netCDF-Java/CDM
and
THREDDS Data Server (TDS)

Ethan Davis

Unidata

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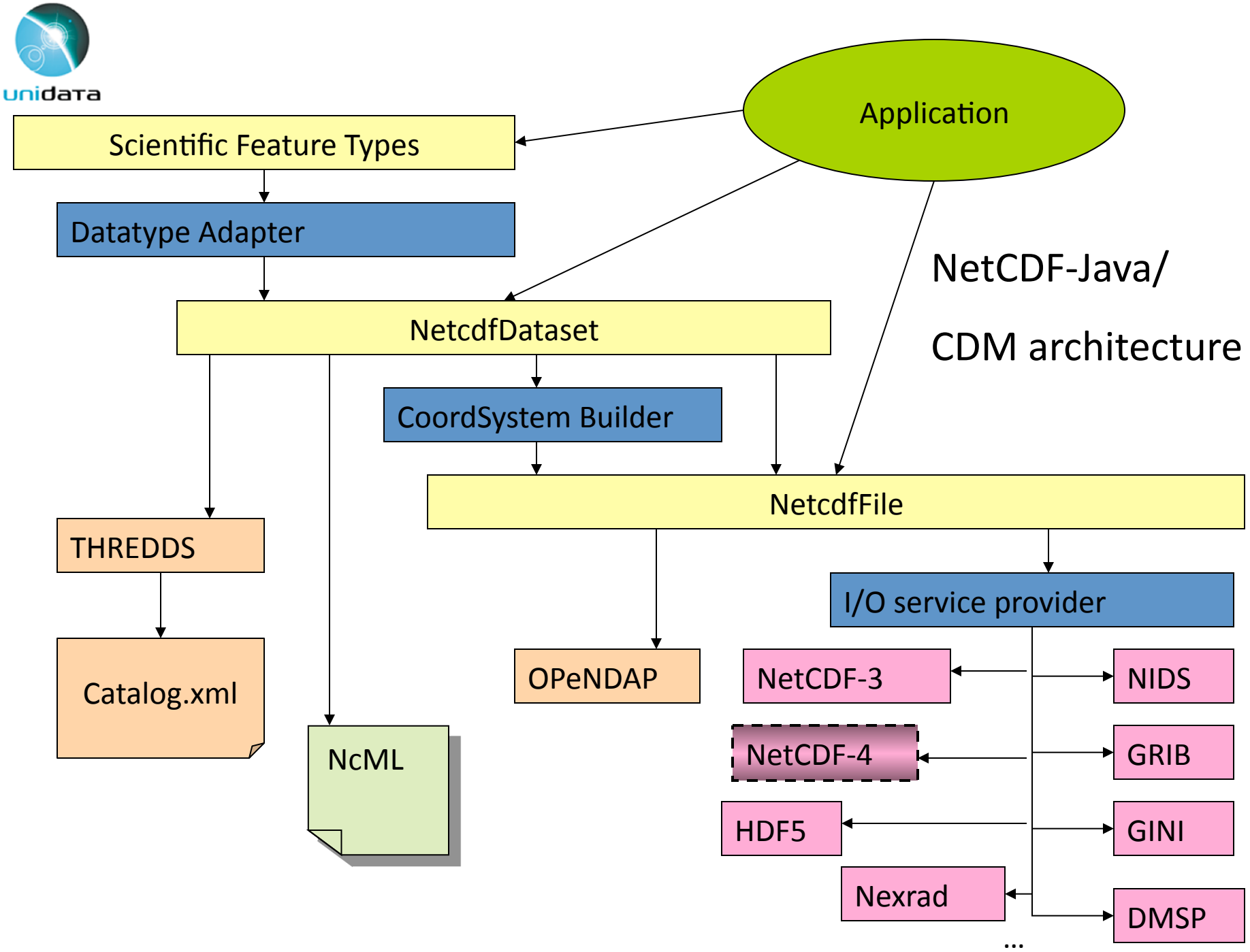
unidata
Application
Scientific Feature Types
Datatype Adapter
NetcdfDataset
NetCDF-Java/
CDM architecture
CoordSystem Builder
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Nexrad
...
NIDS
GRIB
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CDM/netCDF-Java

- NetCDF Data Model API
  - `NetcdfFile`: classic and extended data model (read only)
  - `NetcdfFileWriteable`: netCDF-3 (classic data model) only
- `NetcdfDataset`:
    - scale/offset and missing
    - geospatial coordinate systems
    - NcML: modify existing dataset and aggregate datasets
- Scientific Feature Types:
  - `GridDataset`
  - Discrete Sampling Features: point, station, profile, trajectory

NetcdfFile

```
String filename = "src/test/data/example1.nc";
NetcdfFile ncfile = null;
try {
  ncfile = NetcdfFile.open( filename ) ;
  process( ncfile );
} catch ( IOException ioe ) {
  log.error( "trying to open " + filename, ioe );
}
finally
{
  if ( null != ncfile ) {
    try {
      ncfile.close() ;
    } catch ( IOException ioe ) {
      log.error( "trying to close " + filename, ioe );
    }
  }
}
…
```

NetcdfFile

```
…
String varName = "T";
Variable v = ncfile.findVariable( varName ) ;

Attribute att = v.findAttribute( "long_name") ;
System.out.println( "long_name = " + att.getStringValue() );

att = v.findAttribute( "units") ;
System.out.println( "units = " + att.getStringValue() );

if ( null == v ) return;
try {
  Array data = v.read( "0:1:1, 0:2:1, 0:3:1" ) ;
  NCdumpW.printArray( data, varName, new PrintWriter( System.out), null );
} catch ( IOException ioe ) {
  log.error( "trying to read " + varName, ioe );
} catch ( InvalidRangeException e ) {
  log.error( "invalid Range for " + varName, e );
}
…
```

NetcdfFile

```
long_name = surface temperature
units = degC
T =
  {
    {
      {1.0, 2.0, 3.0, 4.0},
      {2.0, 4.0, 6.0, 8.0},
      {3.0, 6.0, 9.0, 12.0}
    },
    {
      {2.5, 5.0, 7.5, 10.0},
      {5.0, 10.0, 15.0, 20.0},
      {7.5, 15.0, 22.5, 30.0}
    }
  }
```

NetcdfFileWriteable

```
String filename = "target/testWrite.nc";
NetcdfFileWriteable ncfile = null;
try {
  ncfile = NetcdfFileWriteable.createNew( filename, false ) ;
} catch ( IOException e ) {
  log.error( "Problem creating file [" + filename + "].", e);
  return;
}
Dimension latDim = ncfile.addDimension( "lat", 64 ) ;
Dimension lonDim = ncfile.addDimension( "lon", 128 ) ;

ArrayList<Dimension> dims = new ArrayList<Dimension>();
dims.add( latDim );
ncfile.addVariable( "lat", DataType.DOUBLE, dims ) ;
ncfile.addVariableAttribute( "lat", "units", "degrees_north" ) ;

dims.clear();
dims.add( lonDim );
ncfile.addVariable( "lon", DataType.DOUBLE, dims ) ;
ncfile.addVariableAttribute( "lon", "units", "degrees_east" ) ;
…
```

