HYSPLIT

The Hybrid Single-Particle Lagrangian Integrated Trajectory model

OVERVIEW – DAY 1

Part 1: Meteorology

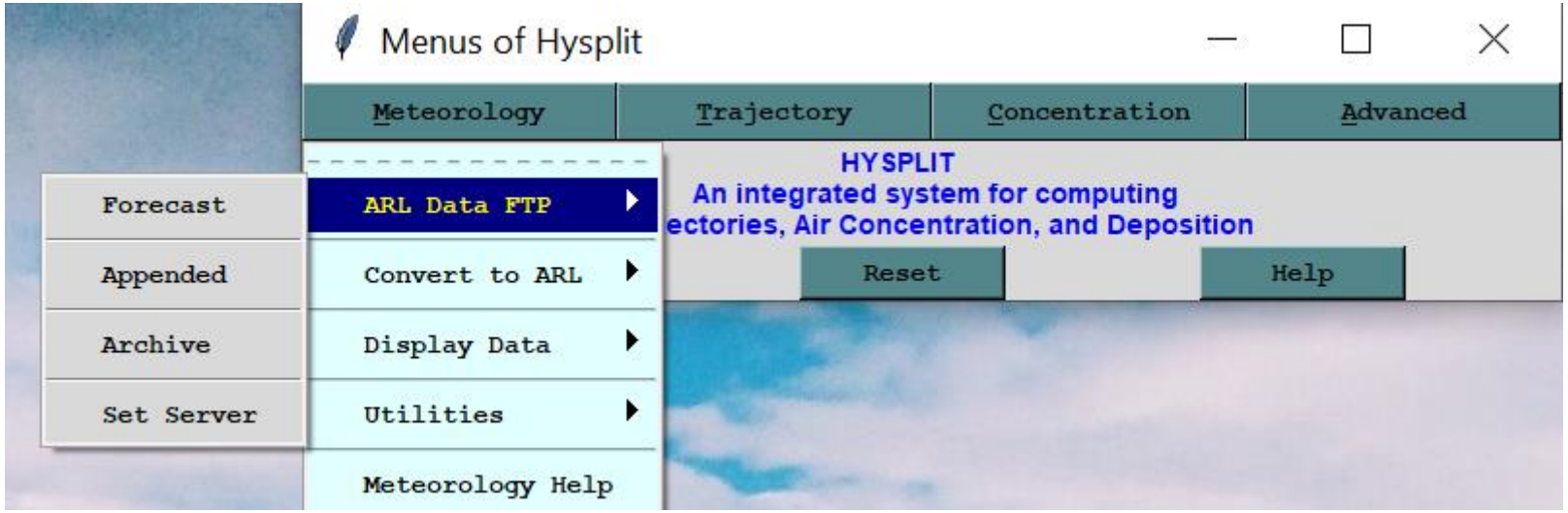
- Getting data
- Converting data
- User-Entered Data – Try it yourself
- Examining data

Part 2: Trajectory

- Set-up
- Equations
- Error
- Case Study (Simple Scenario and Absolute Error Example)
- Apply

PART 1: METEOROLOGY

METEOROLOGY – GETTING DATA



- Forecast: forecast model starting today and looking 1-7 days into the future.
- Appended: forecast model starting1-2 days ago to present day.
- Archive: HYSPLIT meteorological data archives from various datasets.
- Reanalysis: special archive of the NCAR/NCEP global reanalysis dataset.
- Set Server: menu to set options for FTP (file transfer protocol).

METEOROLOGY – GETTING DATA

- FTP can be blocked by IT practices for the computer you are working with .
- Data can also be downloaded to your computer via the HYSPLIT website.

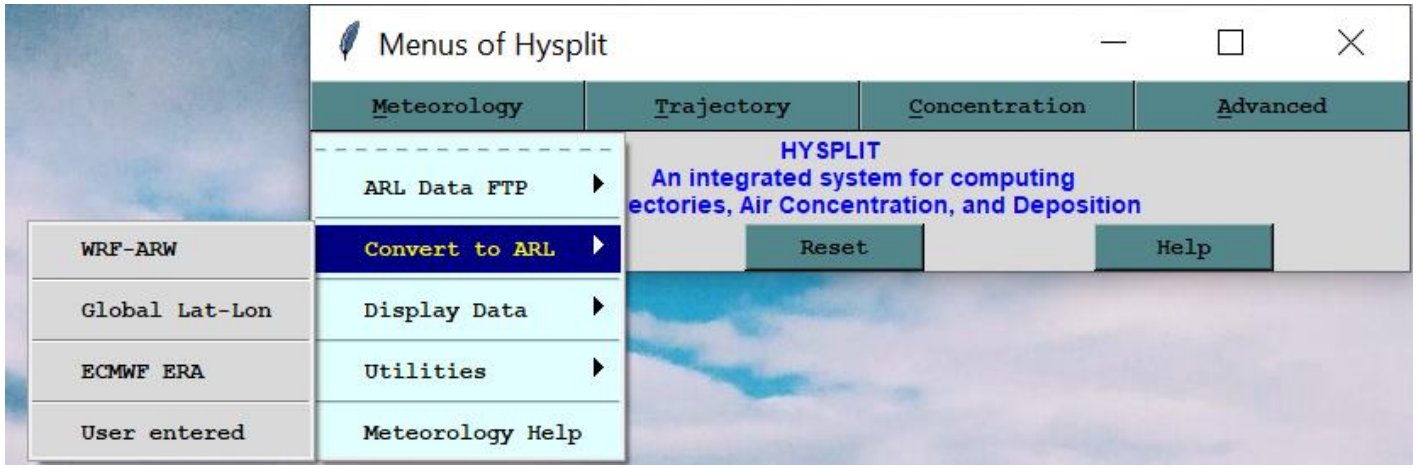
https://www.ready.noaa.gov/HYSPLIT.php

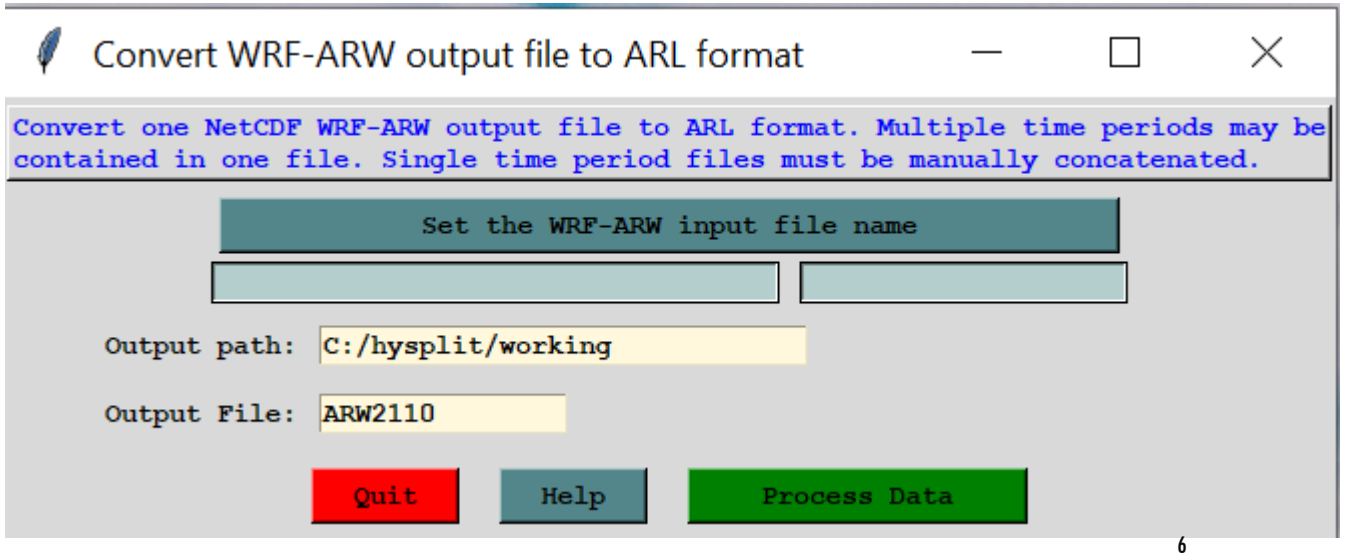
METEOROLOGY - CONVERTING DATA

- Converting data can be done by navigating to:

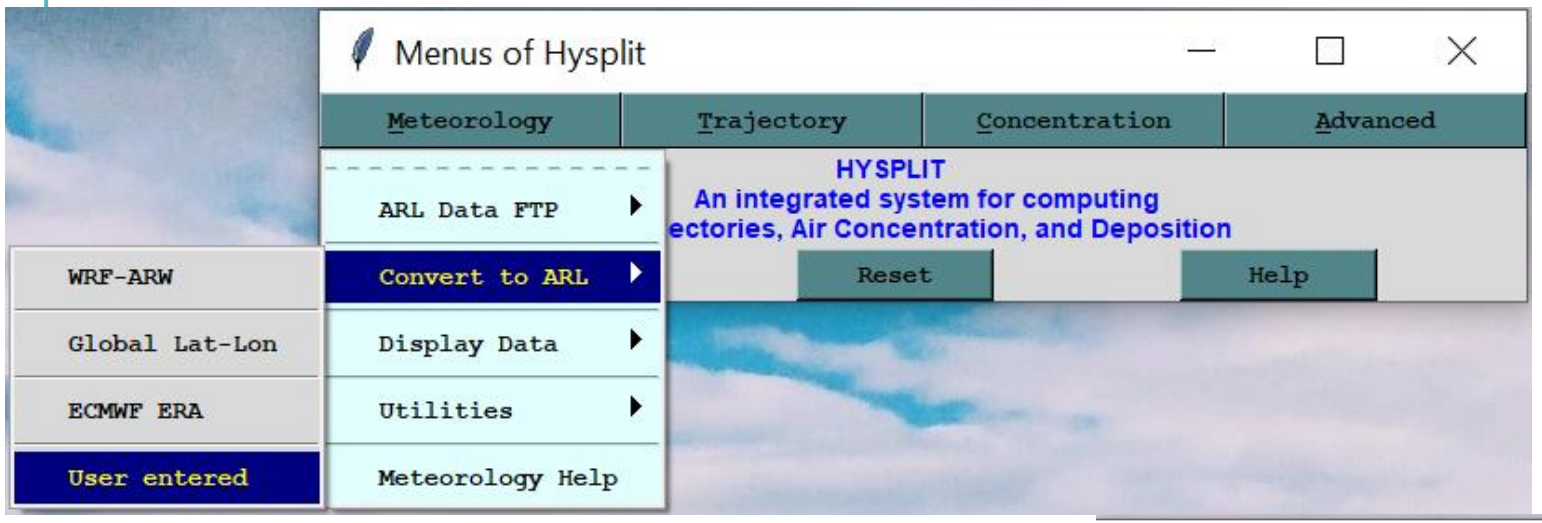
METEOROLOGY→CONVERT TO ARL→*

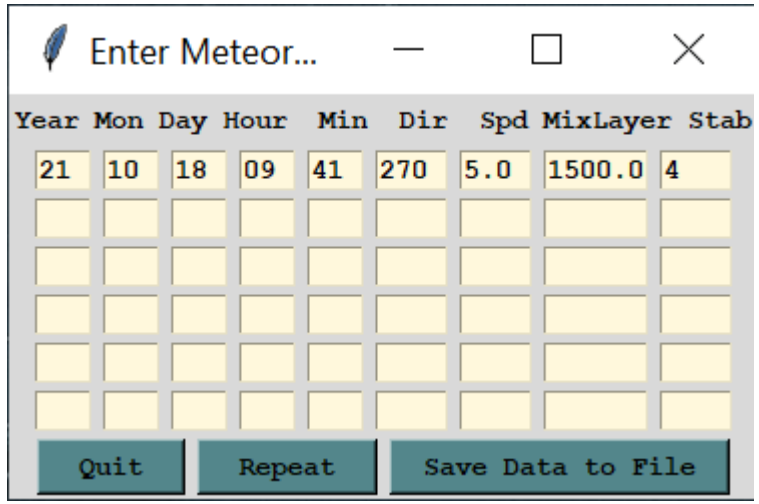
- The GUI has options to convert:
  - **WRF/ARW:** (Advanced Weather Research model output is in NetCDF and can only be done on UNIX).
  - **Global**: (GRIB-1) from NOAA and ECMWF (PC & UNIX).
  - **ECMWF ERA**: (GRIB-1) from ECWMF global reanalysis project (PC & UNIX).
  - **User-Entered**: covered next.



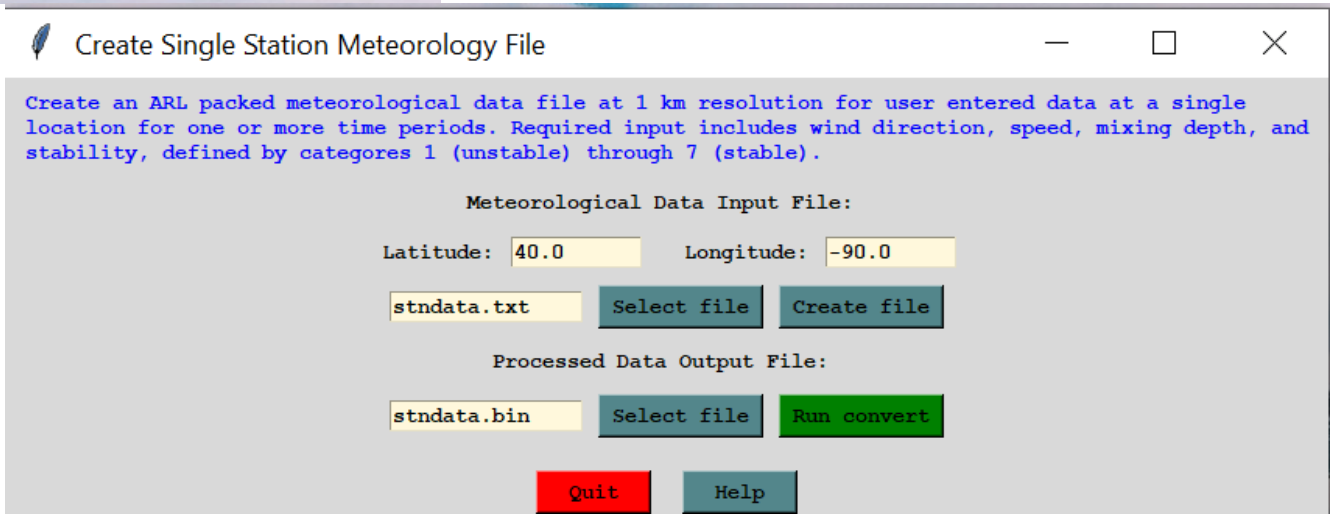


METEOROLOGY – USER-ENTERED DATA



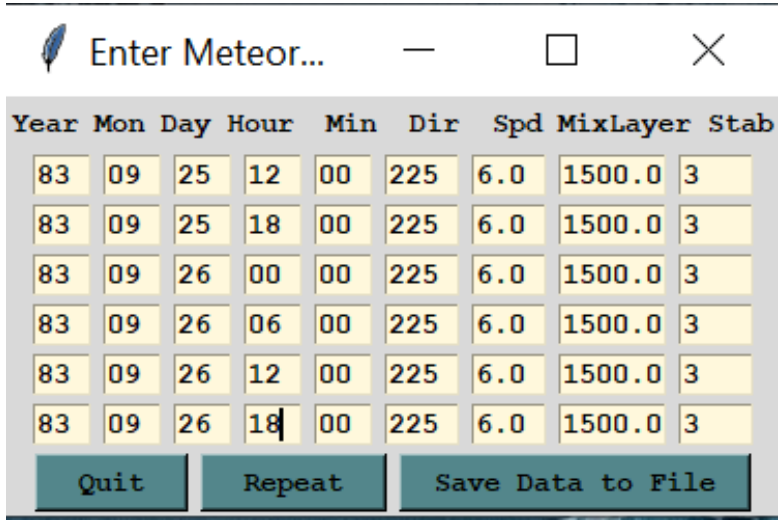


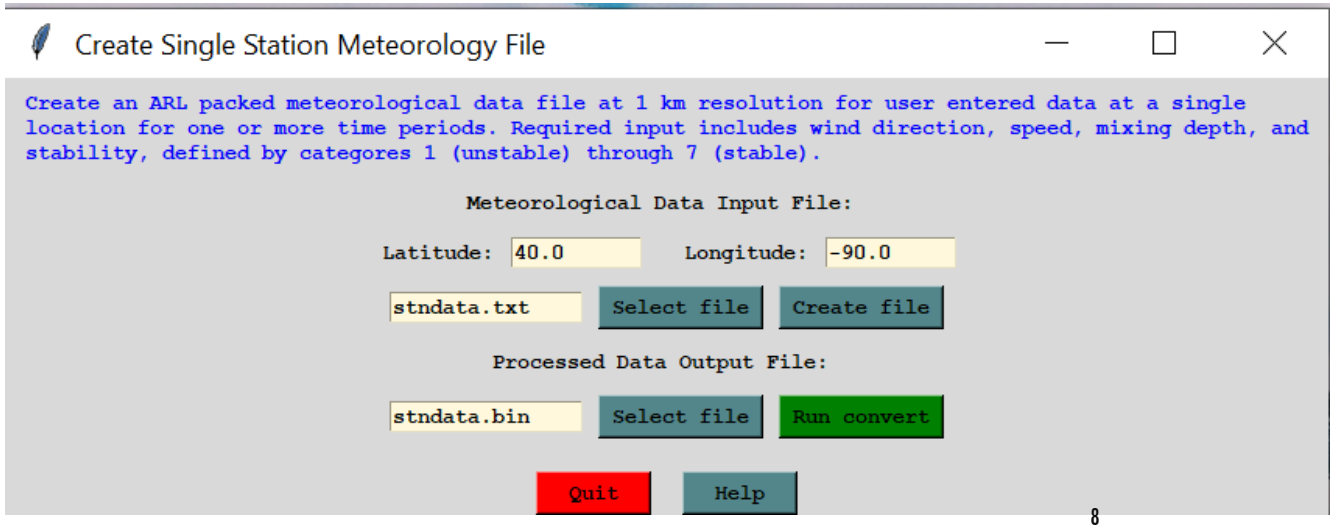
- Enter one observation point for several time periods.
- Makes a spatially homogenous dataset.
- 10km resolution for a 250km by 250km domain



