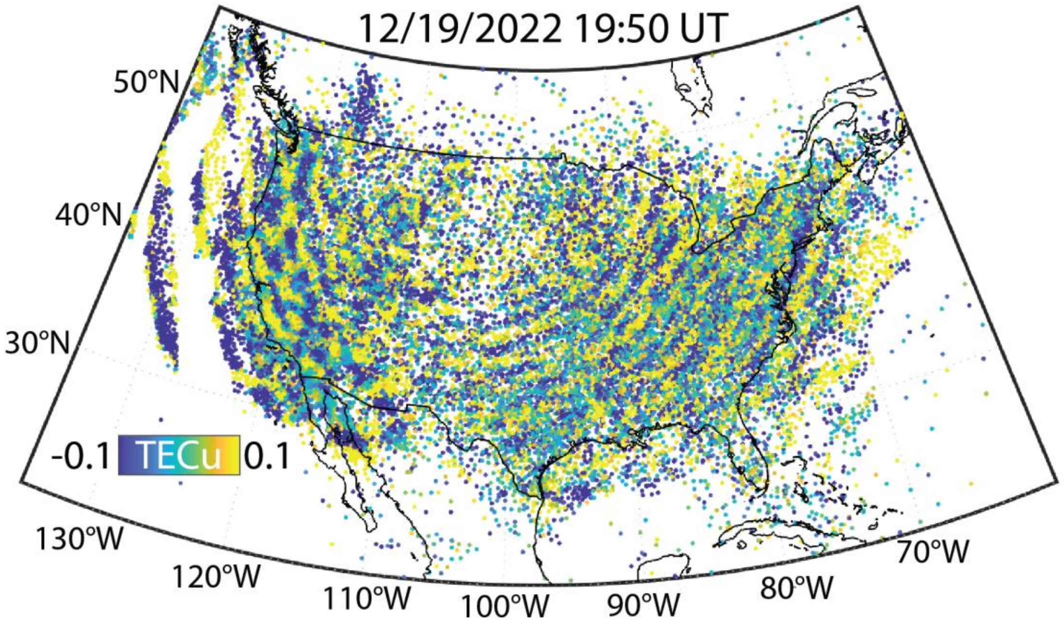
Grand Challenge A: Impact of Terrestrial Weather on the Space Weather of the Ionosphere-Thermosphere-Mesosphere



Jens Oberheide
Clemson University

and the convener team
S. Debchoudhury, L. Goncharenko, G. Liu, S. McDonald, F. Sassi, J. Zhang, D. Aggarwal, B. Bergsson, M. Jones, Z. Qiao

CEDAR 2024, Monday, June 10, 10:50-11:05

Why this GC Workshop?

Advance the understanding of whole atmosphere interconnections between terrestrial and space weather through combined modeling and observations across different spatial and temporal scales

- Some progress in the past but significant gaps in understanding remain
- Ongoing coordinated programs through NASA/LWS, NSF/ANSWERS, ISSI, …
- <u>Join forces with NSF/CEDAR community</u> to synergistically enable a transformed view of terrestrial weather – space weather connections
- Define state-of-the-art in the light of EZIE, DYNAMIC, GDC

Specific Goals

Reveal the critical links between weather and space weather through

1. Quantify the variability of relevant parameters on different spatio-temporal scales: what are the **observational and model baseline data** we have?
2. Develop a **set of metrics** to evaluate data-model comparisons
3. Evaluate state-of-the-art models and assess the **impact of data assimilation** on model performance
4. Identify the **physical mechanisms** that connect terrestrial with space weather

A few examples

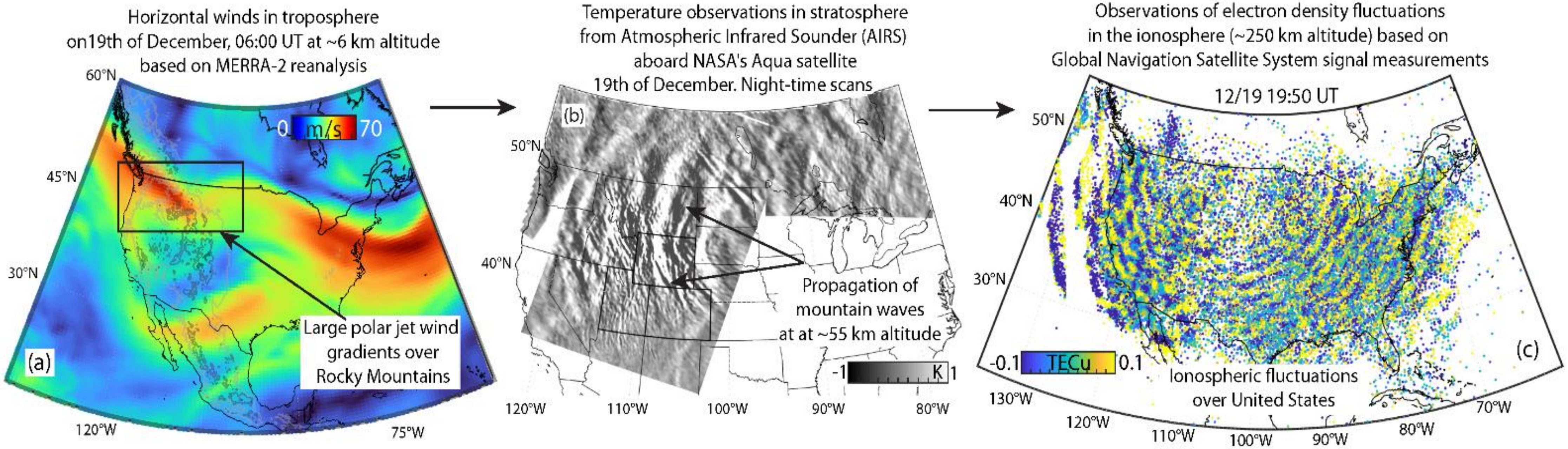
Local/regional & minutes/hours
Acoustic & gravity waves

