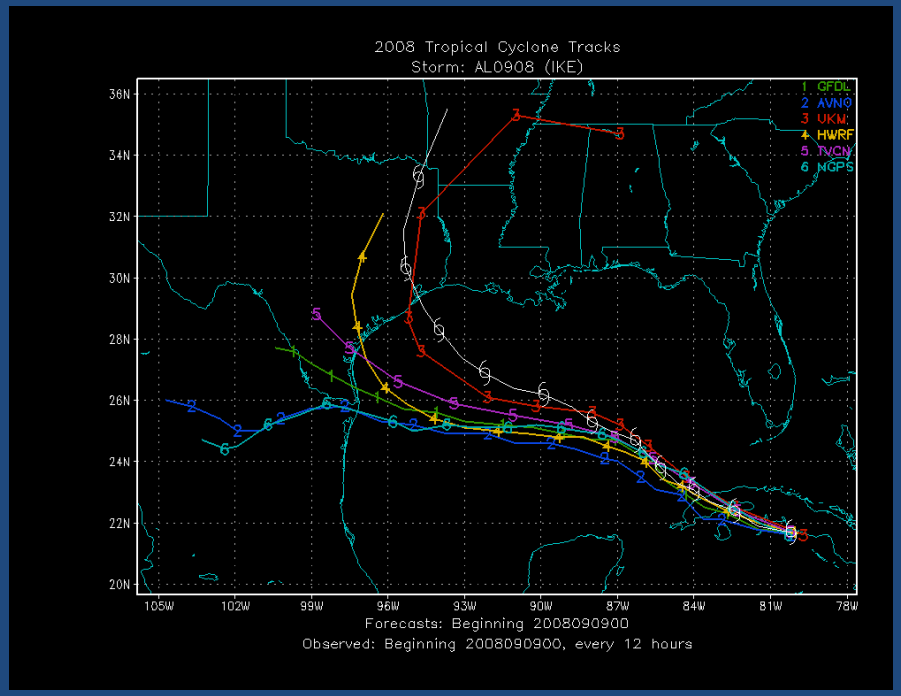
Use of the GFDL Vortex Tracker



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WRF Tutorial for Hurricanes
April 28, 2011

Outline

- History & description of the GFDL vortex tracker
- Inputs & Outputs
- ATCF-plot: GrADS-based track and intensity plotting script

GFDL Vortex Tracker: History

- Requirements:
  - A flexible tracking algorithm to work on a variety of models and resolutions.
  - Must run quickly
  - Must produce output in ATCF format
- Became operational at NCEP in 1998

Purpose of a vortex tracker

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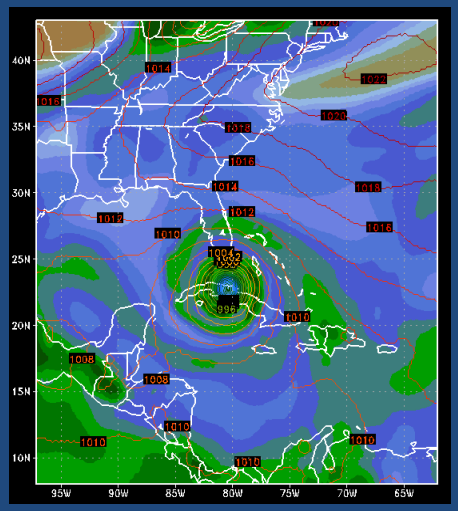
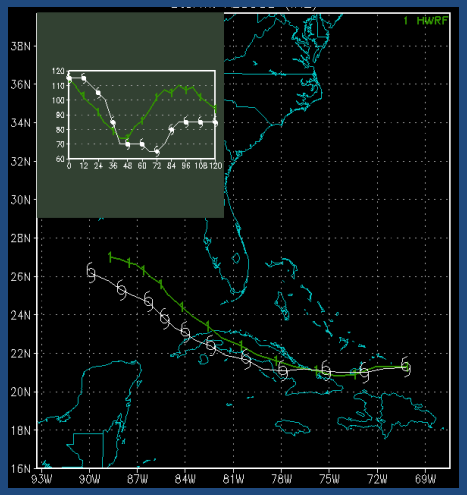
1100010010010010101 0
0001001001111001001 0
1100111000110101000 1
0000101001001100101 1
1010111010110001100 1
1000111010010001010 0
.
.



NOW

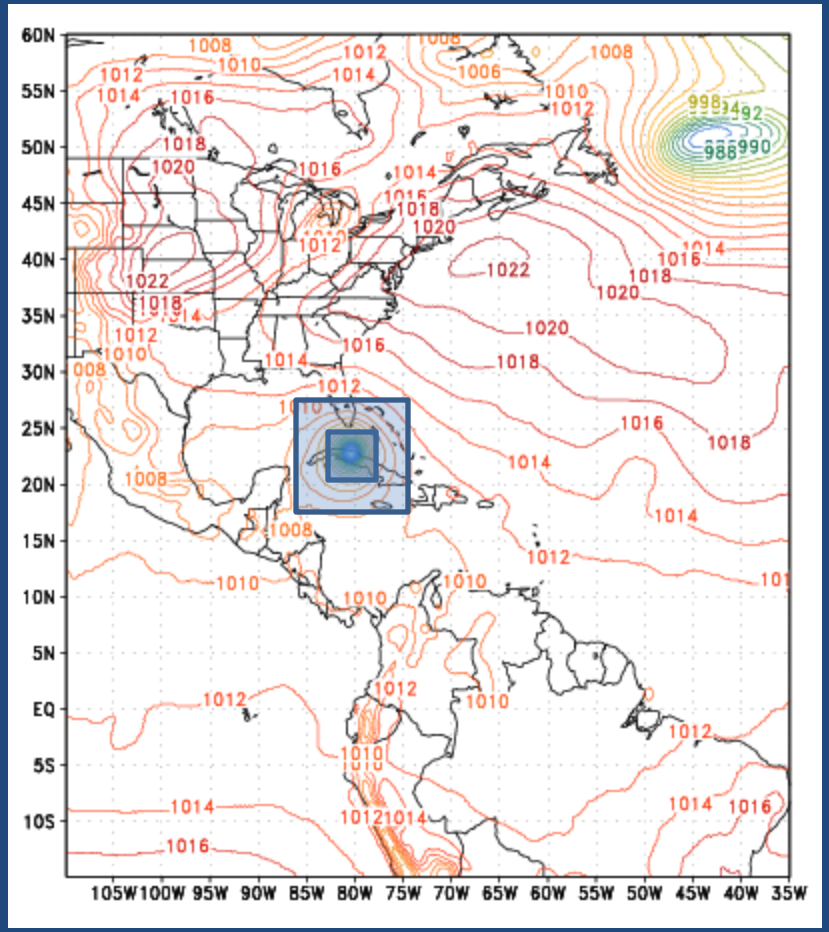
WHAT ?



- Operations: Quick reporting of track and intensity forecast data to NHC, JTWC, others.
- Research: Quick evaluation of the track & intensity skill of a forecast

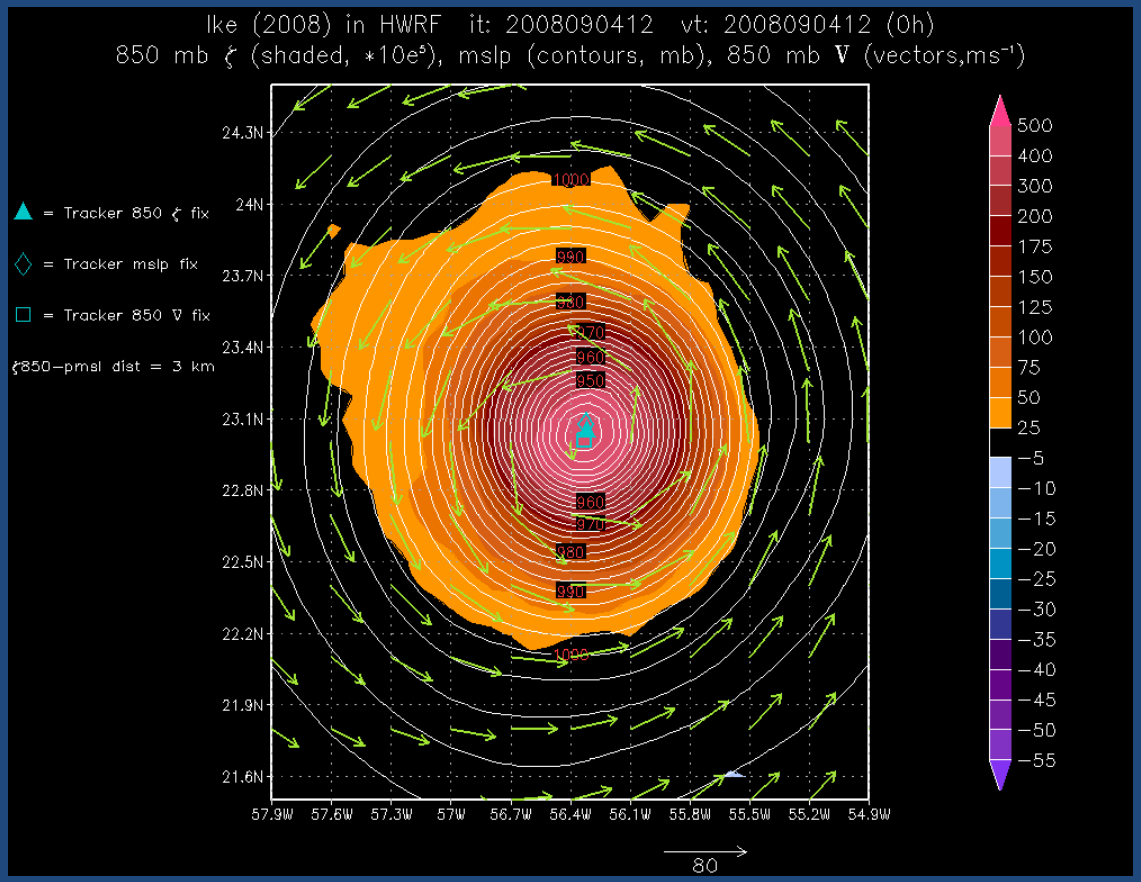
Why the need for an external tracker?

- Valuable CPU time is not wasted during model execution.
- Tracking analysis can be re-done without re-running model.
- Uniform tracking criteria can be applied to multiple models.

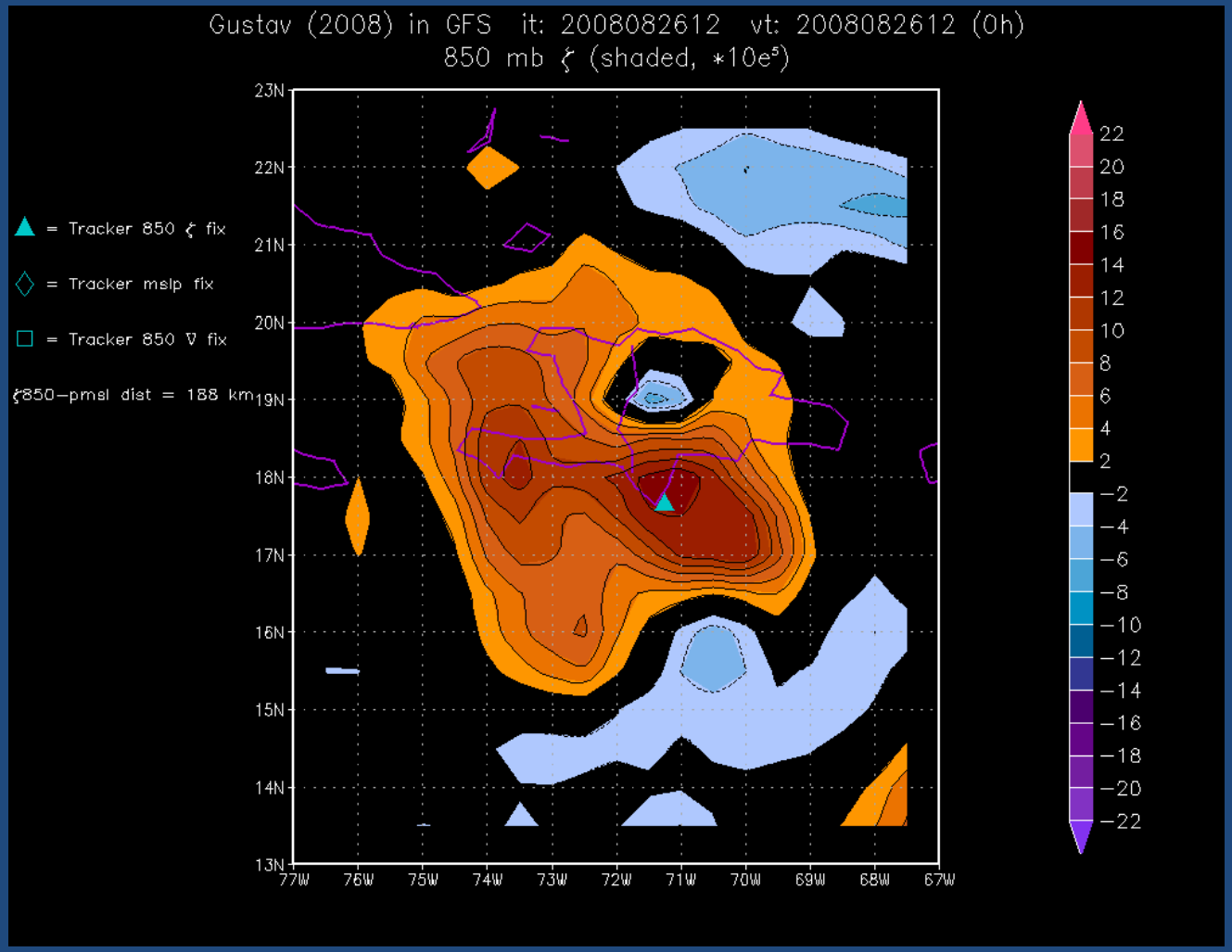


Why the need for an external tracker?

