Vertical Coordinate Interpolation

By Tyler Wixtrom

Objectives

- Create simple function for interpolation of isobaric coordinates to isentropic coordinates

- Create simple function for interpolation of sigma (sigma-p, sigma-theta, hybrid-sigma) coordinates to isobaric coordinates

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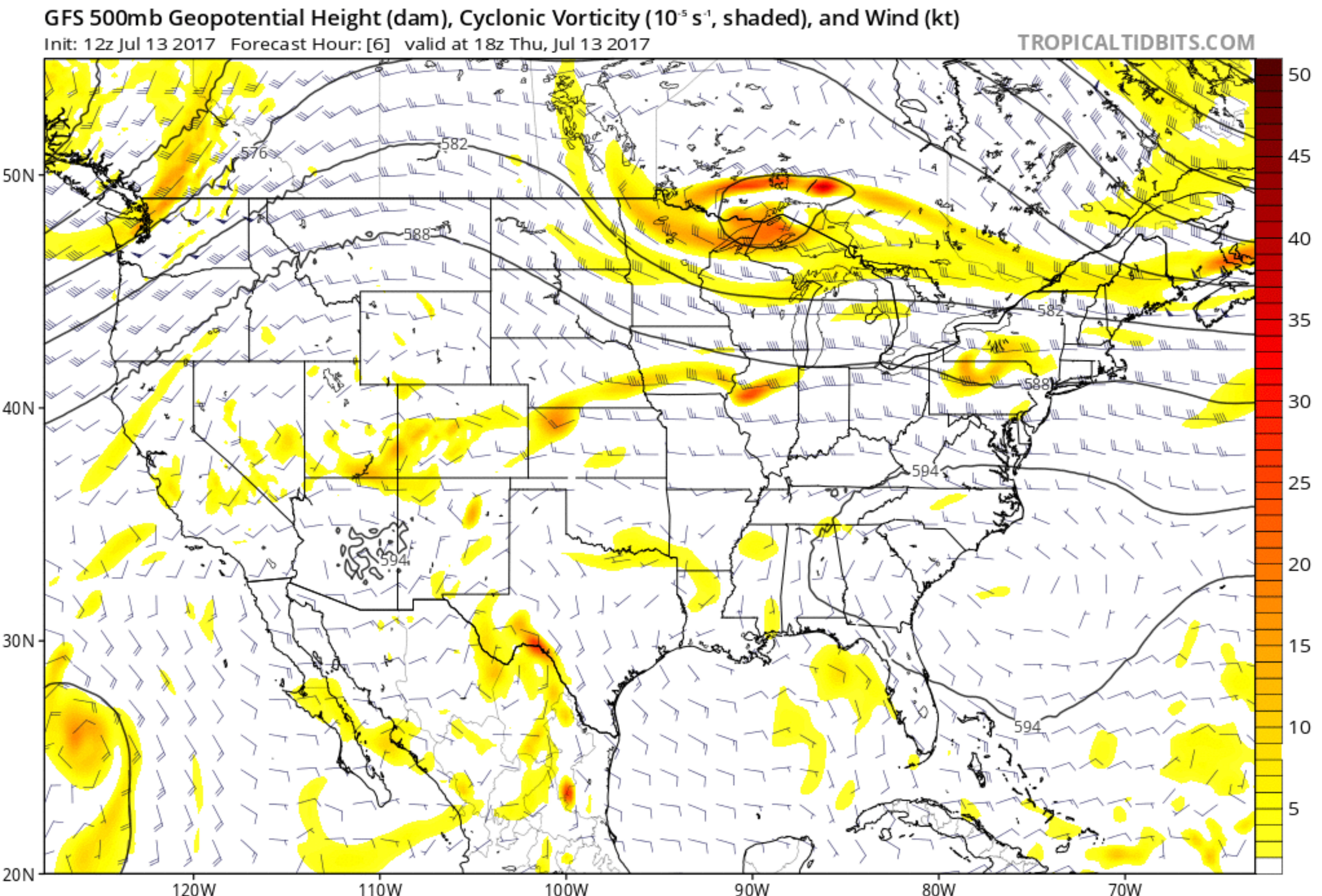
Coordinate Systems

