The origin of semidiurnal neutral wind oscillations in the high-latitude ionospheric dynamo region

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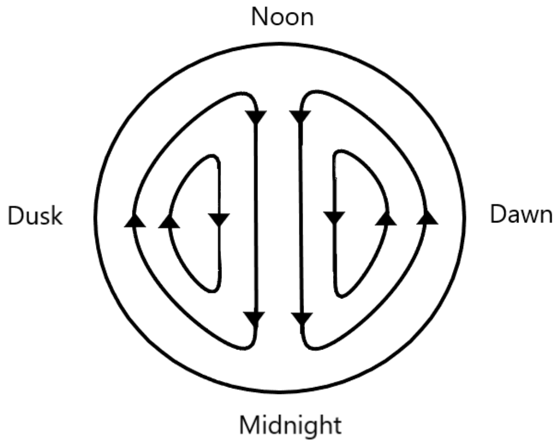
DLR

The classical picture of tidal oscillations

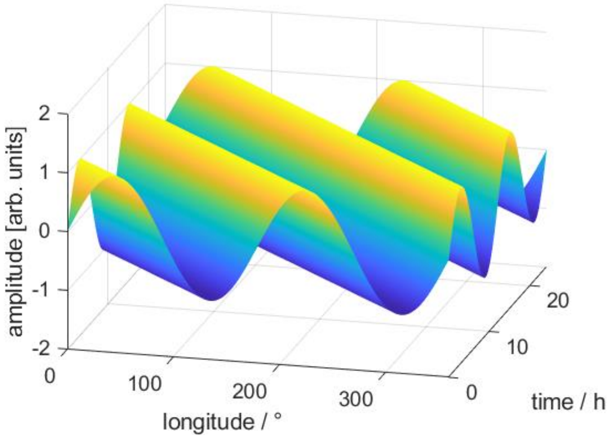
$\sim \mathbf{130-150\ km}$



High latitude polar plasma convection:

➔ neutral wind forced by ion drag
➔ sun-fixed motion
➔ locally observed as **24h oscillation**

$\sim 110-120$ km



Upward propagating atmospheric tides:

➔ mostly **S**emidiurnal **W**estward-propagating Modenumber **2** tide
➔ **12h oscillations** dominate

$\sim \mathbf{70-90\ km}$

The classical picture of tidal oscillations:

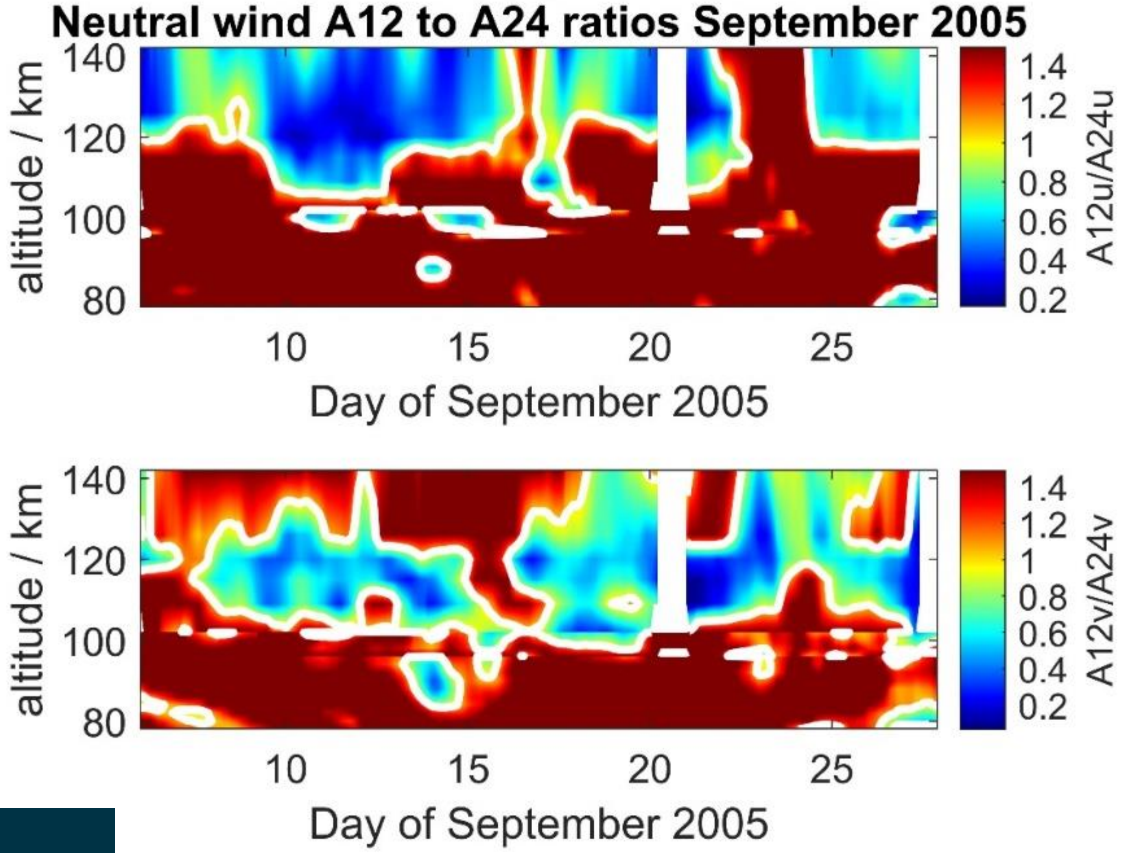
- R. S. Lindzen, *Ann. Rev. Earth Planet. Sci.*, **7**, 199-225, (1979).
- S. Nozawa *et al.*, *J. Geophys. Res.*, **115**, A08312, (2010).
  ➔ <u>measured up to 120 km</u>

