Implementation of MetPy in Meteorological Case Studies in Undergraduate Courses

Wendilyn Flynn, Assoc. Prof., University of Northern Colorado (wendilyn.flynn@unco.edu)

Introduction

The case study project is a commonly used teaching strategy in undergraduate synoptic and mesoscale meteorology courses. In Spring 2017 and Spring 2018 of MET 460: Mesoscale Meteorology, a senior-level undergraduate course at the University of Northern Colorado, I have implemented an approach to the case study project that involves group work and a novel way to plot model data using Unidata's Siphon and MetPy, with Python scripts in Jupyter Notebook. The students have already taken at least one programming course in Python prior to MET 460, and through the project they gain a working knowledge of how to operate in this new environment, which translates to marketable skills for them upon graduation. This approach will be refined for future course offerings, and it is easily adaptable to similar upper-level courses at other institutions.

Case Study Structure

Overview: For the group project, the entire class (typically less than 10 students) decides on one topic, and forms sub-groups to focus on specific mesoscale research questions. The project culminates in a group poster and group paper (15% of grade).

Part 1: Group Decision on Case Study Topic
- Determined through vote, and then agreement if not unanimous

Part 2: Background and Literature Review
- Appropriate MetEd Modules assigned to everyone
- Each student is assigned one peer-reviewed journal article to thoroughly read and answer questions on; act as group discussion leader for that article
- Structured discussion of all materials (MetEd Modules, journal articles) takes place during one lab period
- Research questions and data analysis methods are formulated following discussion
- After approval from instructor, research questions are solidified and small groups assigned

Part 3: Gather data from online sources and perform model data analysis in Python
- Installation of Python and running of sample scripts performed together during class
- One-on-one appointments are held by the instructor with each student
- Students are allowed lab and lecture time to work together and get assistance from the instructor
- Other data such as archived soundings, surface data plots, surface analyses, upper-air analyses, radar and satellite imagery, and isohyetal plots help students form a more complete analysis of the event
- Canvas is used to present installation instructions and provide sample scripts (Fig. 1)

Figure 1. Within Canvas (a Learning Management System), a webpage is created for students to reference installation details, access sample scripts, and learn basics of matplotlib and GFS output variable structure. Only the first few lines are shown here; more of this page is available upon request.

- Students are encouraged to explore the template scripts and adjust them to their focus within the context of the group project:
  - Different model output variables
  - 3D vs. 4D model output
  - experiment with line thickness, pattern, vector styles
  - change colormap, contour settings
  - preliminary MetPy plots shared with class during lab time

Part 4: Poster
- MetPy plots from each student are required (examples in Figs. 2-11)
- Google Slides used for online collaborative work
- Presented at Departmental PosterFest
- Comments from fellow students and instructor guide additional work

Part 5: Paper
- MetPy plots from each student are required (examples in Figs. 2-11)
- Google Docs used for online collaborative work
- AMS format

MET 460 Spring 2017 Case Study:
Atmospheric Rivers Impacting the West Coast of the US (Winter 2016-17)

Student Research Question:
What determines where precipitation will fall in atmospheric river events?