NetcdfFileWriteable

```
…
dims.clear();
dims.add( latDim );
dims.add( lonDim );
ncfile.addVariable( "temperature", DataType.DOUBLE, dims ) ;
ncfile.addVariableAttribute( "temperature", "units", "K" ) ;

try {
  ncfile.create() ;
} catch ( IOException e ) {
  log.error( "Problem creating file [" + filename + "]" + e );
}
…
```

NetcdfFileWriteable

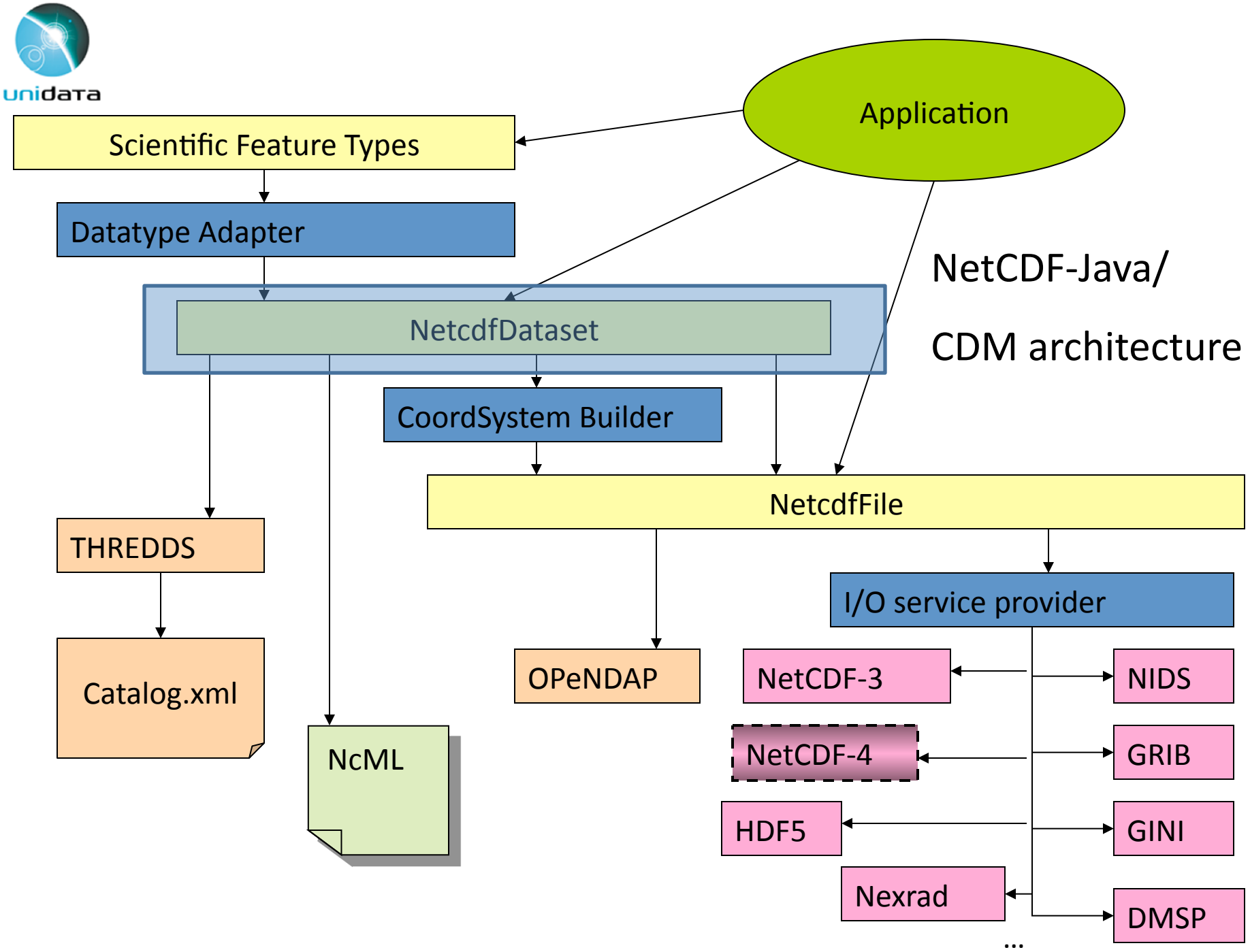
```
…
ArrayDouble A = new ArrayDouble.D2( latDim.getLength(), lonDim.getLength() ) ;
int i, j;
Index ima = A.getIndex() ;
for ( i = 0; i < latDim.getLength(); i++ ) {
  for ( j = 0; j < lonDim.getLength(); j++ ) {
    A.setDouble( ima.set( i, j ), (double) ( i * 1000000 + j * 1000 ) ) ;
  }
}

int[] origin = new int[2];
try {
  ncfile.write( "temperature", origin, A ) ;
} catch ( IOException e ) {
  log.error( "Problem writing file [" + filename + "].", e ); return;
} catch ( InvalidRangeException e ) {
  log.error( "Problem writing file [" + filename + "].", e ); return;
}

try {
  ncfile.close() ;
} catch ( IOException e ) {
  log.error( "Problem closing file [" + filename + "].", e );
}
```

NetcdfFileWriteable

```
Netcdf target/testWrite.nc {
 dimensions:
   lat = 64;
   lon = 128;
 variables:
   double lat(lat=64);
     :units = "degrees_north";
   double lon(lon=128);
     :units = "degrees_east";
   double temperature(lat=64, lon=128);
     :units = "K";
}
```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NetcdfDataset

- NetcdfDataset supports
  - Geospatial coordinate systems
  - Scale/offset and missing data
  - NcML: modify existing dataset and aggregate datasets

