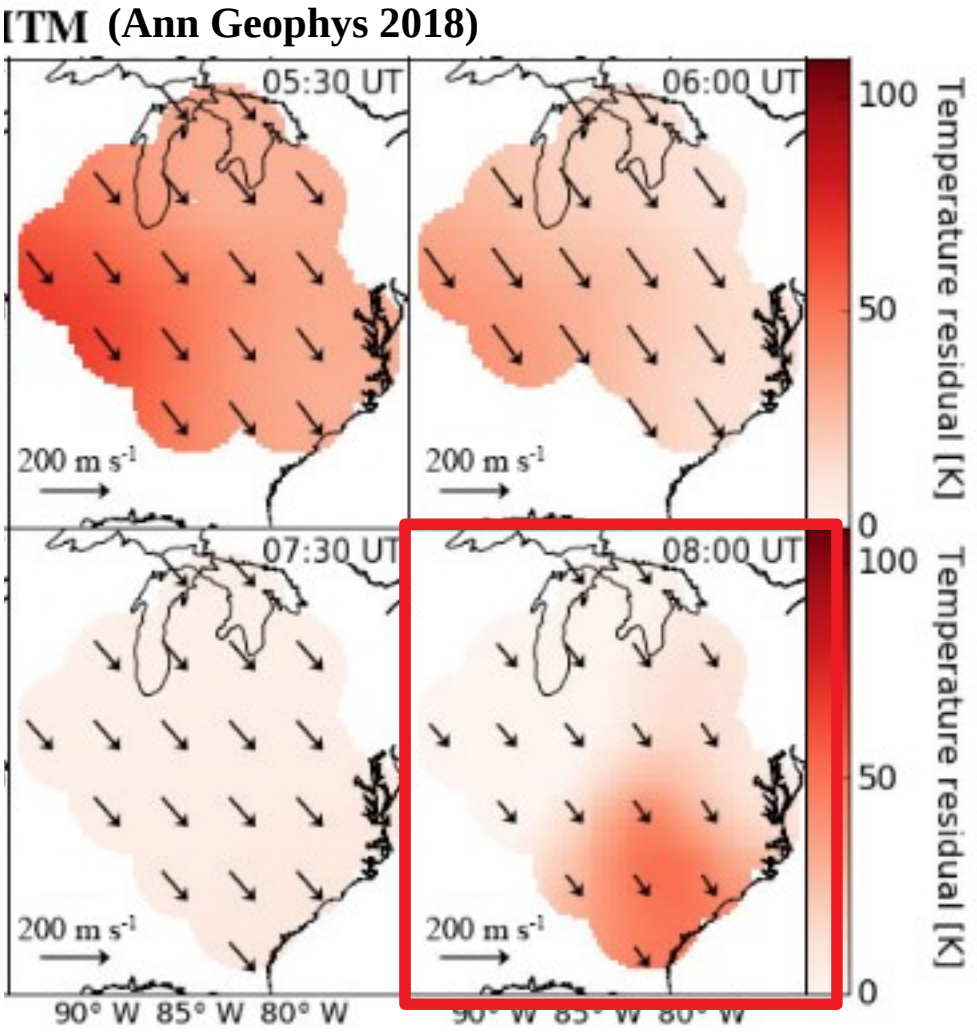
Winds from the NATION dataset

NRL PPD

North American Thermosphere Ionosphere Observing Network:

The primary MTM, and a cessation in the zonal wind, occurs at 0830 UT (0300 LT)