- Ike in HWRF: A well-defined storm with center locations collocated.
- So then… why the need for anything sophisticated?

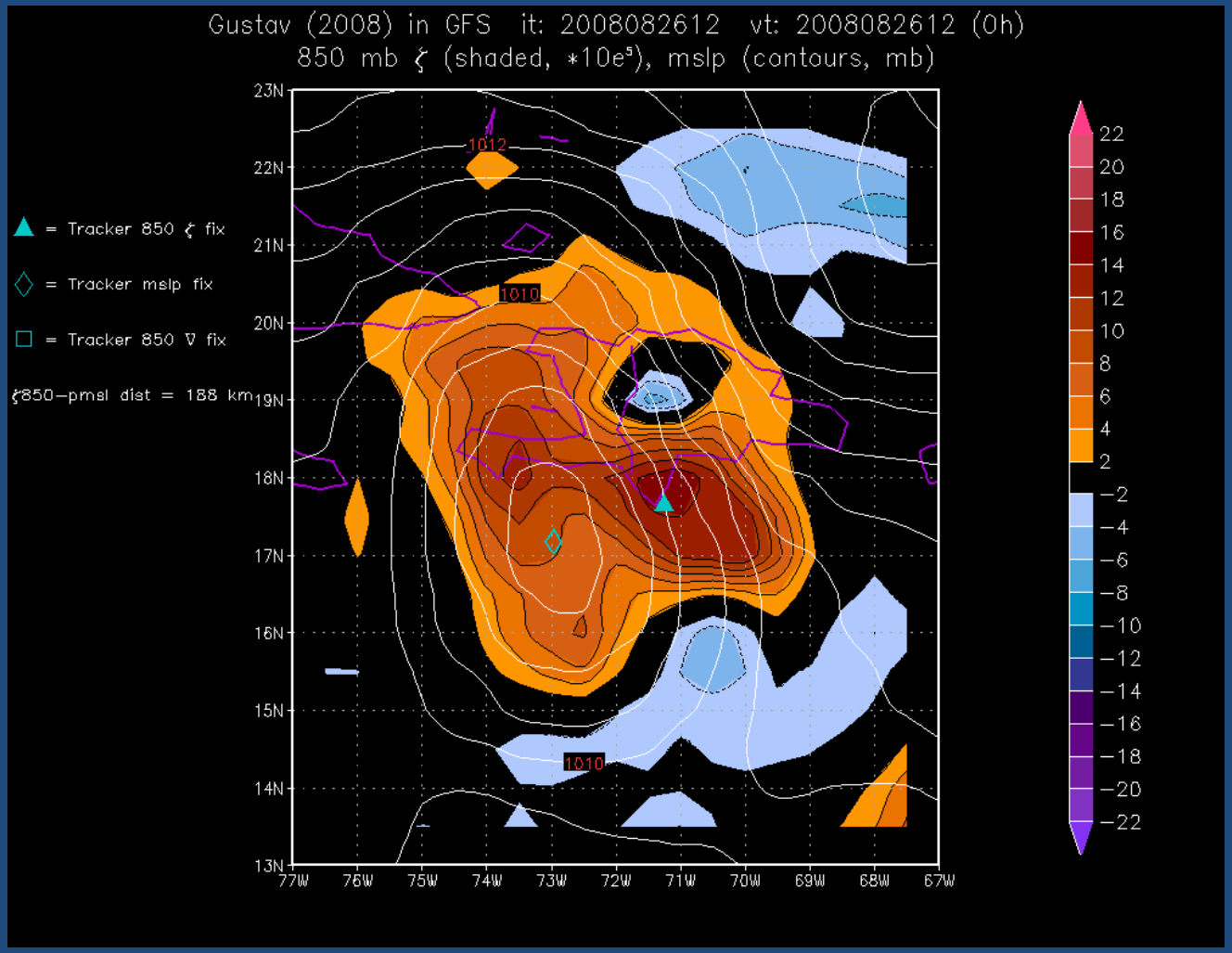


Why the need for an external tracker?



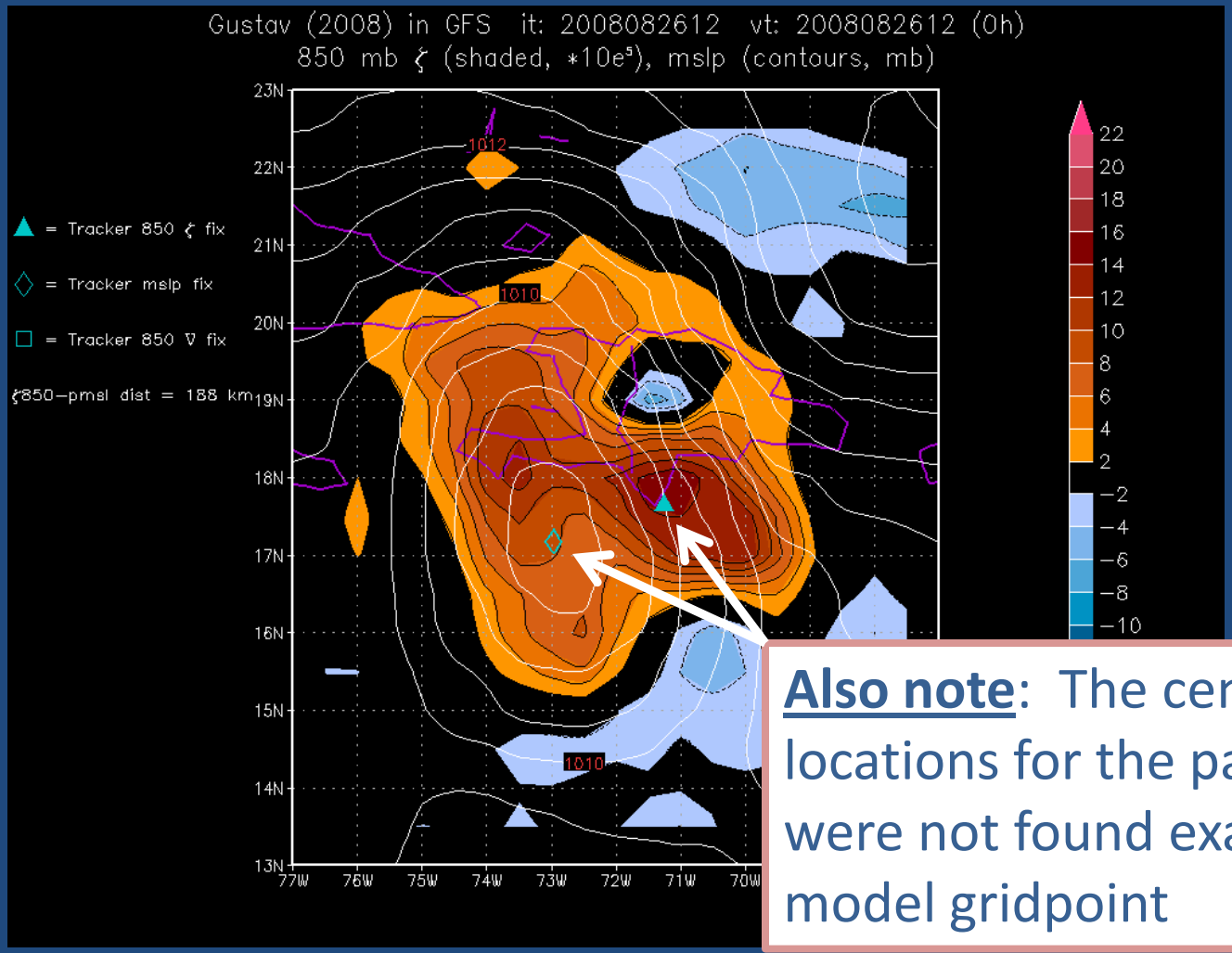
- Gustav in GFS: For an observed 80-knot hurricane, the GFS was initialized with a poorly organized vorticity center.

Why the need for an external tracker?



- Gustav in GFS: The SLP center was found 188 km from the vorticity center. *What is the storm's central position?*

Why the need for an external tracker?



Also note: The center locations for the parameters were not found exactly at a model gridpoint

- Gustav in GFS: The SLP center was found 188 km from the vorticity center.

Tracker Design: Multiple Variables

- A weighted average of the positions of several low-level variables is used.
- 6 Primary parameters:
  - 850 mb vorticity
  - 700 mb vorticity
  - Surface (10 m) vorticity
  - 850 mb gp height
  - 700 mb gp height
  - Mean Sea-Level Pressure
- 3 Secondary parameters:
  - 850 mb minimum in wind speed
  - 700 mb minimum in wind speed
  - Surface (10 m) minimum in wind speed

Tracker Design: Center-fixing algorithm

- Instead of interpolation, a Barnes Analysis is performed on an array of points surrounding a guess storm location:

The Barnes function, B, provides a Gaussian-weighted average value for a variable, F(n), at a given gridpoint, g.

$$B(g) = \frac{\sum_{n=1}^{N} w_n F(n)}{\sum_{n=1}^{N} w_n}$$

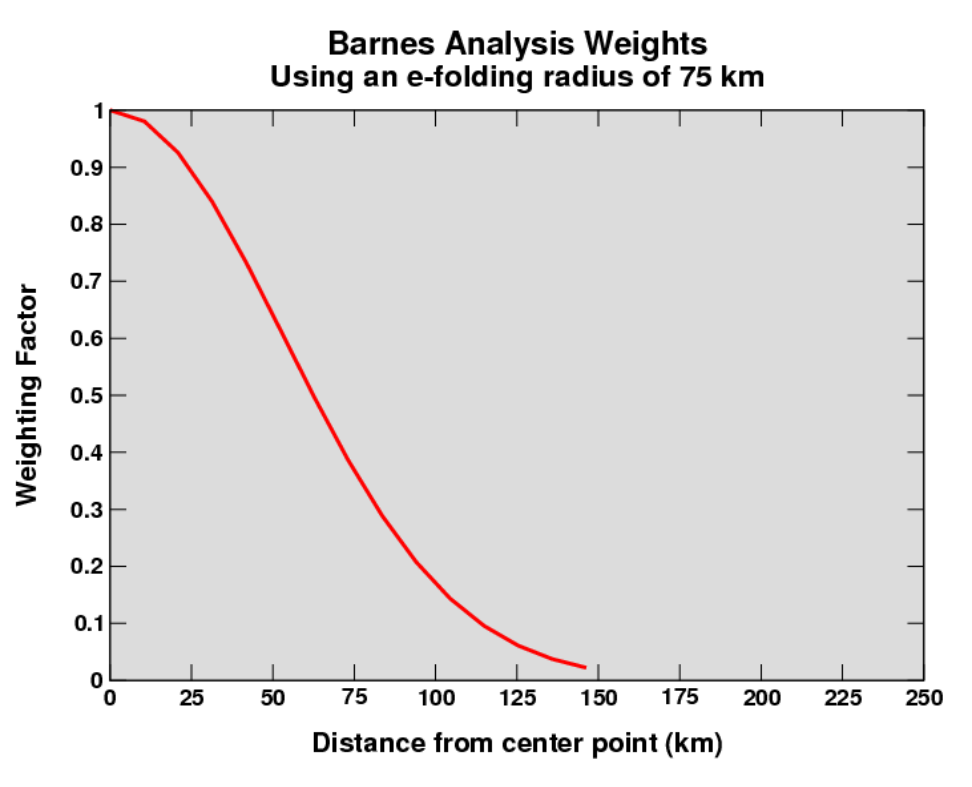
The weighting function, w, is dependent on the distance, d_n, of a point from the origin gridpoint, g, and the choice of the e-folding radius, r_e.

$$w = e^{-(d_n^2 / r_e^2)}$$

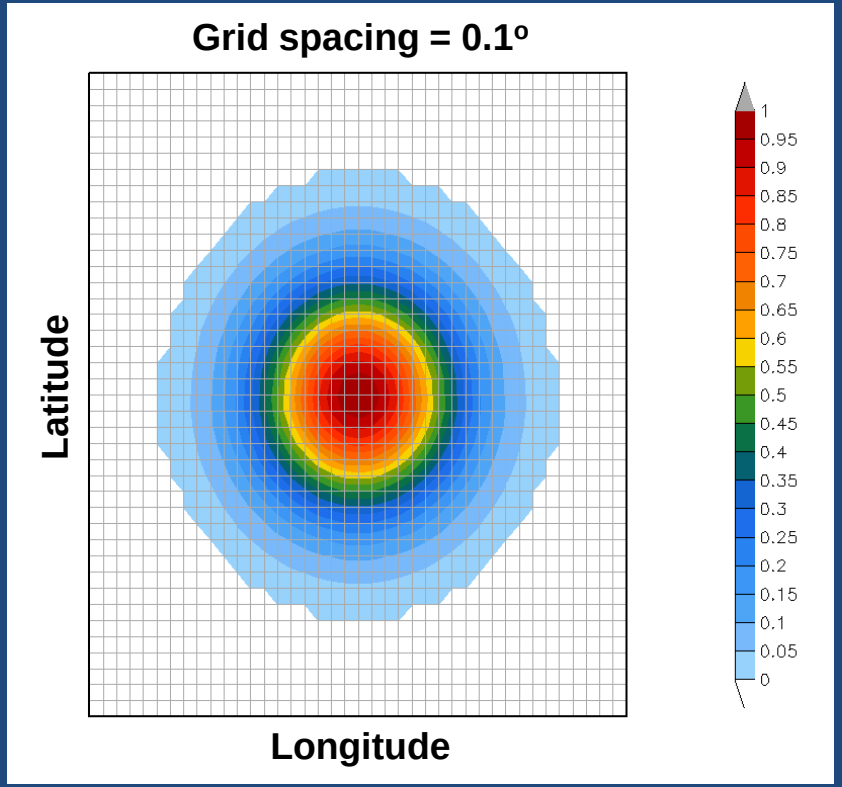
The center is found at the point where this Barnes function is maximized (e.g., NH vorticity) or minimized (e.g., MSLP).

