Short-term tidal variability in the ionospheric dynamo region over one solar cycle

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Objective

• Make the step from “tidal climate” to “tidal weather”
  → How to improve the ~monthly time resolution of tides from satellites?

Outline

• Short-term tidal diagnostics of TIMED/SABER temperatures
  → tidal “deconvolution” instead of Fourier fits

• Tidal “weather” on intra-seasonal (MJO) and PW time scales
  → DE3 (mainly), DW2, DW1
  → Comparative analysis with WACCM-DART, NOGAPS-ALPHA, eCMAM30
Spectral fit -> tidal “climate”

Need 60 days of observations (full local solar time coverage) for tidal spectra.

Useful for
- Solar cycle
- QBO, ENSO
- Seasonal

Tidal “climate”, shorter time scales not resolved
Tidal “deconvolution” of SABER in a nutshell

Wave-1 component of ASC-DSC difference
24 January 2008

Local time difference = 9 h
→ No PWs, GWs, mean
→ Tides: DW2, D0, SW3, SW1, TW4, TW2
→ Same concept for other tidal components

equator

Assumptions

• Semidiurnal and terdiurnal tides can be neglected in a 1st order
  ➔ superposition of two diurnal tides, error analysis

• Tidal upward propagation ➔ can solve for DW2 and D0 amps and phases
  the vertical structure of the observed wave-1

Mathematical details: Oberheide et al., JGR 2002

Did similar studies for CRISTA, LIMS, HRDI, WINDII: (Oberheide et al., JGR 2002; Lieberman et al., JGR 2004, 2013)
Tidal deconvolution -> tidal “weather”

DE3 amplitude @ 100 km, 5-day running mean

Standard Deviation w.r.t. monthly mean, Equator
Tidal “weather” on MJO and PW time scales

DE3, 100 km, equator
DE3 and MJO

Tidal Heating Spectra from MERRA for each day

Bandpass filtered DE3 signal at fixed local time at 0° longitude averaged +/- 10° latitude

MERRA heating @ 8 km, 12 LT
SABER T @ 100 km, ~20 LT

PRELIMINARY
Effect of mean wind not yet studied
Tidal “weather” on PW time scales

Tidal deconvolution (PW time scales)

DE3 amplitude @ 100 km, 5-day running mean

DE3 amplitude @ 100 km, 61-day running mean

Spectral fit (seasonal)
WACCM-DART vs. deconvolution – DE3, 100 km

SABER deconvolution

WACCM-DART, assimilates MLS and SABER temp. from ~15 – 100 km

Standard deviation in the 40-member WACCM+DART ensemble

Pedatella et al., JGR Space Physics, 2016JA022528
DE3 tidal “weather” in the F-region ionosphere

High correlation (0.72) between SABER DE3 (T, 100 km) and COSMIC \(N_m F_2\)

Pedatella et al., JGR Space Physics, 2016JA022528
NOGAPS-ALPHA vs. deconvolution – DW2, 85 km

NOGAPS, U.S. Navy operational forecast model, assimilates MLS and SABER temperatures in MLT region

Deconvolution, SABER

SSW wind reversal

SPW enhancement before SSW, SPW1 + DW1 -> DW2

Lieberman et al., JGR Atmos., 2015JD023739
**eCMAM vs. deconvolution – DW1, equator**

SABER, 100 km

eCMAM30, nudged to ERA-Interim <1 hPa

Similar variability on weekly and 3-weekly scales

Will allow us to study statistical characteristics of short-term variability and causes
Summary and conclusions

Tidal deconvolution is a useful step towards “tidal weather”

- Tidal “weather” variability is persistent and of the same order than the seasonal “climatological” tides
- Assimilation and nudged models (NOGAPS, WACCM-DART, eCMAM30) consistent with SABER

Indication for MJO (intra-seasonal) impact

- Preliminary results suggest a close connection to MJO in tidal heating
- Would imply an MJO signal in F-region ionosphere, due to dynamo action
- COSMIC NmF2 shows short-term DE3 variability consistent with SABER

Substantial variability on PW time scales

- Enhanced DW2 prior to SSW (DW1 + SPW1)
- DE3 variability due to combination of tropospheric forcing, zonal mean atmosphere and wave-wave interactions

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Backup Slides
Sources of DE3 tidal “weather”

High correlation (0.72) between SABER DE3 (T, 100 km) and COSMIC "wave-4" (Nm F2).

-Pedatella et al., JGR Space Physics, 2016JA022528
Tidal “deconvolution” of SABER

- Squared Wave-1 amplitude $T_0^2$ depends on amplitudes of DW2, D0 and a phase factor
  - can be evaluated at extrema and midpoints.

- Provides phase factor $\Psi$ that is a function of
  - Local time difference between ASC & DSC orbit nodes, phase difference between DW2 and D0

- This and the known Wave-1 phase allows for exact solutions at extrema and midpoint levels when assuming upward propagation
  - Amplitudes and phases of DW2 and D0 for a single day

*Mathematical details: Oberheide et al., JGR 2002*