GeoData Python Toolset: High Performance Python for Geoscience

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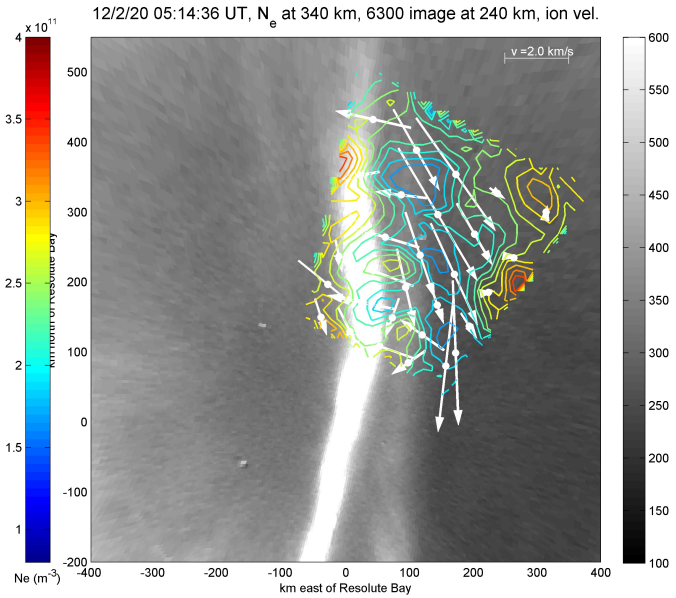
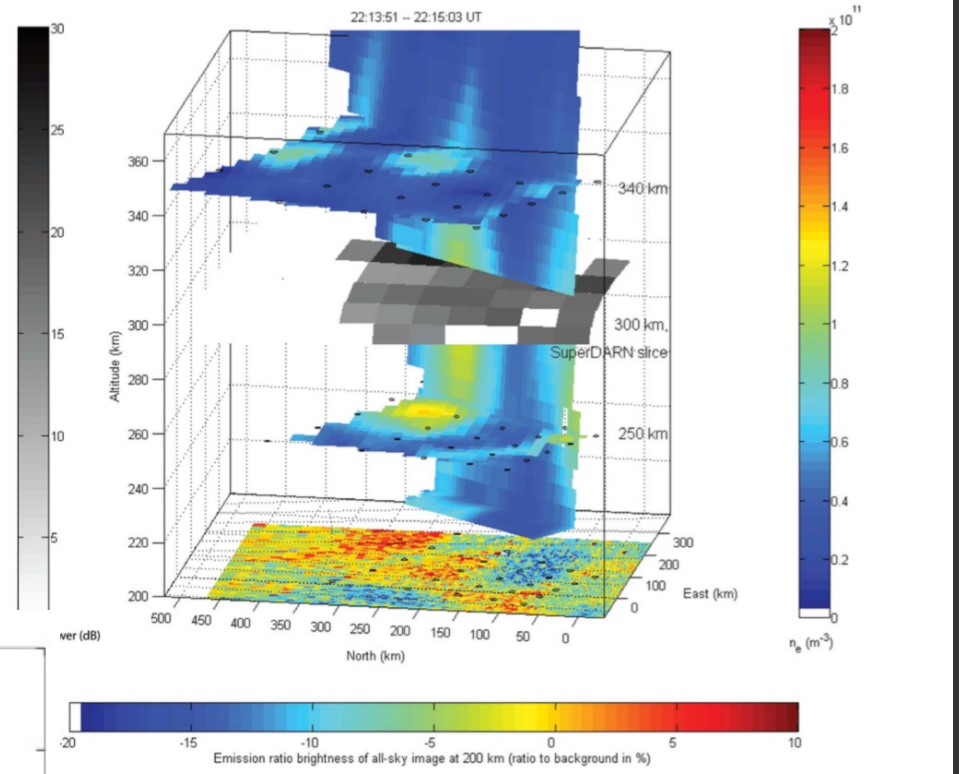
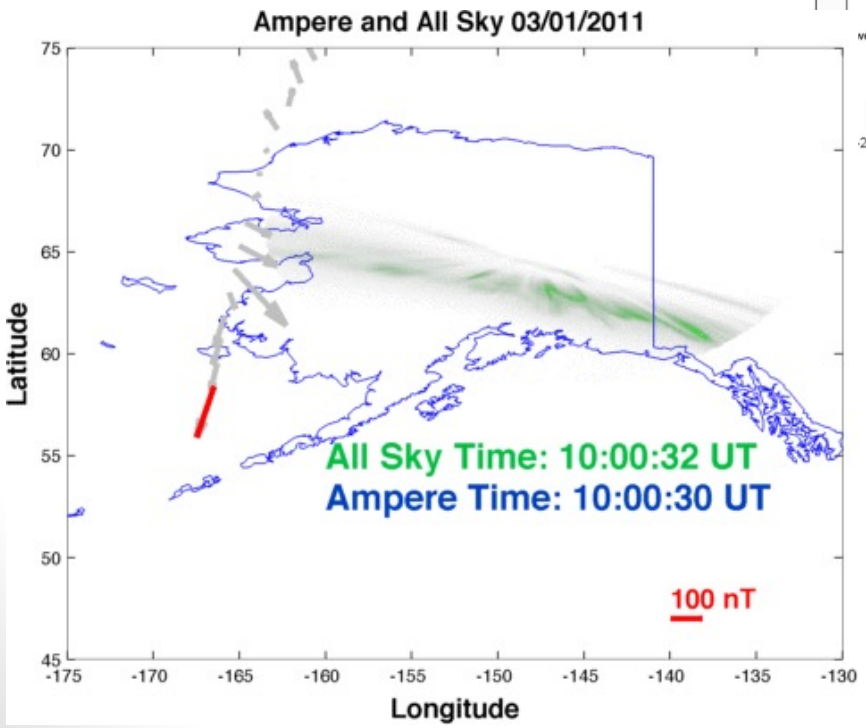
Michael Hirsch – Boston University
Joshua L. Semeter – Boston University