NetcdfDataset

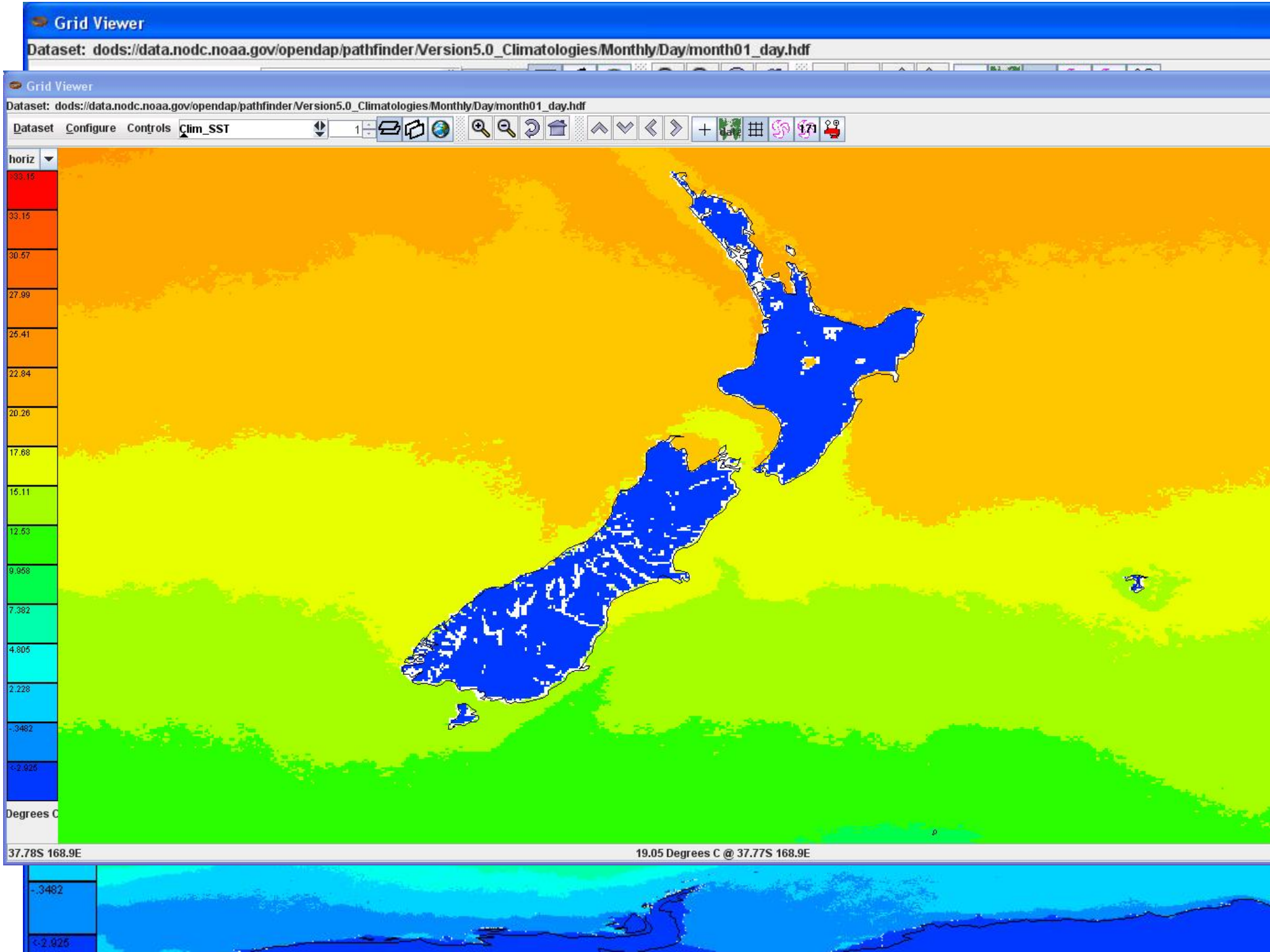
- NetcdfDataset.openFile() does the following:
  - Opens an OPeNDAP remote dataset, if the location is a URL that starts with "**http:**"or "**dods:**"
  - Opens a THREDDS dataset, if the location starts with "**thredds:<catalog>#<datasetId> "**
  - Opens an NcML dataset, if the location ends with "**.xml**" or "**.ncml**"
  - Otherwise, it calls **NetcdfFile.open()**, which handles local file or HTTP access to any CDM file.

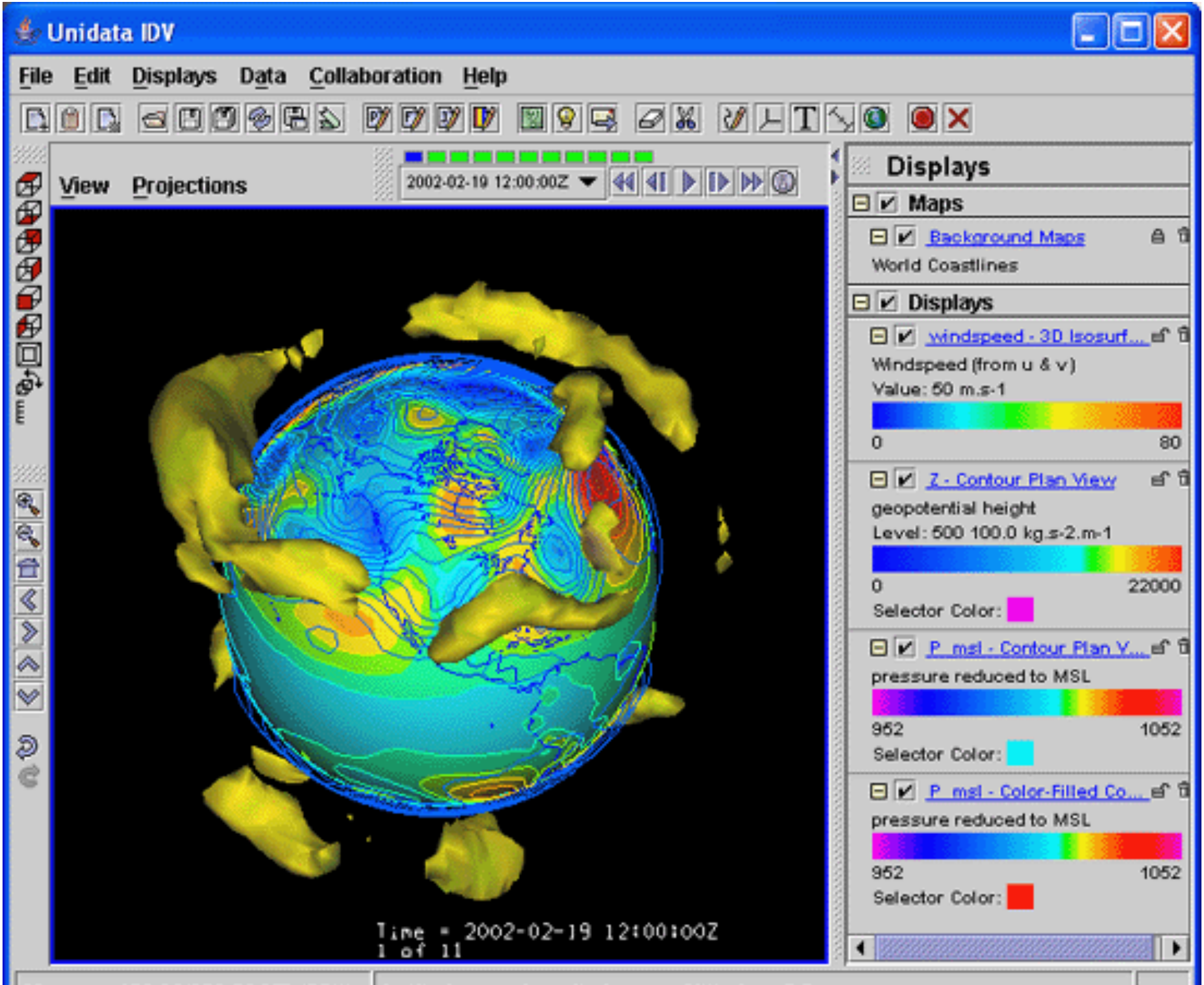
NetcdfDataset

```
…
String filename = "http://motherlode.ucar.edu:8080/thredds/dodsC" +
        "/fmrc/NCEP/GFS/CONUS_95km/files/GFS_CONUS_95km_20101027_1800.grib1";
   NetcdfFile ncfile = null;
   try {
     ncfile = NetcdfDataset.openFile( filename, null ) ;
     process( ncfile );
   } catch ( IOException ioe ) {
     log.error( "Problem opening file [" + filename + "].", ioe );
   }
   finally {
     if ( null != ncfile )
     {
       try {
         ncfile.close() ;
       } catch ( IOException ioe ) {
         log.error( "Problem closing [" + filename + "].", ioe );
       }
     }
   }
…
```

Coordinate Systems Summary

- What?
  - Used for geolocation of data
- How?
  - Write your files using CF Conventions
  - Write your own Java code, plug into CDM
- Why?
  - Standard visualization, debugging, and data manipulation tools
  - Standard servers to make your data remotely accessible


