A look at operational and experimental global deterministic and ensemble forecasts for tricky Tropical Storm Debby

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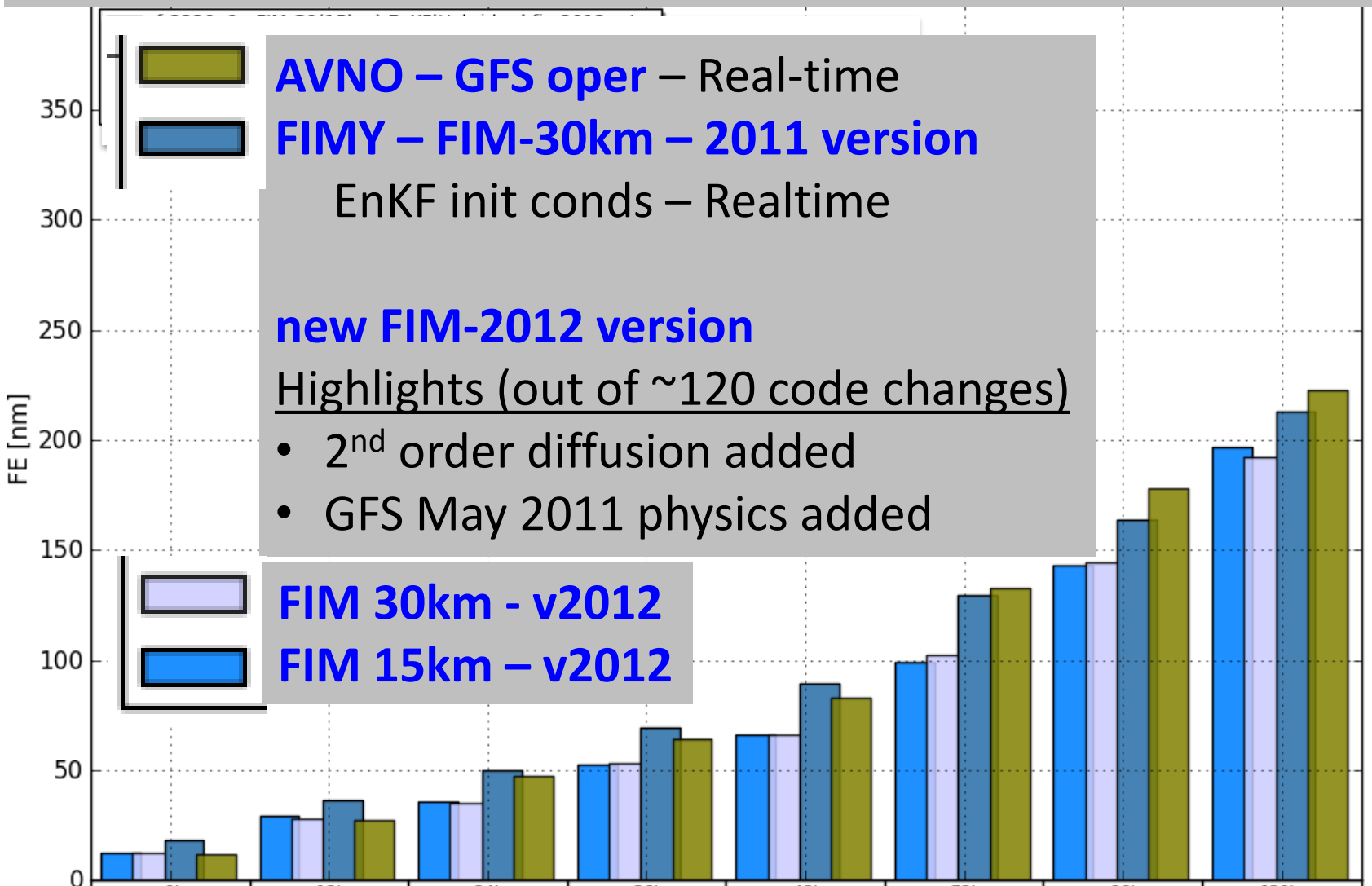
Outline of today's presentation

