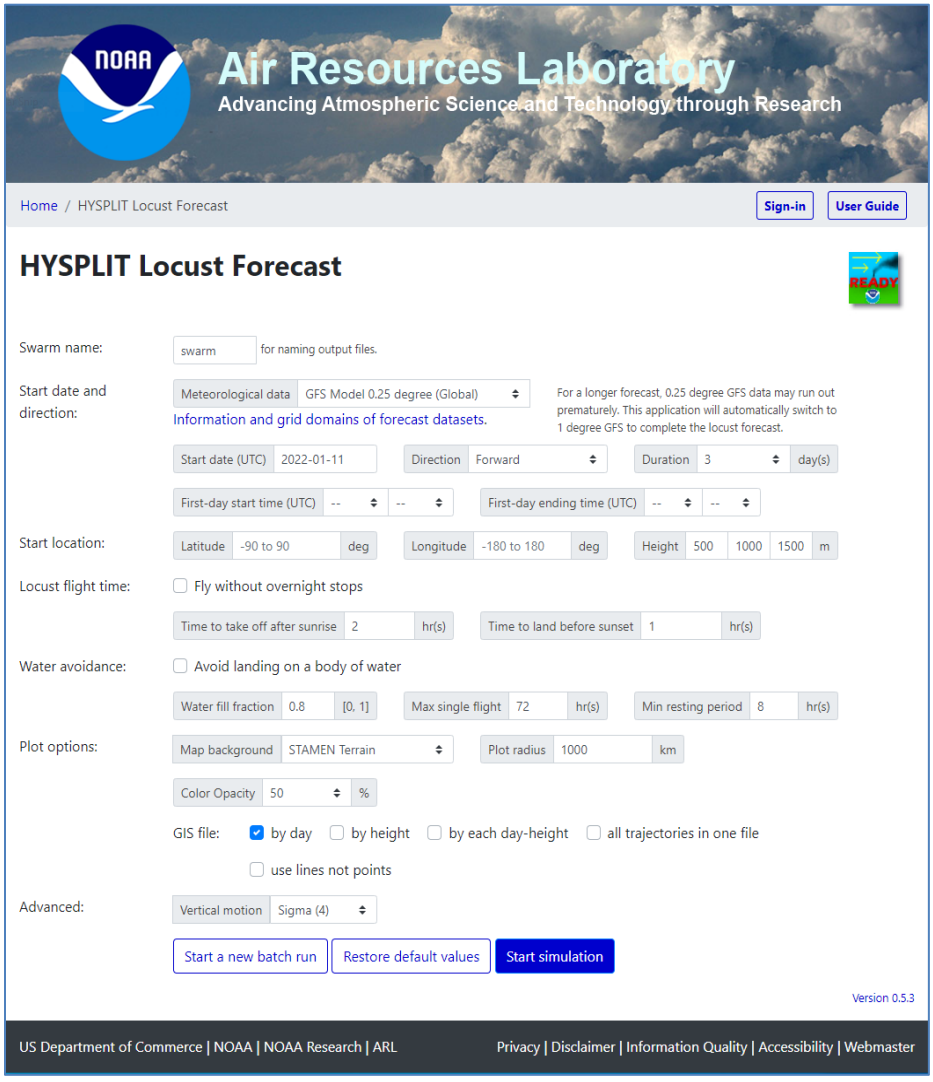
Locust Forecast Web App User Guide

Version 3.0, January 13, 2022

Based on HYSPLIT Locust Forecast

Version 0.5.3



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1. Introduction

Countries in Eastern Africa and the Middle East are affected by outbreaks of desert locust swarms, creating significant threats to food security in these regions. Advance knowledge of where a given swarm might go, and/or where it might have come from, can aid efforts to mitigate the devastating impacts caused by these voracious pests. Locusts are believed to be relatively passive fliers, with movements primarily influenced by the wind. They also fly together in a swarm, making them ideal candidates for simulation using HYSPLIT's air *trajectory* modeling capabilities (as opposed to HYSPLIT's air *dispersion* functionality). This web app allows users to specify takeoff and landing times (e.g., relative to sunset and sunrise) and flying height(s) to create forward or backward flight-path simulations from identified swarm locations. Crucial information output from the simulations are estimates of where a given swarm may land in the coming days.

This web app was developed based on a request from Keith Cressman, the senior locust forecasting officer at the United Nations Food and Agriculture Organization (FAO). The FAO coordinates desert locust response and mitigation efforts globally. FAO's Cressman had been using HYSPLIT for locust forecasting and asked how locust behavior (e.g., taking off and landing each day) could be efficiently accounted for in simulations, and he has been consulted throughout the process in efforts to make the app as useful as possible to locust forecasters. His expertise regarding locust forecasting has played a fundamental role in the development of this tool.

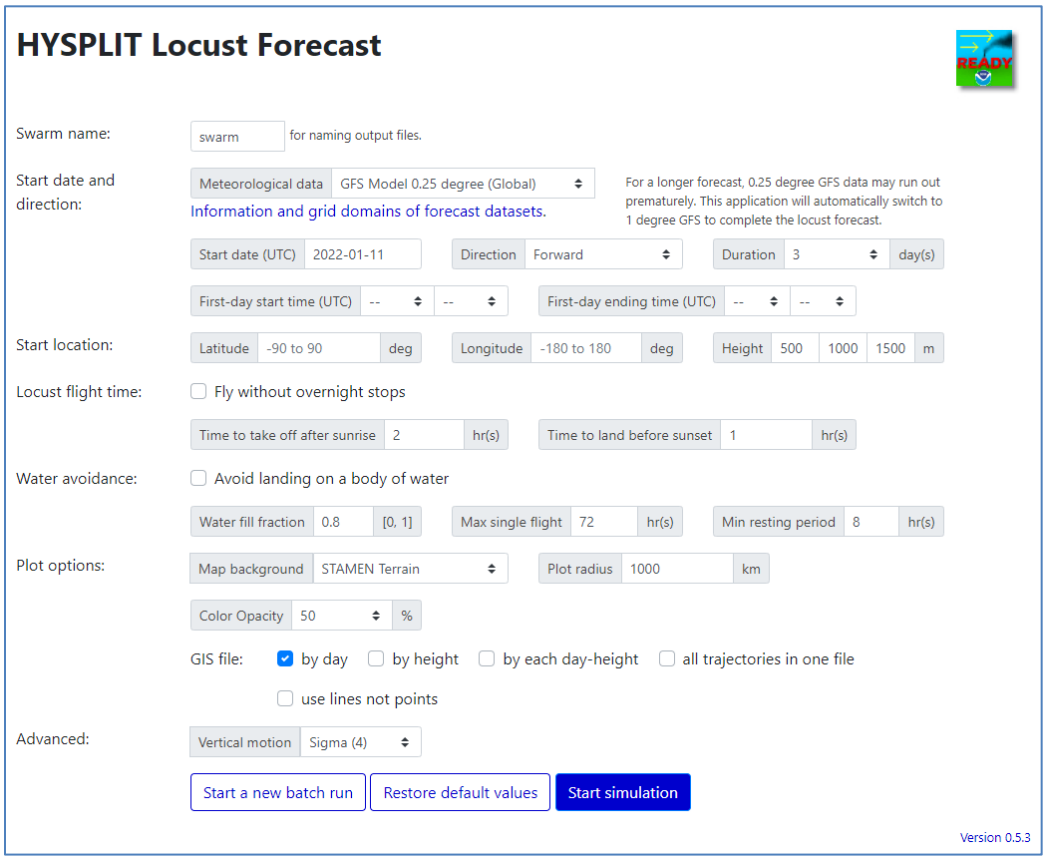
There are three different ways to use this web application:

- **Single Swarm:** The user specifies parameters for the simulation of a single swarm, including swarm name, starting date and location, meteorological data to use, direction (forward or backward), take-off and landing times, flying height(s), and graphical output options. Once inputs are set, the user "Starts Simulation", and a complete set of output data files and graphics are produced that can be downloaded.

- **Multiple Swarms (batch mode):** The user creates a CSV file based on a provided template, with one row for each swarm to be simulated, and columns that provide all of the inputs necessary for simulating that particular swarm. The user uploads the CSV file by "dropping" it onto the batch-run input page. If all inputs are acceptable, the batch run can be started, and a full set of output files and graphics are generated for each swarm in the batch.

- **Multiple Swarms (matrix mode):** Input parameters for this option is similar to those for the Single Swarm option above. The difference is in the setup for starting locations and output files. A matrix run specifies N by M start locations that evenly cover a rectangular area. After N x M swarm runs are completed, the application performs additional analyses to generate plots for showing trajectories, trajectory frequency, and time-of-arrival.

2. Single Swarm Run Specification Page



Swarm name

Enter the user-defined swarm name in this box. All output files from this simulation will have that swarm name associated with them. The name must consist only of alphanumeric characters (not exceeding 20 characters), and there can be no spaces or any special characters other than underscore (_). Example: *Kenya_A_05_14_2020*

Start date and direction

Meteorological data: The user can select either the default GFS Model 0.25º (Global) dataset or the GFS Model 1.0º degree (Global) dataset. The 0.25º dataset has a horizontal resolution of ~25 km, and supports forecasts up to 3 days into the future. The 1.0º dataset has a horizontal resolution of ~100 km and supports forecasts up to 15 days in the future. Additional information on these forecast data sets is available. For simulations (or parts of simulations) that occur in the past, a quasi-analysis version of the GFS Model output is used. In this quasi-analysis version, initial-time-step results are saved from each forecast, and these short-term, more highly accurate results are

patched together to make a continuous dataset. Information about the 1.0º quasi-analysis dataset is available here, and information about the 0.25º quasi-analysis dataset is available here.

Start date (UTC): Selectable in a drop-down calendar, the day you would like the simulation to start, in Universal Time Coordinates (UTC). The default start date is the current date.

Direction: Select Forward (default) or Backward.

Duration: The number of days you would like the simulation to be for. The user can select 1,2,3,5,7,10, or 15 days from the drop-down menu. As noted above, if 0.25º GFS data are used, a maximum of 3 days in the future can be simulated. If 1.0º GFS data are used, the simulation can be carried out for up to 15 days into the future. The default duration is 3 days.

First-day start time (UTC): (optional) The user can enter the UTC hour and minute of the locust take-off time, and this will over-ride any sunrise-offset take-off time set below *for the first day of the simulation*. For subsequent days of the simulation, the sunrise-offset set below is used. This can be used, for example, in the special case where local knowledge of the actual swarm take-off time exists. The default is for this not to be specified.

First-day ending time (UTC): (optional) The user can enter the UTC hour and minute of the locust landing time, and this will over-ride any sunset-offset landing time set below *for the first day of the simulation*. For subsequent days of the simulation, the sunset-offset set below is used. This can be used, for example, in the special case where local knowledge of the actual swarm landing time exists, and this setting might be particularly useful for backward simulations from that particular landing time. The default is for this not to be specified.

Start Location

Latitude: Latitude of the starting location for the first day of the simulation (decimal degrees). North latitudes are positive (e.g., 3.5) and South latitudes are negative (e.g., -3.5), and thus, the value must be between -90 to 90 degrees.

Longitude: Longitude of the starting location for the first day of the simulation (decimal degrees). East longitudes are positive (e.g., 3.5) and West longitudes are negative (e.g., -3.5), and thus, the value must be between -180 and 180 degrees.

Height: Starting height, in meters above ground level, for each day of the simulation. The default vertical motion is to fly at a constant height above ground level (see Vertical Motion Option below), and if this default setting is used, the swarm is assumed to fly at this initial height for its entire flight. The user can optionally set a 2nd and even a 3rd height here as well, and simulations will be done for each starting height. Since wind speed and direction can vary with height, the choice of starting height will generally

make a difference in the forecast swarm paths. The default setting is for three starting heights of 500 m, 1000 m, and 1500 m above ground level to be specified.

Locust Flight Time

Fly without overnight stops: If this box is checked, the swarm is assumed to fly continuously without stopping, once it has taken off, for the duration of the simulation. This may be useful in situations where the swarm is crossing a large body of water and the user knows they will not choose to land in the water. The default is for this box *not* to be checked.

Time to take off after sunrise: The user enters the time (in hours) that the swarm is estimated to take off, after the local sunrise time. The default is 2 hours.

Time to land before sunset: The user enters the time (in hours) that the swarm is estimated to land, before the local sunset time. The default is 1 hour.

Water avoidance

Avoid landing on a body of water: If this box is checked, the application uses the following three parameters for the swarm to avoid landing over a body of water.

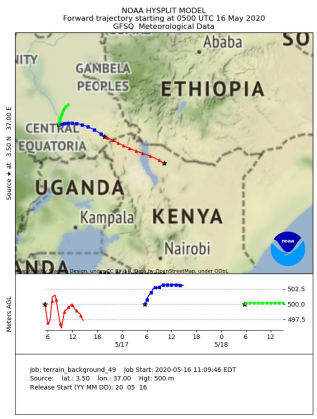
Water fill fraction: This parameter specifies the threshold water fill fraction of a given landuse / landcover grid cell above which landing in the cell will be avoided. The idea here is that cells on the coast or which contain islands may have some water, but also some land, and the user can specify how much “water” must fill the cell before it is avoided. The application currently uses a 0.05 degree grid size (~5 km) for an extended northern Africa domain and a 0.5 degree grid (~50 km) elsewhere in the world. The default is 0.8, but the user can pick any value from 0 to 1. With the default of 0.8, the cell is avoided if more than 80% of the 5 km x 5 km cell in northern Africa or 80% of the 50 km x 50 km cell elsewhere is water-filled.

Max single flight: This parameter specifies the number of hours that a swarm can fly without landing. If this flight time is reached, and the swarm has not encountered a cell with land, it will land in the water. The application tracks this water landing, but then does not allow the swarm to continue. It is as if the swarm ended when it landed on the water. The default value of the parameter is 72 hours, but the user can select any number of hours from 0 to 240.

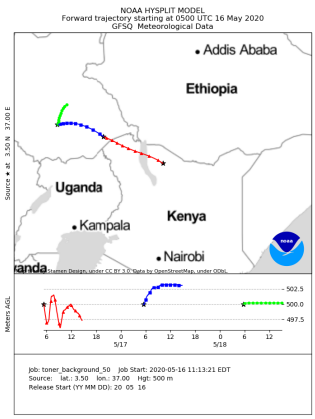
Min resting period: This parameter specifies the minimum resting period (in hours) that a swarm must be allowed, once it lands on a non-water surface, before it is allowed to take off again. The default value is 8 hours, but the user can select any number of hours from 0 to 72.

Plot Options

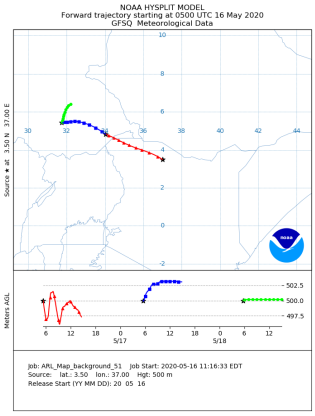
Map background: There are three choices here, and the default is the “STAMEN Terrain” background. Examples of the three types of map backgrounds are shown below. The STAMEN backgrounds are from http://maps.stamen.com/, while the ARL Map background uses the basic HYSPLIT map background graphics.



STAMEN Terrain



STAMEN Toner



ARL Map

Plot radius: The map output is centered on the start location and extends out this distance in each cardinal direction (North, South, East, and West). The default is 1000 km. For longer-duration simulations (or if there are faster wind-speeds), this may need to be increased to show the entire flight path on the map. For shorter-duration simulations (or if there are slower wind-speeds), the user may wish to reduce this radius to create a more zoomed-in view of the flight path. In the above examples, a 1000-km plot radius was used for a 3-day simulation.

Color Opacity: The option is used to set the opacity (or transparency) of colors when coloring trajectories, trajectory frequencies, time-of-arrivals, etc. The color opacity can run from 0% (fully transparent or fully seeing through) to 100% (fully opaque or fully blocking the background). The default value is 50%.

GIS file: Shapefile and associated files can be imported into a GIS application for custom plots. There are five mutually inclusive options that control how GIS files are produced.

by day: GIS files are created for each day for the duration of the run. All trajectories for a given date will be gathered into one shapefile ending _dayD.* where D = 1, 2, 3, … denotes the day number.

by height: GIS files are created for each starting height. Trajectories at a starting height will be gathered into one shapefile ending _HHHHm.* where HHHH is the starting height in meters.

by each day-height: GIS files are created for each day and by each starting height. Trajectories for a given date and at a starting height will be gathered into one shapefile ending _HHHHm_dayD.* where HHHH is the starting height in meters and D = 1, 2, 3, … is the day number.

all trajectories in one file: One shapefile (and its associated files) will be created for this option.

use lines not points: If this option is checked, shapefiles will be created treating endpoints of a trajectory as a point on line. Shapefiles with lines may be convenient to work with as a style change for a line applies to all points of a trajectory.