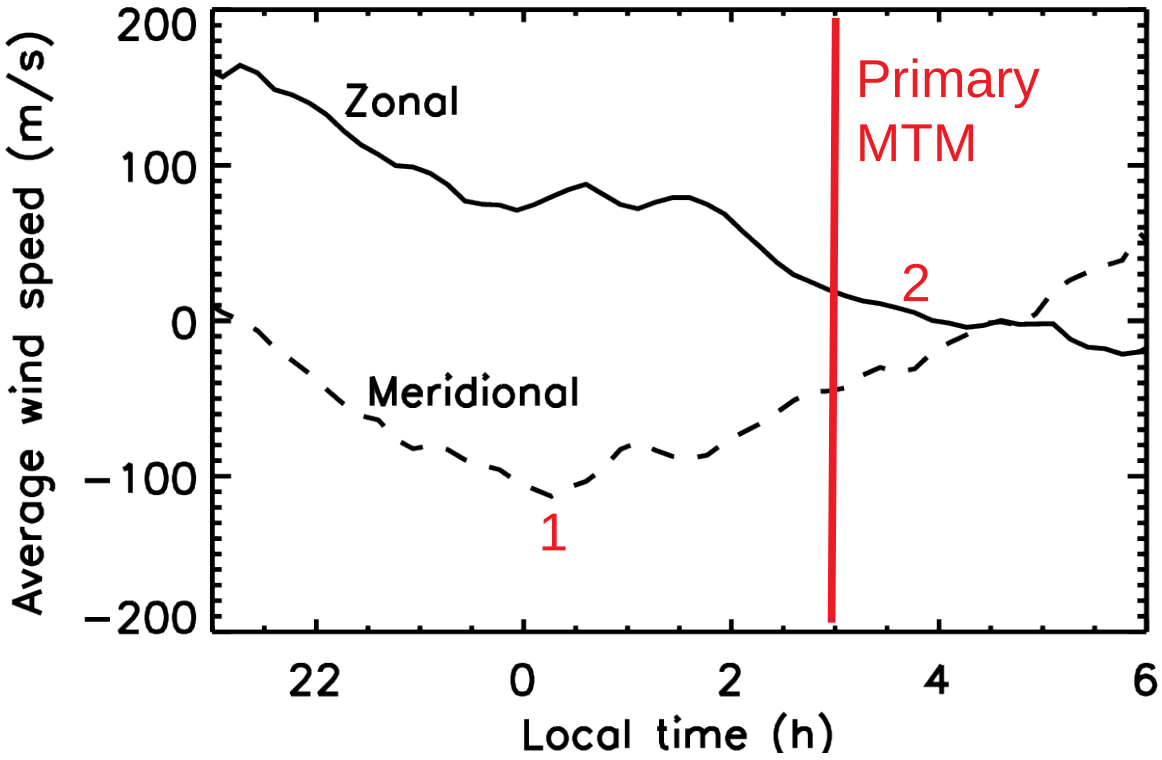
We consider that a sudden cessation of the zonal wind might enhance the growth of equatorial spread F (ESF).



