Tidal variability in NOGAPS-ALPHA

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The purpose of this study is to demonstrate the advantages of one-hourly NOGAPS-ALPHA forecasts for tidal studies.

- Validation with TIMED.
- Tidal evolution, January 2009.
- Pertinence to ionospheric coupling.
- Relationships to PMC.

Why study tides?

Tides are strong-amplitude features of the tropical mesosphere and lower thermosphere (u’ ~ 20 m/s, v’ ~40 m/s) .

Vertically propagating tides transport energy and momentum vertically, and drive the mean flow (~20 m/s/day in the tropics).

Tides carry imprints of tropospheric variability (e. g., ENSO) to high altitudes (Lieberman et al., 2007).

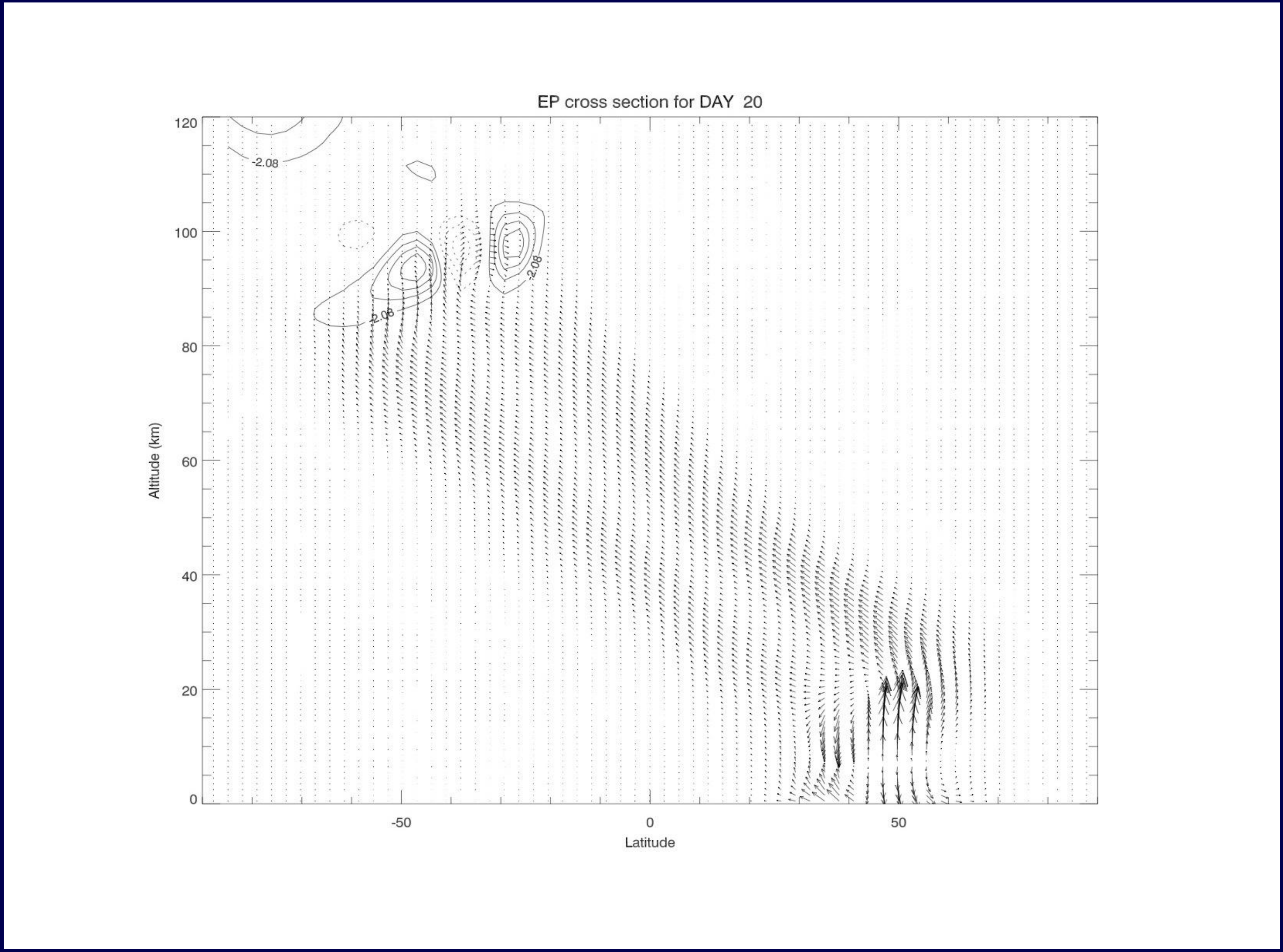
Tides are agents of interhemispheric coupling via their interactions with PW.

Middle/upper atmosphere tidal variability

There is an emerging need in the middle/upper atmosphere disciplines to define global-scale tides on relatively short timescales (< week).

For example:

- Mesospheric tides in single-point data records at high latitudes exhibit variability on day-day-day and weekly timescales (Smith et al, 2007). This behavior is thought to be linked to interactions with wintertime planetary waves.



SW1 forced in Ortland PE model from interaction of PW1 and SD2 radiates upward, and across the equator.

- **There have also been studies showing ionospheric responses to SSW (Goncharenko et al., 2010). It is hypothesized that products of tide-PW interaction propagate above 100 km, perturb electric fields, and modulate plasma densities (Liu et al, 2011).**

- **Traveling PW and migrating tides modulate PMC frequency and occurrence (Merkel et al., 2009; Stevens et al, 2011).**

Understanding tidal effects on PMC is important for interpreting trends in single point measurements (noctilucent clouds), and in global measurements made at limited local times.

Observational Challenges

- **Tidal definitions from precessing satellites (e. g., TIMED) require at least 60 days. *However, time scales involved in variability linked to SSW, and to PMC variability, are much shorter.***
- **Areas of interest (such as high latitudes where PMC occur) are outside the TIMED observing range (e. g., during yaw periods not favoring latitudes > 52°).**
- **Distributed reanalyses (e. g., MERRA, GEOS) do not extend into the upper mesosphere where tidal amplitudes are significant.**