Barnes analysis weighting

Linear Response



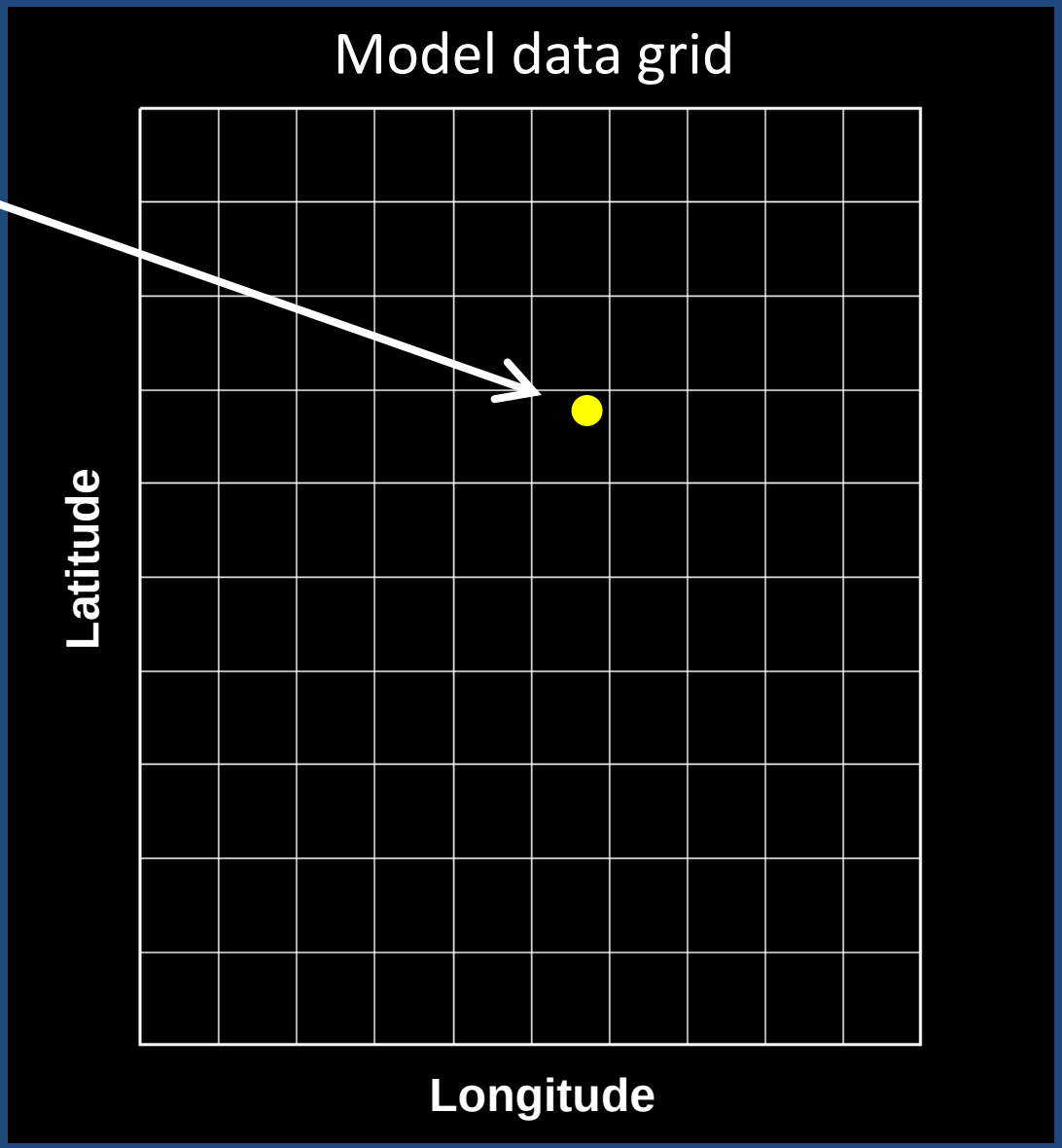
Spatial Response



- Choosing r_e: A balance between including enough points to get a representative sample vs. too much smoothing.
- For most models, we use r_e = 75 km. For dx < 0.1°, r_e = 60 km.

Barnes analysis: multiple search iterations

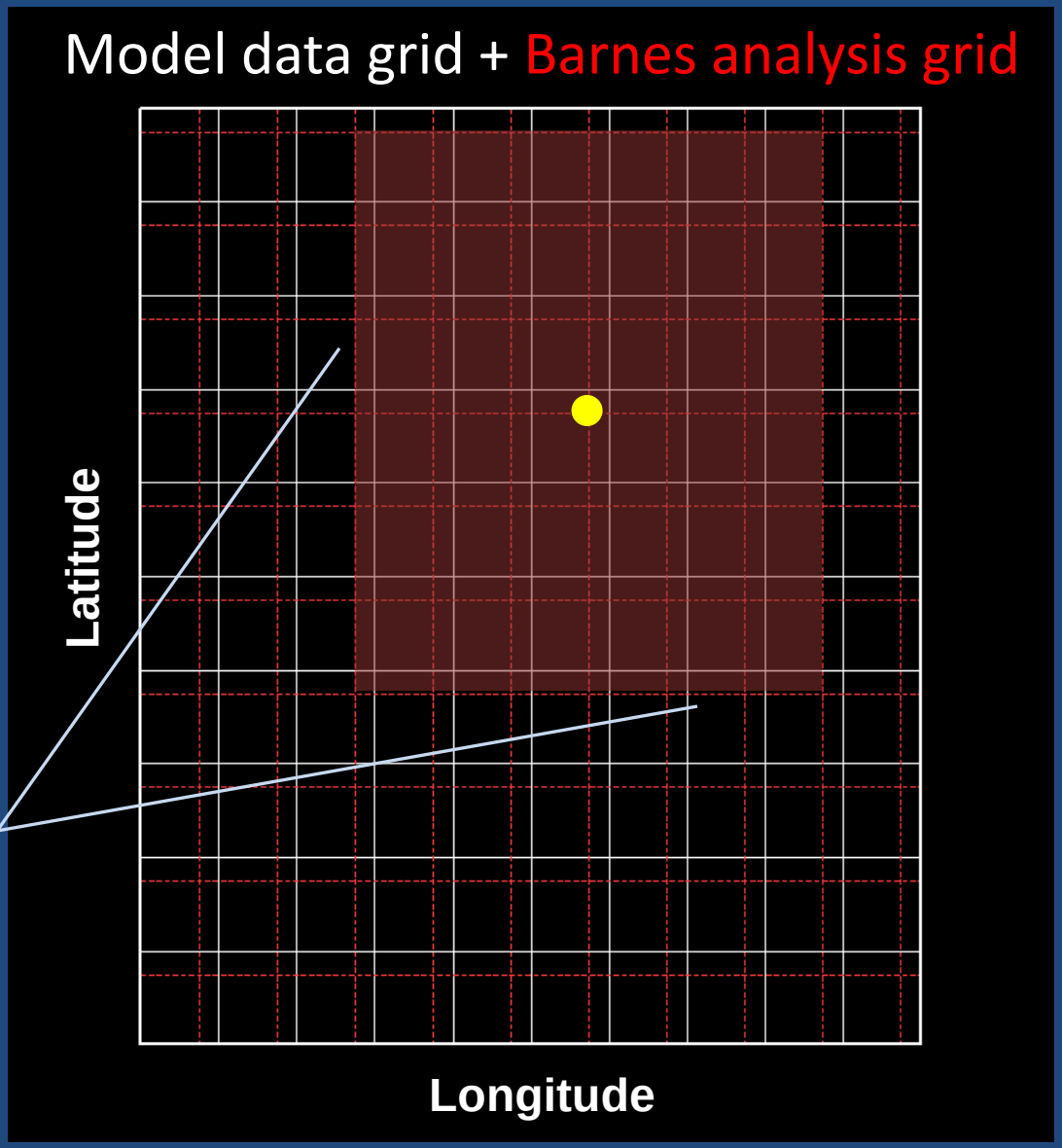
NHC observations indicate a storm initially located here



Barnes analysis: multiple search iterations

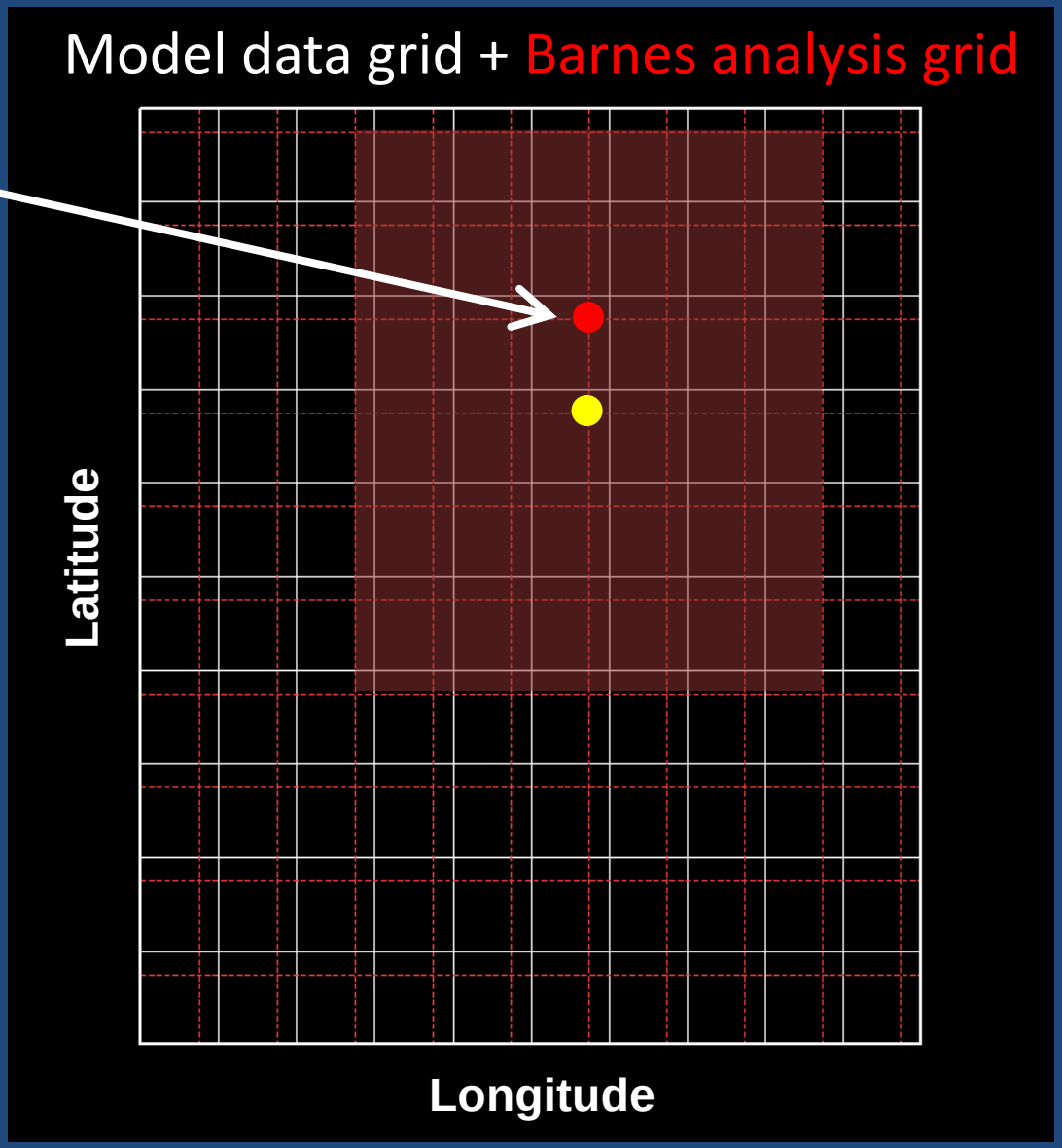
A grid of analysis points is set up, relative to the NHC observed position.