Summary of measurements

EISCAT Tromsø UHF ISR	Kiruna Meteor Radar
• campaign from September 6th to 29th 2005 (Nozawa *et al.*, 2010) • 3D ion velocity vectors obtained from beam-swinging measurements; steady-state ion mobility equation applied to derive neutral winds • covered altitudes: $96 - 142$ km (seven altitude gates) • 6 min time resolution determined by the beam-cycle period	• continuously operated since December 1999 • neutral wind velocities are measured by observation of meteor trail drifts • coverage altitudes: $70 - 110$ km, 2 km resolution • 1 h time resolution • used as lower altitude reference for EISCAT neutral wind measurements

Measurement results

- tidal amplitudes and phases are determined by applying an **Adaptive Spectral Filter**
- **A12 to A24 ratio** shows dominant tidal mode:
    - zonal component:
      single transition from 12h to 24h modulations at ~ 120 km
    - meridional component:
      two-band structure with strong 12h modulations above ~ 130 km
      semidiurnal oscillations clearly reduced during the second half of September



[F. Günzkofer *et al.*, *J. Geophys. Res.*, **127**, 10, e2022JA030861, (2022)]

- **zonal:** tidal oscillations follow the classical picture
- **meridional:** complex mixing of tidal modes

Investigated model runs

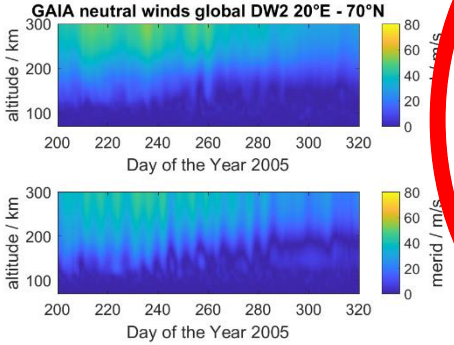
GAIA **(neutral winds up to ∼600 km)**	**WACCM-X(SD)** **(neutral winds up to ∼500-700 km)**
whole-atmosphere models; nudged to reanalysis at lower altitudes	
• constant cross polar potential $\Phi = 30$ kV (low geomagnetic activity) • Liu *et al.*, *JGR Space Physics*, **122(5)**, 5539-5549, 2017.	• geomagnetic activity parameterized by Kp index (Heelis model) • Gasperini *et al.*, *JGR Space Physics*, **125(5)**, e2019JA027649, 2020.