- Isobaric
- Isentropic
- Sigma-p
- Sigma-theta
- Hybrid sigma

Isobaric Coordinates

- Pressure is the vertical
- Commonly used for dy cyclones, etc.
- Most used coordinate s
- example: 500 hPa surfa


GFS 500mb Geopotential Height (dam), Cyclonic Vorticity (10^{-5} s^{-1}, shaded), and Wind (kt)
Init: 12z Jul 13 2017   Forecast Hour: [6]   valid at 18z Thu, Jul 13 2017
TROPICALTIDBITS.COM
576
582
588
594
50N
40N
30N
20N
120W
110W
100W
90W
80W
70W
50
45
40
35
30
25
20
15
10
5

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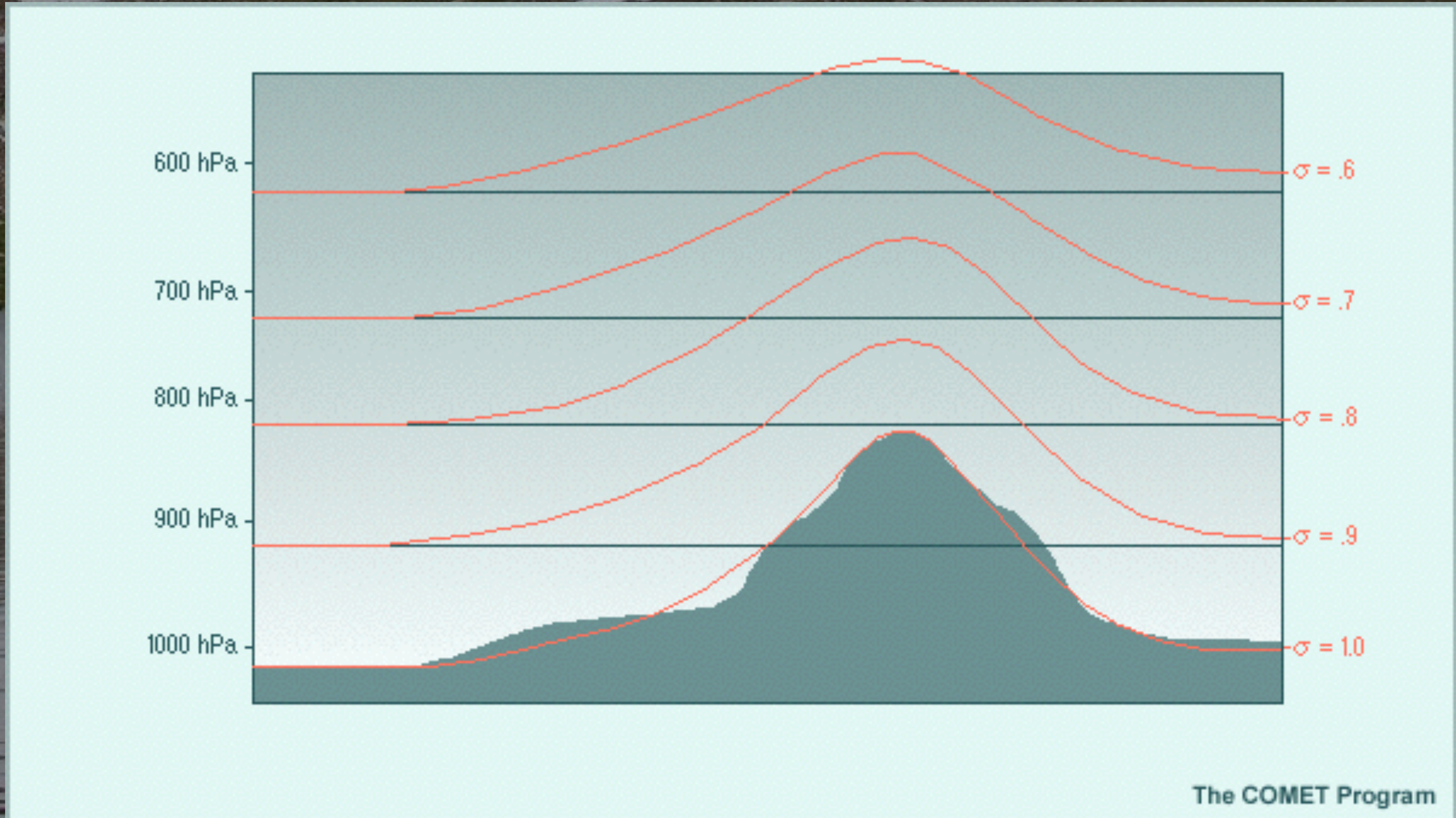
Isentropic Coordinates