- Introduction
  - FIM – what's new since 2011 for HFIP
  - Storm overview for Tropical Storm Debby
  - Models considered for Debby case
- Case study – global model forecast comparisons
  - Model run times discussed for Debby
    - 12z/22 June - First initial time examined
- Conclusions and HFIP-2012 real-time plans

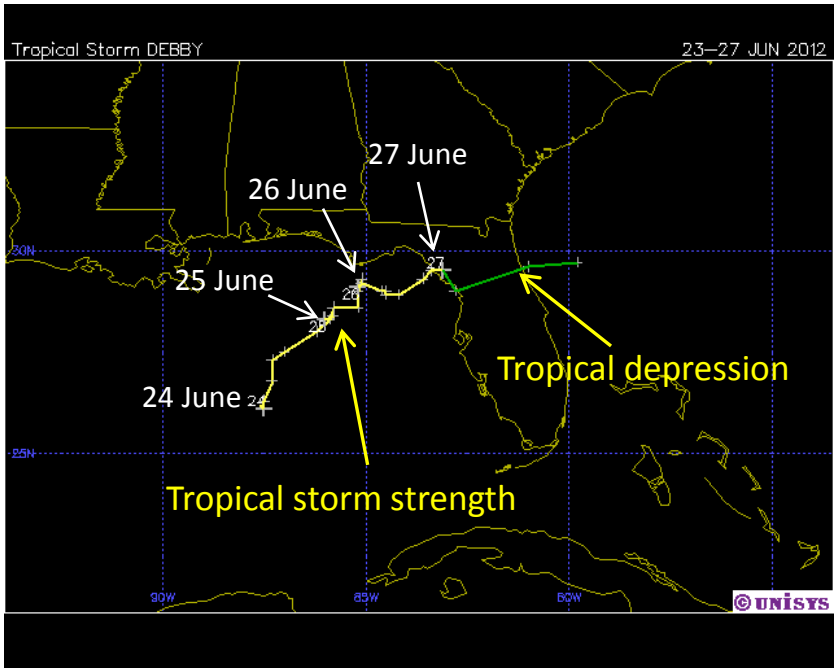
LANT/EPAC Track Error – all 2011 storms – GFS real-time, FIM real-time, new FIM-2012 retro

