4d Visualisation of the tropopause, identification of air mass exchanges and their fate

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MathSEE Modeling Week 2019

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Introduction

- Tropopause layer between stratosphere and troposphere
- Polar vortex regulating climate
- Different in the troposphere and in the stratosphere
- Disturbs the tropopause layer

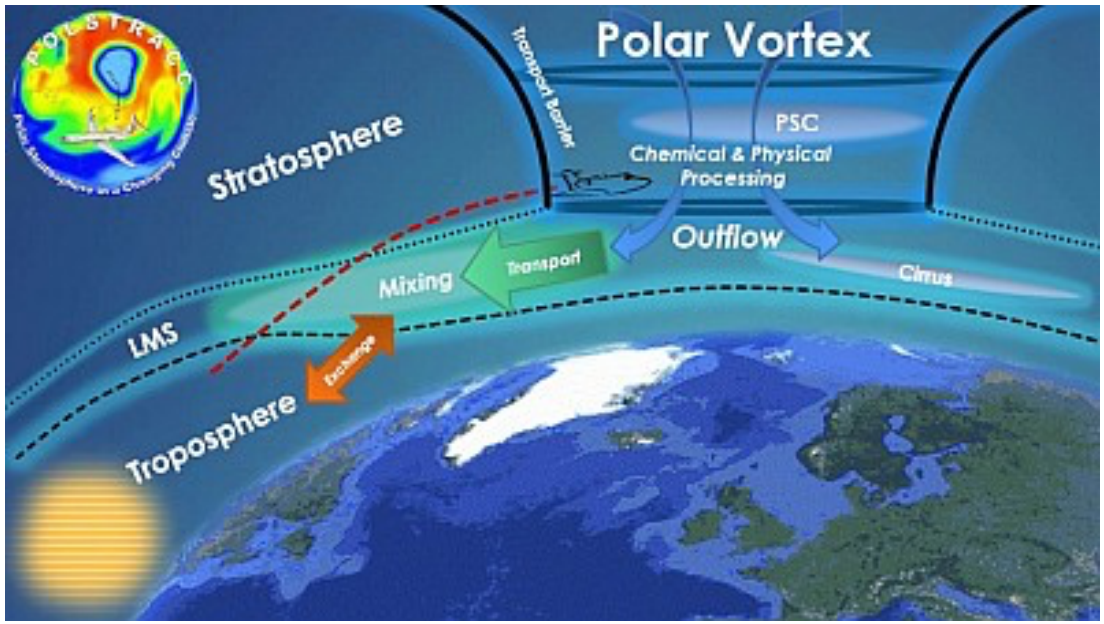

Figure 1: Polar Vortex

Introduction

- German HALO aircraft and POLSTRACC campaign
- Huge data files to analyse
- Concentrating on Potential Vorticity (PV) and Humidity (QV)
- Potential Vorticity : absolute circulation of air, here the athmospheric layers
- Potential Vorticity in Part Per Million to make it easier to read
- Accessing the features faster is important to plan the next flights

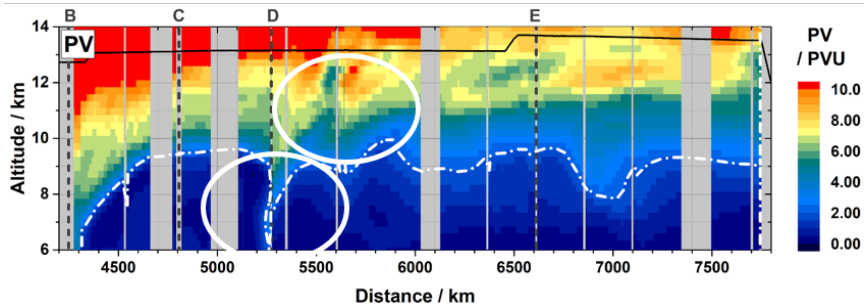

Figure 2: Potential Vorticity values linked to the altitude

Figure 3: German Halo aircraft

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- Split the whole data into slices along different directions