- Potential Temperature (entropy) is the vertical coordinate
- Unsaturated air flows on isentropic surface -> more realistic representation of airflow
- Commonly used in winter forecasting, synoptic scale research, etc
- Horizontal and cross-section plots are common

Other Coordinate Systems

- Terrain following Vertical Coordinates
  - Sigma-p
  - Sigma-theta
  - Hybrid sigma
- Do not intersect ground
- Used in numerical models
- Must convert coordinates in post-processing



The COMET Program

Interpolation to Isentropic Coordinates

NARR Isentropic Cross-Section: 52.5 N, -81.5 E to 34.5 N, -80.5 E
VALID: 1987-04-04 18:00:00
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
52.5
50.0
47.5
45.0
42.5
40.0
37.5
35.0
Latitude (Degrees North)
10
20
30
40
50
60
70
80
90
100
415
410
420
395
390
400
380
385
370
360
350
335
345
325
330
315
320
310
305
300
295
290
285
280
275
VALID: 1987-04-04 18:00:00

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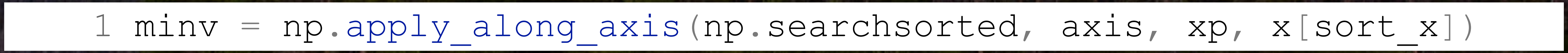
Method

- Assume temperature varies linearly with log of pressure
- Find potential temperature on isobaric levels
- Find index value of isobaric level with potential temperature nearest to desired isentropic level
  - Np.searchsorted applied along specified axis



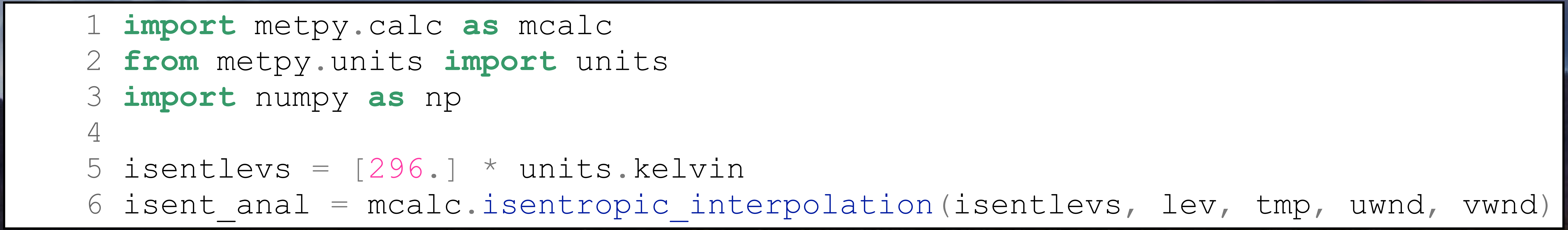
```
minv = np.apply_along_axis(np.searchsorted, axis, xp, x[sort_x])
```

Method

- Use Newton-Raphson iteration to calculate pressure
- Linearly interpolate additional variables
- Returns data interpolated to isentropic space

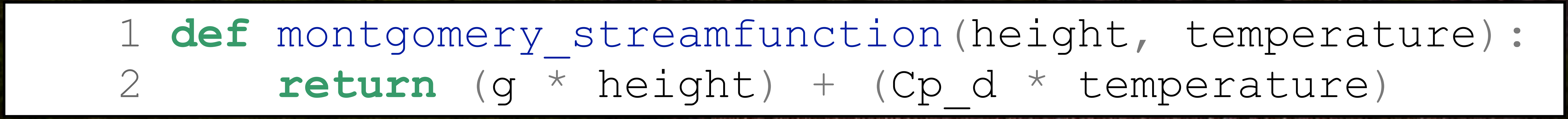
Result

- 2-line addition to user's plotting script for interpolation to isentropic coordinates