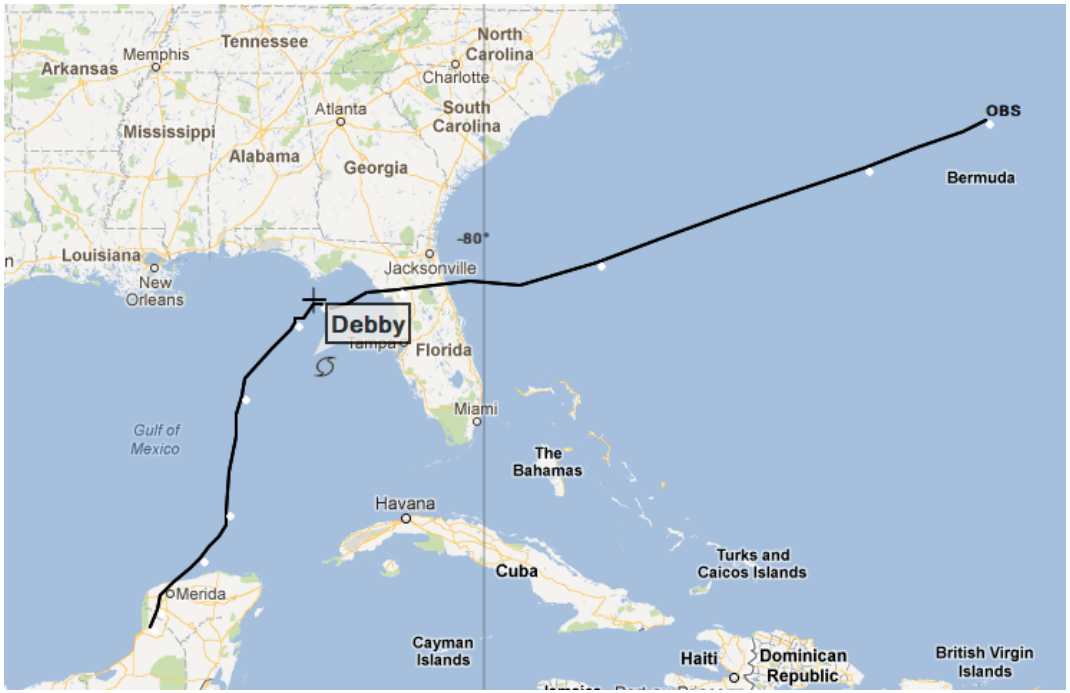


	0h	12h	24h	36h	48h	72h	96h	120h
fr2220g9	13[77]	29[71]	36[63]	52[60]	66[54]	99[47]	143[38]	196[27]
fr2220g8	12[77]	28[71]	35[63]	53[60]	66[54]	102[47]	145[38]	192[27]
fimy	18[77]	36[71]	50[63]	69[60]	89[54]	129[47]	163[38]	213[27]
avno	12[77]	27[71]	47[63]	64[60]	83[54]	133[47]	178[38]	223[27]

Tropical Storm Debby – Late June 2012

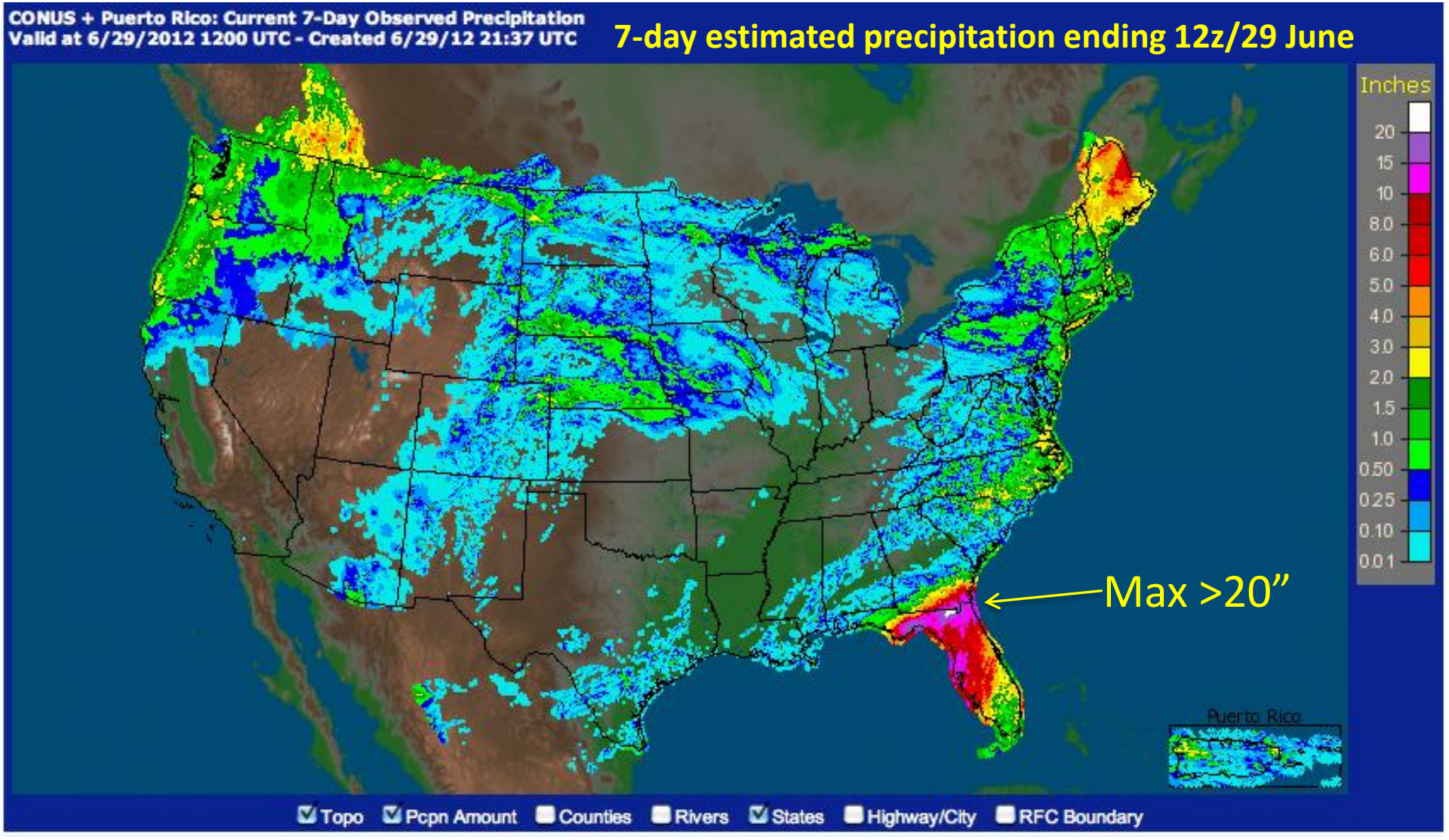
- Develops in the Gulf of Mexico
  - From an easterly wave? Interaction with Pacific system Carlotta?
- Moves slowly east-northeast across northern FL
- Huge precip event in northern FL