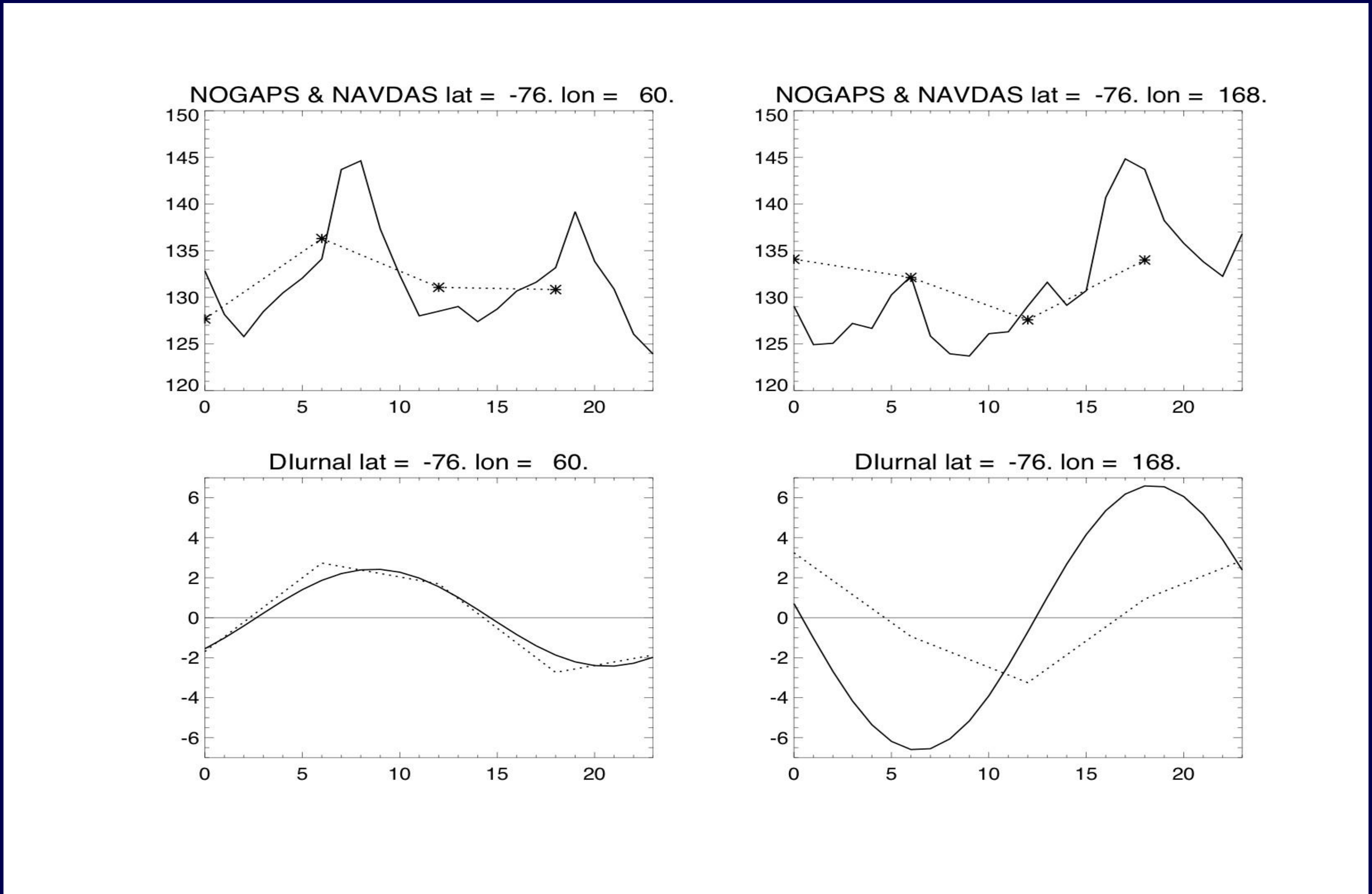
NOGAPS-ALPHA

Recently, a new version of the NOGAPS-ALPHA has been developed that is initialized by the assimilation (NAVDAS) every 6 hours, but uses the physics-based forecast model to provide hourly output up to 15 sh.

NAVDAS is assimilating mesospheric temperatures (SABER and EOS MLS), and realistically describes SSW and key MLT phenomena such as the 2-day wave, and migrating diurnal tides (Coy et al. 2009; McCormack et al., 2009).

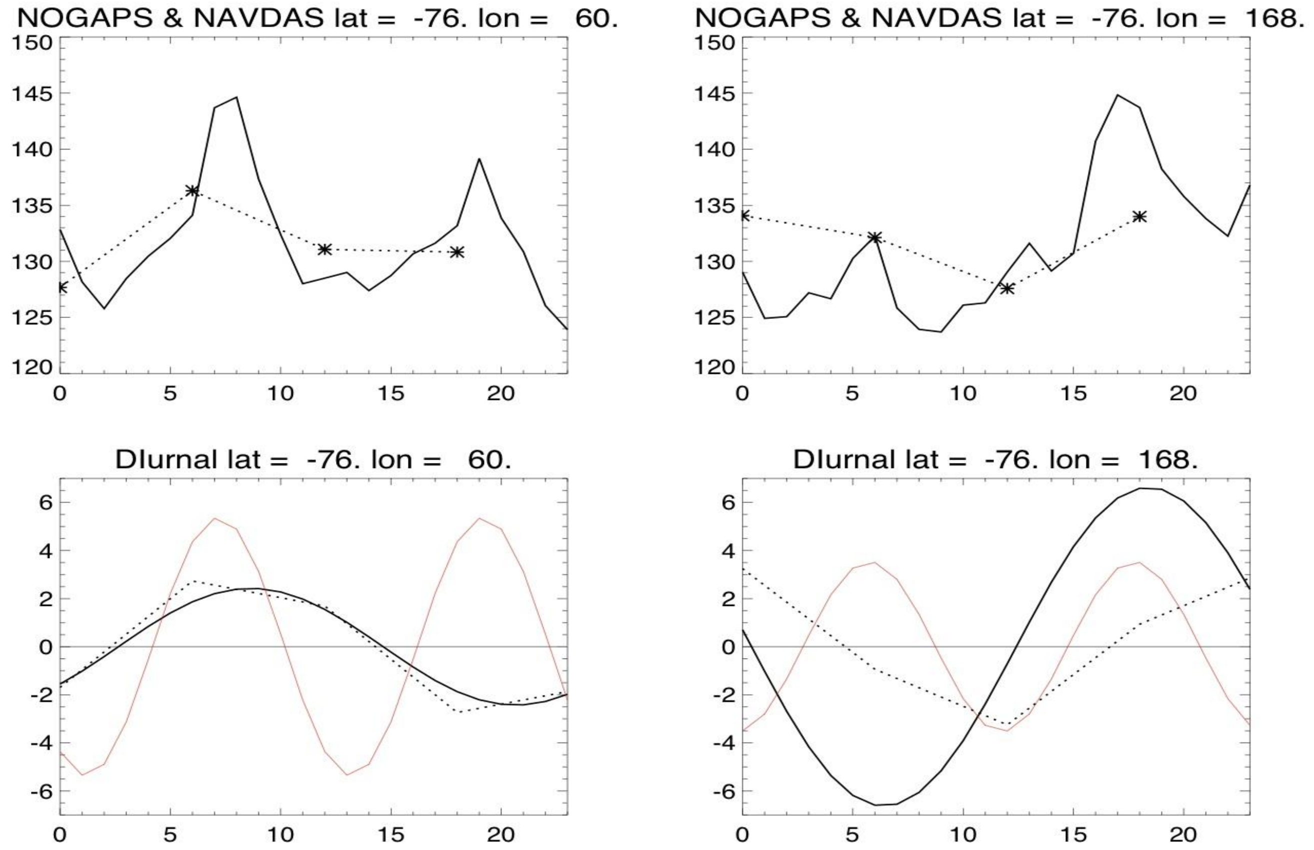
The hourly product allows global definitions of diurnal, semidiurnal and higher-order tidal harmonics on a day-to-day, or at least week-to-week basis.

