HYSPLIT guide for Volcanic Ash Forecasting

NOAA Air Resources Laboratory

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Contents

1 Introduction

This is a short guide for creating HYSPLIT simulations of volcanic ash on the ARL READY website. The website is intended for aiding in the production of volcanic ash forecasts and prototyping quantitative and probabilistic ash forecasts which may be required in the future.

2 Starting a HYSPLIT simulation

This section describes the entries on the web page that launches a HYSPLIT volcanic ash simulation.

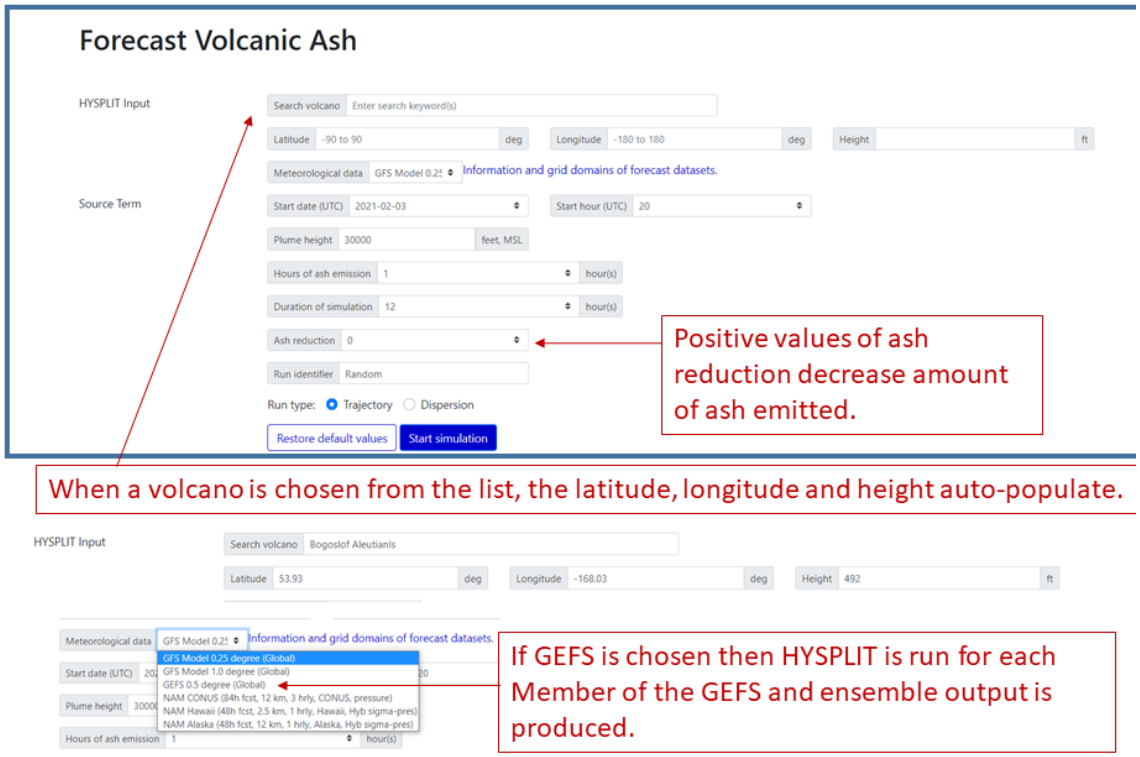

Figure 1: Choosing inputs for HYPSLIT volcanic ash simulation.

1. Start typing a name in the 'Search Volcano' box. Suggestions based on the letters you entered will pop up. Choose one. The latitude, longitude, height values will then automatically be entered for the chosen volcano.

2. Choose the NWP model that you want as input into HYSPLIT.

   - If you choose the GEFS then a HYSPLIT run will be completed for each member in the GEFS and ensemble outputs will be created.