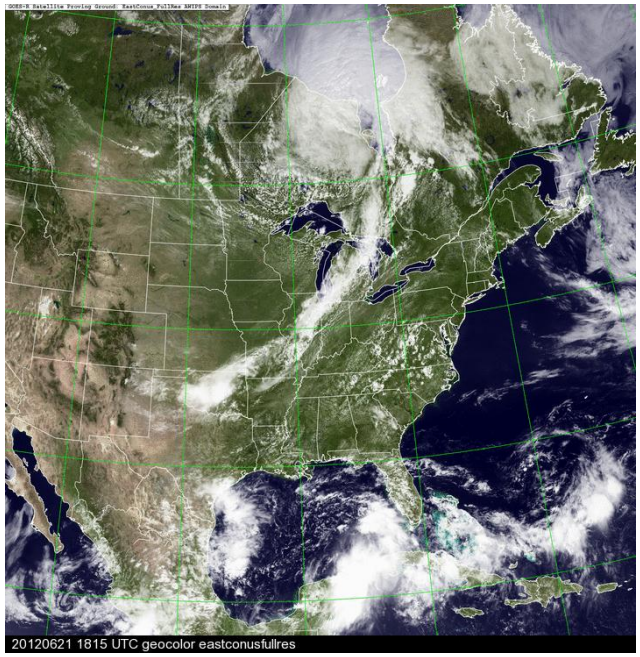


Tropical Storm Debby

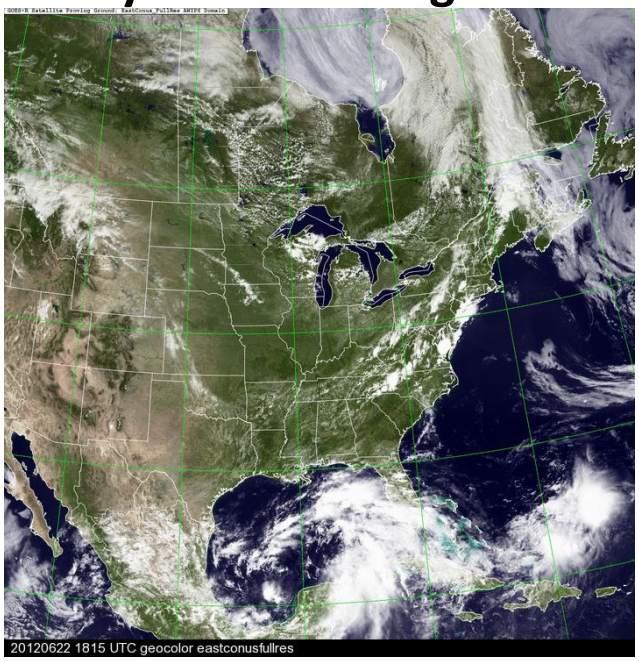
- Biggest impact was the swath of very heavy precipitation in northern Florida