A Barnes analysis is performed for all points within a specified distance from the NHC position.



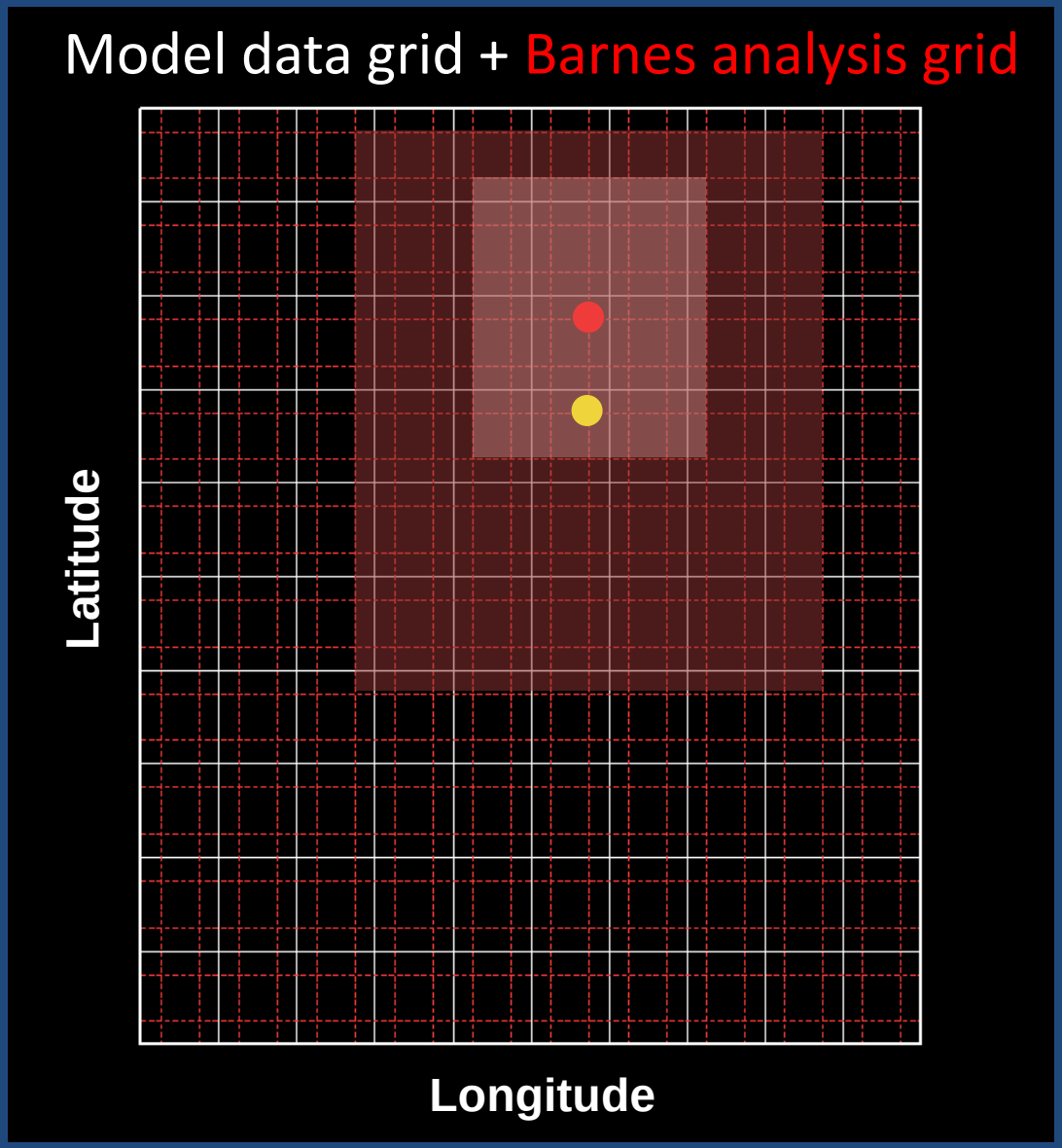
Barnes analysis: multiple search iterations

After the first iteration through all the points, suppose the Barnes analysis identifies the center as being here.



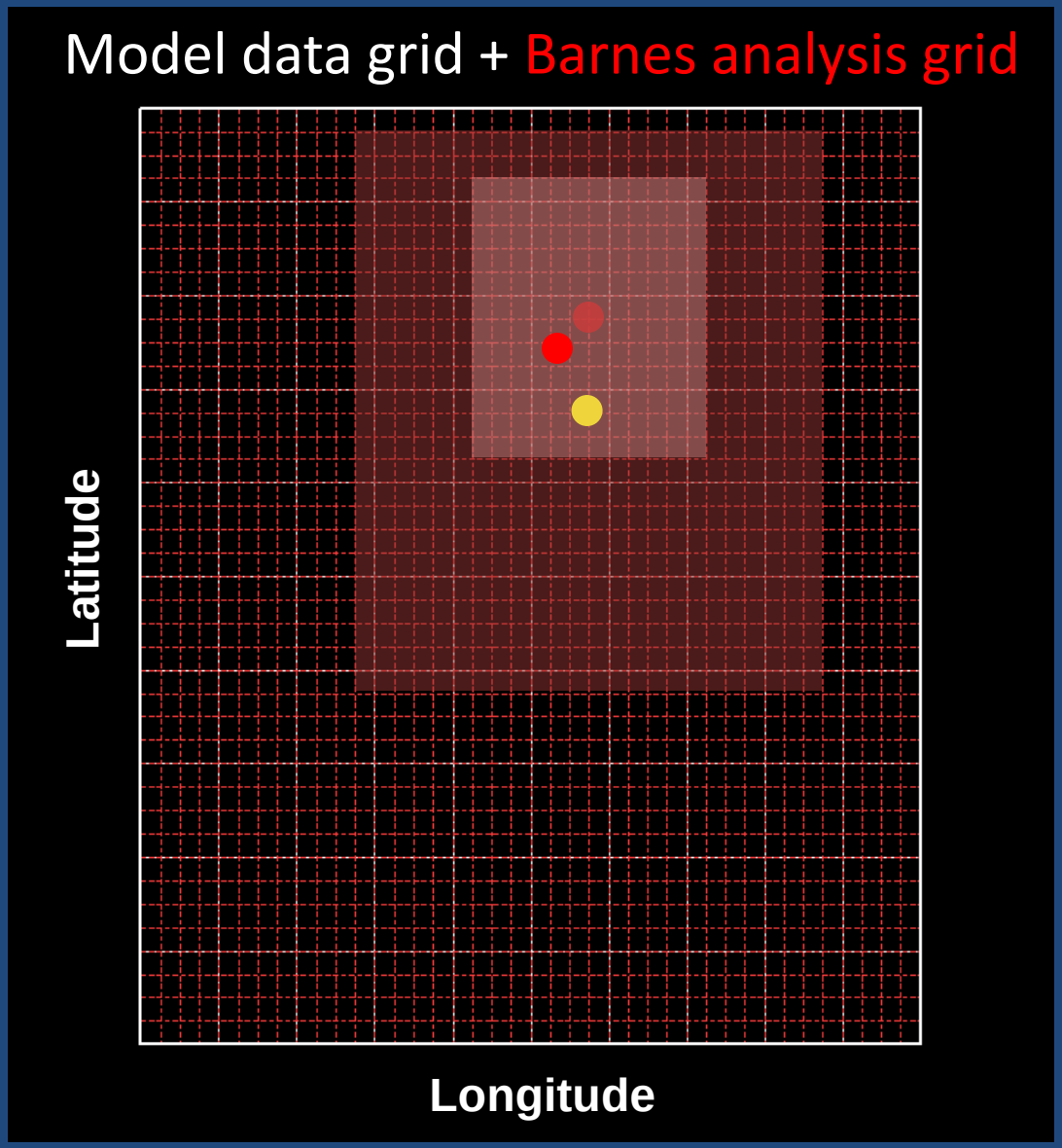
Barnes analysis: multiple search iterations

A second iteration through the Barnes analysis is performed after further limiting the domain and halving the grid spacing.



Barnes analysis: multiple search iterations

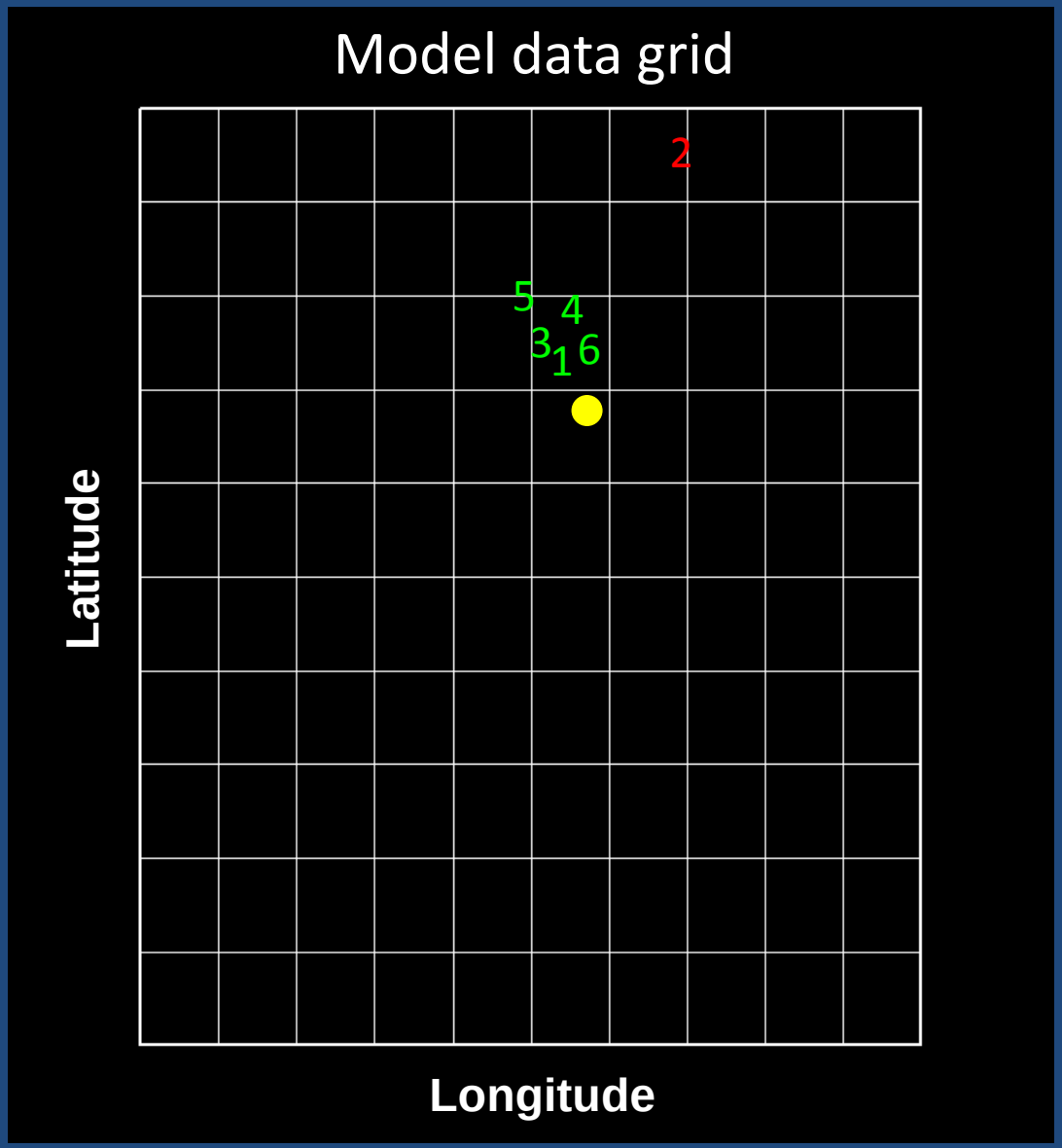
This process is repeated multiple times (up to 5), halving the grid spacing for the Barnes analysis each time, until a center position is fixed using a Barnes analysis grid spacing < 0.1°.



Computing the center position, Part I

The Barnes analysis is repeated for all 6 primary parameters to produce fix positions for each.