Dahlgren



Dahlgren 2012



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OCEAN TEMPS PREDICT U.S. HEAT WAVES 50 DAYS OUT, STUDY FINDS

Pacific pattern often forms

March 28, 2016

BOULDER — The formation of
the North Pacific Ocean can pr
eastern half of the United Stat
scientist at the National Cente

The pattern is a contrast of wa
than-average seas. When it ap
week—or even on a particular
pattern is.

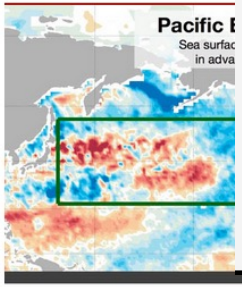
The research is being publishe

"Summertime heat waves are a
impacts on farming, energy us
postdoctoral researcher at NC
and farmers a heads up that e
worst consequences."

The research was largely fund
addition to McKinnon, the res
Washington; Martin Tingley, o
University.

A FINGERPRINT ON THE OC

For the study, the scientists di
heat at the same time. The sci
swath that stretches across m
important agricultural areas a



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Enhancing National Preparedness to Space-Weather Events

OCTOBER 29, 2015 AT 2:00 PM ET BY TAMARA DICKINSON AND BILL MURTAGH

Summary: Today, OSTP hosted an event and announced new materials and commitments to enhance national space-weather preparedness.

Enhancing Preparedness for Space-Weather Events

Our Nation's security, economic vitality, and daily functioning depend on the reliable operations of satellites and aircraft, communications networks, navigation systems, and the electric power grid. As these and other, similar technologies and infrastructures become increasingly ubiquitous and interdependent, the United States – and indeed, the world – faces greater risks from the threats posed by space weather events.

Space weather refers to variations in the space environment between the sun and Earth (and throughout the solar system). In particular, space weather describes the phenomena – solar flares, solar energetic particles, and coronal mass ejections – that impact systems in orbit and on Earth. In recent years, the Obama Administration has played an active role in maintaining and advancing the Nation's ability to forecast and mitigate the various impacts of space weather. This work has included taking steps to replace aging satellite assets essential to monitoring and forecasting space weather, proposing space-weather standards for both the national and international air space, developing regulations to ensure the continued operation of the electric grid during an extreme space weather event, proposing a new option for replacing crucial Extra High Voltage (EHV) transformers damaged by space weather, and developing domestic production sources for EHV transformers.