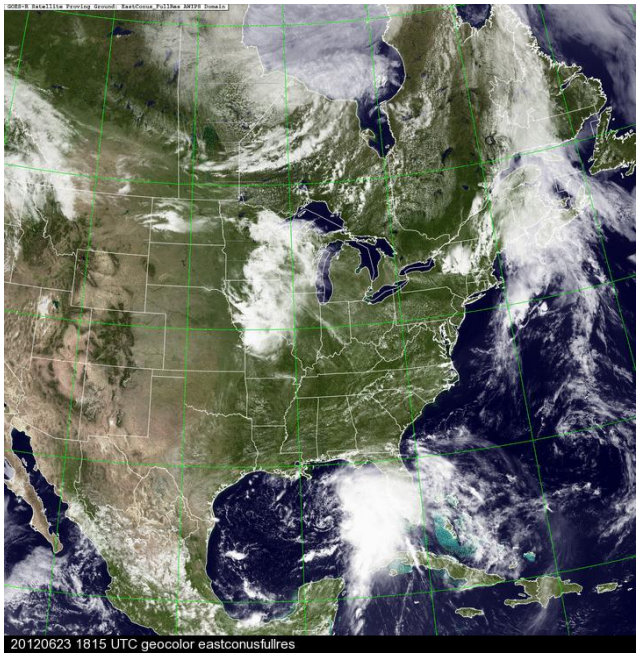
Summary – visible images at 1815z



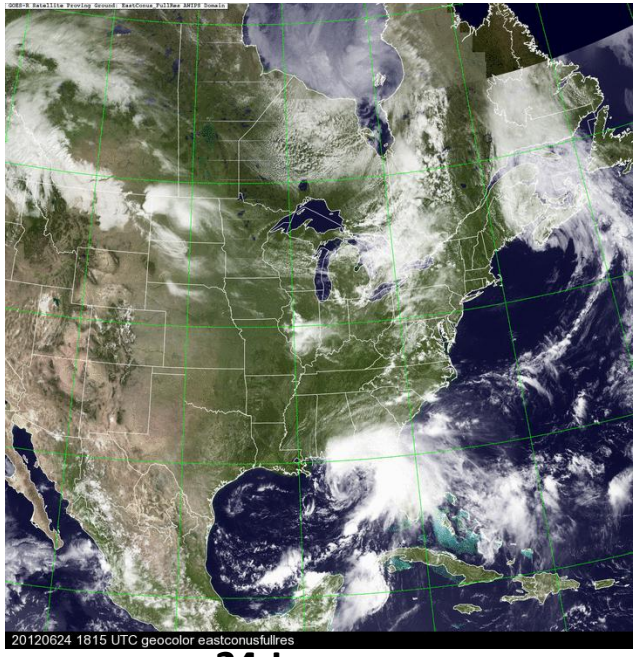
21 June



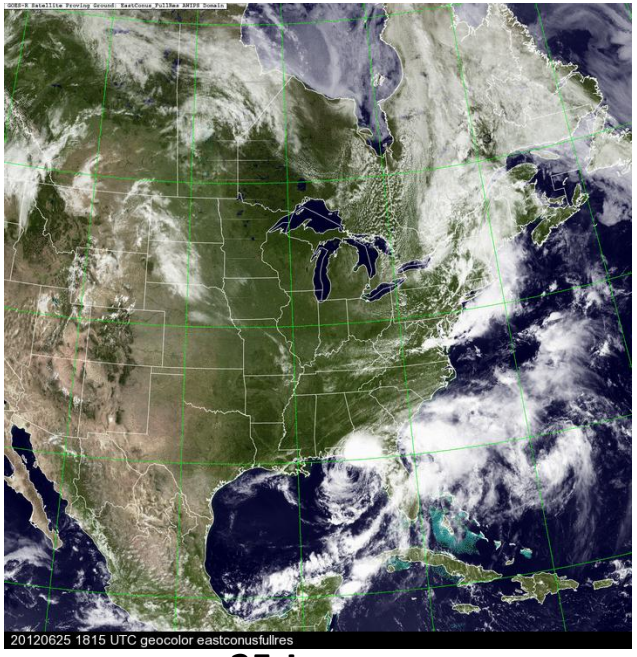
22 June