NATION winds show MTM

NRL PPD

We consider two effects



1. MTM is often preceded by a strong equatorward wind.

2. MTM is associated with cessation of the zonal wind and meridional wind changing from equatorward to poleward.

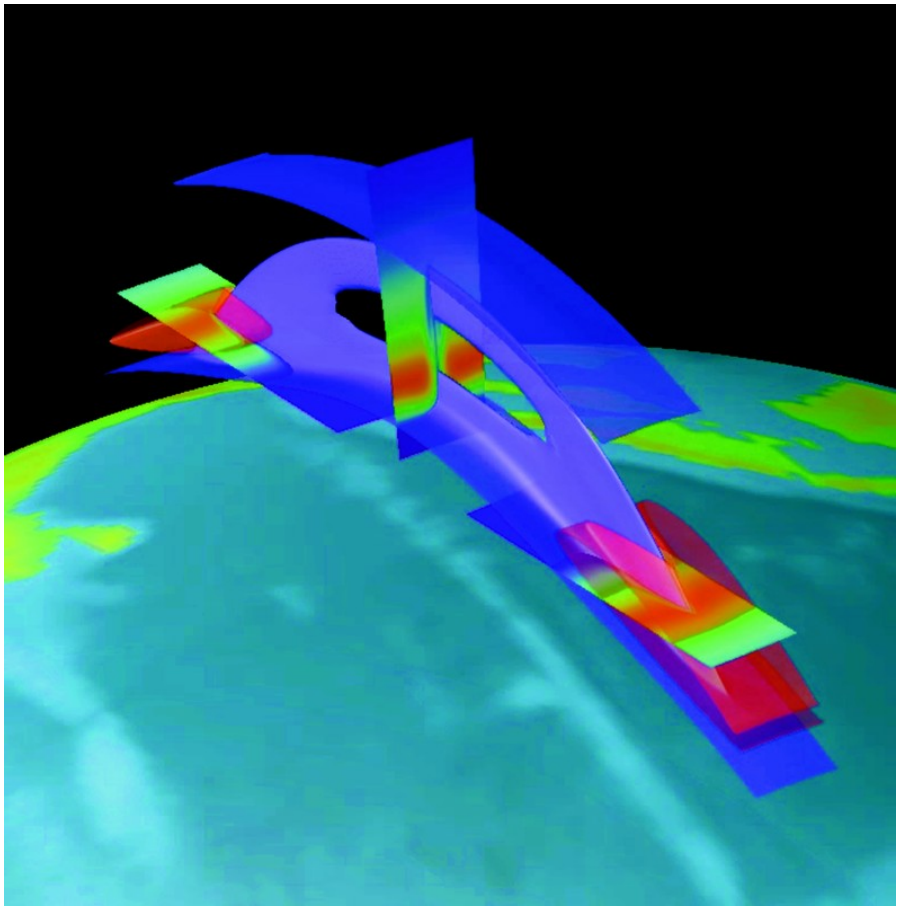
SAMI3/ESF

SAMI3/ESF is SAMI3 constrained to a narrow wedge of the ionosphere

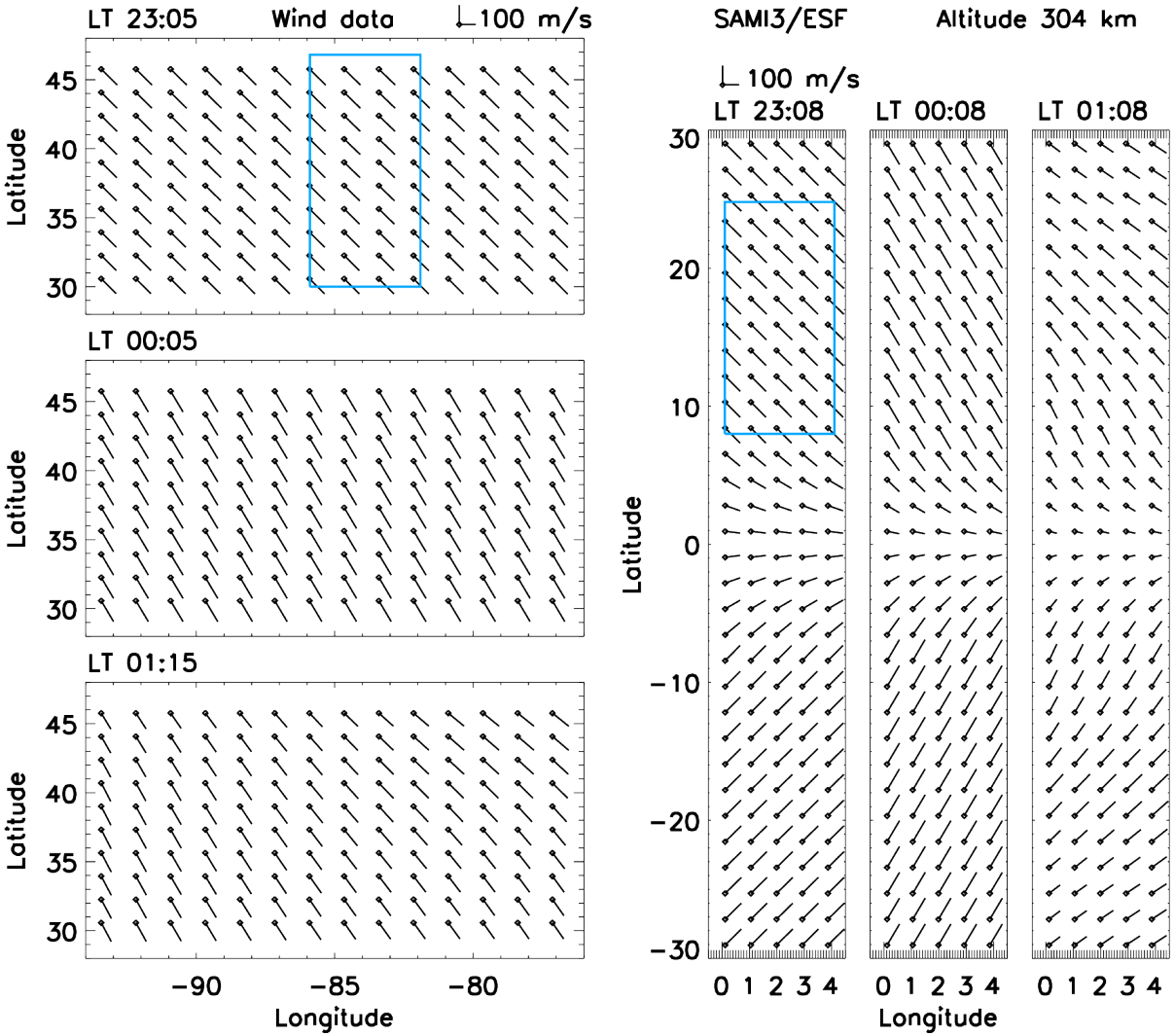
For SAMI3, we need winds over a larger area than is covered by the NATION instrument

We will assume an often-observed north-south symmetry

$$U_{merid,S} = -U_{merid,N}$$



NATION winds in SAMI3/ESF



The measured wind pattern is placed in the northern half of the SAMI3 grid.

