

Atmospheric River Detection Using ERA5 Data

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Global Region: Starting with Pineapple Express

Data: Integrated Water Vapor Transport (northward and eastward)

Other Resources: European Reanalysis 5

Research Project Idea: Atmospheric River Event Detection

Objective: Develop a system that detects and visualizes atmospheric river events

Final Presentation:  Brandon Newman - Atmospheric River Detection

This project uses the Cheyenne supercomputer to simulate and analyze integral water vapor transport in the atmosphere. An atmospheric river (AR) is a stream of water vapor that traditionally moves from the tropics away from the equator. The data I used is from European Reanalysis 5 (ERA5), and my research is focused on a major Pineapple Express event between Dec. 10 and Dec. 22 of 2010. The Pineapple Express is the AR from Hawaii to western North America.

I wrote a Python program that filtered the data to more easily visualize an AR. The filtering, based on definitions of ARs gathered from the sources below. Specifically, I filtered out all data points where the IVT magnitude was less than $200 \text{ kg m}^{-1} \text{ s}^{-1}$. An AR has IVT of at least $250 \text{ kg m}^{-1} \text{ s}^{-1}$, so I wanted to show only where an AR was present and also where an AR could be forming. Second, I filtered out all points with a northward IVT less than $30 \text{ kg m}^{-1} \text{ s}^{-1}$. This is because the average northward IVT in an AR should be above $50 \text{ kg m}^{-1} \text{ s}^{-1}$. Since I was just taking it point by point instead of taking an average, I set the minimum to $30 \text{ kg m}^{-1} \text{ s}^{-1}$. After running the program, I was left with two output files, the filtered northward IVT and the filtered eastward IVT.

The next step was plotting the data on a vector map. I used a modified version of the NCL vector_1 graphic with a domain over the Pineapple Express region. All code and results are shown below.

In conclusion, I was able to make an atmospheric river filter/detection program that accurately singles out ARs. Compared with the original test, my program was much more precise. My future goals are to make the program even more precise by adding in more specifications to the filtering process based on the more advanced defined features of an AR. Then, I plan on creating a program to predict where the atmospheric river might land in terms of rainfall.

