

# How to use the Madrigal database for atmospheric science

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ISR workshop  
Arecibo Observatory  
July 21, 2014

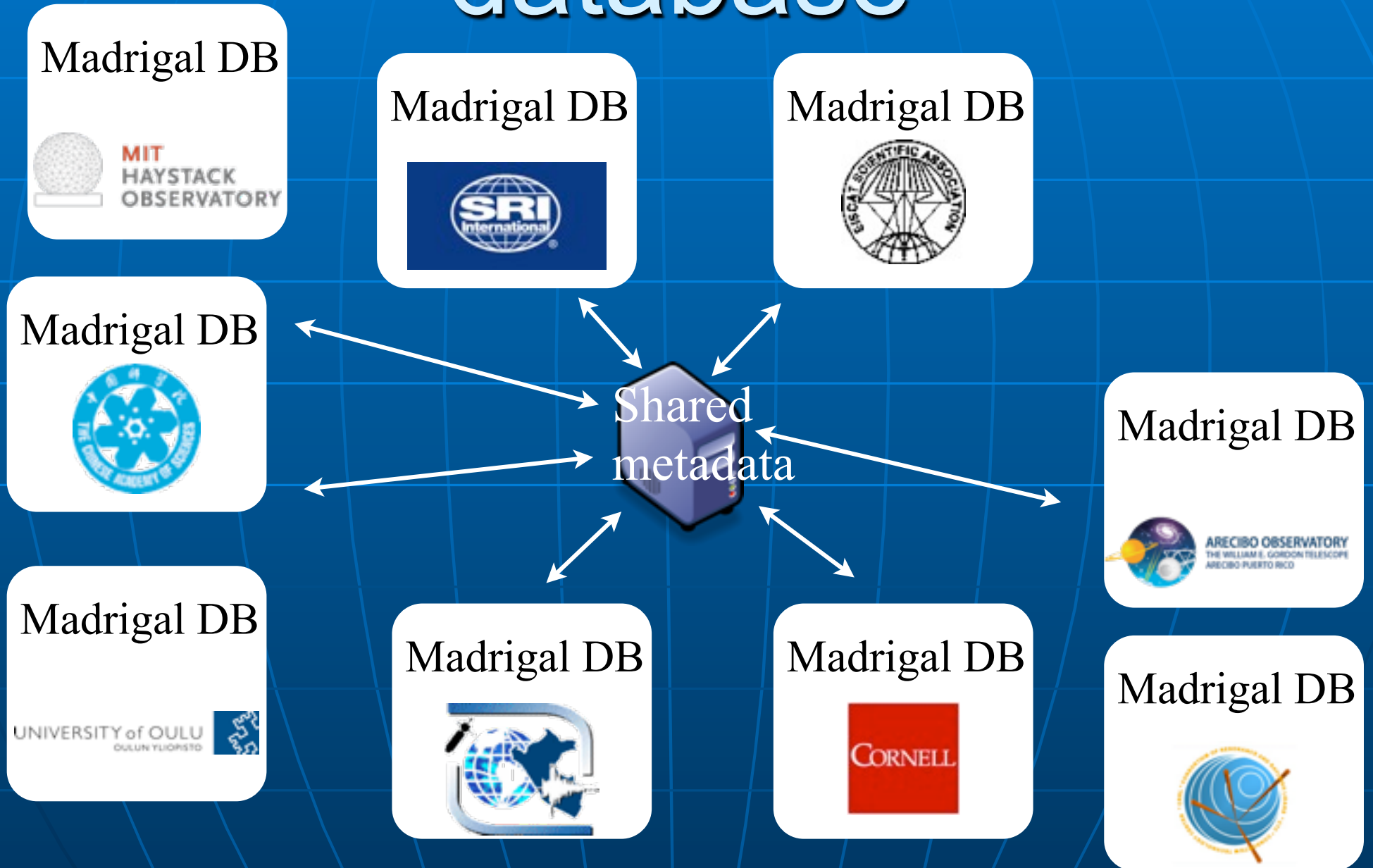
1

# Outline

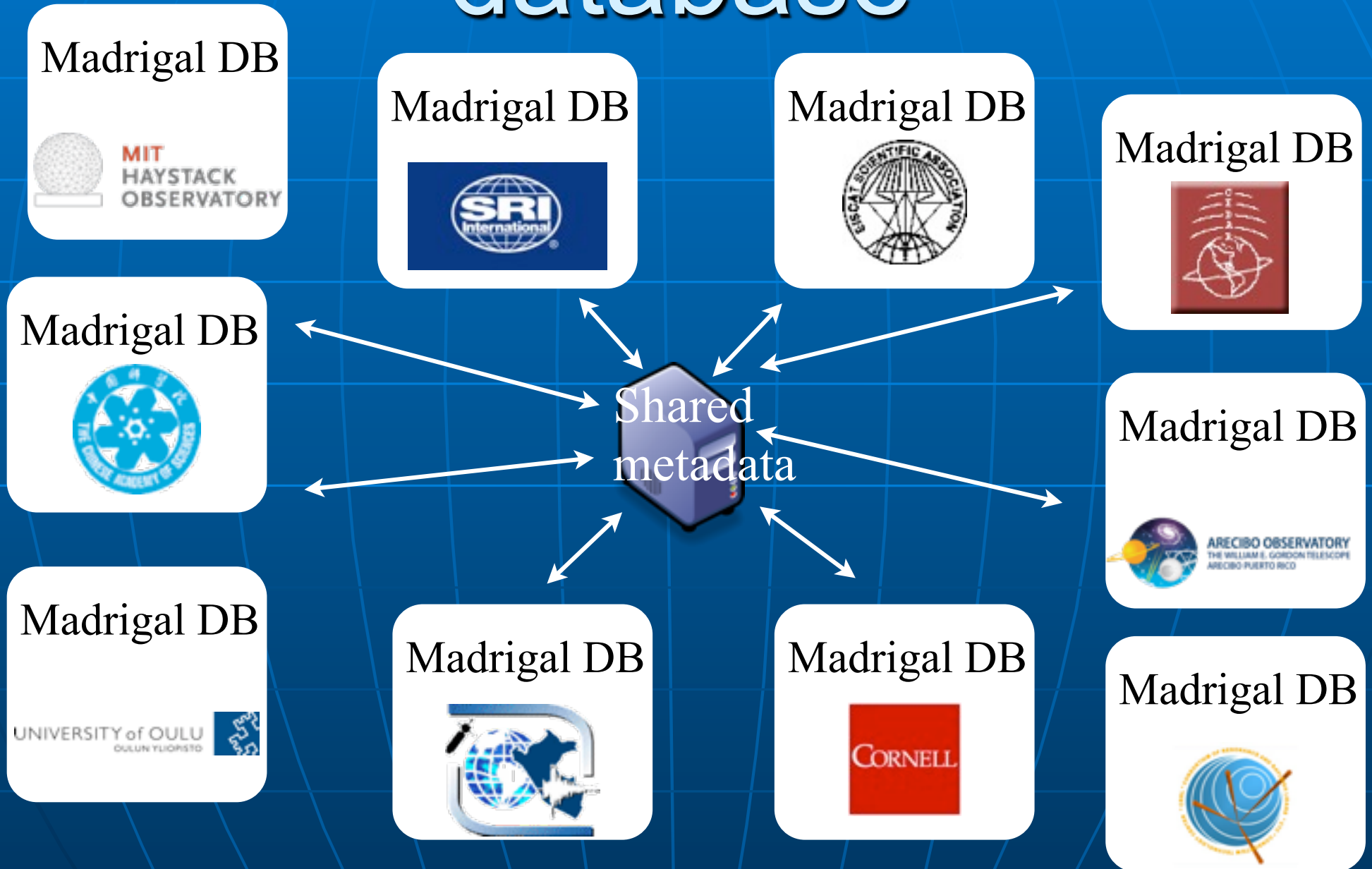
- What is Madrigal?
- What is the CEDAR database format?
- In what formats can I get Madrigal data?
- How do I use Madrigal?
  - Background
  - The website
    - Simple local data access
    - Full Access
  - Script data access
- Group exercises