Examples of Student-Created Plots

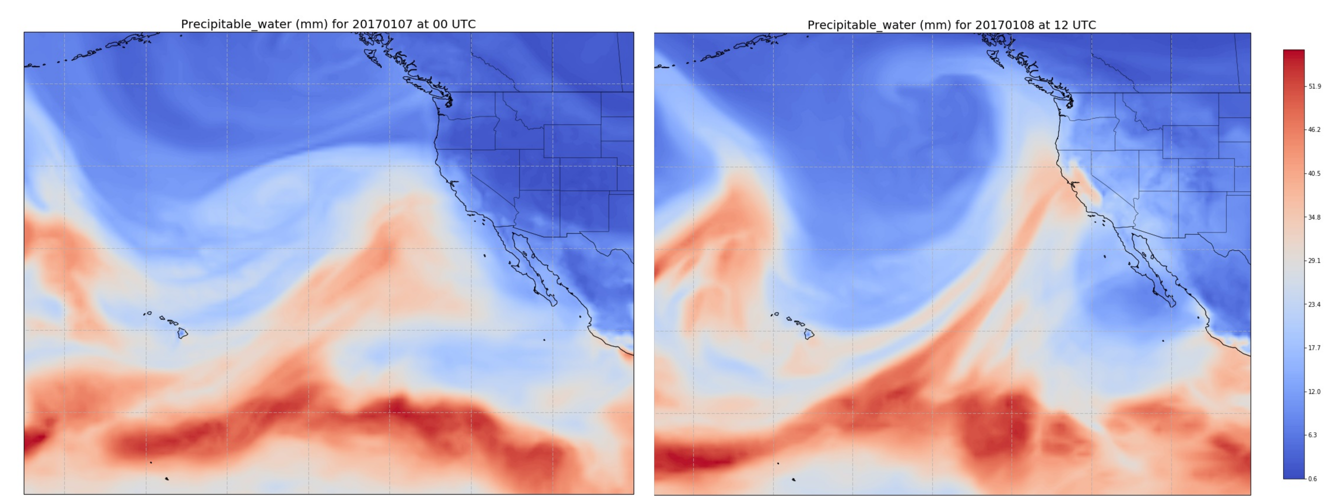


Figure 2. 36-hr comparison of **Precipitable Water (PW)** over the Pacific preceding, then during, the atmospheric river event. Left, GFS-FNL PW valid 0000 UTC 7 Jan 2017. Right, GFS-FNL PW valid 1200 UTC 8 Jan 2017.

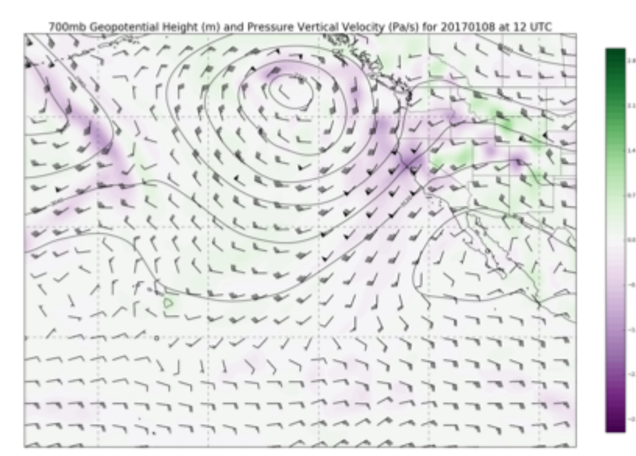


Figure 3. GFS-FNL 1200 UTC 8 Jan 2017 **700 mb height contours (m)** and **pressure vertical velocity (Pa/s)**.

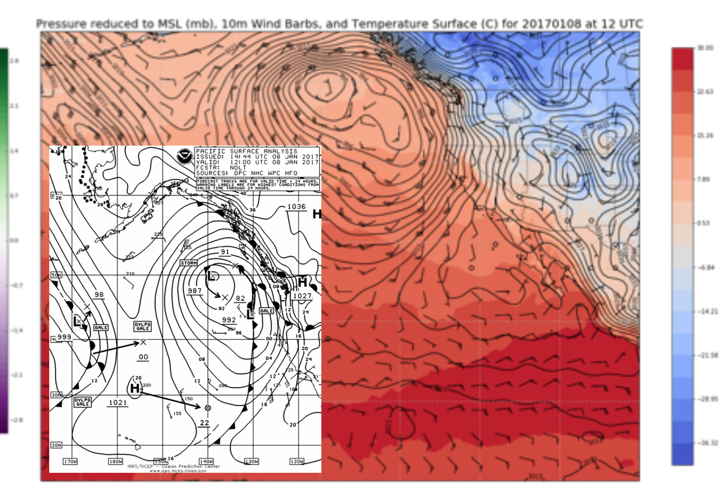


Figure 4. GFS-FNL **MSLP (mb), 10 m wind barbs (kt)**, and **surface temperature (℃)** 1200 UTC 8 Jan 2017; with inset of the Eastern Pacific **surface analysis** from the NOAA NCEI for the same time.