3. Enter the starting time of the ash emissions into the start date and start hour boxes.

4. Enter the approximate plume height in feet above mean sea level.

5. Hours of ash emission. Enter the approximate duration of the ash emission

6. Duration of simulation. Enter how long the HYSPLIT run should be.

7. Ash Reduction. If zero then a default amount of ash is emitted based on an empircal relationship between plume height and mass eruption rate. Setting the ash reduction to a postive number will reduce the amount of ash emitted. Setting the ash reduction to a negative number will increase the amount of ash emitted. This number can be changed after the simulation is run. See Adjusting the mass eruption rate for more information.

8. Choose whether to run trajectory or dispersion run.

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3 Results Page for Dispersion

Figures 2 and 3 show an example of what is available on the results page.

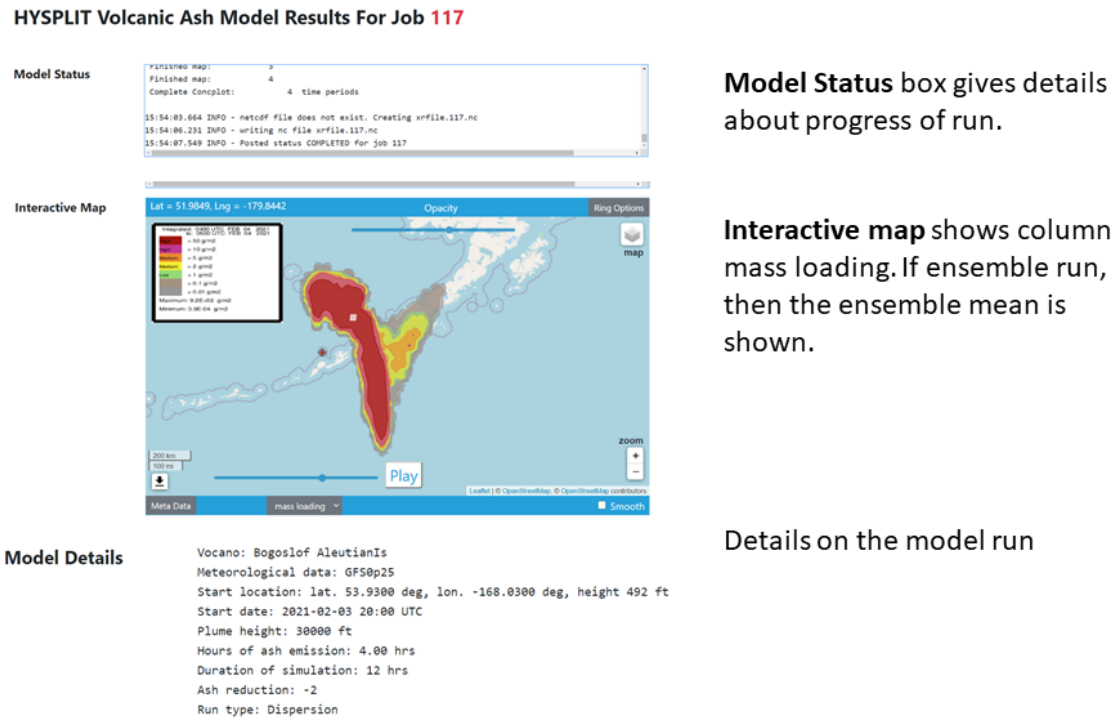

Figure 2: Top part of the results page.