# What is Madrigal?

# Madrigal is a distributed database



# Madrigal is a distributed database



# Cedar Madrigal archive imports all data weekly

Madrigal DB



Madrigal DB



Madrigal DB



Madrigal DB



Madrigal DB



Madrigal DB



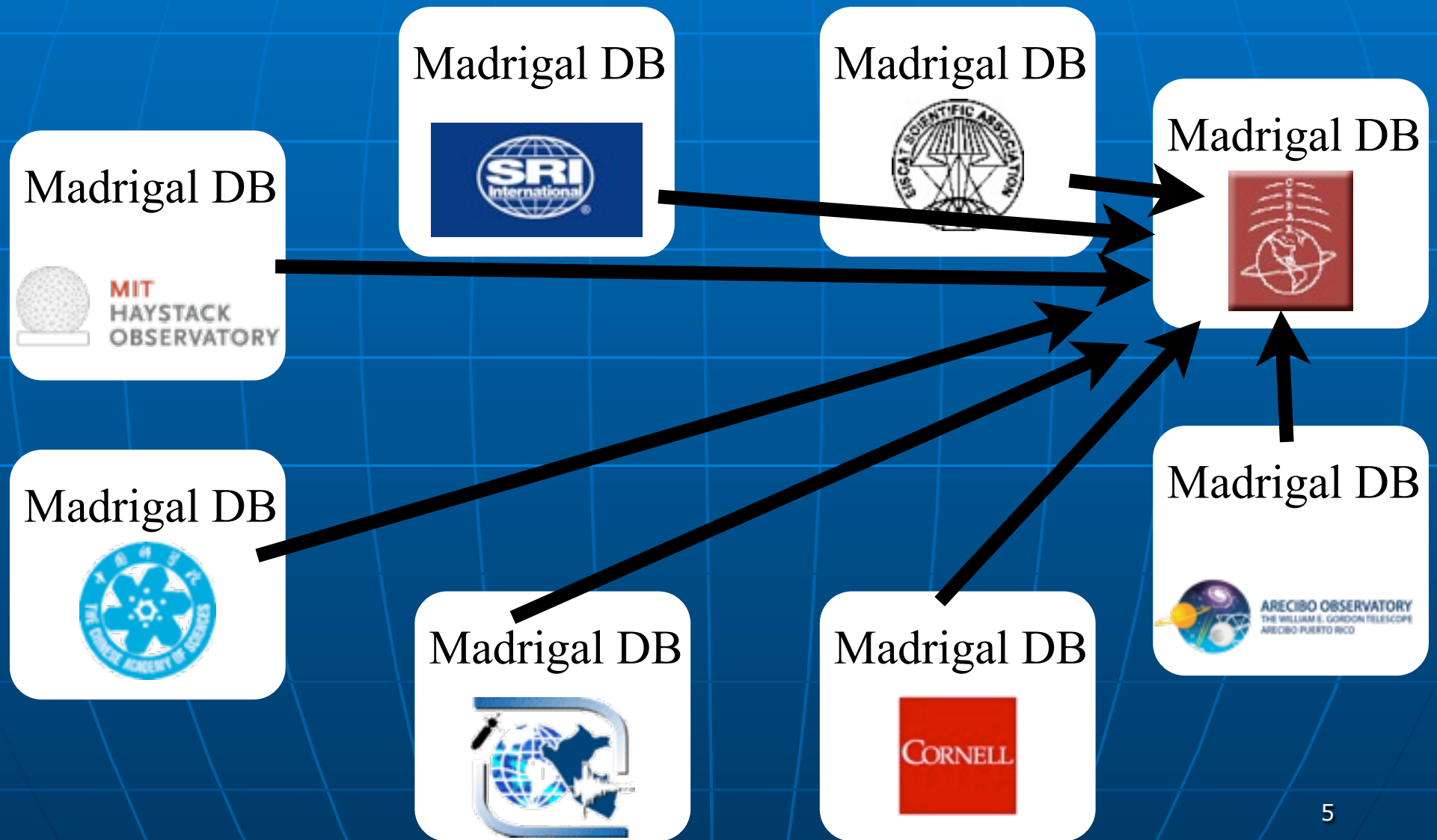
Madrigal DB



Madrigal DB



# Cedar Madrigal archive imports all data weekly



# The Madrigal database stores data from a wide variety of upper atmosphere research instruments

Incoherent Scatter Radar



TEC via GPS



MF Radar



## Number of instruments in Madrigal:

- Incoherent scatter radars: 22
- MST radars: 3
- MF radars: 16
- Meteor radars: 7
- FPI: 23
- Michelson Interferometers: 6
- Lidars: 4
- Photometers: 4



# Madrigal is open-source

**The Open Madrigal Initiative**

The OpenMadrigal project seeks to develop and support an on-line database for geospace data. The project has been led by [MIT Haystack Observatory](#) since 1990, but now has active support from [Iquitos Observatory](#) and other community members. Madrigal is a robust, World Wide Web based system capable of managing and serving archival and real-time data, in a variety of formats, from a wide range of ground-based instruments. Madrigal is installed at a number of sites around the world. Data at each Madrigal site is locally controlled and can be updated at any time, but shared metadata between Madrigal sites allow searching of all Madrigal sites at once from any Madrigal site.