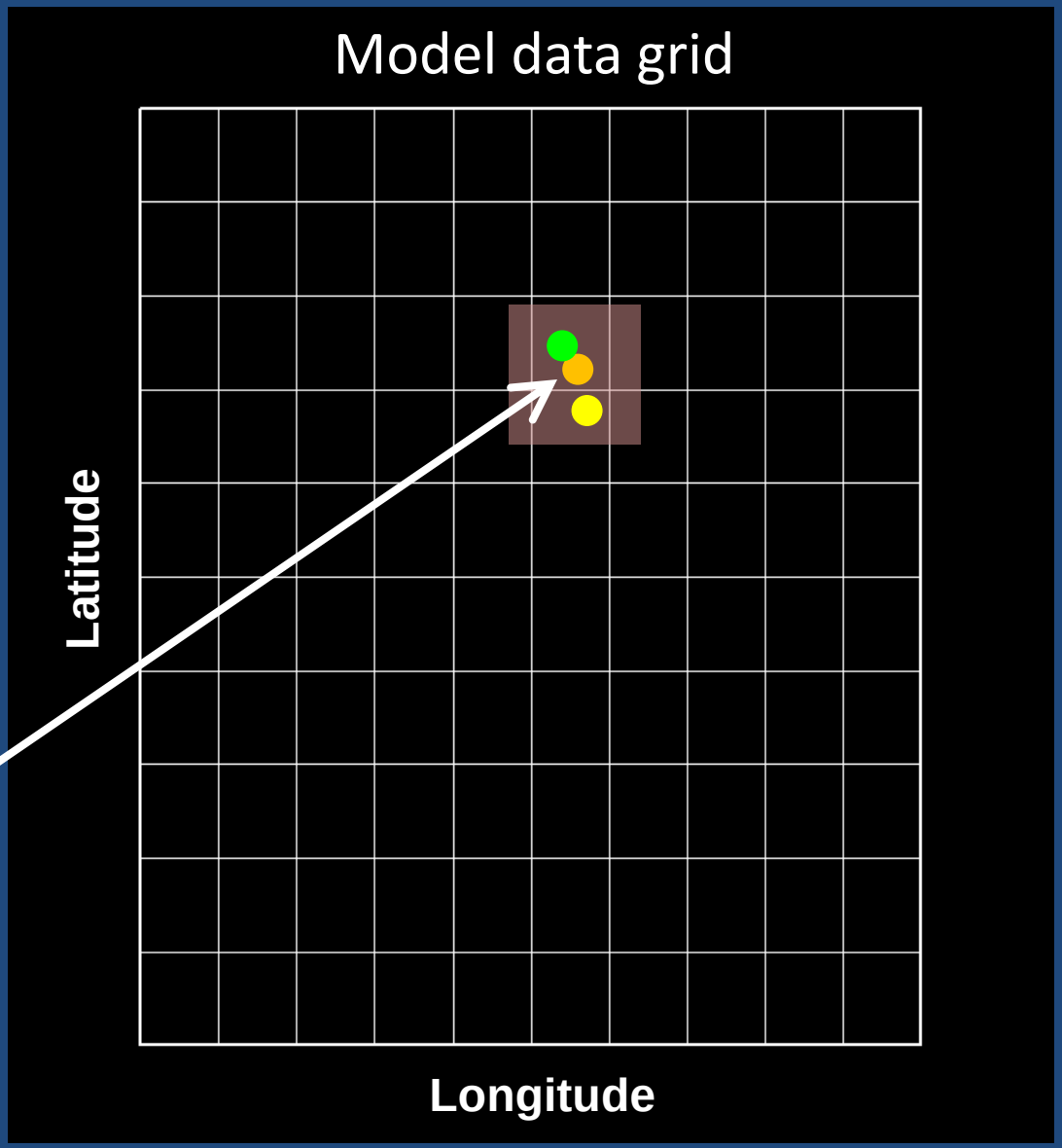
Parameters fixes that are within a specified error distance threshold of the current guess position are used to create a preliminary mean fix.



Computing the center position, Part II

The Barnes analysis is repeated for the 3 secondary, wind-based parameters.

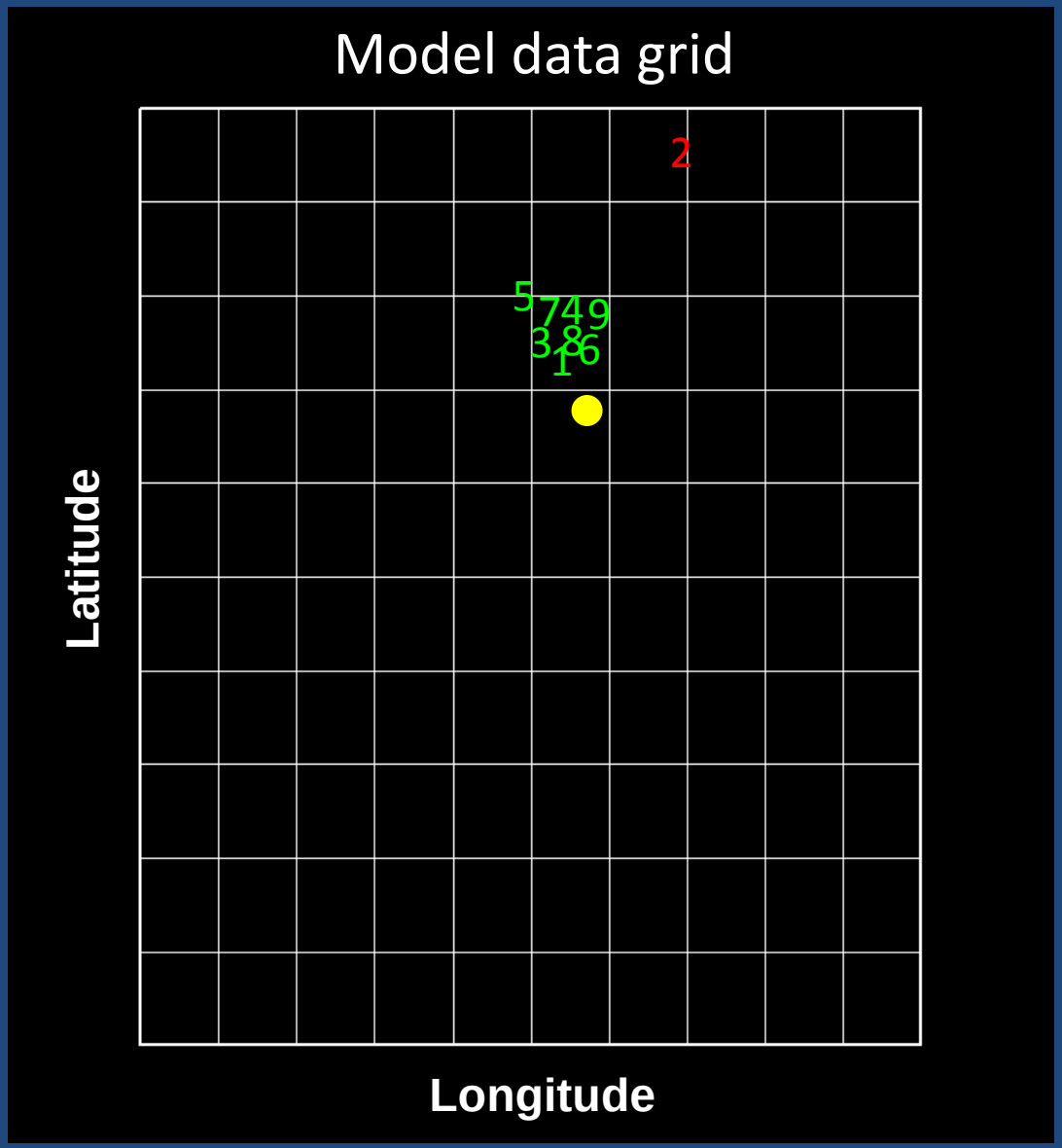
This analysis is performed over a small domain, centered on a position that is a mean of the 6 primary fixes and the guess position.



Computing the center position, Part III

Parameters fixes that are beyond a specified error distance threshold of the current guess position are discarded.

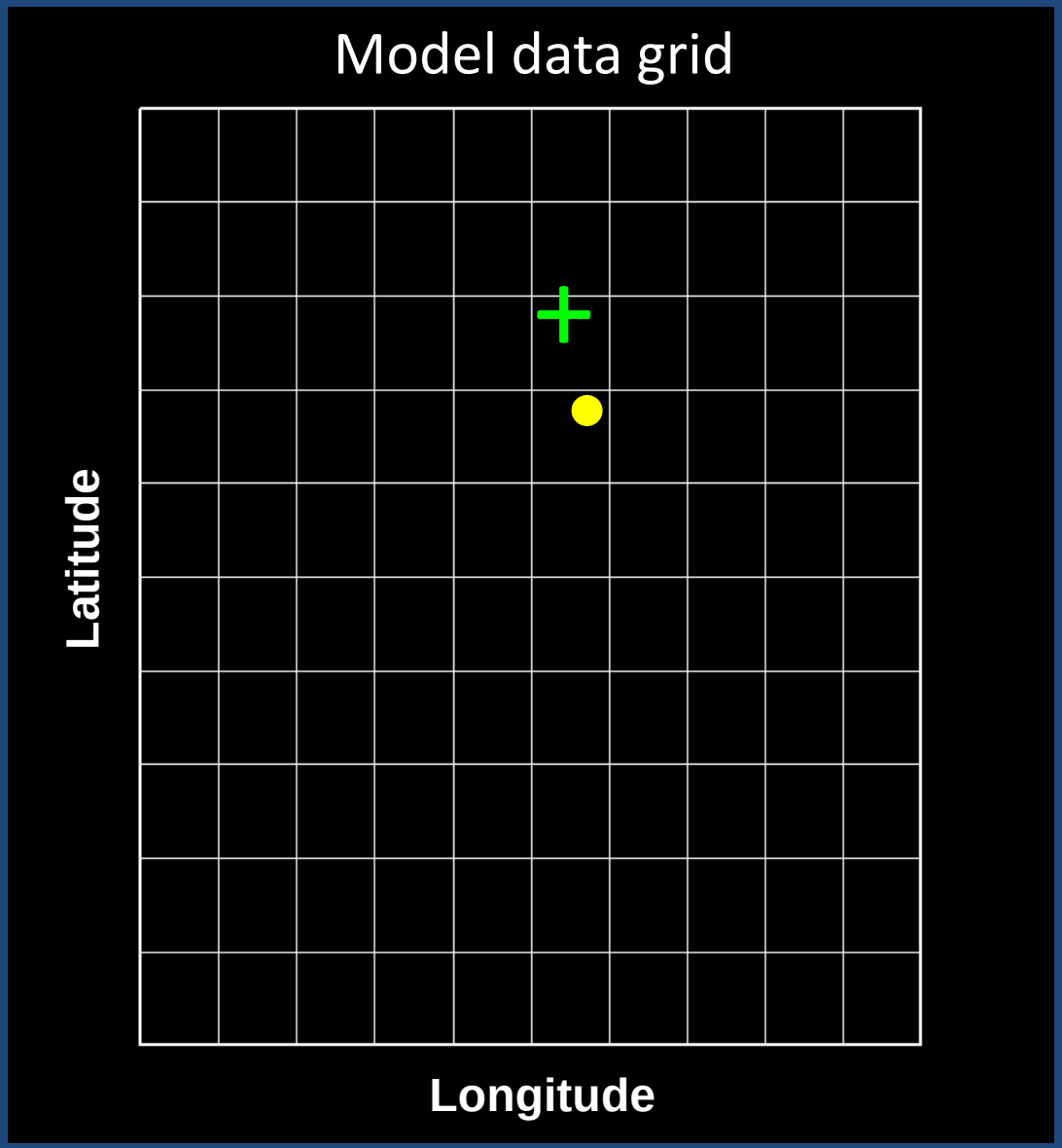
- Error distance thresholds:
  - Initially 275 km
  - At later times, can be a function of spread in previous position fixes



Computing the center position, Part III

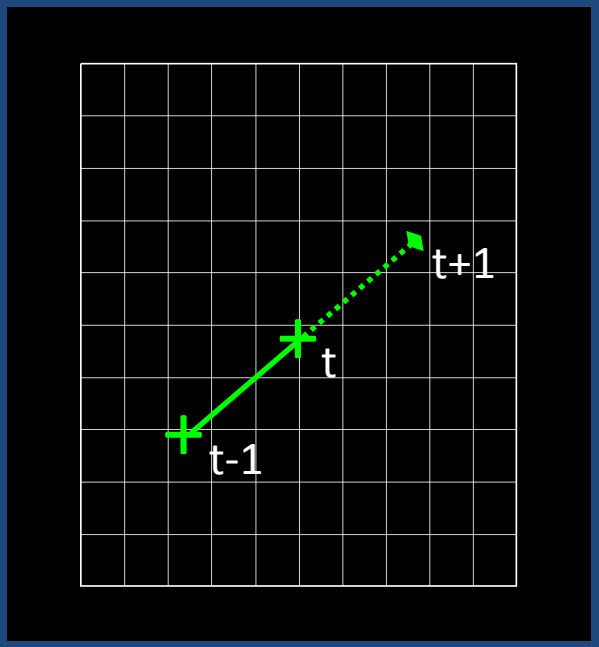
The remaining parameter fixes are averaged to produce the mean position fix for each forecast hour.

