SWIMMR

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Models and data in use and under development

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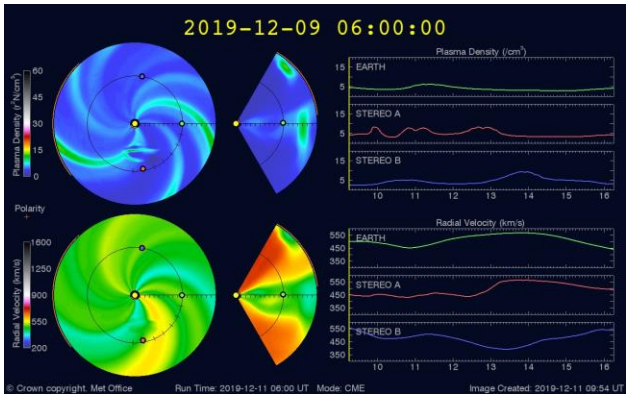
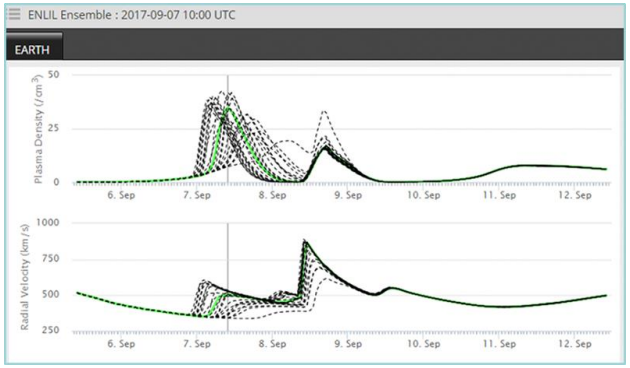
Models currently in use

1. WSA Enlil with CME Analysis Tool (CAT) + Ensemble
2. Solar Wind persistence model
3. Relativistic Electron Forecast Model (REFM)
4. D-Region Absorption Prediction (DRAP)
5. Oval Variation, Assessment, Tracking, Intensity, and Online Nowcasting (OVATION-Prime-2013)
6. Bernese Model
7. Drag Temperature Model 2013 (DTM2013)

WSA Enlil with CME Analysis Tool (CAT)





Operational ensemble prediction system, (Francois Bocquet)

- Models solar wind speed & density (IMF modelled but no Bz input)
- To predict CME arrival times at Earth, Venus, Mercury & Mars
- Inputs:
  - WSA output: WSA uses (GONG) solar magnetograms to predict background solar wind speed & IMF - to provide inner BCs for Enlil (currently use NOAA files)
  - SWPC CAT output: CAT input: STEREO & LASCO images. Subjective fitting of cone over time. CAT uses triangulation between different spacecraft viewpoints. CME parameters (origin, direction, speed, half- width).
- Run every 2 hrs. Average CME arrival time error: +/-7 hrs.
- Enlil ensemble: perturbs CME parameters to get range of possible arrival times

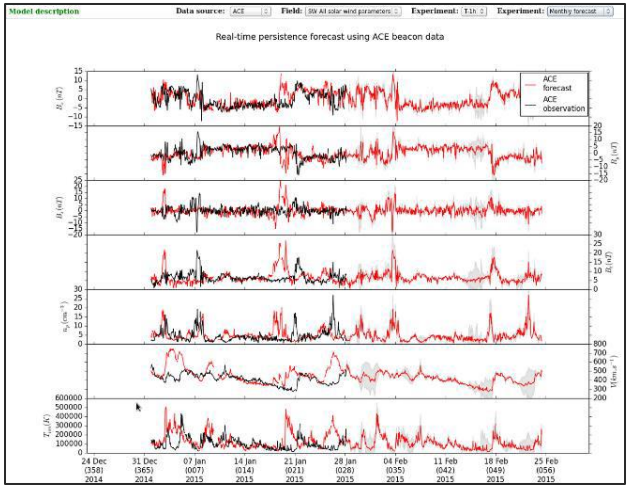
Model information		
Run frequency	**Run time**	**Run location**
Every 2hrs at 01Z, 03Z etc	~58 minutes	HPC (Supercomputer)