Advanced

Vertical motion option: There are five options that can be chosen. The default is option #4 which specifies that the locusts are assumed to stay at the same height above the ground during their entire flight, until landing. With this option, the starting height set above -- in meters above the ground -- is the flying height throughout the simulation.

Here are all of the options:

0: Uses vertical velocities estimated from the meteorological data set. This setting is often used In air-pollution simulations with HYSPLIT, but is not considered the default for the flight of locusts.

1: Isobaric -- vertical height during flight is adjusted so that the locusts encounter the same pressure throughout the flight as when they started.

2: Isentropic -- vertical height during flight is adjusted so that the locusts encounter the same entropy throughout the flight as when they started.

3: Constant Density -- vertical height during flight is adjusted so that the locusts encounter the same air density throughout the flight as when they started.

4: Constant Height above the ground -- vertical height during flight is kept the same as the starting height, in meters above ground level. This is the same as the “constant-sigma” option in HYSPLIT.

Start a new batch run

Pressing this button will take you to the multiple-swarm (batch-mode) run specification page. This functionality is described below.

Restore Default values

Pressing this button will restore all inputs to their default values on the single-swarm run specification page.

Start Simulation

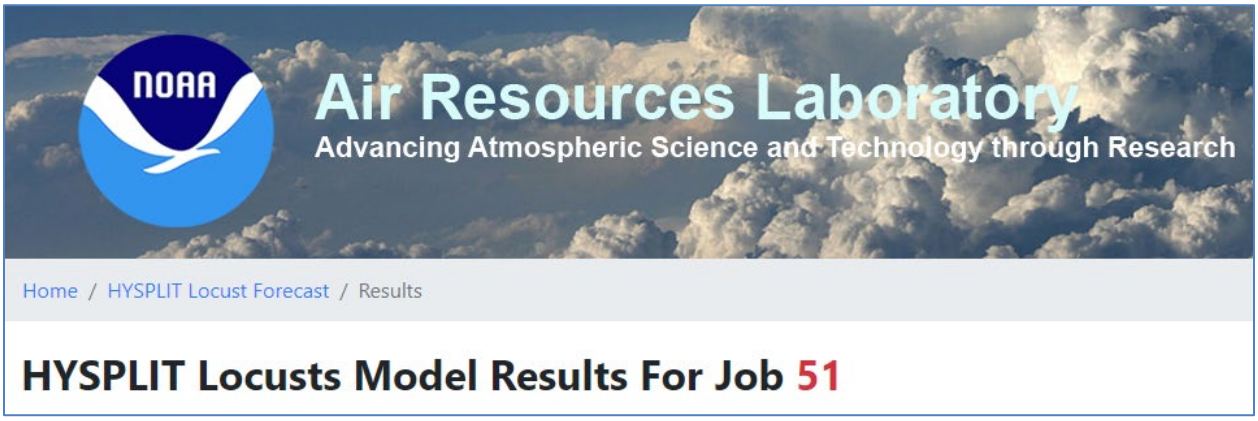
Pressing this button will start the simulation based on the current inputs specified. If there are errors in any of the inputs, or if any required fields are not set, an error message will be displayed. If the inputs are acceptable, and the run is proceeding as expected, one will soon begin to see the “run-time screen outputs” described in the next section.

3. Screen Outputs During Single-Swarm Run

The following elements are displayed on the screen during a successful single-swarm simulation. Not all elements occur immediately, and some are updated throughout the run. The run has finished successfully when the link to a "Zipped file of all graphics and diagnostics (for redistribution)" is displayed at the bottom of the output, in the Links section, as described below.

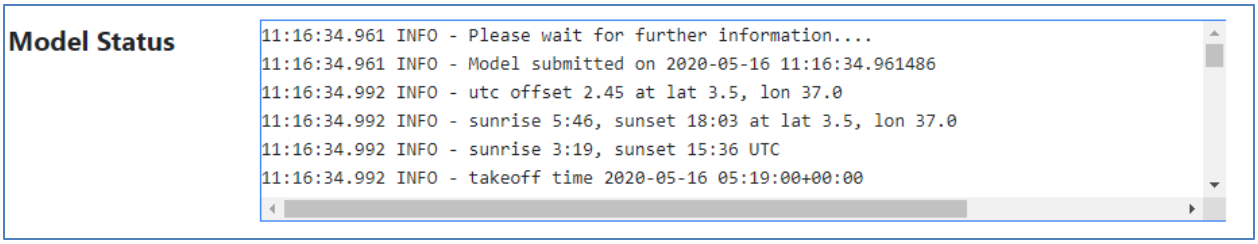
JOB NUMBER

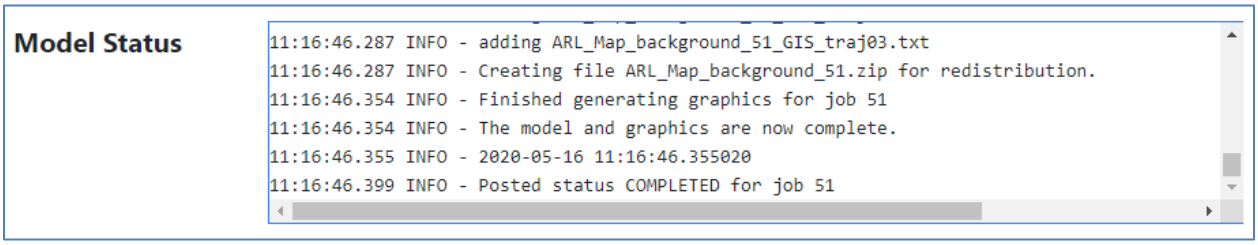
The first item that appears is a title screen that shows the "Job Number" for this particular simulation. This job number is set by the system, but is associated with all of the output files for the simulation. In the examples below, the swarm name chosen was ***ARL_Map_Background*** and the **run-name** is constructed by appending the Job Number (in this example: ***51***) to this swarm name, i.e., in this case, ***ARL_Map_Background_51***. All output files have this run-name associated with them. For example, the png map output has the file name ***ARL_Map_Background_51.png***



MODEL STATUS

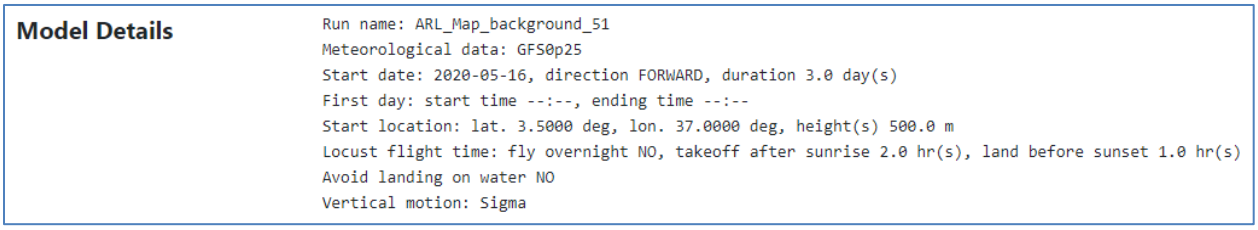
The second item that appears is the Model Status box that scrolls through various intermediate screen outputs as the simulation proceeds. The full contents of this "Model Status" box is included in the run outputs as ***run-name_progress.txt***. In the example shown here, the file name in the outputs would be called ***ARL_Map_background_51_progress.txt***





MODEL DETAILS

The third item that appears is the Model Details box. This is simply a concise summary of the key swarm specifications set by the user for this simulation. The full contents of this “Model Status” box is included in the run outputs as ***run_name_run_setup_summary.txt***. In the example shown here, the file name in the outputs would be called ***ARL_Map_background_51_run_setup_summary.txt***



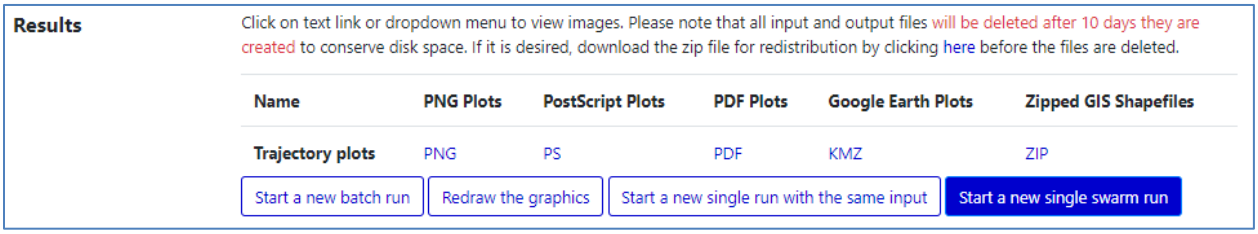
RESULTS

The fourth item that appears is the Results box. When the run finishes successfully, this box should be fully populated with links as shown in the example below. One can click on the “PNG” link to quickly see the map output from the simulation. In this section of the screen output, one can also **Start a new single swarm run**, **Redraw the graphics, Start a new single run with the same input,** or, if desired, **Start a new batch run**.

Note: if it is desired to save all of the output files associated with this run, it is recommended that the user click on the link in the section below to download the **Zipped file of all graphics and diagnostics (for redistribution)**

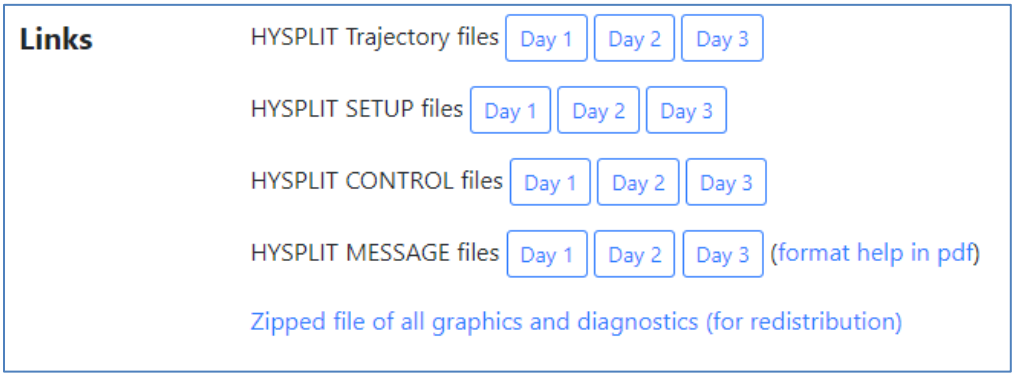
Simulation results are available on the system for a short time. If one has forgotten to download the outputs and would like to go “back” and see the results, and if the simulation has not yet been deleted from the system, one can use the Job Number to create a URL with the following pattern (in the example below, the Job Number is “51”, as it has been throughout this example).

```
https://locusts.arl.noaa.gov/display?id=51
```



LINKS

The item that appears at the bottom is the Links box. When the run finishes successfully, this box should be fully populated with links to HYSPLIT input and output files for each day of the simulation (Trajectory, SETUP, CONTROL, and MESSAGE), as well as a link to download all of these files, plus all of the graphics and other files associated with the run in a zip file.



4. Outputs from Single-Swarm Run

When the zipped file of all graphics and diagnostics (for redistribution) is downloaded, it contains the following files. As noted above, all files associated with the swarm simulation

include the run-name (the swarm-name + the Job Number). In the list of files below, this will be simply expressed as “run-name”.

run-name**_progress.txt**

The full contents of the Model Status box outputs that scroll during the simulation. These are primarily diagnostic outputs that may be useful in troubleshooting if unexpected results are obtained.

run-name**_run_setup_summary.txt**

A concise summary of the key swarm specifications set by the user for this simulation, including: run-name, meteorological data used, start location, start date, duration simulation, direction, locust flight time parameters, and vertical motion option used.

run-name**_trajplot.ps**

The output map for the simulation, in postscript format.

run-name**_trajplot.pdf**

The output map for the simulation, in pdf format.

run-name**_trj_001.png**

The output map for the simulation, in png format.

run-name**_MAPTEXT.txt**

The text that appears at the bottom of the output maps.

run-name**_CONTROL.1.txt**, run-name**_CONTROL.2.txt**, …

The HYSPLIT CONTROL file for each day’s trajectory simulation. The CONTROL file is described in the HYSPLIT documentation here.

run-name**_SETUP.1.txt**, run-name**_SETUP.2.txt**, ...

The HYSPLIT SETUP.CFG file for each day’s trajectory simulation. The SETUP.CFG file is described in the HYSPLIT documentation here.

run-name**_MESSAGE.1.txt**, run-name**_MESSAGE.2.txt**, ...

The HYSPLIT MESSAGE file for each day’s trajectory simulation. The MESSAGE file is described in the HYSPLIT documentation here.

run-name**_tdump.1**, run-name**_tdump.2**, ...

The HYSPLIT tdump (trajectory data dump) file for each day's trajectory simulation. The tdump files are described in the HYSPLIT documentation here. Note that these tdump files are the results *after* the web-app has removed the entries after the landing time. These tdump files are the ones used in making the graphical outputs. For a forward run, the last line in the tdump file will show the latitude and longitude of the estimated landing site for that day, for the given simulation. Here is the last line from tdump.1 for the example being discussed here. The latitude and longitude are shown in red font, and the meaning of each of the columns are shown below the line. If more than one starting height was chosen, there will be one trajectory line for each trajectory for each output time step. The tdump file contains position data at 5-minute intervals, and all times reported are UTC (e.g.., see: Universal Time Coordinate).

1	1	20	5	16	14	35	9	9.3	4.837	34.043	497.3	885.5
Traj Num	Grid Num	YY	MM	DD	HH	mm	fore-cast hour	elapsed time (hours)	lat (deg)	long (deg)	height (m-agl)	pressure (mbar)

run-name**_tdump.1.full**, run-name**_tdump.2.full**, ...

The full HYSPLIT tdump (trajectory data dump) file for each day's trajectory simulation *before* the web-app removes the lines after the landing time. The tdump files are described in the HYSPLIT documentation here. These are intermediate files and are only included for diagnostic purposes.

run-name**_HYSPLITtraj.kmz**

The Google Earth file containing all trajectories. This file can be viewed with Google Earth.

run-name**_day*D*.shp** (where *D* = 1, 2, …)

(Optional) These shapefiles are created only when the 'by day' option for GIS file is specified.

The shapefiles for trajectories organized by day number. *D* = 1 is for the first day. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for trajectories.

run-name***_HHHH*m.shp**

(Optional) These shapefiles are created only when the ‘by height’ option for GIS file is specified.

The shapefiles for trajectories organized by vertical height. *HHHH* is a four digit number denoting the starting height in meters. A height less than 1,000 is padded with one or more zeros to fit the four-digit format. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for trajectories.

run-name***_HHHH*m_day*D*.shp** (where *D* = 1, 2, …)

(Optional) These shapefiles are created only when the ‘by each-day height’ option for GIS file is specified.

The shapefiles for trajectories organized by starting vertical height and by day number. *HHHH* is a four digit number denoting the starting height in meters. A height less than 1,000 is padded with one or more zeros to fit the four-digit format. *D* = 1 is for the first day. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for trajectories.

run-name**_landing_pts.shp**

(Optional) This shapefile is created when one or more options for GIS file are specified.

The shapefile for the locations where each swarm trajectory ends. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for plotting landing points.

run-name**_src_locs.shp**

(Optional) This shapefile is created when one or more options for GIS file are specified.

The shapefile for all starting locations for day 1. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for all source points for the first day.

run-name**_takeoff_pts.shp**

(Optional) This shapefile is created when one or more options for GIS file are specified.

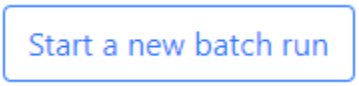
The shapefile for the locations where each swarm trajectory starts. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for plotting takeoff points.