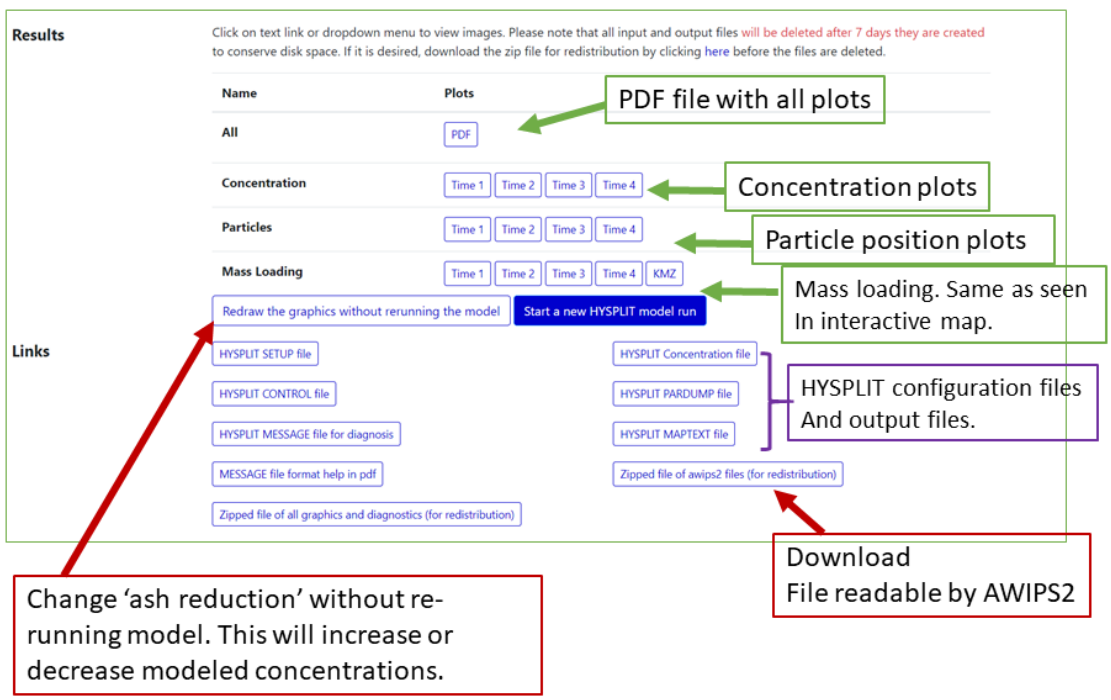

Figure 3: Bottom part of the results page.

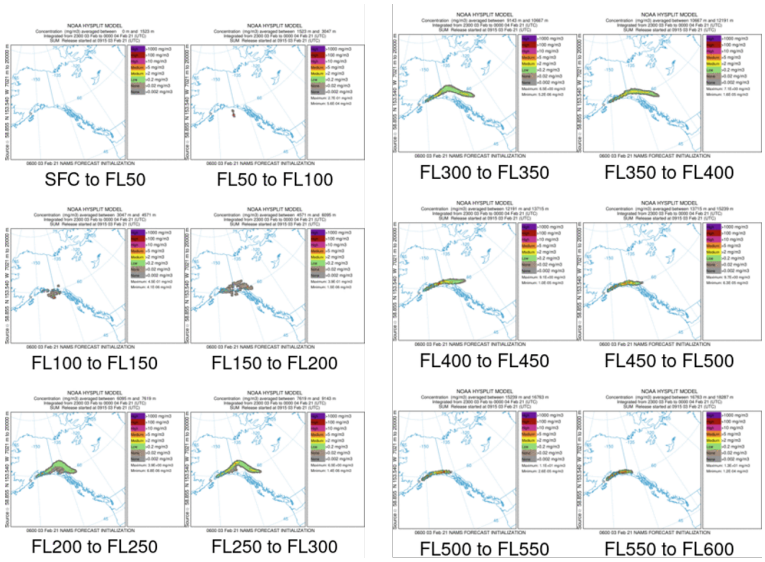

Figure 4: Concentration chart for one time period. Units in mg/m^3. Concentrations are shown at 12 different height levels.

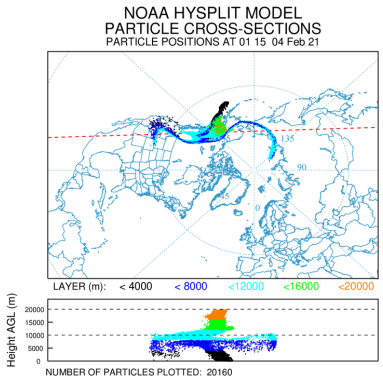

Figure 5: Plot of computational particle positions. The top plot shows the top down view. The bottom plot shows horizontal position vs vertical position. The color indicates the height of the particles.