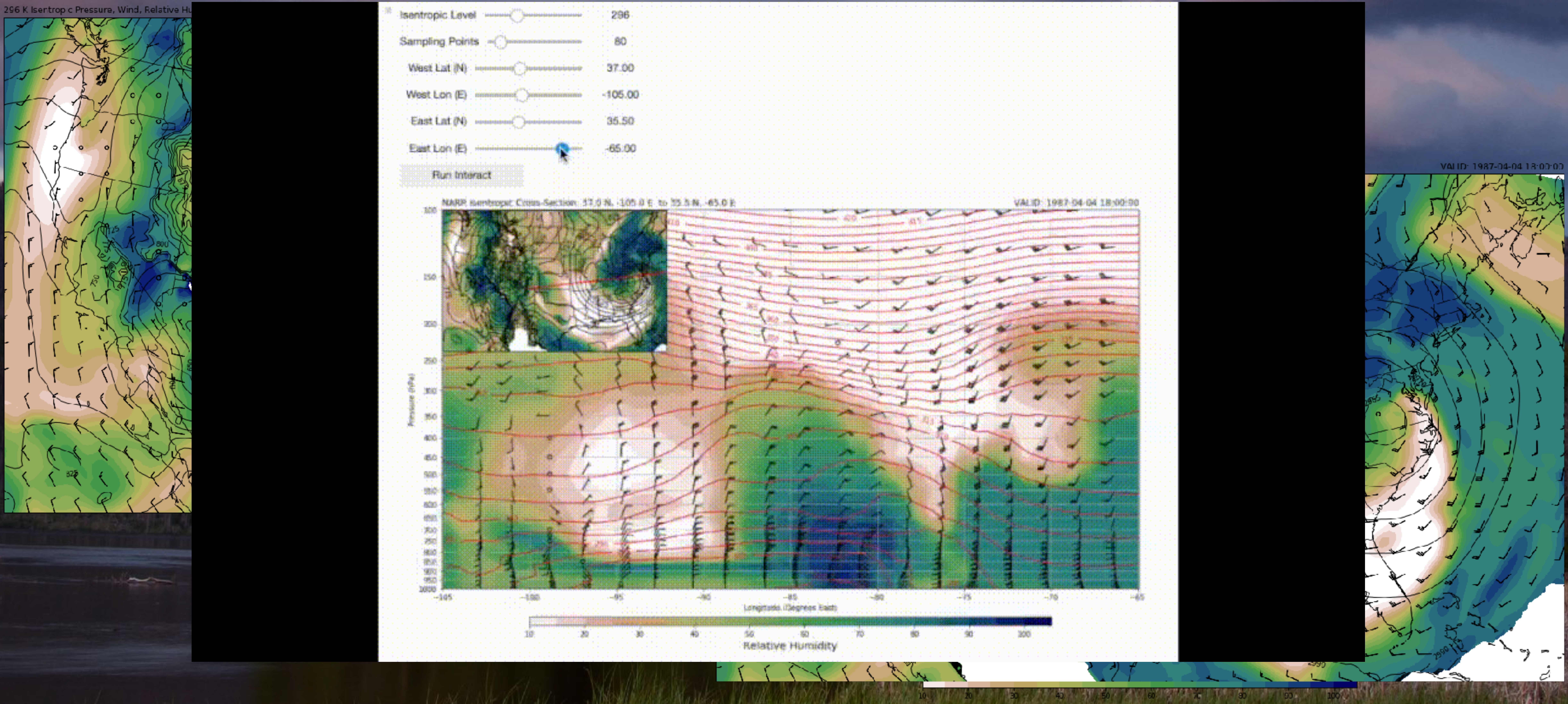
```python
import metpy.calc as mcalc
from metpy.units import units
import numpy as np

isentlevs = [296.] * units.kelvin
isent_anal = mcalc.isentropic_interpolation(isentlevs, lev, tmp, uwnd, vwnd)
```

- Addition of Montgomery Streamfunction, $\psi = gdz + CpT$, for analysis of geostrophic wind



```python
def montgomery_streamfunction(height, temperature):
    return (g * height) + (Cp_d * temperature)
```