USER-ENTERED DATA – TRY IT YOURSELF

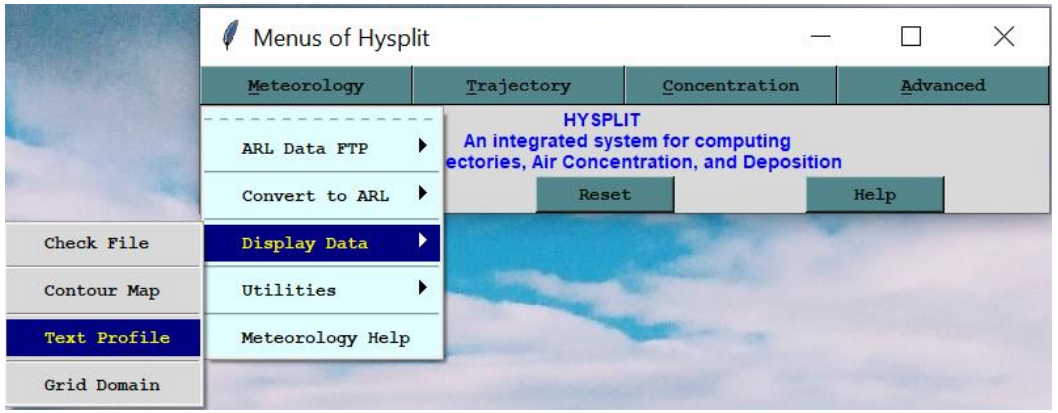
- Enter the first row of data
- Click **REPEAT** to fill in all other rows
- Manually change the day and time
- Click **SAVE DATA TO FILE** and then **QUIT**
- Click **RUN CONVERT**

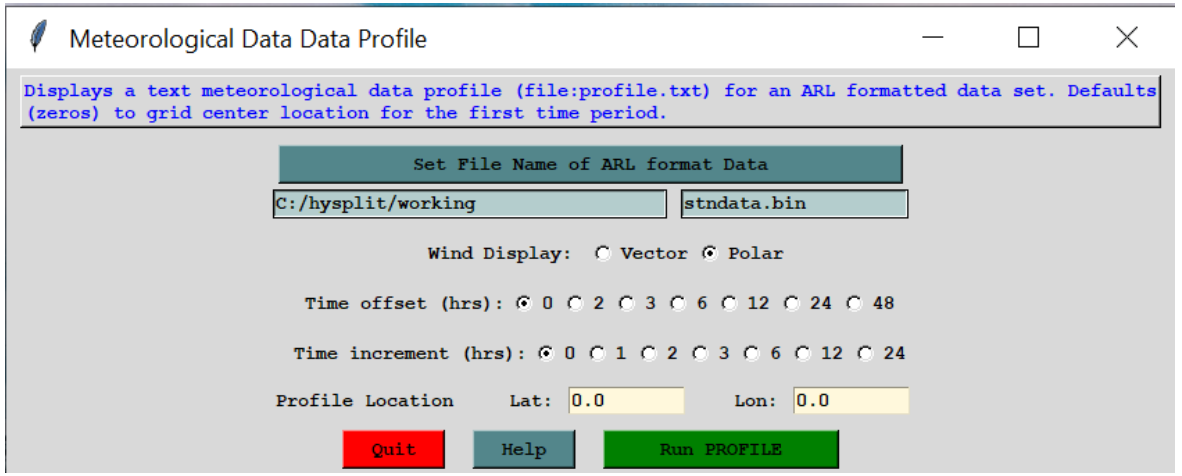


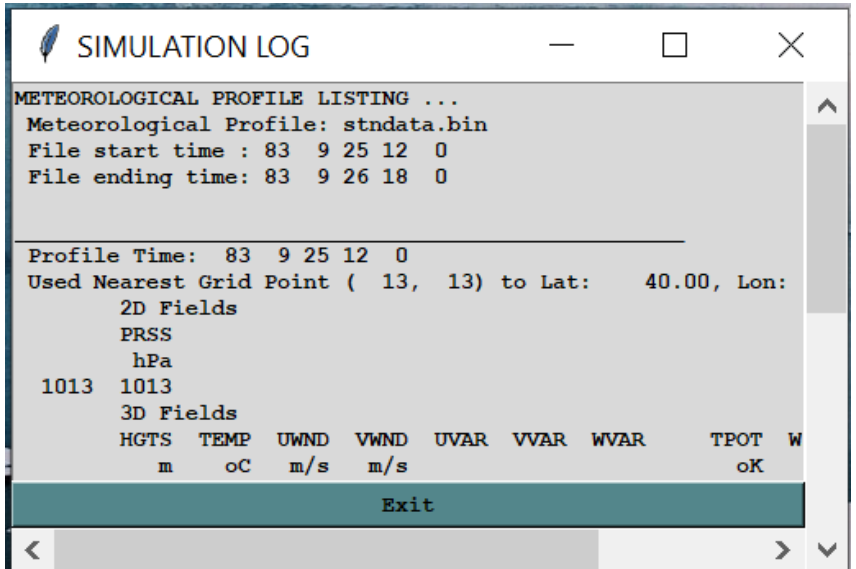


USER-ENTERED DATA – TRY IT YOURSELF

- Next go to **METEOROLOGY → DISPLAY DATA → TEXT PROFILE**
- Select the file you just created in the menu (*stndata.bin*).
- Keep everything else as default.
- Click **RUN PROFILE** to get the sounding.