Input data			
Name	**Format**	**Size**	**Ingestion frequency**
CME predictions from MOSWOC	conefile	Small (kb)	1hr
gong.fits	.fits	~ 100kb	

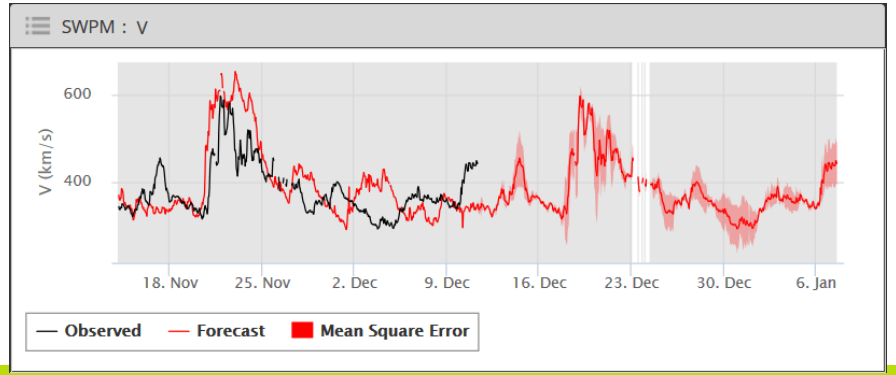
Solar Wind Persistence Model

CHs influence solar wind and thus geomagnetic storms
How do we assess impact?

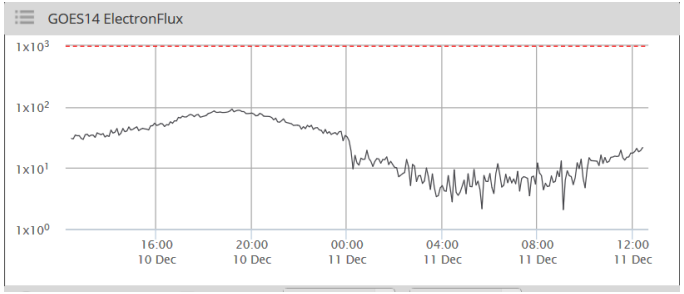
- CH perturbations should be picked up in magnetograms and thus WSA-Enlil initial conditions
- Use recurrence model:
  - CH size can grow / shrink from one solar rotation to the next
  - Driven by ACE / STEREO-A data & assumes space wx (today) = space wx (today -27.25 days)

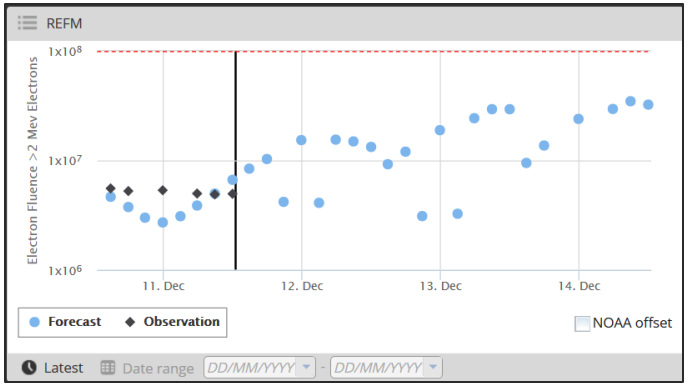


Model information			
Run frequency	**Run time**	**Run location**	**Model format**
Every 1hr	< 1m	Internally	Python
Input data			
Name	**Format**	**Size**	**Ingestion frequency**
Hourly averaged Magnetometer	JSON converted to txt by Freemarker template	Small (kb)	1hr (averaged)
Hourly averaged Solar Wind Plasma	As above	Small (kb)	1hr (averaged)



Relativistic Electron Forecast Model (REFM)