Grid Viewer
Dataset: dods://data.nodc.noaa.gov/opendap/pathfinder/Version5.0_Climatologies/Monthly/Day/month01_day.hdf
Grid Viewer
Dataset: dods://data.nodc.noaa.gov/opendap/pathfinder/Version5.0_Climatologies/Monthly/Day/month01_day.hdf
Dataset
Configure
Controls
Clim_SST
horiz
33.15
30.57
27.99
25.41
22.84
20.26
17.68
15.11
12.53
9.958
7.382
4.805
2.228
-.3482
<-2.925
Degrees C
37.78S 168.9E
19.05 Degrees C @ 37.77S 168.9E
-.3482
<-2.925


Unidata IDV
File Edit Displays Data Collaboration Help
View Projections
2002-02-19 12:00:00Z
Time = 2002-02-19 12:00:00Z
1 of 11
Displays
Maps
Background Maps
World Coastlines
Displays
windspeed - 3D Isosurf...
Windspeed (from u & v)
Value: 50 m.s-1
0
80
Z - Contour Plan View
geopotential height
Level: 500 100.0 kg.s-2.m-1
0
22000
Selector Color:
P_msl - Contour Plan V...
pressure reduced to MSL
952
1052
Selector Color:
P_msl - Color-Filled Co...
pressure reduced to MSL
952
1052
Selector Color:

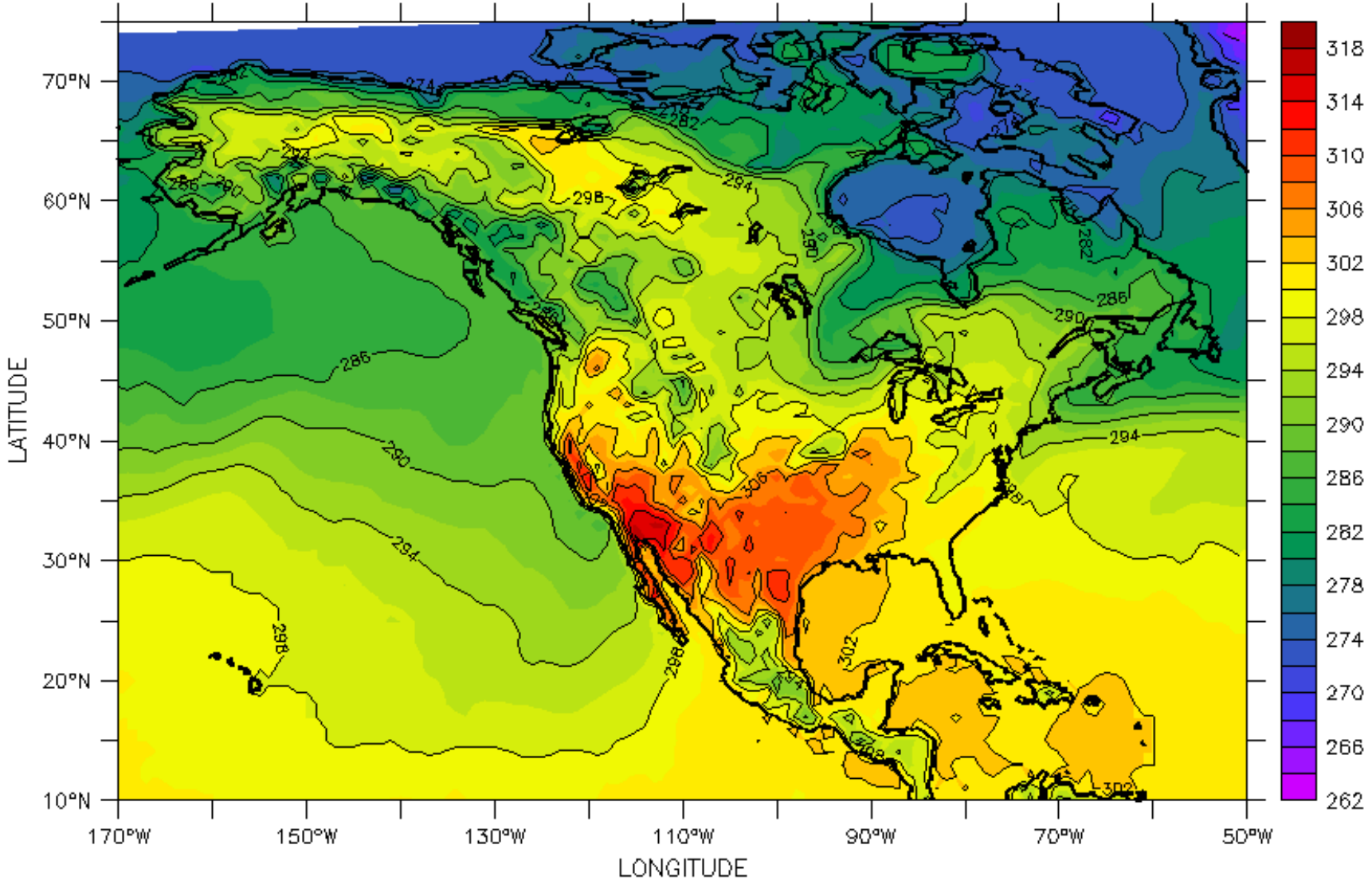
LAS 6.4.1/Ferret 5.80 -- NOAA/PMEL

DODS URL: http://nomads.ncdc.noaa.gov:9091/dods/NCEP_GFS/subsets/

TIME : 01-JUL-2005 00

DATA SET: gfs_3_temps

GFS Model - Analysis Temperature Subset



Air Temperature at 2 meters K (K)

Coordinate Systems

- CF example:

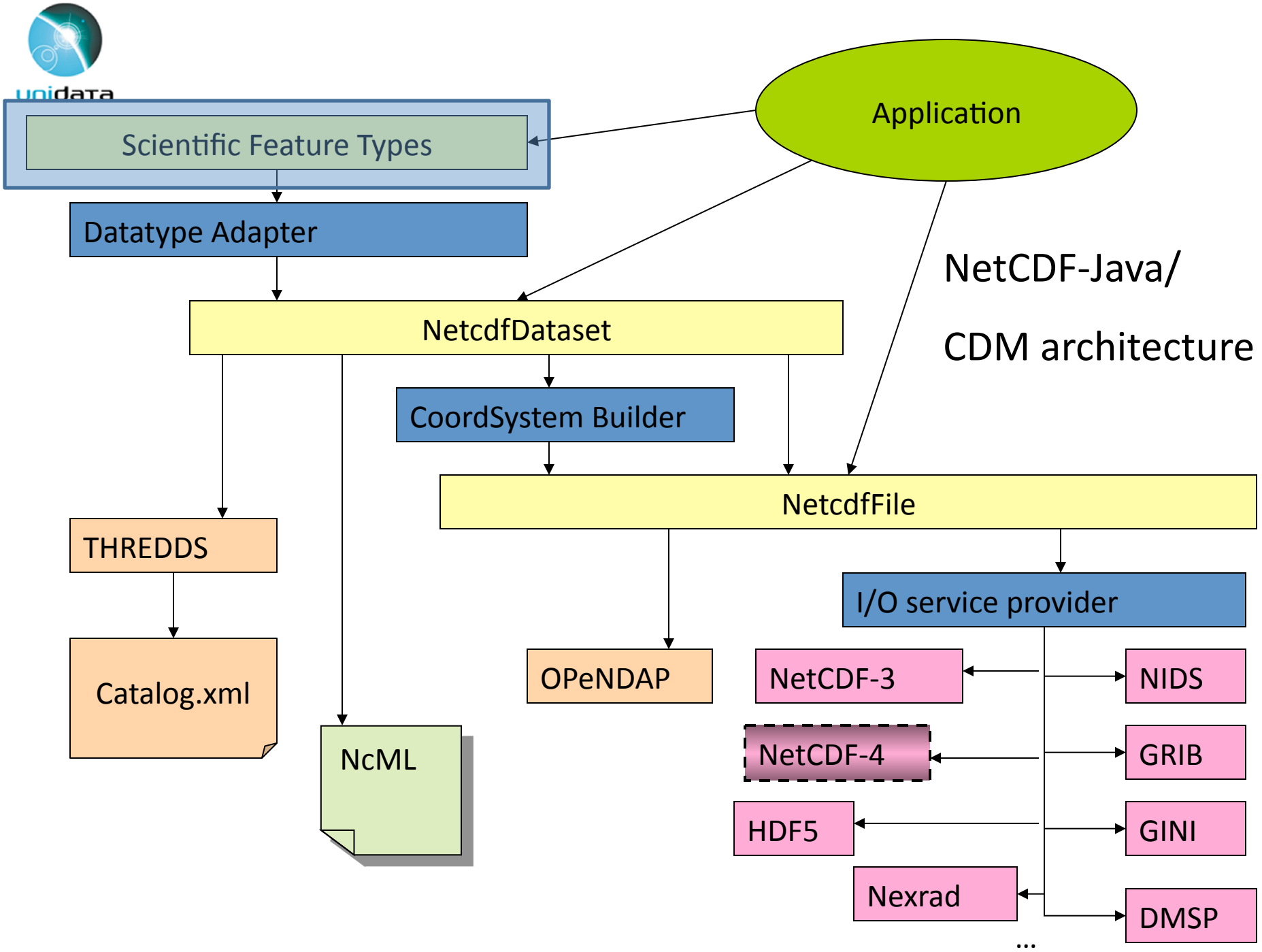
```
netcdf aggExisting.xml {
  dimensions:
    y = 228; x = 306; time = 41;
  variables:
    int Lambert_Conformal;
      Lambert_Conformal:grid_mapping_name = "lambert_conformal_conic";
      Lambert_Conformal:standard_parallel = 25.0;
      Lambert_Conformal:longitude_of_central_meridian = 265.0;
      Lambert_Conformal:latitude_of_projection_origin = 25.0;

    double y(y); … y:standard_name = "projection_y_coordinate" ;
    double x(x); … x:standard_name = "projection_x_coordinate" ;
    double lat(y, x); …
    double lon(y, x); …
    int time(time);   …
    float Temperature(time, y, x);
      Temperature:units = "K";
      Temperature:long_name = "Temperature @ surface";
      Temperature:coordinates = "lat lon";
      Temperature:grid_mapping = "Lambert_Conformal" ;

    :Conventions = "CF-1.4" ;
}
```

Netcdf-Java Library parses these Conventions

- CF Conventions (preferred)
- COARDS, NCAR-CSM, ATD-Radar, Zebra, GEIF, IRIDL, NUWG, AWIPS, WRF, M3IO, IFPS, ADAS/ARPS, MADIS, Epic, RAF-Nimbus, NSSL National Reflectivity Mosaic, FslWindProfiler, Modis Satellite, Avhrr Satellite, Cosmic, ….
- Write your own *CoordSysBuilder* Java class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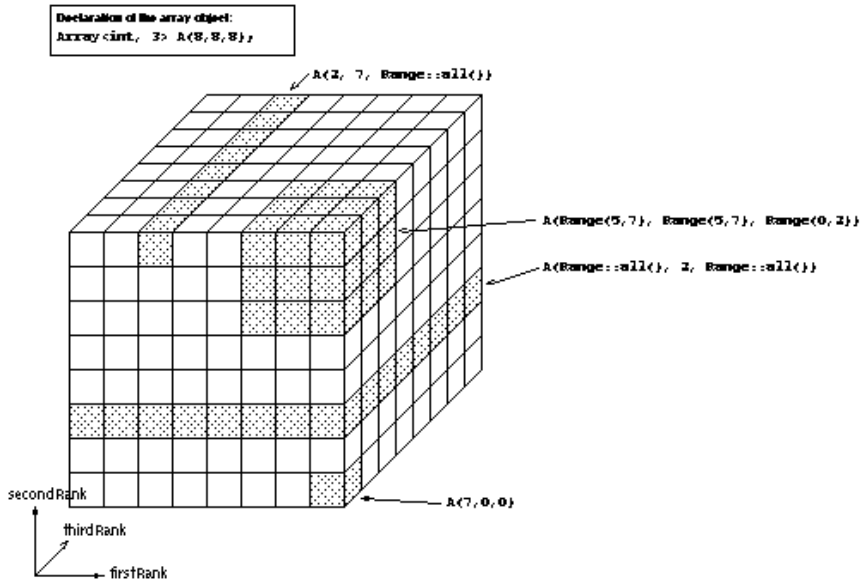
Scientific Feature Types

- Gridded Data
- Swath Data
- Discrete Sampling Features
  - Point data
  - Station data
  - Profile data
  - Trajectory (i.e., aircraft track) data

Gridded Data

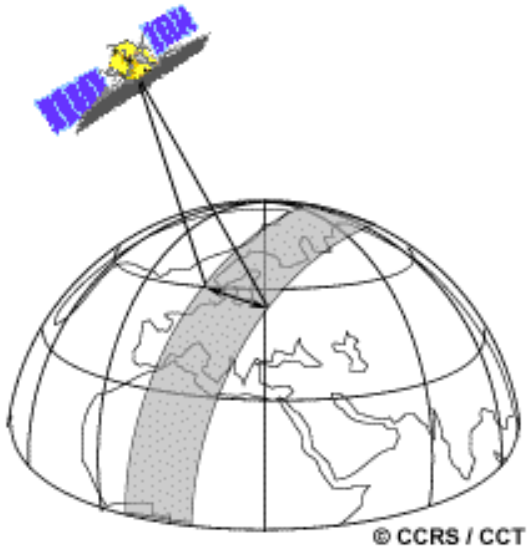
- Cartesian coordinates
- Data is 2,3,4D
- All dimensions have 1D coordinate variables (separable)

```
float gridData(t,z,y,x);
  float t(t);
  float y(y);
  float x(x);
  float z(z);
```



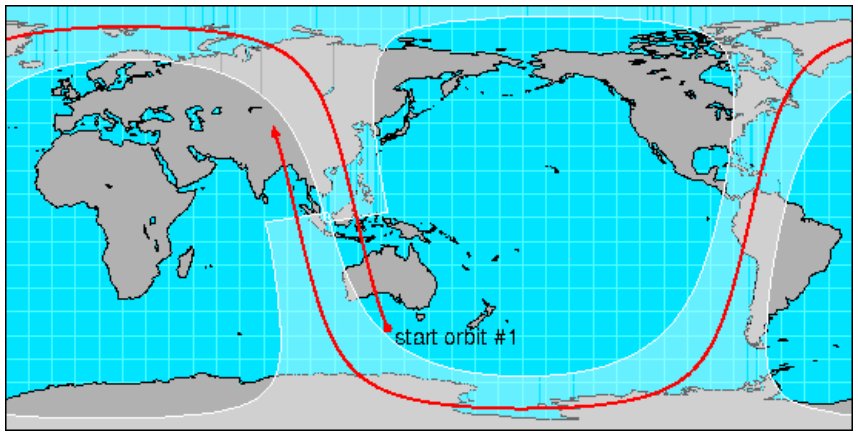
- netCDF: coordinate variables
- OPeNDAP: grid map variables
- HDF: dimension scales