5. Multiple-Swarm (Batch-mode) Simulation

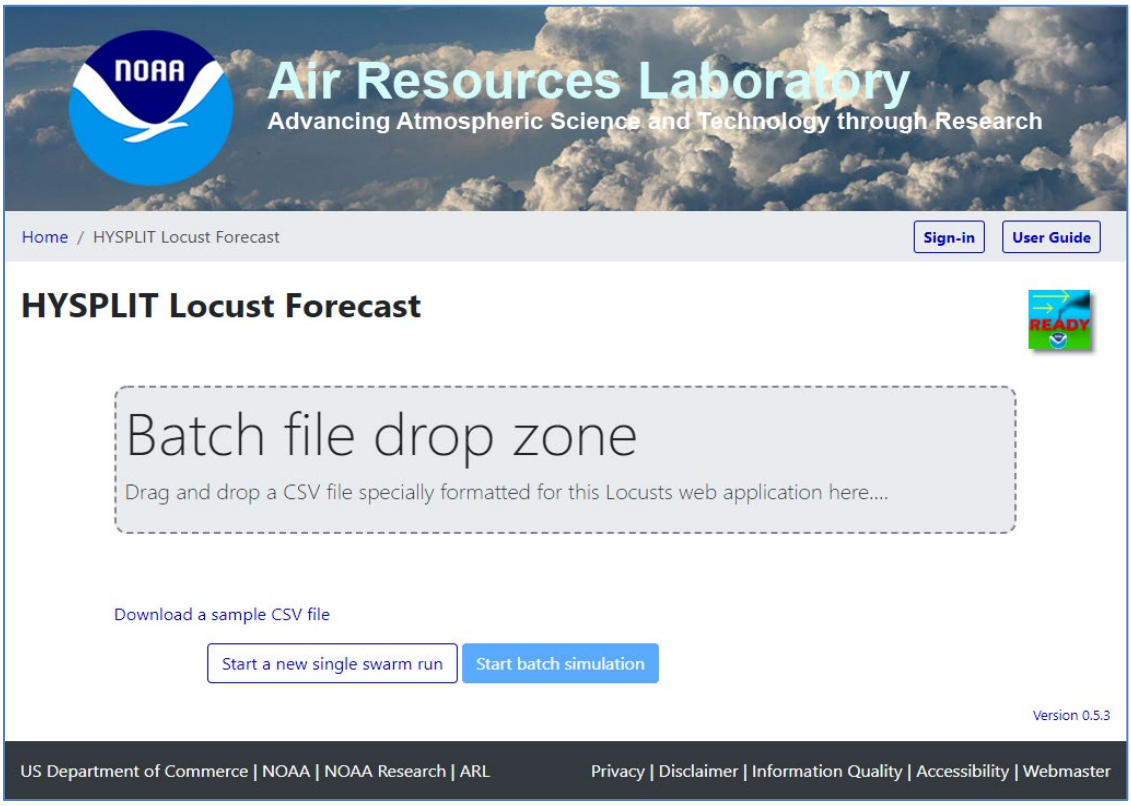
A batch-run functionality is available, in which many swarms can be run at the same time.

Batch-run Input Page

The batch-run input page can be reached from the single-swarm input page or the single-swarm output page, by pressing the button:



This takes you to the batch-run input page:



Carry out a batch-run simulation

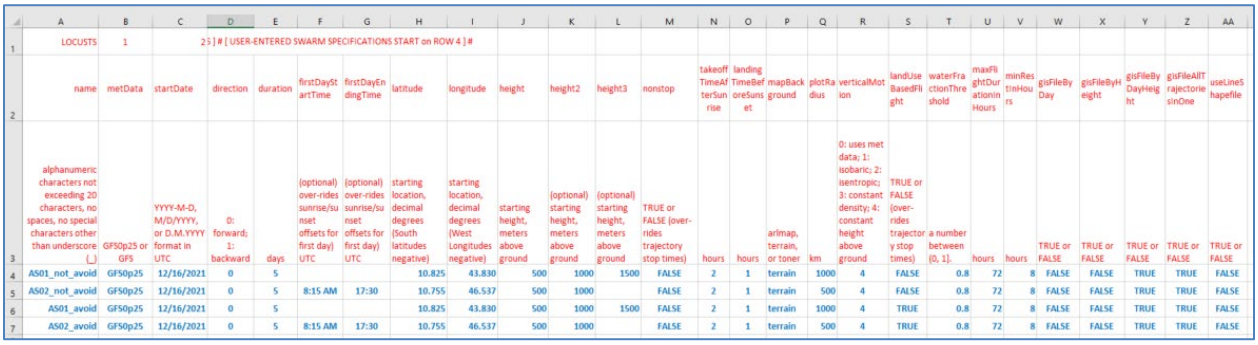
To carry out a batch-run simulation the user drags and drops a specially formatted CSV file into the “Batch file drop zone”.

A sample file is available for download from the “Download a sample CSV file” link. The CSV file can be edited in a spreadsheet like Excel, but must be saved as a CSV file. A

CSV file is a plain-text “Comma Separated Values” file, where each column of data is separated by a comma.

The example screenshot below shows how the CSV looks if it is edited in Excel (or a comparable spreadsheet app). Some formatting has been applied (colored fonts, word-wrapping, etc.) to make the content more readable. Formatting can be done in the spreadsheet file, but a version of the file must be saved as a CSV file for use with the locust batch-processing functionality. When you save the file as a CSV file, any special formatting is lost, as the file is only plain-text. The user may want to save the file as both a CSV file and a spreadsheet file (with formatting) for ease in further work with the template.

The first three lines of the CSV file -- in red text in the screenshot below -- should not be edited, and must be present. User-entered data for each swarm to be simulated begins on the 4th line, and each swarm to be simulated is entered on a different line (2 different swarms are shown in blue text in the screenshot below, on lines 4 and 5). A maximum of 100 swarms can be simulated with the current system.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1	LOCUSTS	1	25] # [USER-ENTERED SWARM SPECIFICATIONS START on ROW 4] #																								
2	name	metData	startDate	direction	duration	firstDaySt artTime	firstDayEn dingTime	latitude	longitude	height	height2	height3	nonstop	takeoff TimeAf terSun rise	landing TimeBef oreSuns et	mapBack ground	plotRa dius	verticalMot ion	landUse BasedFli ght	waterFra ctionThre shold	maxFli ghtDur ationin Hours	minRes tinHou rs	gisFileBy Day	gisFileBy eight	gisFileBy DayHeig ht	gisFileAllT rajectorie sInOne	useLineS hapefile
3	alphanumeric characters not exceeding 20 characters, no spaces, no special characters other than underscore (_)	GFS0p25 or GFS	YYYY-M-D, M/D/YYYY, or D.M.YYYY format in UTC	0: forward; 1: backward	days	(optional) over-rides sunrise/su nset offsets for first day) UTC	(optional) over-rides sunrise/su nset offsets for first day) UTC	starting location, decimal degrees (South latitudes negative)	starting location, decimal degrees (West Longitudes negative)	starting height, meters above ground	(optional) starting height, meters above ground	(optional) starting height, meters above ground	TRUE or FALSE (over-rides trajectory stop times)	hours	hours	arlmap, terrain, or toner	km	0: uses met data; 1: isobaric; 2: isentropic; 3: constant density; 4: constant height above ground	TRUE or FALSE (over-rides trajectory stop times)	a number between (0, 1].	hours	hours	TRUE or FALSE	TRUE or FALSE	TRUE or FALSE	TRUE or FALSE	TRUE or FALSE
4	AS01_not_avoid	GFS0p25	12/16/2021	0	5			10.825	43.830	500	1000	1500	FALSE	2	1	terrain	1000	4	FALSE	0.8	72	8	FALSE	FALSE	TRUE	TRUE	FALSE
5	AS02_not_avoid	GFS0p25	12/16/2021	0	5	8:15 AM	17:30	10.755	46.537	500	1000		FALSE	2	1	terrain	500	4	FALSE	0.8	72	8	FALSE	FALSE	TRUE	TRUE	FALSE
6	AS01_avoid	GFS0p25	12/16/2021	0	5			10.825	43.830	500	1000	1500	FALSE	2	1	terrain	1000	4	TRUE	0.8	72	8	FALSE	FALSE	TRUE	TRUE	FALSE
7	AS02_avoid	GFS0p25	12/16/2021	0	5	8:15 AM	17:30	10.755	46.537	500	1000		FALSE	2	1	terrain	500	4	TRUE	0.8	72	8	FALSE	FALSE	TRUE	TRUE	FALSE

Here is what the CSV-saved version of the above “spreadsheet view” actually looks like in a plain-text editor. This is an example of the actual format of any file that is “dropped” into the batch-file drop zone in the web-app.

```
1  LOCUSTS,1,2,,# [ DO NOT DELETE FIRST 3 ROWS ] # [ USER-ENTERED SWARM SPECIFICATIONS START on ROW 4 ] # ,,,,,,,,,,,,,,,,,,,,,,
2  name,metData,startDate,direction,duration,firstDayStartTime,firstDayEndingTime,latitude,longitude,height,height2,height3,nonstop,takeoffTimeAft
   erSunrise,landingTimeBeforeSunset,mapBackground,plotRadius,verticalMotion,landUseBasedFlight,waterFractionThreshold,maxFlightDurationInHours,mi
   nRestInHours,gisFileByDay,gisFileByHeight,gisFileByDayHeight,gisFileAllTrajectoriesInOne,useLineShapefile
3  "alphanumeric characters not exceeding 20 characters, no spaces, no special characters other than underscore (_)",GFS0p25 or GFS,"YYYY-M-D,
   M/D/YYYY, or D.M.YYYY format in UTC",0: forward; 1: backward,days,(optional) over-rides sunrise/sunset offsets for first day) UTC,(optional)
   over-rides sunrise/sunset offsets for first day) UTC,"starting location, decimal degrees (South latitudes negative)","starting location,
   decimal degrees (West Longitudes negative)","starting height, meters above ground","(optional) starting height, meters above
   ground","(optional) starting height, meters above ground",TRUE or FALSE (over-rides trajectory stop times),hours,hours,"arlmap, terrain, or
   toner",km,0: uses met data; 1: isobaric; 2: isentropic; 3: constant density; 4: constant height above ground,TRUE or FALSE (over-rides
   trajectory stop times),"a number between (0, 1].",hours,hours,TRUE or FALSE,TRUE or FALSE,TRUE or FALSE,TRUE or FALSE,TRUE or FALSE,TRUE or FALSE
4  AS01_not_avoid,GFS0p25,12/16/2021,0,5,,,10.825,43.830,500,1000,1500,FALSE,2,1,terrain,1000,4,FALSE,0.8,72,8,FALSE,FALSE,TRUE,TRUE,FALSE
5  AS02_not_avoid,GFS0p25,12/16/2021,0,5,8:15 AM,17:30,10.755,46.537,500,1000,,FALSE,2,1,terrain,500,4,FALSE,0.8,72,8,FALSE,FALSE,TRUE,TRUE,FALSE
6  AS01_avoid,GFS0p25,12/16/2021,0,5,,,10.825,43.830,500,1000,1500,FALSE,2,1,terrain,1000,4,TRUE,0.8,72,8,FALSE,FALSE,TRUE,TRUE,FALSE
7  AS02_avoid,GFS0p25,12/16/2021,0,5,8:15 AM,17:30,10.755,46.537,500,1000,,FALSE,2,1,terrain,500,4,TRUE,0.8,72,8,FALSE,FALSE,TRUE,TRUE,FALSE
```

Only certain date formats are currently accepted by the app, and the user may have to adjust the formatting of dates in the spreadsheet app being used, or these can be adjusted by editing the CSV file in a text editor. The three acceptable date formats for the UTC Start Date (column 3) are:

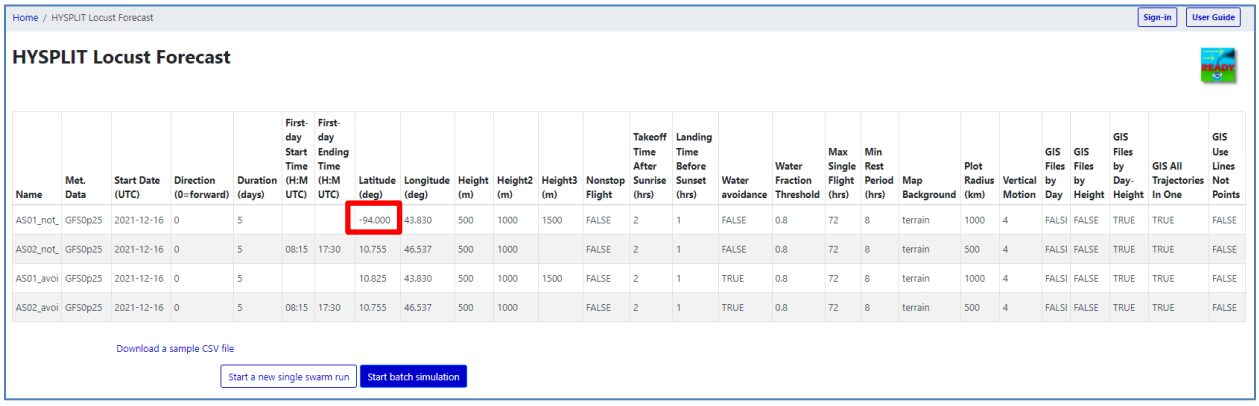
YYYY-M-D - e.g., 2020-05-17

M/D/YYYY - e.g., 5/17/2020

D.M.YYYY - e.g., 17.5.2020

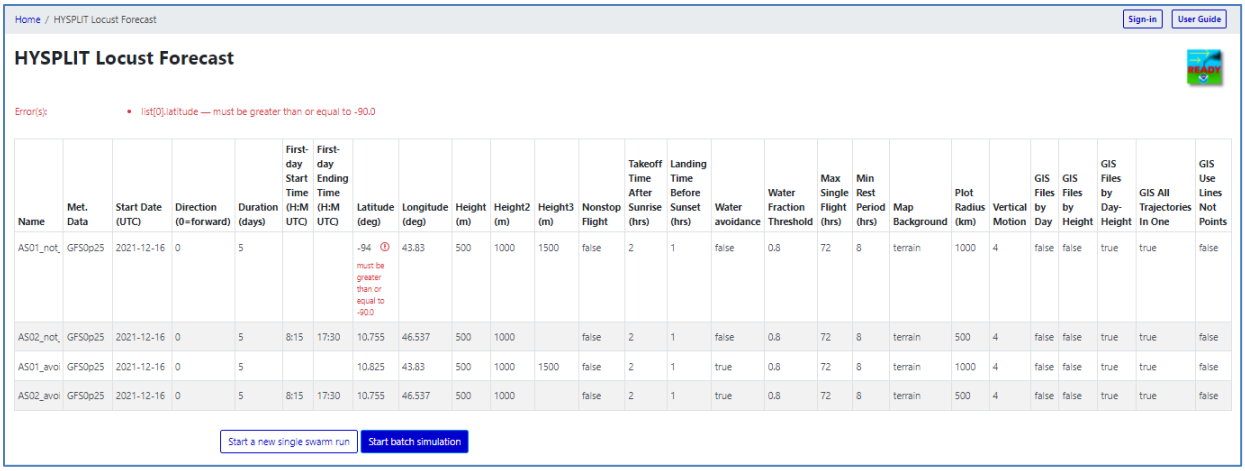
The CSV file is prepared by the user, with one line for each swarm to be simulated. At the current time, there is a maximum of 100 swarms that can be run at the same time.

Once the CSV file is “dropped” into the app, a table is displayed showing the inputs specified in the CSV file for each swarm. In the example below, we have purposely introduced an error in the latitude for the 1st swarm: the latitude is set to -94 degrees, a value outside of the acceptable range. The erroneous latitude is enclosed by a red rectangle for visual identification. The purpose of this intentional error is to show what happens when one tries to run the batch when there is one or more errors.