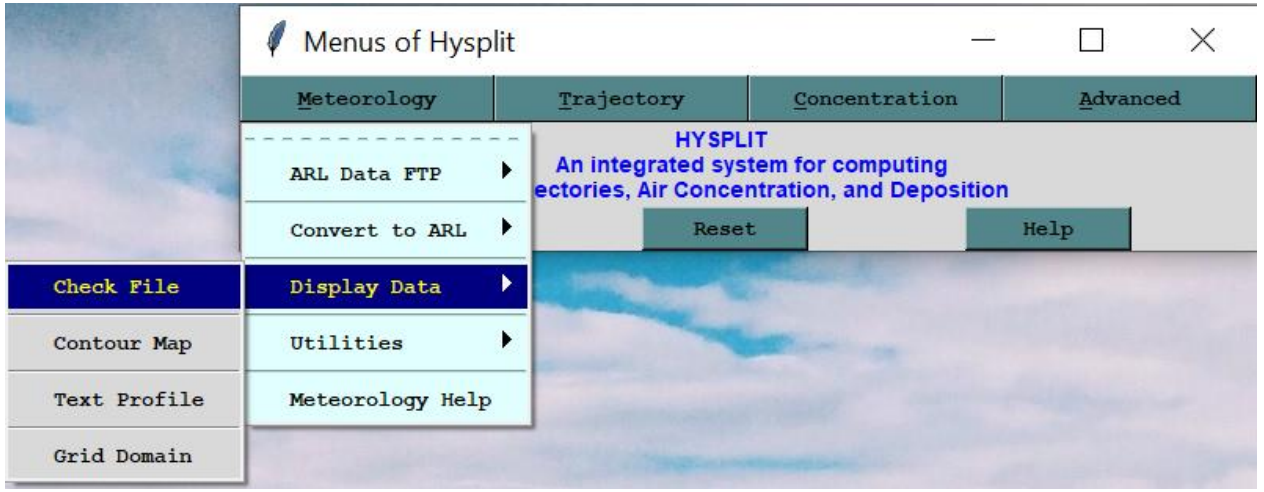


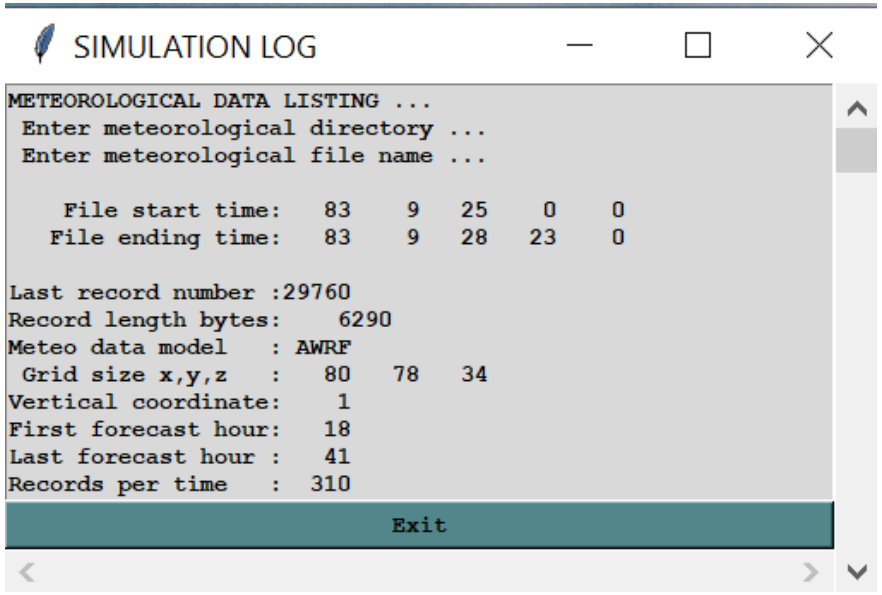
METEOROLOGY – EXAMINING DATA

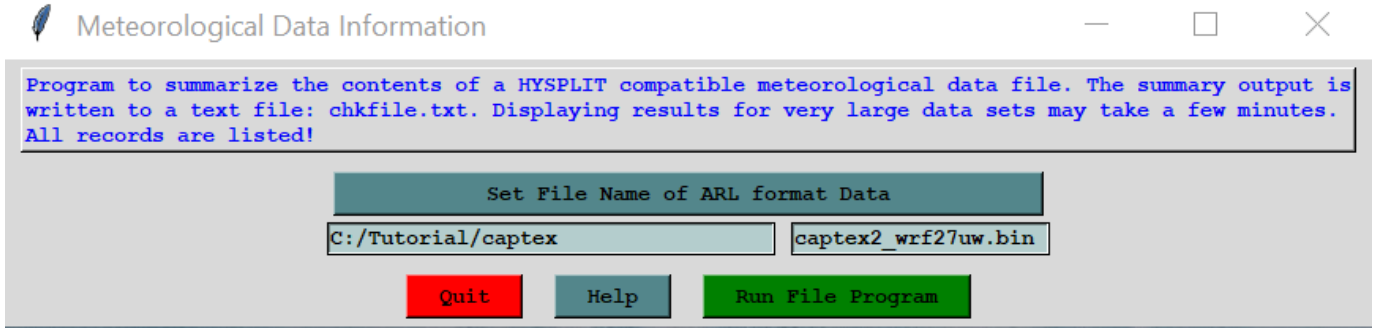
- To get more details about a meteorological file go to:

METEOROLOGY →DISPLAY DATA→CHECK FILE

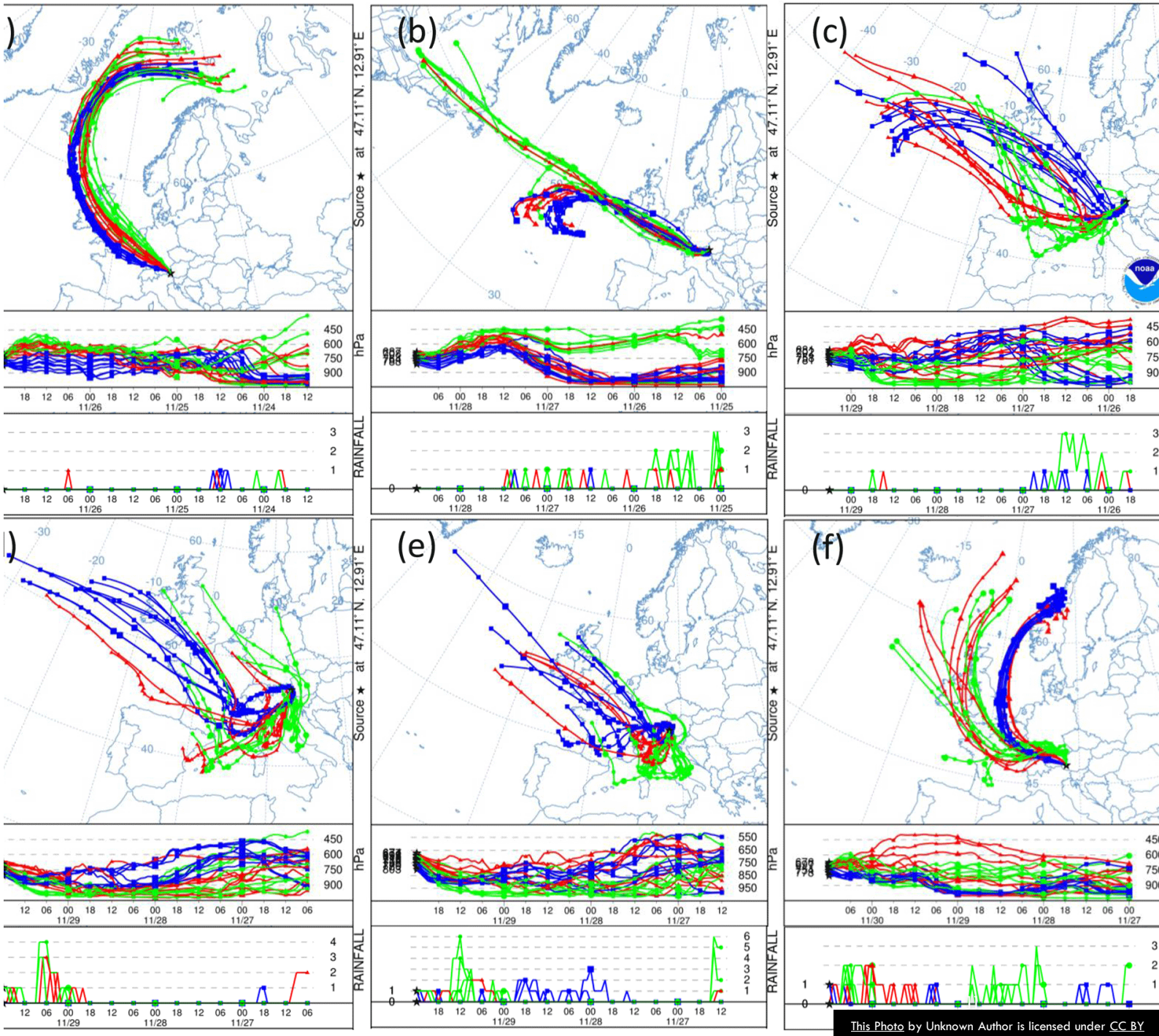
- And then select the file of interest.







PART 2: TRAJECTORY



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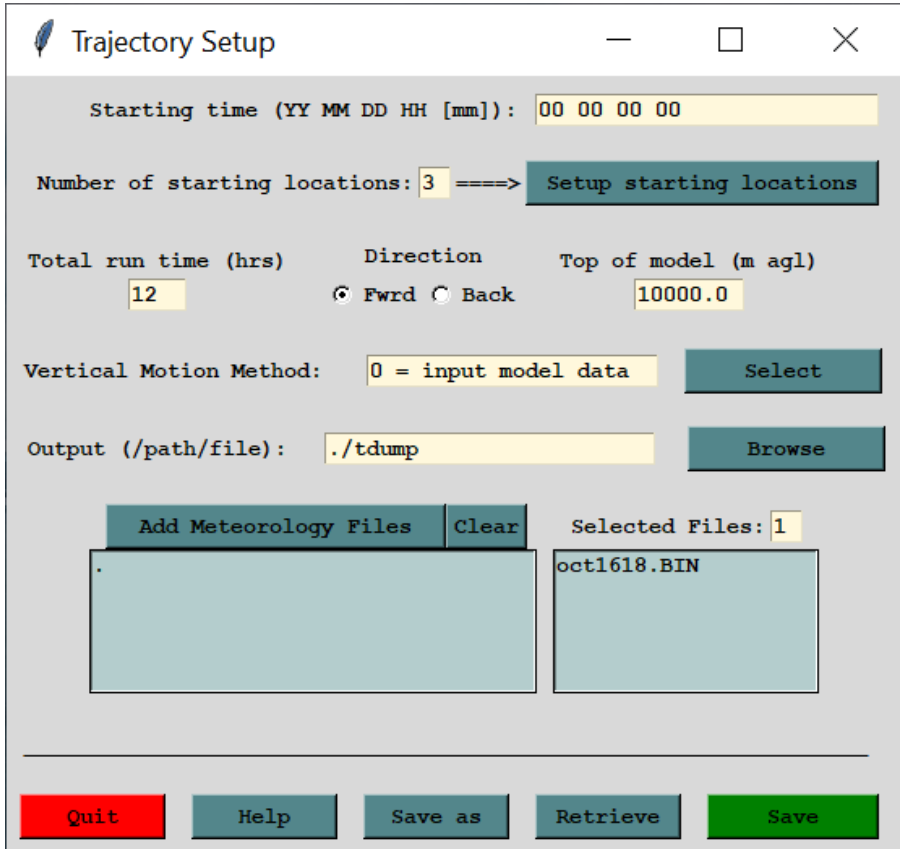
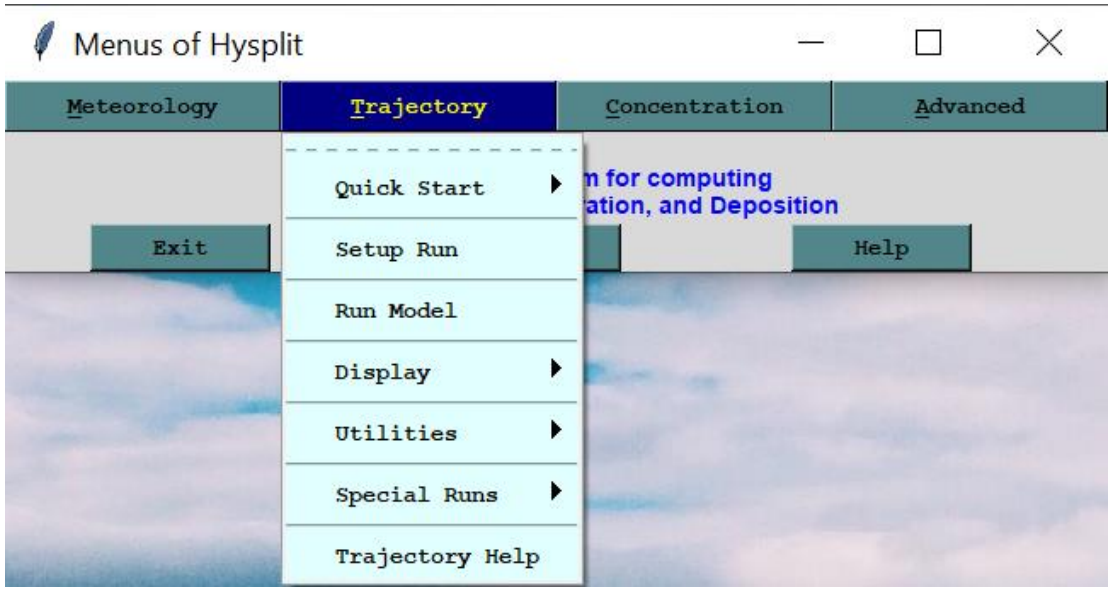
TRAJECTORY – SET-UP