Swath



- two dimensional
- track and cross-track
- not separate time dimension
- aka *curvilinear coordinates*

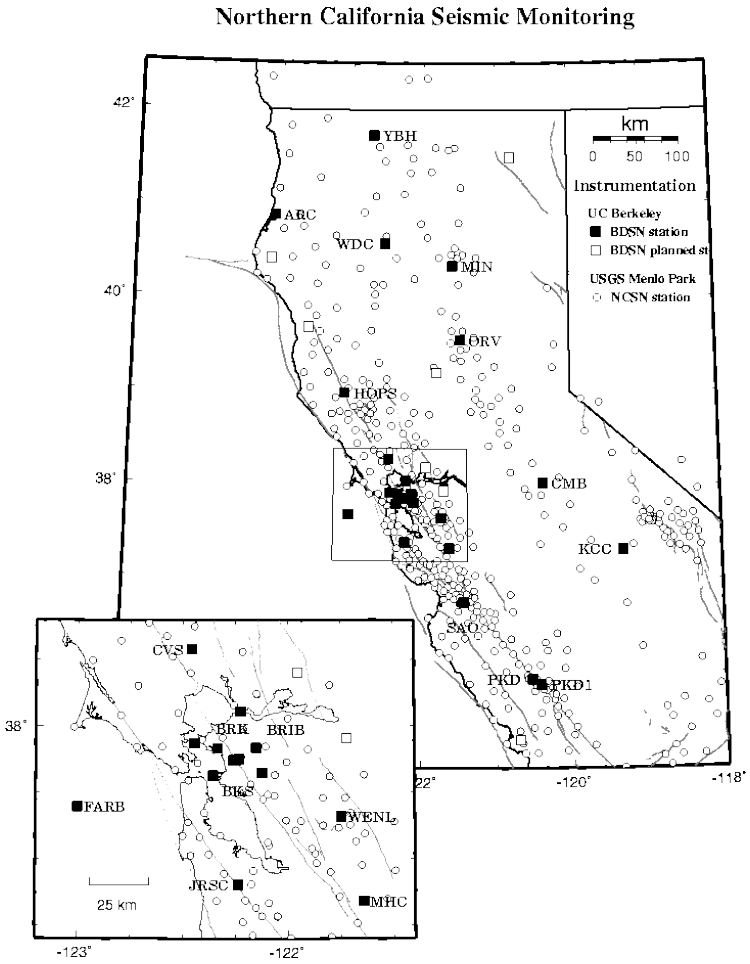
float swathData(track, xtrack)
  float lat(track, xtrack)
  float lon(track, xtrack)
  float alt(track, xtrack)
  float time(track)

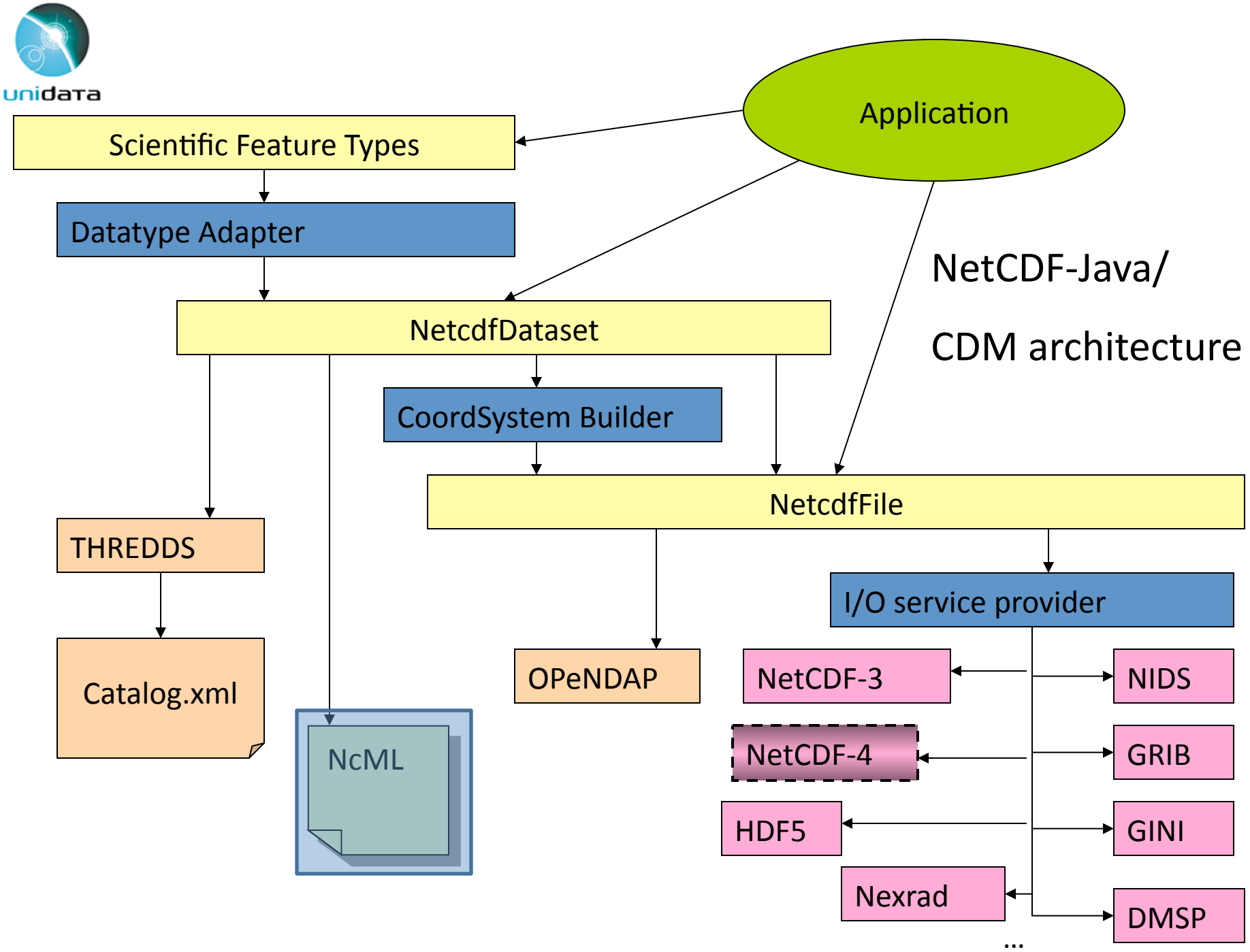


Point Observation Data

- Set of measurements at the same point in space and time = obs
- Collection of obs = dataset
- Sample dimension not connected

```
float obs1(sample);
float obs2(sample);
  float lat(sample);
  float lon(sample);
  float z(sample);
  float time(sample);
```