Output



Isentropic Level 296

Sampling Points 80

West Lat (N) 37.00

West Lon (E) -105.00

East Lat (N) 35.50

East Lon (E) -65.00

Run Interact

296 K Isentropic Pressure, Wind, Relative Hu
NARR Isentropic Cross-Section: 37.0 N, -105.0 E to 35.5 N, -65.0 E
VALID: 1987-04-04 18:00:00
Pressure (hPa)
Longitude (Degrees East)
-105
-100
-95
-90
-85
-80
-75
-70
-65
Relative Humidity
10
20
30
40
50
60
70
80
90
100
VALID: 1987-04-04 18:00:00

Sigma to Isobaric Coordinate

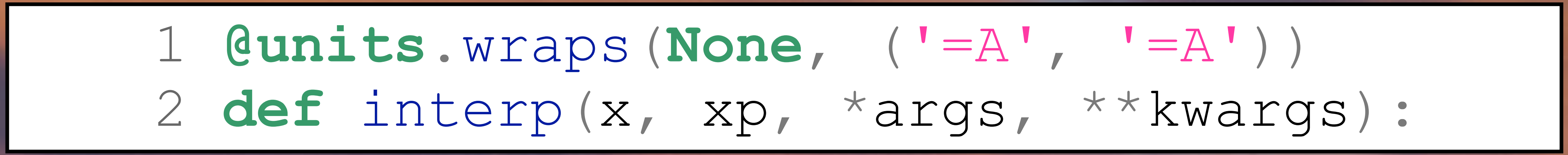
- Model output in sigma coordinates will include pressure as a variable
  - Pressure will be irregular, not constant on each model level
- Use output pressure as x-coordinate for other output variables
- Interpolate variables from irregular pressure to specified pressure levels (500 hPa, 850 hPa, etc)

Method

- Use 1-D log-linear interpolation over a specified dimension of 3-D or greater data
  - NumPy and SciPy 1-D interpolation cannot handle data with greater than 1 dimension
  - Create a 1-D interpolation function for MetPy

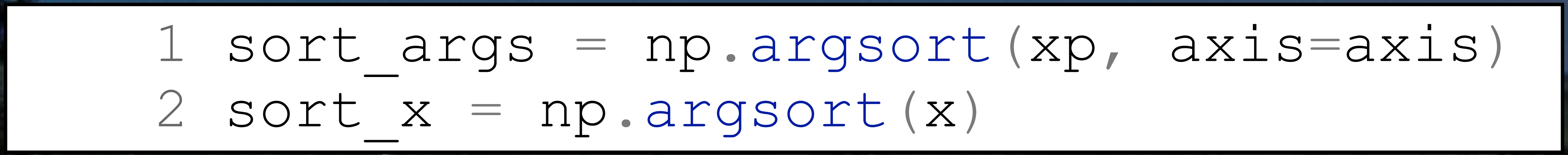
Method

- Convert units and drop from input
  - NumPy doesn't play well with units
  - use Pint wrapper to convert, drop, and reapply at end



```python
@units.wraps(None, ('=A', '=A'))
def interp(x, xp, *args, **kwargs):
```

- Sort data to enforce increasing order



```python
sort_args = np.argsort(xp, axis=axis)
sort_x = np.argsort(x)
```

Method

- Find nearest data point as before
- Apply linear interpolation

```
var_interp = var[below] + ((x_array - xp[below]) /
                                   (xp[above] - xp[below])) * (var[above] -
                                                               var[below])
```

