The EC H2020 project SWAMI:
Space Weather Atmosphere Model and Indices

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H2020-COMPET-5-2017
« Space Weather »

Project objectives

- To develop a model of the whole atmosphere (MOWA) with a science as well as operations-focused approach (MCM). Two existing models of the atmosphere, the UM and the DTM, will be extended and blended to produce this unique new whole atmosphere model, which shall provide estimates of both climatology and space weather variability.

- To provide new high-cadence geomagnetic Kp indices, including its nowcast and predictions to be used in the UM and DTM.

- To develop steps, including provision of software, model output, or data sharing facilities, to transition the improved model system into operations.

Project approach

SWAMI

1) Develop new index

Geomagnetic activity:
New algorithm for
High-cadence Kp

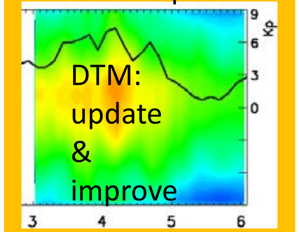
Thermosphere observations

Solar activity:
F30 radio flux

Atmosphere observations

2) Develop MOWA

Thermosphere



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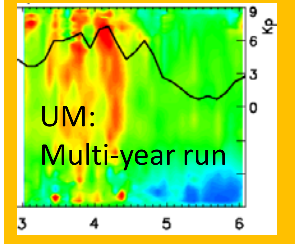
Surface to LT



MOWA
Climatology &
Weather

A - Parallel steps:

Develop high-cadence Kp algorithm

Update and improve DTM
Extend UM to 170 km altitude

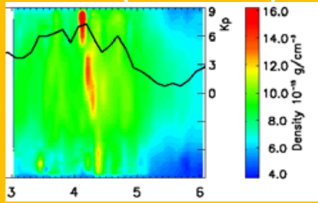
4) Develop Kp forecast model

Geomagnetic activity:
High-cadence Kp &
Nowcast and
Forecast

Solar activity:
F30 radio flux &
Nowcast and
Forecast

3) Develop MCM

MCM (0-1500 km)



Climatology *and* weather re-analysis and predictions:
- *Temperature*
- *Density + composition*
- *Winds*

Project approach

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F30 radio flux

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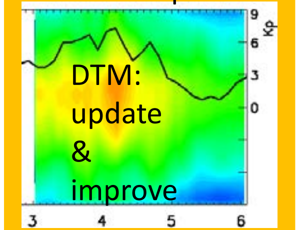

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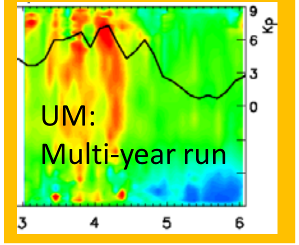

MOWA
Climatology &
Weather

B - Parallel steps:

Update DTM "Kp algorithm"

Tune high-cadence Kp

Multi-year UM run

4) Develop Kp forecast model

Geomagnetic activity:
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Nowcast and
Forecast

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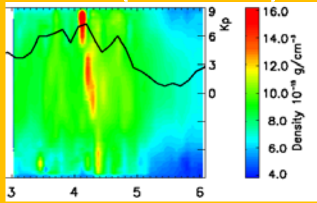
MCM (0-1500 km)



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Project approach

SWAMI

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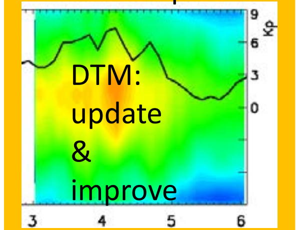

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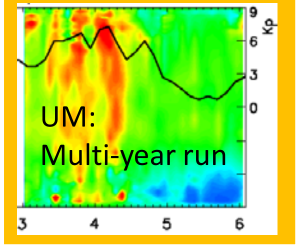
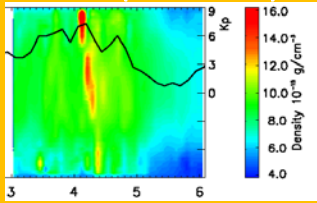


MOWA
Climatology &
Weather

3) Develop MCM

MCM (0-1500 km)



Climatology *and* weather re-analysis and predictions:
- *Temperature*
- *Density + composition*
- *Winds*

C - Parallel steps:
Blend **DTM** and **UM** (120-160 km):
MOWA
Mean=climatology
Difference= weather

Develop Kp forecast model

4) Develop Kp forecast model

Geomagnetic activity:
High-cadence Kp &
Nowcast and
Forecast

Solar activity:
F30 radio flux &
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Project approach

1) Develop new index

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New algorithm for
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Thermosphere observations

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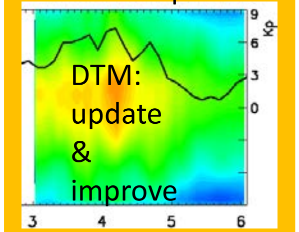

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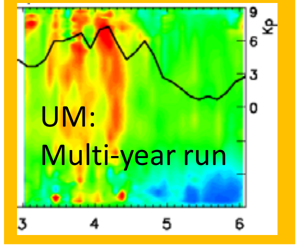

MOWA
Climatology &
Weather

3) Develop MCM

D – Develop **MCM** (table-based plus **DTM**)