Code:

```
import xarray as xr
import numpy as np
import netCDF4 as nc

def calculate_total_magnitude(vertical_file, horizontal_file, output_file_vert, output_file_horiz):
    # Load the vertical and horizontal data
    vertical_data = xr.open_dataset(vertical_file)
    horizontal_data = xr.open_dataset(horizontal_file)
    vertical_data = vertical_data.to_array()
    horizontal_data = horizontal_data.to_array()
    # Calculate the total magnitude
    for j in range(140, 341):
        for k in range(600, 1081):
            magnitude = ((vertical_data[0][42][j][k]).astype(float) ** 2
                          + (horizontal_data[0][42][j][k]).astype(float) ** 2) ** 0.5
            if magnitude < 200 or (vertical_data[0][42][j][k] < 30 and vertical_data[0][42][j][k] > -30):
                vertical_data[0][42][j][k] = 0
                horizontal_data[0][42][j][k] = 0

    # Convert data into new sets
    new_vertical_data = xr.Dataset(
        {
            'vertical_data': vertical_data[0][42]
        },
        coords=vertical_data.coords
    )
    new_horizontal_data = xr.Dataset(
        {
            'horizontal_data': horizontal_data[0][42]
        },
        coords=horizontal_data.coords
    )

    # Save the new dataset to a NetCDF file
    new_vertical_data.to_netcdf(output_file_vert)
    new_horizontal_data.to_netcdf(output_file_horiz)

    # Close the input and output files
    vertical_data.close()
    horizontal_data.close()

    print(f"Filtered data saved to {output_file_vert} and {output_file_horiz}.")

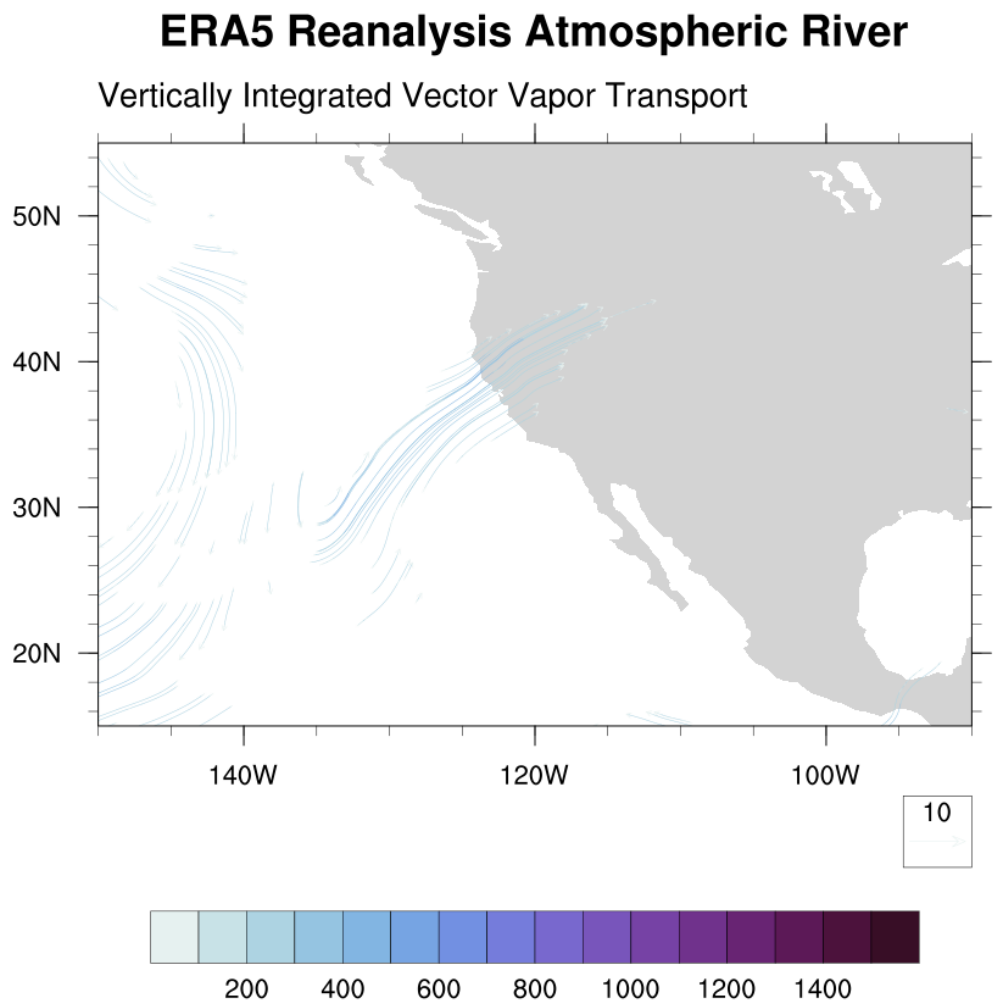
vertical_file = '/glade/scratch/bnewman6/e5.oper.an.vinteg.162_072_viwvn.ll025sc.2010120100_2010123123.nc'
horizontal_file = '/glade/scratch/bnewman6/e5.oper.an.vinteg.162_071_viwve.ll025sc.2010120100_2010123123.nc'
output_file_v = 'ivt2_v.nc'
output_file_h = 'ivt2_h.nc'

calculate_total_magnitude(vertical_file, horizontal_file, output_file_v, output_file_h)
```

Modified vector_1.ncl:

```
;-----  
;  
;  
; These files are loaded by default in NCL V6.2.0 and newer  
; load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"  
; load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"  
  
begin  
  
;---Open netCDF file  
  a = addfile("ivt2_h.nc","r")  
  b = addfile("ivt2_v.nc","r")  
;  
;  
  u      = a->horizontal_data(:, :)  
  v      = b->vertical_data(:, :)  
  lat_uv = b->latitude  
  lon_uv = b->longitude  
  
;---Create plot  
  wks = gsn_open_wks("png","vector7")          ; send graphics to PNG file  
  
  res                                = True          ; plot mods desired  
  
  res@tiMainString                   = "ERA5 Reanalysis Atmospheric River"  
  res@gsnLeftString                  = "Vertically Integrated Vector Vapor Transport"  
  
  res@mpMinLonF                      = 210.          ; select a subregion  
  res@mpMaxLonF                      = 270.  
  res@mpCenterLonF                   = 240.  
  res@mpMinLatF                      = 15.  
  res@mpMaxLatF                      = 55.  
  
  res@vcMonoLineArrowColor           = False  
  
  res@gsnAddCyclic                   = False          ; regional data  
  res@vcLevelPalette                  = "cmocean_dense" ; set color map  
  res@vcLevelSelectionMode           = "ManualLevels"  
; res@vcMinMagnitudeF                = 250.  
; res@vcMaxMagnitudeF                = 1000.  
  res@vcRefMagnitudeF                = 10.0          ; define vector ref mag  
  res@vcExplicitLabelBarLabelsOn     = True  
  res@vcRefLengthF                   = 0.045         ; define length of vec ref  
  res@vcGlyphStyle                   = "CurlyVector" ; turn on curly vectors  
  res@vcMinDistanceF                 = 0.025  
  
  plot=gsn_csm_vector_map(wks,u(:, :),v(:, :),res)  
end
```

Results:



Annotated Bibliography + URLs

<https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=bde074e11d46a8063dc0f5f66b13e594954ffe42>

Dettinger, M. D. (2004). Fifty-two years of “pineapple-express” storms across the West Coast of North America. *US Geological Survey, Scripps Institution of Oceanography for the California Energy Commission, PIER Project Rep.* CEC-500-2005-004, 20.