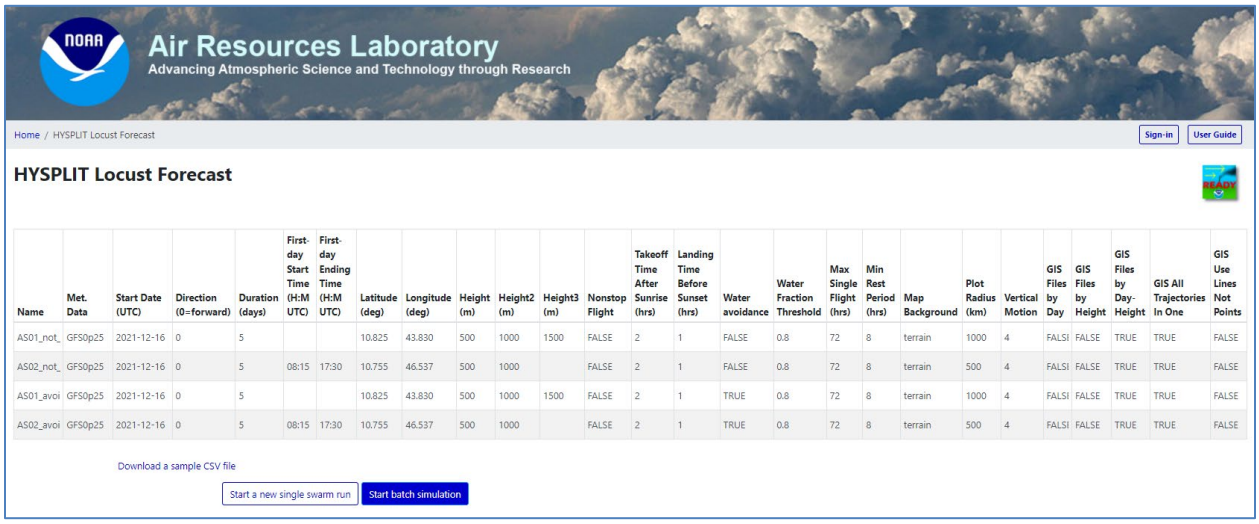


Name	Met. Data	Start Date (UTC)	Direction (0=forward)	Duration (days)	First-day Start Time (H:M UTC)	First-day Ending Time (H:M UTC)	Latitude (deg)	Longitude (deg)	Height (m)	Height2 (m)	Height3 (m)	Nonstop Flight	Takeoff Time After Sunrise (hrs)	Landing Time Before Sunset (hrs)	Water avoidance	Water Fraction Threshold	Max Single Flight (hrs)	Min Rest Period (hrs)	Map Background	Plot Radius (km)	Vertical Motion	GIS Files by Day	GIS Files by Height	GIS Files by Day-Height	GIS All Trajectories In One	GIS Use Lines Not Points
AS01_not_	GFS0p25	2021-12-16	0	5			-94.000	43.830	500	1000	1500	FALSE	2	1	FALSE	0.8	72	8	terrain	1000	4	FALSI	FALSE	TRUE	TRUE	FALSE
AS02_not_	GFS0p25	2021-12-16	0	5	08:15	17:30	10.755	46.537	500	1000		FALSE	2	1	FALSE	0.8	72	8	terrain	500	4	FALSI	FALSE	TRUE	TRUE	FALSE
AS01_avoi	GFS0p25	2021-12-16	0	5			10.825	43.830	500	1000	1500	FALSE	2	1	TRUE	0.8	72	8	terrain	1000	4	FALSI	FALSE	TRUE	TRUE	FALSE
AS02_avoi	GFS0p25	2021-12-16	0	5	08:15	17:30	10.755	46.537	500	1000		FALSE	2	1	TRUE	0.8	72	8	terrain	500	4	FALSI	FALSE	TRUE	TRUE	FALSE

Then, the “START batch simulation” button can be pushed. If there is an error in one or more of the inputs, this will be indicated. In this initial example, the latitude for the first swarm was -94. This is an invalid input because the latitude must be between -90 and 90. If this occurs, the user must edit the CSV file to fix the error, and then re-drop it in the batch-file drop zone. If there are no errors found by the app, the batch-run simulation will commence.



Here is the screenshot of the table displayed after the CSV file was edited to change the offending latitude to a valid number (in this case, changed from -94 to 10.825, for the 1st swarm).

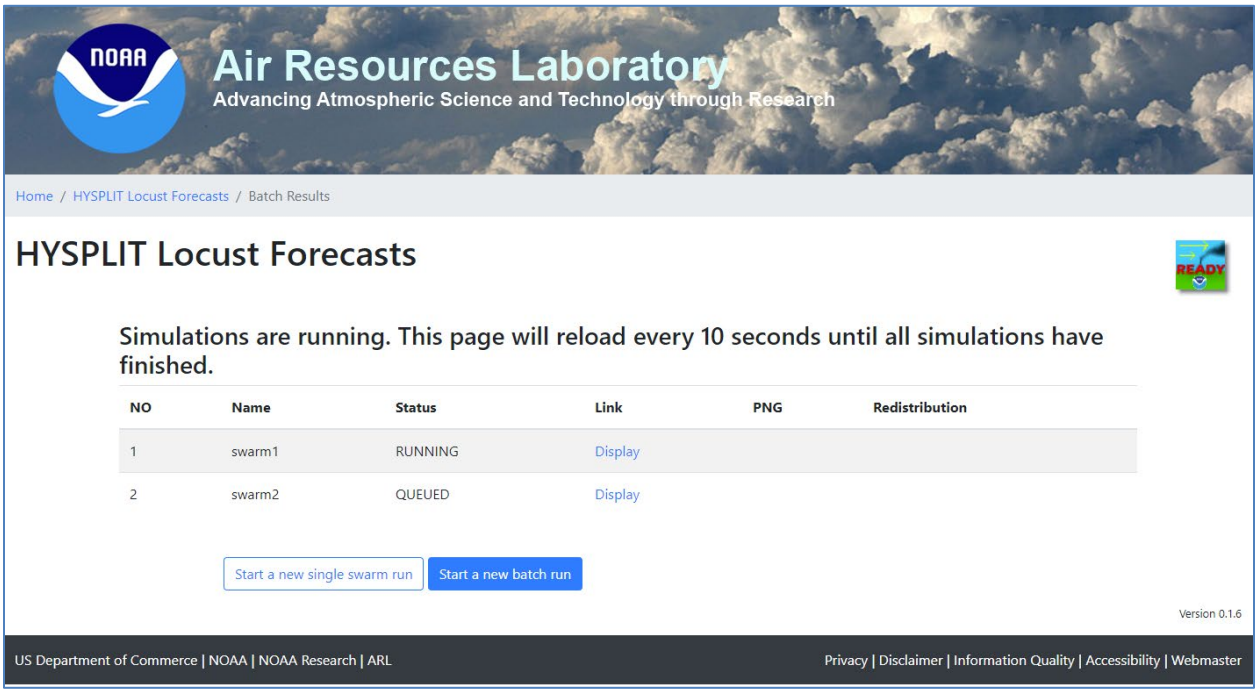


As noted above, if there are no errors found by the app, the batch-run simulation will commence.

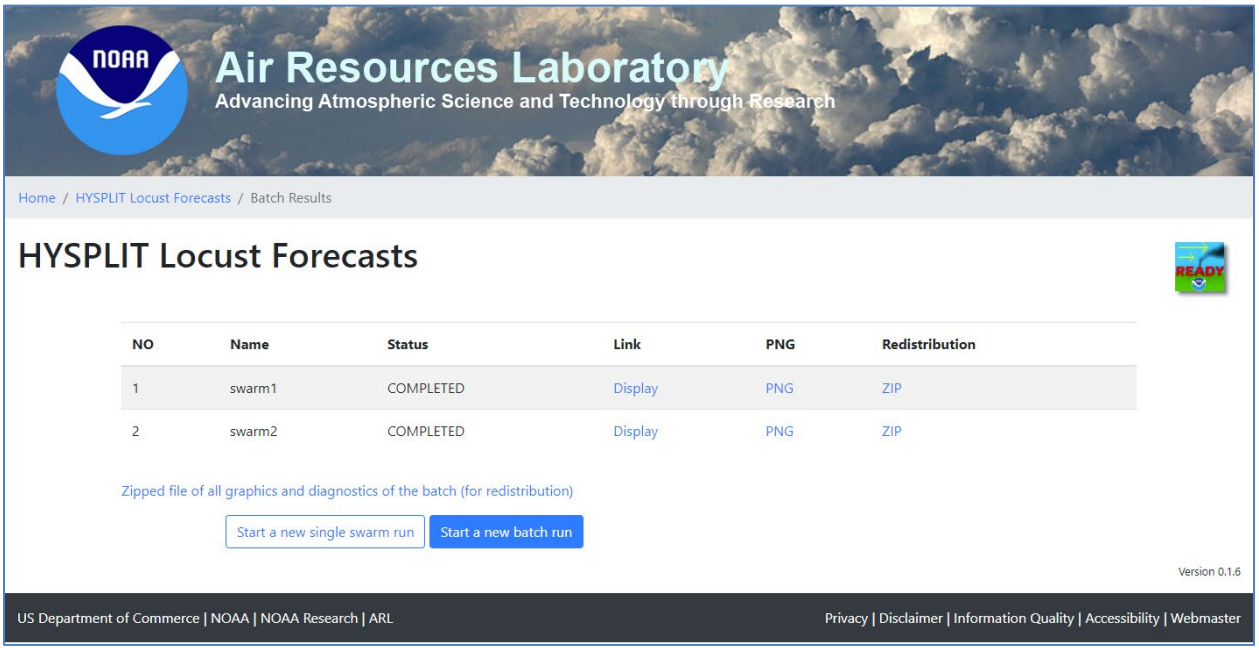
Screen outputs during batch-run simulations

During execution of the batch run, the user will see the status of each swarm as being either RUNNING, QUEUED, or COMPLETED.

In the first screenshot, below, the first swarm is being run, and the 2nd swarm is queued (i.e., waiting to run).



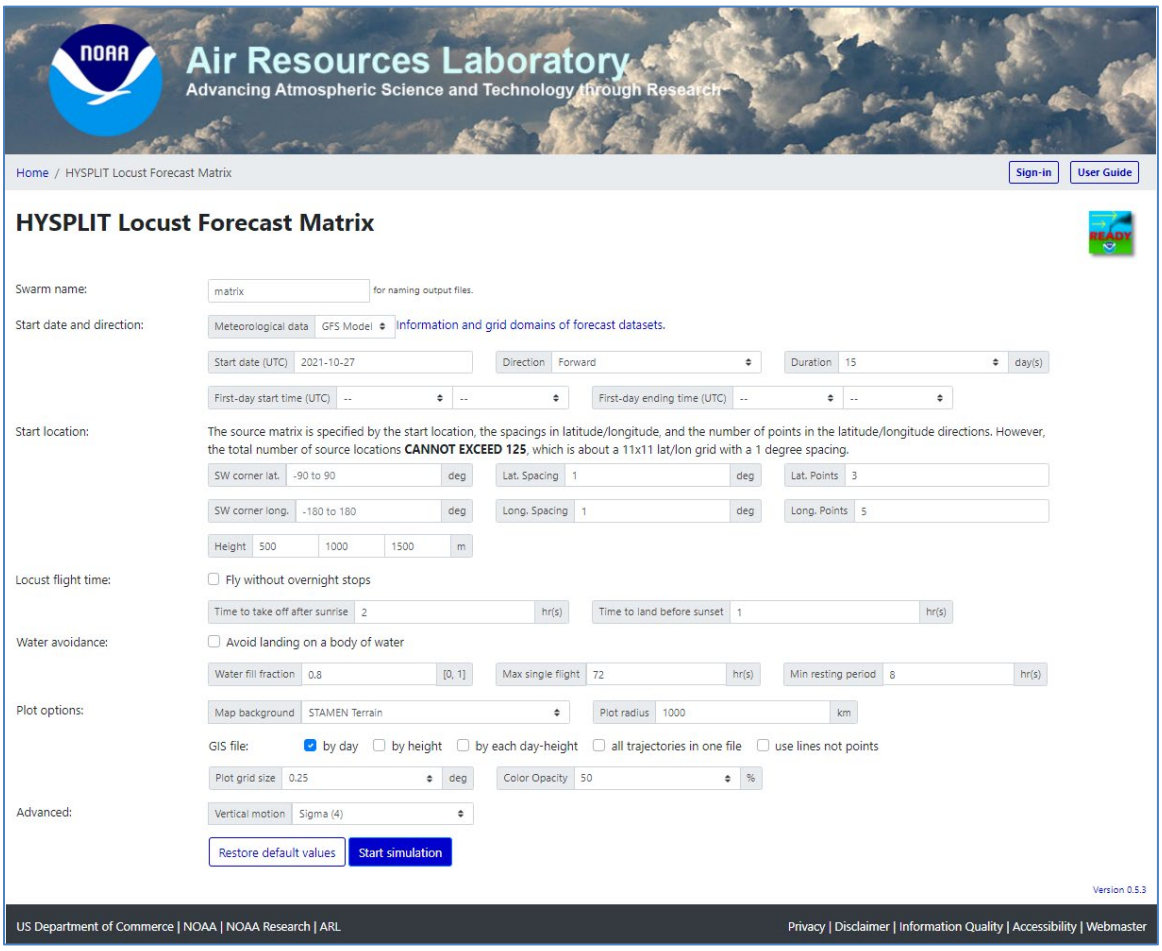
In the next screenshot, below, both swarms are now completed. The user can look at the run-time output display for a given swarm, the PNG map of a given swarm, or download the full set of output files for a given swarm. The user can also download a full set of output files for all of the swarms in a single zip file.



Output Files from Batch-Run Simulations

The same files as described above for the single-swarm runs are provided for each swarm run in batch mode. When a single zip file is downloaded with the results, all of the output files are included in a single folder. This was done so that the user can easily see all of the graphics file (e.g., all of the png output maps) without having to move from one folder to another. Also, if the shapefiles are imported into a GIS system, they can be imported easily without having to switch among folders for each individual swarm.

6. Matrix Run Specification Page



Swarm name

Enter the user-defined swarm name in this box. All output files from this simulation will have that swarm name associated with them. The name must consist only of

alphanumeric characters (not exceeding 20 characters), and there can be no spaces or any special characters other than underscore (_). Example: *Kenya_A_05_14_2020*

Start date and direction

Meteorological data: The user can select either the default GFS Model 0.25º (Global) dataset or the GFS Model 1.0º degree (Global) dataset. The 0.25º dataset has a horizontal resolution of ~25 km, and supports forecasts up to 3 days into the future. The 1.0º dataset has a horizontal resolution of ~100 km and supports forecasts up to 15 days in the future. Additional information on these forecast data sets is available. For simulations (or parts of simulations) that occur in the past, a quasi-analysis version of the GFS Model output is used. In this quasi-analysis version, initial-time-step results are saved from each forecast, and these short-term, more highly accurate results are patched together to make a continuous dataset. Information about the 1.0º quasi-analysis dataset is available here, and information about the 0.25º quasi-analysis dataset is available here.

Start date (UTC): Selectable in a drop-down calendar, the day you would like the simulation to start, in Universal Time Coordinates (UTC). The default start date is the current date.

Direction: Select Forward (default) or Backward.

Duration: The number of days you would like the simulation to be for. The user can select 1,2,3,5,7,10, or 15 days from the drop-down menu. As noted above, if 0.25º GFS data are used, a maximum of 3 days in the future can be simulated. If 1.0º GFS data are used, the simulation can be carried out for up to 15 days into the future. The default duration is 15 days for a matrix run.

First-day start time (UTC): (optional) The user can enter the UTC hour and minute of the locust take-off time, and this will over-ride any sunrise-offset take-off time set below *for the first day of the simulation*. For subsequent days of the simulation, the sunrise-offset set below is used. This can be used, for example, in the special case where local knowledge of the actual swarm take-off time exists. The default is for this not to be specified.

First-day ending time (UTC): (optional) The user can enter the UTC hour and minute of the locust landing time, and this will over-ride any sunset-offset landing time set below *for the first day of the simulation*. For subsequent days of the simulation, the sunset-offset set below is used. This can be used, for example, in the special case where local knowledge of the actual swarm landing time exists, and this setting might be particularly useful for backward simulations from that particular landing time. The default is for this not to be specified.

Start Location

Source locations will be evenly spaced within a rectangle (or a source matrix) using six input parameters described below. Note that the number of source locations (excluding heights) cannot exceed 125.

SW corner lat.: The latitude of the southwest corner of the source matrix. It is a starting location for the first day of the simulation (decimal degrees). North latitudes are positive (e.g., 3.5) and South latitudes are negative (e.g., -3.5), and thus, the value must be between -90 to 90 degrees.

SW corner long.: The longitude of the southwest corner of the source matrix. It is a starting location for the first day of the simulation (decimal degrees). East longitudes are positive (e.g., 3.5) and West longitudes are negative (e.g., -3.5), and thus, the value must be between -180 and 180 degrees.

Lat. Spacing: Spacing in latitude between two vertically adjacent starting locations. The value must be in the range (0, 10] degrees excluding zero. The default value is 1.

Long. Spacing: Spacing in longitude between two horizontally adjacent starting locations. The value must be in the range (0, 10] degrees excluding zero. The default value is 1.

Lat. Points: Number of starting locations in the latitude direction, at a fixed longitude. This number times the corresponding number in the longitude direction cannot exceed 125.

Long. Points: Number of starting locations in the longitude direction, at a fixed latitude. This number times the corresponding number in the latitude direction cannot exceed 125.

Height: Starting height, in meters above ground level, for each day of the simulation. The default vertical motion is to fly at a constant height above ground level (see Vertical Motion Option below), and if this default setting is used, the swarms are assumed to fly at these initial heights for their entire flight. The user can optionally unset a 3rd and even a 2nd height here as well. Since wind speed and direction can vary with height, the choice of starting height will generally make a difference in the forecast swarm paths. The default setting is for three starting heights of 500 m, 1000 m, and 1500 m above ground level to be specified.

Locust Flight Time

Fly without overnight stops: If this box is checked, the swarms are assumed to fly continuously without stopping, once they have taken off, for the duration of the simulation. This may be useful in situations where the swarms are crossing a large body

of water and the user knows they will not choose to land in the water. The default is for this box *not* to be checked.

Time to take off after sunrise: The user enters the time (in hours) that the swarms are estimated to take off, after the local sunrise time. The default is 2 hours.

Time to land before sunset: The user enters the time (in hours) that the swarms are estimated to land, before the local sunset time. The default is 1 hour.

Water avoidance

Avoid landing on a body of water: If this box is checked, the application uses the following three parameters for the swarms to avoid landing over a body of water.

