CW3E 2021 Summer Intern Report

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1. Introduction The goal of my summer was to create python scripts that can analyze the outputs of the West-WRF model (West-Weather Research and Forecasting model) which is used at CW3E for atmospheric river (AR) data assimilation. Specifically, the goal of my scripts was to analyze the impact that dropsonde data has on the West-WRF model.

2. Importance of AR Reconnaissance (Recon) AR Recon refers to an observational campaign that occurs yearly in the cool season to improve forecasts of the landfall and impacts of ARs on the West Coast at lead times of 1-5 days. AR Recon has been demonstrated to fill data gaps caused by thick clouds that satellites are either unable to penetrate or have coarse vertical resolutions. There are several components to AR Recon: (1) dropsondes, (2) radio occultation, (3) buoys, and (4) weather balloons. My project focuses on the data collected from dropsondes, radiosonde instruments dropped out of airplanes flying over ARs and record standard weather measurements as they fall (temperature, relative humidity, wind speed, and pressure). My work contributes to the mission of AR Recon because I am developing codes, analysis, and visualization methods for dropsonde data denial simulations to support AR Recon flight sequence planning.

3. Methods This summer, I've coded in the JupyterNotebooks environment. Libraries used include: ***wrf***, ***cartopy***, ***xarray***, *matplotlib.pyplot*, *numpy*, *os*, *xesmf*, and ***netCDF4***. Data used: outputs from the West-WRF Data Assimilation system. The scripts I've created generate two new data files: (1) a ncfile with variables for integrated water vapor (IWV), integrated water vapor transport (IVT), and specific humidity (Q) (2) a ncfile with regridded data. The flow chart (Fig.1) helps to explain the process I've used to turn the raw data outputs of the West-WRF model into easy to visualize results.

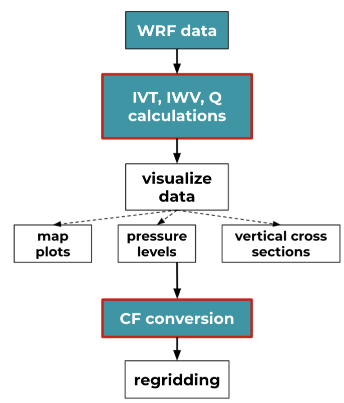

Figure 1. Flow chart of my summer's outline.

$$\mathrm{IWV} = \frac{1}{g}\int_{p_{\mathrm{sfc}}}^{100\,\mathrm{hPa}} q\,dp,$$

$$\mathrm{IVT} = \frac{1}{g}\int_{p_{\mathrm{sfc}}}^{100\,\mathrm{hPa}} q\mathbf{V}\,dp,$$

Figure 2. Formulas for calculating Integrated Water Vapor (IWV) and Integrated Water Vapor Transport (IVT).

To calculate IWV and IVT (Fig. 2), I created 21 set pressure levels: 1000, 975, 950, 925, 900, 850, 800, 750, 700, 650, 600, 550, 500, 450, 400, 350, 300, 250, 200, 150, 100. I then implemented the formulas (at left) after calculating specific humidity, using its relationship between relative humidity to accomplish this. Then for IVT, I used the zonal and meridional wind components to multiply by specific humidity.

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4. Script Summary 1) IWV & IVT ncfile creation: performs calculations mentioned in the previous section and creates a new NetCDF4 file with these variables and new pressure levels. 2) 2D plots: creates 2D map plots for any desired variable (IVT, IWV, Q, and SLP). 3) Pressure level 2D plots: plots IVT, IWV, and Q at a certain pressure level; mostly looked at 500 hPa as this is where a lot of atmospheric dynamics occur. 4) Vertical Cross Sections: creates vertical cross section plots and can create a difference cross section as well. 5) CF (Climate and Forecast)

Convention Conversion: regrids the IWV & IVT ncfile to have 0.25 degree resolution instead of 9km so it can be validated with ERA5 data; creates a NetCDF4 file.

5. Data analysis Using the 2D plots script, I was able to visualize the development of an atmospheric river. The 2D map plot of IVT (Fig. 3) is from intensive observational period 8 (IOP8) — Jan 28, 2021. And the other 2D plot (Fig. 4) is of layered IVT centered at 500 hPa.

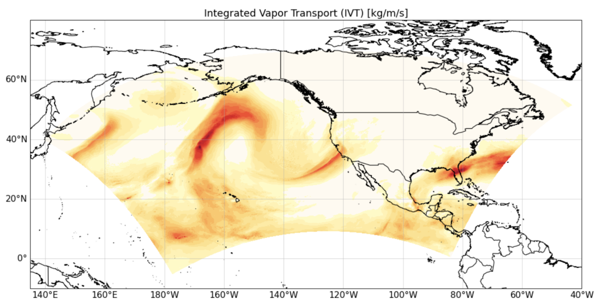

Figure 3. IVT for AR on Jan 28, 2021. Summed over all pressure levels.

