MEGI- Multi-element Geospace Investigation

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Understand NSF Imperatives


- NSF Budget is $7.8B
  - NSF Geoscience Directorate Budget is $1.3B
  - NSF AGS is about $134M
  - NSF Geospace is about $45M (GEM, CEDAR, SHINE, facilities, etc)
  - MREF budget $200M/yr

- The foundation’s six research big ideas are:
  - Harnessing Data;
  - Shaping the New Human Technology Frontier;
  - The Rules of Life;
  - Quantum Leap: Leading the Next Quantum Revolution;
  - Navigating the New Arctic;
  - Windows on the Universe: the Era of Multi-Messenger Astrophysics;

- And the three process ideas are:
  - Convergent Research;
  - Mid-scale Research; and
  - NSF 2050.

- To get an MREFC we have to have a “big idea”
Unde venimus et quo vademus?

- How is our home planet connected to the Sun and space?
  - Why is the Earth different from Mars and Venus?
  - With the thousands of exoplanets discovered how many Earth-like worlds might there be?
  - What is the role of the Earth’s magnetic field is shaping the evolution of our home?
  - ……lots of other questions all the way down….
  - How does the coupled I/T system respond to variations in the high latitude inputs/
  - How do we distinguish that from forcing from below?
Within the Vision there are Themes Driven by the Need to “Use” and “Know”

- We tend to think of scientific programs as a linear “requirements flowdown” or “traceability matrix”
- The MREFC goals can be thought of as a “matrixed approach” that make connections from the Sun to the Earth
We are taking our first steps:

- We are developing a Multi-Element Geospace Investigation consisting of ground-, air- and space-based instruments. International collaboration is a key element of that as is the ability to seamlessly connect scientists and information (data and model results as well as analysis products).
- Our goal is to produce an inclusive, international team that addresses a wide set of problems with a general theme and then sell and write an NSF MREFC proposal to establish the elements of this system.
- This constellation of resources can be applied to address a range of problems.
Initial steps are:
- Frame the problem
- Hold a workshop to establish the solution approach
- Use OSSEs to determine where we need additional information
  - Establish the need for facilities
  - Incorporate existing facilities as part of the solution to establish the need for continued support

Exit state
- Establish community roles and build support
- Marketing materials for NSF
- Final report
Example of why we need a global approach
F18 Disk – 2013/075
Orbits 17568–17582

OI 1304  (blue, 4207 R max (data), 5000 R max (color scale))
OI 1356  (green, 2137 R max (data), 400 R max (color scale))
LBH short (red, 2420 R max (data), 1000 R max (color scale))
F18 Disk – 2015/075
Orbits 27877–27888

O1 1304 (blue, 4207 R max (data), 5000 R max (color scale))
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F18 Disk - 2013/076
Orbits 17583–17596

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F18 Disk – 2015/076
Orbits 27892–27905

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LBH short (red, 2420 R max (data), 1000 R max (color scale))
F18 Disk - 2013/077
Orbits 17597–17608

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F18 Disk – 2015/077
Orbits 27905–27919

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F18 Disk – 2013/078
Orbits 17612–17624

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LBH short (red, 2420 R max (data), 1000 R max (color scale))
F18 Disk – 2015/078
Orbits 27919–27933

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OI 1356 (green, 2137 R max (data), 400 R max (color scale))
LBH short (red, 2420 R max (data), 1000 R max (color scale))
Movie by Rob Barnes
AMPERE, SuperDARN, SuperMag and SSUSI
New platforms for exploring our world
- UAVs and Stratospheric platforms
- Commercial suborbital and rideshares
- Buoys
- Aircraft (like Rivet Joint?)

Virtual reality environments for exploring our data and model results

Integrated HSC environment that enables
- Particle filters
- Interaction with the solution trajectories
- Quantification of impact of uncertainties
- Development of OSSE
- Ensemble modeling
- Realtime assimilative modeling
- Small satellites can image the aurora in the UV/visible
How do we resolve fundamental questions?

- If we determine that there is fundamental information in the cusp/polar cap the MREFC can be our vehicle for studying it.
  - Long duration UAVs **could** host instruments at 75,000 feet for days
  - Small satellites could be used to provide continuous coverage
    - CHANGE EMPHASIS from satellites to instruments
  - An aircraft can keep pace with MLT
Dominant form from 12UT March 18 until 20 UT March 19
Other Examples of Asymmetry
3/17/15 Storm

- Detailed small scale phenomena imaged by SSUSI - not reproduced by climatological models – corresponding response of neutrals (not shown here)

- Much stronger aurora in south

- Waves instabilities?

- Collapse of oval in south, discrete arcs in the north
March 16, 2015
Pre-storm IMF Bz fluctuations
Appears to be increased precipitation at cusp
A number of discrete auroral arcs
Southern polar cap arc on dusk side, northern arc on dawnside
Figure 17. Antarctic stations (in red) and mapped conjugate points of selected northern stations.
Magnetometer sites in the Antarctic

- **Challenge:** Groundbased observations need “ground”
- **Solution:** Buoys (in the air and water) can provide the needed coverage and provide information on the surface to space processes and interconnections.
- Community can develop new approaches and new instruments
- Launch on a regular basis from facilities in the Antarctic
Challenge:
Determine the optimal composition and distribution of sensors to specify the system and its response.

Solution: OSSEs, data assimilation and sophisticated modeling techniques (particle filters, ensemble techniques, etc) need to replace our current naive approach in order to determine the limits of our understanding.

Outcome: Demonstration that the problem can be adequately specified.
Enabling exploration and discovery

- We use techniques that are over 200 years old to share our results
- Challenges include
  - Data analytics
  - Computer-assisted “vision”
  - VR interactions
- Bring in other communities
- Lead other communities
  - Anomaly resolution requires timely results
  - Exploitation requires speed and accuracy
MEGI Outcomes

- Incorporate and provide an umbrella for existing CEDAR/GEM capabilities
  - Does NOT co-opt/redirect these activities
- Establish a scientific basis for the need for instrument/model investment in a new facility
- Determine the size, scope and means for establishing the MREFC
- Delineate the means and expected outcomes of the investment in terms of fundamental scientific questions that are readily understood by all NSF stakeholders

MEGI is to be a PI-led COMMUNITY facility