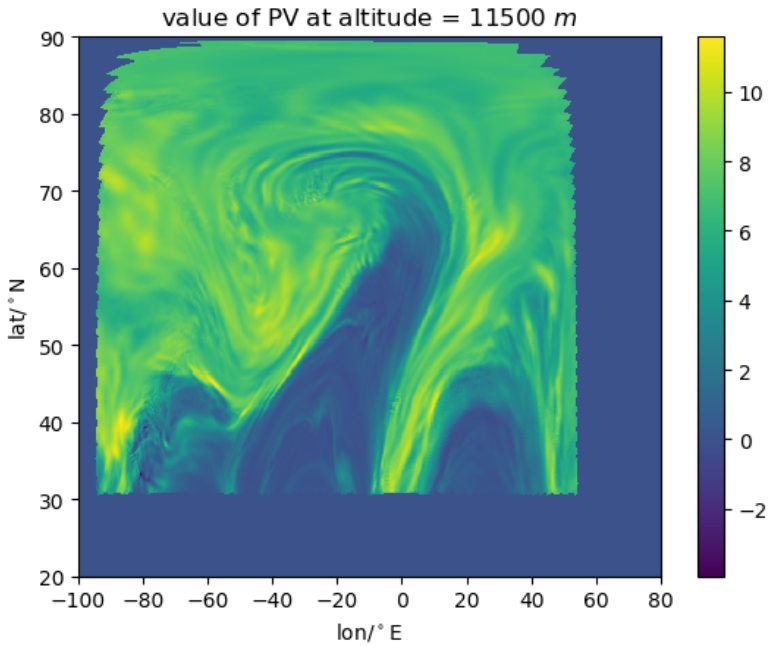

Figure 4: Value of potential vorticity on different dimensions

Extraction of the data and visualisation

The viewer in Python

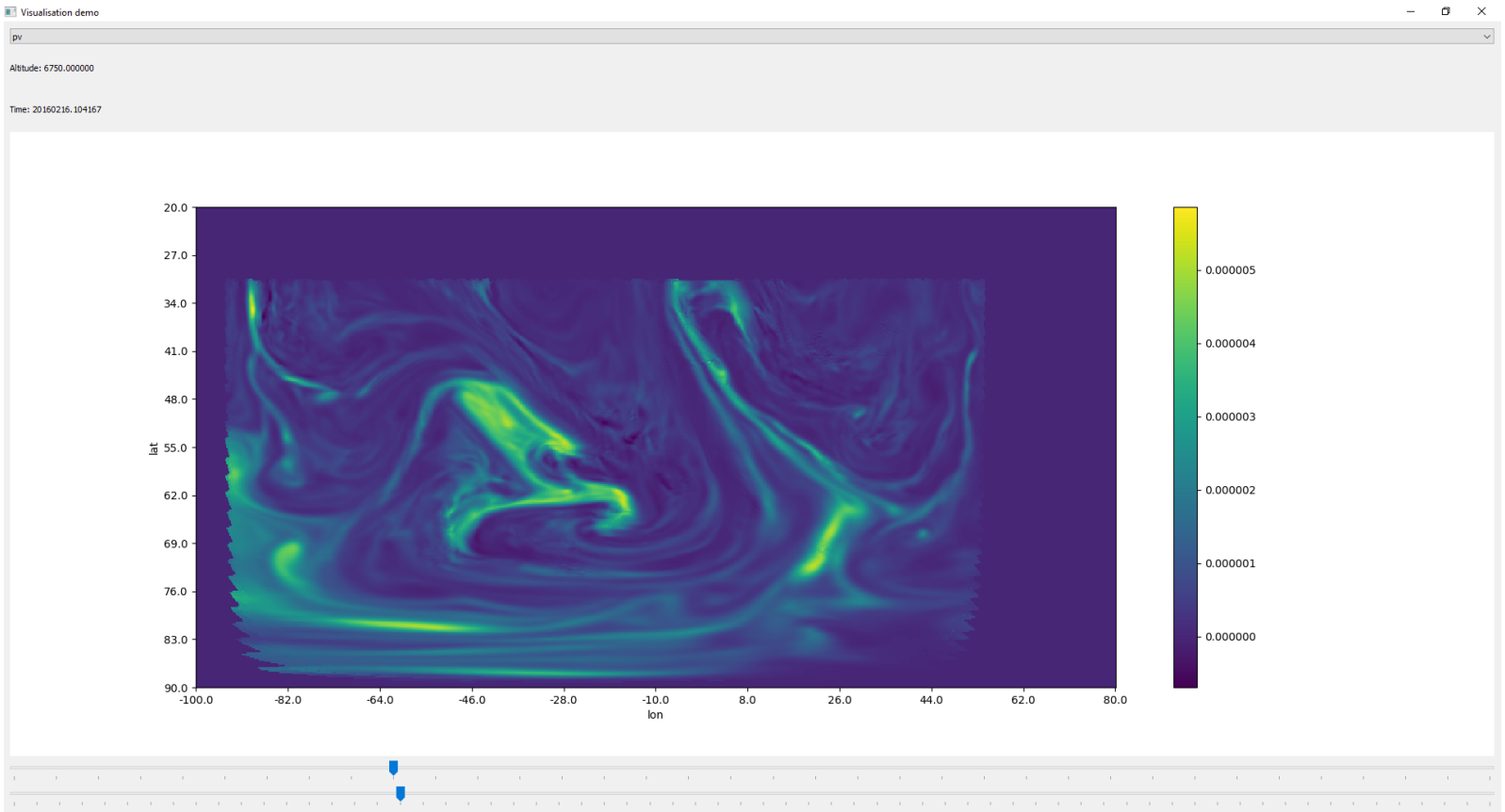

Figure 5: Slice of Potential Vorticity and Humidity with longitude and latitude seen in the viewer