TIE-GCM I **standard inputs**	**TIE-GCM II** **no tidal input**	**TIE-GCM III** **low EUV forcing**
ionosphere model with lower boundary at ~ 98 km altitude		
geomagnetic activity parameterized by Kp index (Heelis model)		
• climatological tidal input from GSWM model at lower boundary • EUV parametrization with F10.7 index	• zero tidal oscillations at atmospheric boundary • EUV parametrization with F10.7 index	• climatological tidal input from GSWM model at lower boundary • constant low EUV forcing (F10.7 = 40)

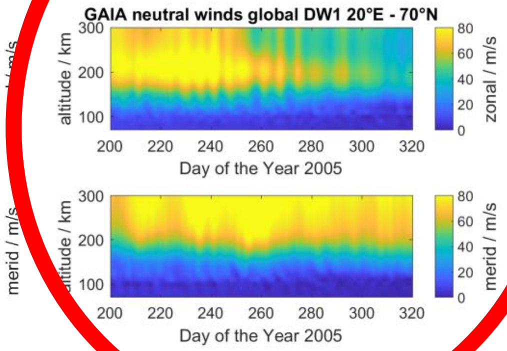
Global tidal modes in GAIA

➔ **Global Adaptive Spectral Filter** allows to distinguish tidal modes by wave number