Severe cold weather outbreaks directly impact the space environment

MERRA-2
troposphere

AIRS
stratosphere

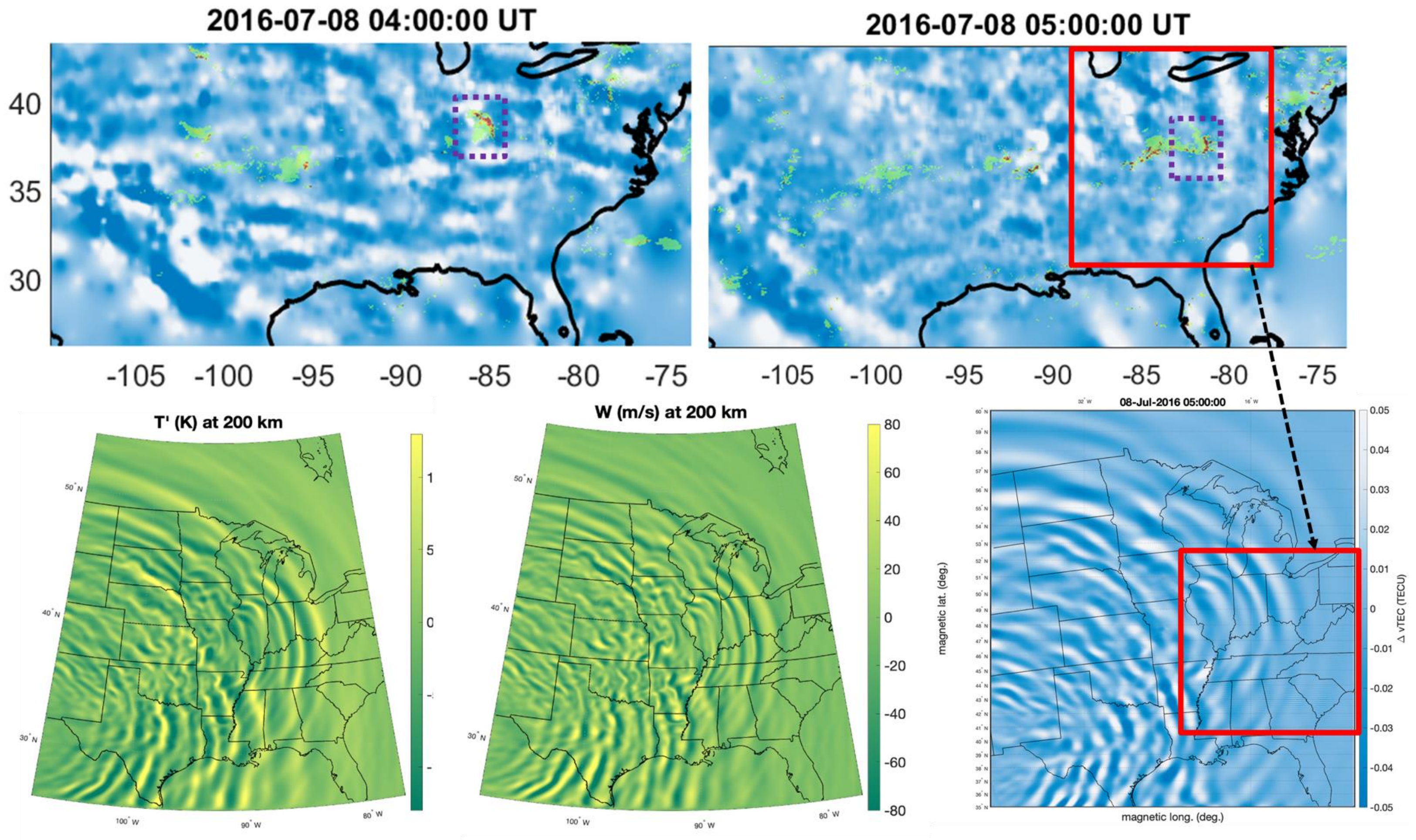
GNSS
ionosphere



The North American winter storm event in December 2022 excited a wide spectrum of acoustic and gravity waves that made their way up to the ionosphere