Extraction of the data and visualisation

The viewer in Python

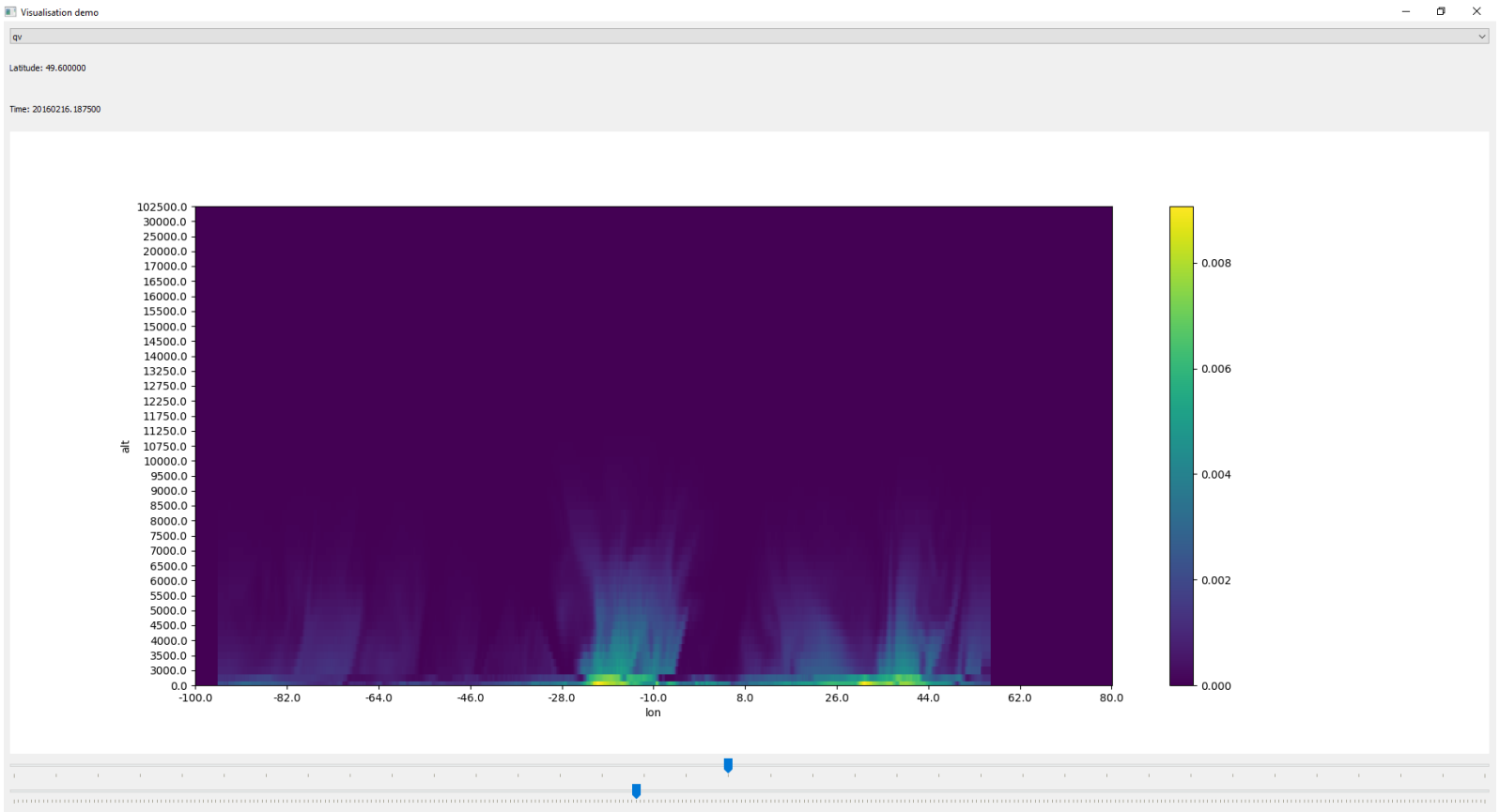

Figure 6: Slice of Humidity in latitude seen in the viewer

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Identification of the tropopause

- Criterion: the value of potential vorticity is equal to 2 PVU
- Choose different tolerances $\delta = 10^{-2}, 10^{-3}, 10^{-4}$
- Acquire the coordinates for further analysis

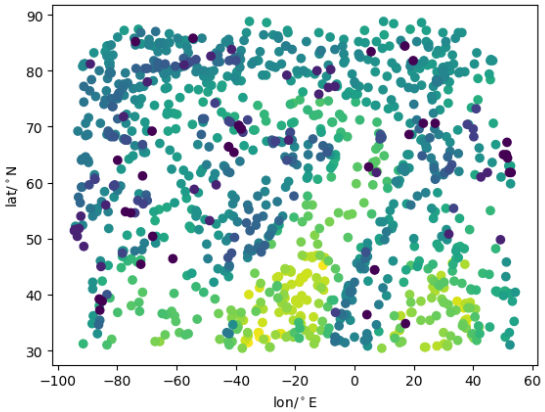

Figure 7: Acquired coordinates of tropopause with $\delta = 10^{-3}$

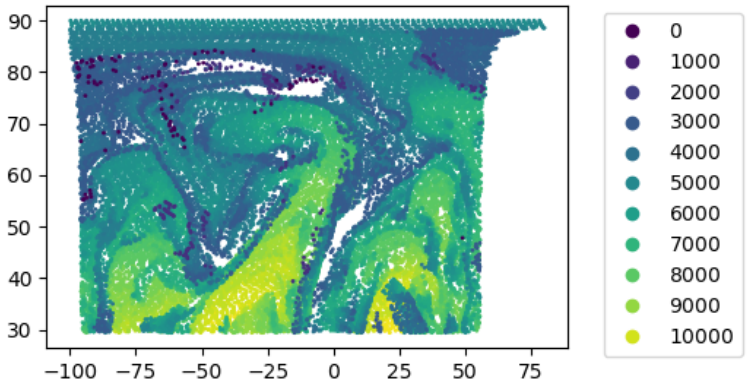

Figure 8: Acquired coordinates of tropopause with $\delta = 10^{-2}$

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Extraction of the tropopause's features

3d viewer

- The humidity values for the tropopause are coherent with what is expected, humidity is higher when close the ground level