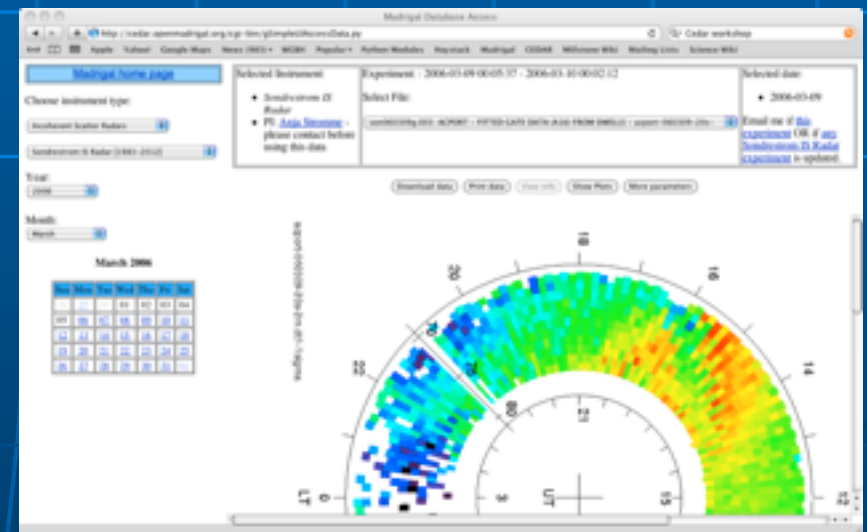
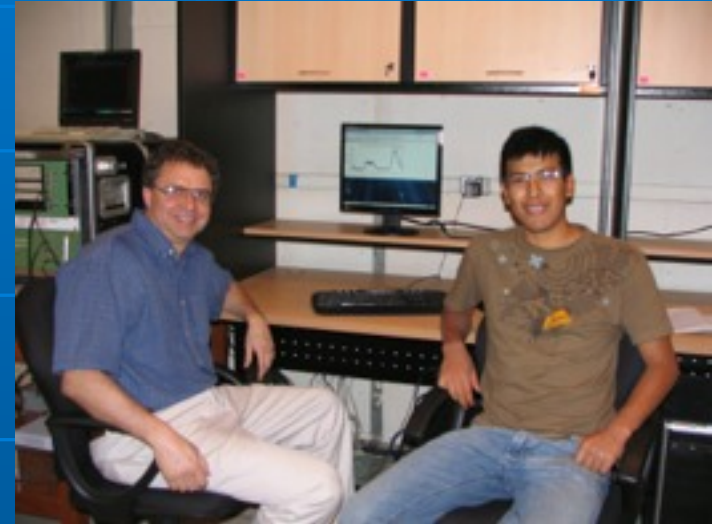
Madrigal is a robust, World Wide Web based system capable of managing and serving archival and real-time data, in a variety of formats, from a wide range of instruments. Data can be accessed from the Madrigal sites at [Milestone Hill, USA](#), [EISCAT, Norway](#), [SRI International, USA](#), [Arecibo, Puerto Rico](#), [Cornell University, USA](#), [Iquitos, Peru](#), the [Institute of Geology and Geophysics](#), the Chinese Academy of Sciences, and the [CEDAR Madrigal archive](#) using standard Web browsers; and directly, using APIs which are available for python, Matlab, and IDL.

- [What is Madrigal?](#)
- [Download/update Madrigal](#) - includes Madrigal server and client APIs
- [Documentation](#)
  - [Web access](#)
  - [Script access](#)
- [Empirical Ionospheric Models](#)
- [Subversion Source Control](#)
- [Mailing Lists](#)
- [Announcing OpenMadrigal](#)

Suggestions and comments could be sent to [madrigal@haystack.edu](mailto:madrigal@haystack.edu)

Logos: MIT Haystack Observatory, Iquitos Observatory, EISCAT, SRI International, Cornell University, Institute of Geology and Geophysics, Chinese Academy of Sciences, CEDAR Madrigal archive.

Link to Subversion (source code)



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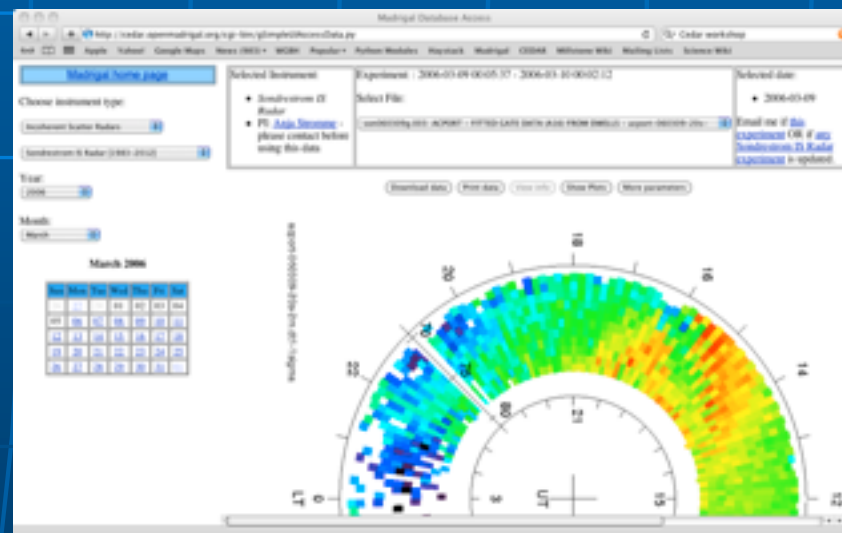
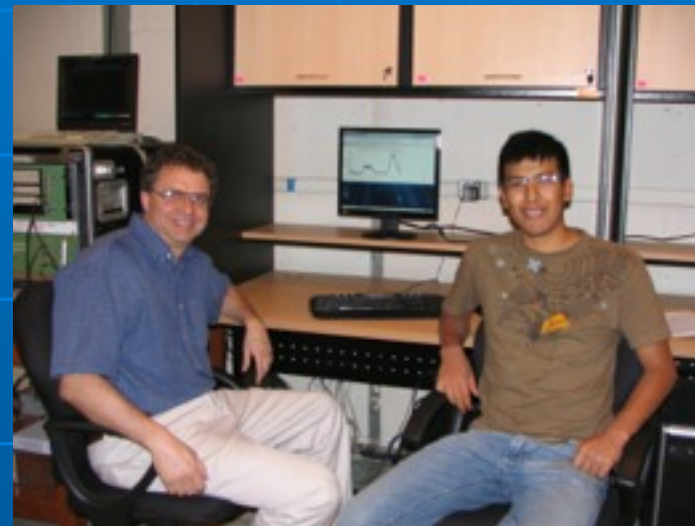
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- [Subversion Source Control](#)
- [Mailing Lists](#)
- [Advertising OpenMadrigal](#)

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Suggestions and comments could be directed to [madrigal@haystack.edu](mailto:madrigal@haystack.edu)

Link to Subversion (source code)