Inchin et al., 2024JA032485

Severe thunderstorm (derecho) impacts on the IT system



Observation

MAGIC-GEMINI modeling

High resolution modeling reliably captures the morphology and spatio-temporal scales of acoustic and gravity waves in the IT system

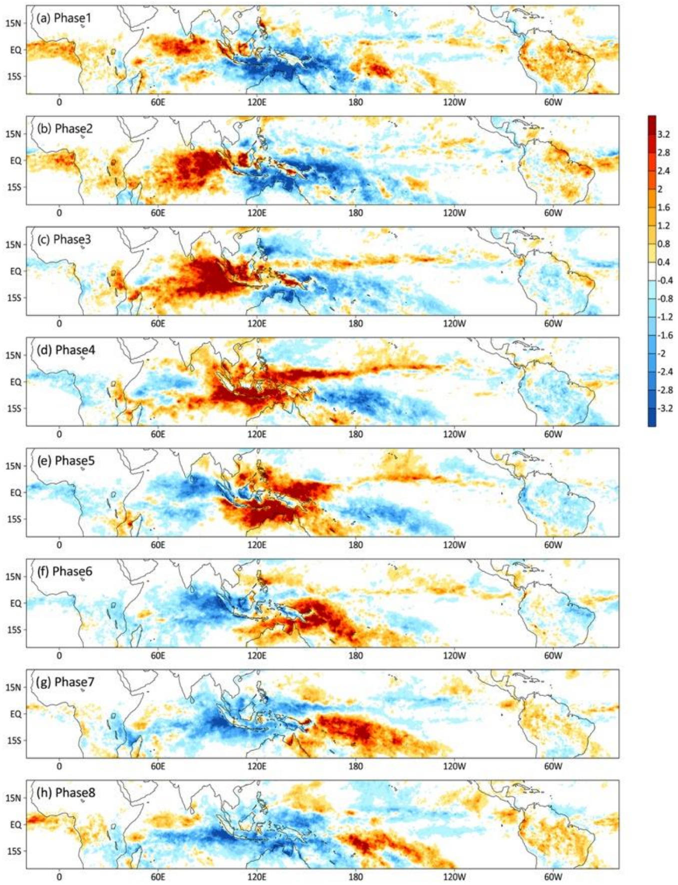
Figure courtesy of Shantanab Debchoudhury

A few examples

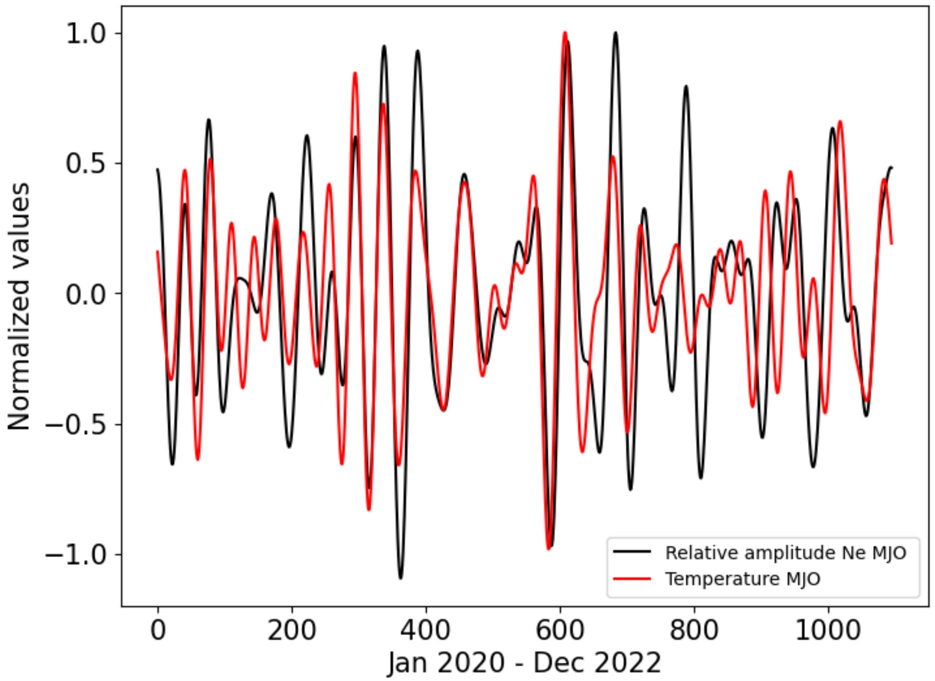
Mesoscale/global & hours/days
Tides & planetary waves