Yet gaps remain in our capacity to understand, model, predict, respond to, and recover from space-weather events. That's why today, the White House Office of Science and Technology Policy

average—and
extreme heat in

Usual Procedure

- Read in the data.
  - Different sensors.
  - Same data, different sources.
- Register the data in time and space.
  - Different coordinate systems.
  - Different time systems.
- Map data into a common coordinate system.
  - Different interpolation/projection methods.
- Plotting
  - Everything is just screwed up by then.

Can We Do Better?

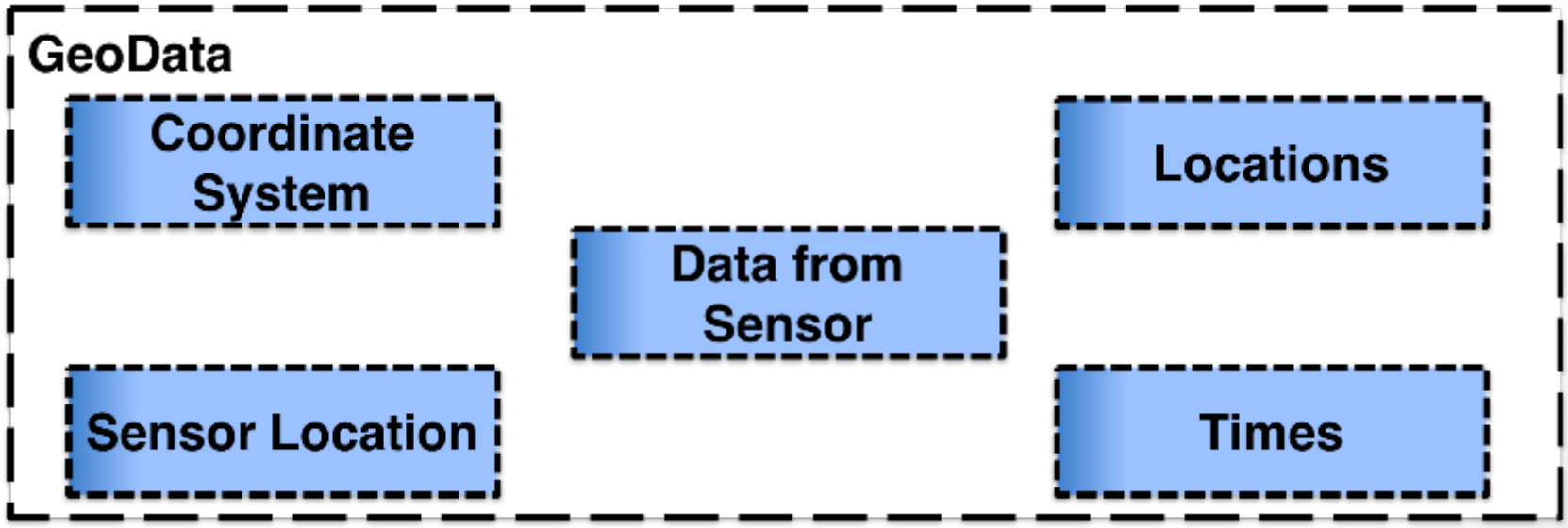
- Reuse code more effectively and reduce OTR
  - Save Time!
  - Save Money!
- Need to be able to use multiple sensors.
- Must be able to incorporate new sensors as data becomes available.
- Plotting in multiple spatial dimensions.

GeoData

- API for using sensor data
  - Reading
  - Registration in time and space
  - Interpolation
  - Plotting
    - Matplotlib for 1 and 2D
    - Mayavi for 3D
- Standard format for data
  - Also have methods to save out data
- New sensors/data can be used once data is in format