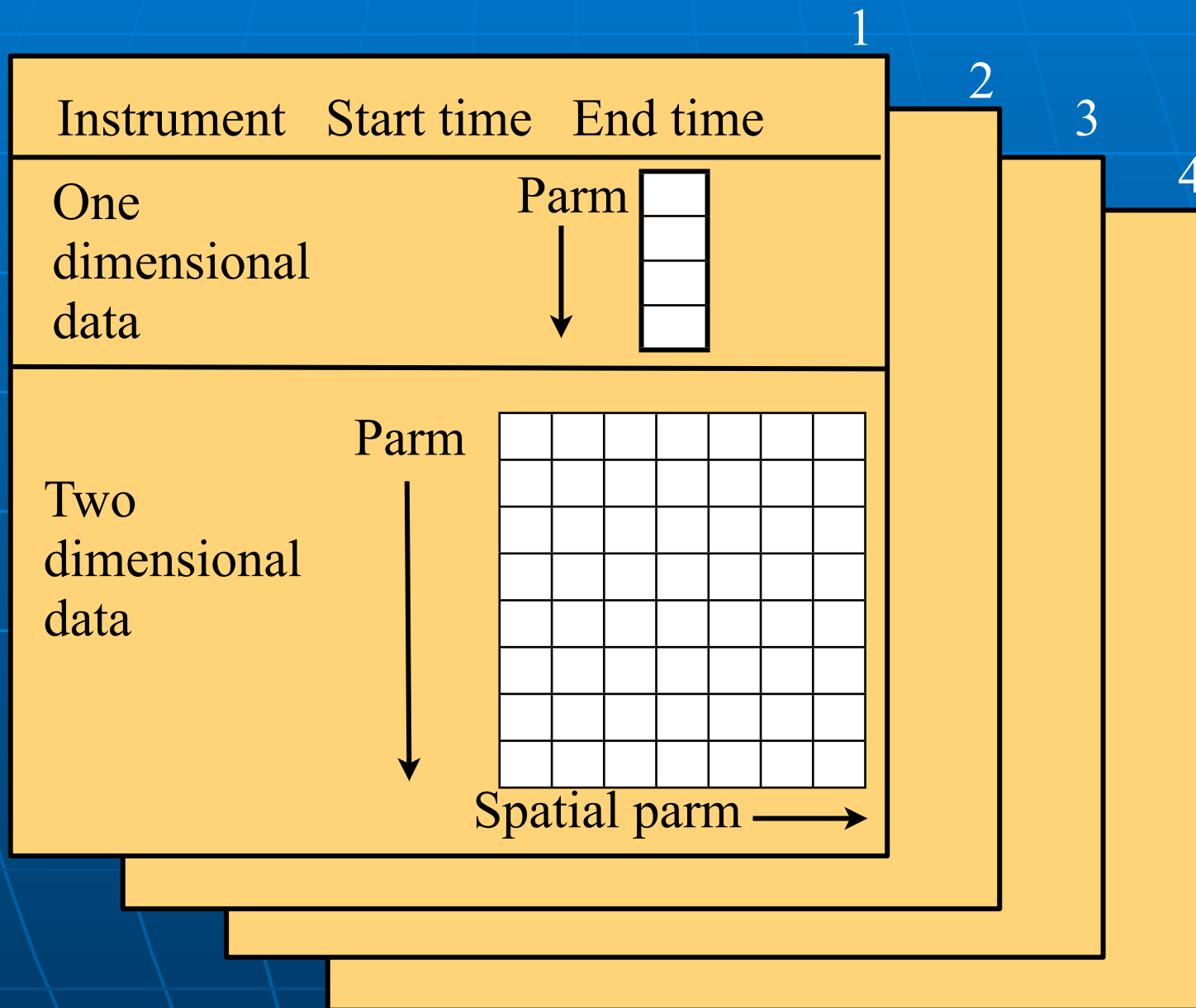
[www.openmadrigal.org](http://www.openmadrigal.org)

- What is the CEDAR database format?

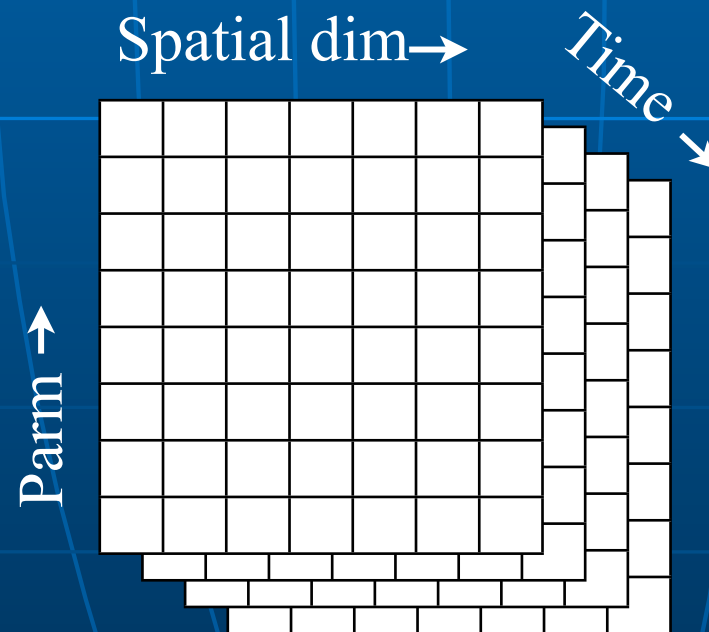
# Well defined parameters

- Standard descriptions of all parameters
- Allows the existence of derivation engine
- Madrigal allows extended descriptions
- All parameters have corresponding error parameters
- Missing, Assumed