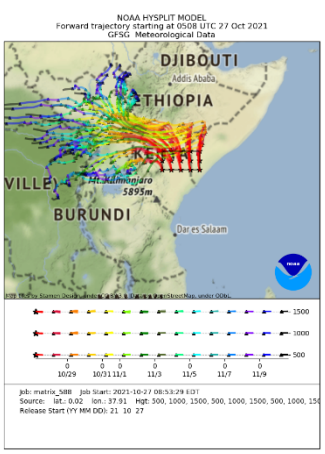
Water fill fraction: This parameter specifies the threshold water fill fraction of a given landuse / landcover grid cell above which landing in the cell will be avoided. The idea here is that cells on the coast or which contain islands may have some water, but also some land, and the user can specify how much “water” must fill the cell before it is avoided. The application currently uses a 0.05 degree grid size (~5 km) for an extended northern Africa domain and a 0.5 degree grid (~50 km) elsewhere in the world. The default is 0.8, but the user can pick any value from 0 to 1. With the default of 0.8, the cell is avoided if more than 80% of the 5 km x 5 km cell in northern Africa or 80% of the 50 km x 50 km cell elsewhere is water-filled.

Max single flight: This parameter specifies the number of hours that a swarm can fly without landing. If this flight time is reached, and the swarm has not encountered a cell with land, it will land in the water. The application tracks this water landing, but then does not allow the swarm to continue. It is as if the swarm ended when it landed on the water. The default value of the parameter is 72 hours, but the user can select any number of hours from 0 to 240.

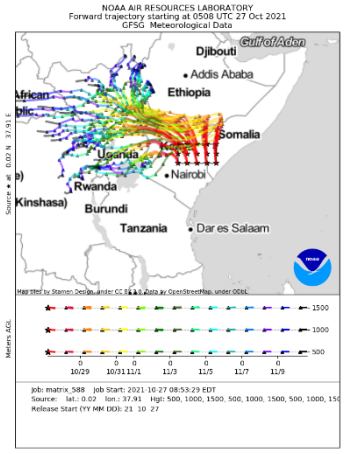
Min resting period: This parameter specifies the minimum resting period (in hours) that a swarm must be allowed, once it lands on a non-water surface, before it is allowed to take off again. The default value is 8 hours, but the user can select any number of hours from 0 to 72.

Plot Options

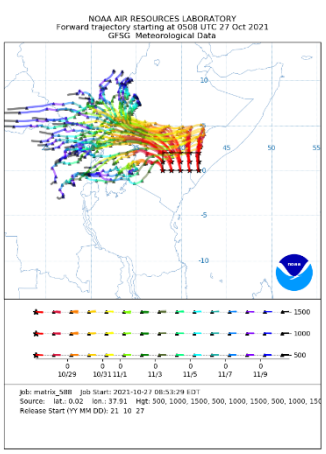
Map background: There are three choices here, and the default is the “STAMEN Terrain” background. Examples of the three types of map backgrounds are shown below. The STAMEN backgrounds are from http://maps.stamen.com/, while the ARL Map background uses the basic HYSPLIT map background graphics.



STAMEN Terrain



STAMEN Toner



ARL Map

Plot radius: The map output is centered on the start location and extends out this distance in each cardinal direction (North, South, East, and West). The default is 1000 km. For longer-duration simulations (or if there are faster wind-speeds), this may need to be increased to show the entire flight path on the map. For shorter-duration simulations (or if there are slower wind-speeds), the user may wish to reduce this radius to create a more zoomed-in view of the flight path. In the above examples, a 1000-km plot radius was used for a 3-day simulation.

GIS file: Shapefile and associated files can be imported into a GIS application for custom plots. There are five mutually inclusive options that control how GIS files are produced.

> **by day:** GIS files are created for each day for the duration of the run. All trajectories for a given date will be gathered into one shapefile ending _dayD.* where D = 1, 2, 3, … denotes the day number.
>
> **by height:** GIS files are created for each starting height. Trajectories at a starting height will be gathered into one shapefile ending _HHHHm.* where HHHH is the starting height in meters.
>
> **by each day-height:** GIS files are created for each day and by each starting height. Trajectories for a given date and at a starting height will be gathered into one shapefile ending _HHHHm_dayD.* where HHHH is the starting height in meters and D = 1, 2, 3, … is the day number.
>
> **all trajectories in one file:** One shapefile (and its associated files) will be created for this option.
>
> **use lines not points:** If this option is checked, shapefiles will be created treating endpoints of a trajectory as a point on line. Shapefiles with lines may be convenient to work with as a style change for a line applies to all points of a trajectory.

Plot grid size: This option specifies the spatial resolution in degrees for trajectory frequency and time-of-arrival analyses and their respective plots. The value must be in the range (0, 2] degrees excluding zero. The default is 0.25 degrees.

Color Opacity: The option is used to set the opacity (or transparency) of colors when coloring trajectories, trajectory frequencies, time-of-arrivals, etc. The color opacity can run from 0% (fully transparent or fully seeing through) to 100% (fully opaque or fully blocking the background). The default value is 50%.

Advanced

Vertical motion option: There are five options that can be chosen. The default is option #4 which specifies that the locusts are assumed to stay at the same height above the ground during their entire flight, until landing. With this option, the starting height set above -- in meters above the ground -- is the flying height throughout the simulation.

Here are all of the options:

0: Uses vertical velocities estimated from the meteorological data set. This setting is often used In air-pollution simulations with HYSPLIT, but is not considered the default for the flight of locusts.

1: Isobaric -- vertical height during flight is adjusted so that the locusts encounter the same pressure throughout the flight as when they started.

2: Isentropic -- vertical height during flight is adjusted so that the locusts encounter the same entropy throughout the flight as when they started.

3: Constant Density -- vertical height during flight is adjusted so that the locusts encounter the same air density throughout the flight as when they started.

4: Constant Height above the ground -- vertical height during flight is kept the same as the starting height, in meters above ground level. This is the same as the “constant-sigma” option in HYSPLIT.

Restore Default values

Pressing this button will restore all inputs to their default values on the matrix run specification page.

Start Simulation

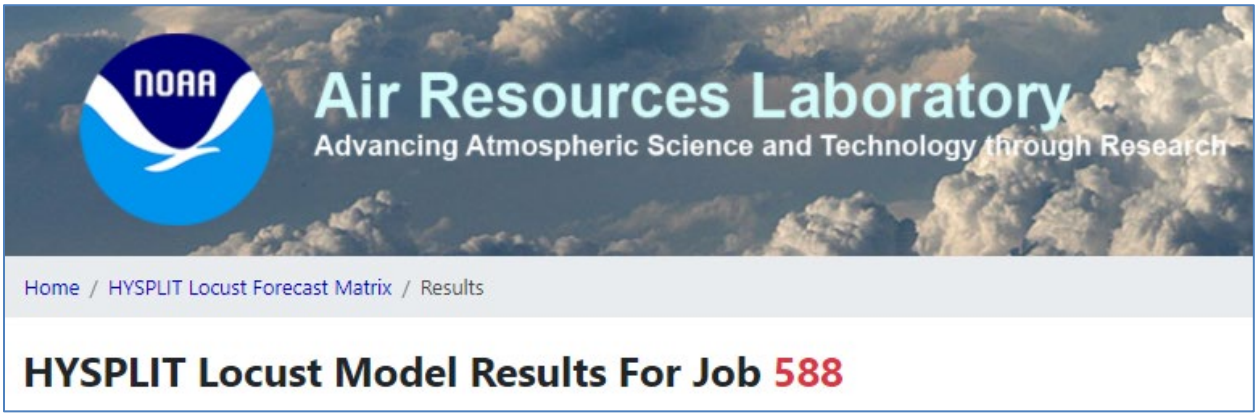
Pressing this button will start the simulation based on the current inputs specified. If there are errors in any of the inputs, or if any required fields are not set, an error message will be displayed. If the inputs are acceptable, and the run is proceeding as expected, one will soon begin to see the “run-time screen outputs” described in the next section.

7. Screen Outputs During Matrix Run

The following elements are displayed on the screen during a successful matrix simulation. Not all elements occur immediately, and some are updated throughout the run. The run has finished successfully when the link to a "Zipped file of all graphics and diagnostics (for redistribution)" is displayed at the bottom of the output, in the Links section, as described below.

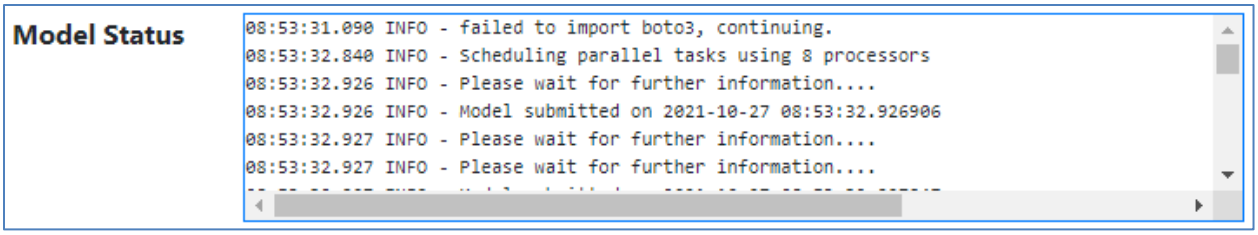
JOB NUMBER

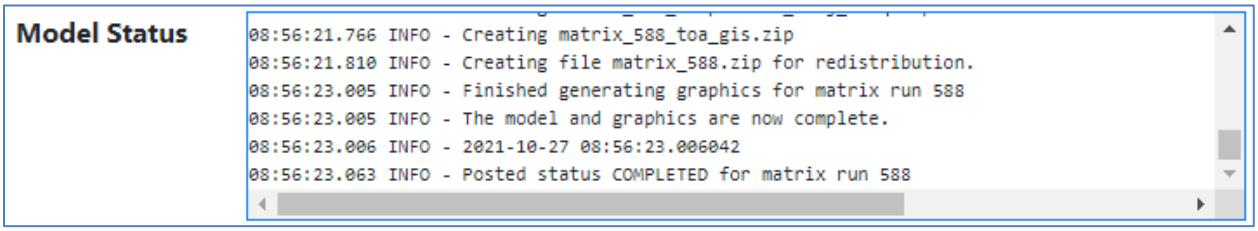
The first item that appears is a title screen that shows the "Job Number" for this particular simulation. This job number is set by the system, but is associated with all of the output files for the simulation. In the examples below, the swarm name chosen was ***matrix*** and the **run-name** is constructed by appending the Job Number (in this example: ***588***) to this swarm name, i.e., in this case, ***matrix_588***. All output files have this run-name associated with them. For example, the png time-of-arrival output has the file name ***matrix_588_toa.png***



MODEL STATUS

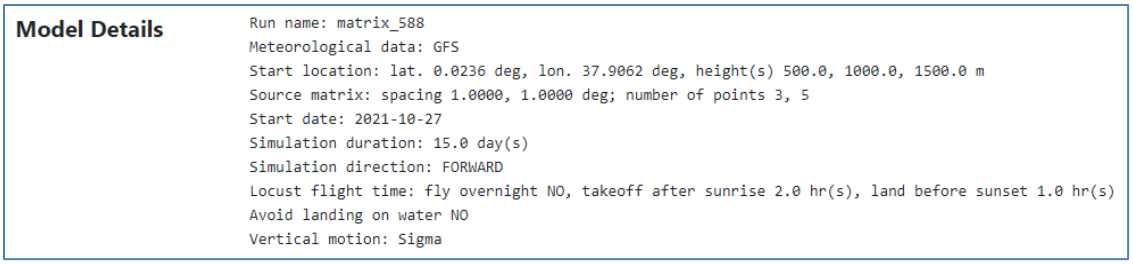
The second item that appears is the Model Status box that scrolls through various intermediate screen outputs as the simulation proceeds. The full contents of this "Model Status" box is included in the run outputs as ***run-name_progress.txt***. In the example shown here, the file name in the outputs would be called ***matrix_588_progress.txt***





MODEL DETAILS

The third item that appears is the Model Details box. This is simply a concise summary of the key matrix specifications set by the user for this simulation. The full contents of this “Model Status” box is included in the run outputs as ***run_name_run_setup_summary.txt***. In the example shown here, the file name in the outputs would be called ***matrix_51_run_setup_summary.txt***



RESULTS

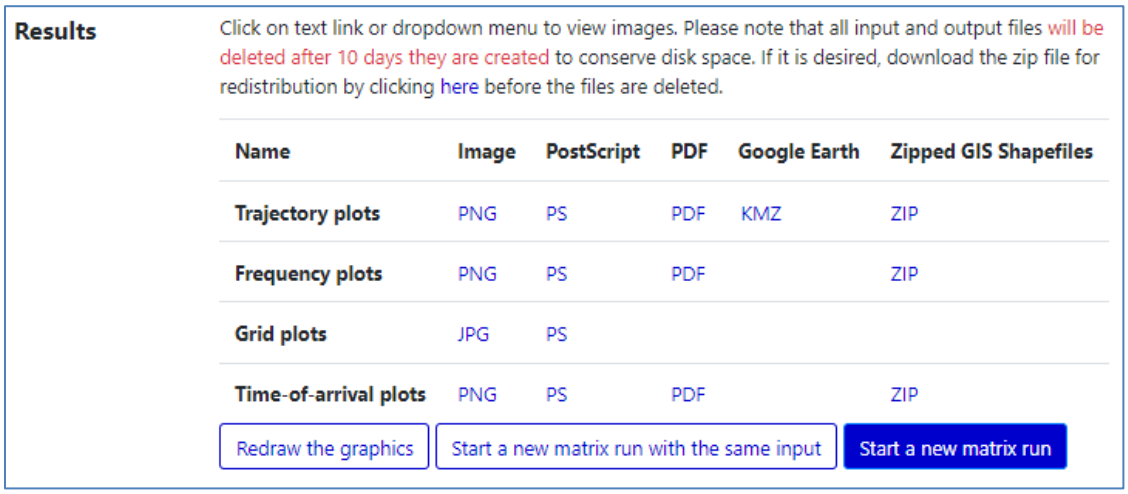
The fourth item that appears is the Results box. When the run finishes successfully, this box should be fully populated with links as shown in the example below. One can click on the “PNG” link to quickly see the map output from the simulation. In this section of the

screen output, one can also **Start a new matrix run** or, if desired, **Redraw the graphics** or **Start a new matrix run with the same input**.

Note: if it is desired to save all of the output files associated with this run, it is recommended that the user click on the link in the section below to download the **Zipped file of all graphics and diagnostics (for redistribution)**

Simulation results are available on the system for a short time. If one has forgotten to download the outputs and would like to go "back" and see the results, and if the simulation has not yet been deleted from the system, one can use the Job Number to create a URL with the following pattern (in the example below, the Job Number is "588", as it has been throughout this example).

```
https://locusts.arl.noaa.gov/matrixdisplay?id=588
```



LINKS

The item that appears at the bottom is the Links box. When the run finishes successfully, this box should be populated with the link to a "Zipped file of all graphics and diagnostics (for redistribution)."