High energy electron flux forecasts at GEO are based on:

- Assessment of CHs
- Assessment of NRT data from GOES
- Model (REFM) forecasts of >2 MeV fluence at GEO
  - o Used to gauge: trend in fluence
  - o Development in progress – to improve visualisation of 3hrly runs
  - ○ Recurrence / persistence model developed for verification benchmark (Mike Sharpe)

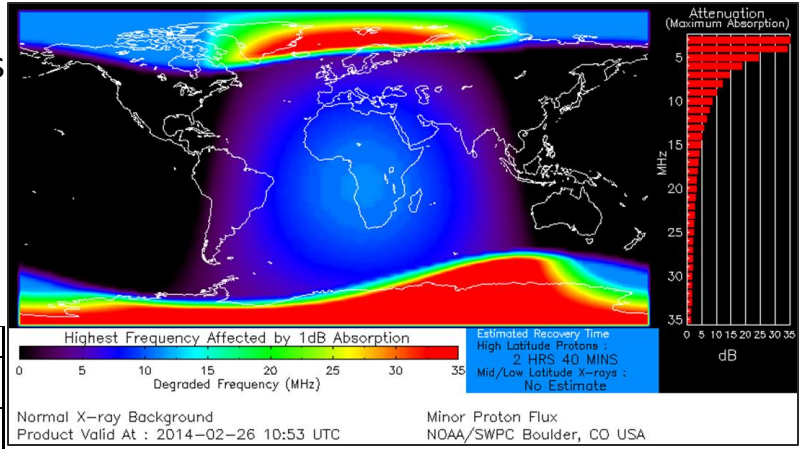
Model information			
Run frequency	**Run time**	**Run location**	**Model format**
Every 3hrs	1hr	Internally	Python

Input data			
Name	**Format**	**Size**	**Ingestion frequency**
Solar Wind Speed	JSON	Small (kb)	1hr
Electron flux	JSON	Small (kb)	5m
Zwickled corrected proton flux	JSON	Small (kb)	5m
Previous model raw output	JSON	Small (kb)	N/A
Previous model modified output	JSON	Small (kb)	N/A
Model offsets	JSON	Small (kb)	N/A

D-Region Absorption Prediction (DRAP)

D-Region Absorption Prediction

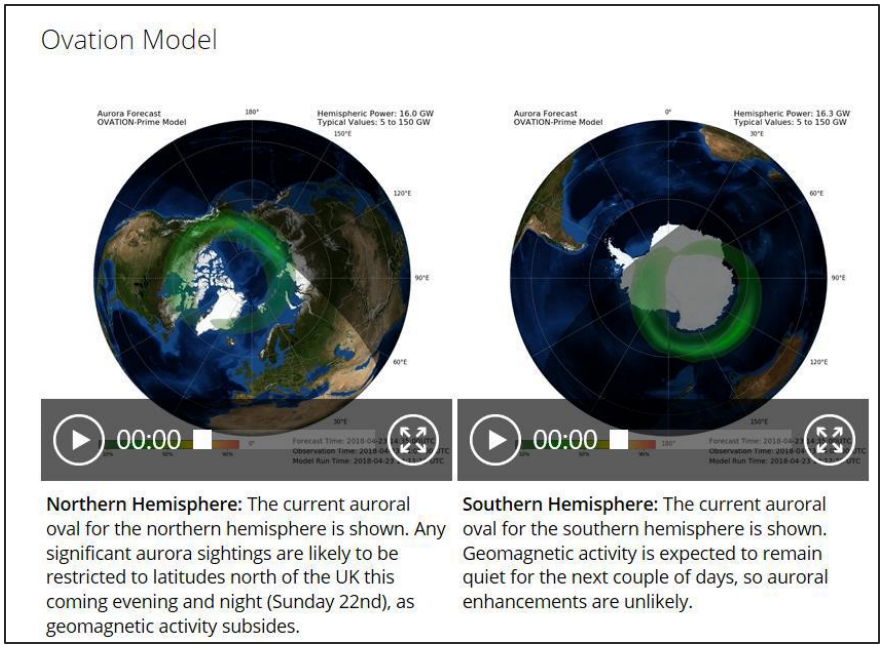
- Real-time global map showing impact of flares & SEPs on HF radio comms
- Understanding of radio signal degradation/blackouts
- Driven by one-minute GOES X-ray flux data and by five-minute GOES proton flux data
- Used as a *qualitative indicator* of highly perturbed conditions (SWPC validation report)