3.1 Interactive map

The interactive map displays mass loading or ensemble mean mass loading as a function of time. HYSPLIT outputs are every 3 hours and show a 1 hour average.

3.2 AWIPS2 files

NETCDF4 files suitable for ingest into AWIPS2 can be downloaded. A configuration file for AWIPS2 is needed as well. The AWIPS2 files contain gridded concentration data. For ensemble output, concentrations for each ensemble member are included. One file per time period is included in the zipped file. See appendix A for more information.

3.3 Concentrations

Concentration is the quantity of interest to aviation. Concentrations are output on a 0.25x0.25 degree grid with vertical levels at a resolution of FL50. Concentrations are a 1 hour average output every 3 hours. Plots of the concentration at each level may be viewed by clicking on the buttons. An example is shown in Figure 4. The gridded concentration information can also be found in the AWIPS2 files so that this information can be viewed in the AWIPS2 system.

3.4 Particle Positions

Particle position plots are accessible by choosing the buttons shown in Figure 3. An example of one is shown in Figure 5. These plots can be useful for gaining an understanding of the three dimensional structure of the simulated plume.

3.5 Mass Loading

The column mass loading is the amount of mass per unit area in a 0.25x0.25 degree column from the ground to FL600. The units are usually in g/m^2. This is the modeled quantity that is most comparable to satellite data. Plots of column mass loading are found in the interactive map and can also viewed by clicking on the buttons shown in Figure 3. Gridded column mass loading is also found in the AWIPS2 files.

4 Adjusting the mass eruption rate

Changing the mass eruption rate will increase or decrease the concentrations and mass loadings as shown in Figure 6.

If you choose 'Redraw the graphics without rerunning the model' button shown in Figure 3 then it will bring you to the page shown in Figure 7.

The default mass eruption rate is calculated from an empirical relationship between mass eruption rate and plume height. Thus larger eruptions will have a larger default mass eruption rate. The empirical relationship has a large uncertainty and so the mass eruption rate should be adjusted to match observations.

Changing the mass eruption rate will only change the shape of the modeled plume when areas drop below or rise above the threshold for plotting. This is shown in Figure 6.

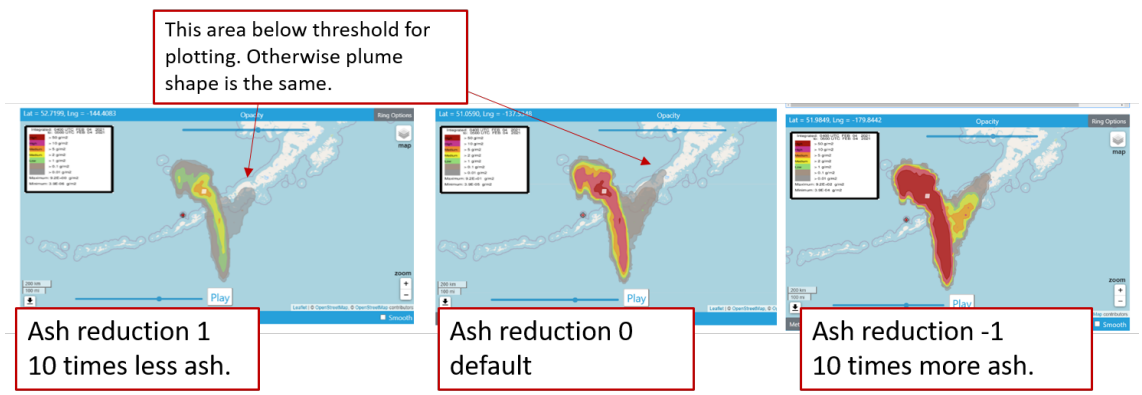

Figure 6: Demonstration of using ash reduction.

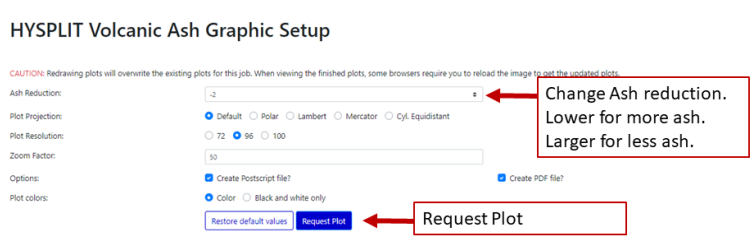

Figure 7: How to redraw plots with different ash reduction.