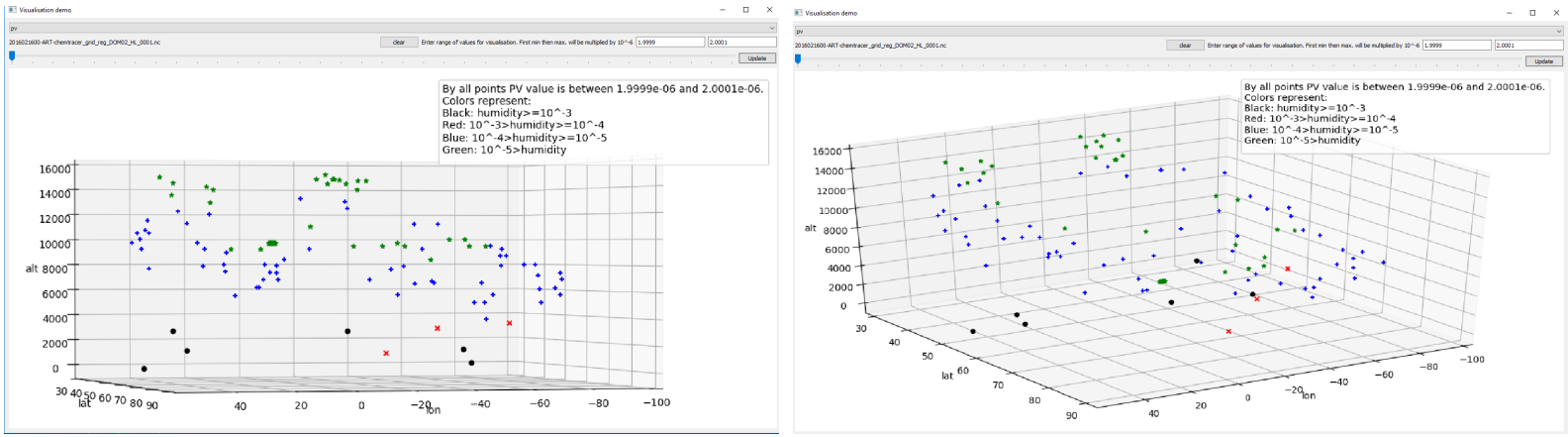

Figure 9: Humidity variation in the tropopause

Extraction of the tropopause's features

Now we are in tropopause

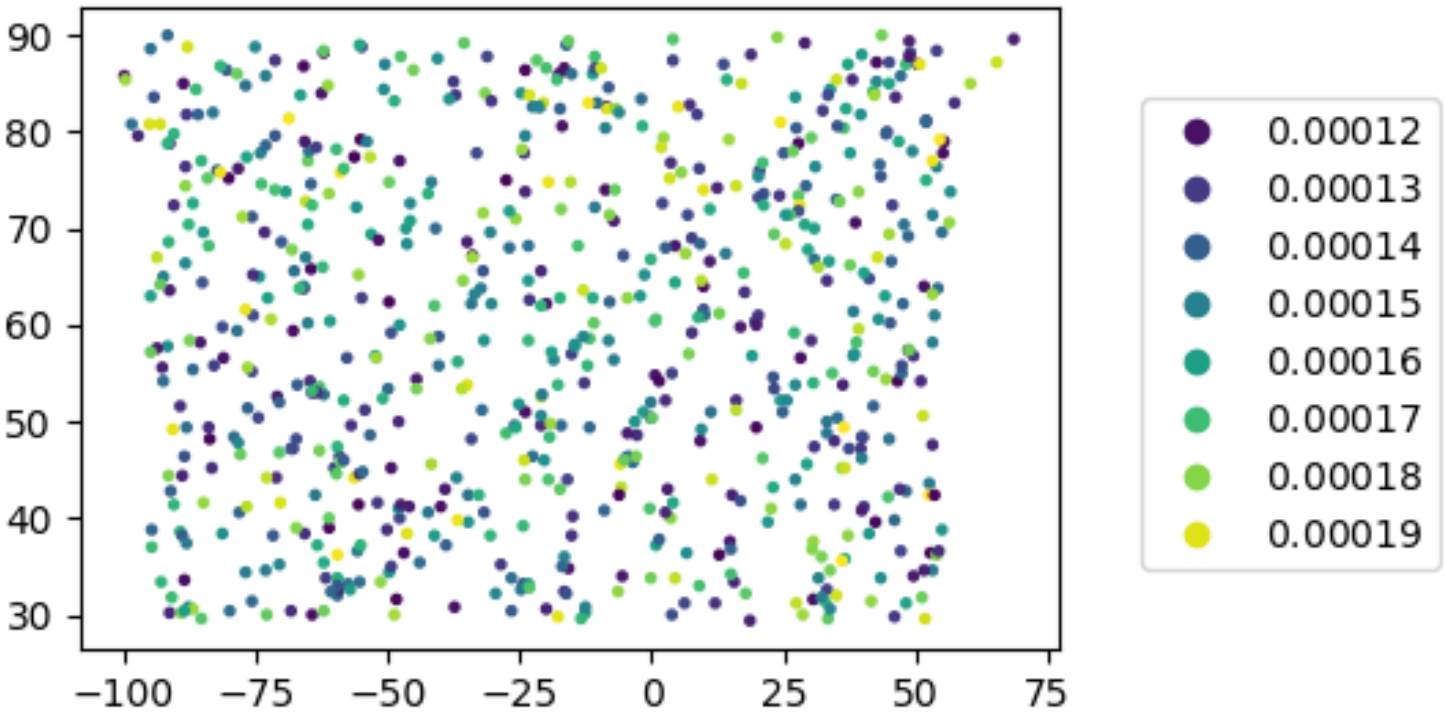

Figure 10: humidity where the data points exceeds a threshold of $+-25\%$ of the mean value of humidity by keeping potential vorticity fixed.