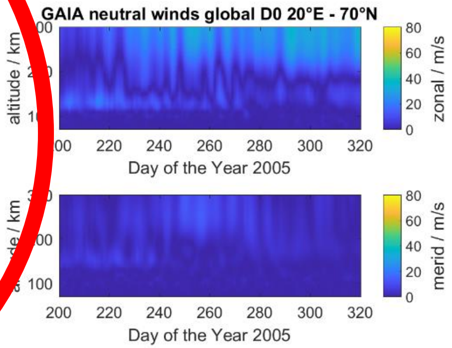
DW2


GAIA neutral winds global DW2 20°E - 70°N

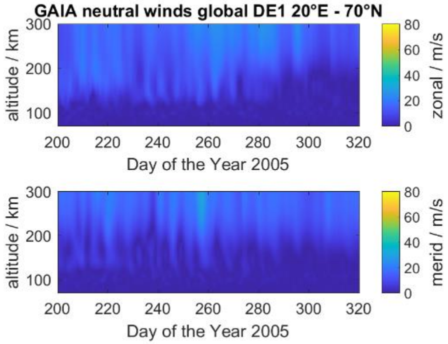
DW1


GAIA neutral winds global DW1 20°E - 70°N

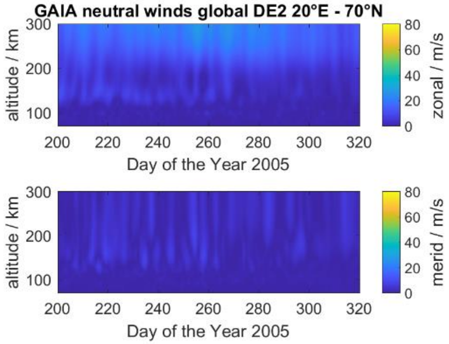
D0


GAIA neutral winds global D0 20°E - 70°N

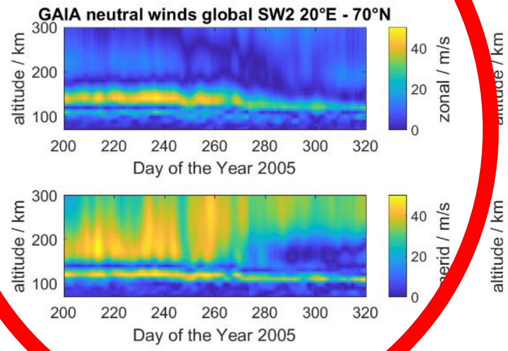
DE1


GAIA neutral winds global DE1 20°E - 70°N

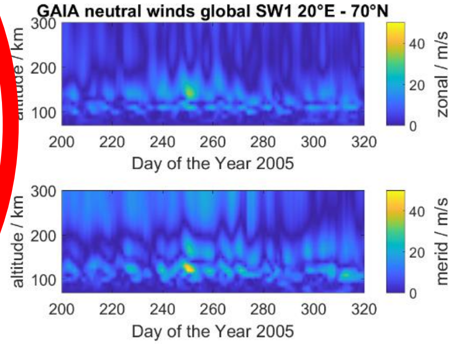
DE2


GAIA neutral winds global DE2 20°E - 70°N

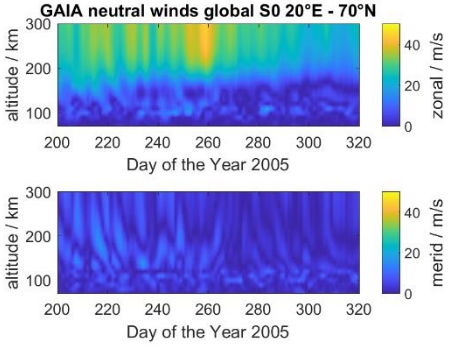
SW2


GAIA neutral winds global SW2 20°E - 70°N

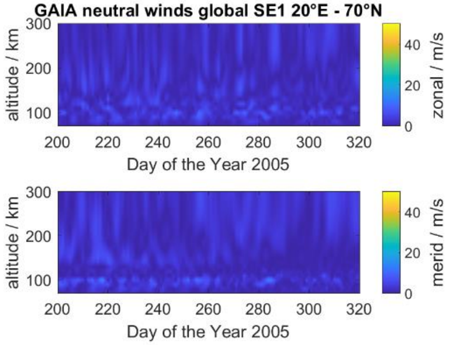
SW1


GAIA neutral winds global SW1 20°E - 70°N

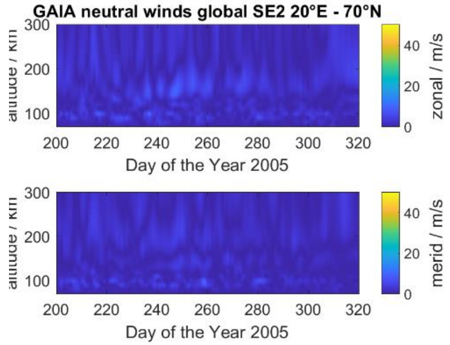