4.1 More information

- In the future, the HYSPLIT system will ingest satellite data when available and automatically tune the mass eruption rate.

5 HYSPLIT ensemble output

5.1 Mass loading

The ensemble mean column mass loading is shown in the interactive plot. Mass loading for each ensemble member is available in the AWIPS2 formatted files and can be viewed in AWIPS2.

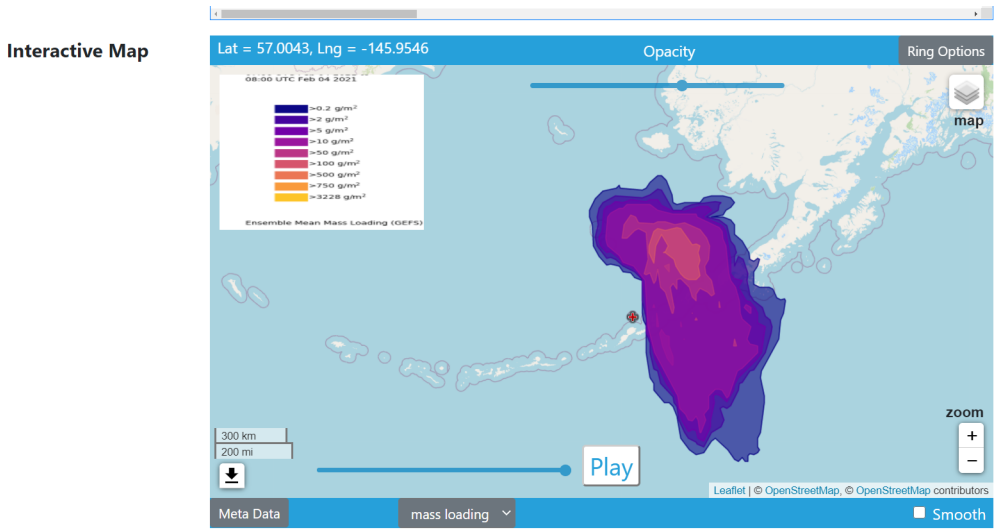

Figure 8: Ensemble mean mass loading. A HYSPLIT simulation is performed for each member of the GEFS. The mean value of the mass loading of all the outputs is plotted. Generally the ensemble mean plume will cover more area and have somewhat lower values than individual members.

5.2 Ensemble relative frequency or probability of exceedance

In the case of volcanic ash forecasting, several concentration thresholds have been identified as meaningful for aviation. Ensemble output can provide guidance on the likelihood of exceeding a given concentration threshold.

The U.S. Developmental Testbed Center, operated jointly by NOAA, the National Center for Atmospheric Research (NCAR), and the U.S. Air Force, has a Model Evaluation Tools (MET) users guide that provides this guidance: *"The ensemble relative frequency is the simplest method for turning a set of deterministic forecasts into something resembling a probability forecast. MET will create the ensemble relative frequency as the proportion of ensemble members forecasting some event. For example, if 5 out of 10 ensemble members predict measurable precipitation at a grid location, then the ensemble relative frequency of precipitation will be 5/10=0.5. If the ensemble relative frequency is calibrated (unlikely) then this could be thought of as a probability of precipitation"* Link to source.

For volcanic ash, the event is the concentration exceeding a given threshold. Figure 9 shows an example of HYSPLIT simulation output for the ensemble relative frequency. It is produced simply by counting the number of simulations in each grid square exceeding the threshold and dividing by the number of simulations.

Currently the web page only produces plots for exceedances of the 0.2mg/m^3 threshold. Additional plots for larger (or smaller) thresholds may be added.