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NcML

- Modifying existing dataset
  - Adding/Removing attributes
  - Renaming variables
  - Adding variables
- Aggregation
  - Union
  - Join along an existing dimension
  - Join with a new dimension
  - Forecast Model Run Collection (FMRC)

Example: Modify Existing Dataset

```
netcdf aggExisting.xml {
  dimensions:
    lat = 18 ; lon = 36 ;
  variables:
    double lat(lat) ;
    double lon(lon) ;
    float temp(lat, lon) ;
      temp:long_name = "temperature" ;
      temp:units = "K" ;
      temp:grid_mapping = "crs" ;
    int crs ;
      crs:grid_mapping_name = "latitude_longitude";
      crs:longitude_of_prime_meridian = 0.0 ;
      crs:semi_major_axis = 6378137.0 ;
      crs:inverse_flattening = 298.257223563 ;

    :Conventions = "EF-1.Z" ; // oops! Typo
}
```

```
<netcdf xmlns="http://www.unidata.ucar.edu/namespaces/netcdf/ncml-2.2">
  <attribute name="Conventions" type="CF-1.4" />
</netcdf>
```

Example: Join Existing

```
netcdf jan.nc {
  dimensions:
    lat = 3;
    lon = 4;
    time = 31 ;
  variables:
    int time(time=31);
    float lat(lat=3);
    float lon(lon=4);
    double P(time=31, lat=3, lon=4);
    double T(time=31, lat=3, lon=4);
}
```

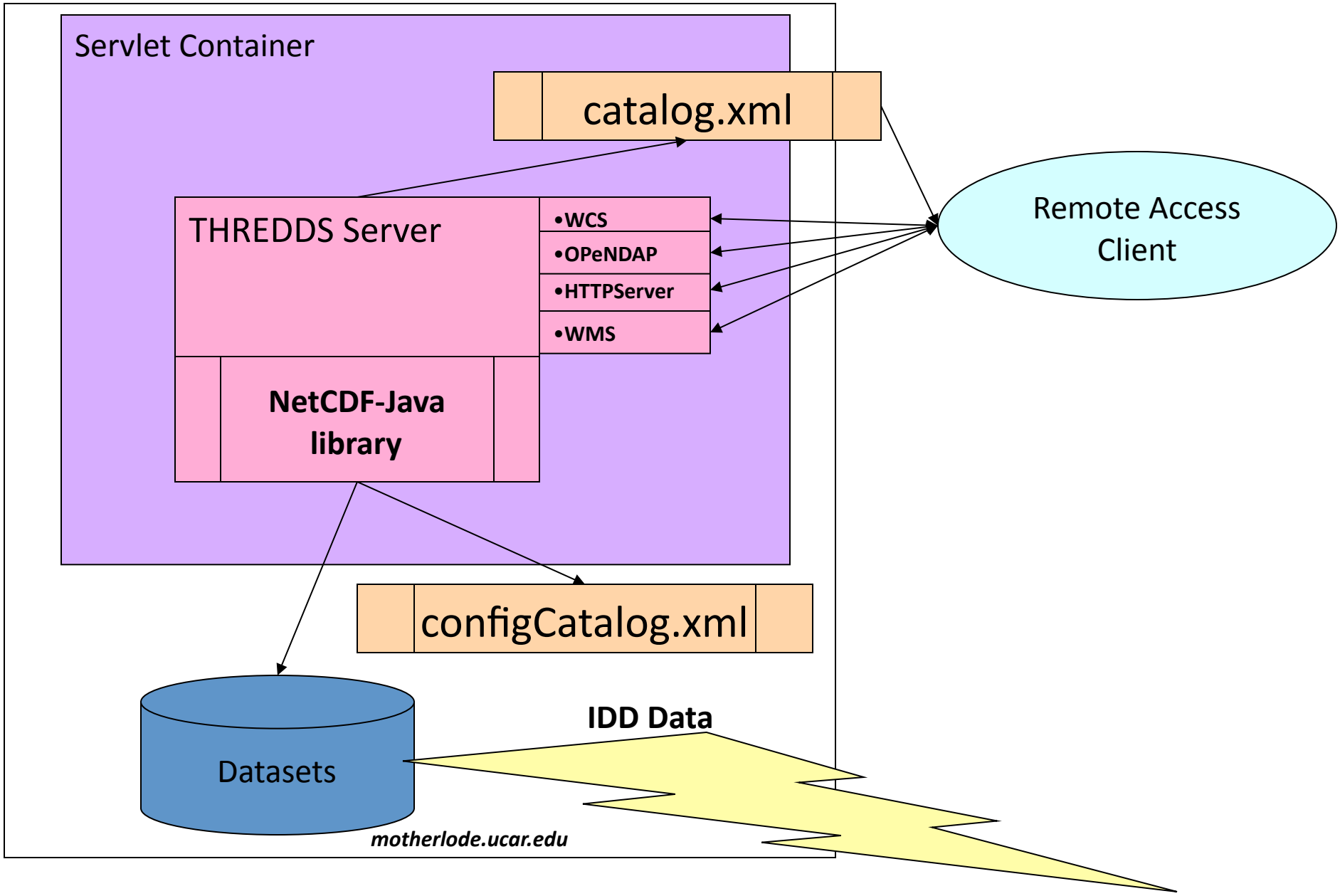
```
netcdf feb.nc {
  dimensions:
    lat = 3;
    lon = 4;
    time = 28 ;
  variables:
    int time(time=28);
    float lat(lat=3);
    float lon(lon=4);
    double P(time=28, lat=3, lon=4);
    double T(time=28, lat=3, lon=4);
}
```

Example: Join Existing

```
<netcdf xmlns="http://www.unidata.ucar.edu/namespaces/netcdf/ncml-2.2">
  <aggregation dimName="time" type="joinExisting">
    <netcdf location="jan.nc" />
    <netcdf location="feb.nc" />
  </aggregation>
</netcdf>
```

```
netcdf aggExisting.xml {
  dimensions:
    lat = 3;
    lon = 4;
    time = 59 ;
  variables:
    int time(time=59);
    float lat(lat=3);
    float lon(lon=4);
    double P(time=59, lat=3, lon=4);
    double T(time=59, lat=3, lon=4);
}
```