- These additional parameters are computed once the center fix is made:
  - Max surface wind
  - R_{max}
  - Minimum MSLP
  - 34-, 50- and 64-kt wind radii



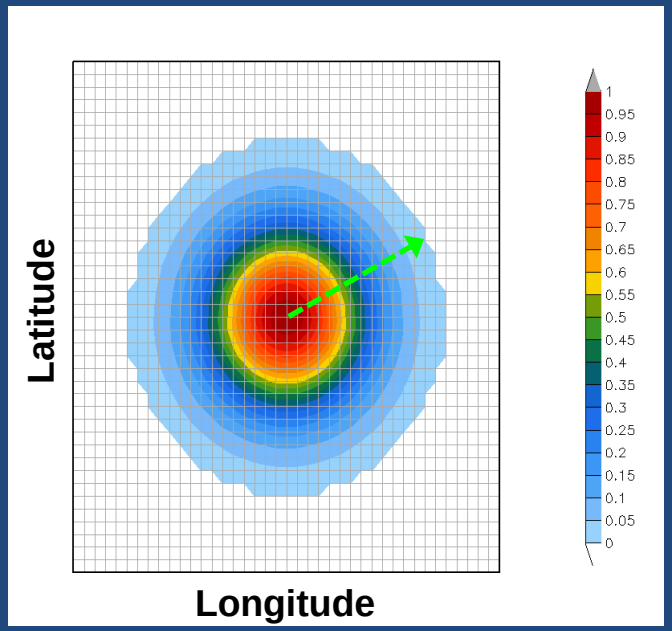
Tracking from one lead time to the next

Linear extrapolation



The guess positions from these 2 methods are averaged to compute a final guess position for the search at the next lead time.

Barnes analysis & advection



A Barnes analysis with a large r_e at 850, 700 & 500 mb is used to compute mean steering winds. A parcel is advected to a guess position at the next lead time.

"Quality Control"

A series of checks is applied to ensure that the tracker is following a storm that is the system of interest

MSLP Gradient: Gross check to ensure minimum gradient (~0.5 mb / 300 km) exists within 300 km of center. Set in script: "mslpthresh" variable

V_T (850 mb): Mean V_T within 225 km must be cyclonic and exceed threshold. Default (1.5 ms^{-1}) is set in script: "v850thresh" variable

$DIST_{(MSLP\text{-}Zeta850)}$: This distance between the MSLP and $Zeta_{850}$ parameter fixes must not exceed a distance defined in source by "max_mslp_850" (usually set to 323 km).

Translational speed: Speed of storm movement must not exceed threshold, set by "maxspeed_tc" variable (usually set to 60 knots).

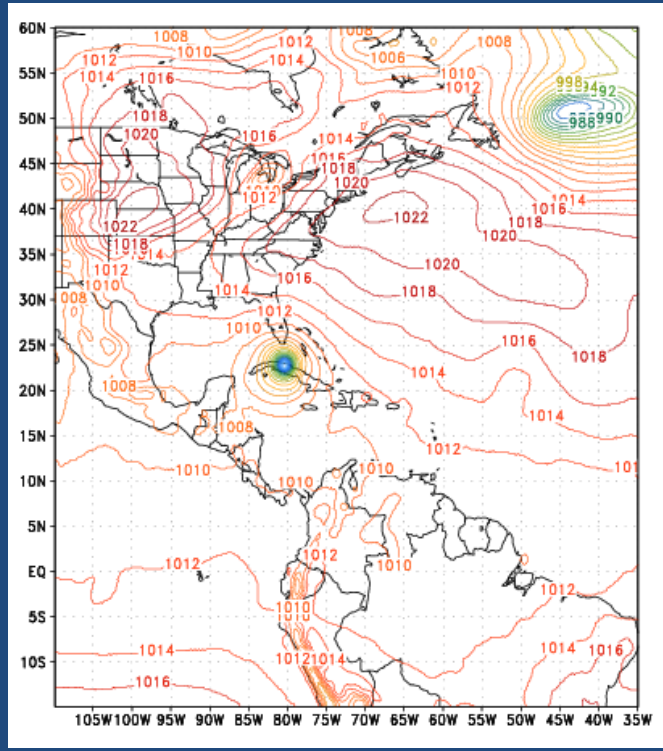
Outline

- History & description of the GFDL vortex tracker
- Inputs & Outputs
- ATCF-plot: GrADS-based track and intensity plotting script

Tracker inputs: Synoptic data

- Data must be in Gridded Binary (GRIB) Version 1 format.
- Data points must increment from northwest (1,1) to southeast (imax, jmax).
- Data must be on a lat/lon grid.
- dx does not need to equal dy, but both must remain uniform over the domain.

(1,1)

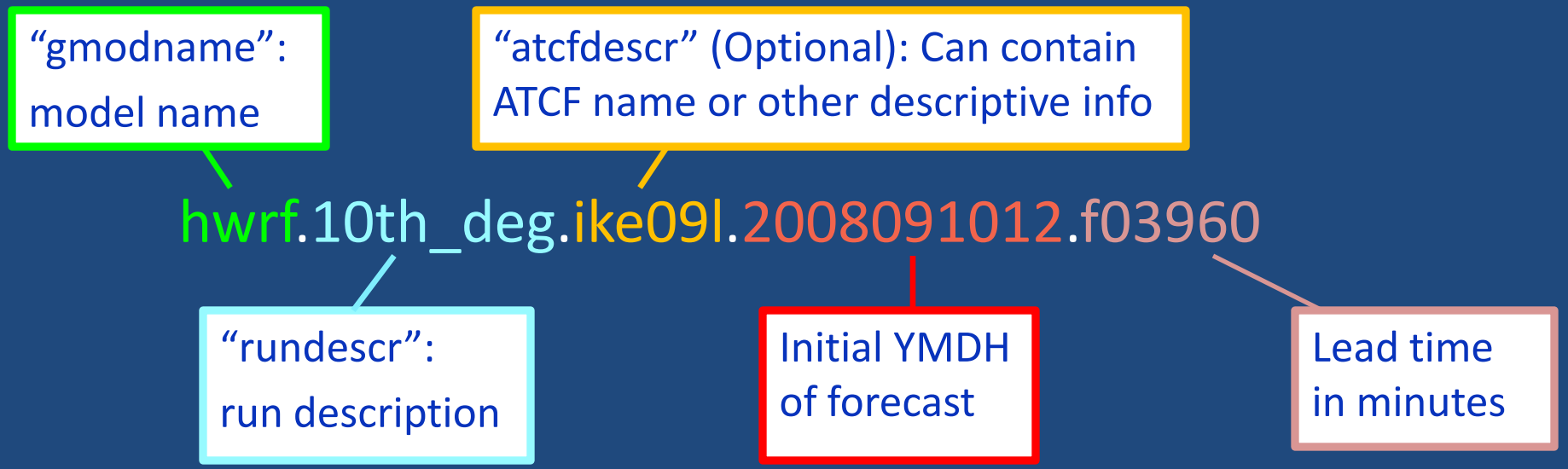


(imax,jmax)

- Data lead time intervals do not need to be evenly spaced

Tracker inputs: GRIB files & names

- GRIB files can either contain individual files for each tau or can contain records for all taus in one big file.
- If using one big file, the file is linked from the script and the file name format is flexible.
- If using separate files for each tau, the files are opened internally, and a specific file name format must be followed. Example:



Tracker inputs: Observed TC data

- Tracker searches for a vortex initially at a location specified by NHC or JTWC on a "TC Vitals record":

NHC 12L KATRINA 20050829 0000 272N 0891W 335 046 0904 1006 0649 72 037
0371 0334 0278 0334 D 0204 0185 0139 0185 72 410N 815W 0167 0167 0093

ATCF ID (12L = 12th storm in the Atlantic).

E = Eastern Pacific

C = Central Pacific

W = Western Pacific

Report date and time

Observed storm latitude & longitude

Observed direction of storm motion in degrees from north (335 = ~NNW), and storm translation speed (046 = 4.6 ms^{-1})

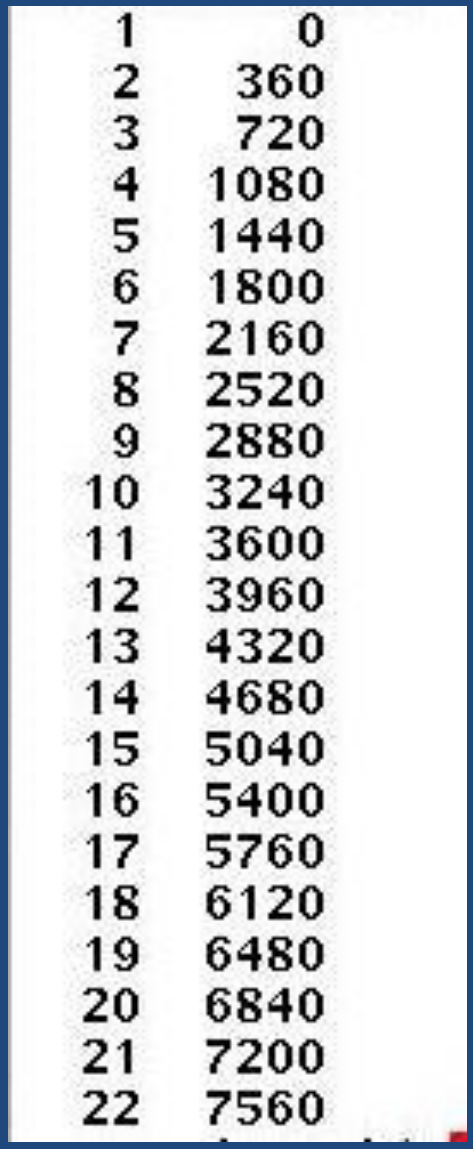
Tracker inputs: Namelist options

```
&datein
  inp%bcc=${CC},
  inp%byy=${YY},
  inp%bmm=${MM},
  inp%bdd=${DD},
  inp%bhh=${HH},
  inp%model=17,
  inp%lt_units='minutes',
  inp%file_seq='multi'/
&atcfinfo
  atcfnum=83,
  atcfname='${ATCFNAME}',
  atcfymdh=${YYYY}${MM}${DD}${HH}/
&trackerinfo
  trkrinfo%westbd=260.0,
  trkrinfo%eastbd=350.0,
  trkrinfo%northbd=40.0,
  trkrinfo%southbd=1.0,
  trkrinfo%type='tracker',
  trkrinfo%mslpthresh=0.0015,
  trkrinfo%v850thresh=1.5000,
  trkrinfo%gridtype='regional',
  trkrinfo%contint=100.0,
  trkrinfo%out_vit='y'/
&phaseinfo
  phaseflag='n',
  phasescheme='both'/
&structinfo
  structflag='n',
  ikeflag='n'/
&fnameinfo
  gmodname='gfdl',
  rundescr='6thdeg',
  atcfdescr='ike091'/
```

- Starting date & time
- ID number for model in the executable. Leave as ‘17’
- Indicator for GRIB data lead time units
- “multi” = 1 file for each tau; “onebig” = 1 file for all taus
- Obsolete, leave as ‘83’
- ATCF model name: “HWRF”, “HAHW”, “TEST”, etc
- Starting yyyymmddhh for output ATCF record
- For genesis tracking use. Fill with any values, as shown.
- ‘tracker’, ‘midlat’, ‘tcgen’. Only use ‘tracker’ here
- Thresholds for mslp gradient and V_{850}
- Model grid type: ‘regional’ or ‘global’
- Not yet supported. Leave values as they are….
- File name info, if “multi” option chosen for inp%file_seq

Tracker inputs: List of forecast hours

- The tracker can handle lead times that are stored in the GRIB file header either in units of minutes or hours.
- Explicitly detailing the forecast hours allows for irregularly spaced intervals.
- Regardless of whether your GRIB data lead time units are in minutes or hours, you must supply a text file as input that has the lead times listed in minutes (code will convert to hours).



1	0
2	360
3	720
4	1080
5	1440
6	1800
7	2160
8	2520
9	2880
10	3240
11	3600
12	3960
13	4320
14	4680
15	5040
16	5400
17	5760
18	6120
19	6480
20	6840
21	7200
22	7560