4) Develop Kp forecast model

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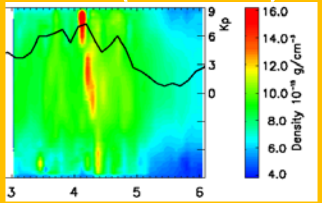
MCM (0-1500 km)



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High-Cadence Global *Kp* Index

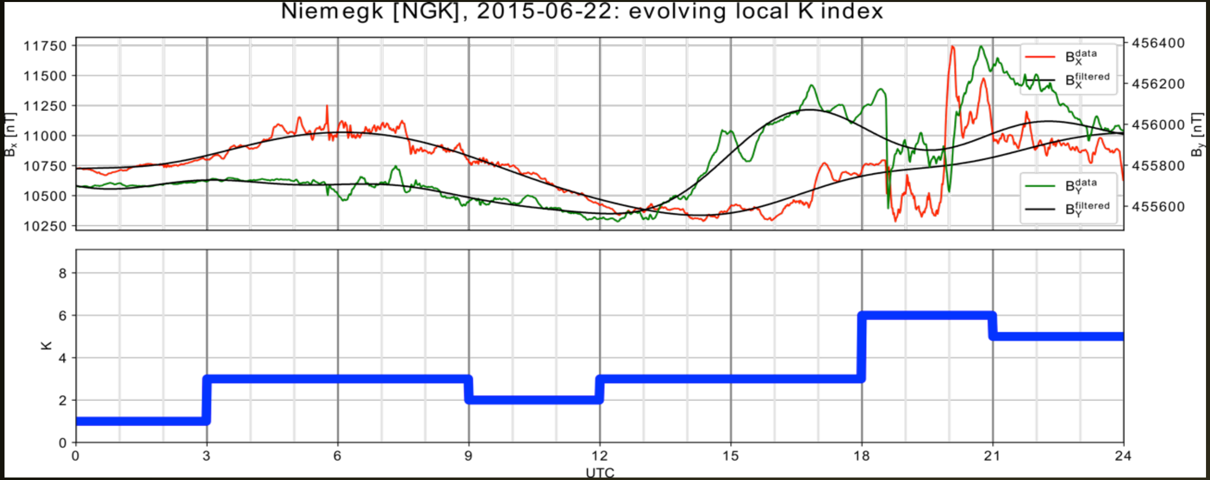
New high-cadence *Kp* index

- Useful for a wide range of space weather services that rely on rapid geomagnetic activity specification
- Will be used to drive the models, enabling accurate phasing of storm events

From standard to high-cadence

- Adaptation of mature algorithms and implementations for the 3-hour cadence: local *K* index

Local *K* and Global *Kp* Indices



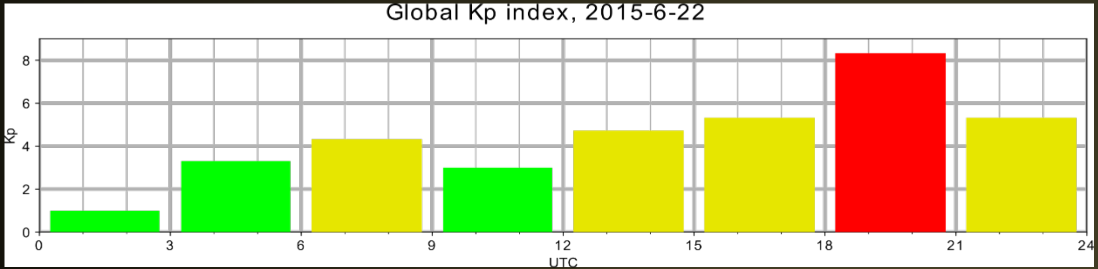
Local *K* index

- Niemegk station (e.g.): mean values of ***Bx*** and ***By*** components
- Quiet-day variation pattern removal procedure
- ***K*** index: **3-hourly** time intervals for the most disturbed field component

K* → *Ks* → *Kp

Standardized *Ks* index

- Geographic/geomagnetic coordinates of stations: an annual cycle of daily variations
- ***Ks*** index: conversion tables to eliminate these effects