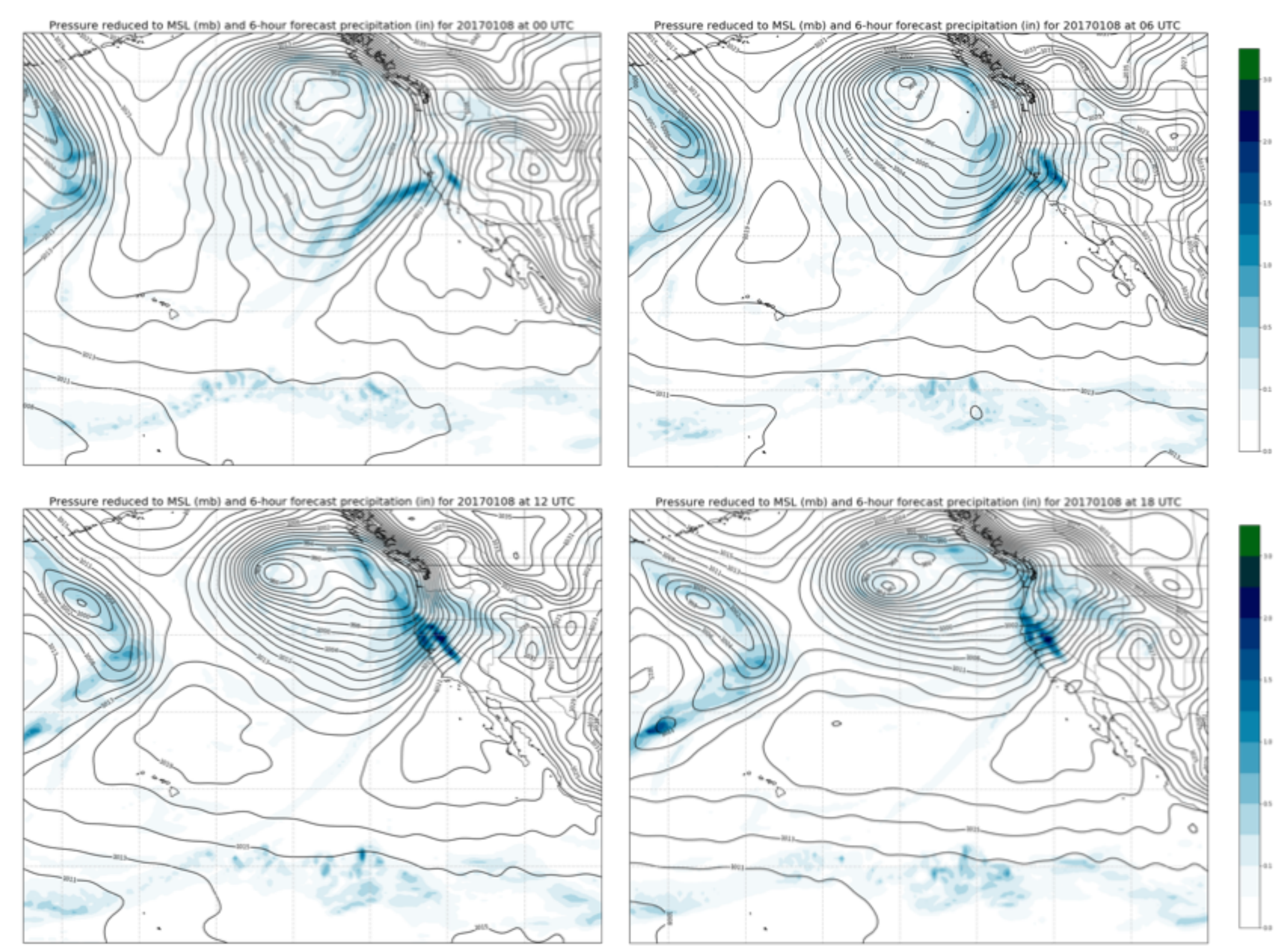


Figure 5. GFS-FNL **MSLP (mb)** and **6-hr forecasted precipitation (in)**. **(a)** 0000 UTC 8 Jan 2017 to 0600 UTC 8 Jan 2017, **(b)** 0600 UTC 8 Jan 2017 to 1200 UTC 8 Jan 2017, **(c)** 1200 UTC 8 Jan 2017 to 1800 UTC 8 Jan 2017, **(d)** 1800 UTC 8 Jan 2017 to 0000 UTC 9 Jan 2017.

MET 460 Spring 2018 Case Study:
Supercells in Northeastern CO & Southeastern WY on June 12, 2017

Student Research Questions:
What synoptic-scale and mesoscale factors acted as "triggers" for initiation?
Why wasn't this a "deep hail" event?

Examples of Student-Created Plots

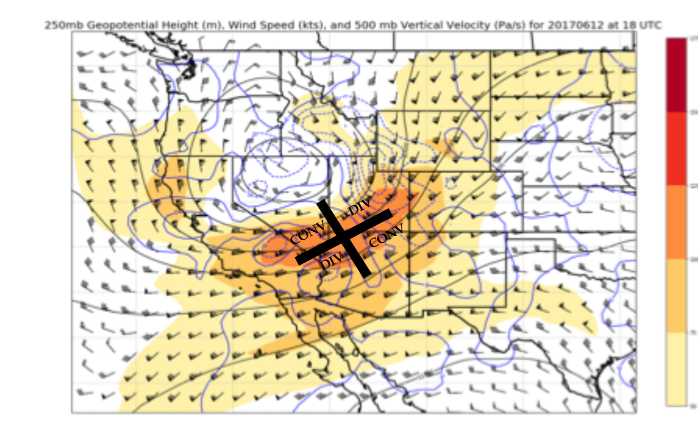


Figure 6. 250 mb jet streak dynamics were not conducive for convection over Colorado during storm initiation. Black lines indicate **geopotential height (m);** blue lines are **vertical velocity (Pa/s)**. A curved jet with an embedded streak exists over Arizona and Utah.