NOGAPS versus NAVDAS 24-hour trace

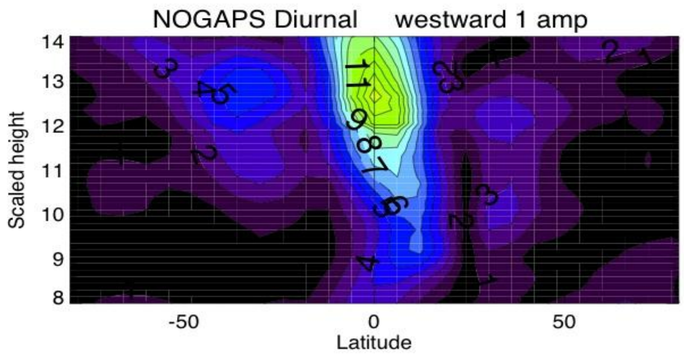


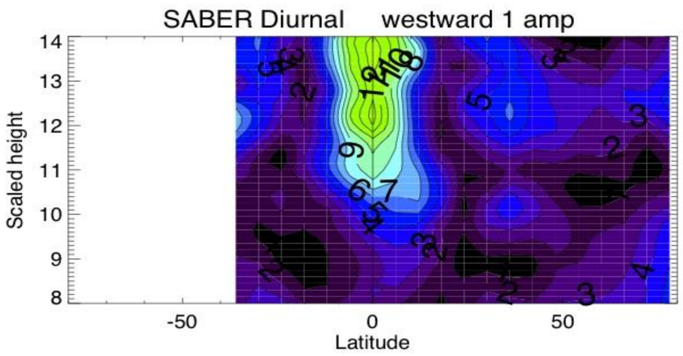
Accuracy of diurnal tide in NAVDAS depends upon magnitude and phasing of the semidiurnal tide.

NOGAPS versus NAVDAS 24-hour trace

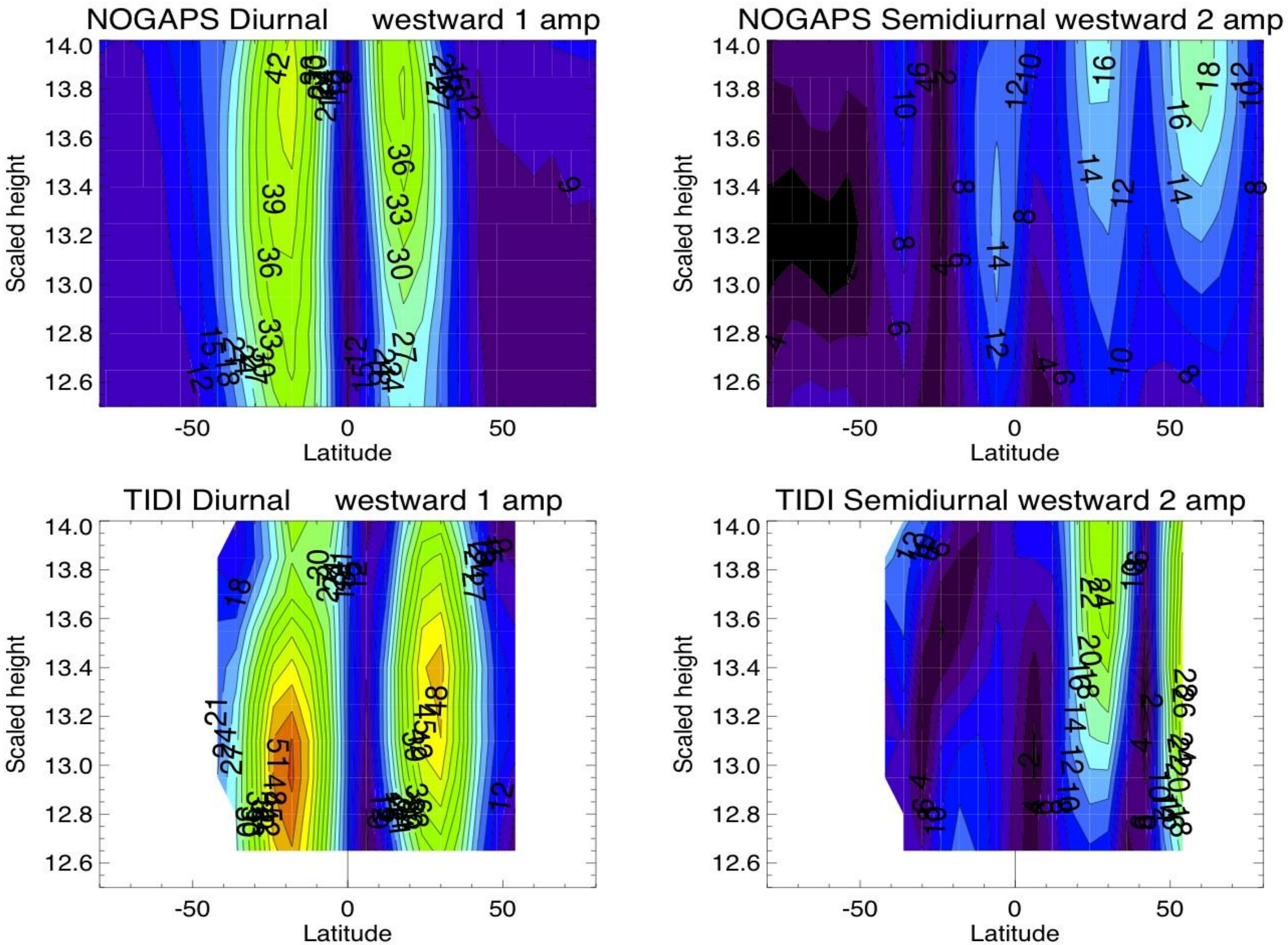


Accuracy of diurnal tide in NAVDAS depends upon magnitude and phasing of the semidiurnal tide.





Data averaged between January 12-March 15, 2009.



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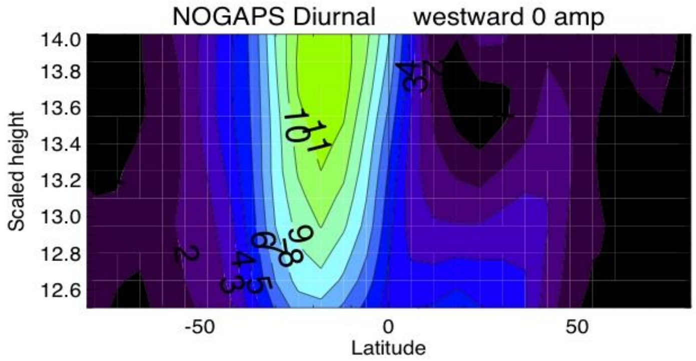

