Is SWMF Ready for R2O?

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What is Needed for Space Weather Forecasting?

- Solve the data sparsity problem
  - Solar tomography
  - Ionospheric tomography
  - But what about the space between the corona and the ionosphere?

- Develop coupled model chains
  - SWMF (Michigan)
  - CISM model chain (BU)
  - Magnetosphere-Ionosphere model (UNH)

- Validate
  - Sub-grid parametrization
  - Missing physics
  - Ensemble forecasting
In situ space weather observations are like spear fishing: you can get one fish at a time (if you are good and lucky).
Modern spear fishing equipment can be very expensive and sophisticated, but one can get only one fish at a time (if you do not miss…).
Large Fleet of Simple Spacecraft

Fishing nets contain a very large number of simple (and identical) nodes and are capable to catch huge quantities of fish.
How to Solve the Data Sparsity Problem

>$1B for 4 sophisticated spacecraft for a two year prime mission (gold plated spear fishing)

$1M for a simple CubeSat mission. One can have >1000 identical CubeSats “netfishing” in the space environment and create a new paradigm of space weather observations.
What is Needed for Space Weather Forecasting?

- 5 large spacecraft orbiting the Sun
  - 1 L1 monitor
  - 2 STEREO type s/c 120° from Earth
  - 2 Ulysses type s/c above the N/S poles
  - Identical instrumentation
    - Coronagraphs
    - EUV and soft x-ray images/spectroscopy
    - Vector magnetograms
    - Magnetometer, plasma and SEP package
- A fleet of $\sim10^3$ CubeSat type “space weather stations”
  - Magnetometer, thermal plasma package and SEP detector
- At least two (but preferably 3) independent Sun-to-Earth model chains that provide ensemble forecast
Thermodynamic Solar Wind Model
(van der Holst, Oran and Sokolov)

- Sub-photosphere model
  - Multigroup radiation transport
  - MHD
  - Magnetic flux emergence
- Low corona \((1R_\odot < r < 2.5 R_\odot)\)
  - \(\gamma=5/3\), single temperature
  - Heat conduction
  - Transport and dissipation of total energy of Alfvénic turbulence \((E_\pm)\)
    - Wave dissipation represents sources for the plasma momentum and internal energy
  - Additional coronal heating is obtained from the “unsigned flux” model (Abbett 2007) and observed X-ray luminosity (Pevtsov 2003)
- Corona \((2.5R_\odot < r < 20R_\odot)\)
  - \(\gamma=5/3\), separate ion and electron temperatures
  - Transport and dissipation of frequency resolved Alfvén wave intensity, \(I_\pm(\omega)\)
    - Kolmogorov spectrum is assumed at the inner boundary
- Observational inputs:
  - Magnetogram driven potential field extrapolation (synoptic maps from GONG or MDI)
  - Density and temperatures near the sun are predicted by the DEMT (Differential Emission Measure Tomography) results of Vasquez and Frazin (2009).
  - WSA formula determines total Alfvénic turbulence energy at the surface
Boundary Conditions for CR2077
with no Free Parameters

GONG magnetogram

Br [Gauss]

Te [MK]

Ne [$10^8 \text{ cm}^{-3}$]

STEREO/EUVI Differential Emission Measure Tomography (Vasques & Frazin)
In the fast wind:
- Electrons are cold (due to adiabatic cooling)
- Ions are hot (due to Alfvén wave heating)

In the slow wind:
- Electrons are hot (due to heat conduction)
- Ions are cold (no Alfvén wave heating)
New Corona Model

EIT 171Å  EIT 195Å  EIT 284Å  SXT AlMg

CR1913
Old SC model synthesis
New LC model synthesis
Observation: Aug 27, 1997

Is SWMF Ready for R2O?

- Is it user friendly/robust?
  - Good user manual
  - Multiplatform/portable
  - Wide accuracy/robustness trade space
  - Runs 24/7 at CCMC since 2002

- Strengths
  - Shock arrival time is ±10h
  - All clear prediction
  - Open/closed field line boundary
  - CPCP, Dst, regional dB/dt, open/closed boundary, etc
  - Continuously evolving

- Weaknesses
  - Validation is incomplete
  - Too many knobs to turn
  - Continuously evolving

- Ready for R2O, but buyer beware!