Model information			
Run frequency	**Run time**	**Run location**	**Model format**
Every 5m	< 1m	Internally	Python

Input data			
Name	**Format**	**Size**	**Ingestion frequency**
Goes X-Ray	JSON converted to csv	Small (kb)	1m
Goes Integral Protons	JSON converted to csv	Small (kb)	1m
Kp Planetary Indices	JSON converted to csv	Small (kb)	3hr
Mcilwain L Coordinates	JSON converted to csv	Small (kb)	N/A (Static)

Oval Variation, Assessment, Tracking, Intensity, and Online Nowcasting (OVATION-Prime-2013)



- Developed by John Hopkins University
- Empirical model which predicts intensity of auroral energy at locations on Earth for next 30mins
- Based on current solar wind at L1
- Now running and evaluating 3-days forecast version driven by Kp forecast

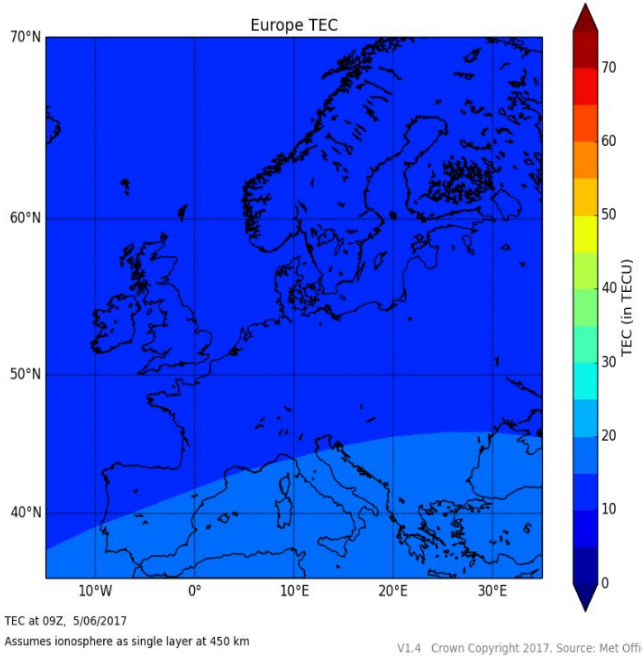
	Model information			
	Run frequency	**Run time**	**Run location**	**Model format**
Nowcast	Every 5minutes	~ 3 minutes	Internally	Python
Forecast	Once per day	1hr	AWS	Python in scalable docker container(s)

	Input data			
	Name	**Format**	**Size**	**Ingestion frequency**
Nowcast	L1 Solar wind – Magnetometer	JSON	Small (kb)	Every 1m
	L1 Solar wind – Plasma	JSON	Small (kb)	Every 1m
	L1 Ephemerides	JSON	Small (kb)	Every 5m
Forecast	Kp/KuK forecast	JSON	Small (kb)	As forecast (3 hourly)