- To access the Trajectory model go to:

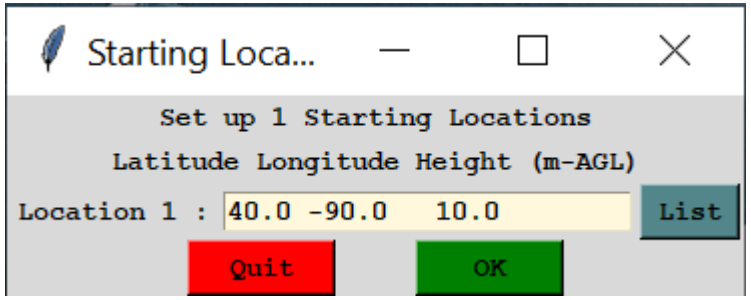
TRAJECTORY →SETUP RUN

- Here you can select various options which we will cover in the next few slides.

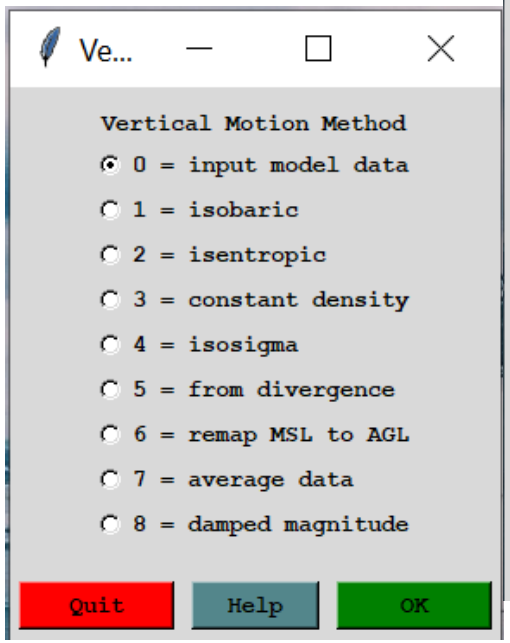
TRAJECTORY SET-UP - OPTIONS

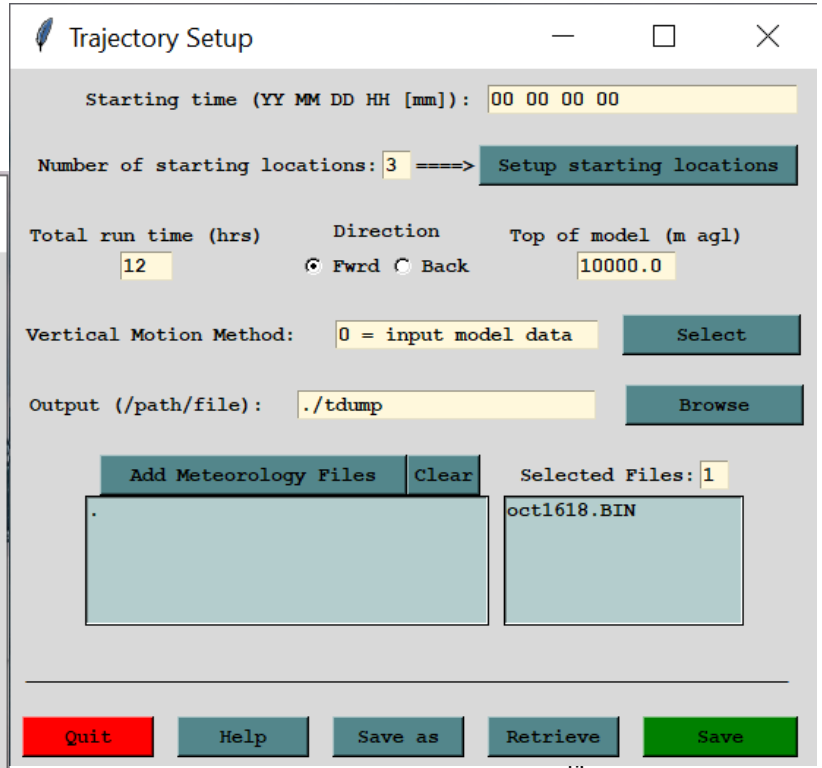
Within the trajectory setup menu you can specify:

- The **start time** of your trajectory (this MUST be within your met data domain).
- The number of **starting locations.**
- **Lat/lon** and **height** of the starting location (i.e. where the pollutant is being injected from).
- **Total run time**
- **Direction** (forwards/backwards)
- **Top of model** for your setup.
- The **vertical motion method.**
- The **Meteorological file.**
- Name of your **output file.**
- **Save** your setting preferences.
- **Retrieve** past saved setups.



*Round up/down to the closest hour rather than using minutes. If you do choose to use minutes: ensure the integration time-step is consistent with the start time.





TRAJECTORY – EQUATIONS

- Particles and puffs are computed as the 3-D velocity vectors at the initial-position P(t) and first guess position P'(t+Δt). Velocity vectors are interpolated in both space and time.
- First guess position:

$$P'(t+\Delta t) = P(t) + V(P,t)\,\Delta t$$

- Final position:

$$P(t+\Delta t) = P(t) + 0.5\,[\,V(P,t) + V(P',t+\Delta t)\,]\,\Delta t.$$

- Δt can vary during the simulation, and is calculated to fill the requirement that the advection distance per time-step is less than the grid spacing:

$$U_{max}(\text{grid-units min}^{-1})\,\Delta t\,(\text{min}) < 0.75\,(\text{grid-units})$$

*the varying time-step can lead to inconsistencies in calculation results, this is especially the case is multiple trajectories are running versus an individual trajectory from that group.

TRAJECTORY – EQUATION NOTES

- Higher order integration methods will not make the model more accurate as it relies on linearly interpolated data observations.
- Trajectories will terminate if they leave the meteorological boundary.
- Trajectories that intersect the ground will still have continuing advection along the surface.
- Trajectories that hit the top of the model will reflect back.
- Horizontal integration of the position vector is done in grid units.
- Vertical integration of the position vector is done using normalized sigma coordinate system:

$$\sigma = (Z_{top} - Z) / (Z_{top} - Z_{gl}), \qquad \text{[all heights MSL]}$$

- Z = height at MSL, gl = height of ground level, top = scaling height of top of model (default = 25km) *If calculations not needed at a certain level, you can reduce run time by shrinking default values.