# Cedar file data model

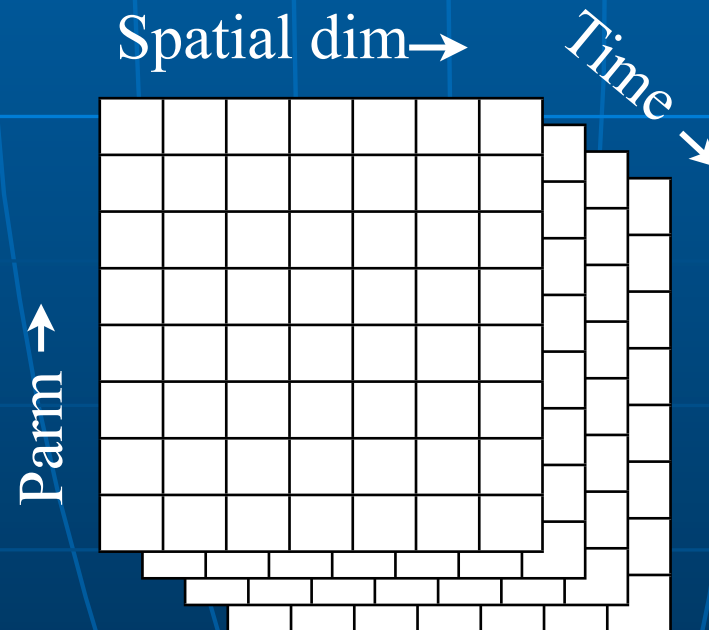


# Flexibility versus ease-of-plotting



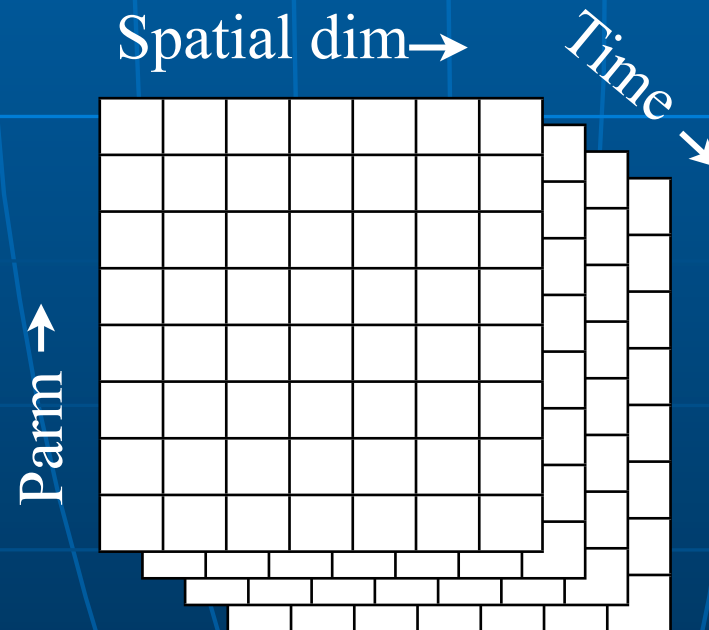
# Flexibility versus ease-of-plotting

- Does not require consistent parameters



# Flexibility versus ease-of-plotting

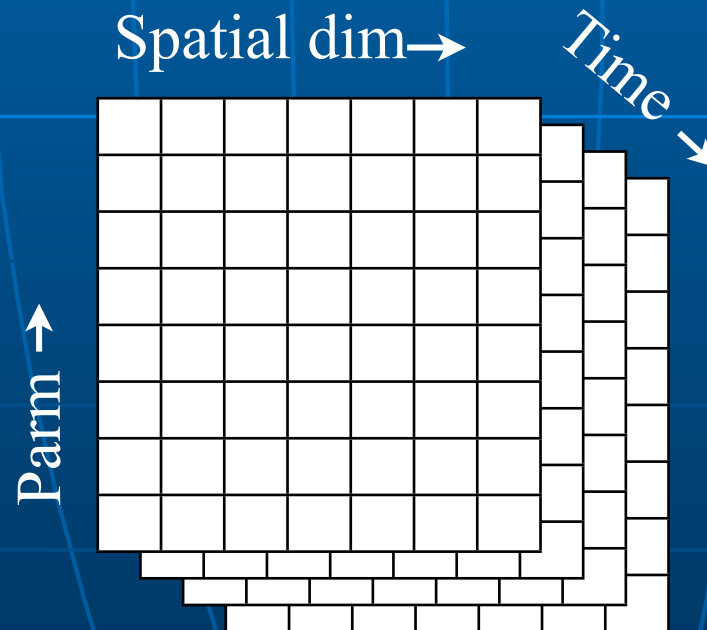
- Does not require consistent parameters
- Does not require consistent spatial steps





# Flexibility versus ease-of-plotting

- Does not require consistent parameters
- Does not require consistent spatial steps
- Often data is uniform



In what formats can I get  
Madrigal data?

# Cedar file format: past and future

## Cedar file format

- Developed in 1980
- 16 bit integer
  - Dynamic range problems

## Hdf5

- Scientific standard
- Float based
- Flexible arrangement
- Table data, optional grid

# Madrigal versions

<b>Release</b>	<b>Madrigal 2.6 (now)</b>	<b>Madrigal 3.0</b>
<b>Underlying format</b>	Cedar file format	Hdf5
<b>Output formats</b>	Ascii, Hdf5, Cedar file format	Ascii, Hdf5, netCDF4 Cedar file
<b>Formats with deriv parms</b>	Ascii	Ascii, Hdf5, netCDF4

- What do I need to understand about Madrigal to use it?

# Madrigal Data Model

**Madrigal site**  
(typically a facility with scientists and a Madrigal installation)



Data shared among all Madrigal sites



Data unique to one Madrigal site

**Instruments**  
(ground-based, typically with a set location)

**Experiments**  
(typically of limited duration, with a single contact)

**Experiment Files**  
(represents data from one analysis of the experiment)

**Records**  
(measurement over one period of time)

# Madrigal Derivation Engine

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- Derived parameters appear to be in file



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- Engine determines all parameters that can be derived

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- Derived parameters appear to be in file
- Engine determines all parameters that can be derived
- Easy to add new derived parameters using code written in C or Fortran

# Classes of derived parameters

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# Classes of derived parameters

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- Magnetic
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- Models
  - Examples: MSIS, IRI

- Using Madrigal



# How can the Madrigal database be accessed?



User



Web interface

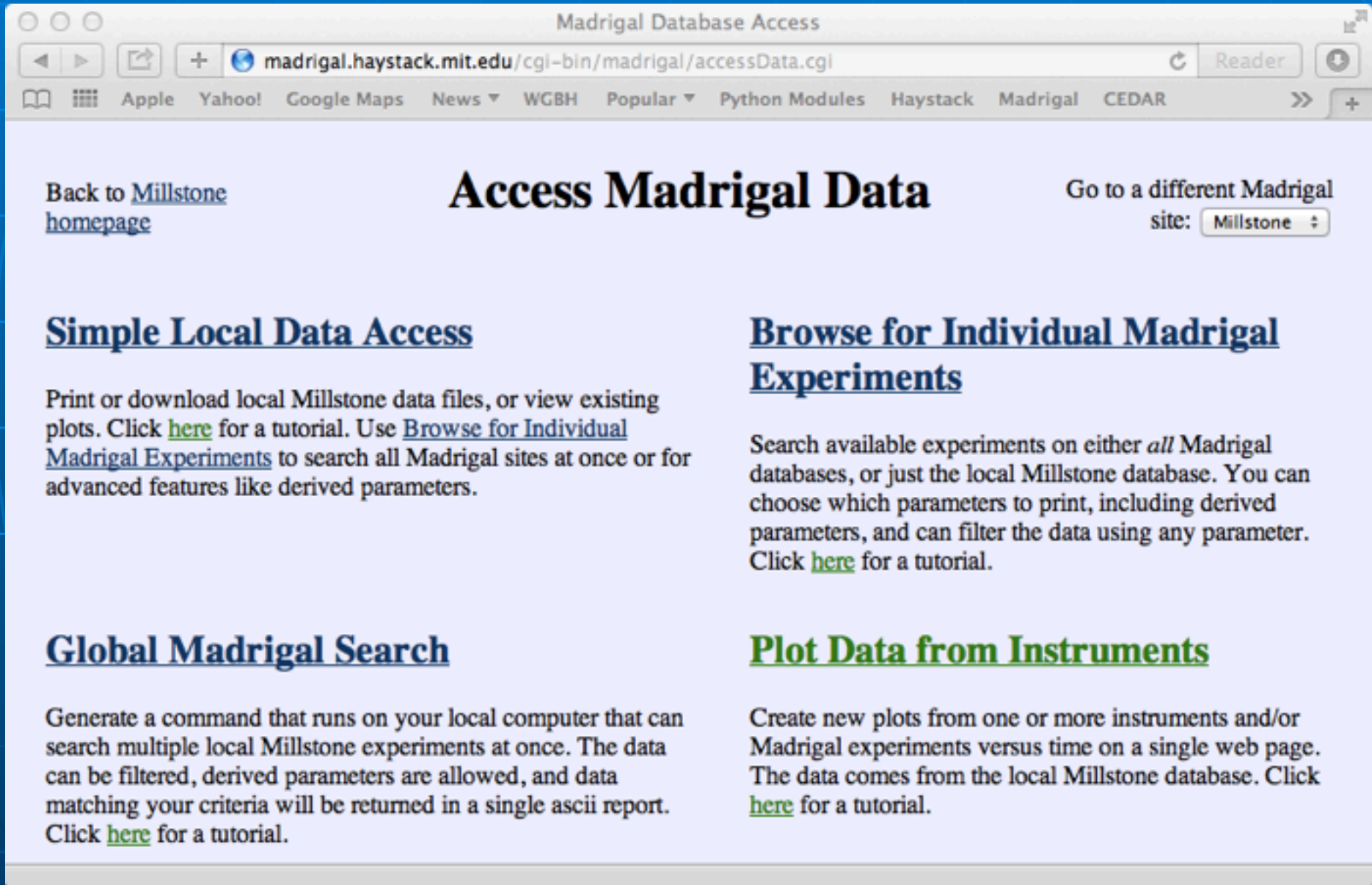
Web services API

- From anywhere on internet
- Python API
- Matlab API
- IDL API
- Other could be written

