Facilitating Heliophysics Research by the Virtual Wave Observatory (VWO) Context Data Search Capability

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Abstract

Wave phenomena, ranging from freely propagating electromagnetic radiation (e.g., solar radio bursts, AKR) to plasma wave modes trapped in various plasma regimes (e.g., whistlers, Langmuir and ULF waves) and atmospheric gravity waves, are ubiquitous in the heliosphere. Because waves can propagate, wave data obtained at a given observing location may pertain to wave oscillations generated locally or from afar. While wave data analysis requires knowledge of wave characteristics specific to different wave modes, the search for appropriate data for heliophysics wave studies also requires knowledge of wave phenomena. In addition to deciding whether the interested wave activity is electrostatic (i.e., locally trapped) or electromagnetic (with propagation over distances), considerations must be given to the dependence of the wave activity on observer’s location or viewing geometry, propagating frequency range and whether the wave data were acquired by passive or active observations. Occurrences of natural wave emissions in the magnetosphere (e.g., auroral kilometric radiation) are often dependent also on the state (i.e., context) of the magnetosphere that varies with the changing solar wind, IMF and geomagnetic conditions. Fung and Shao [2008] showed recently that magnetospheric state can be specified by a set of suitably time-shifted solar wind, IMF and the multi-scale geomagnetic response parameters. These parameters form a magnetospheric state vector that provides the basis for searching magnetospheric wave data by their context conditions. Using the IMAGE Radio Plasma Imager (RPI) data and the NASA Magnetospheric State Query System (MSQS) [Fung, 2004], this presentation demonstrates the VWO context data search capability under development and solicits feedback from the Heliophysics research community for improvements.
Waves are Ubiquitous in the Heliosphere

- Electromagnetic, electrostatic, fluid-dynamical
- Freely propagating or trapped
- Different frequencies
Wave Data Products

- Dynamics Spectrograms (as shown) are typical
- Multiple wave modes can occur at same frequency
Other Wave Data Products

(A) Time series
- Bipolar Pulse Duration ~ 80 µs
- Bipolar Pulse Duration ~ 155 µs

(B) Wave map
- 11.5 MLT, 11.8 kHz, 23.5 MLT
- IMF Bz > 0
- IMF Bz < 0

(C) Plasmagram
- Direct Echoes From Plasmapause and Plasmasphere
- Discrete

From active radio sounding
Complex Wave Phenomena in Earth’s Magnetosphere

- Searching pertinent data for analysis can be challenging, particularly to non-experts
Querying Data With VWO

• By time, observing platforms, instruments, data products
  – Traditional data query (e.g., CDAWeb)
  – Can includes defined event lists

• By context
  – Magnetospheric state conditions
    • Sunspot numbers or F10.7 flux
    • Solar wind (velocity, $P_{sw}$)
    • IMF
    • Multi-scale geomagnetic indices ($K_p$, $D_{st}$, AE)
  – Location

• Use Query Builder to construct complex data query
Example of querying data by *Time & Measurement Types*
Selecting Data by Magnetospheric State

- Currently under construction
- Search for data intervals under user-specified magnetospheric conditions
  - Use Magnetospheric State Query System (MSQS) to determine pertinent time intervals (within a time span)
  - Submit MSQS time intervals to data sources to get data
# Magnetospheric-State Search Results

## Step 1: MSQS Query:

**Query Parameters:**
- 2003-01-01 <= t < 2008-01-01
- 7.0 <= Kp <= 9.7
- 0 (Fz), Ave. over: 1 (hr)

## Step 2: Retrieved Multi-Satellite Wave Data

<table>
<thead>
<tr>
<th>Time Intervals</th>
<th>IMAGE_RPI, Cluster/WHISPER Data</th>
<th>IMAGE_RPI Data</th>
<th>CLUSTER/WHISPER Data</th>
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<tr>
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</tbody>
</table>

### Query Conditions

<table>
<thead>
<tr>
<th>2003 &lt; Time &lt; 2008</th>
<th>Geotail, IMAGE, Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 &lt;= Kp &lt;= 9</td>
<td>37 intervals (various durations)</td>
</tr>
</tbody>
</table>
7 < 10*Kp < 9
IMAGE & Cluster Orbits
Sept 11, 2005 0600-1000 UT

Kp > 7

\[ R = (Y^2 + Z^2)^{1/2}_{GSE} \]
10*Kp < 10
IMAGE &
Cluster Orbits
July 6, 2005
1200-1800 UT

Kp < 1
Summary

• Wave phenomena occur in all Heliophysics regimes
• Search for wave data can be challenging
  – Spectral data are not time series
  – Multiple wave phenomena can appear in same frequency range
  – Wave signals can be generated locally or remotely
  – Data selection requires knowledge of wave physics/phenomena
    • EM, ES, polarization, dispersion (cutoff, resonance) & propagation
  – Wave detections depend on space environmental conditions & observing locations
  – Diverse data products/sources (active, passive, space- & ground-based)

• VWO addresses these challenges in part by developing context data search, for examples, by magnetospheric state conditions and observing locations