Vertical Interpolation in MetPy: Sigma to Isobaric to Isentropic

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Objectives

1. Develop user-friendly functions for vertical coordinate interpolation of gridded fields.
   - Sigma to isobaric and isobaric to isentropic coordinate conversions are commonly requested features for the MetPy package
   - Similar software can calculate these conversions, but contain older graphics engines than is available within the Python language
   - Users have requested an easy to use method for vertical coordinate interpolation in MetPy
2. Implement these calculations through accepted, peer-reviewed methods

Introduction

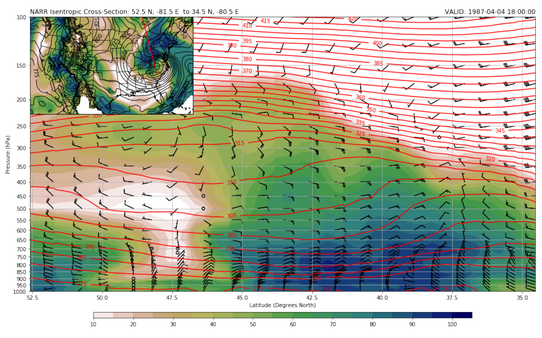

Figure: 1. North American Regional Reanalysis (NARR) Isentropic cross section from 18 UTC 4 April 1987 demonstrating the powerful computational and graphics capability of the Python language.

Vertical coordinate interpolation is commonly desired functionality of meteorological analysis software for research, teaching, and operational applications. The Python language has gained popularity among atmospheric scientists due to its relative ease of use, numerous community maintained packages, and modern graphics capabilities. Vertical coordinate interpolation support does not currently exist within common, actively maintained packages, and has been a highly requested feature by users of the MetPy package. Therefore, it is necessary that support for these calculations be added to the MetPy suite while maintaining a user interface that is both powerful and flexible while remaining simple to understand and use.

Sigma to Isobaric

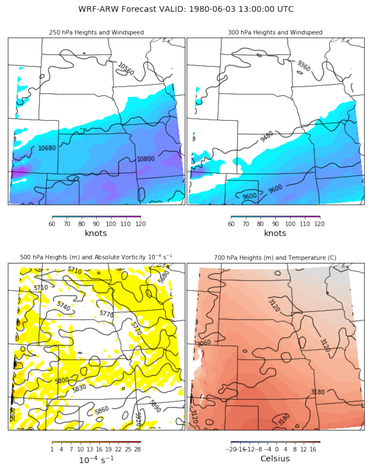

Figure: 2. 4-panel plot of 250 hPa height and winds (upper left), 300 hPa height and winds (upper right), 500 hPa height and relative vorticity (lower left) and 700 hPa height and temperature (lower right) for 13 UTC 3 June 1980. Interpolation with MetPy.

Sigma coordinates are often used within numerical weather prediction models since they are terrain-following and thus defined over the entire domain. However, since sigma coordinates are not at a constant pressure or height, interpolation to isobaric coordinates is often conducted during post-processing to allow for easier interpretation of model forecasts.

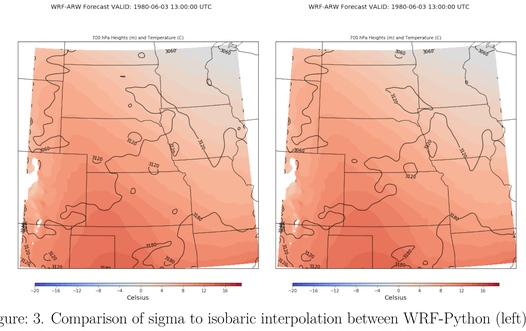

Figure: 3. Comparison of sigma to isobaric interpolation between WRF-Python (left) and MetPy (right) for 700 hPa height and temperature for 13 UTC 3 June 1980.

- Use output pressure as x-coordinate of other variables.
- Apply log-linear interpolation along vertical axis to interpolate to mandatory levels.
- Flexible for N-dimensional input datasets.
- Computationally efficient
- Produces results similar to other software

Isobaric to Isentropic

Isentropic coordinates are often used in synoptic and dynamic meteorology as a complementary view to the traditional Quasi-Geostrophic theory, as well as for Potential Vorticity analysis. Interpolation to isentropic coordinates requires an iterative process, which becomes very slow when written with the traditional for-loop methods of compiled languages. Isentropic interpolation has been desired functionality for the Python scientific community, and now becomes possible with the aid of vectorized calculations in NumPy.

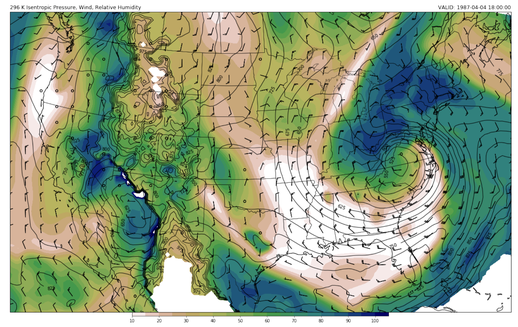

Figure: 4. NARR 296 K pressure, wind, and relative humidity for 18 UTC 4 April 1987. Interpolation with MetPy.

- Assume a linear dependence of temperature with the natural log of pressure and a stable atmosphere (Ziv and Alpert, 1994).
- Apply Newton-Raphson iteration to find the pressure at each isentropic level
- Linearly interpolate any additional variables
- Optional calculation of Montgomery Streamfunction (Lackmann, 2011)
- Flexible for multiple data sources

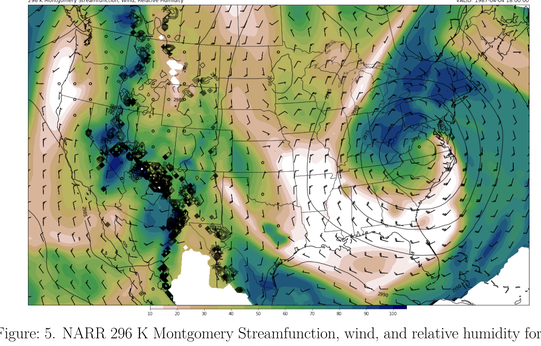

Figure: 5. NARR 296 K Montgomery Streamfunction, wind, and relative humidity for 18 UTC 4 April 1987. Interpolation with MetPy.

Sample Code

```
isentropic_interpolation(isentlevs, lev, relh)

log_interp(plevs, pres, hgt, axis=1)
```

Conclusion

Added functionality for sigma to isobaric and isobaric to isentropic coordinate conversions

- Code available in MetPy $\geq$ 0.6. Examples can be found in the Unidata Python Gallery (`unidata.github.io/python-gallery`) and the MetPy documentation (`unidata.github.io/MetPy/latest`).

Future improvements:

- Improve interpolation to be more flexible regarding input data types
- Conduct additional testing against other software

New MetPy Features

Support for the following has been added to MetPy:

- Sigma to Isobaric interpolation
- Isobaric to Isentropic interpolation
- 1-D linear interpolation for N-D arrays
- Calculation of Montgomery Streamfunction

References

Lackmann, G., 2011: *Midlatitude Synoptic Meteorology*. Amer. Meteor. Soc.

van der Walt, S., S. C. Colbert, and G. Varoquaux, 2011: The numpy array: A structure for efficient numerical computation. *Computing in Science and Engineering*, **13**, 22–30.

Ziv, B. and P. Alpert, 1994: Isobaric to isentropic interpolation errors and implication to potential vorticity analysis. *J. Appl. Meteor.*, **33**, 694–703.

Acknowledgements

This work funded primarily by the National Science Foundation (Grant NSF-1344155)