S0


GAIA neutral winds global S0 20°E - 70°N

SE1

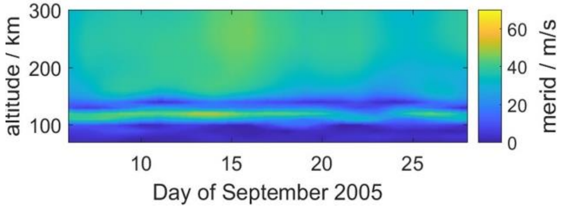
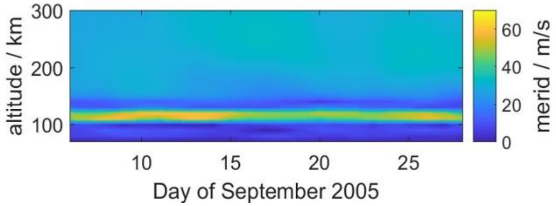
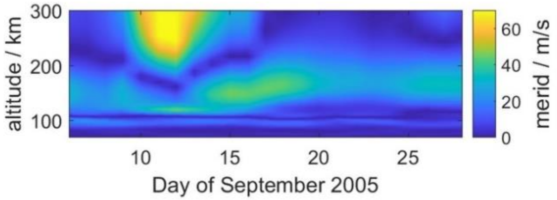
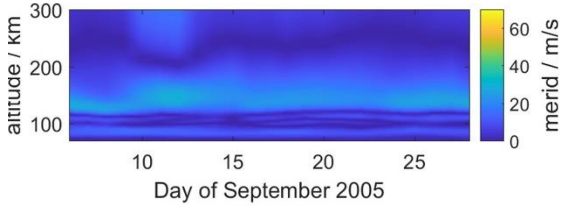
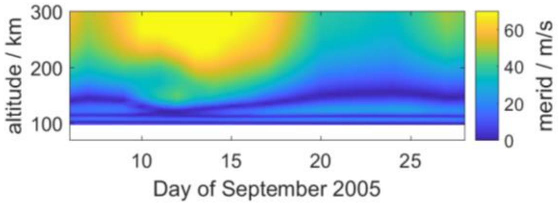
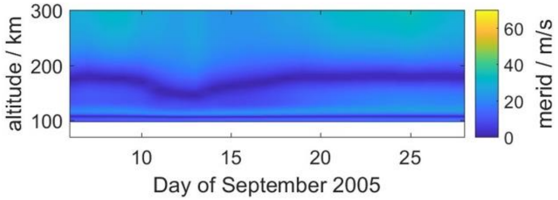
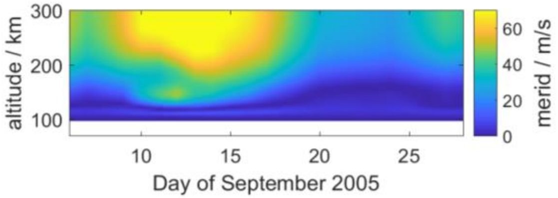
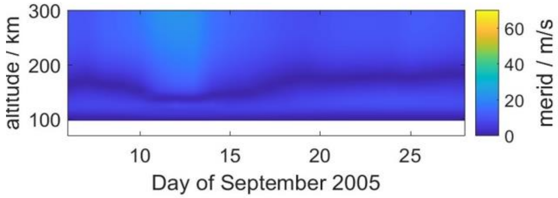
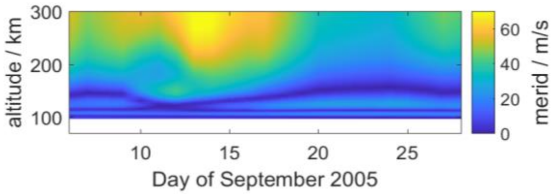
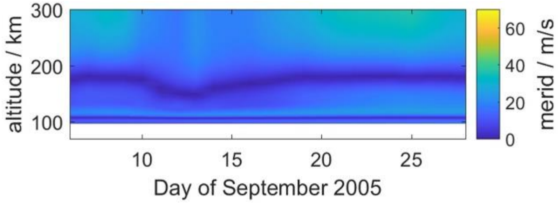

GAIA neutral winds global SE1 20°E - 70°N

SE2


GAIA neutral winds global SE2 20°E - 70°N

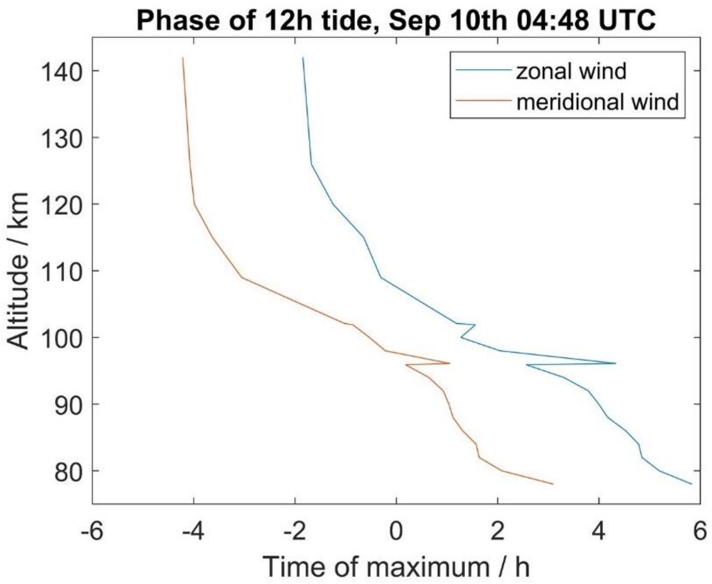
➔ migrating modes (DW1 and SW2) dominant