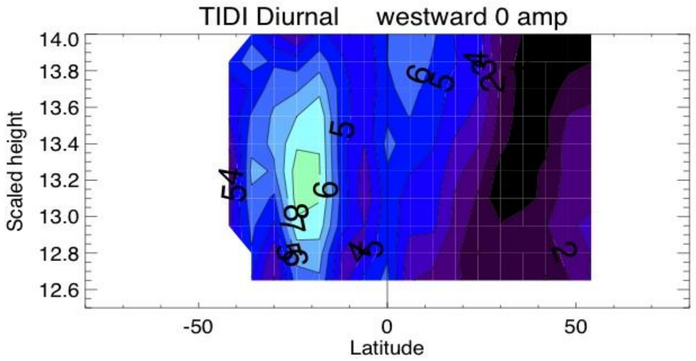

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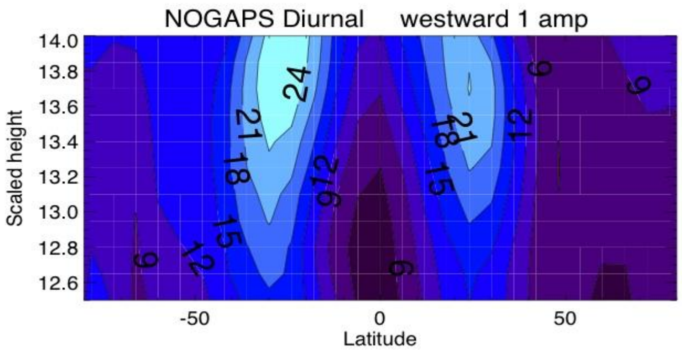
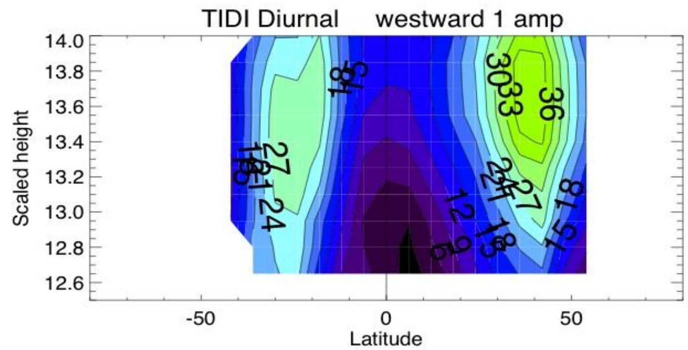




Data averaged between January 12-March 15, 2009.

Tide-PW interaction

Advective forces between tides and strong-amplitude PWs have been proposed as leading sources of nonmigrating tides during solstices (Vial and Teitelbaum, 1991). This process has been invoked to explain tidal variations at high latitudes, and in the Ionosphere.

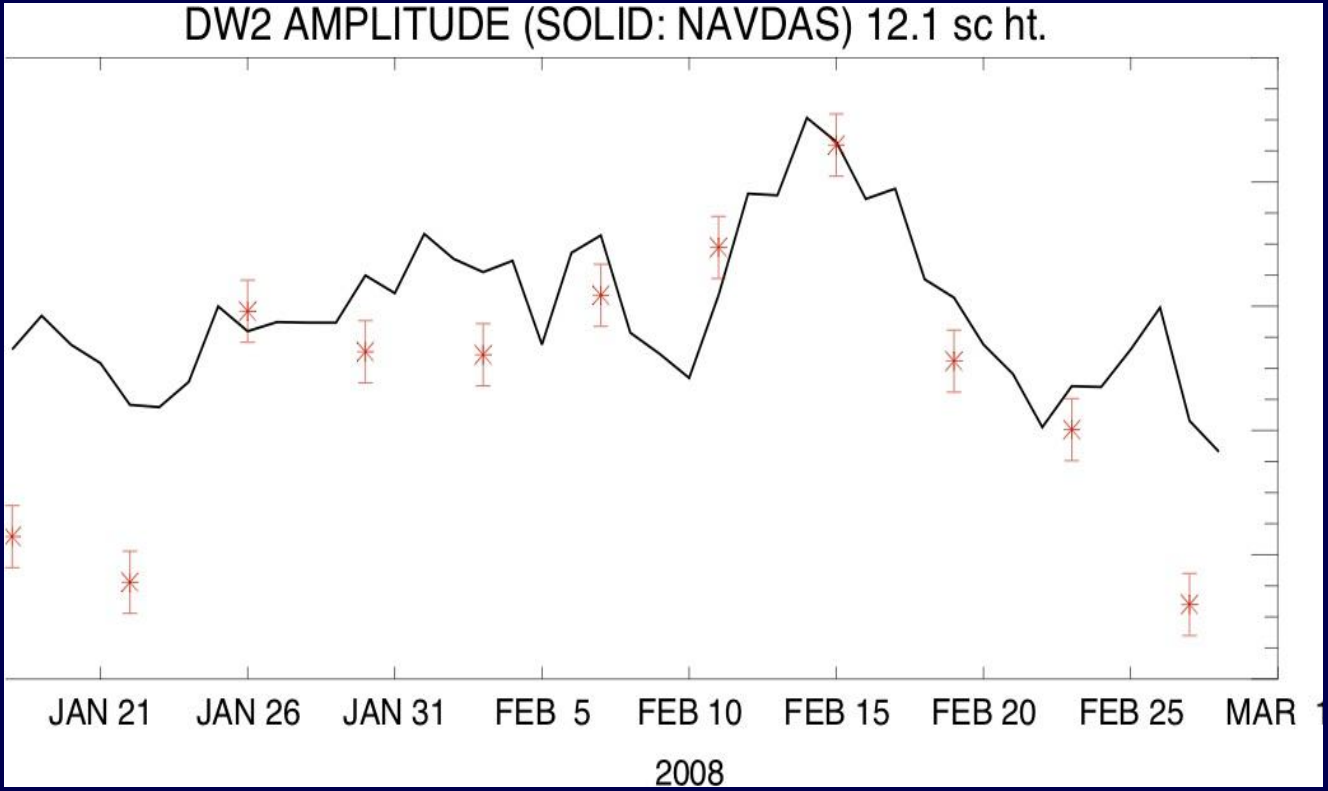
The most common of these harmonics are (1,0), (1,2) resulting from diurnal tide-PW1 interaction, and (2,1) and (2,3) resulting from semidiurnal tide-PW1 interaction.