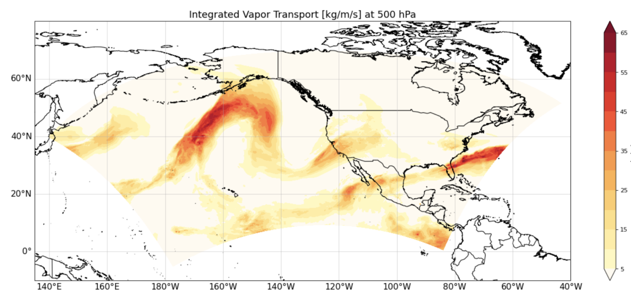

Figure 4. IVT for AR on Jan 28, 2021. Only at one pressure level, 500 hPa.

However, the most interesting results from my data analysis come from difference plots. In these plots, I am using two sets of data: withDrop and noDrop. WithDrop data refers to West-WRF model outputs after assimilating all traditional *and* dropsonde data, whereas noDrop means *only* traditional data, no dropsondes. As we can see in the 2D map difference plot (Fig. 5), as time goes on from hour 0 to 12, the impact that dropsondes make on the West-WRF model increases. In the vertical cross section plot (Fig. 6), we see that the dropsonde data enhances moisture from 450 to 650 hPa, and reduces moisture content from 650 to 850 hPa.

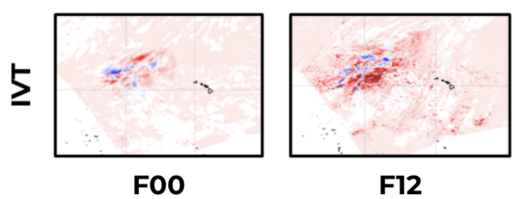

Figure 5. 2D difference plot for IVT (withDrop - noDrop) at time step 0 hr and 12 hr.

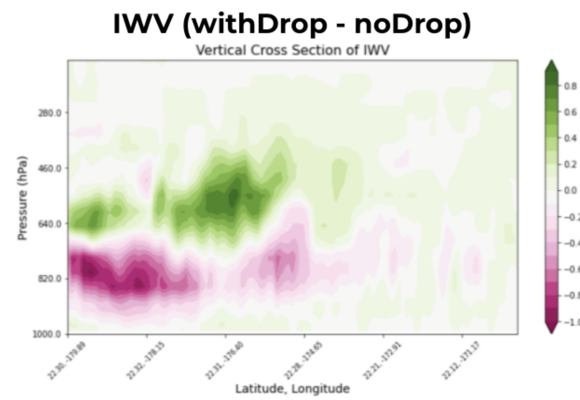

Figure 6. IWV difference cross section (withDrop - noDrop) on the path 22.29N, -179.99W to 22N, -169.98W.

6. Field Work Also this summer, I had the opportunity to install two stream gauges in offshoots of the Yuba River. At each of the stream gauge sites, we installed a stilling well with Solinst levelogger, a nearby Solinst barologger, and a staff plate. In doing so, not only did I have the opportunity to perform field measurements and various instrument installations, but I gained a new appreciation for the observations I've used in my data analysis. Going forward, I hope to go on more field work in addition to using observational data to make meaningful conclusions.

7. Personal Improvements This summer I've gained more familiarity with the Earth Science libraries of python, as well as how to navigate large data sets. Furthermore, I've improved my knowledge on the importance of data assimilation and how to use data denial runs to see the effect of a model's initial condition. Lastly, this summer has given me the opportunity to take independence in my research—struggle with the code, develop my own research interests, and then utilize the scripts I've made to analyze data denial runs and ultimately find some answers.

8. Conclusions & Future Work In the future, I hope to expand my summer project by applying my scripts to more flight sequence data, and in doing so I would like to improve my understanding of AR physics and how a changed initial condition can influence the downstream forecast accuracy. Furthermore, looking at the cross section plots, I am very interested to see whether enhanced moisture in 450 to 650 hPa and decreased moisture from 650 to 850 hPa is a common theme. Also going forward, I would like to further validate all of my data with ERA5, which means utilizing the regridded data.

References:

1. Ralph et al. "West Coast forecast challenges and development of atmospheric river reconnaissance" Bulletin of the American Meteorological Society, 101(8), pp.E1357-E1377
2. Zheng et al. "Data gaps within atmospheric rivers over the northeastern Pacific" Bulletin of the American Meteorological Society, 102(3), pp.E492-E524.
3. Zheng et al. 2021 "Improved forecast skill through assimilating dropsonde observations from Atmospheric River Reconnaissance" Journal of Geophysical Research - Atmosphere, accepted.
4. Ralph et al. 2005 "Dropsonde Observations in Low-Level Jets over the Northeastern Pacific Ocean from CALJET-1998 and PACJET-2001: Mean Vertical-Profile and Atmospheric-River Characteristics"

Thank you to my wonderful mentors Mingua Zheng and Luca Delle Monache! As well as the field team: Carly Ellis, Kerstin Paulsson, and Ava Cooper. And finally to the intern coordinators and programming resources: Cody Poulsen, Will Chapman, and Pat Mulrooney.