# Live demo of Madrigal web page

- Start at any Madrigal server (e.g., <http://cedar.openmadrigal.org> or <http://madrigal.naic.edu/madrigal>)

# Web interface review



The screenshot shows a web browser window titled "Madrigal Database Access". The address bar contains the URL "madrigal.haystack.mit.edu/cgi-bin/madrigal/accessData.cgi". The browser's search bar shows "Reader". The navigation bar includes links for "Apple", "Yahoo!", "Google Maps", "News", "WGBH", "Popular", "Python Modules", "Haystack", "Madrigal", and "CEDAR".

[Back to Millstone homepage](#)

## Access Madrigal Data

Go to a different Madrigal site:

### Simple Local Data Access

Print or download local Millstone data files, or view existing plots. Click [here](#) for a tutorial. Use [Browse for Individual Madrigal Experiments](#) to search all Madrigal sites at once or for advanced features like derived parameters.

### Global Madrigal Search

Generate a command that runs on your local computer that can search multiple local Millstone experiments at once. The data can be filtered, derived parameters are allowed, and data matching your criteria will be returned in a single ascii report. Click [here](#) for a tutorial.

### Browse for Individual Madrigal Experiments

Search available experiments on either *all* Madrigal databases, or just the local Millstone database. You can choose which parameters to print, including derived parameters, and can filter the data using any parameter. Click [here](#) for a tutorial.

### Plot Data from Instruments

Create new plots from one or more instruments and/or Madrigal experiments versus time on a single web page. The data comes from the local Millstone database. Click [here](#) for a tutorial.

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Simpler to use, only local data, no derived parameters

# Web interface review

The screenshot shows a web browser window titled "Madrigal Database Access" with the URL "madrigal.haystack.mit.edu/cgi-bin/madrigal/accessData.cgi". The page content includes a navigation bar with "Back to [Millstone homepage](#)", a central heading "Access Madrigal Data", and a dropdown menu for "Go to a different Madrigal site:" with "Millstone" selected. The main content is divided into four sections: "Simple Local Data Access", "Browse for Individual Madrigal Experiments", "Global Madrigal Search", and "Plot Data from Instruments". Annotations include a blue oval around "Simple Local Data Access" and a blue callout bubble pointing to the "Browse for Individual Madrigal Experiments" section. A grey text box at the top right contains the text "Search all Madrigal sites, any parameter, more complex". A grey text box at the bottom left contains the text "Simpler to use, only local data, no derived parameters".

Madrigal Database Access

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- Simple Local Data Access**: "Print or download local Millstone data files, or view existing plots. Click [here](#) for a tutorial. Use [Browse for Individual Madrigal Experiments](#) to search all Madrigal sites at once or for advanced features like derived parameters." A callout bubble points to this section with the text: "Simpler to use, only local data, no derived parameters".
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- Global Madrigal Search**: "Generate a command that runs on your local computer that can search multiple local Millstone experiments at once. The data can be filtered, derived parameters are allowed, and data matching your criteria. Click [here](#) for a tutorial." A callout bubble points to this section with the text: "Generates scripts - to be discussed".
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# Group exercise 1

- Break into your groups
- See [tinyurl.com/2014ISR](http://tinyurl.com/2014ISR) -> Madrigal Exercise 1
- Talk starts again in 20 minutes

# Remote Access to Madrigal Data



# Remote Access to Madrigal Data

- Built on web services

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- Like the web, available from anywhere on any platform

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# Remote Access to Madrigal Data

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- Like the web, available from anywhere on any platform
- Read only API
- Complete Python, Matlab, and IDL APIs written
- More APIs available on request or via contribution