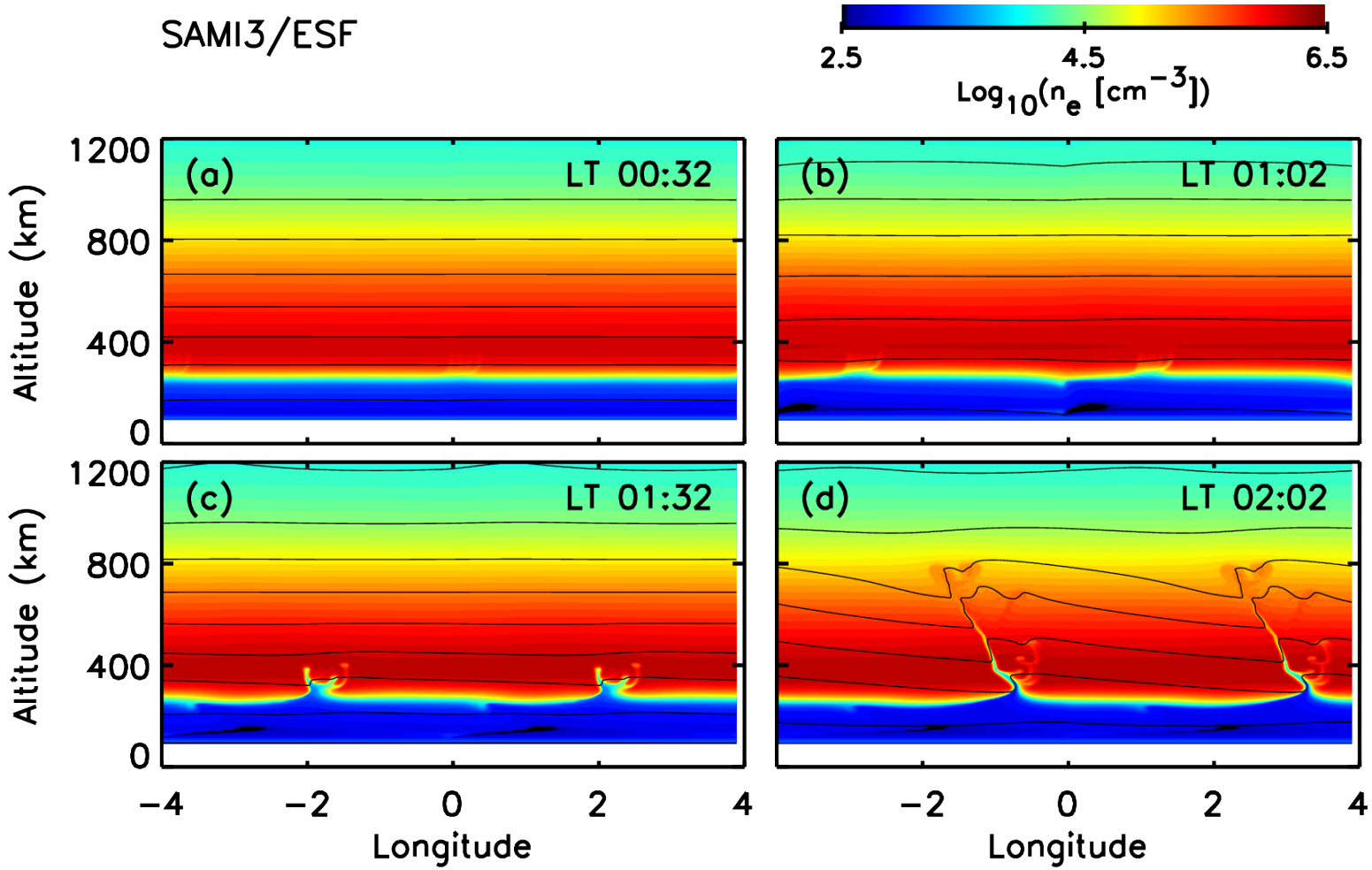
What about the southern half?