Bernese Model

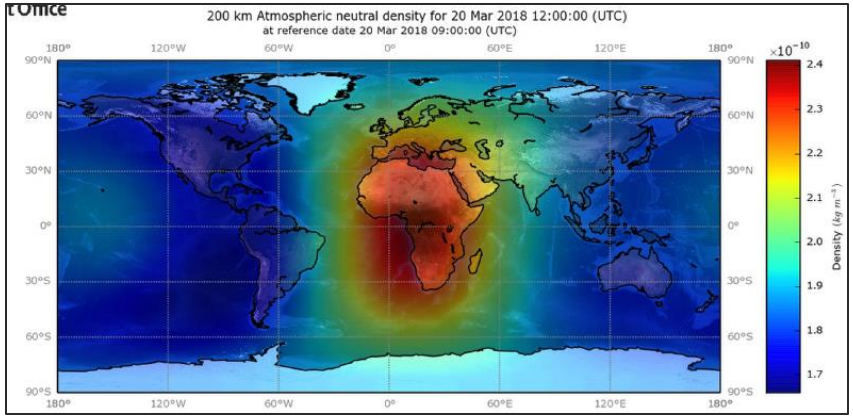
Ionospheric Total Electron Content (TEC)

- Nowcasts based on ground GPS data
- Europe and Global maps every 15 mins and 60 mins, resp.
- Single shell ionosphere model so no vertical structure
- Same model produces Total Column Water Vapour for NWP



Model information			
Run frequency	**Run time**	**Run location**	**Model format**
Global - Every 1hr	N/A	Internally	N/A
Europe – Every 15m		Internally	N/A
Input data			
GNSS time-delay data from internal Met DB collected from a variety of networks.			

Drag Temperature Model 2013 (DTM2013)



Atmospheric density service based on the semi-empirical model DTM2013 (developed and maintained by CNES).

- Forecast and prior estimates of thermospheric total neutral density in the altitude range 120 – 1500 km.

- Three total neutral density products:
  - Higher cadence 3-day forecast issued every 3 hours,
  - 27-day forecast produced daily,
  - Historic prior density estimate.

Driven by:

Forecast : F30 Index Forecast Absolute 30-day (CLS).

Measured: F30 (absolute)

Geomagnetic Index:

Forecast: ap Index Forecast 3-day (BGS), Ap Index Forecast 27-day (BGS).

Measured: Definitive Ap index (GFZ)

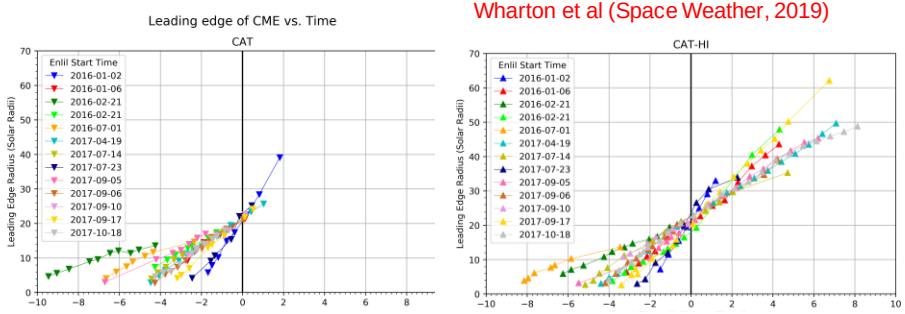
Models under development

Improvements to Enlil

CAT-HI – extension of CAT to include HI data:

- Proof of Concept study shows benefit in pruning ensembles rather than improved CME forecasts

Wharton et al (Space Weather, 2019)



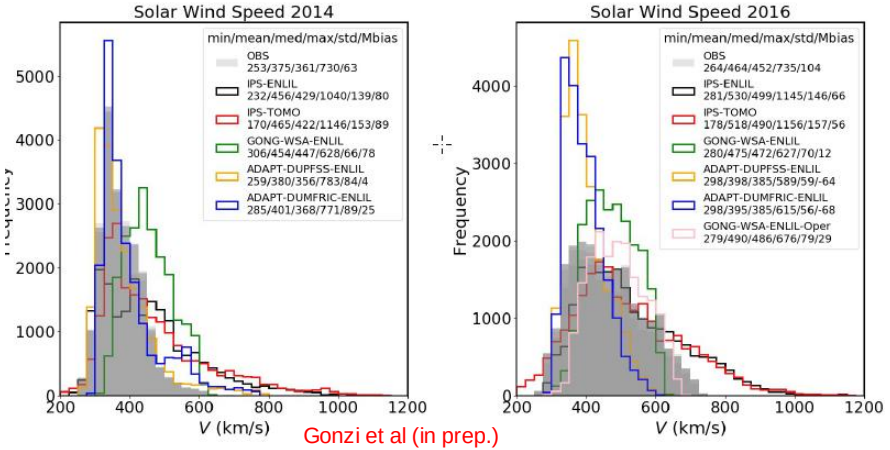
ADAPT replacing WSA GONG in operational demonstrator