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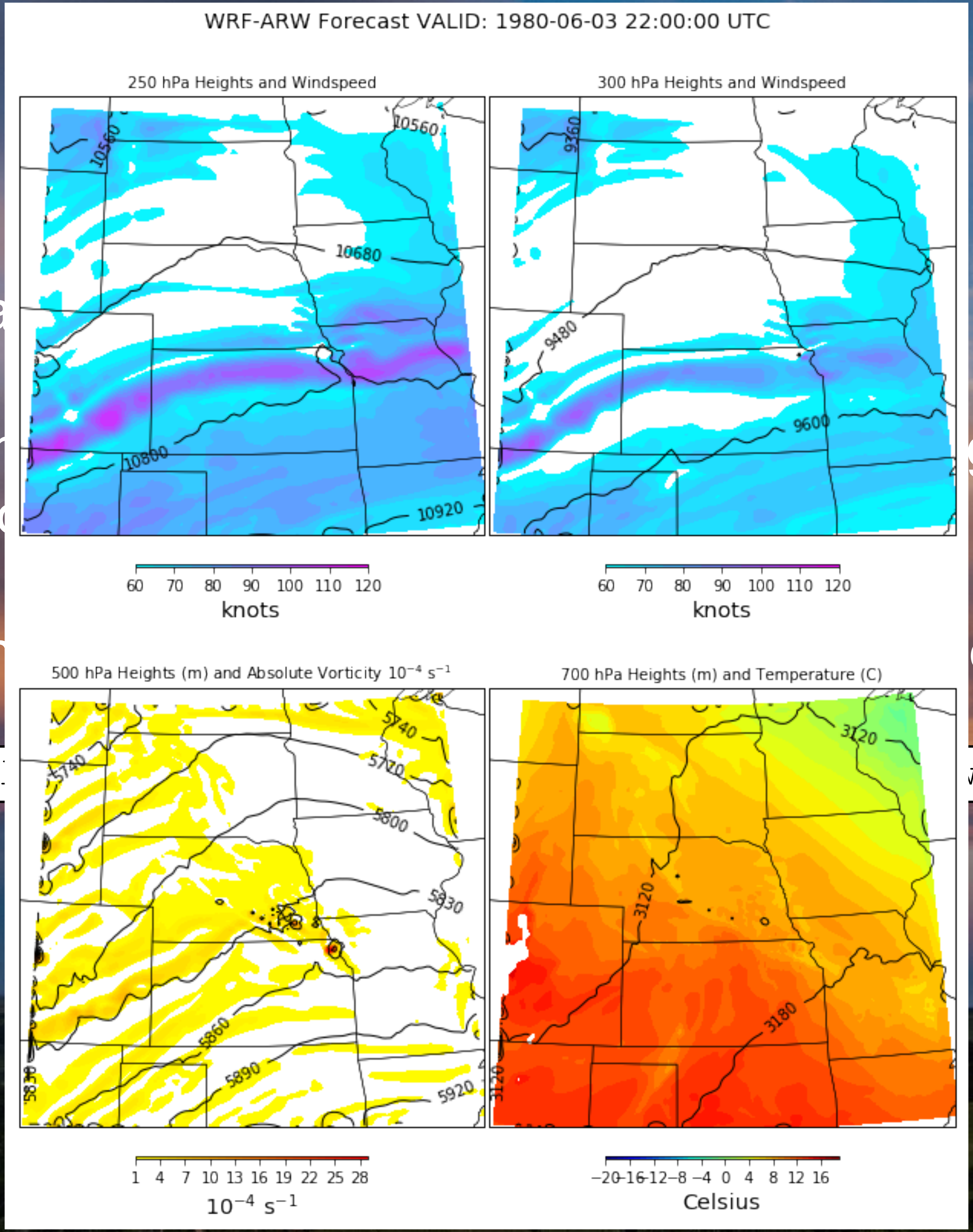
- Flexible 1-D linea

- Can be implemen g. isentropic_interp

- Allows for one-lin coordinates

```
isobaric_leve                                       wnd, vwnd, axis=1)
```



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Conclusion

- Added functionality for:
  - Isobaric to isentropic interpolation
  - Generalized interpolation along a single axis of N-dimensional data
- Code and examples available at https://github.com/Unidata/MetPy and next stable release of MetPY (September 2017)
  - Isobaric to Isentropic interpolation
  - Sigma to Isobaric interpolation
  - Isentropic cross-section