This paper covers the history of the Pineapple Express from 1948 and to 1999. A fascinating statement is that all atmospheric rivers occurred between October and February, meaning I can practically skip data for over half of each year in my own research. Additionally, it marked 206 days that the Pineapple Express was “active,” which is great for me to use as my markers in my testing and trial data to know my program’s accuracy. However, the data is not recent, so I will meet problems when trying to find any sort of mappable/modelable data. Since this paper is a large history of the Pineapple Express, atmospheric rivers are very well defined and explained throughout the paper. I will be able to use these definitions, along with the datasets used, in my own project.

<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022JD037284>

Gonzales, K. R., Swain, D. L., Roop, H. A., & Diffenbaugh, N. S. (2022). Quantifying the Relationship Between Atmospheric River Origin Conditions and Landfall Temperature. *Journal of Geophysical Research: Atmospheres*, 127(20), e2022JD037284.

This paper has a focus on clarifying assumptions that atmospheric rivers with warmer origin conditions have warmer landfall temperatures. Pineapple Express-like atmospheric rivers are used as the key focus of the research. In the end, they conclude that warmer origin conditions are correlated with warmer rainfall temperatures, however there are also more variables that lead to warmer rainfall temperatures. These include longer lifetimes and stronger vapor transport of atmospheric rivers.

<https://journals.ametsoc.org/view/journals/bams/100/2/bams-d-18-0023.1.xml>

Ralph, F. M., Rutz, J. J., Cordeira, J. M., Dettinger, M., Anderson, M., Reynolds, D., Schick, L. J., & Smallcomb, C. (2019). A Scale to Characterize the Strength and Impacts of Atmospheric Rivers, *Bulletin of the American Meteorological Society*, 100(2), 269-289. doi: <https://doi.org/10.1175/BAMS-D-18-0023.1>

This research article gives the exact definition of an atmospheric river in terms of the numbers. An atmospheric river has integrated water vapor transfer (IVT) greater than or equal to 250 kg m⁻¹ s⁻¹. Using this, I can use data to manually mark atmospheric rivers wherever past logs don’t reach. It talks about the categorization of ARs, with categories 1-5 marked at every 250 between 250 and 1,250. AR’s that last fewer than 24 hours are categorized down and over 48 hours up. This article is from the Bulletin of the American Meteorological Society, so the focus is mainly on the US.

<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL070470>

Shields, C. A., & Kiehl, J. T. (2016). Atmospheric river landfall-latitude changes in future climate simulations. *Geophysical Research Letters*, 43(16), 8775-8782.

This paper is interesting because it uses the Community Climate System Model, version 4 (CCSM4). Being able to analyze how this software works will open up opportunities to expand on my own research. Additionally, this paper focuses on two regions, one being the Pineapple Express. It explains that the Pineapple Express is due to push towards the equator in the future, with higher rainfall rates especially in Southern California.

<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL069476>

Shields, C. A., & Kiehl, J. T. (2016). Simulating the pineapple express in the half degree community climate system model, CCSM4. *Geophysical research letters*, 43(14), 7767-7773.

This paper also used the CCSM4 used in the second paper. The results of this paper follow with the predictions of the previous two papers: that the frequency and intensity of the Pineapple Express will increase in the future. Something that stands out especially in this paper is how much they focus on the accuracy of the model. The CCSM4 seems like a very good software to use, however I still plan on using WRF.

<https://onlinelibrary.wiley.com/doi/full/10.1002/env.2143>

Weller, G. B., Cooley, D. S., & Sain, S. R. (2012). An investigation of the pineapple express phenomenon via bivariate extreme value theory. *Environmetrics*, 23(5), 420-439.

This paper will be key due to the fact that it uses the WRF model and directly focuses on the Pineapple Express in a unique and effective way. It explains different variables to use, such as sea-level pressure, that can be directly linked to the extreme precipitation events. Similar to the second paper, this paper found a likely increase in the number of and the intensity of Pineapple Express precipitation in the future.