Extraction of the tropopause's features

Correlation between the Potential Vorticity and the Humidity

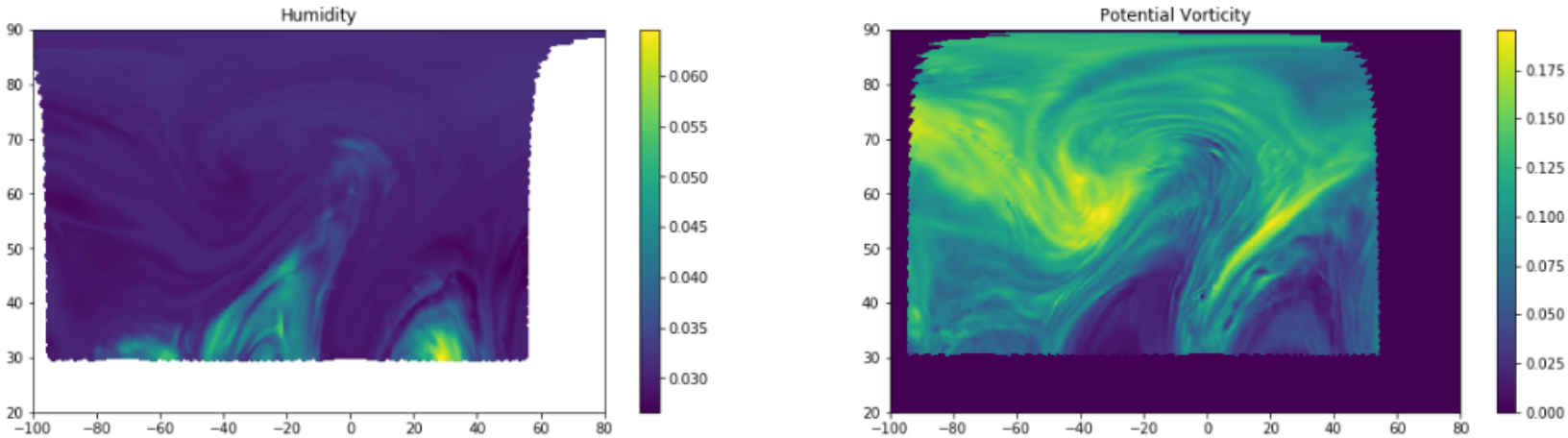

Figure 11: Humidity and Potential Vorticity on altitude = 14.5km

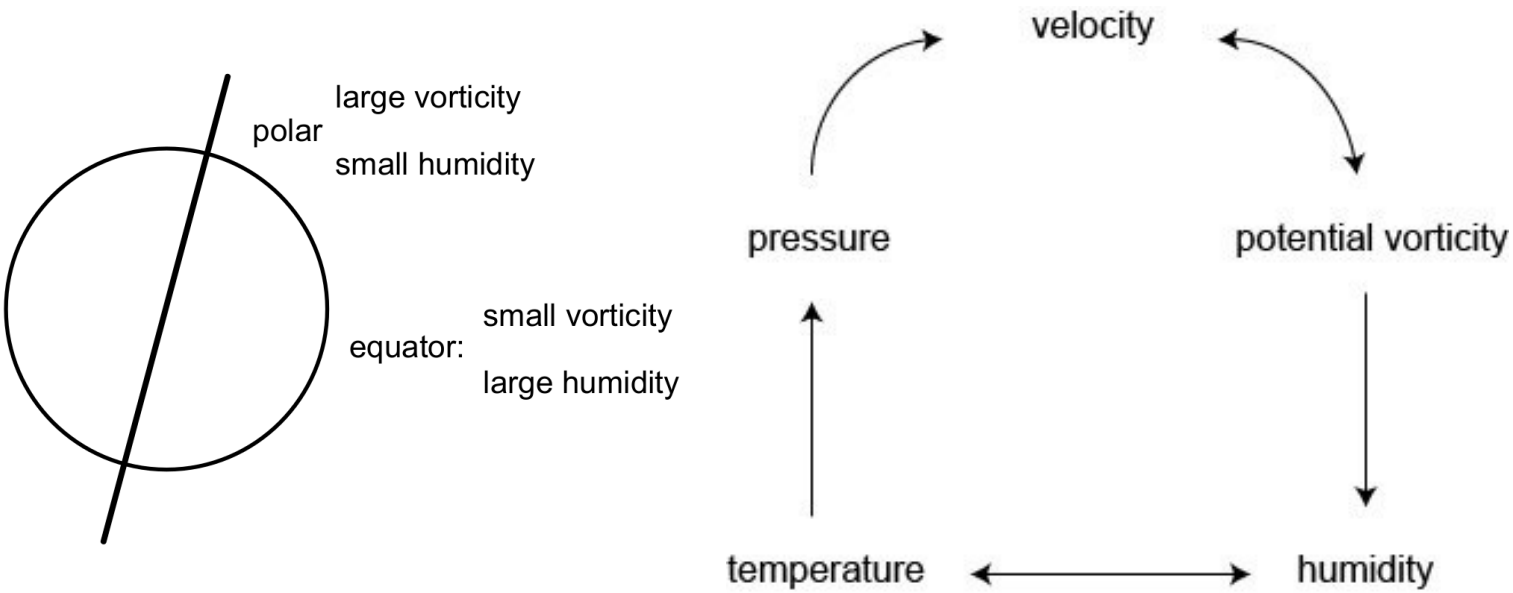

Figure 12: Schematic of correlation between potential vorticity and humidity

Extraction of the tropopause's features

Correlation between the Potential Vorticity and the Humidity

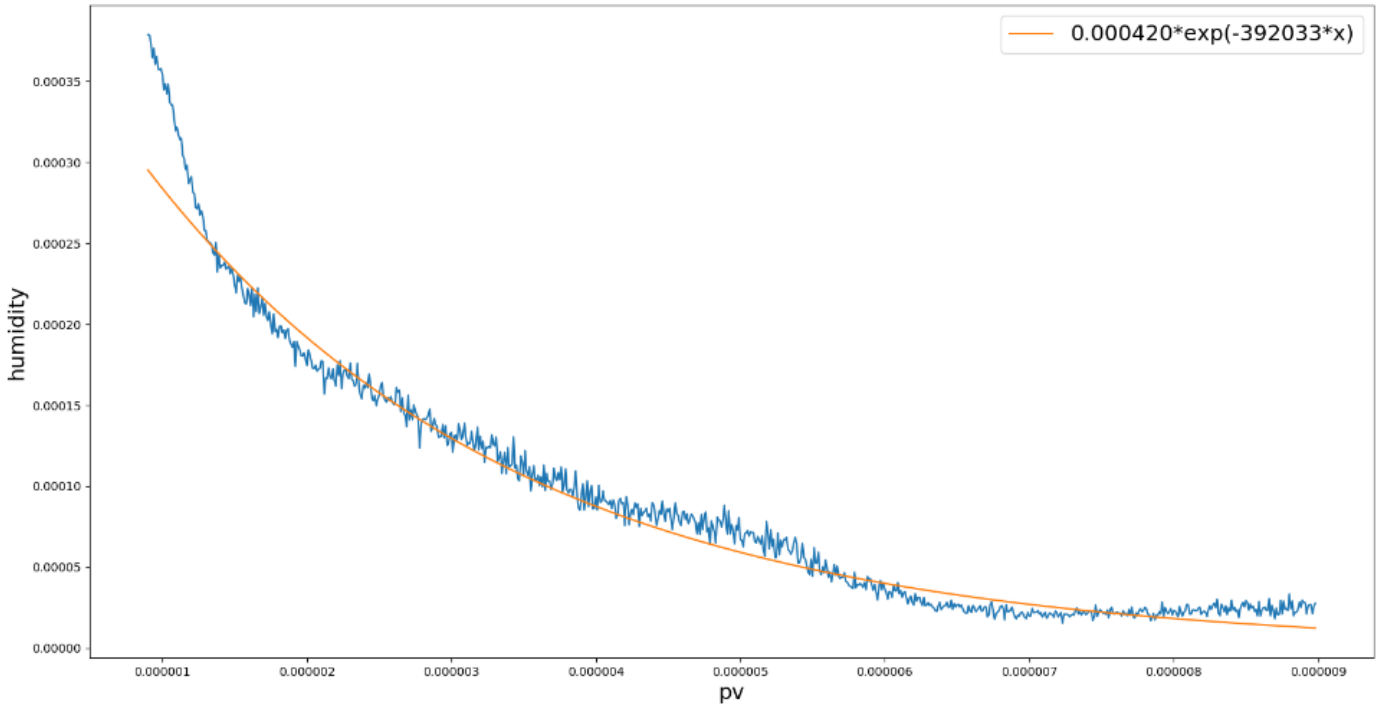