Tracker output: Standard ATCF file

- Text format. Minimum of 1 record per lead time (⬇), maximum of 3.
  - 1st record contains track & intensity info, plus radii for 34-knots winds
  - 2nd record: Same track & intensity info, plus radii for 50-knot winds, if present.
  - 3rd record: Same track & intensity info, plus radii for 64-knot winds, if present.

```
AL, 09, 2008091012, 03, HWRF, 000, 239N,  855W,  68,  969, XX,  34, NEQ, 0163, 0146, 0086, 0124,    0,    0, 064
AL, 09, 2008091012, 03, HWRF, 000, 239N,  855W,  68,  969, XX,  50, NEQ, 0090, 0088, 0063, 0070,    0,    0, 064
AL, 09, 2008091012, 03, HWRF, 000, 239N,  855W,  68,  969, XX,  64, NEQ, 0067, 0000, 0000, 0048,    0,    0, 064
AL, 09, 2008091012, 03, HWRF, 006, 240N,  861W,  95,  960, XX,  34, NEQ, 0262, 0285, 0168, 0214,    0,    0, 052
AL, 09, 2008091012, 03, HWRF, 006, 240N,  861W,  95,  960, XX,  50, NEQ, 0114, 0122, 0092, 0095,    0,    0, 052
AL, 09, 2008091012, 03, HWRF, 006, 240N,  861W,  95,  960, XX,  64, NEQ, 0084, 0087, 0049, 0073,    0,    0, 052
AL, 09, 2008091012, 03, HWRF, 012, 244N,  866W,  97,  958, XX,  34, NEQ, 0255, 0239, 0136, 0159,    0,    0, 046
AL, 09, 2008091012, 03, HWRF, 012, 244N,  866W,  97,  958, XX,  50, NEQ, 0160, 0122, 0090, 0091,    0,    0, 046
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AL, 09, 2008091012, 03, HWRF, 018, 249N,  872W,  99,  954, XX,  34, NEQ, 0263, 0245, 0182, 0241,    0,    0, 035
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AL, 09, 2008091012, 03, HWRF, 018, 249N,  872W,  99,  954, XX,  64, NEQ, 0094, 0095, 0049, 0078,    0,    0, 035
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                                                                                                    .
```
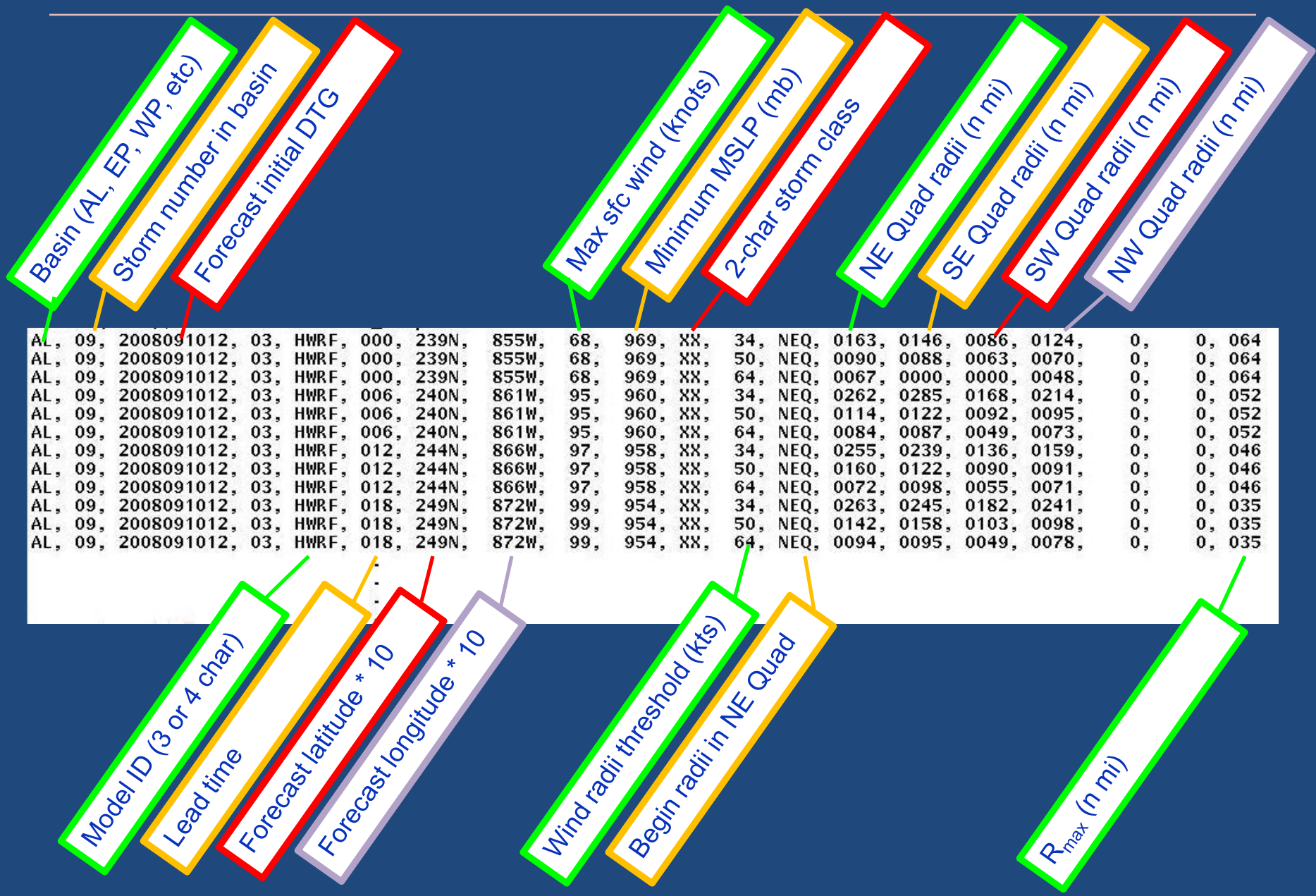
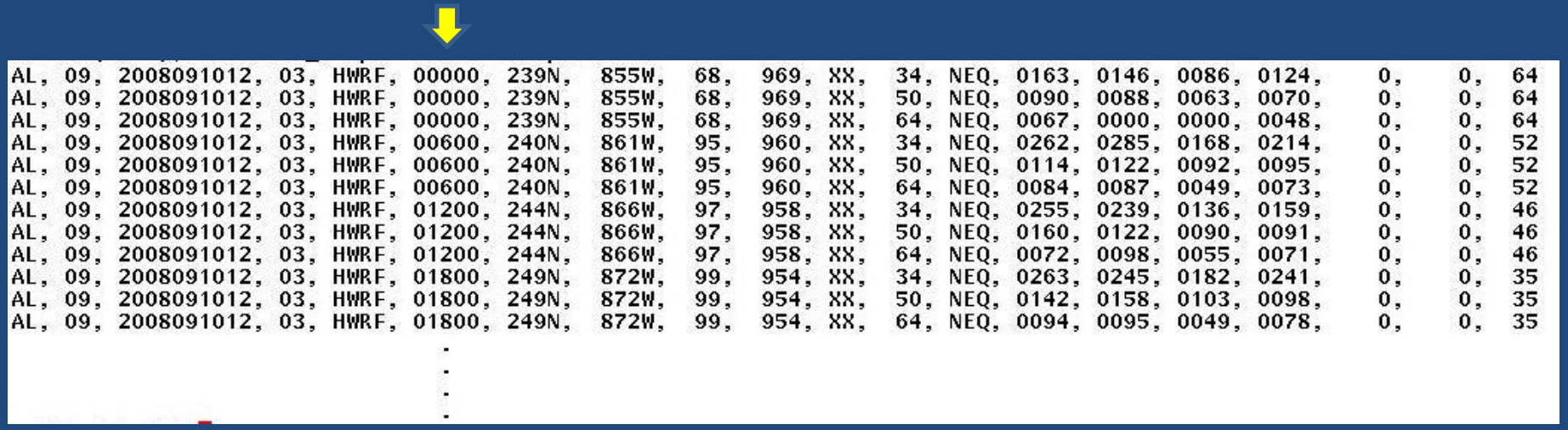

Tracker output: Standard ATCF file



Tracker output: Modified ATCF file

- Nearly same format as standard ATCF file, except the lead time (⬇) has 2 extra places for fraction of an hour, allowing for ATCF-style output at non-hourly times.
  - Example: "04825" would be 48.25 hours, or 48 hours, 15 minutes.



```
AL, 09, 2008091012, 03, HWRF, 00000, 239N,  855W,  68,  969, XX,  34, NEQ, 0163, 0146, 0086, 0124,    0,    0,  64
AL, 09, 2008091012, 03, HWRF, 00000, 239N,  855W,  68,  969, XX,  50, NEQ, 0090, 0088, 0063, 0070,    0,    0,  64
AL, 09, 2008091012, 03, HWRF, 00000, 239N,  855W,  68,  969, XX,  64, NEQ, 0067, 0000, 0000, 0048,    0,    0,  64
AL, 09, 2008091012, 03, HWRF, 00600, 240N,  861W,  95,  960, XX,  34, NEQ, 0262, 0285, 0168, 0214,    0,    0,  52
AL, 09, 2008091012, 03, HWRF, 00600, 240N,  861W,  95,  960, XX,  50, NEQ, 0114, 0122, 0092, 0095,    0,    0,  52
AL, 09, 2008091012, 03, HWRF, 00600, 240N,  861W,  95,  960, XX,  64, NEQ, 0084, 0087, 0049, 0073,    0,    0,  52
AL, 09, 2008091012, 03, HWRF, 01200, 244N,  866W,  97,  958, XX,  34, NEQ, 0255, 0239, 0136, 0159,    0,    0,  46
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AL, 09, 2008091012, 03, HWRF, 01800, 249N,  872W,  99,  954, XX,  34, NEQ, 0263, 0245, 0182, 0241,    0,    0,  35
AL, 09, 2008091012, 03, HWRF, 01800, 249N,  872W,  99,  954, XX,  50, NEQ, 0142, 0158, 0103, 0098,    0,    0,  35
AL, 09, 2008091012, 03, HWRF, 01800, 249N,  872W,  99,  954, XX,  64, NEQ, 0094, 0095, 0049, 0078,    0,    0,  35
                                                                                                    .
                                                                                                    .
                                                                                                    .
                                                                                                    .
```

Tracker output: Standard out

- A table is printed out that lists the tracker-derived fixes for each parameter and distance from the guess.

Maximum allowable distance that a parameter fix can be from the guess location in order to be included

Storm & lead time info

Guess location for this lead time

Max or min barnes-averaged value found by tracker

Distance of parameter fix from guess location

```
At beg of fixcenter, stderr(ist,ifh-1) =    16.64  xavg_stderr=    11.70
At beg of fixcenter, errpgro =  1.25000000000000000
At beg of fixcenter, errinit =  275.000000000000000
At beg of fixcenter, errpmax =  485.000000000000000
At beg of fixcenter, ifh=  17  errmax=  275.000000000000000

-------------------------------------------------
Individual fixes follow..., fhr=    96:00  09L  IKE
Gen ID (if available): 2008091012_F000_238N_0853W_09L
Model name = GFDT
Values of -99.99 indicate that a fix was unable to be
made for that paramater.  Parameters 4 & 6 are not used.
Vorticity data values are scaled by 1e5.  errdist is the
distance that the position estimate is from the guess
position for this time.  MSLP value here may differ from
that in the atcfunix file since the one here is that
derived from the area-averaged barnes analysis, while
that in the atcfunix file is from a specific gridpoint.
Guess location for this time:  266.46E  ( 93.54W)    37.48
```

parm#	parm	Max/Min	Lon_fix(E)	Lon_fix(W)	Lat_fix	Max/Min_value	calcparm	errdist(km)
1	zeta 850	Max	267.73	92.27	37.94	59.92	T	122.74
2	zeta 700	Max	267.99	92.01	38.05	43.82	T	148.76
3	vmag 850	Min	267.40	92.60	38.15	12.30	T	110.81
4	NOT USED	NOT USED	.00	.00	.00	.00	F	.00
5	vmag 700	Min	267.40	92.60	38.65	8.79	T	153.44
6	NOT USED	NOT USED	.00	.00	.00	.00	F	.00
7	gph 850	Min	267.75	92.25	37.60	1253.22	T	114.48
8	gph 700	Min	267.78	92.22	37.67	2917.31	T	118.31
9	MSLP	Min	267.72	92.28	37.53	98165.14	T	111.22
10	vmag sfc	Min	267.40	92.60	37.65	6.58	T	84.76
11	zeta sfc	Max	267.34	92.66	37.65	19.72	T	80.13

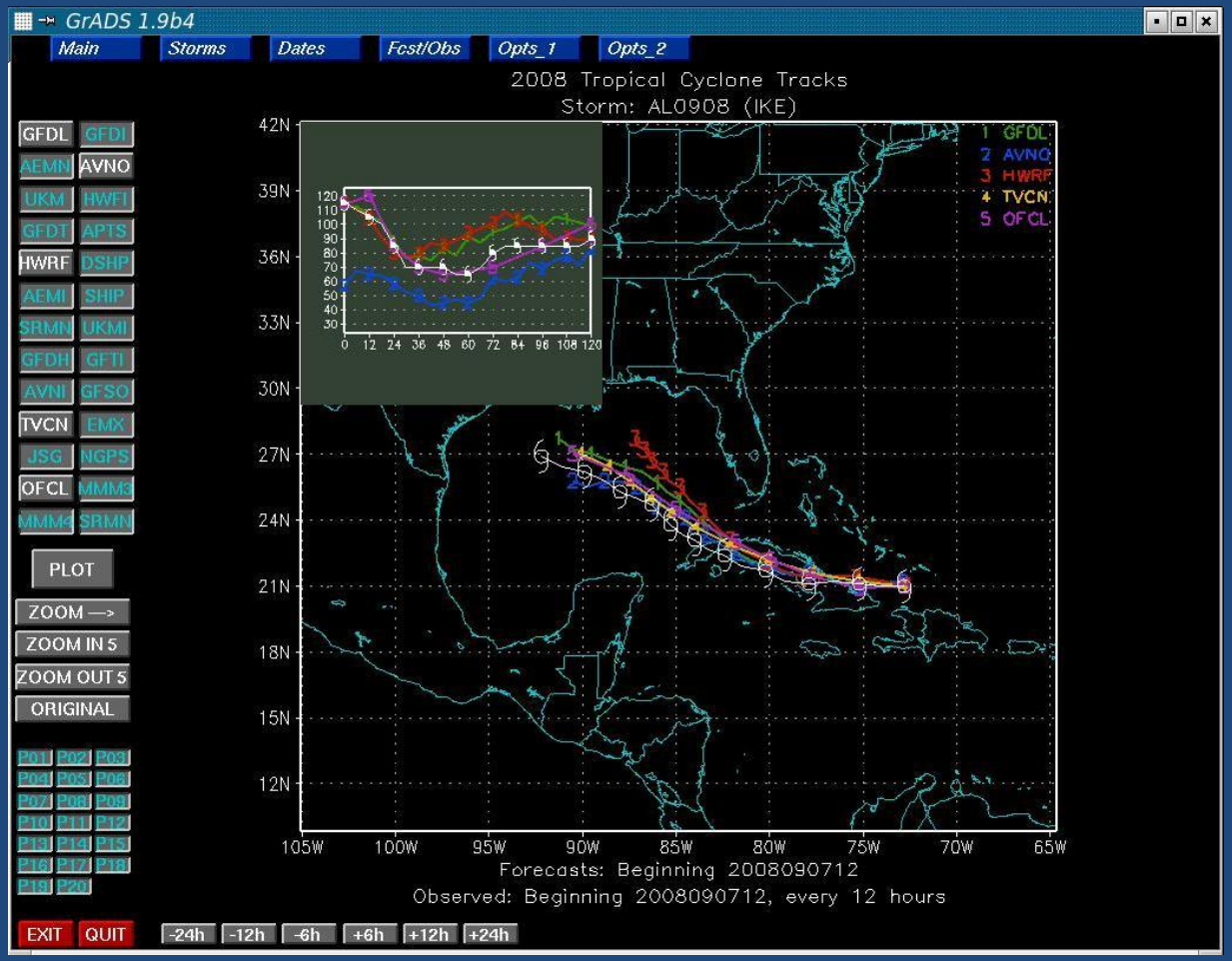
Flag to indicate if parameter fix is within errmax distance and will be included in fix average for this lead time