We set

$U_{merid,S} = -U_{merid,N}$

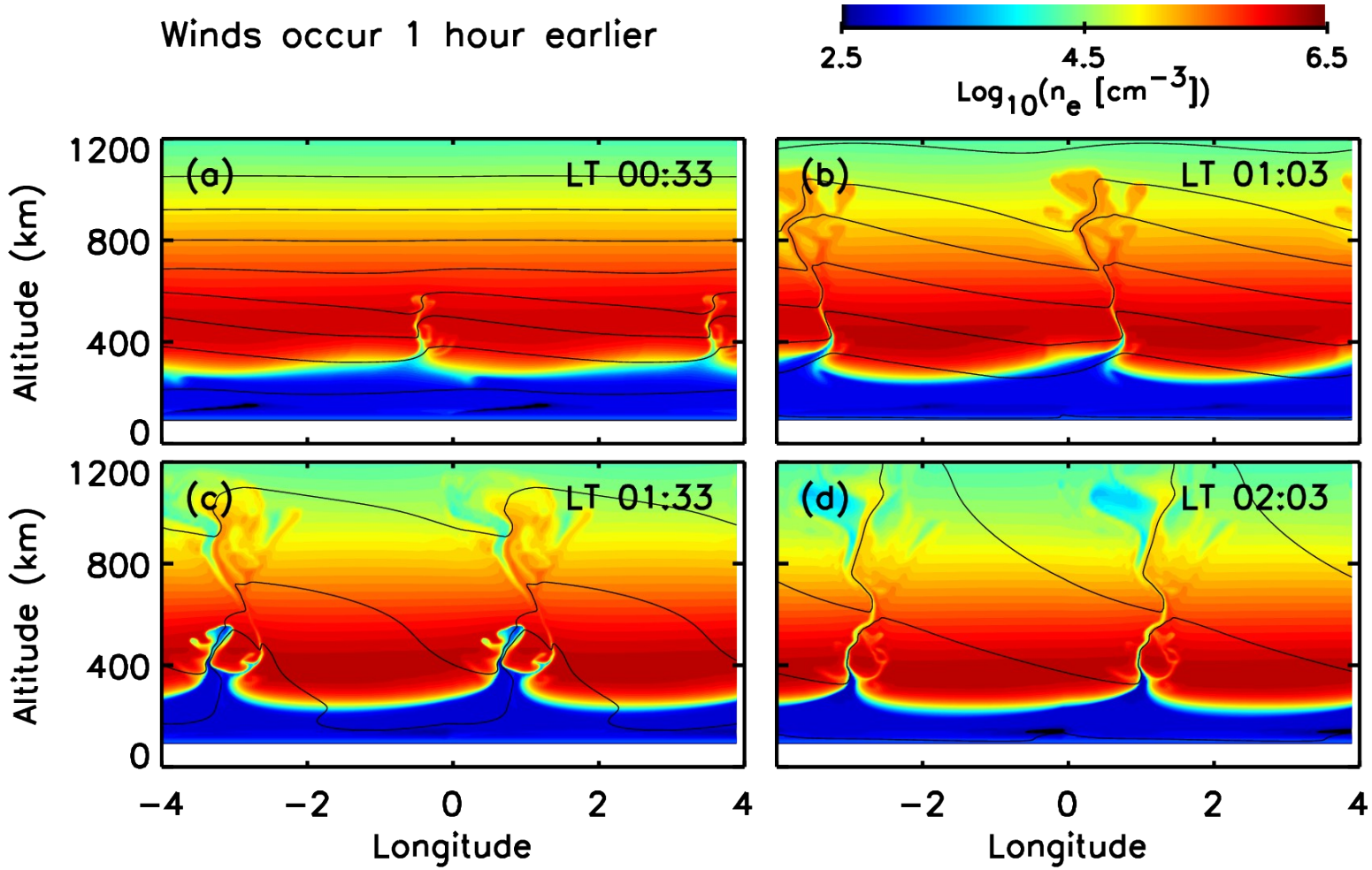
(wind is indicated by the direction of line *away* from the dot)

SAMI3/ESF result



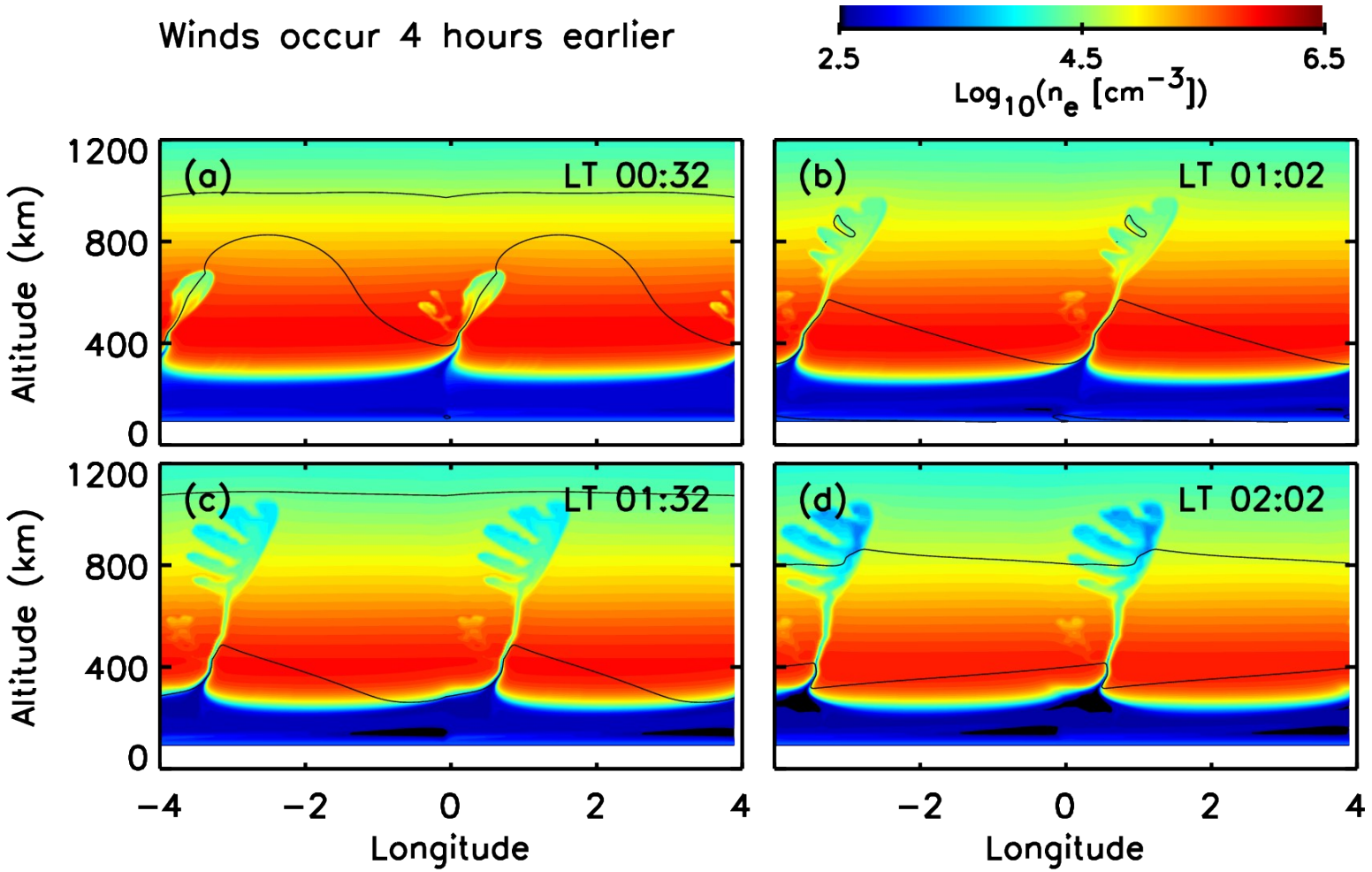
ESF grows 3 hours after the initial seed is imposed at 23h LT