Recurring weather patterns modulate the F-region plasma through tides

Madden-Julian Oscillation
in rainfall, 30-96 days



Jiang et al., 2019JD030911



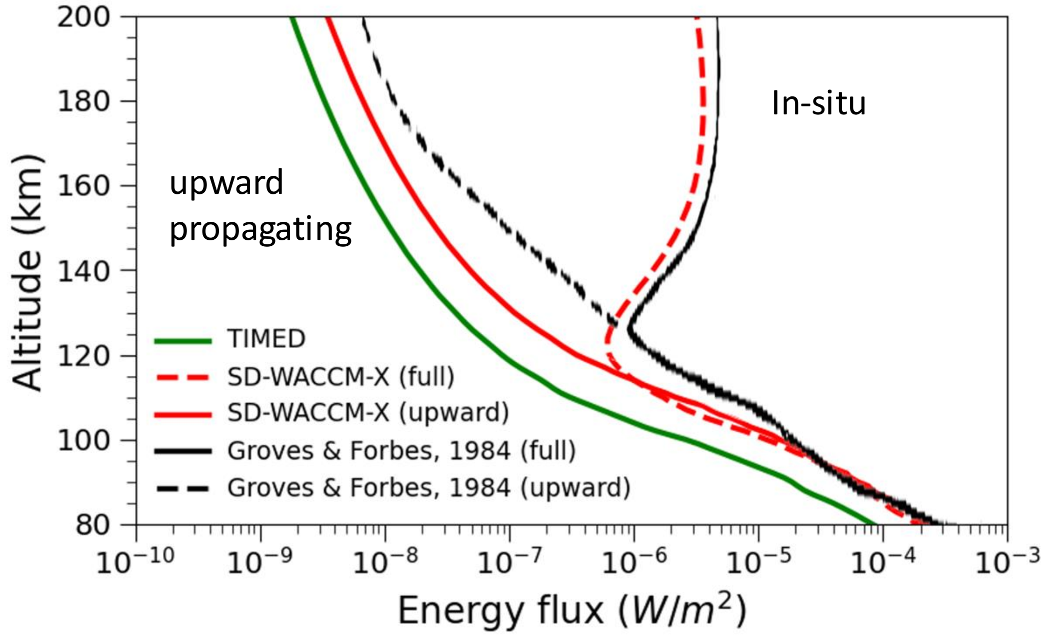
MJO in DE3 tide from **SABER**
in the E-region dynamo
after Kumari et al., 2021JD034595

MJO in F-region **electron density**
from **COSMIC-2** at 15N MLAT
courtesy of Deepali Aggarwal

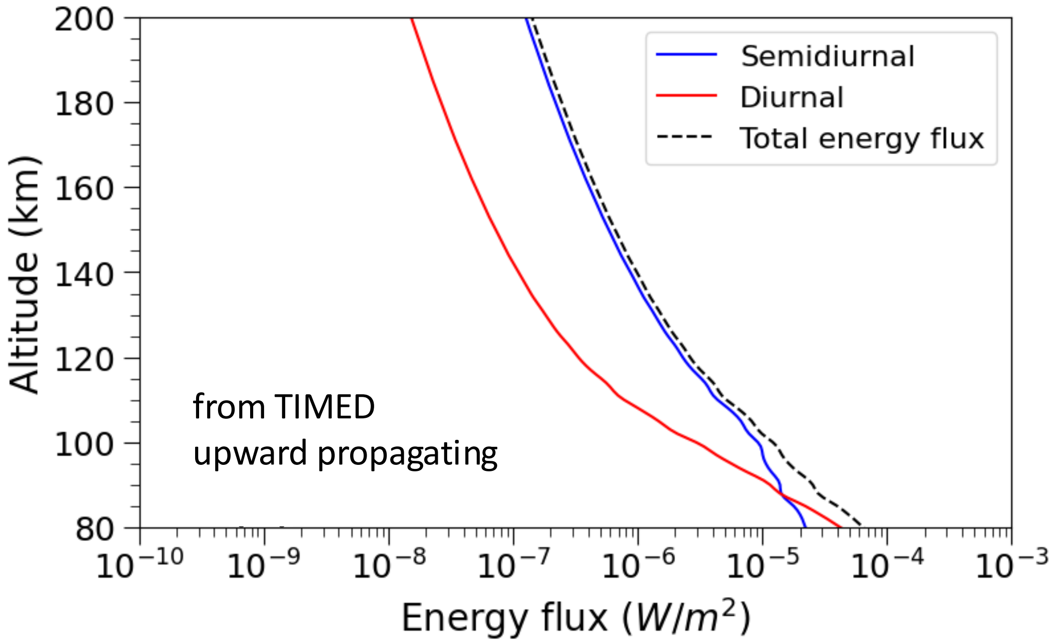
The ionospheric response to the MJO is up to 30%
and has predictability potential.