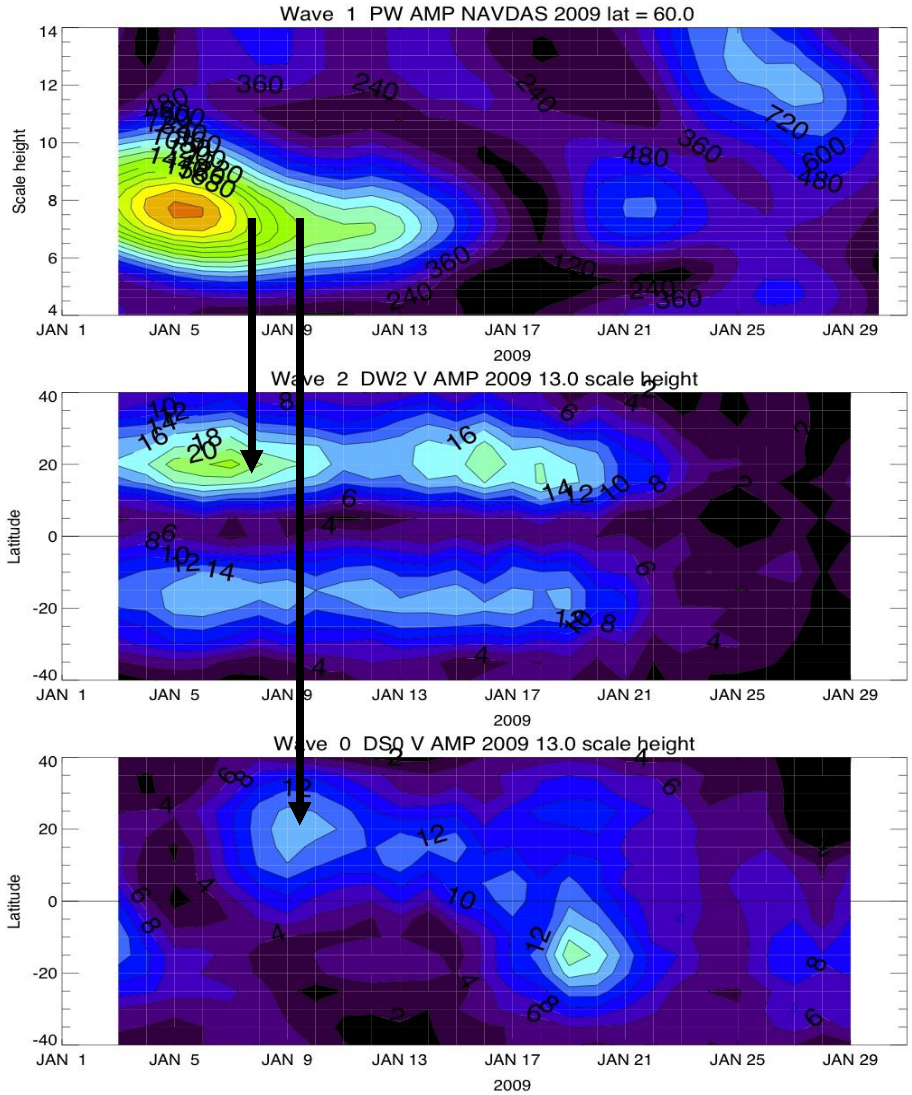
There is substantial numerical evidence (Hagan and Roble, 2001; Liu et al., 2011), ***but very little observation support for tide-PW coupling mechanism*** **(Oberheide et al., 2002; Lieberman et al. 2004).**

The NOGAPS hourly product makes is possible to explore the evolution of tides concurrently with PW.

Short-term tidal evolution

Global-scale tidal definitions have been made in January 2008 SABER T using deconvolution methods developed by Oberheide et al. (2002). These compare well with tides derived from NAVDAS. (Hourly NOGAPS-ALPHA unavailable in 2008.)

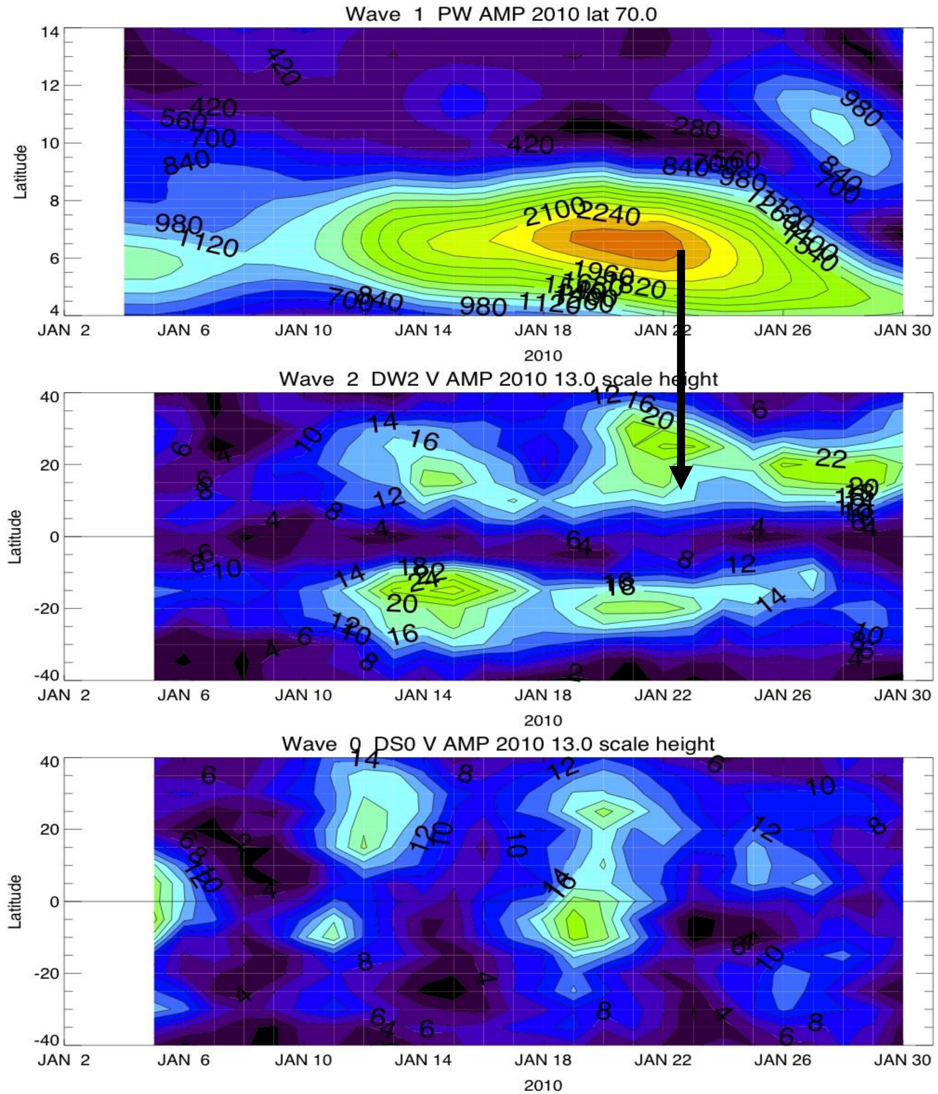




Stratospheric PW 1 was very strong in the NH in early January 2009. (NAVDAS)