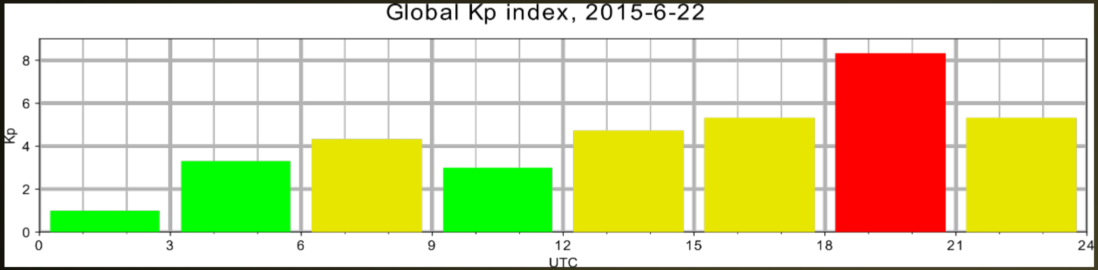


Global *Kp* index

- $$Kp = \frac{1}{11}\sum_{i=1}^{11} Ks_i$$

Local *K* and Global *Kp* Indices

K* ➔ *Ks* ➔ *Kp



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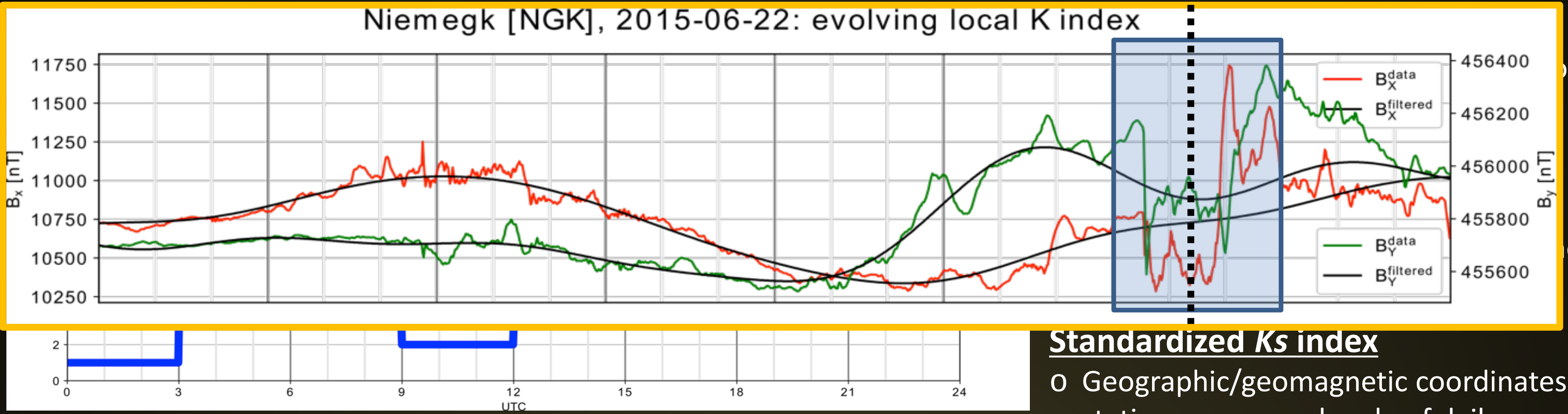

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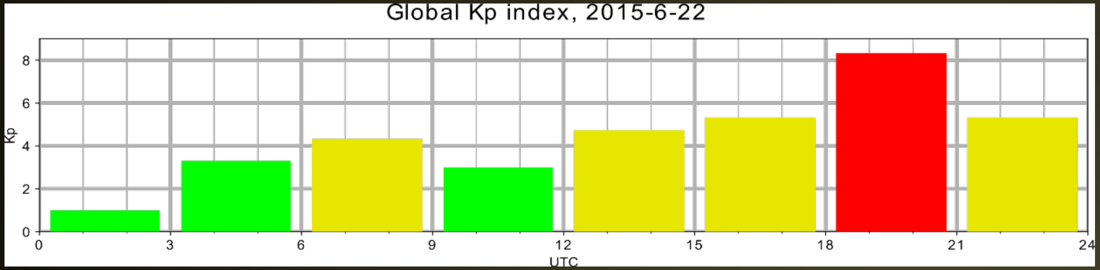

Global *Kp* index

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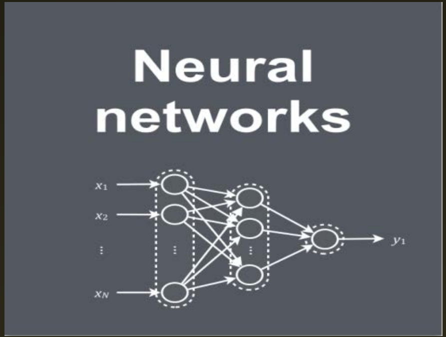
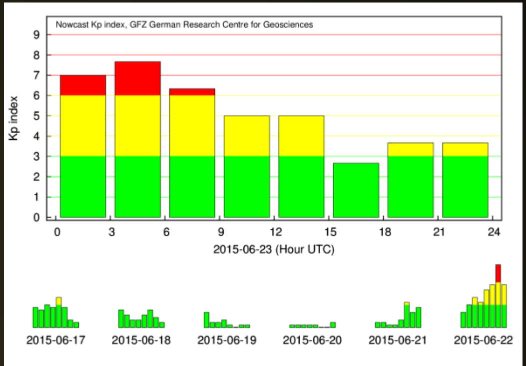
Kp forecast: Methodology

Inputs

Time history of Kp and
(1) solar wind speed,
(2) proton density,
(3) IMF B,
(4) IMF Bz.