Global wave energy input into the thermosphere

Migrating diurnal tide, spring



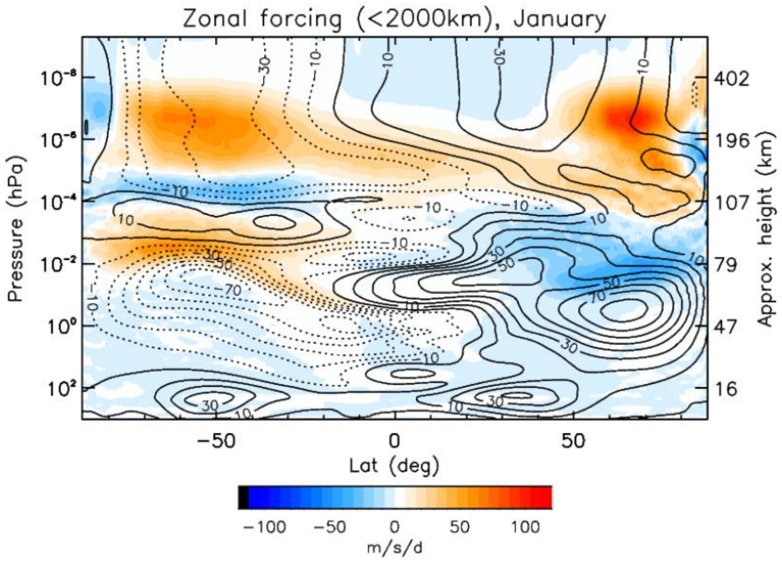
Migrating and nonmigrating tides, annual mean

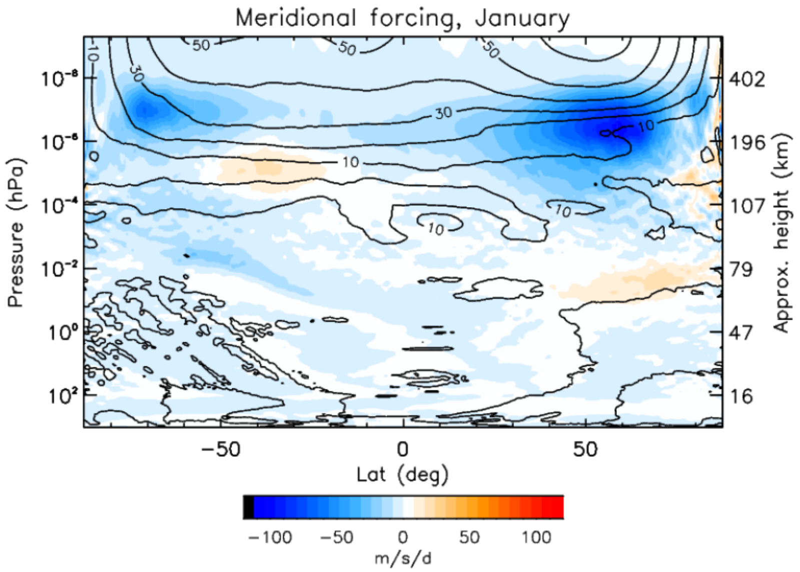


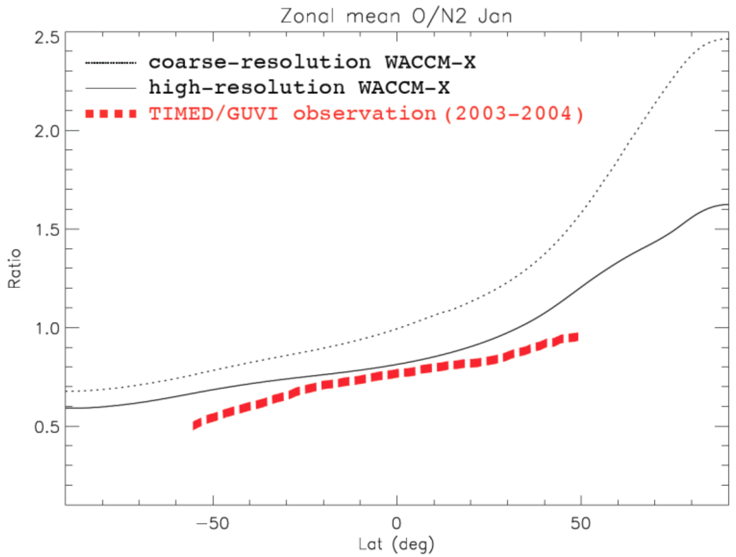
Advances in data analysis now allow us to quantify tidal wave energy fluxes into the thermosphere from observations

Figures courtesy of Mukta Neogi

Mesoscale wave impact on the mean state of the IT







High resolution WACCM-X modeling can partially resolve mesoscale waves and produces a more realistic thermospheric composition