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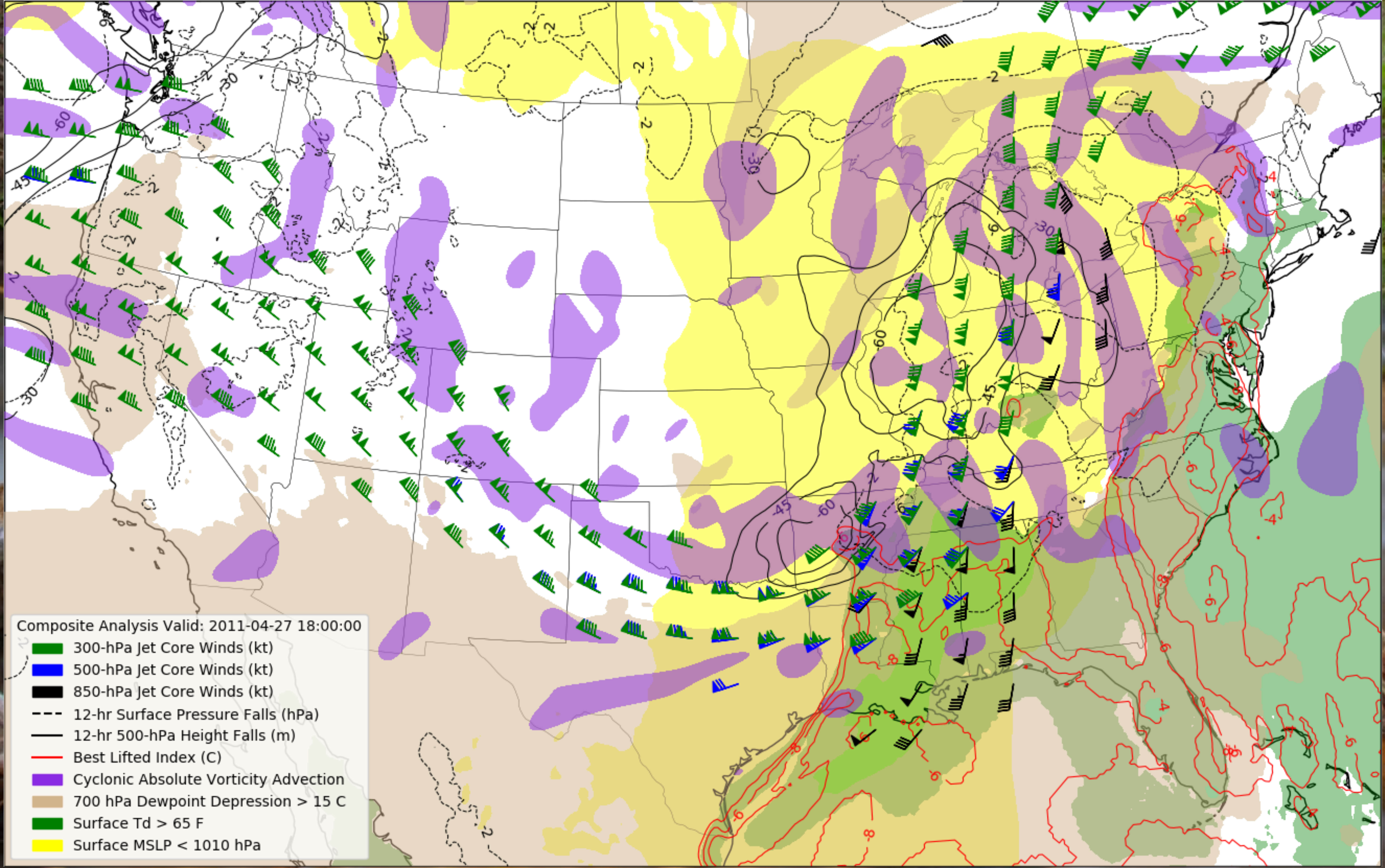
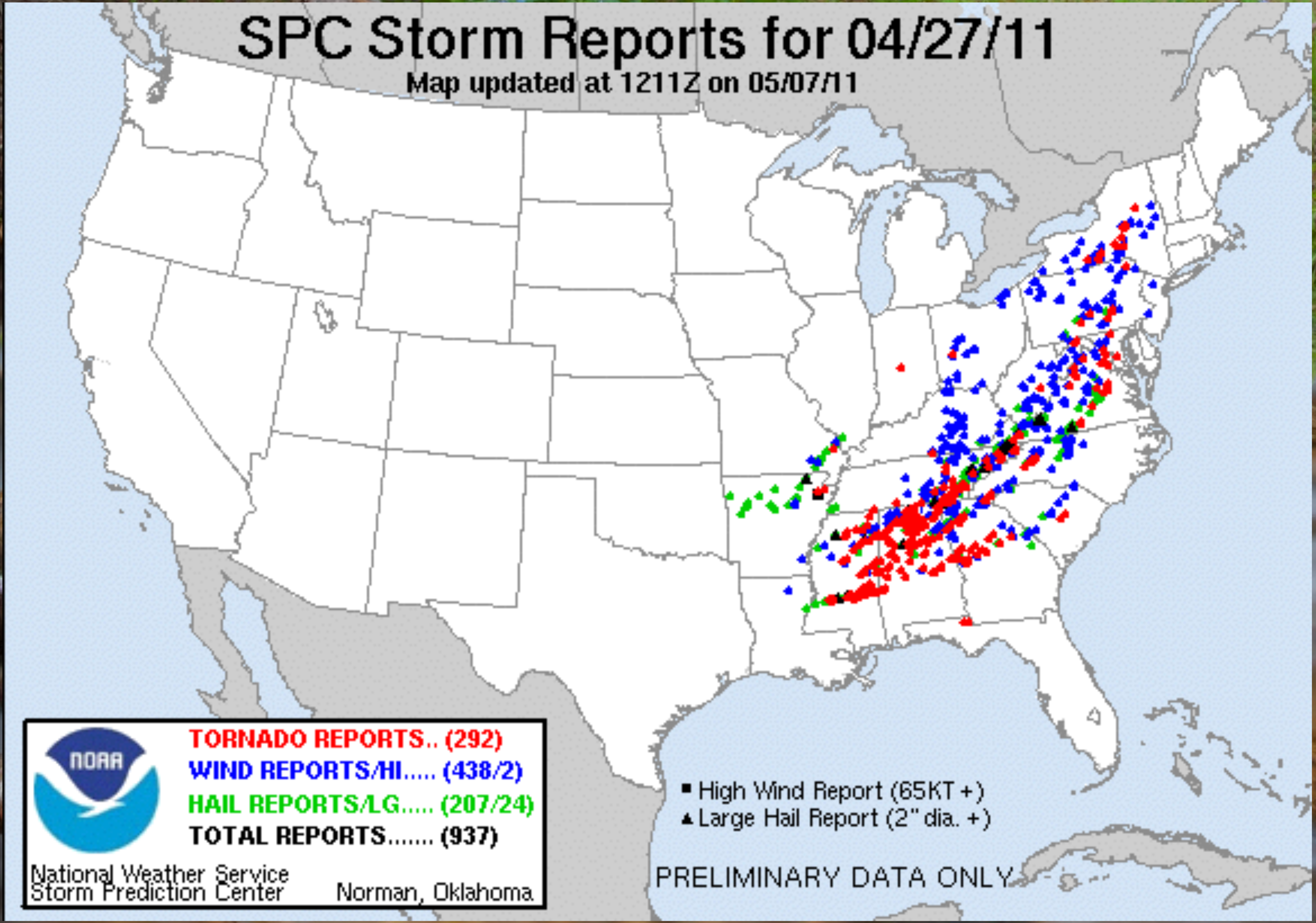
Future Work