- 12 members ensemble of ambient wind

Research on replacing WSA with

- DuMFRic (NLFFF model) – better coronal magnetic field evolution?
- IPS – resolution in case of loss of coronagraphs

- No clear winner! e.g DuMFRic best in 2014 but not 2016
- ADAPT v GONG / DuMFRic v WSA shows choice of coronal model more important than ADAPT / GONG differences for L1 forecasts



Gonzi et al (in prep.)

Models under development

High energy proton flux forecasts at GEO

Forecasts are currently based on:
- AR analysis
- Assessment of NRT data from GOES

Plan to implement SPARX model operationally:
- Flare trigger – need GOES 16 flare detection product

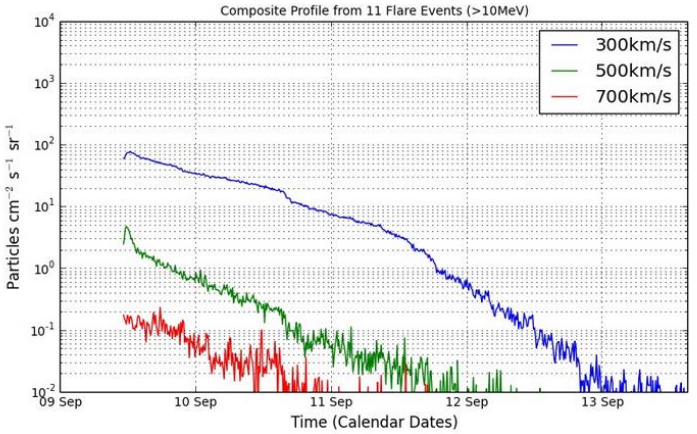
SPARX: a modelling system for Solar Energetic Particle Radiation Space Weather forecasting

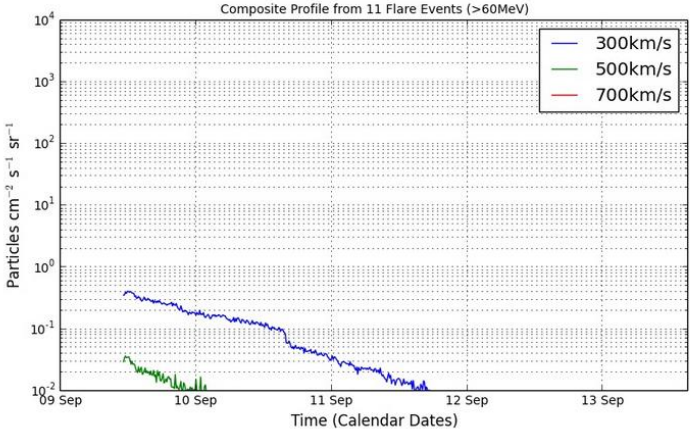
M. S. Marsh,[1,2] S. Dalla,[1] M. Dierckxsens,[3] T. Laitinen,[1] and N. B. Crosby,[3]

SEP modelling challenges:

- Complexity of physics of their propagation in the 3D turbulent plasma
- Computational expense due to timescales required to produce actionable forecast