TRAJECTORY – ERROR

Three types of trajectory error:

1. Computational Trajectory Error: The lowest of all three errors.
2. Meteorology Trajectory Error:
   - The most important source of error, as it can constantly be fluctuating depending on the conditions
   - It is highly dependant on the time step and complexity of the terrain and weather conditions
3. Absolute Trajectory Error:
   - The average deviation from ground truth trajectory per frame.
   - Brings all the error together.
   - Can be determined using the nearest approach distance method. *(we will do this later)*

TRAJECTORY – CASE STUDY

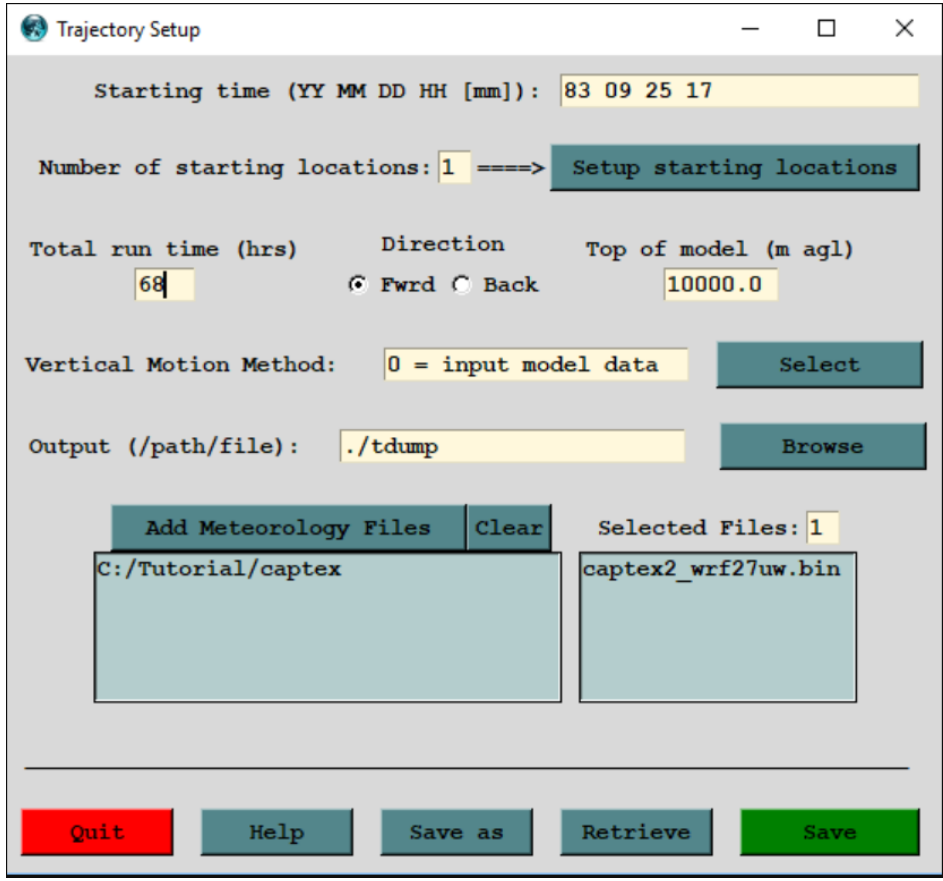
We will be using data from the Cross Appalachian Tracer Experiment (CAPTEX):

- Six 3-hour releases of perfluorocarbon (C7F14) tracers: four in Dayton, Ohio and two in Sudbury, ON
- Samples collected at 84 sites, 300-800km from the release over 3-6 hour averaging periods for 48-72 hours
- Aircraft also collected data for short time periods (6-10 mins): the lowest level was 914m MSL and the highest was 2134m MSL
- This aircraft data can identify the plume centerline. Computing the backwards trajectory of it should pass over the tracer release location.
- Later, we are going to use this data to conduct the nearest approach distance method for measuring **absolute trajectory error**.
- More information can be found here: https://journals.ametsoc.org/view/journals/apme/56/8/jamc-d-16-0345.1.xml

TRAJECTORY – SIMPLE SCENARIO

*Make sure you have the *Hysplit basic tutorial downloaded as we will be using this data.https://www.ready.noaa.gov/HYSPLIT_Tutorials.php*

1. Go to: **TRAJECTORY→SETUP RUN.**
2. First we will enter the start time as: **83 09 25 17** (when the tracer was released).
3. We will simplify the scenario by having **1** starting location, which will be at **39.90 -84.22** and **600 mAGL**. *default for hysplit is AGL.
4. The run time can be set to **68** hours.
5. Vertical motion will be the data field from the meteorological input file.
6. Call the output **tdump_fwrd.**
7. We will be using the **captex2_wrf27uw.bin** meteorological file.
8. Press **SAVE** to exit.



TRAJECTORY – SIMPLE SCENARIO

9. Now we will run the model. Go to:

   TRAJECTORY→RUN MODEL

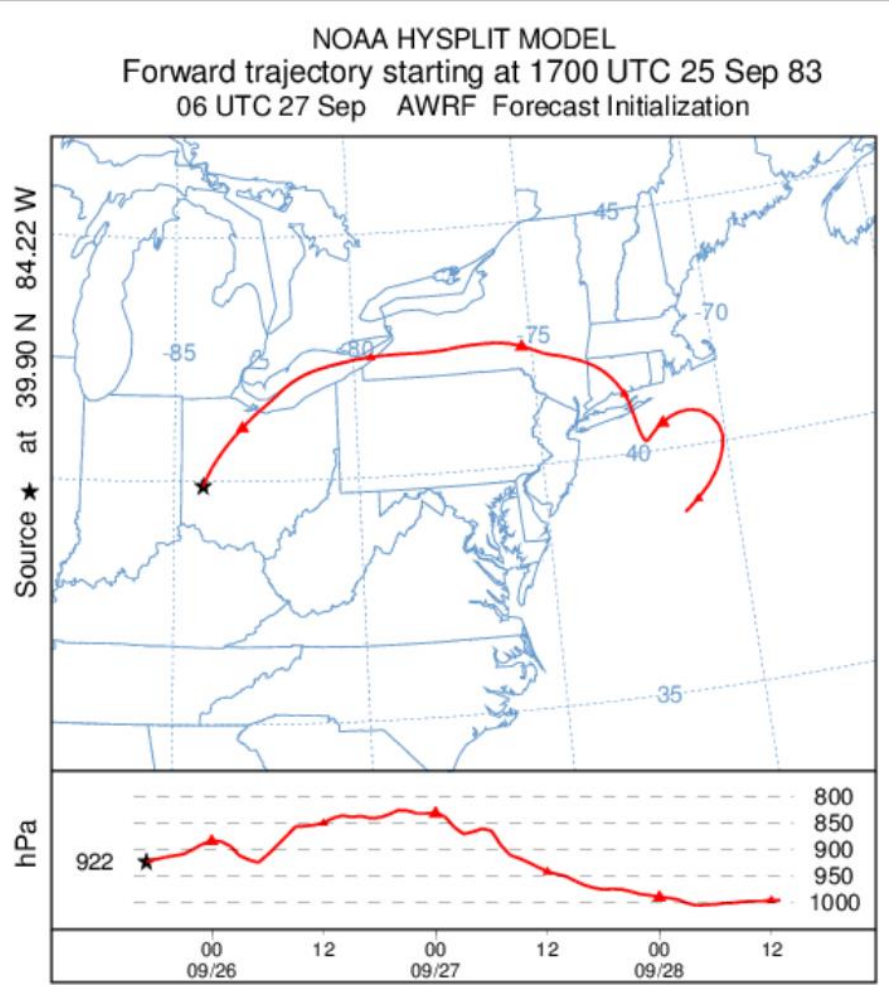
   The pop up box will provide progress on the run.

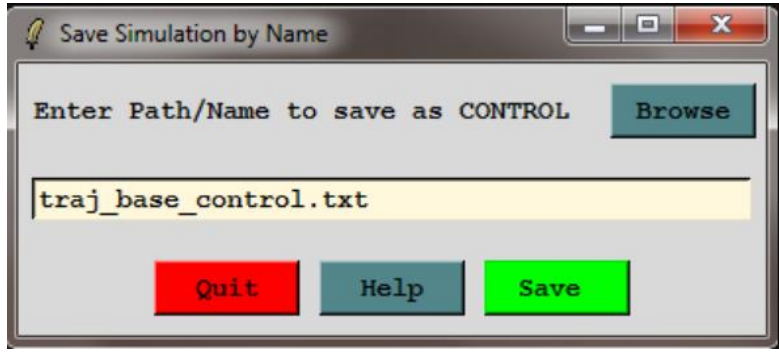
10. After it is complete we will look at the display. Go to:

    TRAJECTORY→DISPLAY→TRAJECTORY

    Allow all defaults by clicking **EXECUTE DISPLAY**

11. We can now save our settings by going back to the **SETUP RUN** menu and clicking **SAVE AS.** We will save the settings as **traj_base_control.txt.**





ABSOLUTE TRAJECTORY ERROR

1. Input the **START TIME, START LOCATION,** and **START HEIGHT** for the **914m** aircraft data. Information on this data can be found in its textfile:

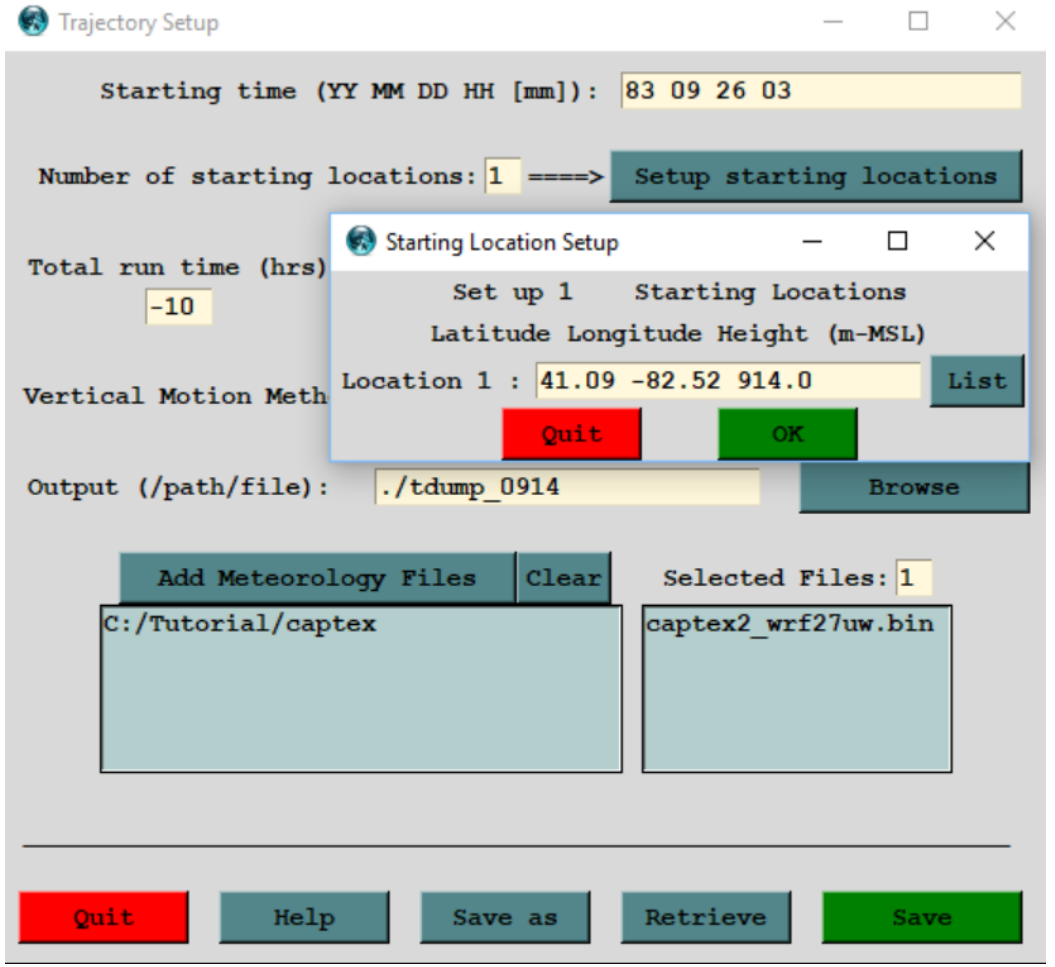
TUTORIAL →CAPTEX→FLIGHT0914.TXT

*We will be starting our simulation at the highest concentration. (see input on right)

2. The tracer was released at 17 UTC on Sept 25, and the collection was at 03 UTC (26th), so run duration should be **-10** with **BACK** trajectory selected.

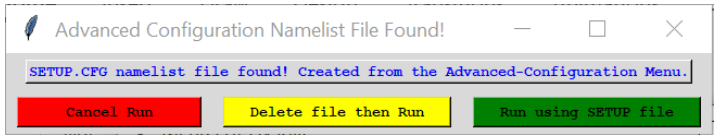
3. We will be using the following meteorology: **captex2_wrf27uw.bin.**

4. Name the output: **tdump_0914.** Hit **SAVE** to exit.



TRAJECTORY – ADVANCED CONFIGURATION OPTIONS

*When you modify the advanced menu you will be prompted when you run the model to use those settings or the defaults. If you meant to make advanced changes, click the right most button, otherwise click the center button.



5. Next we will need to go into the Advanced Configuration tab. Since the data is given in MSL we will need to change the default of AGL. Go to:

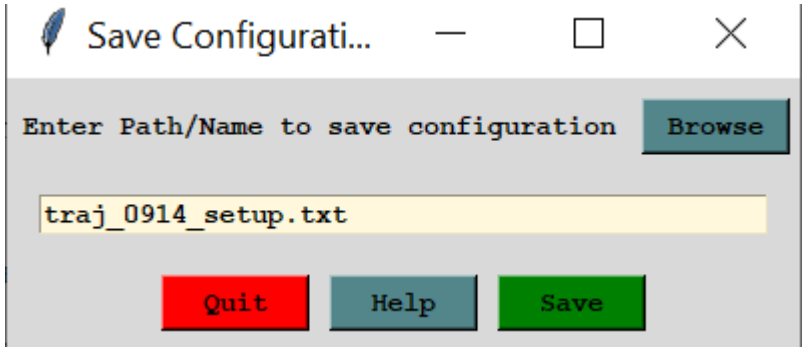
   ADVANCE CONFIGURATION→TRAJECTORY→MENU #2

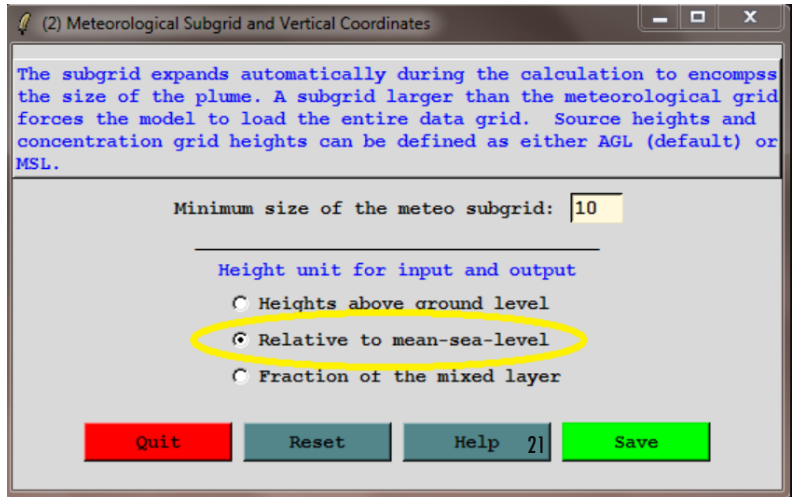
   Select the button for **MSL**. Hit **SAVE** to exit Menu #2.

   Similar to the SETUP RUN we can also save our advanced configuration files.

   Go to **SAVE AS** and type call it traj_0914_setup.txt.

   Then hit **SAVE** to exit.





ABSOLUTE TRAJECTORY ERROR CONTINUED

6. Now we will run the model. Go to:

   TRAJECTORY→RUN MODEL

   The pop up box will provide progress on the run.

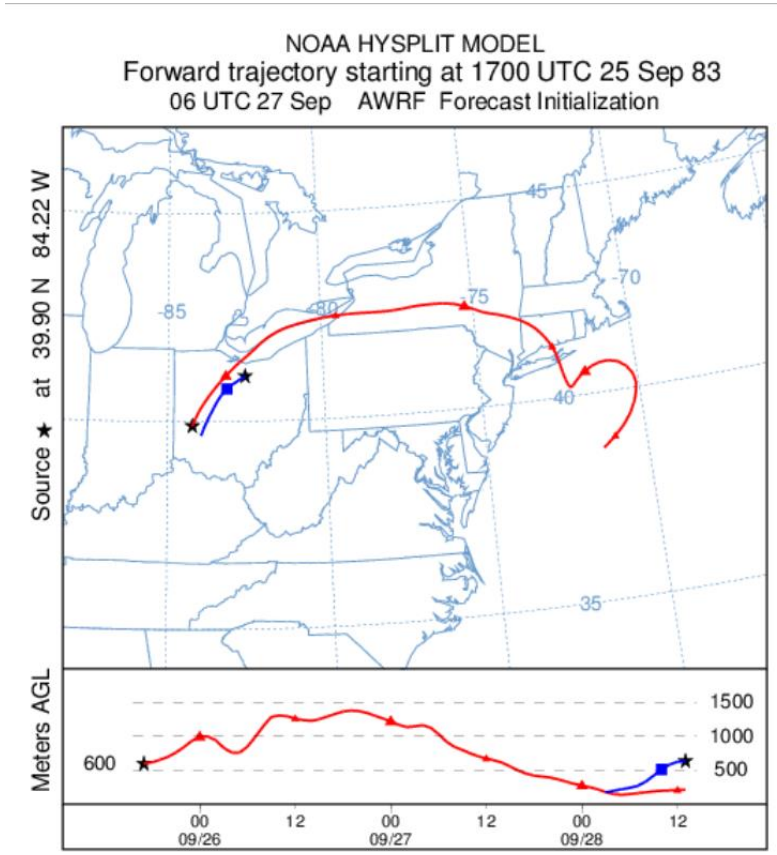
7. After it is complete we will look at the display. Go to:

   TRAJECTORY→DISPLAY→TRAJECTORY

   This time we will plot the previous trajectory alongside the aircraft data. In the **INPUT ENDPOINTS CELL** type in **./tdump_fwrd+tdump_0914.**

   *the first time-step is the one plotted, so if you want the the full extent of a certain time-step, put it first.