8. Outputs from Matrix Run

When the zipped file of all graphics and diagnostics (for redistribution) is downloaded, it contains the following files. As noted above, all files associated with the swarm simulation

include the run-name (the swarm-name + the Job Number). In the list of files below, this will be simply expressed as “run-name”.

run-name**_freq.png,** run-name**_freq.pdf,** run-name**_freq.ps**

The trajectory frequency map for the simulation, in png format, in pdf format, and in postscript format.

run-name**_gridplot.jpg,** run-name**_gridplot.ps**

The grid plot for the simulation, in jpg format and in postscript format.

run-name**_infile**

The text file listing all trajectory dump files. This file can be used by the trajplot program.

run-name**_MAPTEXT.txt**

The text that appears at the bottom of the output maps.

run-name**_progress.txt**

The full contents of the Model Status box outputs that scroll during the simulation. These are primarily diagnostic outputs that may be useful in troubleshooting if unexpected results are obtained.

run-name**_run_setup_summary.txt**

A concise summary of the key swarm specifications set by the user for this simulation, including: run-name, meteorological data used, start locations, start date, duration simulation, direction, locust flight time parameters, and vertical motion option used.

run-name**_toa.png,** run-name**_toa.pdf,** run-name**_toa.ps**

The time-of-arrival map for the simulation, in png format, in pdf format, and in postscript format.

run-name**_trajplot.pdf,** run-name**_trajplot.ps**

The output map for the simulation, in pdf format and in postscript format.

run-name**_trj_001.png**

The output map for the simulation, in png format.

run-name**_trjfreq.bin**

The trajectory frequency data file in binary format.

hysplit/run-name**_*S*_CONTROL.*D*.txt** (where *S*, *D* = 1, 2, …)

The HYSPLIT CONTROL file for each day's trajectory simulation. *S* and *D* in the filename denote the source location number and the day number, respectively. *S* runs from 1 to *M* x *N* x *H* where *M*, *N*, and *H* are the number of source locations in latitude, in longitude, and in vertical height. The CONTROL file is described in the HYSPLIT documentation here.

hysplit/run-name**_*S*_SETUP.*D*.txt** (where *S*, *D* = 1, 2, …)

The HYSPLIT SETUP.CFG file for each day's trajectory simulation. *S* and *D* in the filename denote the source location number and the day number, respectively. *S* runs from 1 to *M* x *N* x *H* where *M*, *N*, and *H* are the number of source locations in latitude, in longitude, and in vertical height. The SETUP.CFG file is described in the HYSPLIT documentation here.

hysplit/run-name**_ *S*_MESSAGE.*D*.txt** (where *S*, *D* = 1, 2, …)

The HYSPLIT MESSAGE file for each day's trajectory simulation. *S* and *D* in the filename denote the source location number and the day number, respectively. *S* runs from 1 to *M* x *N* x *H* where *M*, *N*, and *H* are the number of source locations in latitude, in longitude, and in vertical height. The MESSAGE file is described in the HYSPLIT documentation here.

hysplit/run-name**_*S*_tdump.*D*** (where *S*, *D* = 1, 2, …)

The HYSPLIT tdump (trajectory data dump) file for each day's trajectory simulation. *S* and *D* in the filename denote the source location number and the day number, respectively. *S* runs from 1 to *M* x *N* x *H* where *M*, *N*, and *H* are the number of source locations in latitude, in longitude, and in vertical height. The tdump files are described in the HYSPLIT documentation here. Note that these tdump files are the results *after* the web-app has removed the entries after the landing time. These tdump files are the ones used in making the graphical outputs. For a forward run, the last line in the tdump file will show the latitude and longitude of the estimated landing site for that day, for the given simulation. Here is the last line from tdump.1 for the example being discussed here. The latitude and longitude are shown in red font, and the meaning of each of the columns are shown below the line. If more than one starting height was chosen, there will be one trajectory line for each trajectory for each output time step. The tdump file contains position data at 5-minute intervals, and all times reported are UTC (e.g.., see: Universal Time Coordinate).

```
   1      1    20     5    16    14    35      9        9.3     4.837    34.043     497.3     885.5
Traj   Grid    YY    MM    DD    HH    mm   fore-  elapsed       lat      long    height  pressure
 Num    Num                                 cast     time       (deg)     (deg)   (m-agl)    (mbar)
                                          hour   (hours)
```

hysplit/run-name_***S***_tdump.***D***.full (where *S*, *D* = 1, 2, …)

The full HYSPLIT tdump (trajectory data dump) file for each day's trajectory simulation *before* the web-app removes the lines after the landing time. *S* and *D* in the filename denote the source location number and the day number, respectively. *S* runs from 1 to *M* x *N* x *H* where *M*, *N*, and *H* are the number of source locations in latitude, in longitude, and in vertical height. The tdump files are described in the HYSPLIT documentation here. These are intermediate files and are only included for diagnostic purposes.

shapefiles_traj_freq/run-name_**grid.shp**

The shapefile for trajectory frequency. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, and **.shx**) in the same subdirectory can be imported into a GIS application for trajectory frequency.

shapefiles_toa/run-name_**landing_pts.shp**

The shapefile for the locations where each swarm trajectory ends. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for plotting landing points.

shapefiles_toa/run-name_**src_bbox.shp**

The shapefile for the bounding box of all starting locations for day 1. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for the box enclosing all source points for the first day.

shapefiles_toa/run-name_**src_locs.shp**

The shapefile for all starting locations for day 1. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for all source points for the first day.

shapefiles_toa/run-name**_takeoff_pts.shp**

The shapefile for the locations where each swarm trajectory starts. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for plotting takeoff points.

shapefiles_toa/run-name**_toa_gis.shp**

The shapefile for the time-of-arrival (in days) plot. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for plotting time-of-arrival.

shapefiles_traj_day/run-name**_day*D*.shp** (where *D* = 1, 2, …)

(Optional) These shapefiles are created only when the 'by day' option for GIS file is specified.

The shapefiles for trajectories organized by day number. *D* = 1 is for the first day. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for trajectories.

shapefiles_traj_height/run-name**_*HHHH*m.shp**

(Optional) These shapefiles are created only when the 'by height' option for GIS file is specified.

The shapefiles for trajectories organized by vertical height. *HHHH* is a four digit number denoting the starting height in meters. A height less than 1,000 is padded with one or more zeros to fit the four-digit format. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for trajectories.

shapefiles_traj_height_day/run-name**_*HHHH*m_day*D*.shp** (where *D* = 1, 2, …)

(Optional) These shapefiles are created only when the 'by each-day height' option for GIS file is specified.

The shapefiles for trajectories organized by starting vertical height and by day number. *HHHH* is a four digit number denoting the starting height in meters. A height less than 1,000 is padded with one or more zeros to fit the four-digit format. *D* = 1 is for the first day. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for trajectories.

shapefiles_traj_aggregated/run-name**_all_trajs.shp**

(Optional) This shapefile is created only when the 'all trajectories in one file' option for GIS file is specified.

This shapefile contains all trajectories obtained from the matrix run. This file (ending with **.shp**) and associated files (ending with **.dbf**, **.prj**, **.shx**, **.att**, and **.txt**) in the same subdirectory can be imported into a GIS application for trajectories.

9. Examples of Water Landing Avoidance Functionality

A new water-landing-avoidance feature was added to the application version 0.5.3 released in January 2022. As a result, new user-input parameters were added to the single-swarm, batch, and matrix simulations. An illustration of these new parameters is shown in Figure 9.1 below, for the single-swarm run setup. The new water-landing-avoidance parameters are in the red box.

The user can enable this new feature, or not. If not enabled, the application reverts to the previous behavior in which water landings are allowed, and the takeoffs and landings are only governed by the time schedule set by the user. If the new feature is enabled – i.e., as shown in the example by checking the appropriate box – then three additional parameters must be specified.

The "Water fill fraction" parameter specifies the threshold water fill fraction of a given landuse / landcover grid cell above which landing in the cell will be avoided. The idea here is that cells on the coast or which contain islands may have some water, but also some land, and the user can specify how much "water" must fill the cell before it is avoided. The application currently uses a 0.05 degree grid size (~5 km) for northern Africa (spanning from latitude = -20.30° to 41.90° and from longitude = -24.35° to 62.45°) and 0.5 degree (~50 km) elsewhere. The default is 0.8, but the user can pick any value from 0 to 1. With the default of 0.8, the cell is avoided if more than 80% of the 5 km x 5 km cell in northern Africa or 80% of the 50 km x 50 km cell elsewhere is water-filled.

The "Max single flight" parameter specifies the number of hours that a swarm can fly without landing. If this flight time is reached, and the swarm has not encountered a cell with land, it will

land in the water. The application tracks this water landing, but then does not allow the swarm to continue. It is as if the swarm ended when it landed on the water. The default value of the parameter is 72 hours, but the user can select any number of hours from 0 to 240.

The “Min resting period” parameter specifies the minimum resting period that a swarm must be allowed, once it lands on a non-water surface, before it is allowed to take off again. The default value is 8 hours, but the user can select any number of hours from 0 to 72.

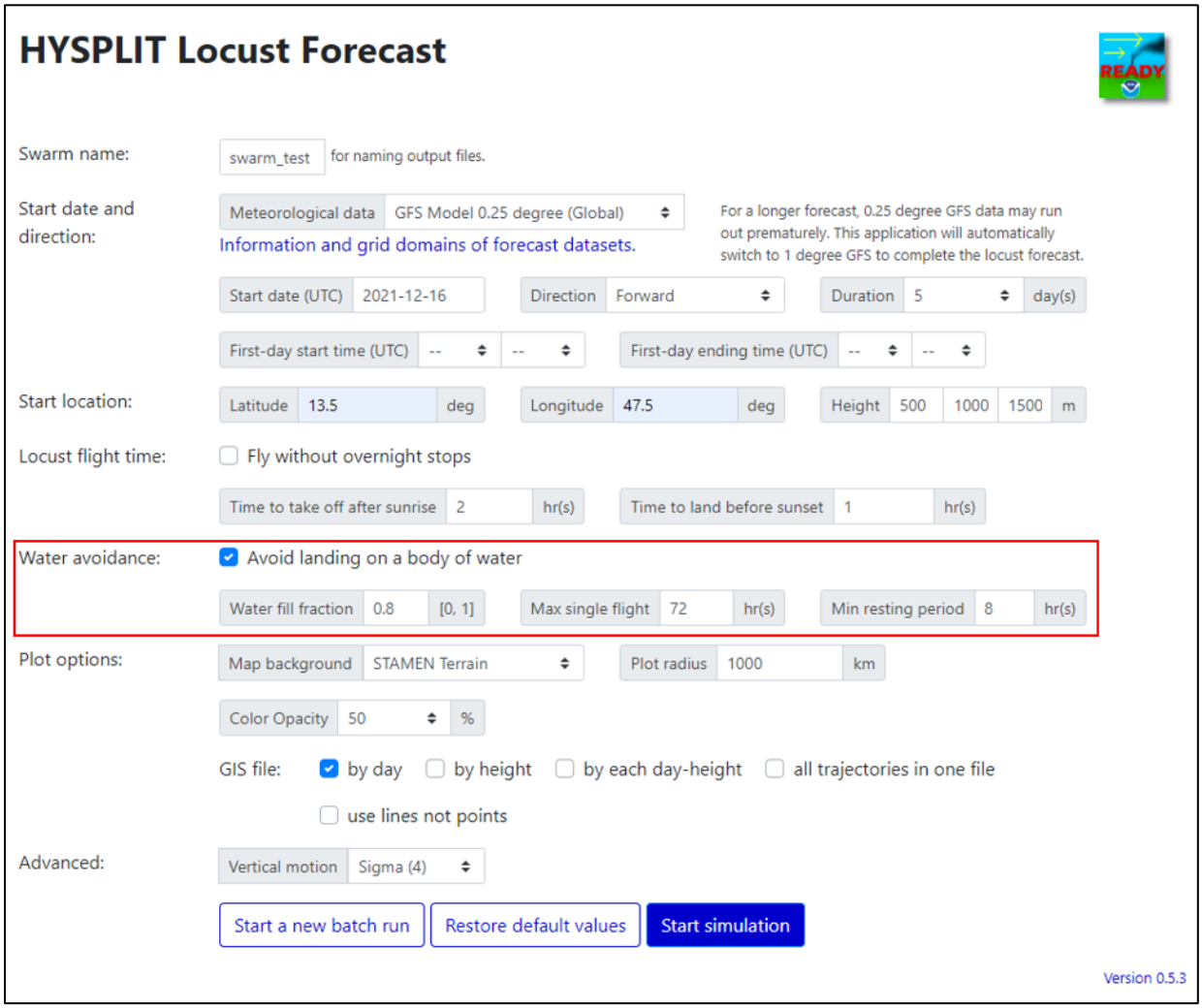


Figure 9.1 New user-input parameters associated with water-landing-avoidance feature.

A series of tests were carried out to test and demonstrate the new water-landing avoidance functionality of the application, using 13 hypothetical coastal starting locations, as shown in Figure 9.2 below. The coastal locations were chosen to have a higher probability that one or more of the projected flight paths would encounter potential water landings.

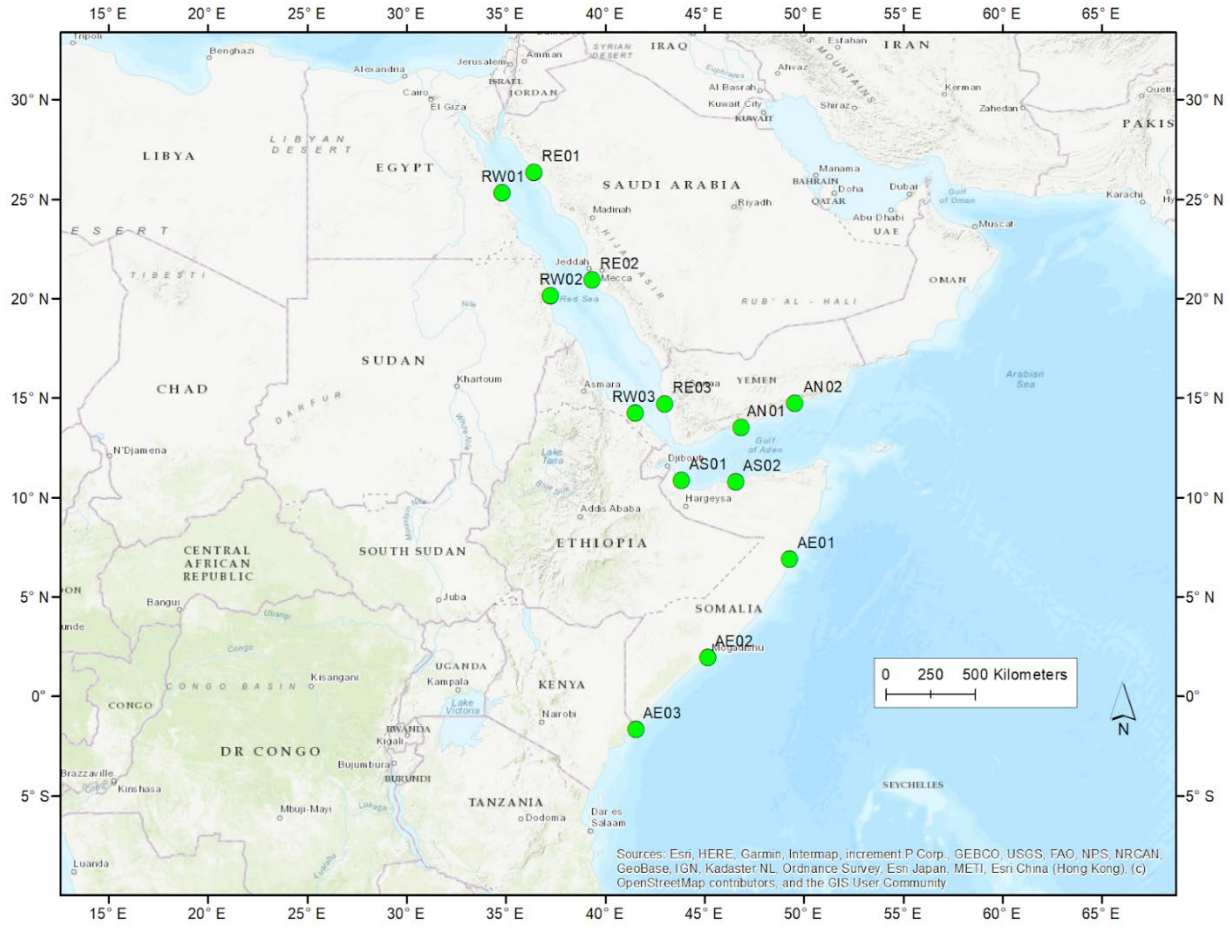


Figure 9.2 Hypothetical swarm starting locations where water-landing-avoidance tests were carried out.

In these tests, simulations were carried out for each of these 13 sites on for hypothetical migrations starting Dec 16, 2021, using the batch functionality, to test the new water avoidance functionality:

- ¼-degree GFS meteorological data (GFS0p25)
- Start date = Dec 16, 2021; 5 days total potential flight time
- 3 migration trajectories simulated for each case, corresponding to 500m, 1000m, and 1500m AGL (above ground level) flight elevations
- For each site:
    - one simulation was done using system without any water avoidance, i.e., the existing system without using the optional new water avoidance functionality

- another simulation was done using the new water-avoidance functionality, with the following parameters:
    - water fraction threshold = 0.8;
    - maximum flight time = 72 hrs;
    - minimum rest time = 8 hrs

Examples of the results, for hypothetical starting location RE03 (Red Sea East coast location #3) are shown in the Figures below.

Figure 9.3 shows the 500m, 1000m, and 1500m trajectories without using the new water-landing-avoidance feature. It can be seen that for two of the trajectories, there are several days for which landings would occur in the water. In this case, each day's migration trajectory starts and ends at the nominal time.

Figure 9.4 shows the 500m, 1000m, and 1500m trajectories using the new water-landing-avoidance feature. It can be seen that the 500m AGL trajectory stays over land the entire time and is the "same" as the previous case. But for the 1000m and 1500m AGL trajectories, the water-landing-avoidance feature causes the hypothetical swarm to continue flying until a non-water-landing is possible. In this example, non-water landings are possible before the specified maximum flight time of 72 hours specified for this example.

Figure 9.5 and Figure 9.6 show just the 1500m AGL flight path in Google Earth without the new water-landing-avoidance feature. In these figures, several day's landing locations are seen to be in the Red Sea.

