SpacePy and LanlGeoMag

Software libraries for space science data analysis, modelling and space weather forecasting

SpacePy team: Steve Morley; Brian Larsen; Dan Welling; Jon Niehof
LanlGeoMag team: Mike Henderson; Steve Morley; Brian Larsen; Jon Niehof
Intended Audience
What are they for?

- SPENVIS (Web)
- SpacePy (Python)
- SPEDAS (IDL)
- IRBEMlib (FORTRAN)
- LanlGeoMag (C)

Plot & data visualization tools
B-field models & tracing
Other SW tools
Coordinate conversion
Time conversions

AutoPlot, SWTK, PaPCo, CDAWeb, ESPAS, …
Why Open Source?
Rationale for SpacePy and LanIGeoMag

- **Free software**
  - No licence required
  - Widely used programming languages

- **Source code available under version control**
  - No “black box” routines
  - Bug trackers, feature requests, quick feedback

- **Common routines available to whole community**
  - Work is reproducible

- **Good for scripted jobs**
  - LGM is threadsafe and re-entrant, uses OpenMP
  - Python has easy multi-processing capabilities
Models Included
An Incomplete Selection

SpacePy
- B-field models from IRBEM library
- AE-8/AP-8 (IRBEM)
- Plasmapause
  - Carpenter & Anderson
  - Moldwin et al.
- Magnetopause standoff
- L* neural network
- 1-D RB diffusion model
  - Ensemble Kalman filter

LanlGeoMag
- CDip; EDip; IGRF; Chen & Schulz; Jenson-Cain
- T87; T89c; T96; TSK03; T02; TS04; TS07
- Olsen-Pfitzer
  - Static; Dynamic
- Simplified Mead
- NRLMSISE-00
- B from scattered mesh
- AE8/AP-8
## Tools Included

### An Incomplete Selection

**SpacePy**
- Tracing
  - Field lines; Drift shells
- Superposed epoch analysis
  - 1D; 2D
- Bootstrap CI
- Association analysis
- Windowing mean (time based, points based)
- Time & Coordinate conversions

**LanlGeoMag**
- Tracing
  - Field lines; Drift shells
- Octree; k-D Tree
- SGP4 orbit propagator
- PSD(µ,K) calculation
- Diffusion coefficients
  - Bounce-averaging in arbitrary fields
- Quaternion operations
- Time & Coordinate conversions
A Data Model
Similar to HDF5 Model

- Two basic datatypes:
  - Group
  - Dataset
- Both have metadata
- Groups can contain groups or datasets
- Datasets are array-like
- Supports many metadata standards
File Types Conversion via a common data model

- HDF5
- netCDF MATLAB save
- NASA CDF
- JSON-headed ASCII
- SpacePy Data Model Representation
- SWMF binary
- HTML table
# "Pmin_gsm": { "DESCRIPTION": "Location of minimum-\(|B|\) point (in GSM coords).",
# "NAME": "Pmin_gsm",
# "TITLE": "Minimum-\(|B|\) point (in GSM Coordinates)",
# "LABEL": "T01S Pmin_gsm (R!BE)",
# "UNITS": "R!BE!N",
# "DIMENSION": [ 3 ],
# "START_COLUMN": 100,
# "ELEMENT_NAMES": [ "Pmin_gsm_x", "Pmin_gsm_y", "Pmin_gsm_z" ],
# "ELEMENT_LABELS": [ "T01S Pmin_gsm!Bx!N , R!BE", "T01S Pmin_gsm!By!N , R!BE", "T01S Pmin_gsm!Bz!N , R!BE" ],
# "FILL_VALUE": -1e31 }

UNCLASSIFIED
In use: PyBATS
Space Weather Modeling Framework

BATS-R-US output
Tracing done in SpacePy

Ionospheric Electro-dynamics (IE) module

Solar wind data through SpacePy OMNI module
In Use: SeaPy
Analysis of GPS particle data

CXD: 0.77-1.25 MeV

Counts/sec

L' = 6.5 (T89)

Counts/sec

L' = 7.5 (T89)

Counts/sec

L' = 4.5 (T89)


Operated by Los Alamos National Security, LLC for the U.S. Department of Energy’s NNSA
ITRF and WGS84 are same to within \~cm.

IAU-76/FK5

GCRF and ECI(J2000) are same within uncertainty of FK5.
ViewDriftShell: 3D visualizer

Multiple Coordinate Systems
ViewDriftShell: 3D Visualizer

Visualizing Drift Shells

GSM Coordinates:
- Date: Sep 9, 2002 (2002/252)
- Time: 23:17:30.000 UTC
- Camera: 4.84, -13.40, 4.75 Re
In use: Real-time DREAM
Radiation Belt Nowcasting

\[ \mu = 984.21 \text{ [MeV/G]}; \ K = 0.11 \text{ [Re G}^{1/2}] \]

Last update at 2014-09-22T07:56:58
Data Flow: Real-time DREAM

SpacePy (Red); LGM (Blue)

- realtime Kp, Dst indices
- realtime solar wind
- satellite ephemeris
- real-time energetic particles
- real-time magnetic field
- real-time differential flux
- magnetic field model
- PSD(μ,K)
- DREAM Diffusion/assimilation
- rtDREAM output

Data Flow: Real-time DREAM

SpacePy (Red); LGM (Blue)
In use: Magnetic Ephemeris
Van Allen Probes, MMS, GPS

Position, Attitude, e.g.
- $\text{GEI}_{\text{J2000}}$, WGS84
- GSE, GSM, SM

Field Quantities, e.g.
- $\vec{B}$, $B/B_0$, FL length & type
- $I(\alpha)$, $L^*(\alpha)$, $L_m(\alpha)$
- $\kappa(E) \ [\text{adiabaticity parameter}]
  - (\text{Min. radius of curvature})
  / (\text{maximum gyroradius})$
- Footpoint locations
Where to get code and help…
And what’s coming next?

- **SpacePy** (current v0.1.4; new release imminent)
  - Code repository (git) on SourceForge
    [sourceforge.net/projects/spacepy](sourceforge.net/projects/spacepy)
  - Online documentation
    [spacepy.lanl.gov](spacepy.lanl.gov)

- **LanlGeoMag** (currently no official release cycle)
  - Code repository (git) on GitHub
    [github.com/drSteve/LANLGeoMag](github.com/drSteve/LANLGeoMag)
  - Documentation in repository

LanlGeoMag interface in SpacePy is under development