Liu et al., 2023GL107453

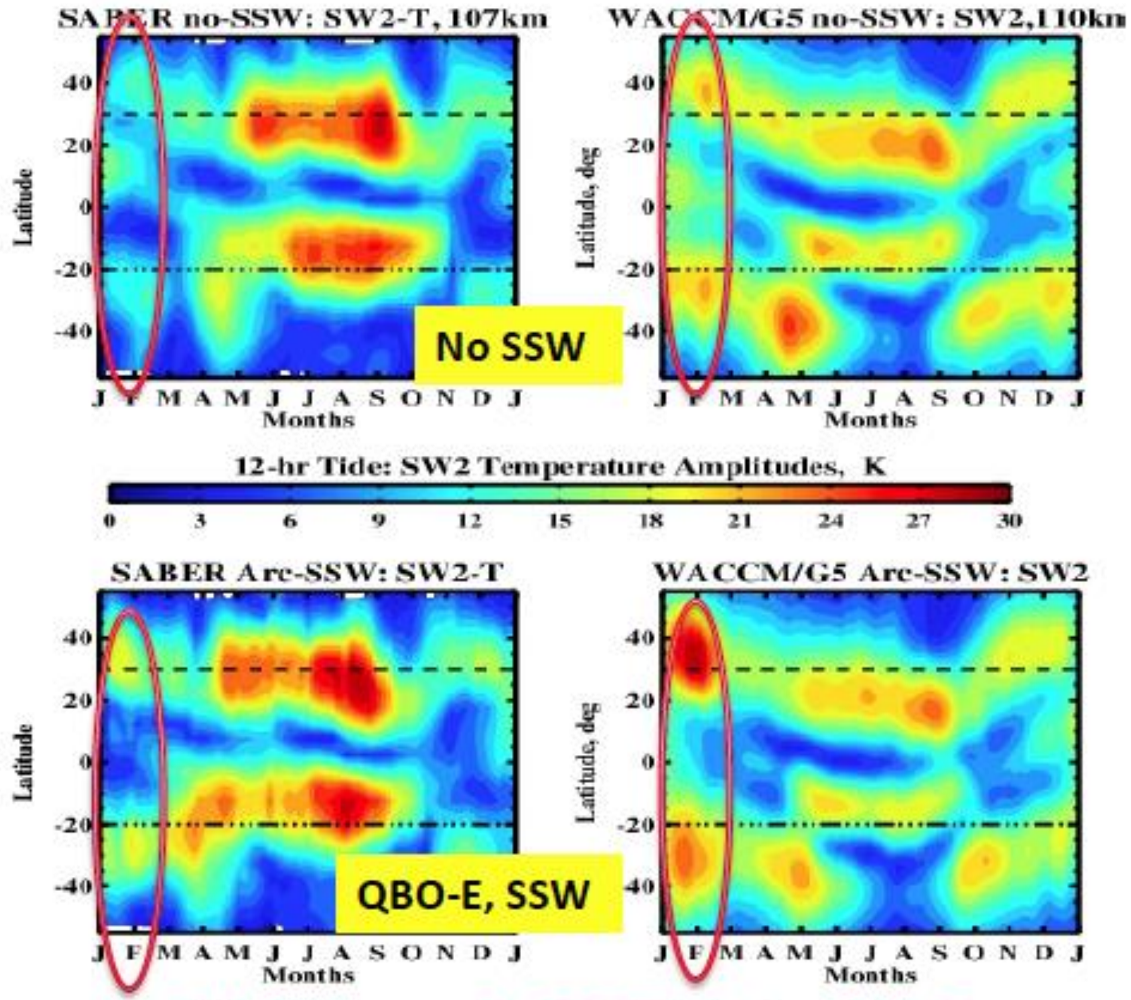
A few examples

Intra- and interannual

Impact of stratospheric QBO on the semidiurnal tide SW2 during Arctic SSW

SABER

WACCM/G5



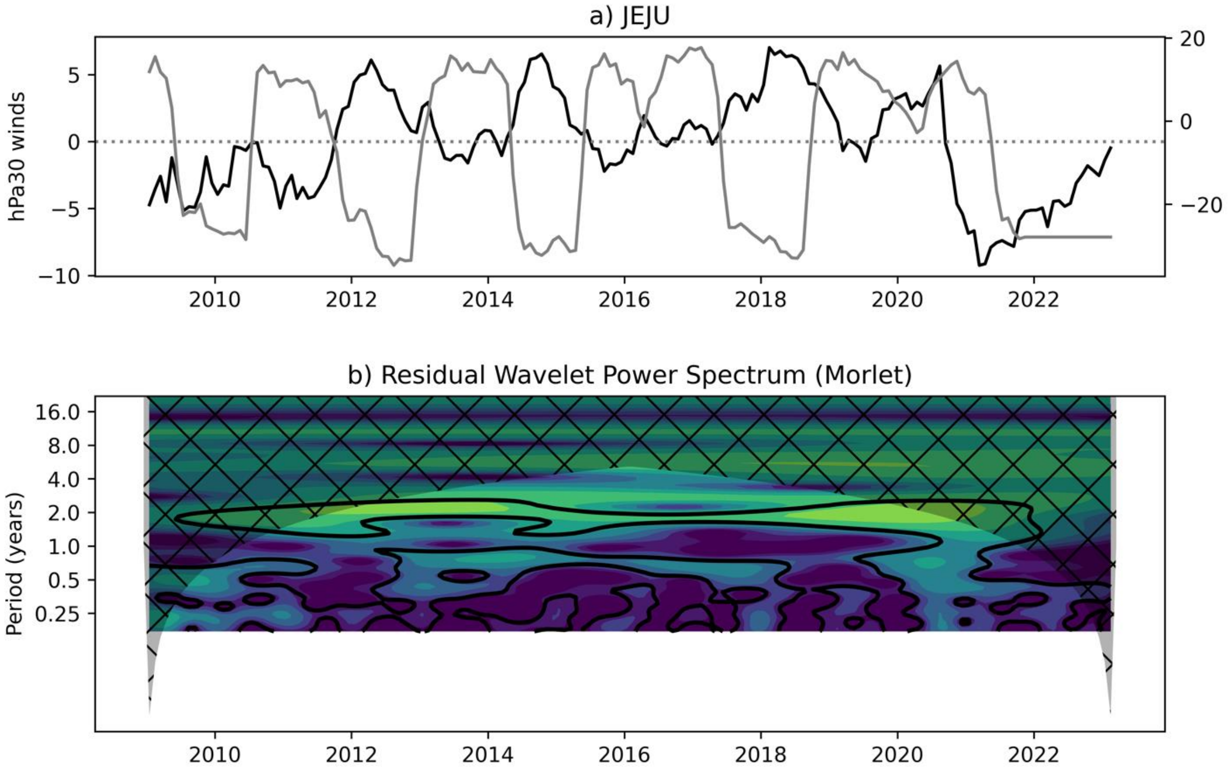
Jan-Feb SW2 growth ~50-75% during QBO-E years