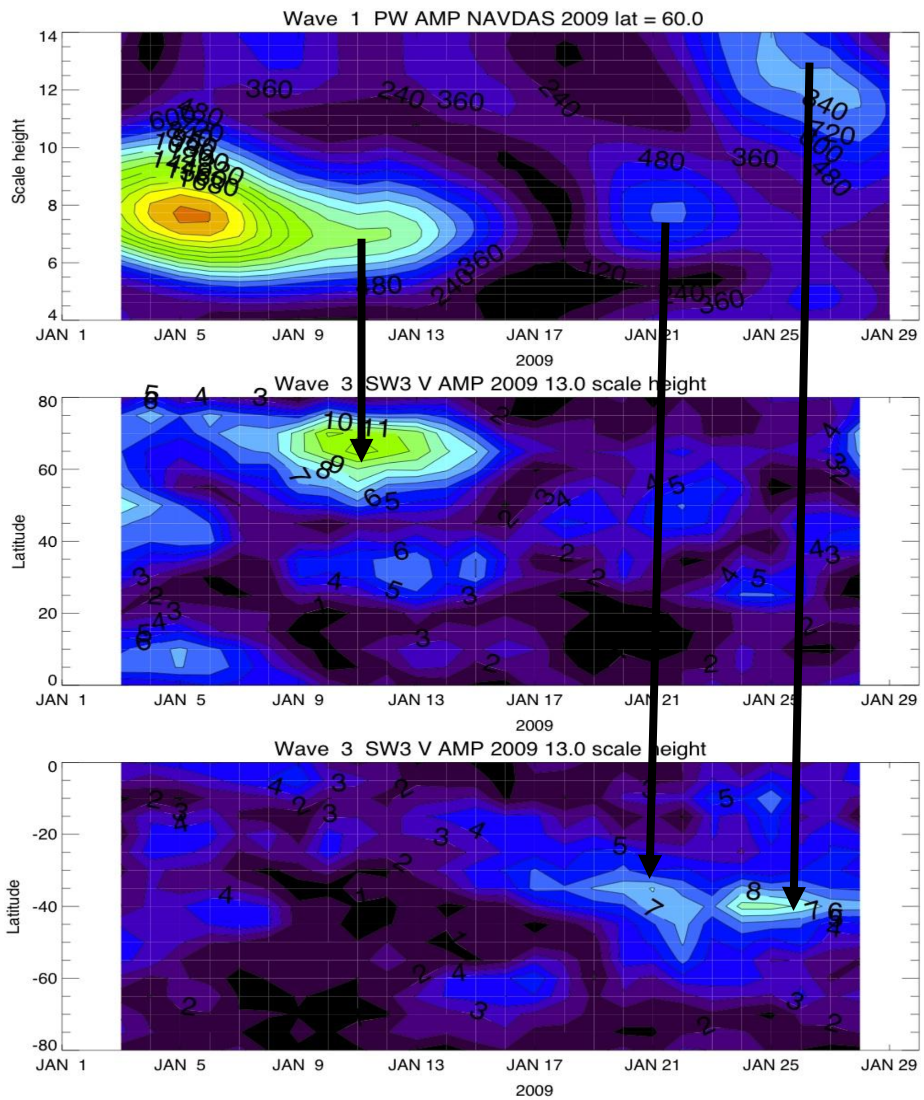
DW2 and DS0 are hypothetical products of migrating diurnal (1,1) and PW 1 interaction. (NOGAPS-hourly forecast)

DW2 and DS0 increases with PW in early January. Note: these waves have other, non-PW sources. (NOGAPS-hourly forecast)



Stratospheric PW 1 was very strong in the NH in mid-January 2010. (NAVDAS)

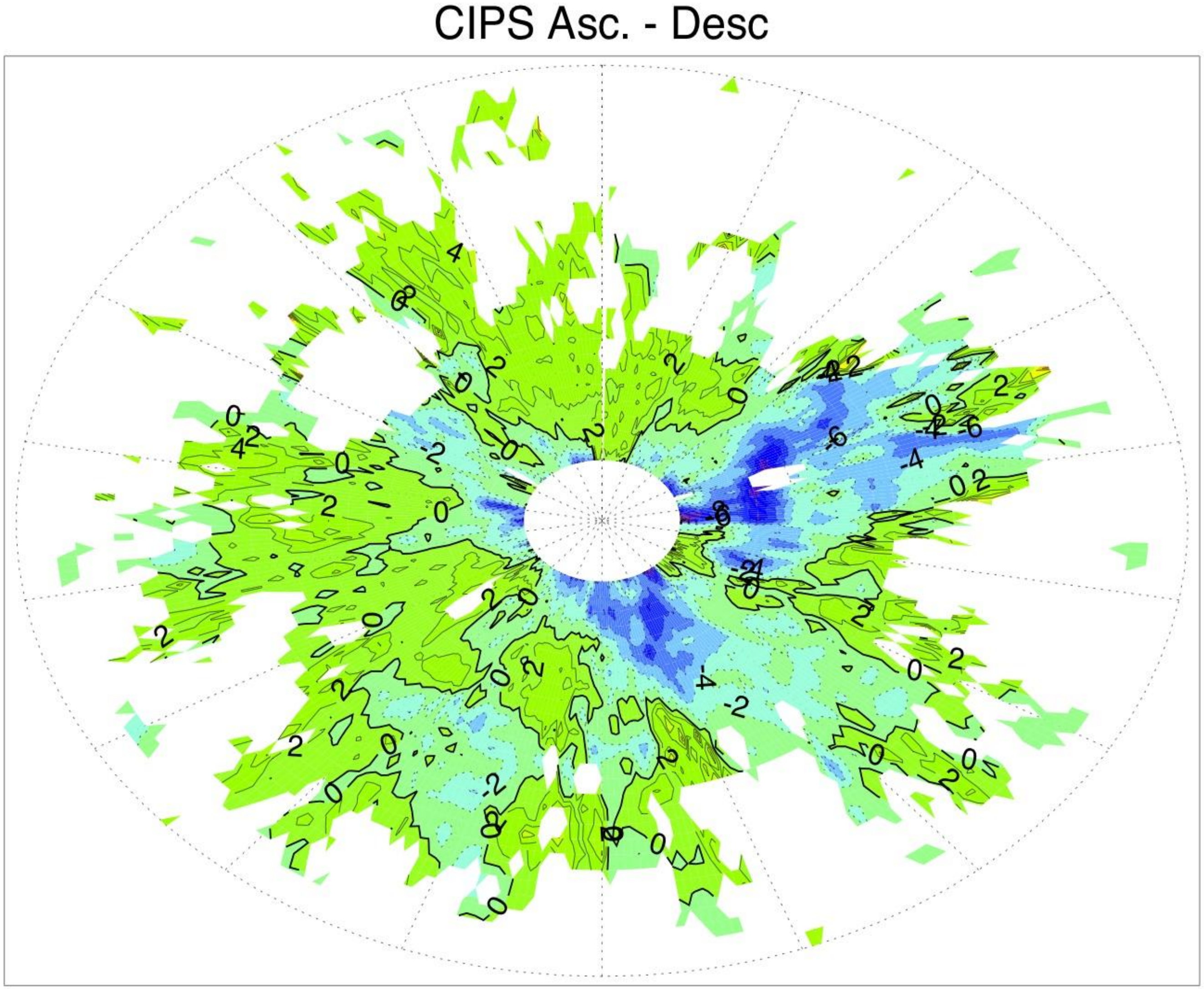
DW2 and DS0 increase with PW in mid-January. These waves have other, non-PW sources. (NOGAPS-hourly forecast)



Stratospheric PW 1 was very strong in the NH in early January 2009.