5.3 Evaluation and calibration

When observations are available, how well the ensemble probabilities are calibrated may be evaluated with measures such as reliability diagrams and receiver operating characteristic (ROC) curves. Outcomes from the evaluations

In the future, the ensemble capability may be expanded to include 'source term' ensemble as well the NWP ensemble. This could involve running HYSPLIT simulations for various plume heights, start and end times, and mass eruption rates. It could also involve ingesting satellite observations to produce several estimations of the source terms. The goal would be to improve ensemble calibration.

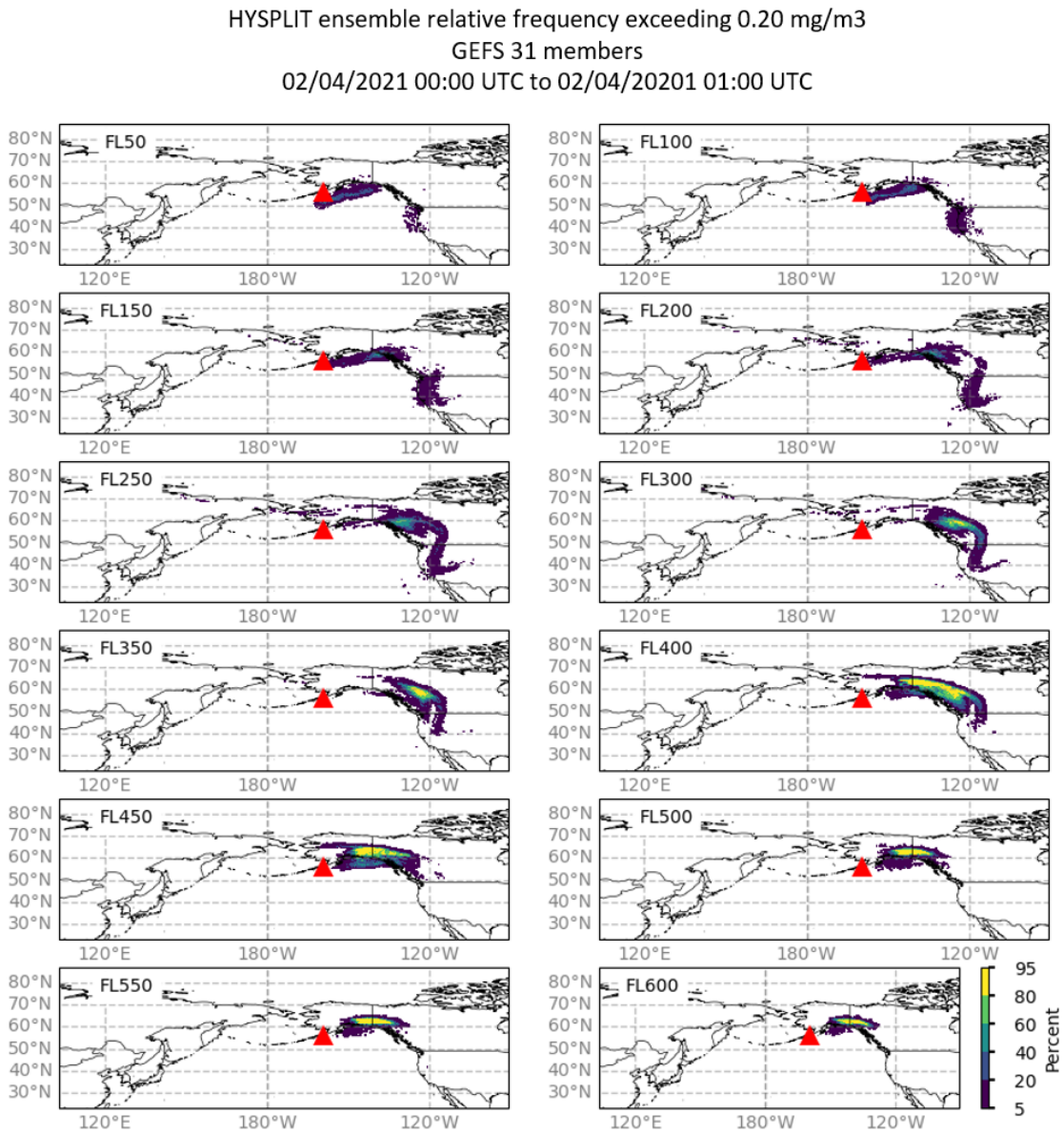

Figure 9: Ensemble relative frequency concentration $> 0.2\text{mg/m}^3$ for all vertical levels.