Figure 9.7 and Figure 9.8 show the same 1500m AGL flight path forecast using the new water-landing-avoidance feature. It can be seen that the first day's migration is lengthened until the flight path passes over an island, and the swarm is forecast to land at that point. For the 2nd period of the migration, the swarm encounters another island on the migration path and is forecast to land at that point. For the 3rd period of the migration, the hypothetical swarm does

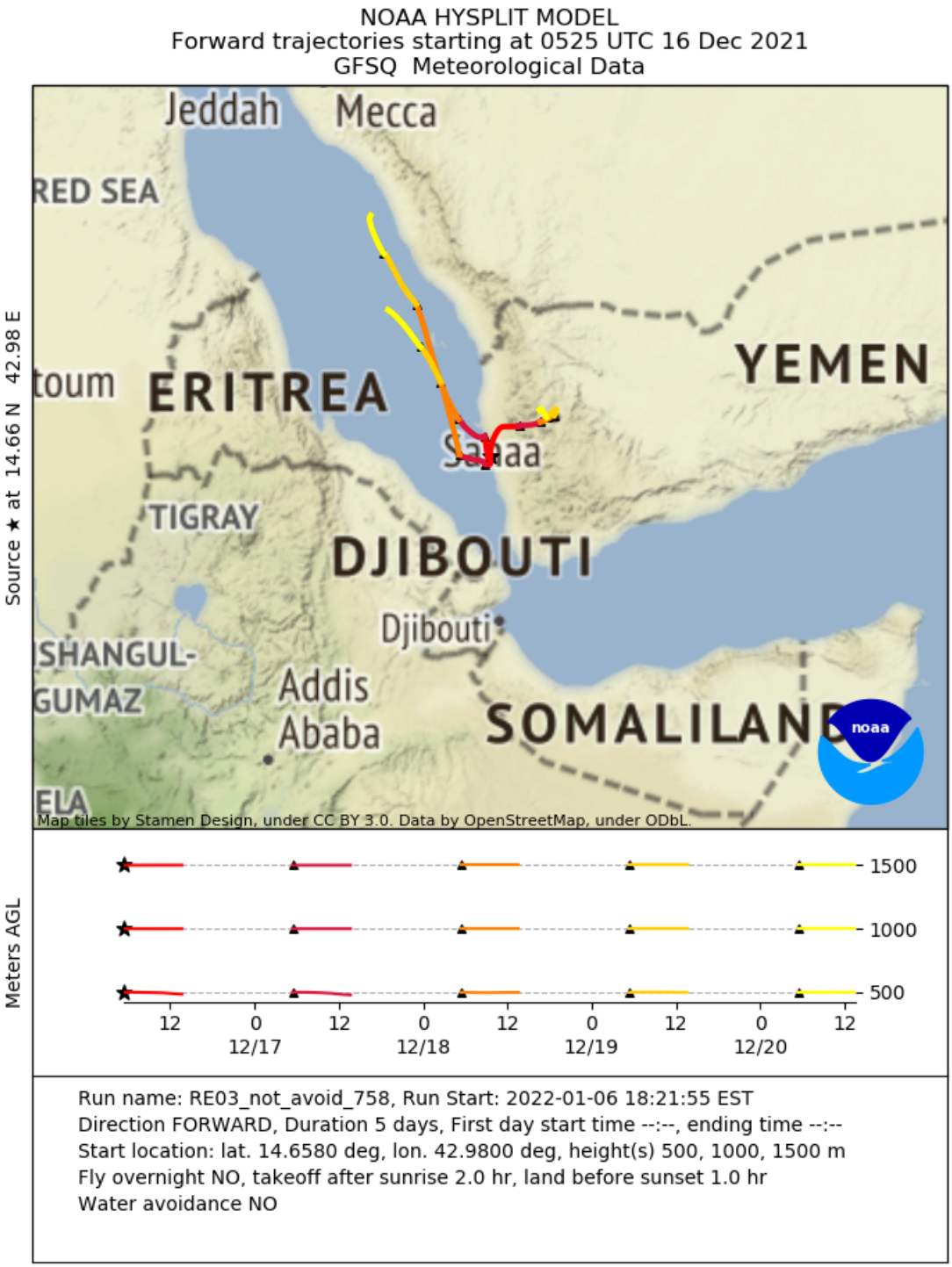


Figure 9.3 Example migration from location RE03 starting Dec 16, 2021, without using the new water-landing avoidance feature.

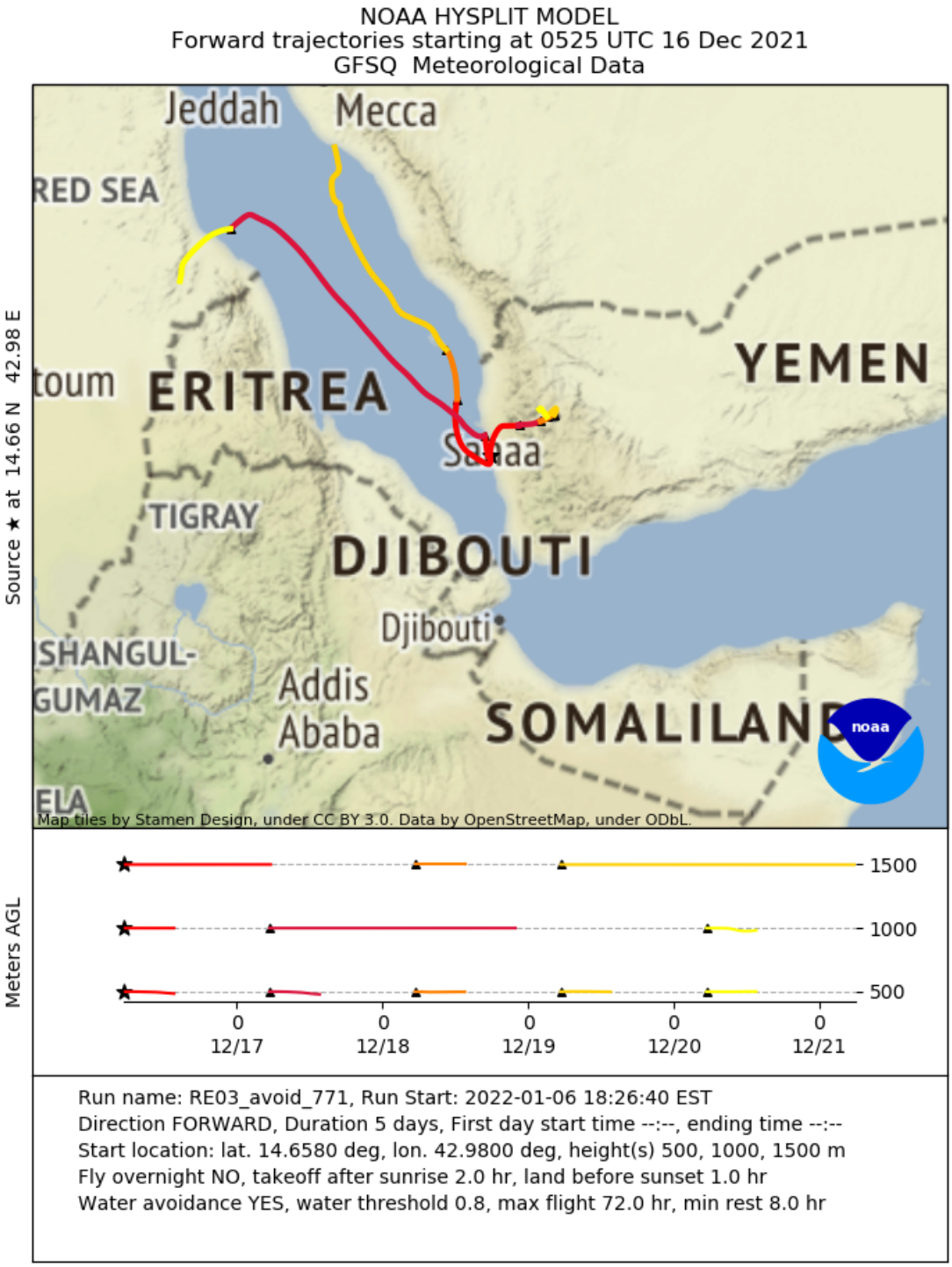


Figure 9.4 Example migration from location RE03 starting Dec 16, 2021, using the new water-landing avoidance feature.

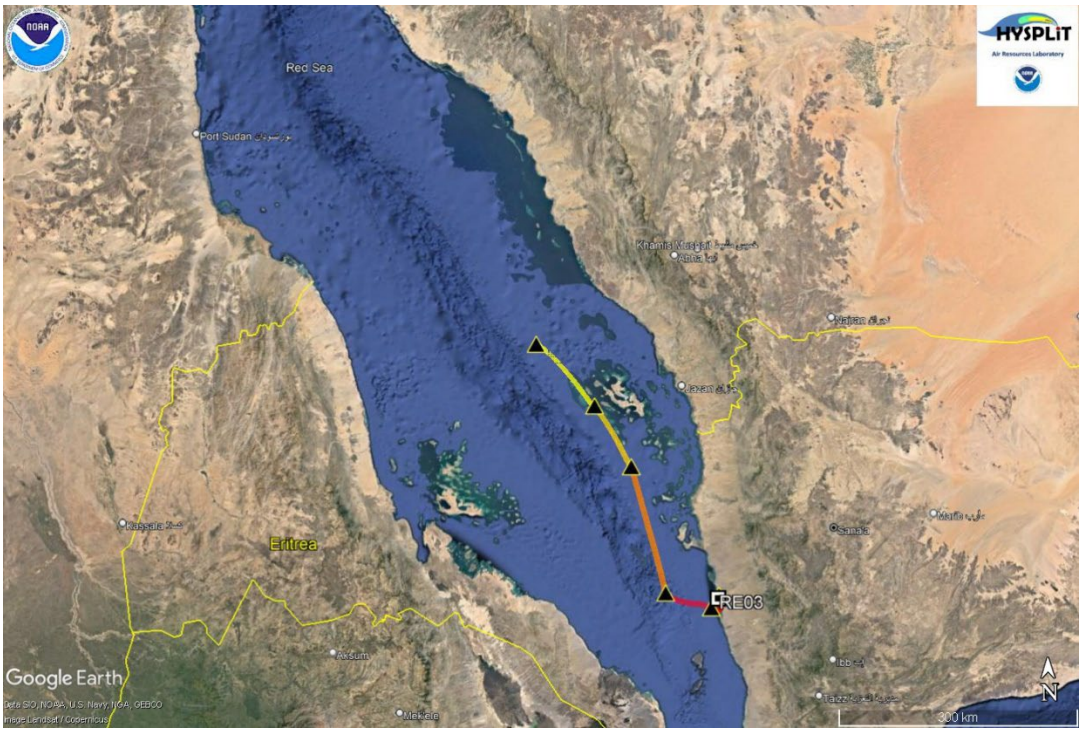


Figure 9.5 Example migration from location RE03 starting Dec 16, 2021, without using the new water-landing avoidance feature (1500m AGL flight elevation).

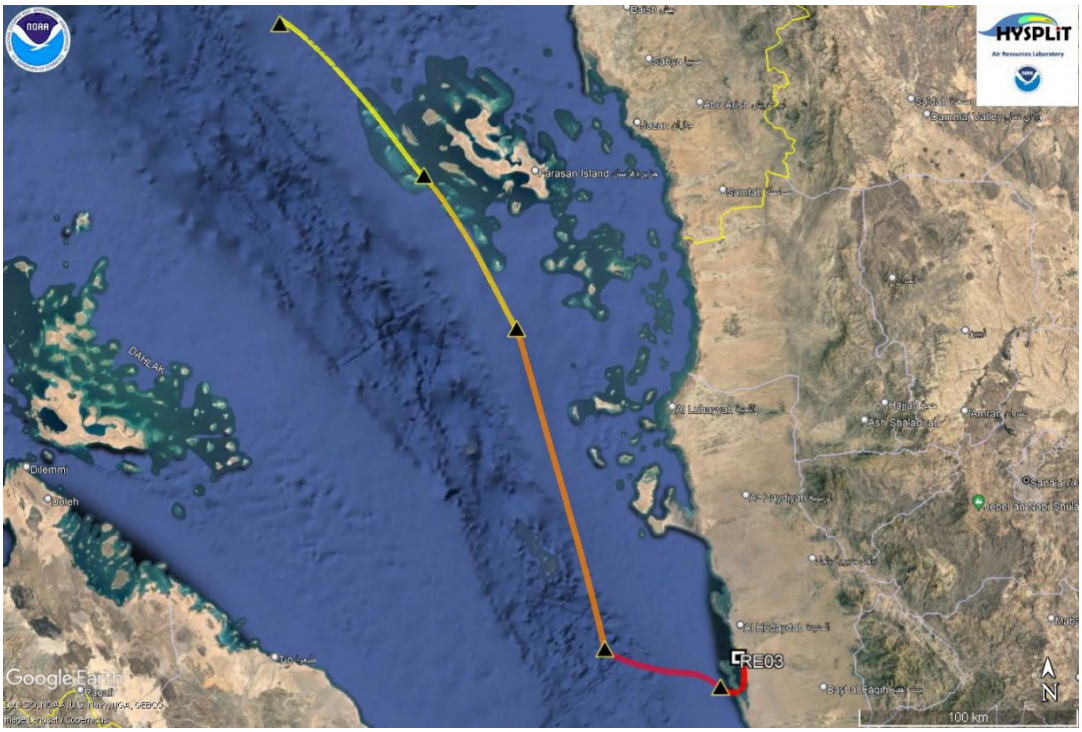


Figure 9.6 Zoomed-in view of example migration from location RE03 starting Dec 16, 2021, without using the new water-landing avoidance feature (1500m AGL flight elevation).

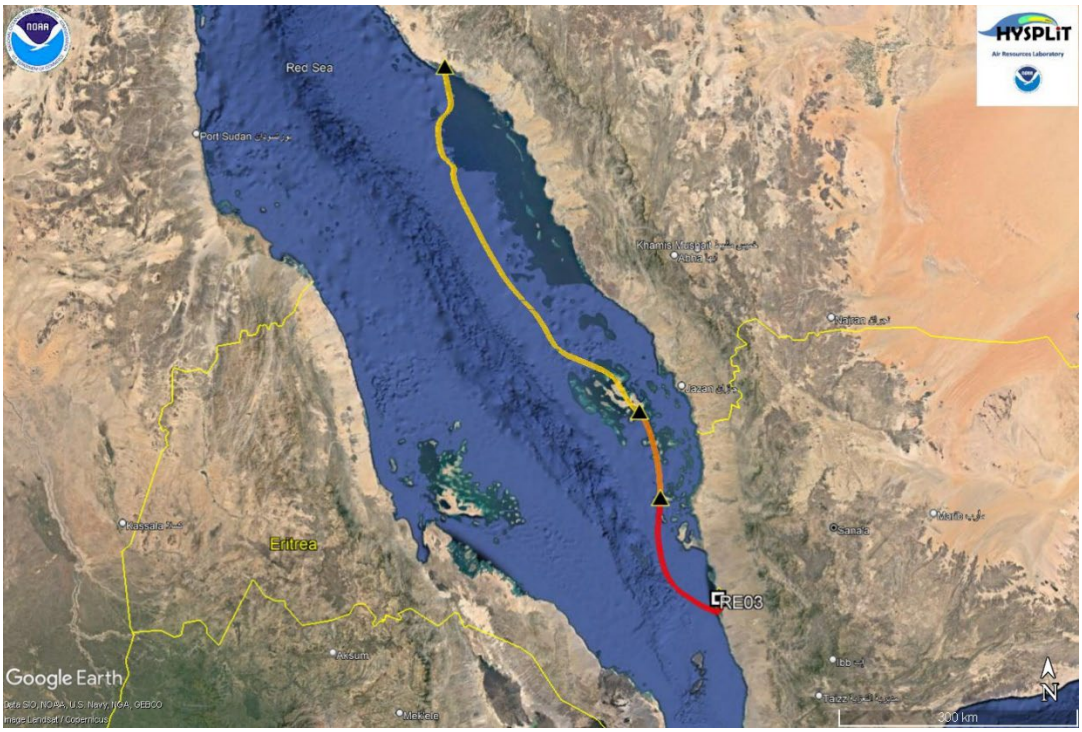


Figure 9.7 Example migration from location RE03 starting Dec 16, 2021, using the new water-landing avoidance feature (1500m AGL flight elevation).

Figure 9.8 Zoomed-in view of example migration from location RE03 starting Dec 16, 2021, using the new water-landing avoidance feature (1500m AGL flight elevation).

A series of tests of the use of the new water-landing-avoidance feature were also carried out in conjunction with the matrix functionality, to ensure that the extension of the matrix simulations to include the new feature were working properly.