- Greater flexibility for input data types
  - e.g. interp expects 1-D interpolation points, N-D for both data points and interpolation points is desired
- Reduce code needed for cross-section plot

Miller Composite Example


Composite Analysis Valid: 2011-04-27 18:00:00
🟩 300-hPa Jet Core Winds (kt)
🟦 500-hPa Jet Core Winds (kt)
⬛ 850-hPa Jet Core Winds (kt)
- - - 12-hr Surface Pressure Falls (hPa)
— 12-hr 500-hPa Height Falls (m)
— Best Lifted Index (C)
🟪 Cyclonic Absolute Vorticity Advection
🟫 700 hPa Dewpoint Depression > 15 C
🟩 Surface Td > 65 F
🟨 Surface MSLP < 1010 hPa

SPC Storm Reports - 4/27/2011


SPC Storm Reports for 04/27/11
Map updated at 1211Z on 05/07/11
TORNADO REPORTS.. (292)
WIND REPORTS/HI..... (438/2)
HAIL REPORTS/LG..... (207/24)
TOTAL REPORTS....... (937)
NOAA
National Weather Service
Storm Prediction Center
Norman, Oklahoma
■ High Wind Report (65KT +)
▲ Large Hail Report (2" dia. +)
PRELIMINARY DATA ONLY