Model results – SW2 amplitudes

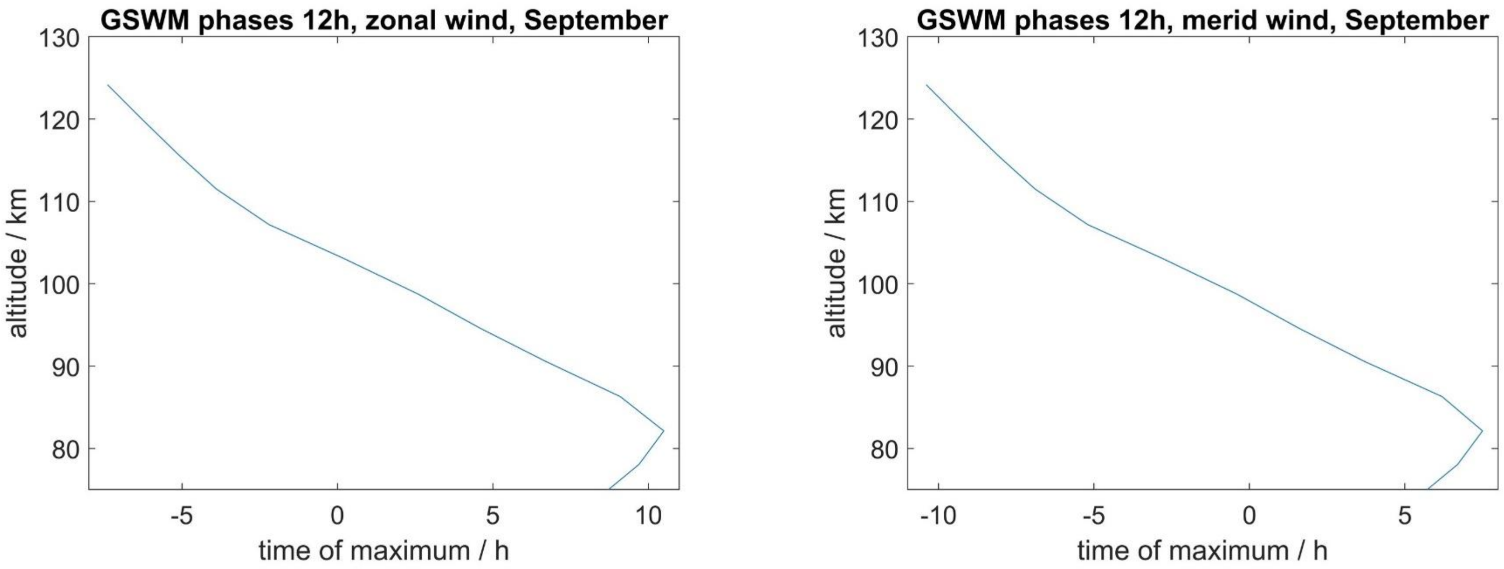
Model Run / Latitude	70° N (Tromsø)	44° N
GAIA **(low geomagnetic activity)**		
WACCM-X(SD) **(default)**		
TIE-GCM I **(default)**		
TIE-GCM II **(no atmospheric tides)**		
TIE-GCM III **(low EUV forcing)**		

Phase of semidiurnal tide in measurements and models

EISCAT and Meteor Radar



GSWM



- **EISCAT:** transition from steady phase progression to constant phase at $\sim 110 - 120$ km
  ➔ upward propagating tides are dominant up to the transition region
  ➔ in situ forced tidal oscillations are dominant above
- **GSWM:** steady phase progression up to ~ 125 km
  ➔ no in situ forced tidal modes included

Summary and Conclusion

1. Semidiurnal oscillations can be the dominant tidal mode at altitudes > 130 km
2. Model runs allow studying the impact of different forcing mechanisms
3. Semidiurnal oscillations at altitudes $\gtrsim 120$ km are *in situ* forced
   - ➔**ion convection** and **EUV absorption** contribute **significantly**
   - ➔**upward propagating atmospheric tides** might contribute **slightly**

For complete results:

F. Günzkofer *et al.*, “Determining the Origin of Tidal Oscillations in the Ionospheric Transition Region with EISCAT Radar and Global Simulation Data”, *J. Geophys. Res.*, **127**, 10, e2022JA030861, (2022)