Vertical Coordinate Interpolation

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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
Coordinate Systems

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

- Pressure is the vertical coordinate.
- Commonly used for dynamic analysis of jet streams, mid-latitude cyclones, etc.
- Most used coordinate system among forecasters.
- Example: 500 hPa surface.
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-$\rho$
- Sigma-theta
- Hybrid sigma
- Do not intersect ground
- Used in numerical models
- Must convert coordinates in post-processing
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

```python
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
• 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)
```
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

• Sort data to enforce increasing order

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

1 sort_args = np.argsort(xp, axis=axis)
2 sort_x = np.argsort(x)
```
Method

- Find nearest data point as before
- Apply linear interpolation

```
1 var_interp = var[below] + ((x_array - xp[below]) / 
2 (xp[above] - xp[below])) * (var[above] - 
3 var[below])
```
• Flexible 1-D linear interpolation
• Can be implemented within existing MetPy functions, e.g., `isentropic_interpolation`, `get_layer`
• Allows for one-line interpolation from sigma to isobaric coordinates

```python
isobaric_levels = mcalc.log_interp(plevs, pres, hgt, uwnd, vwnd, axis=1)
```
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
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)**
- **Cyclogonic Absolute Vorticity Advection**
- **700 hPa Dewpoint Depression > 15 C**
- **Surface Td > 65 F**
- **Surface MSLP < 1010 hPa**

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