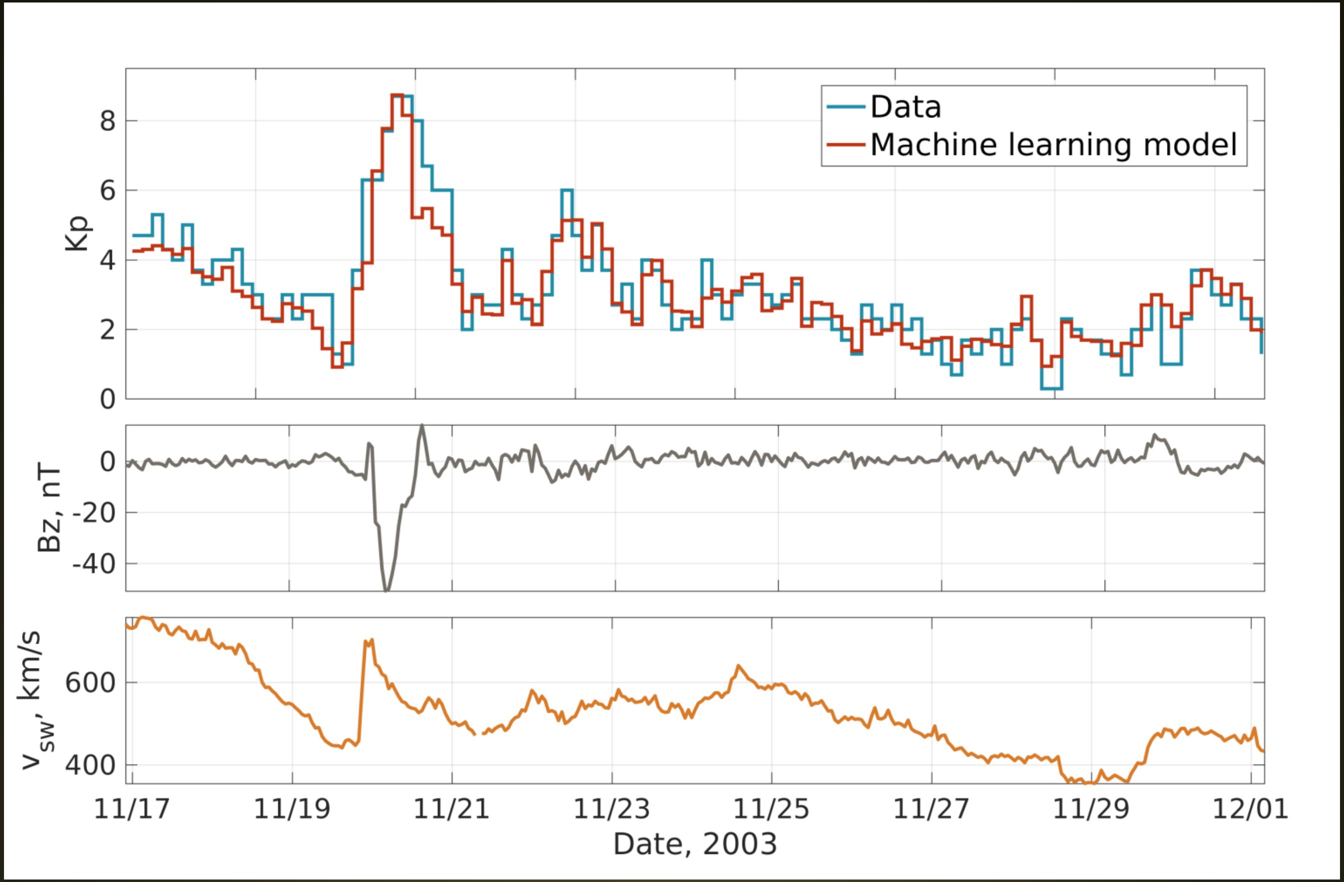
Kp prediction



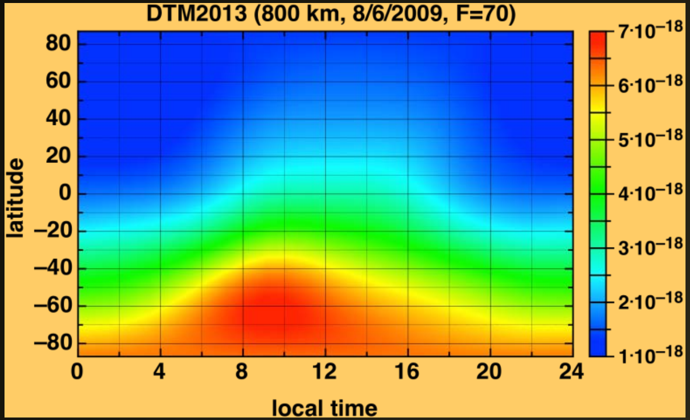
- Methodology: neural network based empirical modelling.
- Data: solar wind and IMF data from ACE (available at OMNIWeb), Kp index from GFZ Potsdam, 1993 - 2017.

Wing, S., J. R. Johnson, J. Jen, C.-I. Meng, D. G. Sibeck, K. Bechtold, J. Freeman, K. Costello, M. Balikhin, and K. Takahashi (2005), Kp forecast models, J. Geophys. Res., 110, A04203, doi:10.1029/2004JA010500
Wintoft, P., Wik, M., Matzka, J. and Shprits, Y. (2017) Forecasting Kp from high and low resolution solar wind and limitations on lead time, Journal of Space Weather and Space Climate, https://doi.org/10.1051/swsc/2017027

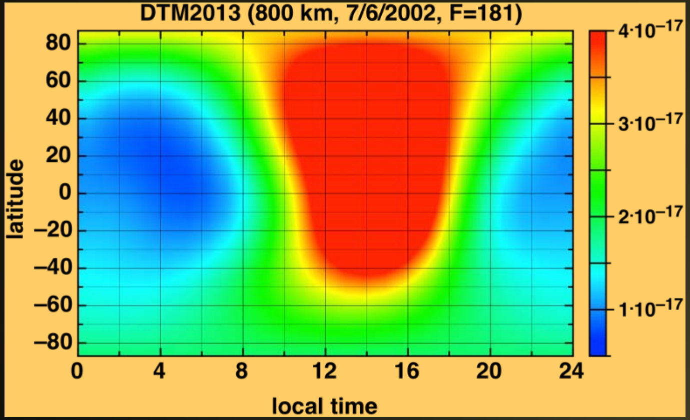
Kp-forecast: Preliminary results



Thermosphere: DTM model



DTM: CIRA optional model



Semi-empirical model:

- Low resolution
- Easy and fast in use
- Relatively accurate
- Climatology

Temperature and constituents (i.e., the winter Helium bulge is present) are modeled:

Concentration at 120 km

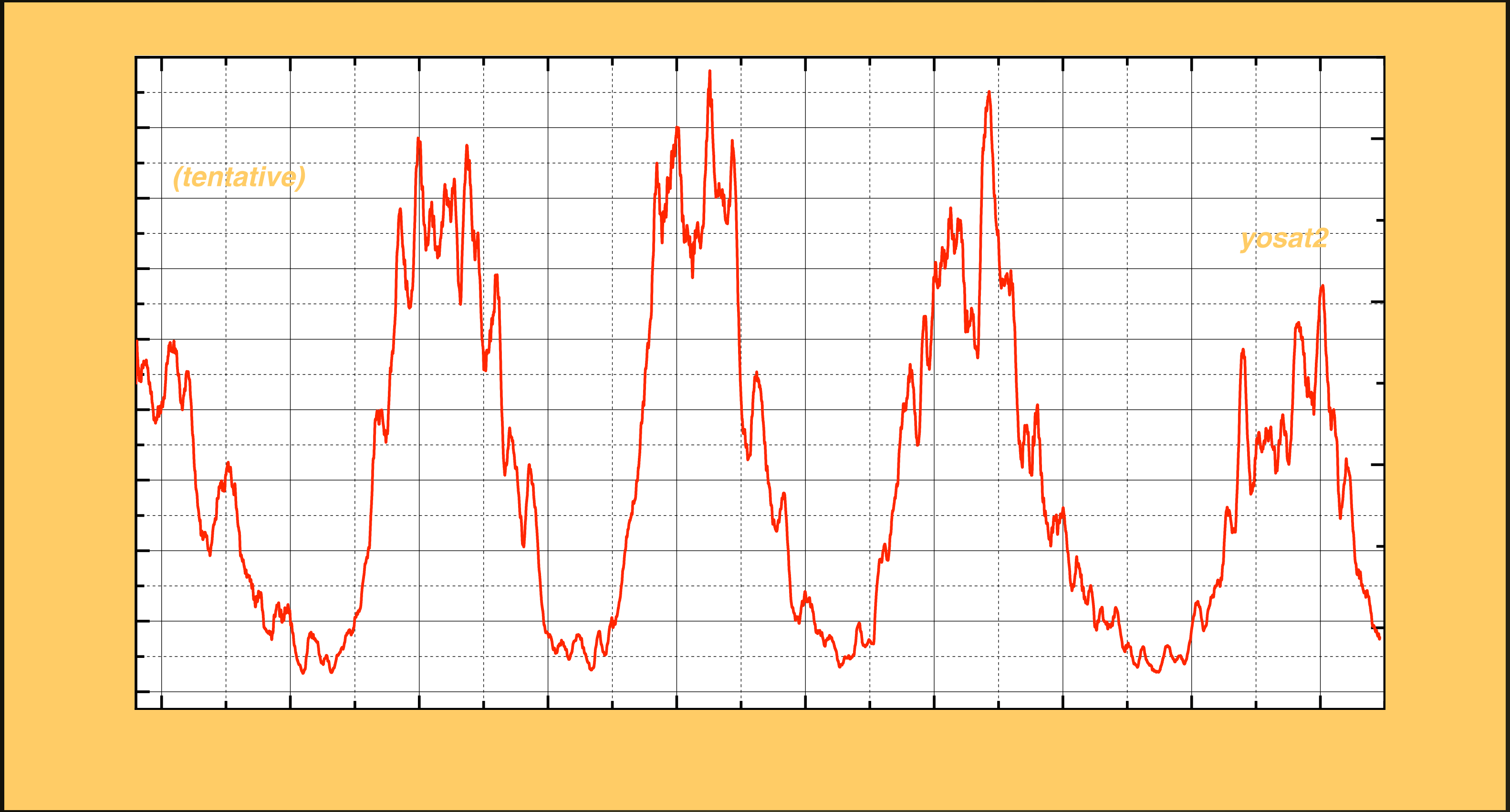
Height function