6 Additional Information

6.1 Links to other resources

- HYSPLIT simulations triggered by VOLCAT alerts.
- HYSPLIT trajectories for selected volcanoes.
- HYSPLIT dispersion simulations for selected volcanoes.

6.2 code version

v0.2

7 Appendix A: AWIPS2 netcdf file format

See section on AWIPS2 files for more information

```
Coordinates:
  * ensid           (ensid) int32 1 2 3 4 5 6 7 8 9 ... 23 24 25 26 27 28 29 30
  * latitude        (latitude) float32 26.044998 26.294998 ... 63.045 63.295
  * longitude       (longitude) float32 188.245 188.495 ... 265.745 265.995
  * time            (time) datetime64[ns] 2021-01-24T21:00:00
Dimensions without coordinates: bnds, contour_levels
Data variables:
    FL50            (time, ensid, latitude, longitude) float32 ...
    FL100           (time, ensid, latitude, longitude) float32 ...
    FL150           (time, ensid, latitude, longitude) float32 ...
    FL200           (time, ensid, latitude, longitude) float32 ...
    FL250           (time, ensid, latitude, longitude) float32 ...
    FL300           (time, ensid, latitude, longitude) float32 ...
    FL350           (time, ensid, latitude, longitude) float32 ...
    FL400           (time, ensid, latitude, longitude) float32 ...
    FL450           (time, ensid, latitude, longitude) float32 ...
    FL500           (time, ensid, latitude, longitude) float32 ...
    FL550           (time, ensid, latitude, longitude) float32 ...
    FL600           (time, ensid, latitude, longitude) float32 ...
    MassLoading     (time, ensid, latitude, longitude) float32 ...
    Contour_levels  (contour_levels) float32 ...
    ensemble        (ensid) object ...
    source          (ensid) object ...
    time_bnds       (time, bnds) datetime64[ns] ...
Attributes:
    jobid:                    1001
    time_origin:              2021-01-25 14:49:27
    concentration_mass_unit:  mg
    massloading_mass_unit:    g
    MER:                      202286.15136931252
    MER_unit:                 kg/s
    soure_latitude:           56.17
    soure_longitude:          -159.38
    source_name:              Veniaminof
    emission_start:           2021-01-24 14:15:00
    emission_duration_hours:  12

In [6]: d1.FL50.ensid
Out[6]:
<xarray.DataArray 'ensid' (ensid: 30)>
array([ 1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16, 17, 18,
       19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30], dtype=int32)
Coordinates:
  * ensid    (ensid) int32 1 2 3 4 5 6 7 8 9 10 ... 22 23 24 25 26 27 28 29 30

In [7]: d1.ensemble
Out[7]:
<xarray.DataArray 'ensemble' (ensid: 30)>
array(['gec00', 'gep01', 'gep02', 'gep03', 'gep04', 'gep05', 'gep06', 'gep07',
       'gep08', 'gep09', 'gep10', 'gep11', 'gep12', 'gep13', 'gep14', 'gep15',
       'gep16', 'gep17', 'gep18', 'gep19', 'gep20', 'gep21', 'gep22', 'gep23',
       'gep24', 'gep25', 'gep26', 'gep27', 'gep28', 'gep29'], dtype=object)
Coordinates:
  * ensid    (ensid) int32 1 2 3 4 5 6 7 8 9 10 ... 22 23 24 25 26 27 28 29 30

In [8]:
```

Figure 10: Contents of one of the netcdf files in the AWIPS2 zipped file. The zipped file contains one netcdf file for each time period.

8 Appendix B: Changes and updates log

8.1 February 2021

The initial user guide was created for code version v0.2