# Remote Access to Madrigal Data

Simple

Most complex



I just want to download lots of files to my PC



globalDownload



I want to only download filtered data with derived parameters



globalIsprint

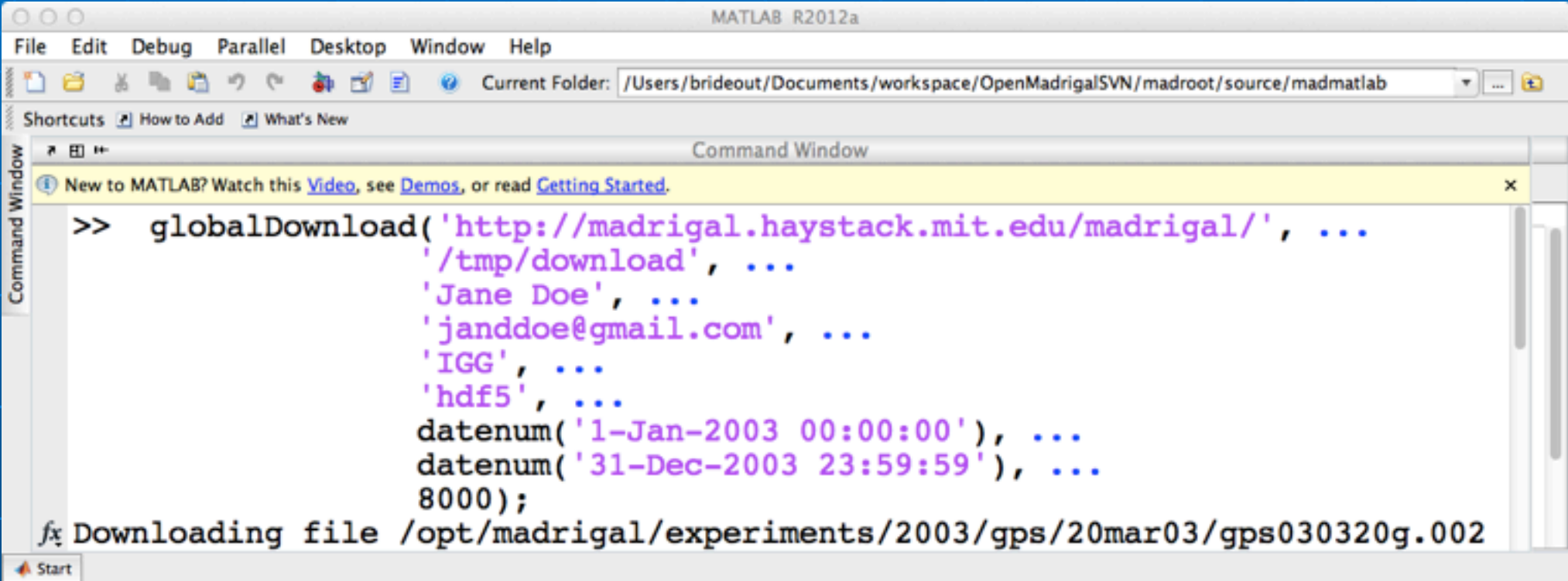


I want to write my own script



Work with API's

# Matlab globalDownload does it with one command!



The screenshot shows the MATLAB R2012a Command Window. The current folder is `/Users/brideout/Documents/workspace/OpenMadrigalSVN/madroot/source/madmatlab`. The command window contains the following code:

```
>> globalDownload('http://madrigal.haystack.mit.edu/madrigal/', ...  
                  '/tmp/download', ...  
                  'Jane Doe', ...  
                  'janddoe@gmail.com', ...  
                  'IGG', ...  
                  'hdf5', ...  
                  datenum('1-Jan-2003 00:00:00'), ...  
                  datenum('31-Dec-2003 23:59:59'), ...  
                  8000);
```

The output shows the command is downloading a file:

```
f⌘ Downloading file /opt/madrigal/experiments/2003/gps/20mar03/gps030320g.002
```

- New release as of May 3, 2014
- Uses wget if available, unreliable matlab urlread if not
- Full documentation: [http://madrigal.haystack.mit.edu/madrigal/rr\\_matlab.html#globalDownload](http://madrigal.haystack.mit.edu/madrigal/rr_matlab.html#globalDownload)

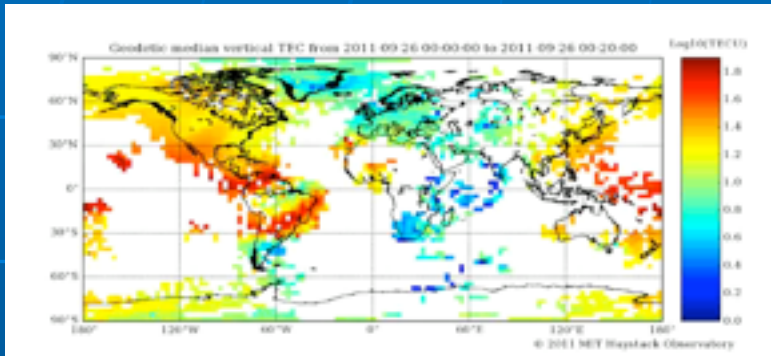
# Python version

```
>> globalDownload.py --url= http://madrigan.iggcas.ac.cn/madrigan/ \  
--outputDir=/tmp --user_fullname="Jane Doe" \  
--user_email=janedoe@gmail.com --user_affiliation=IGG \  
--format=hdf5 --startDate=01/01/2003 \  
--endDate=-01/30/2003 --inst=8000
```

- No need to understand python
- Install from <http://madrigan.haystack.edu/madrigan/madDownload.html>
- Formats: 'hdf5', 'ascii' - 'hdf5' faster
- Full documentation: <http://madrigan.haystack.mit.edu/madrigan/madpyDoc/remotePythonAPI/madriganWeb/globalDownload.py.html>

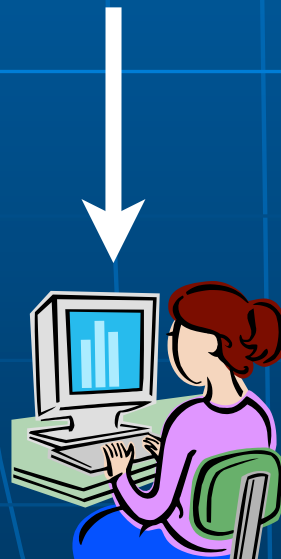


# More advanced globallsprint scripts



<http://madrigal.iggcas.ac.cn/madrigal/>

TEC data: instrument id = 8000



Show me only data  
where  $TEC > 100TEC_u$   
when  $Kp > 7$  in 2003

# The web interface will generate the script for you

Back to [Millstone homepage](#)

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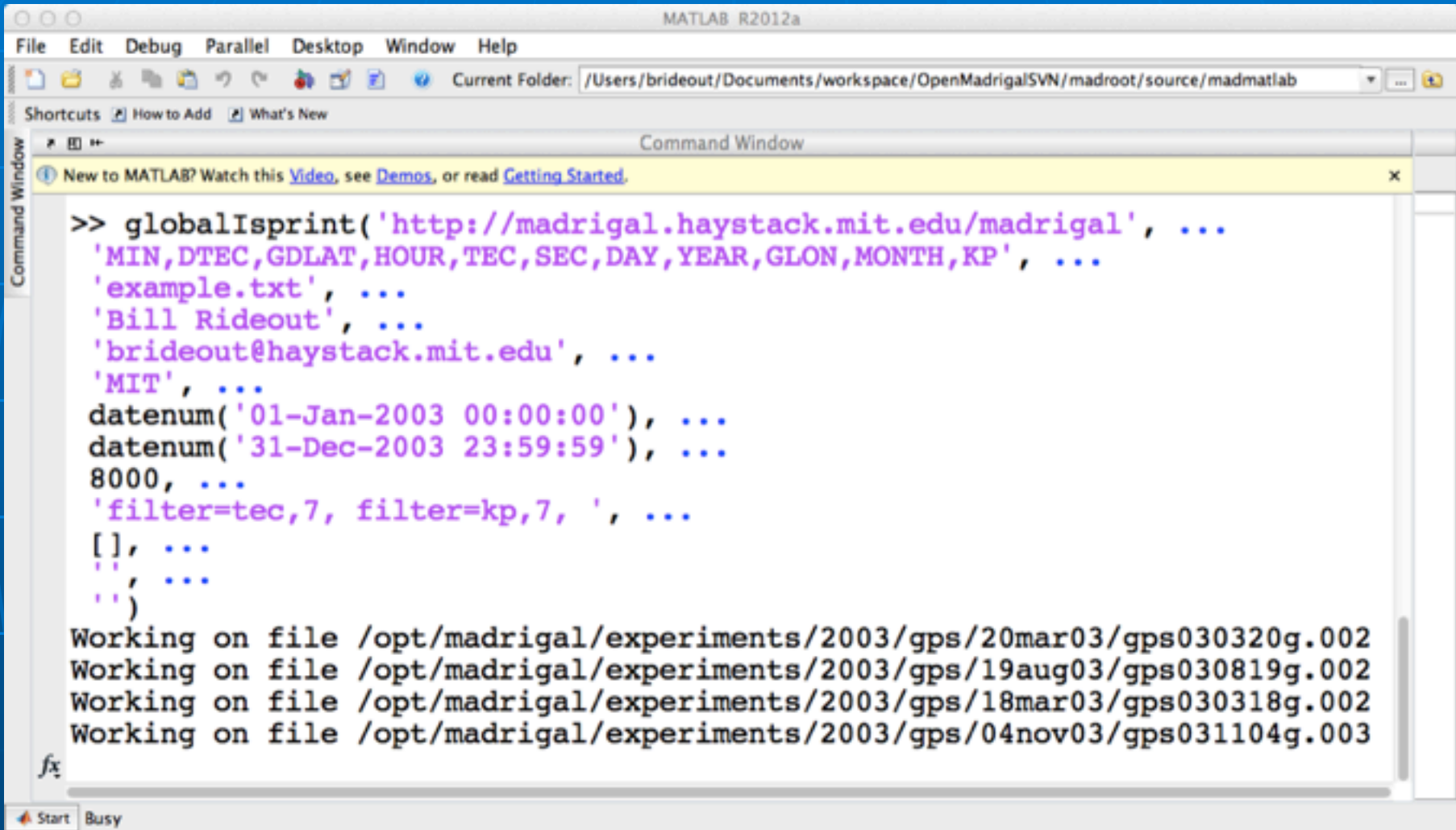
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Demo for example above