GeoData

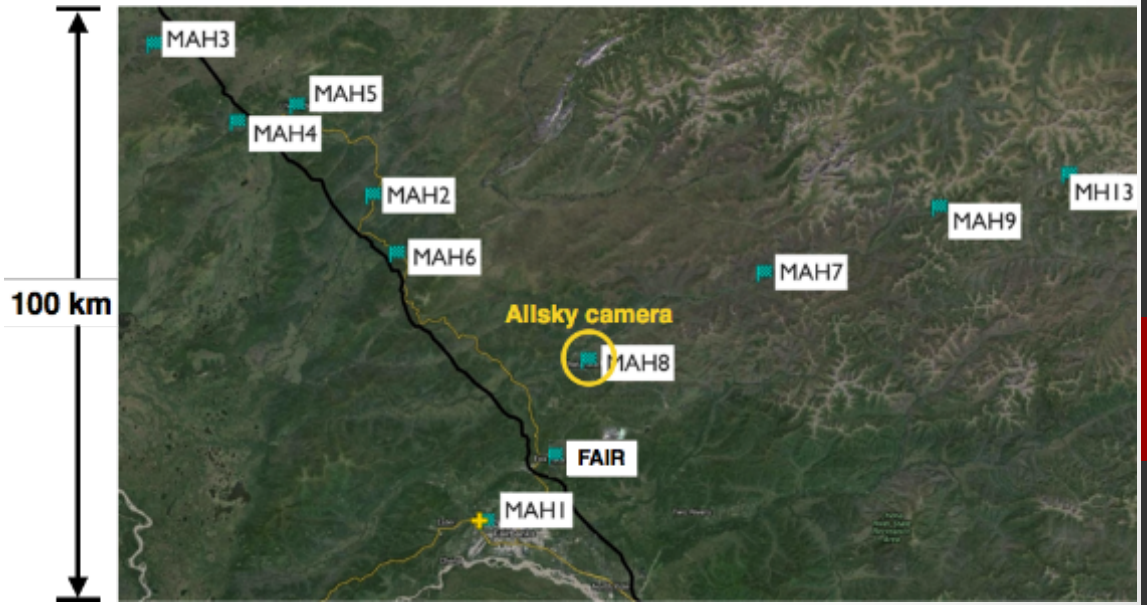
- GeoData class abstracts a data set into an object.
  - The data, location, times, coordinate systems are all attributes of this object.