Converging meridional winds



ESF grows much faster

Cessation in zonal winds



ESF grows much faster

Discussion

Strong post-midnight ESF growth associated with strong converging meridional winds; these can occur prior to MTM

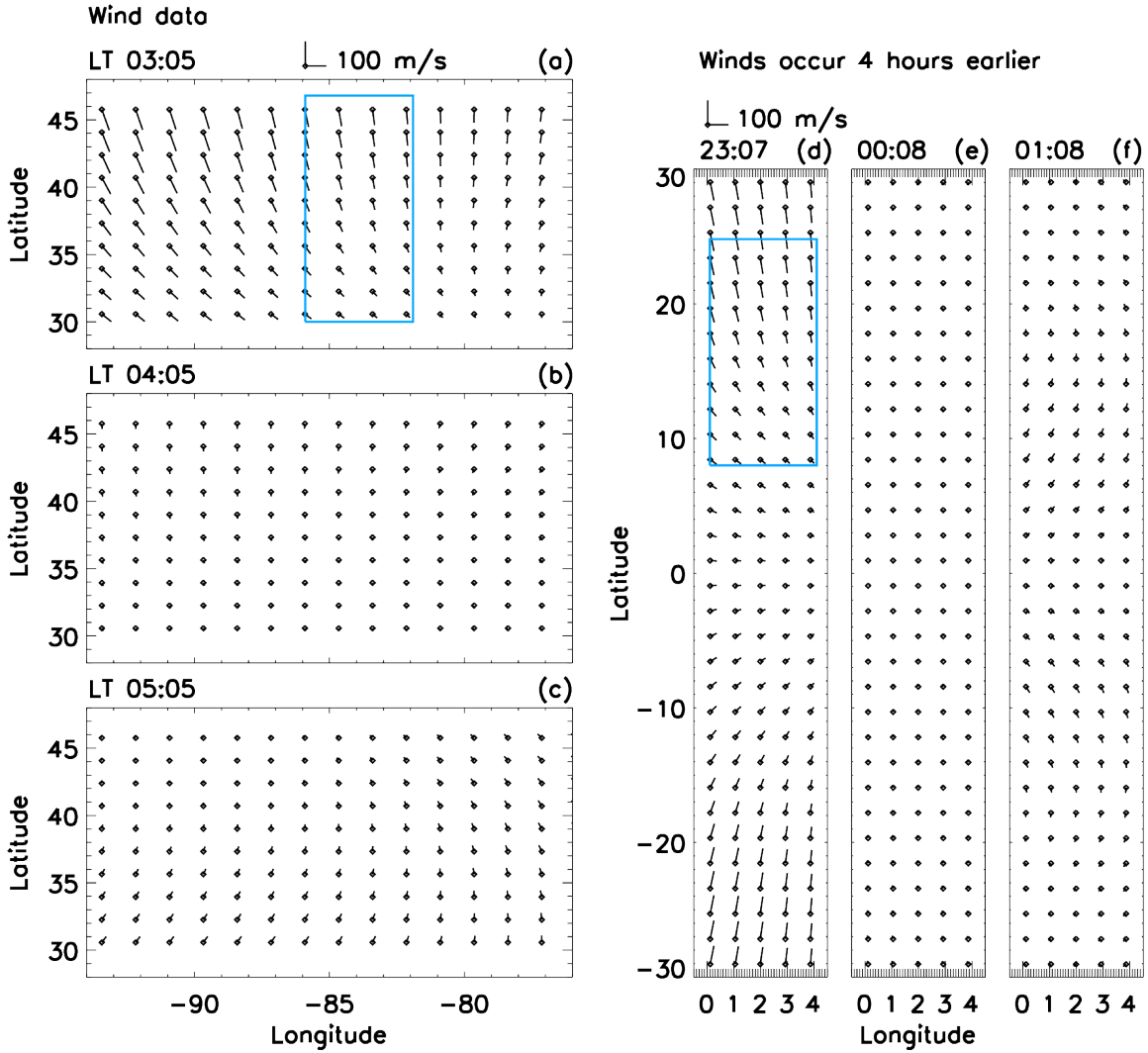
Strong post-midnight ESF growth associated with cessation of the zonal wind; this effect is associated with MTM