   Allow all other defaults by clicking **Execute Display**



ABSOLUTE TRAJECTORY ERROR CONTINUED

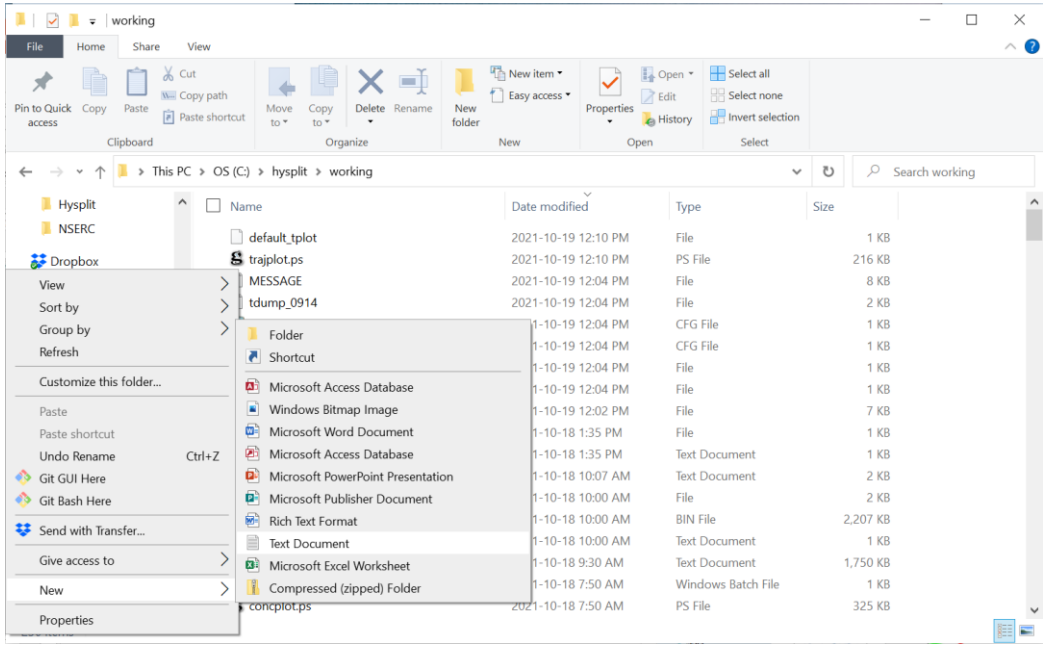
We will now add the 4 other aircraft flights and see how they compare to the model.

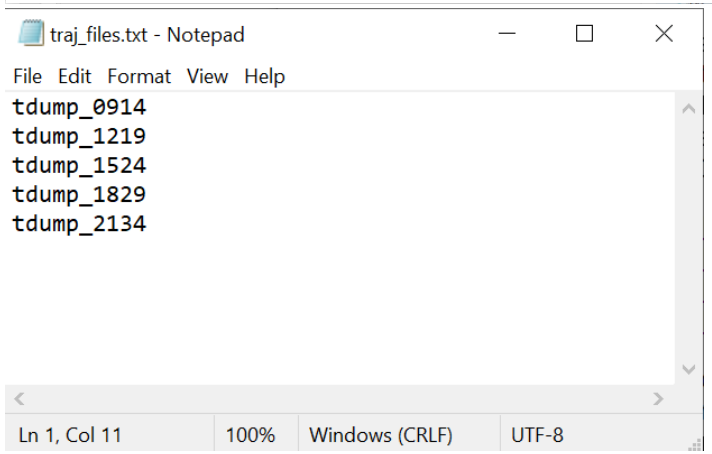
1. Save the **SETUP RUN** as traj_0914_control.txt.
2. Create 4 new output files. **SETUP** each and **RUN** it before starting the next one.
    1. flight1219.txt: Start Time: **83 09 26 23; 1** Start Location @**42.70 -76.17 1219.0; -30 hours; and output to tdump_1219.**
    2. flight1524.txt: Start Time: **83 09 26 04; 1** Start Location @**41.17 -82.79 1524.0; -11 hours;** and output to **tdump_1524.**
    3. flight1829.txt: Start Time: **83 09 26 19; 1** Start Location @**42.38 -76.14 1829.0; -26 hours;** and output to **tdump_1829.**
    4. flight2134.txt: Start Time: **83 09 26 20; 1** Start Location @**43.46 -76.15 2134.0; -27 hours;** and output to **tdump_2134.**

ABSOLUTE TRAJECTORY ERROR CONTINUED

3. To display the results we will take a different approach this time. Go to your working directory for hysplit. **C:/HYSPLIT/WORKING.** Create a new text file called **traj_files.** In this file you will list each of the files you just created (i.e. tdump_*), each on a new line.

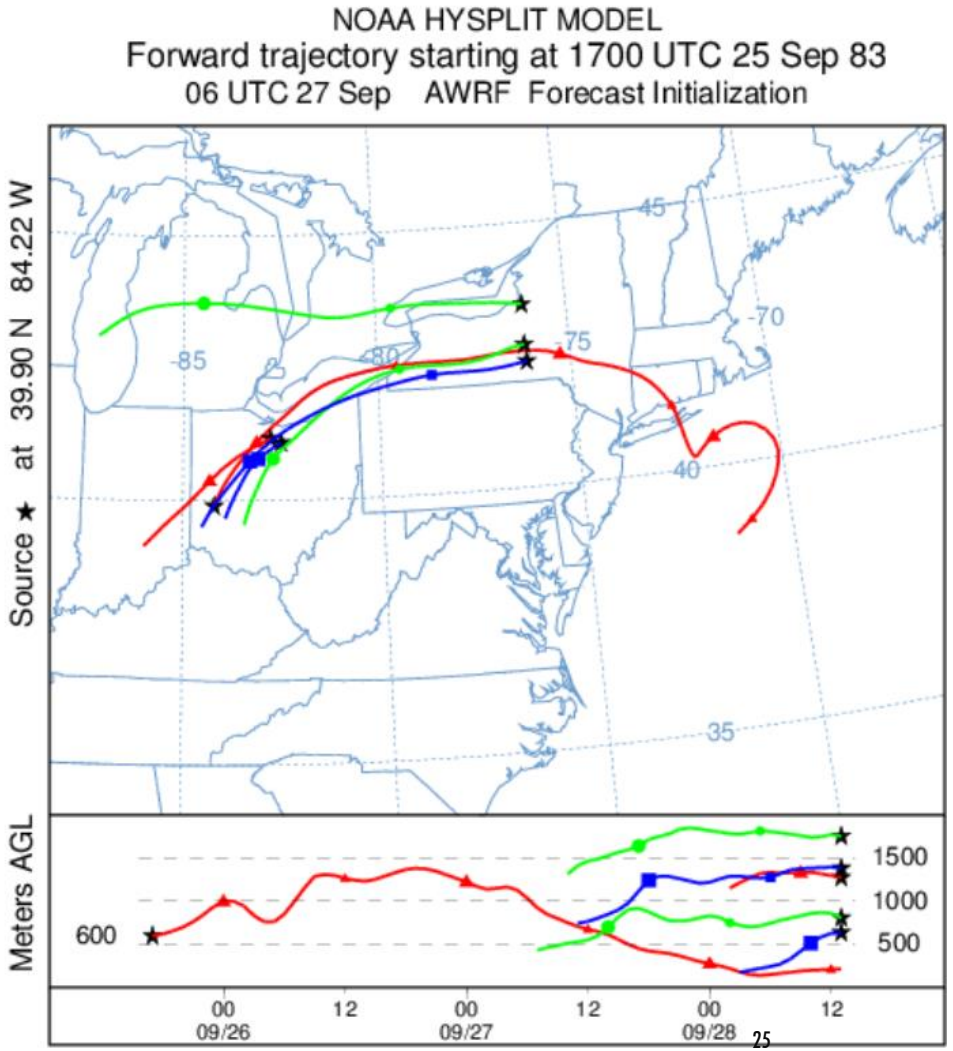
4. Then go to **TRAJECTORY→DISPLAY→TRAJECTORY** and in the input endpoints, type in +./traj_files (or browse for the file to get the right path). Then **EXECUTE DISPLAY.**





ABSOLUTE TRAJECTORY ERROR CONTINUED

- The mid-boundary layer height that was chosen for the tdump_fwrd trajectory, does do a good job of describing most of the other heights that are above the boundary layer (1222m in this case).
- However, it does not describe ALL the trajectories, as the most northern one behaves quite differently than the other three.
- This indicates that a single trajectory CANNOT describe the complex and diffuse ground-level concentration pattern.



TRAJECTORY – APPLY

- If you have time, try running the traj_base_control.txt scenario again, but with different meteorology. Start in the **SETUP RUN** and click **RETRIEVE.** Type the file into the field to change all your settings back to this simple scenario.
- Make sure to save your output with different names so that you can superimpose them onto each other to compare.
- What models do you think are best at running the trajectory model? (*hint take a look at the time steps and resolution of each)