# Matlab globalIsprint example



```
MATLAB R2012a
File Edit Debug Parallel Desktop Window Help
Current Folder: /Users/brideout/Documents/workspace/OpenMadrigalSVN/madroot/source/madmatlab
Shortcuts How to Add What's New
Command Window
New to MATLAB? Watch this Video, see Demos, or read Getting Started.
>> globalIsprint('http://madrigal.haystack.mit.edu/madrigal', ...
'MIN,DTEC,GDLAT,HOUR,TEC,SEC,DAY,YEAR,GLON,MONTH,KP', ...
'example.txt', ...
'Bill Rideout', ...
'brideout@haystack.mit.edu', ...
'MIT', ...
datenum('01-Jan-2003 00:00:00'), ...
datenum('31-Dec-2003 23:59:59'), ...
8000, ...
'filter=tec,7, filter=kp,7, ', ...
[], ...
'', ...
)
Working on file /opt/madrigal/experiments/2003/gps/20mar03/gps030320g.002
Working on file /opt/madrigal/experiments/2003/gps/19aug03/gps030819g.002
Working on file /opt/madrigal/experiments/2003/gps/18mar03/gps030318g.002
Working on file /opt/madrigal/experiments/2003/gps/04nov03/gps031104g.003
fx
Start Busy
```

- Uses wget if available, unreliable matlab urlread if not
- Full documentation: [http://madrigal.haystack.mit.edu/madrigal/rr\\_matlab.html#globalIsprint](http://madrigal.haystack.mit.edu/madrigal/rr_matlab.html#globalIsprint)

# Python example

```
>> globallsprint.py --url=http://madriganal.haystack.mit.edu/madriganal \  
--parms=year,month,day,hour,min,sec,gdlat,glon,tec,dtec,kp \  
--output=/tmp/gps.txt --user_fullname="Jane Doe" \  
--user_email=janedoe@gmail.com --user_affiliation=IGG --inst=8000 \  
--startDate=01/01/2003 --endDate=12/31/2003 \  
--filter=kp,7, --filter=tec,100,
```

- You pick the output parameters
- Install from <http://madriganal.haystack.edu/madriganal/madDownload.html>
- Only ascii output - all to one file
- Full documentation: <http://madriganal.haystack.mit.edu/madriganal/madpyDoc/remotePythonAPI/madriganalWeb/globalIsprint.py.html>

# Most complex - write your own Matlab script

## ■ Methods

- getInstrumentsWeb
- getExperimentsWeb
- getExperimentFilesWeb
- getParametersWeb
- isprintWeb
- madDownloadFile
- madCalculatorWeb
- globalIsprint

## ■ Methods match Madrigal model

# Simple Matlab example

```
filename = '/usr/local/madroot/experiments
           /2003/tro/05jun03/NCAR_2003-06-05_tau2pl_60_uhf.bin';

eiscat_cgi_url = 'http://www.eiscat.se/madrigal/cgi-bin/';

% download the following parameters from the above file: ut, gdalt, ti

parms = 'ut,gdalt,ti';

filterStr = 'filter=gdalt,200,600 filter=ti,0,5000';

% returns a three dimensional array of double with the dimensions:
%
% [Number of rows, number of parameters requested, number of records]
%
% If error or no data returned, will return error explanation string instead.
data = isprintWeb(eiscat_cgi_url, filename, parms, filterStr);
```

**Matlab  
Madrigal  
API call**



## ■ Matlab API Links

- Reference: [http://madrigal.haystack.mit.edu/madrigal/rr\\_matlab.html](http://madrigal.haystack.mit.edu/madrigal/rr_matlab.html)
- Tutorial: [http://madrigal.haystack.mit.edu/madrigal/rt\\_matlab.html](http://madrigal.haystack.mit.edu/madrigal/rt_matlab.html)

# Live Matlab API demo

- See `demoMadrigalWebServices.m` at [http://www.haystack.mit.edu/cgi-bin/madrigal\\_viewcvs.cgi/madroot/source/madmatlab/](http://www.haystack.mit.edu/cgi-bin/madrigal_viewcvs.cgi/madroot/source/madmatlab/)



# Example python script

```
# create the main object to get all needed info from Madrigal
madrigoalUrl = "http://www.haystack.mit.edu/madrigoal"
testData = madrigalWeb.madrigoalWeb.MadrigoalData(madrigoalUrl)

# get all MLH experiments in 1998
expList = testData.getExperiments(30, 1998, 1, 1, 0, 0, 0, 1998,
                                   12, 31, 23, 59, 59)

for exp in expList:
    # print out all experiments
    print exp

# print list of all files in first experiment
fileList = testData.getExperimentFiles(expList[0].id)
    for thisfile in fileList:
        print thisfile
```

# Python Remote API

- Can run on any platform with python (PC, Unix, Mac, etc)
- Fully documented with examples
- Links
  - **Reference:** <http://madrigan.haystack.mit.edu/madrigan/madpyDoc/remotePythonAPI/index.html>
  - **Tutorial:** [http://madrigan.haystack.mit.edu/madrigan/rt\\_python.html](http://madrigan.haystack.mit.edu/madrigan/rt_python.html)

# IDL Remote API

- Methods
  - madGetAllInstruments
  - madGetExperiments
  - madGetExperimentFiles
  - madGetExperimentFileParameters
  - madSimplePrint
  - madPrint
  - madDownloadFile
  - madCalculator
  - madGlobalPrint
- Methods again match Madrigal model

# Madrigal Web Services

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- Simple delimited output via CGI scripts

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- Simple delimited output via CGI scripts
- Not based on SOAP or XmlRpc since no support in languages such as Matlab
- CGI arguments and output fully documented at <http://www.haystack.edu/madrigal/remoteAPIs.html>

# Extending/contributing to Madrigal

- Madrigal is completely open source
- See [www.openmadrigal.org](http://www.openmadrigal.org) for CVS
- All new code is Python or C. Imported derivation methods sometimes in Fortran.
- I appreciate all contributions
  - Suggestions and ideas
  - Finding bugs
  - Code



# Group exercise 2

- Break into your groups
- See [tinyurl.com/2014ISR](http://tinyurl.com/2014ISR) -> Madrigal Exercise 2