Outline

- History & description of the GFDL vortex tracker
- Inputs & Outputs
- ATCF-plot: GrADS-based track and intensity plotting script

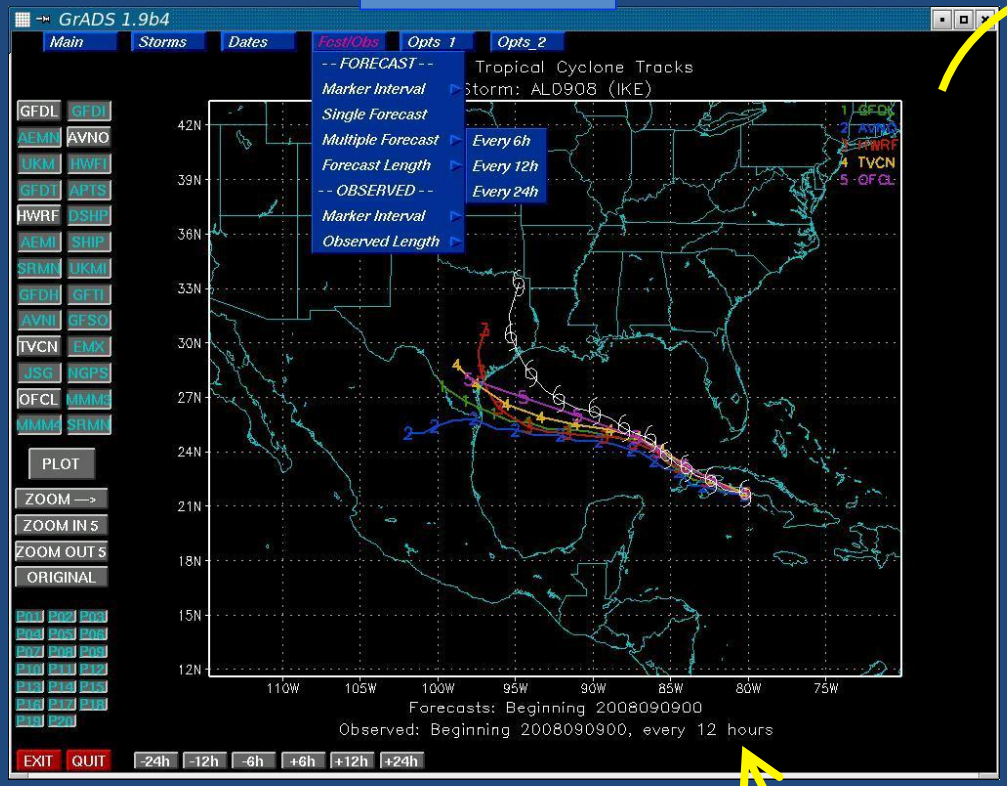
ATCF_plot: GrADS-based plotting tool

- Interactive GrADS tool for plotting both track and intensity.



ATCF_plot: How it works

atcfplot.gs



User-input selections for models, storm, date, etc, are passed to unix scripts.

Unix scripts

The unix scripts pull only the requested ATCF records from the ATCF file for the user-selected storm…

.
.
aal072008.dat
aal082008.dat
aal092008.dat
aal102008.dat
.
.
aal172008.dat

The ATCF records from those flist and vlist text files are read by atcfplot.gs, and the track and intensity plots are created.

flist
vlist

…and dumps those ATCF records into text files.

ATCF_plot: Script setup

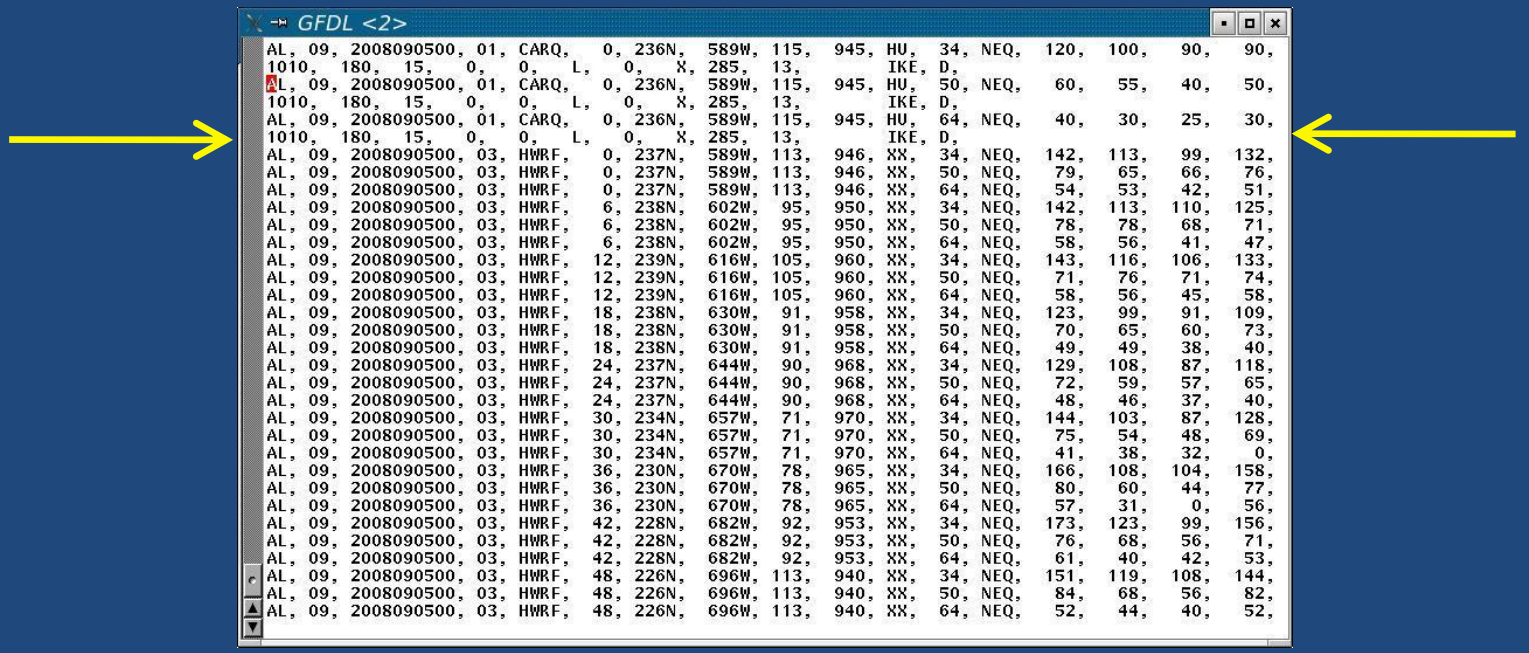
- Edit path names to replace $USER with your username in your version of atcfplot.gs:

_rundir=”/glade/home/$USER/HWRF/src/gfdl-vortextracker/trk_plot/plottrak/"
_netdir=”/glade/home/$USER/HWRF/src/gfdl-vortextracker/trk_plot/plottrak/tracks/“

- For all atcfplot unix scripts here at the tutorial, all paths are defined using environmental variables $HOME and $USER. Back at home, be sure to change the path names accordingly.

ATCF_plot: Input data

- atcf_plot reads in standard ATCF format records, but it needs the *operational* ATCF files, since it keys off of the observational "CARQ" records and uses that data to plot the observed track and intensity (note: Real-time data used, not Best Track).
- Be sure to insert your ATCF records in the ATCF file specifically named a${basin}${storm_ID}${YYYY}.dat after the CARQ records for the correct DTG:

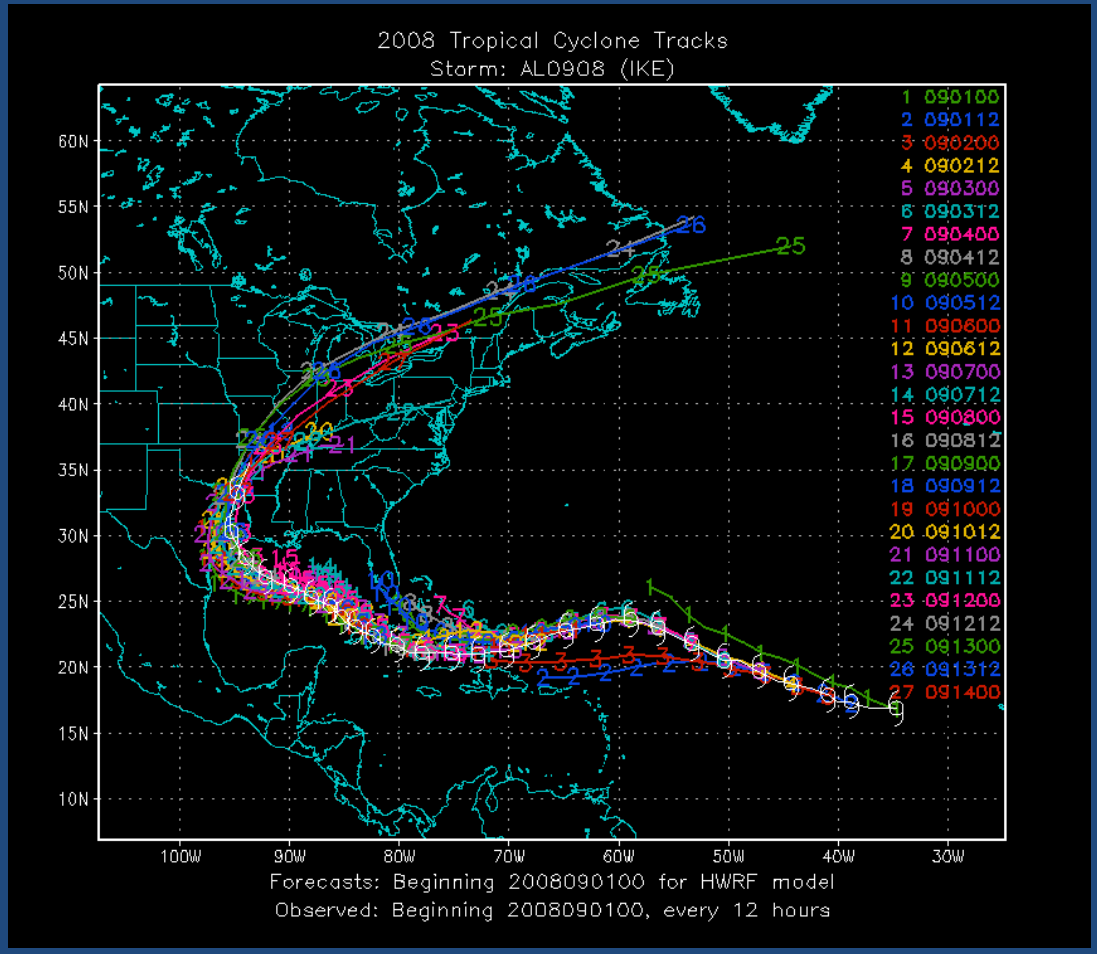


ATCF_plot: Input data

- atcf_plot opens up a GrADS ctl file (plottrak.ctl) that points to a meaningless data set with a global domain. By opening this ctl file and plotting a variable, GrADS now has global dimensions over which we can plot tracks for TCs anywhere on the globe.
- Be sure to also have the plottrak.grib file, then from your unix prompt run the command “gribmap –v –i plottrak.ctl”. In the output, you should see one line that says “MATCH”.
- To run, enter this command from your unix prompt:
  atcfplot.sh YYYY basin
  where basin = al, ep, wp, etc….

ATCF_plot: Some features

- Plot tracks alone, intensity alone, or tracks with an intensity inset window.
- Plot tracks that span from the current DTG through the end of the storm's lifecycle
- The ability to click & drag to zoom in on a particular track segment.



Questions?

Delaware River flooding River Road in Washington Crossing, Pennsylvania, after Hurricane Ivan. September, 2004.