Figure 13: Humidity decreases following an inverse exponential function as the Potential Vorticity increases

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Temporal evolution of the location of the tropopause

- The time cursor in the viewer allows the operator to travel through time

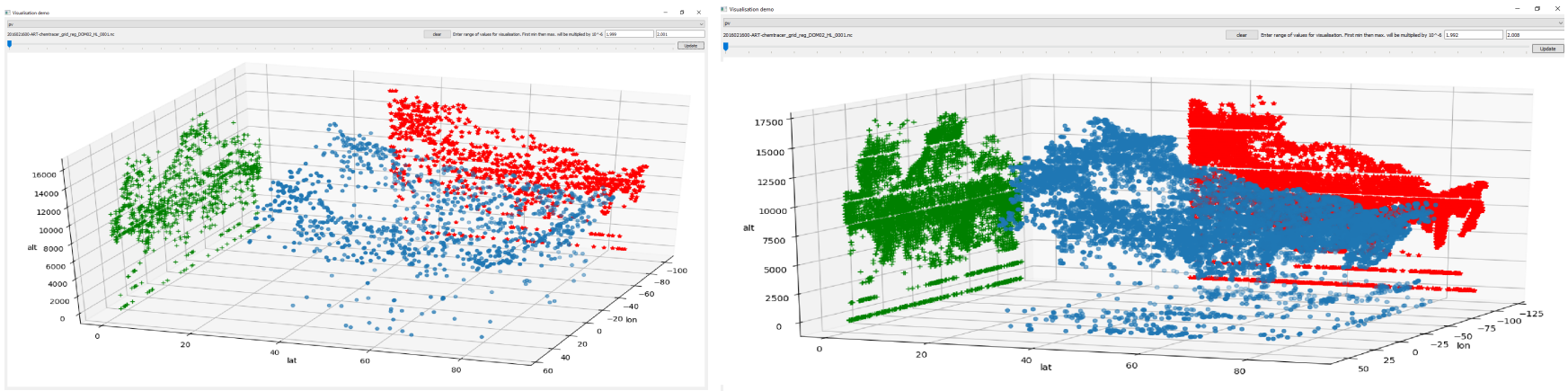

Figure 14: Location of the tropopause (blue) with its altitude projection in longitude (green) and latitude (red)