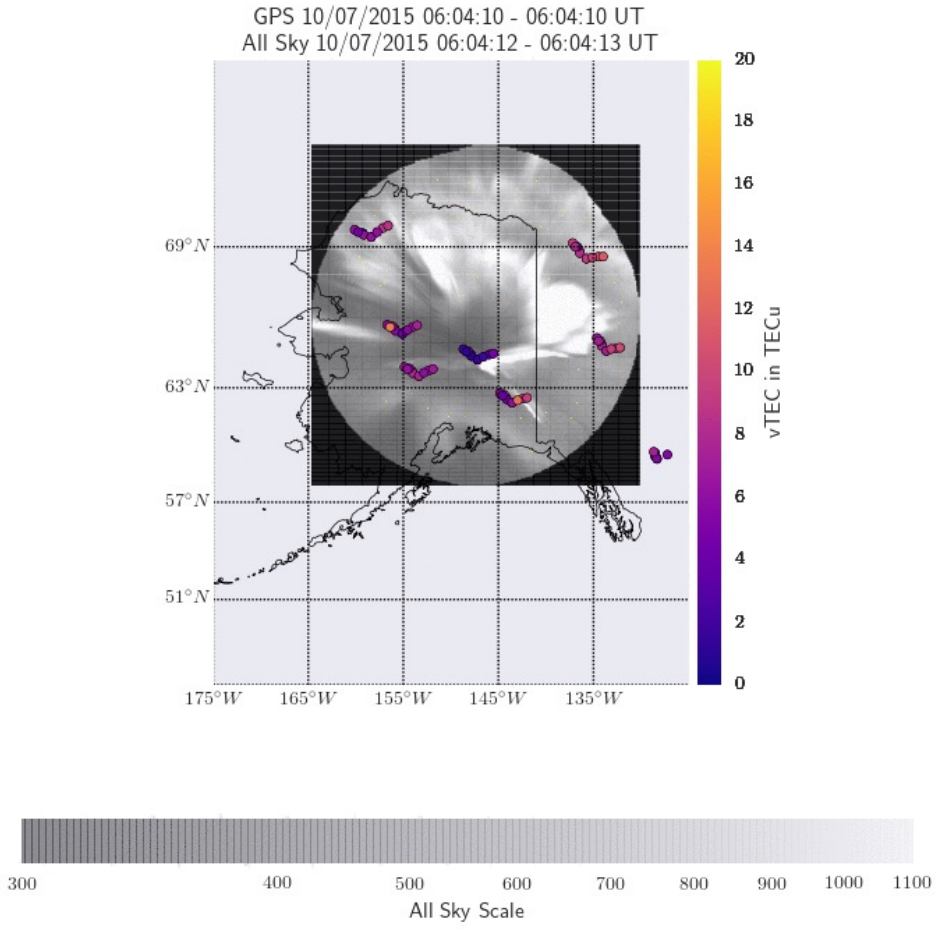
Mahali

- Funded research project to test the utility of a dense network of GPS receivers.
  - Use GPS Total Electron Content (TEC) measurements

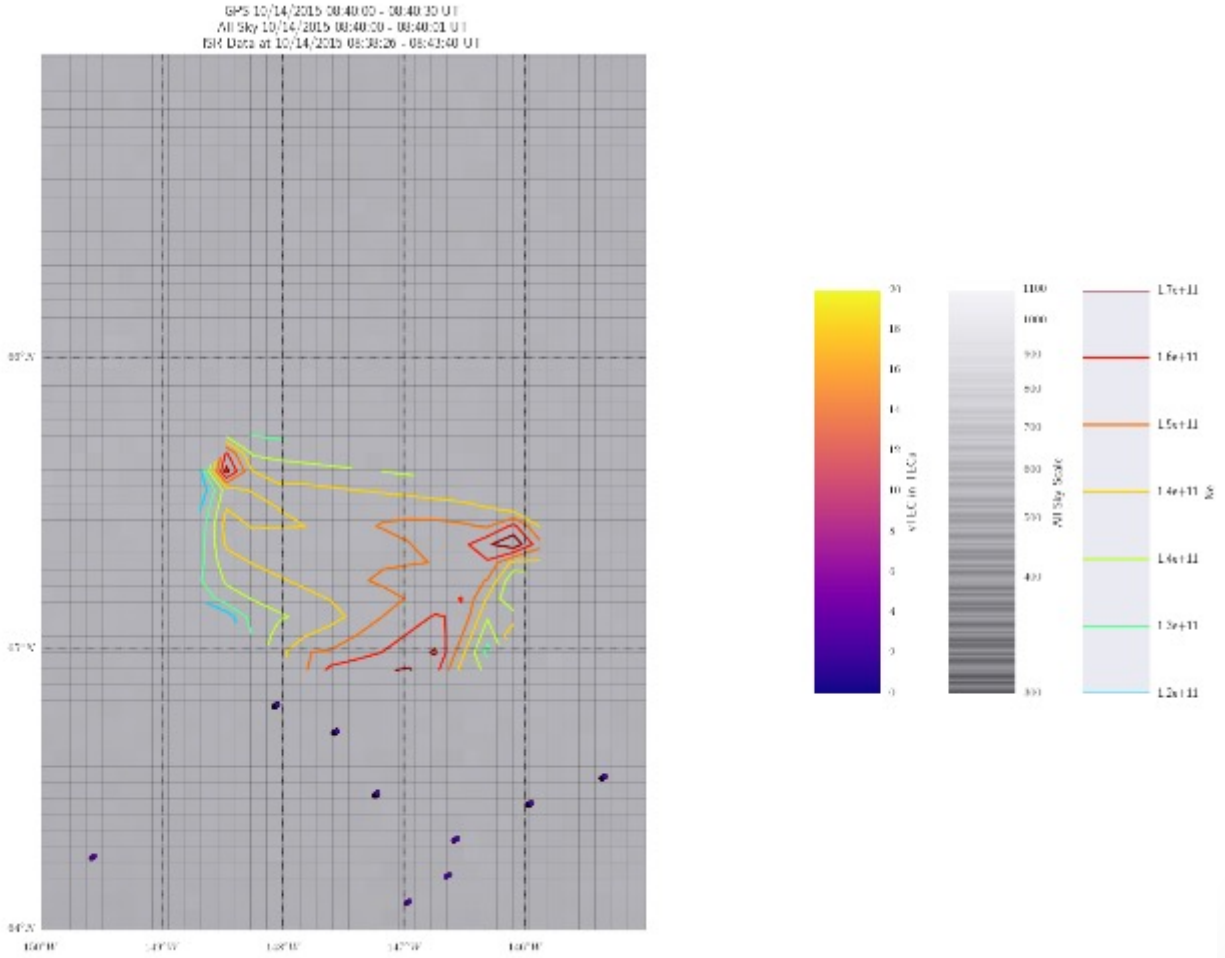
- Fuse different different data sets together.
  - GPS
  - Optical, Allsky
  - ISR