$$\rho(z) = \sum_i \frac{m_i}{N_A} c_i(120\ \mathrm{km}) f_i(z) \exp(G_i(L))$$

Spherical harmonics

DTM model: data

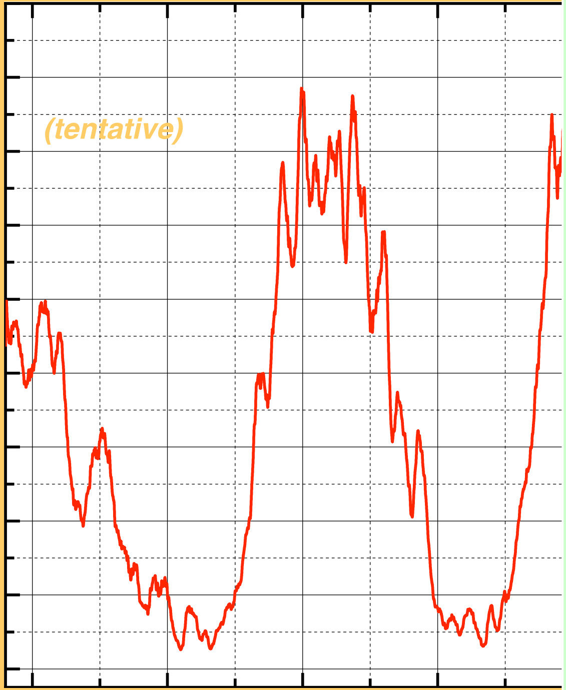
NB: No data above 1000 km; data is sparse below 300 km

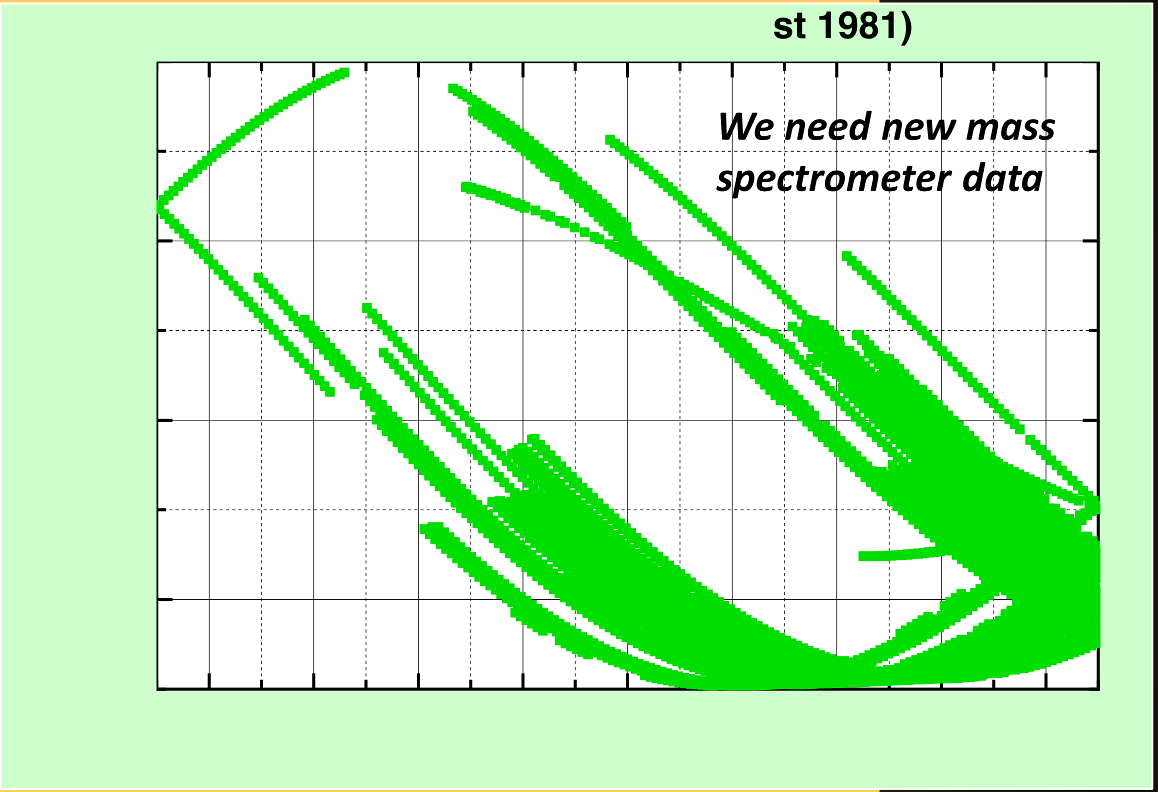


And:
QB50?
Dellingr?
GOLD?
APOD?
GRACE-FO?
…?