Most Recent Proton Event Forecast





Models under development

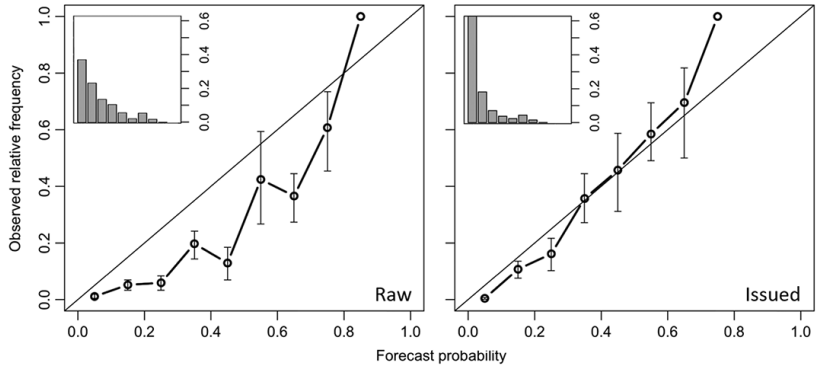
Flare forecasts

Statistical model is used links complexity of ARs with probability of occurrence of different classes of flares

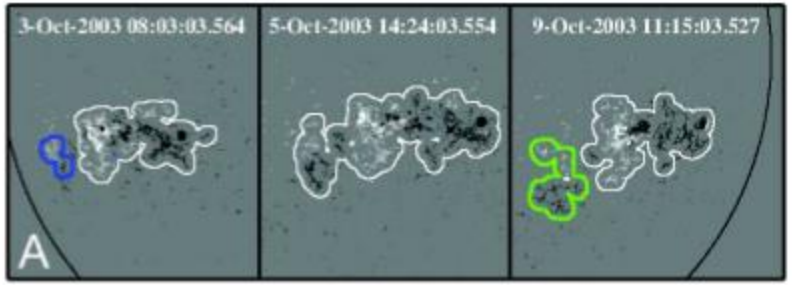
- Forecaster uses experience to modify this before issuing forecast
- Flare forecast verification: MOSWOC issued forecasts better than raw model output - forecasters add value

How to improve?

- Operational implementation of SMART (Solar Monitor AR Tracker) – potential to use other forecast methods based on AR analysed quantities
- Ensemble flare forecasts? – FLARECAST results incomplete so need to rethink



Murray et al (Space Weather, 2017)