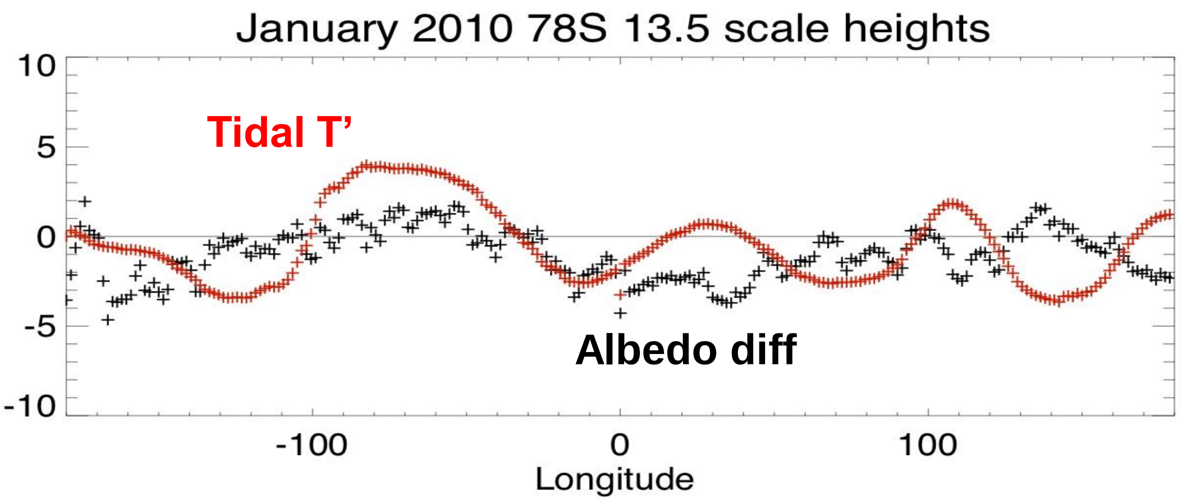
SW3 is a hypothetical products of migrating semidiurnal (2,2) and PW 1 interaction.

SW3 increases following PW in early January.



CIPS ascending-descending node albedo, June 20, 2008. (10^{-6} sr^{-1})

CIPS & T



CIPS ascending-descending node albedo differences, January 1-10, 2010, are in antiphase with temperature perturbations computed from diurnal and semidiurnal tides (derived from NOGAPS-ALPHA hourly forecast output), and sampled identically to CIPS.

Summary

•NOGAPS-ALPHA hourly fields are an excellent (and perhaps only) resource for short-term tidal analysis at high latitudes and high altitudes (> 60 km),

•Diurnal tides in NOGAPS ALPHA agree well with SABER T and TIDI (u,v). Semidiurnal tides show more structure in TIMED observations.

•Utility of short-term tidal definitions demonstrated during periods of PW and tidal enhancement. Further diagnostic-modeling-needed to link PW-tide advective forcing to interaction products.

•PMC tidal proxies in antiphase with tidal T' in January 2010.

Thank you for your attention.

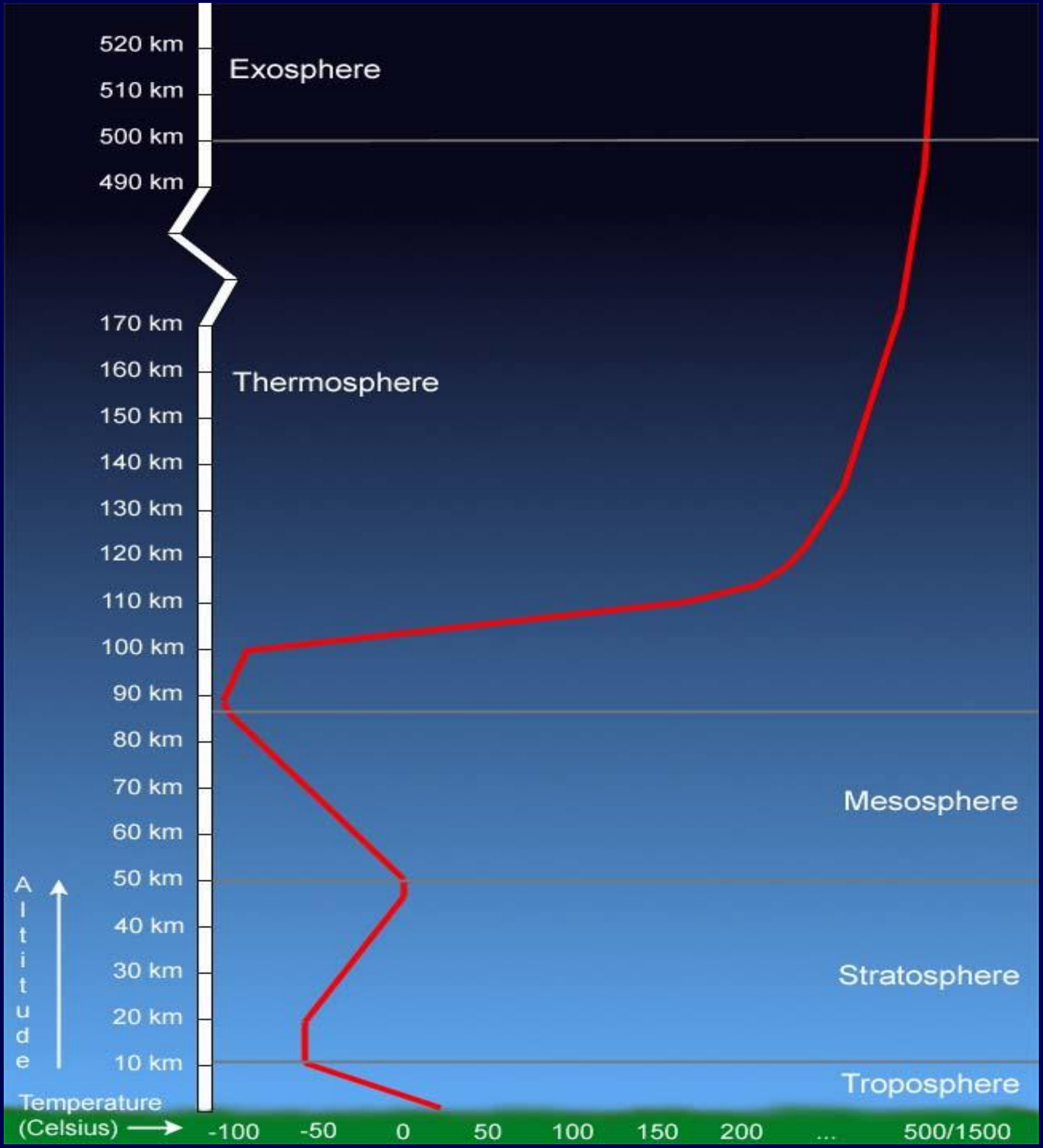
Additional slides

Migrating tides and traveling PW are known to modulate PMC frequency and occurrence. Understanding their effects on PMC are important for interpreting single point measurements (aka *noctilucent* clouds), and global measurements made at limited local times.

Tides may be also be agents of SSW-ionospheric coupling:

Tide-PW interaction generates "child waves" (nonmigrating tides) that propagate above 100 km and perturb electric fields.

These perturbations lead to vertical displacements within the ionosphere, and modulations of plasma densities (Liu et al, 2011).