To predict ESF, wind predictions needed in both hemispheres near the magnetic equator

The NATION network is provides an amazing regional wind dataset; something similar is needed to nowcast ESF

Future: Global SAMI3 code with high-resolution thermosphere

Extra: winds four hours earlier

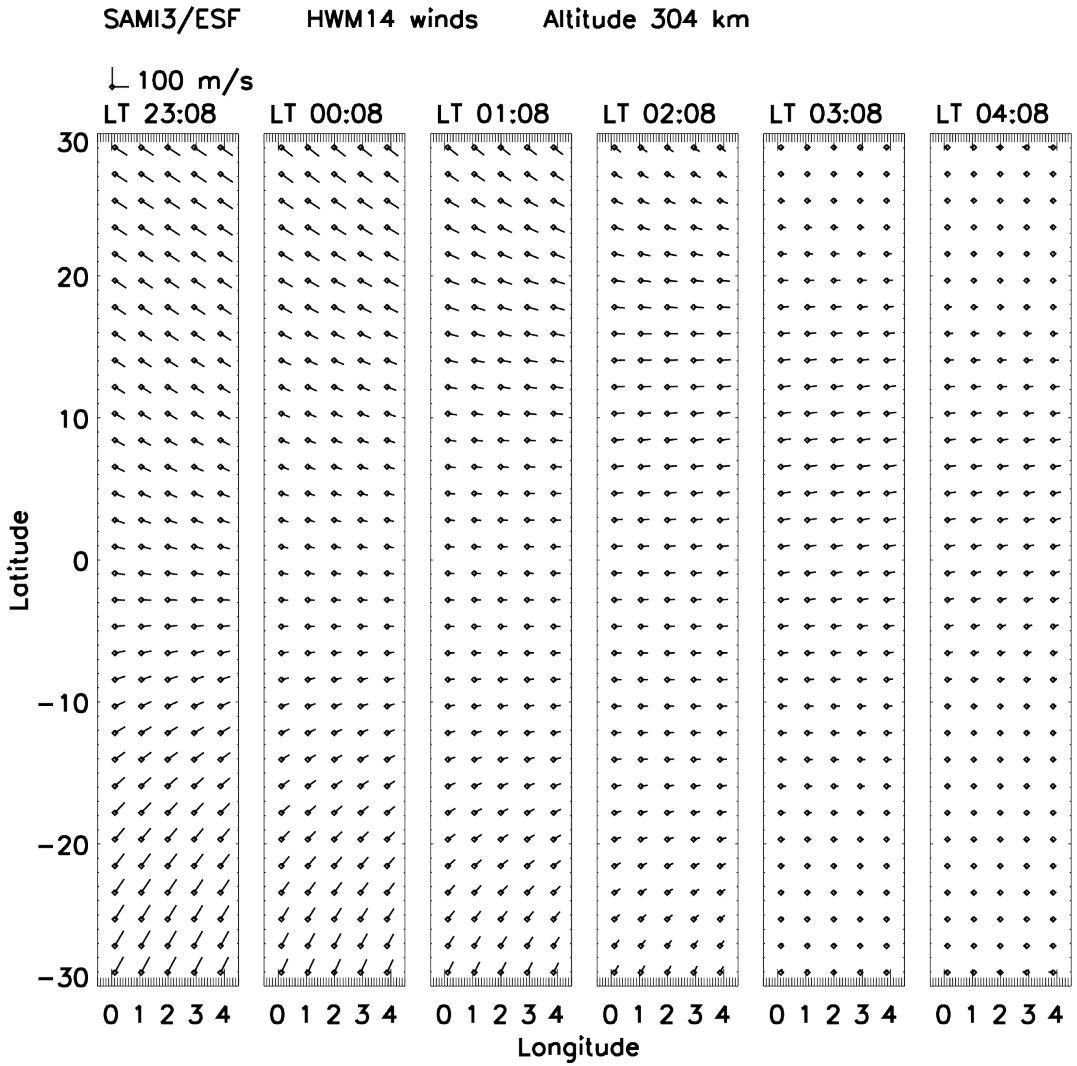


If winds occur four hours earlier, a residual converging meridional wind and a lack of zonal wind can support ESF.