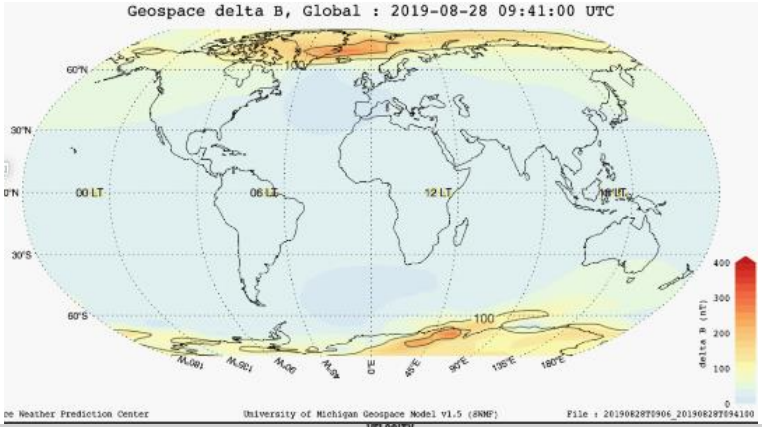
Models under development

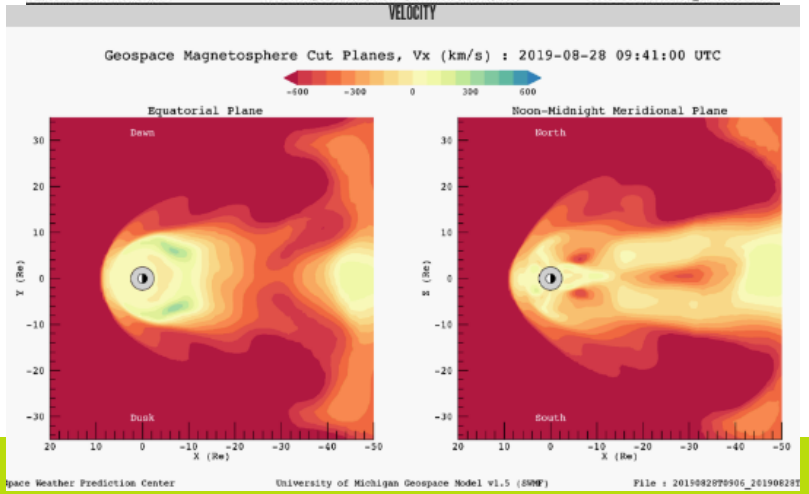
Magnetosphere

SWMF (Michigan) model being implemented – similar to that used at SWPC

Global estimates of ΔB

- BATS-R-US MHD mag/sphere model
- Ridley Ionosphere e/dynamics Model
- an inner mag/sphere ring-current model

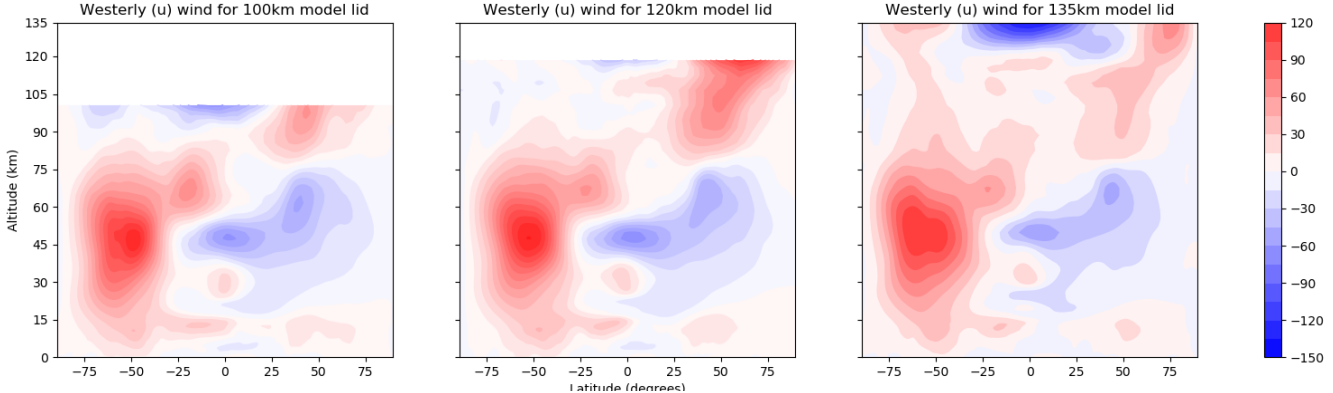


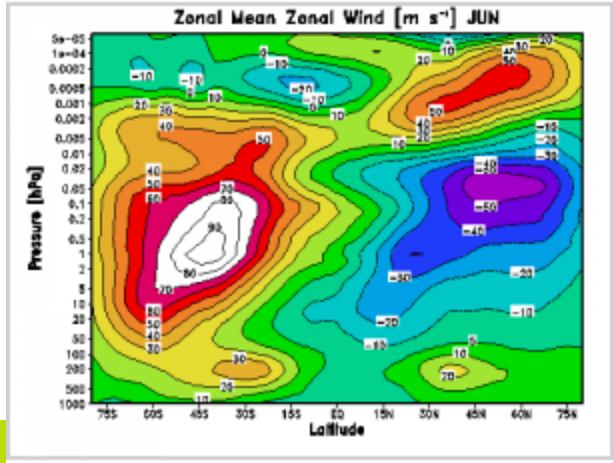


Models under development

Thermosphere / ionosphere

- Raising UM (to ~150 km) in development:
  - SWAMI H2020 project – blend with DTM to produce new 0-1500 km semi-empirical model for operations
  - Coupling to TIEGCM - planned MOSWOC operations (1st step towards whole atmosphere model)
- Eventually whole atmosphere NGMS (UM successor) (to ~600 km) to couple with other space wx models





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