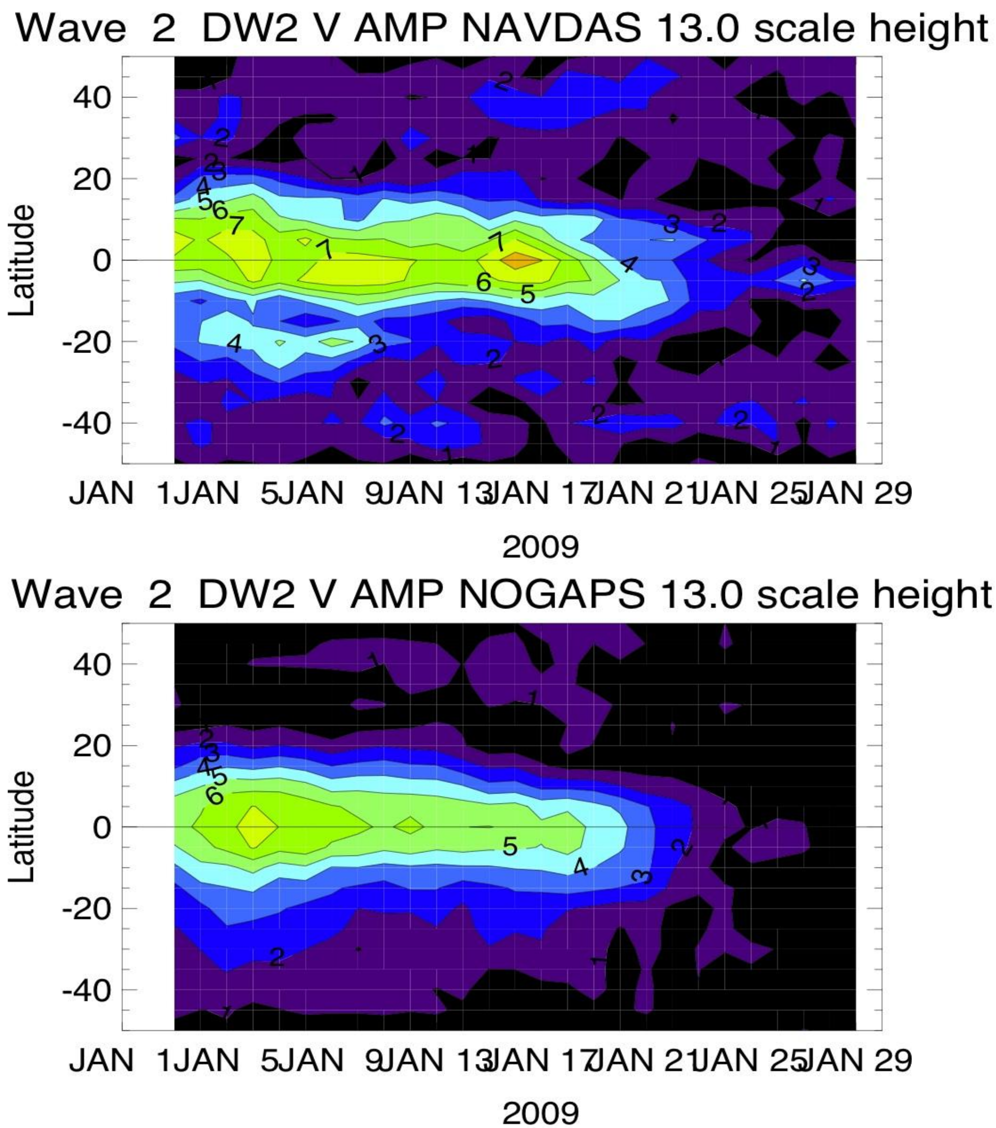


EUV heating: 10 W/kg

O_2 heating: 1W/kg

O_3 heating: 0.1 W/kg

H_2O_v + LH: 0.01 W/kg


Wave 2 DW2 V AMP NAVDAS 13.0 scale height
Latitude
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20
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-20
-40
JAN 1
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Wave 2 DW2 V AMP NOGAPS 13.0 scale height
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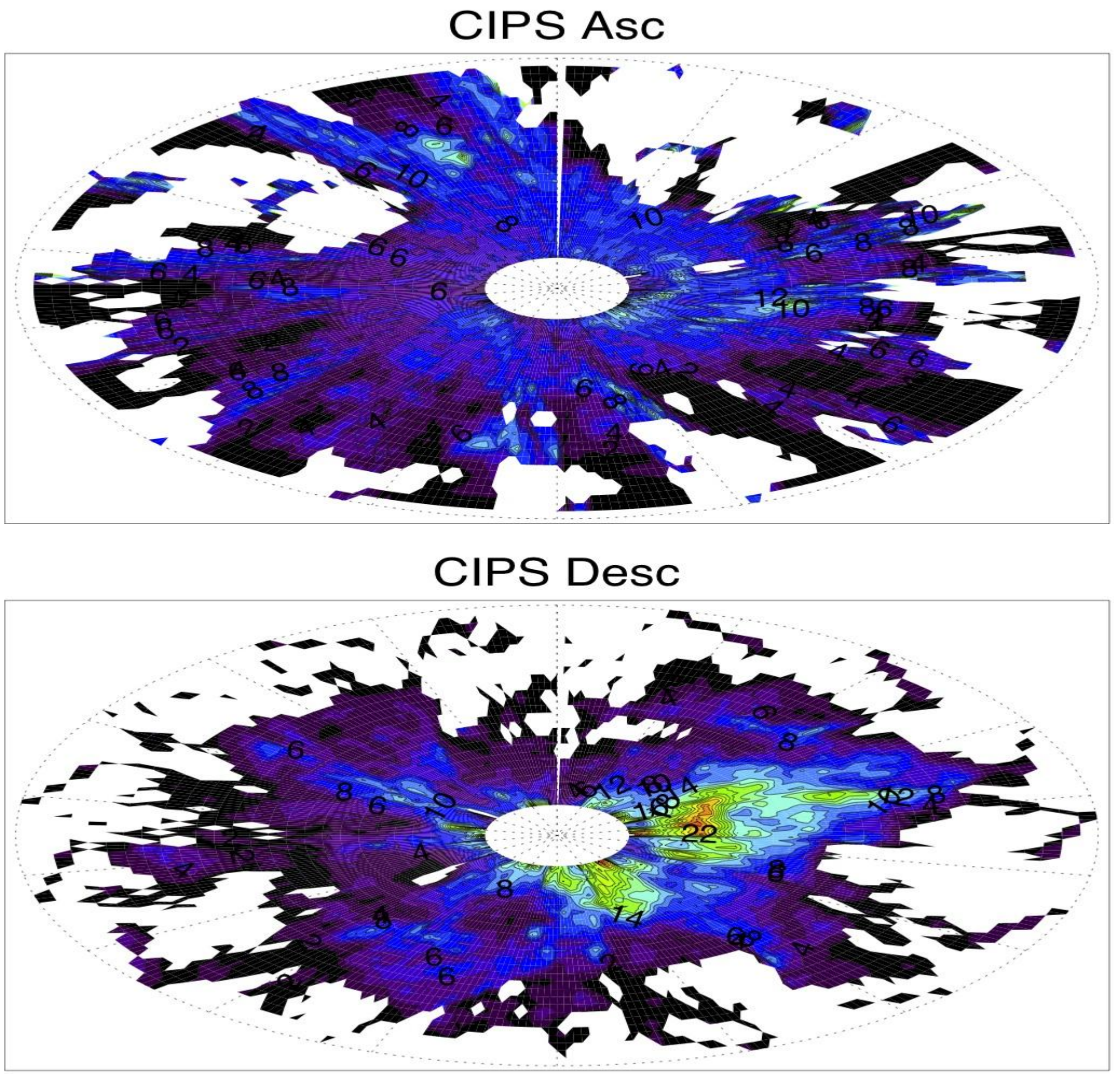

CIPS ascending node albedo, June 20, 2008

CIPS descending node albedo, June 20, 2008