QBO-E phases trigger more frequent SSWs with mid-winter tidal growth

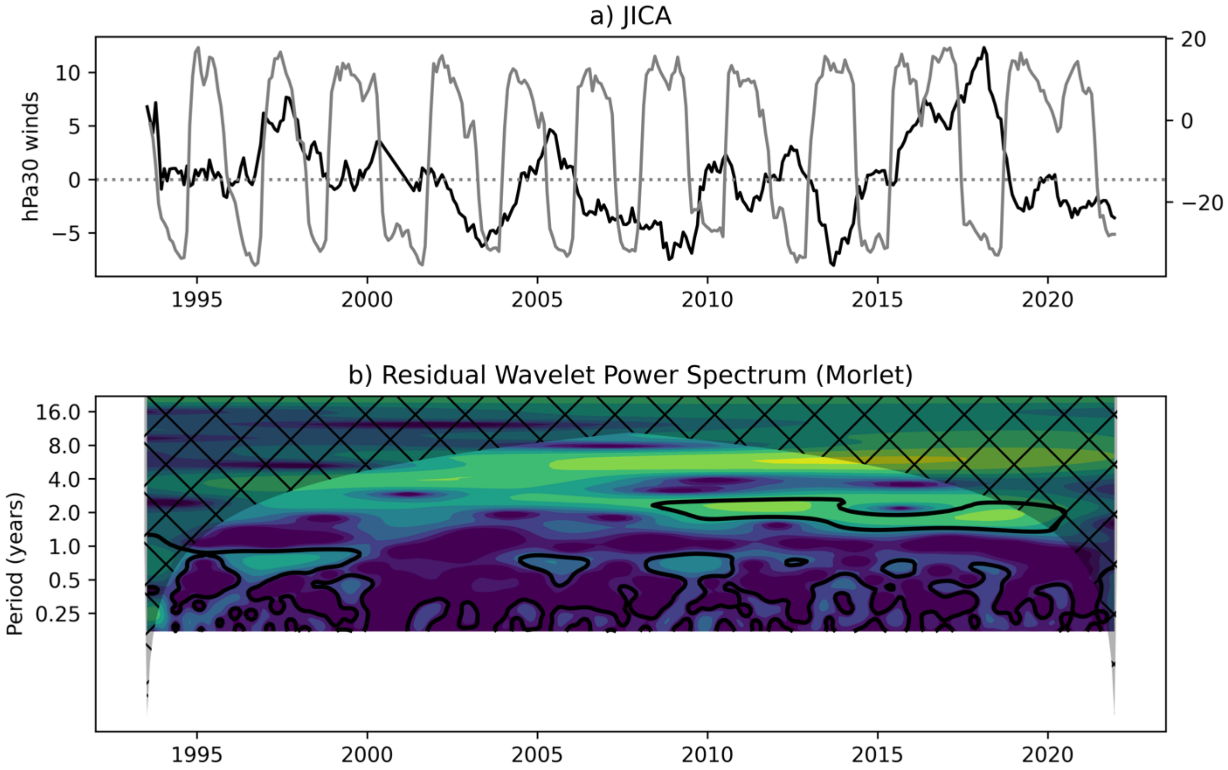
courtesy of Valery Yudin

Impact of stratospheric QBO on the ionosphere

JEJU (Korea) ionosonde residuals



JICA (Jicamarca) ionosonde residuals



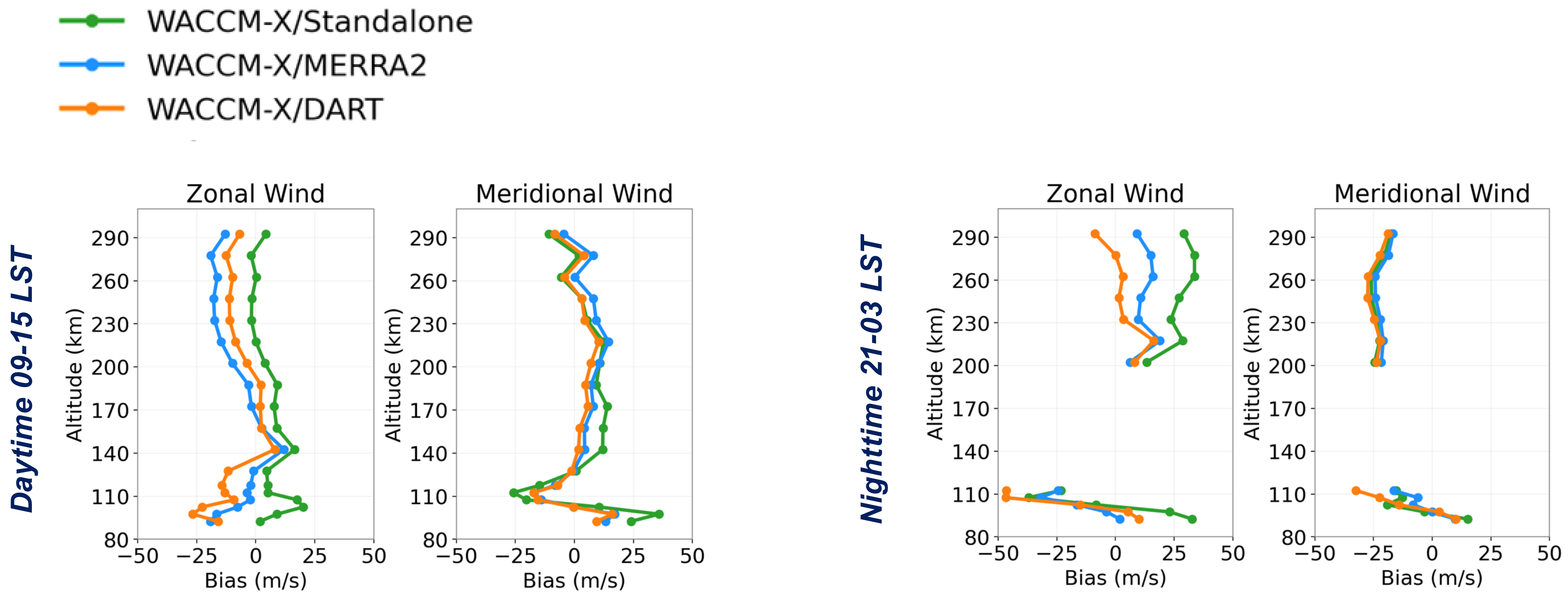
New empirical model for local NmF2 allows one to identify QBO-like signal at several ionosonde stations

courtesy of Dupinder Singh & Larisa Goncharenko

A few examples

Impact of data assimilation on model performance

WACCM-X/DART performance against MIGHTI neutral winds



Meridional winds on the average show similar bias in all three WACCM-X flavors
Zonal wind results are mixed: least daytime bias for WACCM-X/Standalone but least nighttime bias for WACCM-X/DART

courtesy of Manbharat Dhadly

Timeline

Year 1

- Goals 1 & 2: observational baseline data and state of models

Year 2

- Goals 2 & 3: Data-model comparisons and impact of data assimilation

Year 3

- Goal 4: physical mechanisms

Monday: 1:30 – 3:30
Wednesday: 10 – 12

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Monday 1:30 – 3:30

F. Gasperini – UFKW in the IT

M. He – nonlinear PW interactions

M. Dhadly – DE3 from ICON & TIMED

S. Philips – local wave coupling

D. Singh – empirical NmF2 model

S. Zhang – Millstone Hill ISR results

V. Yudin – Space Weather Oriented Models

E. Shume – NASA R2O2R program

Wednesday 10 – 12

X. Lu – NSF-ANSWERS results

C. Krier – GOLD tides

J. Forbes – Mean state responses

D. Rowland – GDC+DYNAMIC

G. Liu – NAVGEM+WACCMX & SABER

S. Khadka – Tides/DMSP/SWARM

S. Chakraborty – MSTID/SuperDARN

B. Williams – CGWaveS campaign