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Tracing of the features of interest and their temporal evolution

Method 1 : Mean values

Latitude = 32.4

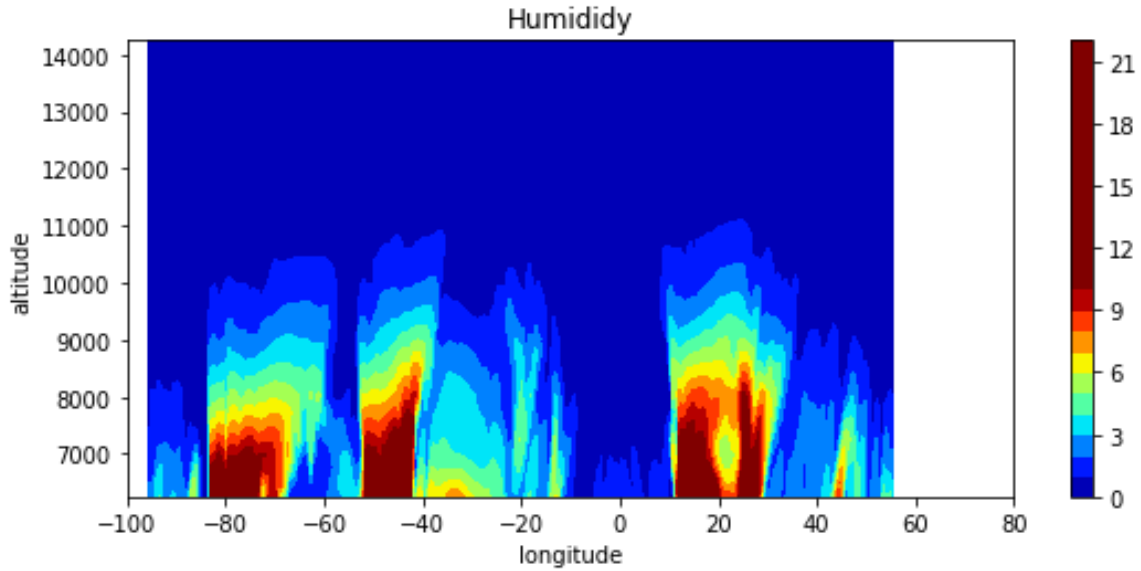


Figure 15: Tracked feature with mean method on latitude

All coordinates given by the tracker :
Latitude : 29.4 - 48.6

Tracing of the features of interest and their temporal evolution

Method 1 : Mean values

Longitude = 42.0

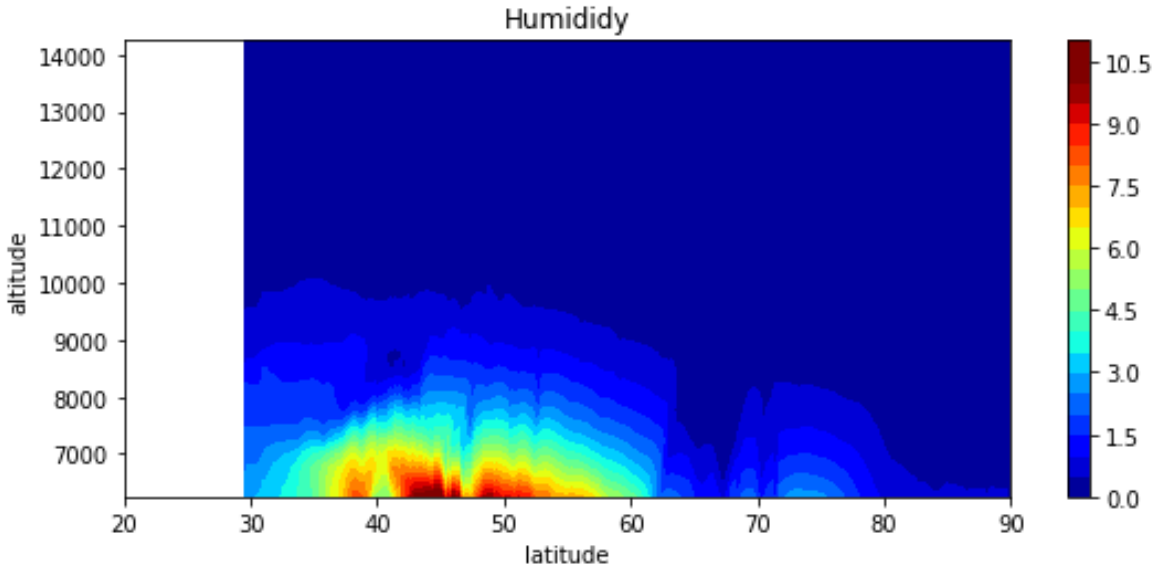


Figure 16: Tracked feature with mean method on longitude

All coordinates given by the tracker :
Longitude : 39.4 - 43.2

Altitude fixed Gradient for 2D (latitude / longitude) with numpy library :

$$\begin{cases} Grad(x_i) = \frac{f(x_{i+1}) - f(x_i)}{h} + \mathrm{O}(h) & Boundaries \\ Grad(x_i) = \frac{f(x_{i+1}) - f(x_{i-1})}{2h} + \mathrm{O}(h^2) & Otherwise \end{cases}$$