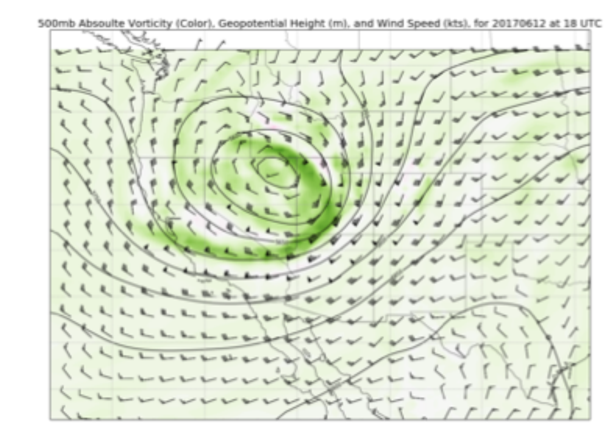


Figure 7. Absolute Vorticity June 12th at 18 UTC from the GFS. Center of strongest positive vorticity is over Utah, far from the region of storm initiation in Colo**at 500 mb** rado. Some weak positive vorticity is observed along the Front Range of Colorado.

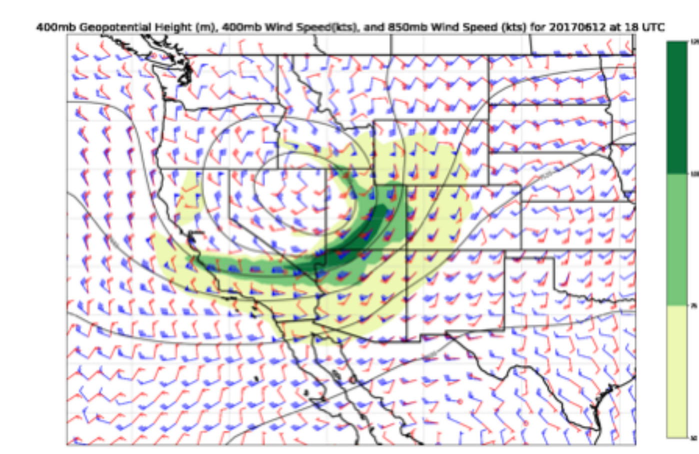


Figure 8. Analysis of the 850 mb and 400 mb winds, acting as a **proxy for the 0-6 km wind shear**. Red barbs represent "surface" (850 mb) winds, and blue barbs represent 6 km (400 mb) winds, as per SPC convention. The 0-6 km wind shift is nearly 90 degrees over northern Colorado.

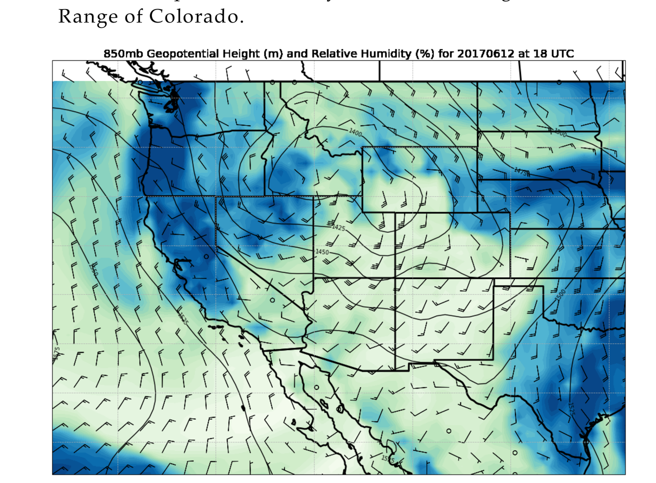


Figure 9. 850 mb Relative Humidity (%) and **Geopotential Height (m)**. Note considerable moisture (near the surface). At 700 mb (figure not shown here) moisture is less widespread and shows evidence for a drier environment. The storms could have thus encountered entrainment which would have influenced storm lifecycle during this event.