DTM model: data

NB: No data above 1000 km; data is sparse below 300 km

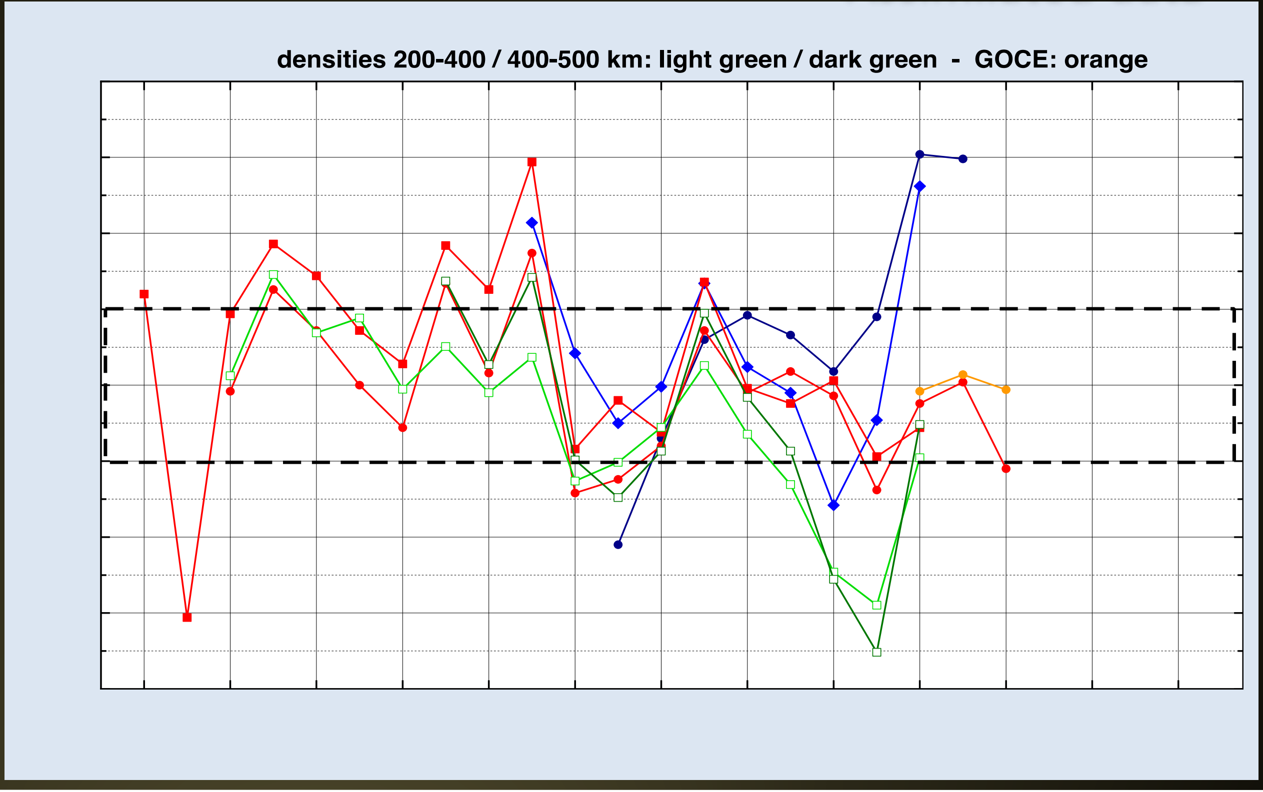




DTM2013: benchmark

DTM2013 ***annual mean density ratios*** (O/C): all altitudes (satellites)

Assimilated data



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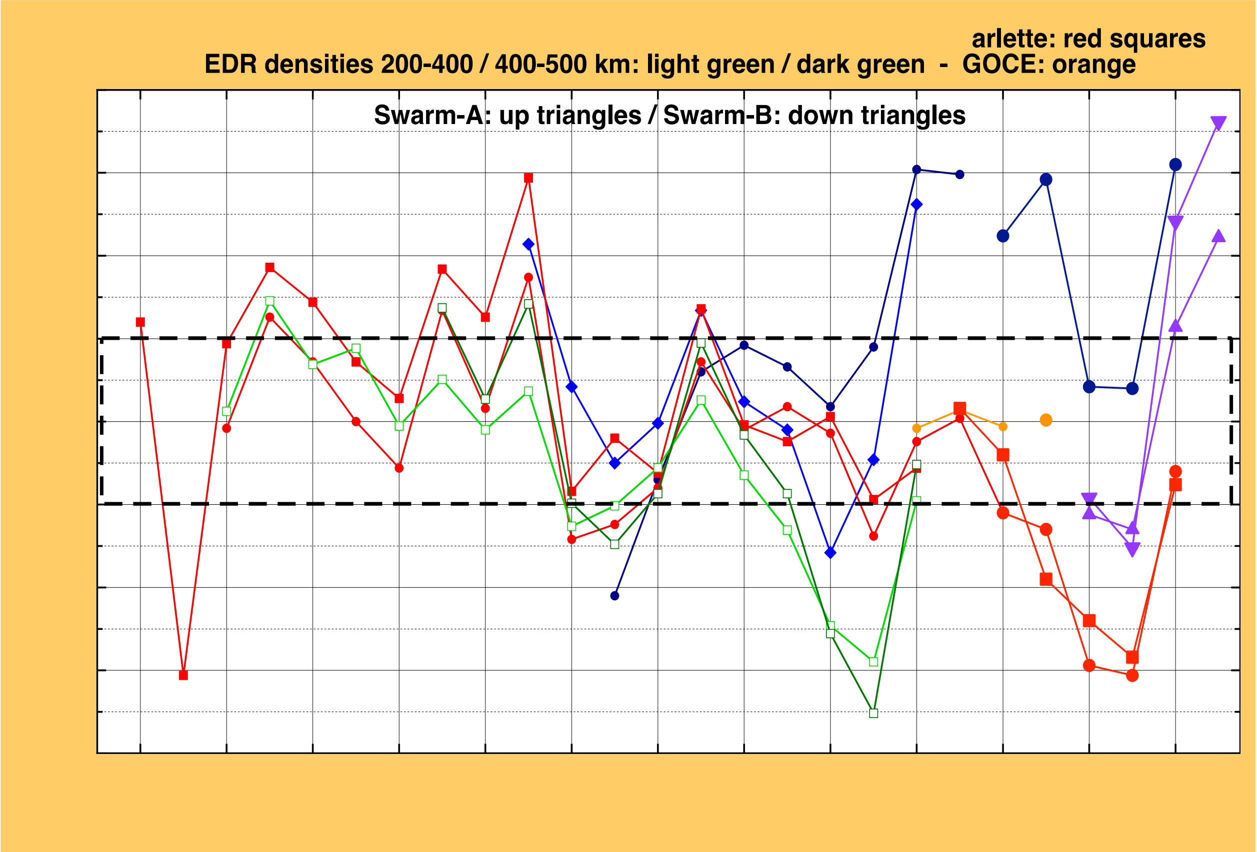