THREDDS Data Server



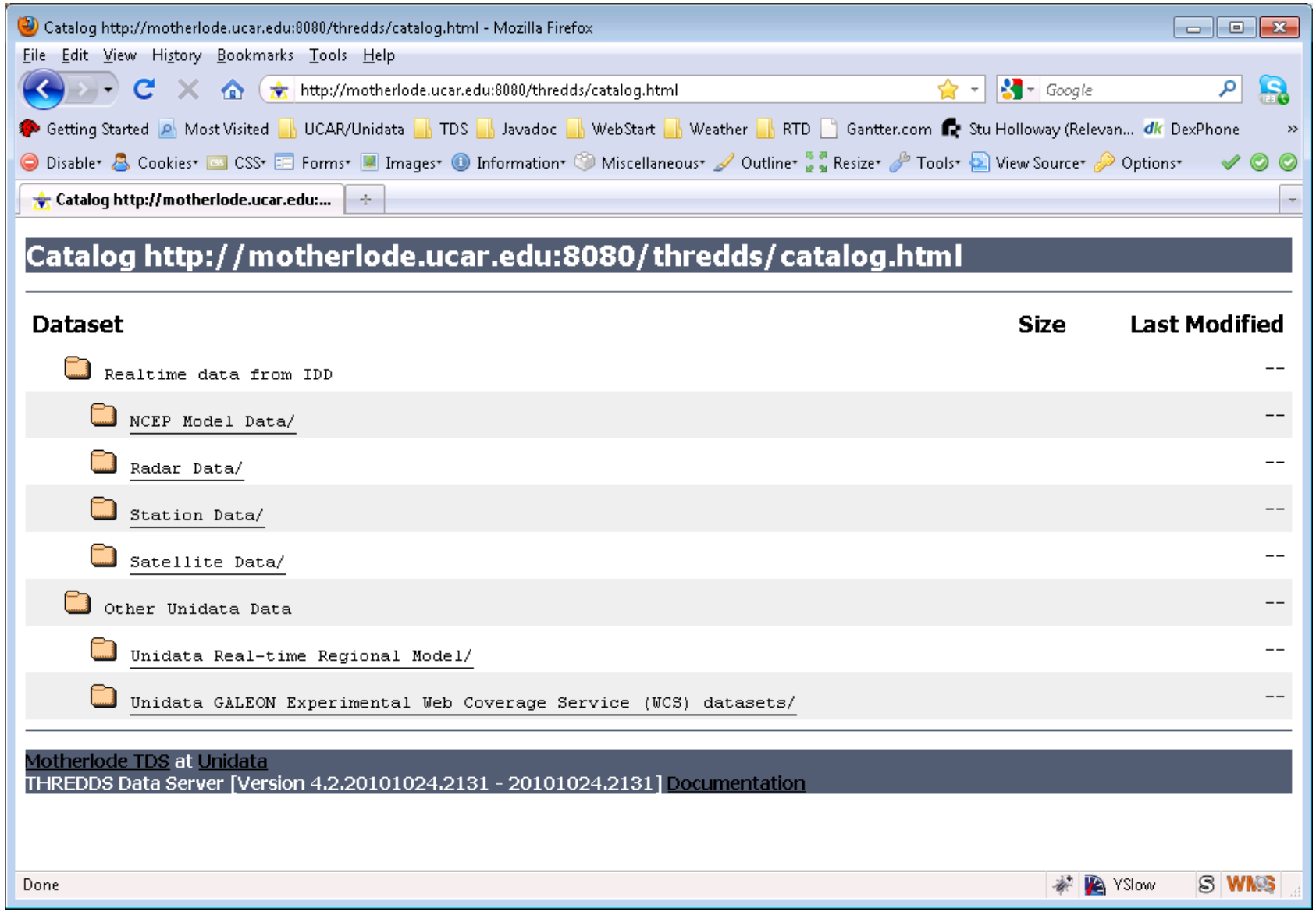
THREDDS Data Server (TDS)

- Serves scientific data over various data access protocols, e.g.,
  - OPeNDAP, OGC WMS & WCS, NCSS, HTTP.
- Serves any dataset the netCDF-Java library can read, e.g.,
  - netCDF 3&4, HDF 4&5 (and HDF–EOS), GRIB 1&2
- Serves THREDDS catalogs
- Some access protocols only available for certain data types (e.g., WMS and WCS are only available for gridded data).

THREDDS Catalogs

```
<?xml version='1.0' encoding='UTF-8'?>
<catalog xmlns="http://www.unidata.ucar.edu/namespaces/thredds/InvCatalog/v.0"
         xmlns:xlink="http://www.w3.org/1999/xlink" version="1.0.2">
  <service name="odap" serviceType="OPENDAP" base="/thredds/dodsC/" />
  <dataset name="TDS Tutorial: example 2">
    <metadata inherited="true">
      <serviceName>odap</serviceName>
    </metadata>
    <dataset name="TDS Tutorial: example data 1" urlPath="test/example1.nc" />
    <dataset name="TDS Tutorial: example data 2" urlPath="test/example2.nc" />
    <dataset name="TDS Tutorial: example data 3" urlPath="test/example3.nc" />
    <catalogRef xlink:title="My Other Catalog"
                xlink:href="myOtherCatalog.xml" />
    <catalogRef xlink:title="Far Away Univ catalog"
                xlink:href="http://www.farAwayU.edu/thredds/catalog.xml" />
  </dataset>
</catalog>
```

THREDDS Catalogs



TDS Configuration Catalogs

```
…
  <service name="odap" serviceType="OpenDAP" base="/thredds/dodsC/" />

  <datasetScan name="Test all files in a directory" ID="testDatasetScan"
               path="my/test/all" location="/my/data/testdata" >
      <metadata inherited="true">
        <serviceName>odap</serviceName>
      </metadata>
  </datasetScan>
…
```

NcML
Modify and serve through TDS

```
<dataset name="Polar Orbiter Data" urlPath ="idd/sat/PolarData" >

   <netcdf location="/data/sat/P02393.hdf">
      <attribute name="Conventions" value="CF-1.4"/>
      <variable name="Reflectivity" orgName="R34768">
         <attribute name="units" value="dBZ" />
         <attribute name="coordinates" value="time lat lon" />
      </variable>
   </netcdf>

</dataset>
```

TDS / NcML
Modify all files in datasetScan

```
<datasetScan name="Polar Orbiter" path="/data/sat/"
      location= "/data/hdf/polar/">

   <netcdf>
      <attribute name="Conventions" value="CF-1.4"/>
      <variable name="Reflectivity" orgName="R34768">
         <attribute name="units" value="dBZ" />
         <attribute name="coordinates" value="time lat lon" />
      </variable>
   </netcdf>

</datasetScan>
```

TDS / NcML aggregation

```
<dataset name="WEST-CONUS_4km Aggregation"
         urlPath="satellite/3.9/WEST-CONUS_4km">

  <netcdf>
    <aggregation dimName="time" type="joinExisting">
      <scan  location="/data/satellite/WEST-CONUS_4km/" suffix=".gini" />
    </aggregation>
  </netcdf>

</dataset>
```

TDS FMRC Aggregation

```
…
 <featureCollection name="NCEP-NAM-Polar_90km" featureType="FMRC"
       harvest="true" path="fmrc/NCEP/NAM/Polar_90km">
   <collection spec="/data/NAM_Polar_90km_#yyyyMMdd_HHmm#.grib2$"
               recheckAfter="15 min" olderThan="5 min"/>
   <update startup="true" rescan="0 5 3 * * ? *" />
   <protoDataset choice="Penultimate" change="0 2 3 * * ? *" />
   <fmrcConfig regularize="true" datasetTypes="TwoD Best Files Runs" />
 </featureCollection>
 …
```

Status: CDM/netCDF-Java & TDS

- netCDF-Java 4.2
  - Stable version as of October 2010
  - Changes from netCDF-Java 4.1
    - GRIB processing improved (correctly identify time interval variables).
    - FMRC aggregations code refactored.
    - Extended caching system and code to manage large dataset collections.
    - OPeNDAP parsing grammar shared with the OPeNDAP/netCDF C library.
- TDS 4.2
  - Stable version … real soon now!
  - Changes from TDS 4.1
    - Refactor FMRC aggregation to simplify configuration and improve performance.
    - Improved integration with ncWMS code including adding the Godiva2 browser based WMS client.
    - Uses CDM/netCDF-Java 4.2