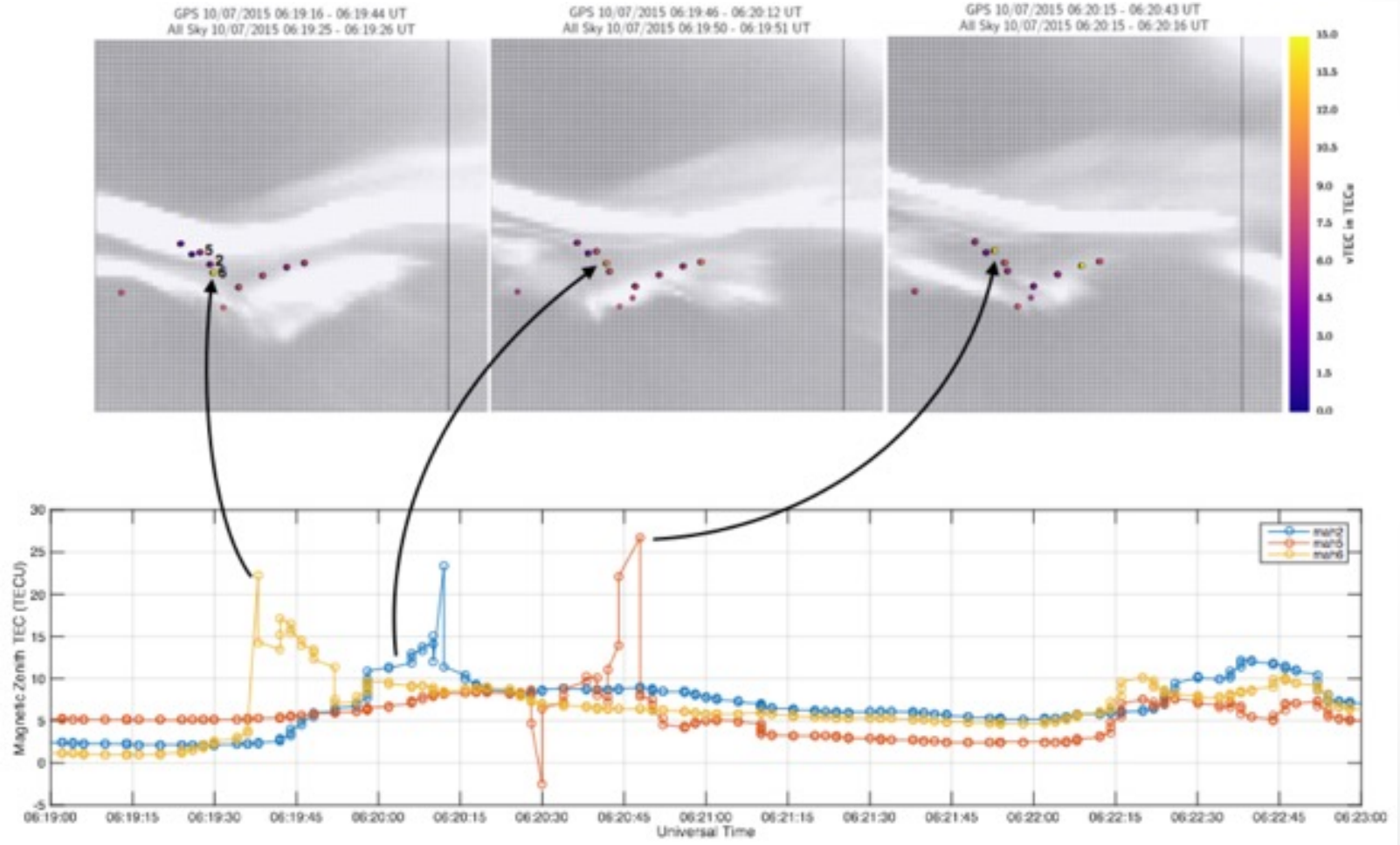
Mahali


GPS 10/07/2015 06:04:10 - 06:04:10 UT
All Sky 10/07/2015 06:04:12 - 06:04:13 UT
69°N
63°N
57°N
51°N
175°W
165°W
155°W
145°W
135°W
20
18
16
14
12
10
8
6
4
2
0
vTEC in TECu
300
400
500
600
700
800
900
1000
1100
All Sky Scale