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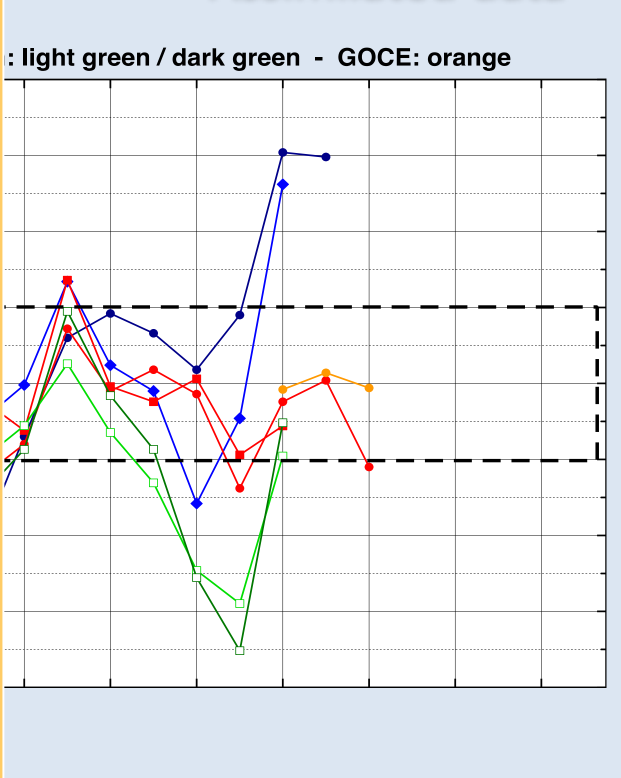
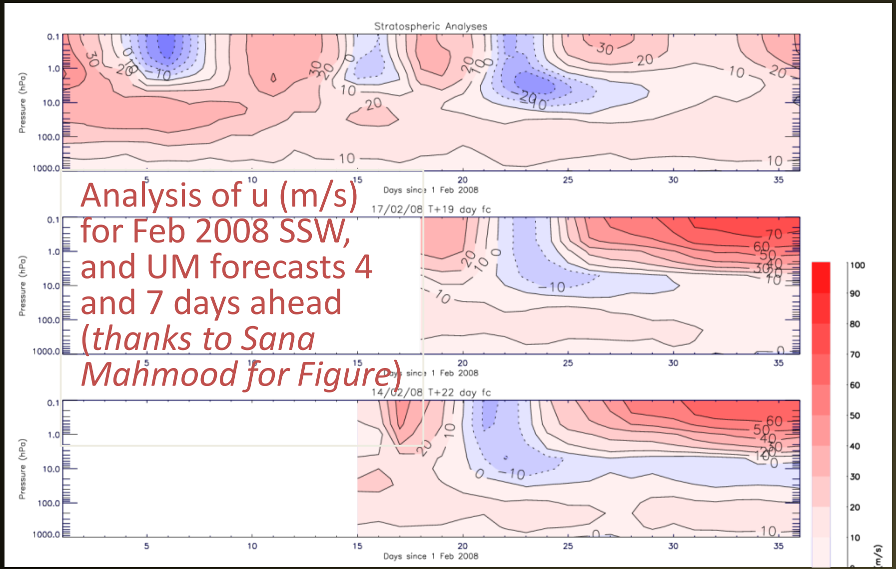


UM is a good candidate to represent MLT

Unified Model (UM) has the distinct advantage of non-hydrostatic, deep atmosphere dynamical formulation (unlike other models: TIEGCM, WAM, WACCM,…)

❖ Comprehensive dynamics and physics;

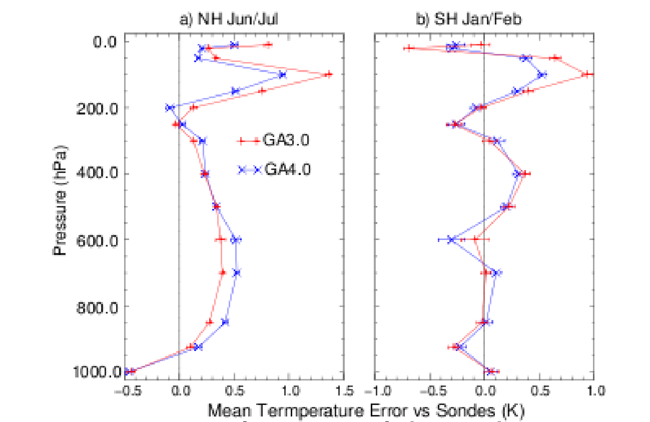
all key waves (and associated atmospheric variability) well represented



Analysis of u (m/s) for Feb 2008 SSW, and UM forecasts 4 and 7 days ahead *(thanks to Sana Mahmood for Figure)*

❖ Accurate;

Analysis / short-term forecasts have mean errors typically < 1 K. Multi-year climate run (w/o assimilation) have errors =< 5 K



Walters et al (2014)

Timeline products