Check points that verify :

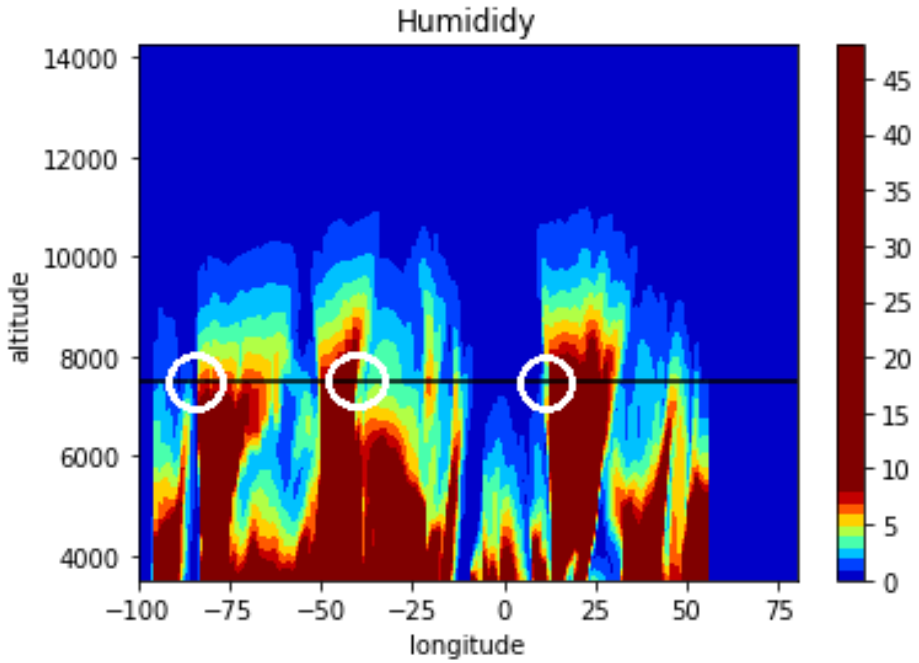
$$\|Grad(x_i, y_j)\| > 0.8 * max(Grad(:,:)).$$

Tracing of the feature of interest and its temporal evolution

Method 2 : gradient

–> 2 lists relative either on the latitude either on longitude :

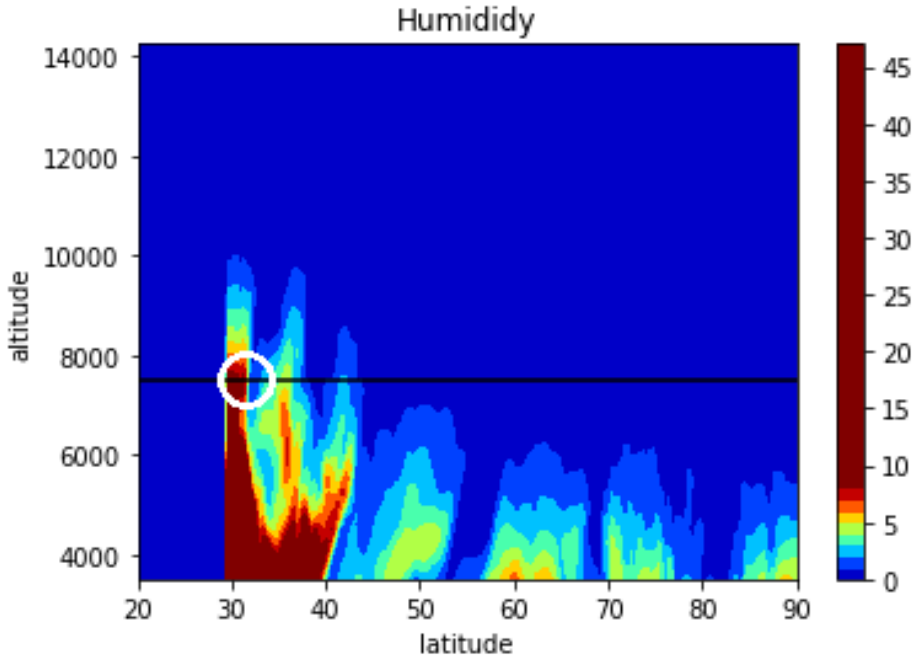
Longitude :



Latitude : 34.0
Detected longitude :
-83.4, -39.8 ,12.8

Figure 17: Given slice from tracker on longitude axis gradient

–> 2 lists relative either on the latitude either on longitude :
Latitude :



Longitude : -52.8
Detected latitude :
31.2

Figure 18: Given slice from tracker on latitude axis gradient

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Conclusion

- Viewer in 2d and 3d with cursors to visualise the data
- Huge amount of data
- Correlation between Potential Vorticity and Humidity
- Gradient based tracing algorithm
- Potential improvement on computational efficiency and on the tracing algorithm