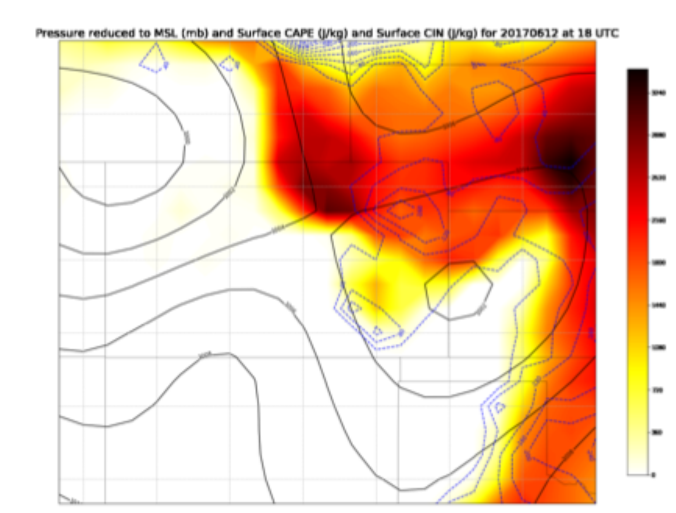


Figure 10:**MSLP (mb)**, Surface-based **CAPE** (color-filled contours) and **CIN** (blue, dashed) for June 12th at 18 UTC. There are high CAPE and low CIN values over northern Colorado near Fort Collins where storms first began.

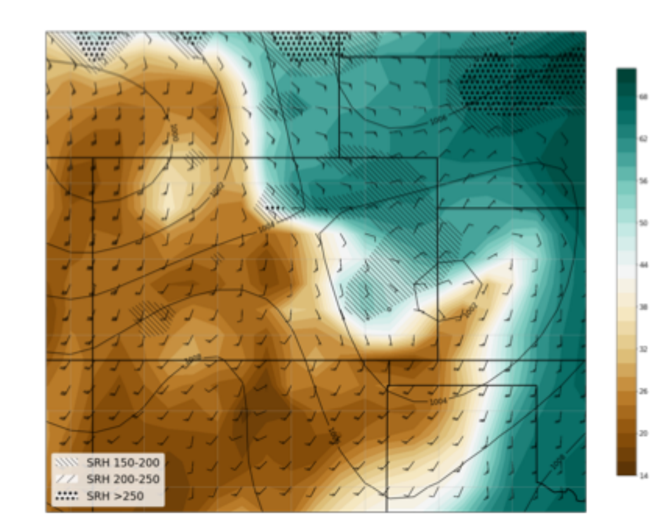


Figure 11. MSLP (mb), 10 m Wind Barbs (kts), Dew Point Temperature (F, color), and **Storm Relative Helicity (m2/s2, hatched)** for June 12th, 2017 at 18 UTC. High Storm Relative Helicity observed around Front Range of CO into Nebraska.

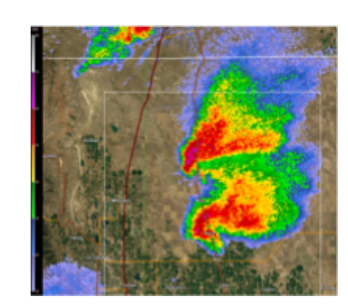
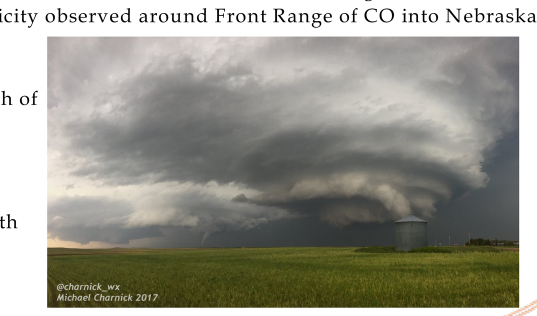


Figure 12 (Left). 0.5 degree elevation angle scan from the KFTG radar of supercells north of Greeley, CO on June 12, 2017 viewed in GR2Analyst.

Figure 13 (Right). Photo of three mesocyclones, one producing a tornado north of Greeley, CO on June 12, 2017. National Weather Service (Michael Charnick 2017).



Conclusions

- Siphon and MetPy are useful tools to help students investigate the synoptic and sub-synoptic atmospheric environment in group case study projects in a senior-level undergraduate meteorology course. Students used Jupyter Notebook to modify template scripts and created their own plots from GFS data, which introduced them to modern methods of accessing meteorological data, and allowed them to utilize Python skills in a new context.
- A few improvements to Siphon and MetPy could enhance the utility for simple case studies. Plotting model data was relatively easy, but plotting archived surface observations and upper-air data was not possible for our cases. Ability to plot and contour upper-level maps and archived surface data would be a welcomed addition, as will more GEMPAK-like functionality.