One example of the test results are shown below, for a matrix run with the following specifications:

- meteorological data: GFS 0.25 degree (GFS0p25)
- starting date: Dec 16, 2021
- 5 day forward migration forecast
- Flight elevations: 500m, 1000m, and 1500m above ground level
- Lower left grid point latitude: 13.3
- Lower left grid point longitude: 43.4
- Number of latitude grid points: 3, spaced 1.0 degrees apart
- Number of longitude grid points: 3, spaced 1.0 degrees apart

Two simulations with the above specifications were carried out – one without the new water-landing-avoidance feature, and one with the new feature enabled.

Figure 9.9 shows the migration trajectories without water-landing-avoidance, and it can be seen that several landing locations are over water in the Red Sea. Figure 9.10 shows the comparable results with the water-landing-avoidance feature enabled, and it can be seen that landings do not generally occur unless the trajectory encountered land, either an island (see zoomed-in view in Figure 9.11) or a coast. In one case, the maximum flight time was achieved without encountering land, and the hypothetical swarm in the example was forecast to land over water as specified in the application's landing algorithm (see zoomed-in view in Figure 9.12).

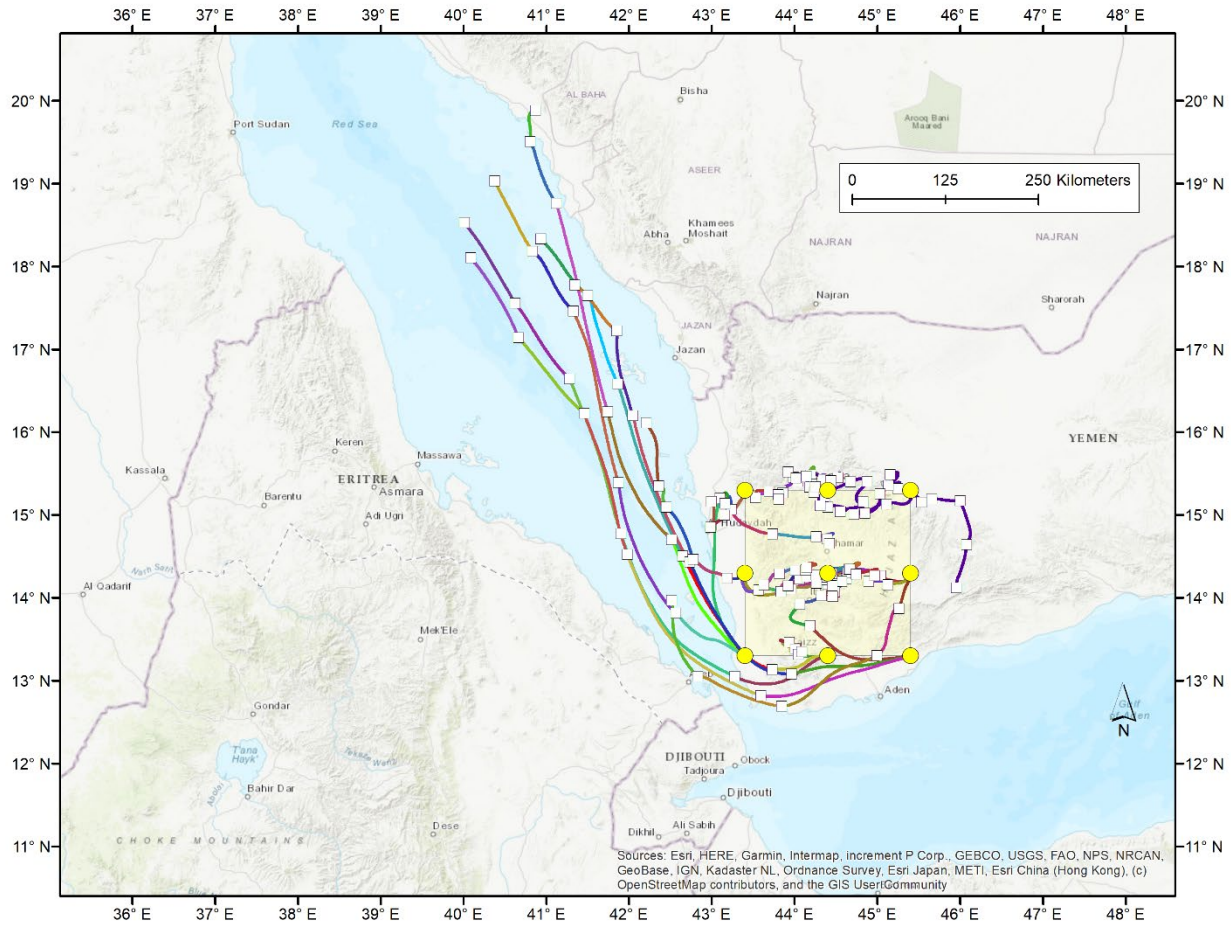


Figure 9.9 Matrix simulation without water-landing-avoidance: forecast migration trajectories for example described in text. Source grid shown with yellow circles bounded by yellow box. Numerous landings over water locations are seen.

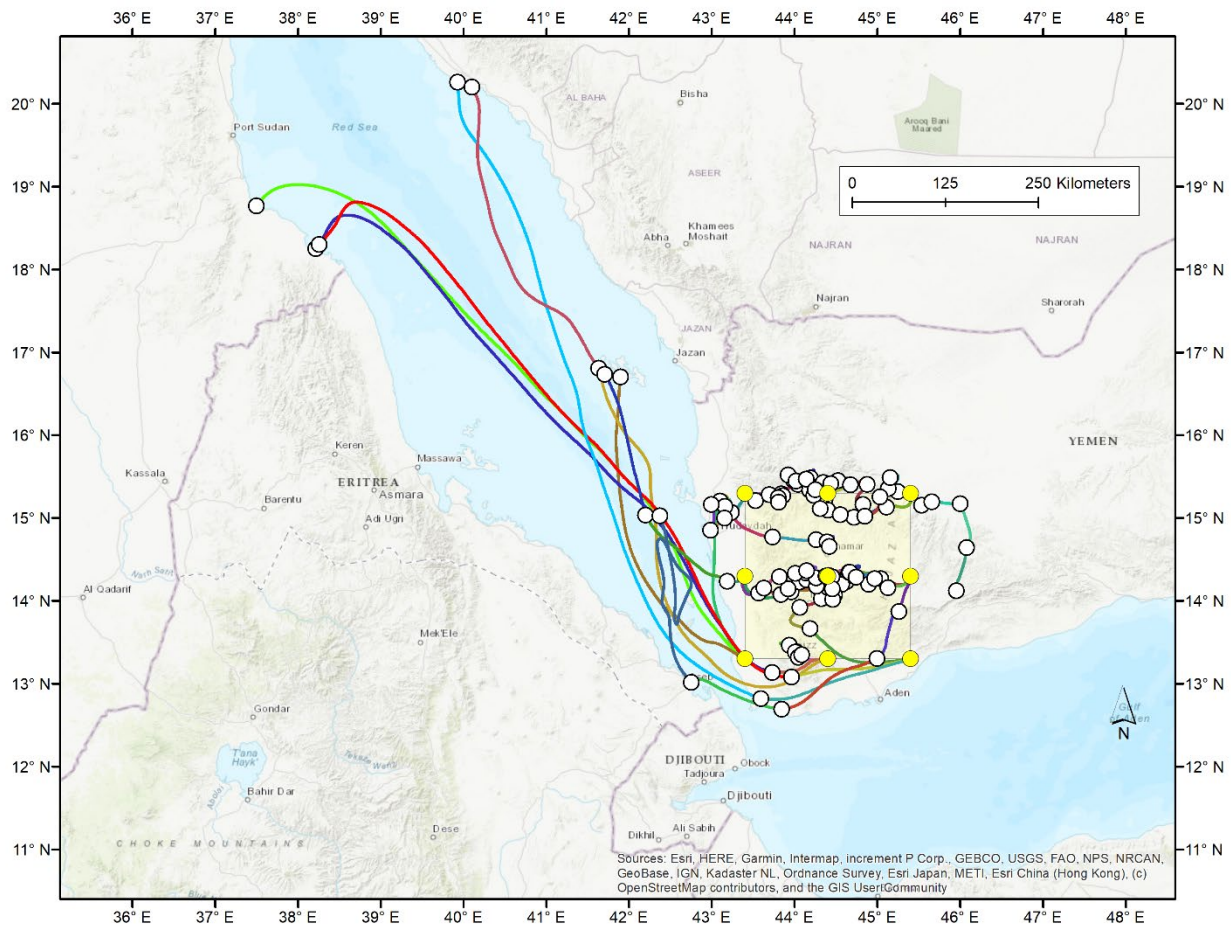


Figure 9.10 Matrix simulation with water-landing-avoidance: forecast migration trajectories for example described in text. Source grid shown with yellow circles bounded by yellow box. Landings are generally only seen on islands or after the trajectory reached the

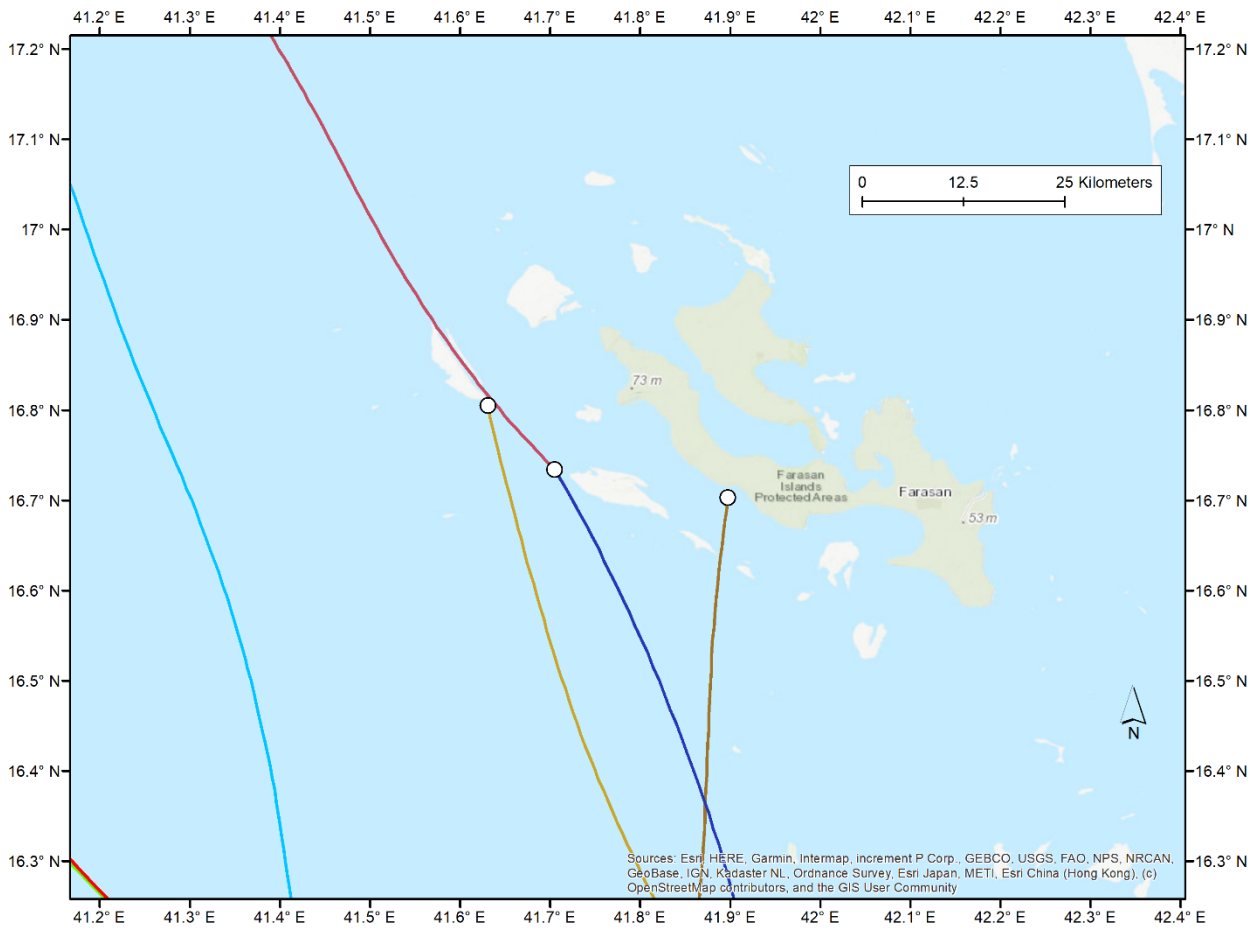


Figure 9.11 Zoomed-in view of examples of island-landings in matrix simulation with water-landing-avoidance. This shows three landing locations associated with islands. For two of the landings, this was the end of the 5-day forecast flight path. For one, 5 days ha

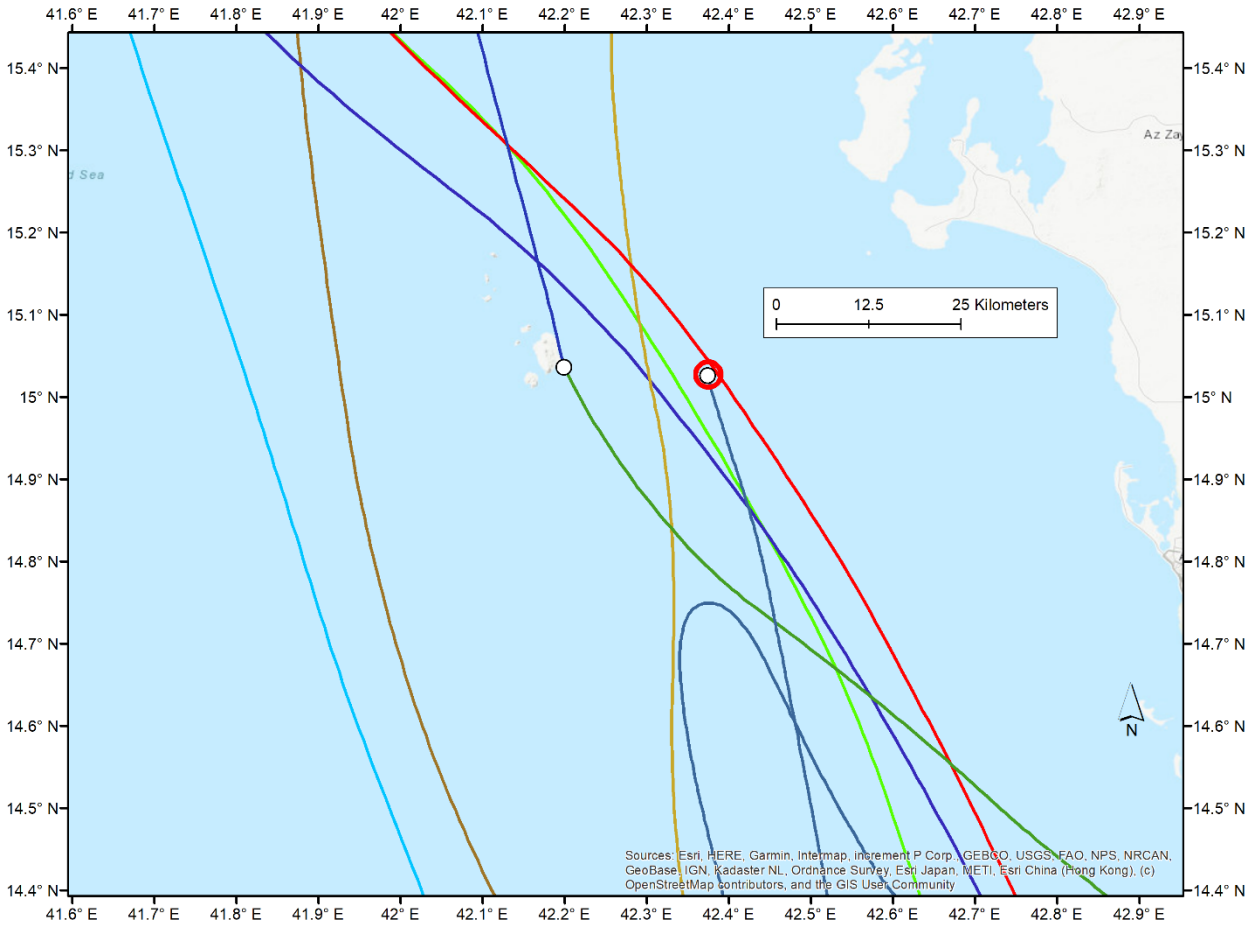


Figure 9.12 Zoomed-in view of one example of an island landing (white circle) and one example of a water landing (red circle) after maximum flight time was reached, in matrix simulation with water-landing-avoidance. As noted in the text, if land has not been reached after the swarm has flown for the "maximum flight time", then the swarm lands in the water. After that point the swarm does not continue and is assumed "lost". The default maximum flight time is 72 hours, but the user can set this to any number of hours between 0 and 240.