Mahali


GPS 10/14/2015 08:40:00 - 08:40:30 UT
All Sky 10/14/2015 08:40:00 - 08:40:01 UT
ISR Data at 10/14/2015 08:38:26 - 08:43:40 UT

Mahali


GPS 10/07/2015 06:19:16 - 06:19:44 UT
All Sky 10/07/2015 06:19:25 - 06:19:26 UT
GPS 10/07/2015 06:19:46 - 06:20:12 UT
All Sky 10/07/2015 06:19:50 - 06:19:51 UT
GPS 10/07/2015 06:20:15 - 06:20:43 UT
All Sky 10/07/2015 06:20:15 - 06:20:16 UT
vTEC in TECu
Magnetic Zenith TEC (TECU)
Universal Time

References and Software

Software

- GitHub: jswoboda
  - https://github.com/jswoboda
- GeoData
  - Contributors
    - John Swoboda
    - Michael Hirsch
    - Greg Starr
    - Anna Stuhlmacher

Reference

- H. Dahlgren, G. W. Perry, and J. L. Semeter, “Space-time variability of polar cap patches: Direct evidence for internal plasma structuring,” *J. Geophys. Res. Space Physics*, 2012.

Using Python with compiled code (Fortran/C/C++)

F2Py (part of Numpy) allows importing **Fortran** easily

- Use Fortran compiler & flags of your choice
- Auto-generates `import` of Fortran subroutines & functions
- NO modifications necessary to Fortran code typically
  - If old Fortran w/o Intents, use !f2py intent(inout)
- Typically easier than Matlab MEX

```
1   C-----------------------------------------------------------------------
2         SUBROUTINE GTD7(IYD,SEC,ALT,GLAT,GLONG,STL,F107A,F107,AP,MASS,D,T)
3   c        Implicit None
4   C
5   C     NRLMSISE-00
6   C     -----------
7   C        Neutral Atmosphere Empirical Model from the surface to lower
8   C        exosphere
136       Real,Intent(OUT):: D(9), T(2)
137       Real,Intent(In) :: SEC,ALT,GLAT,GLONG,STL,F107A,F107,AP(7)
138       Integer,Intent(IN)::IYD,MASS
```

- I write new Fortran code: speed up iterative loops
  - Linear algebra: tough to beat Numpy/Scipy

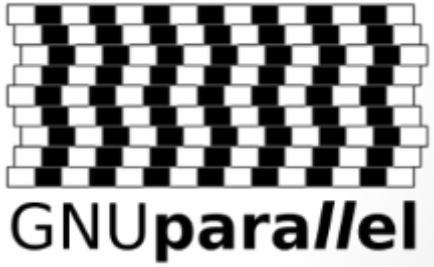
- Tradeoffs in ease of use / less original code modification / runtime speed

Worthwhile to go compiled?

- Researcher time-to-implement
  - Value of Matlab & Simulink
  - Iterative loops->separate function & compile
  - Intel MKL now free-of-charge

- Continuum of choices
  - Numba (LLVM compile of plain Python with decorator)
  - Cython (Python-like code)
  - Nuitka (compile standalone executables)
  - SWIG / Weave

- For embarrassingly parallel problems, run on multiple CPU cores and/or multiple PCs via GNU Parallel or Fabric
  - Simulating basis set of monoenergetic electron beams



https://www.gnu.org/software/parallel/

Verification

Code without test case = broken

- Innocent changes -> surprising impacts on program output
  - compiler/OS/CPU quirk
- Python + Github + Travis CI = free, simple, automated test case runs
  - Mac OS, Linux, (Window)
  - Clang, GCC 4-6, Cmake, etc.
  - Pull requests and Pushes

- Coveralls – shows percentage of code actually executed in tests

- Examples
  https://bit.ly/geotravis