Huba et al. (2009, GRL) show that zonal winds are stabilizing.

(wind is indicated by the direction of the line *away* from the dot)

Extra: are model winds realistic?

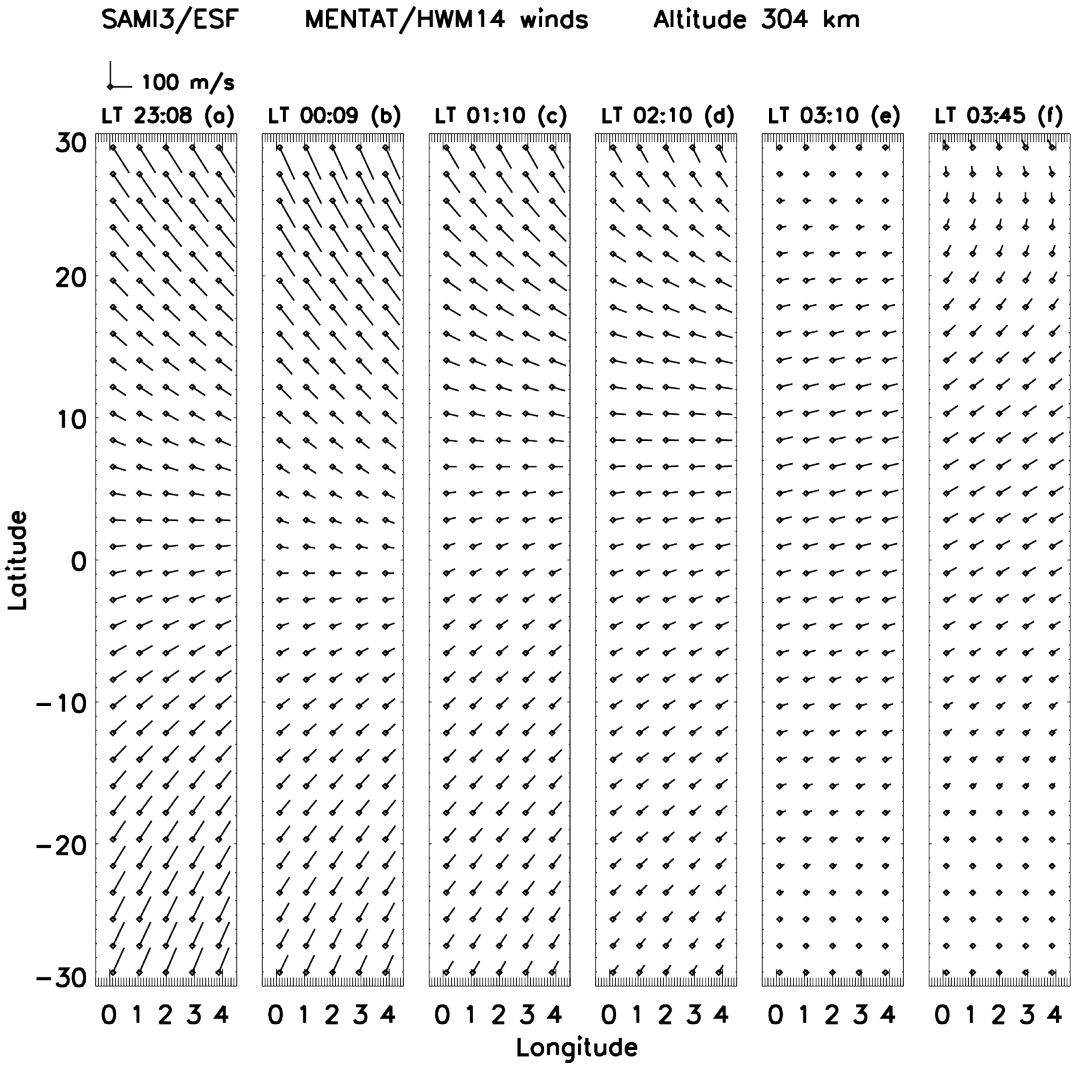


The HWM14 empirical wind model (Drob et al., 2015) gives typical winds for a specified day.

HWM14 for day 80 (equinox) shows a wind pattern similar to MTM winds, but weaker.

(wind is indicated by the direction of the line *away* from the dot)

Extra: are model winds realistic?



The MENTAT model (Dandenault, 2018) gives meridional winds based on ionosonde data.

MENTAT finds converging meridional winds as strong as ours only a few percent of the time.

(winds is indicated by the direction of the line *away* from the dot)