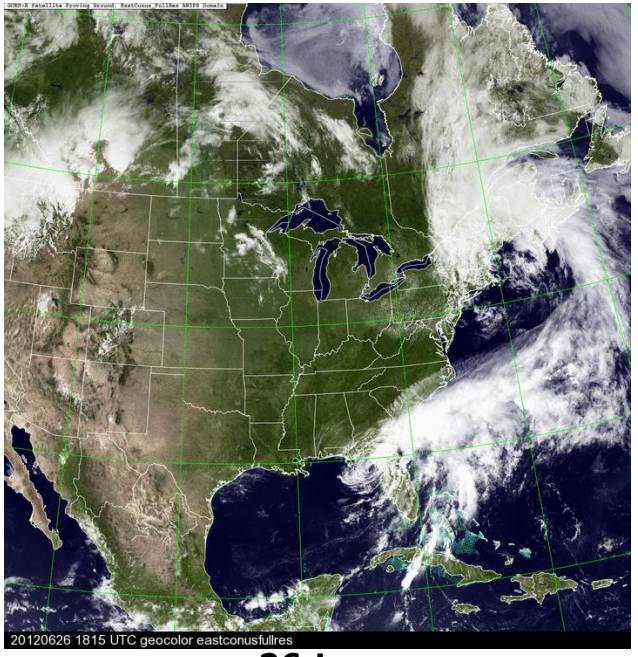
23 June



24 June



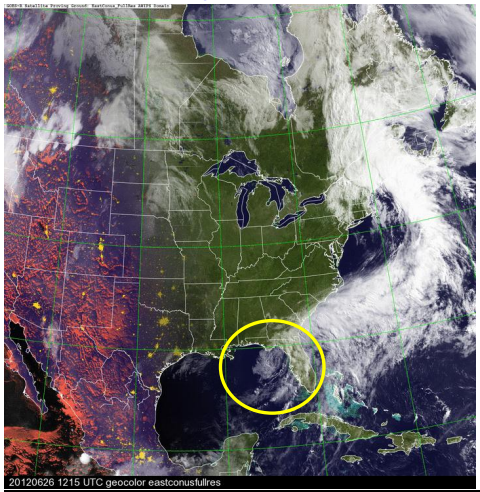
25 June

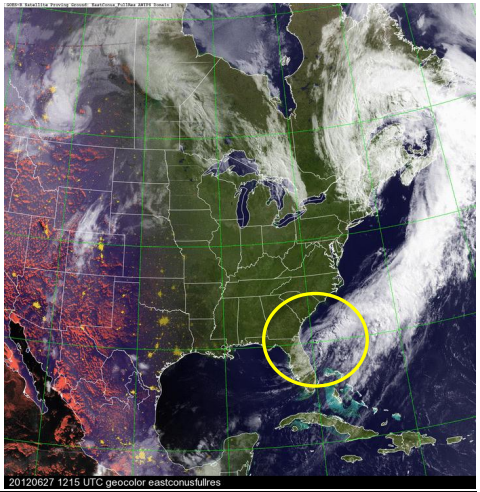


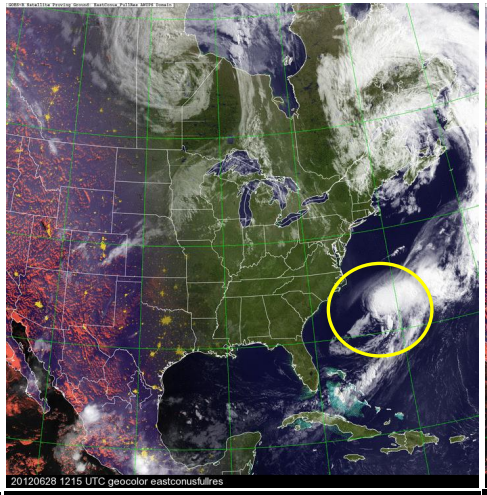
26 June

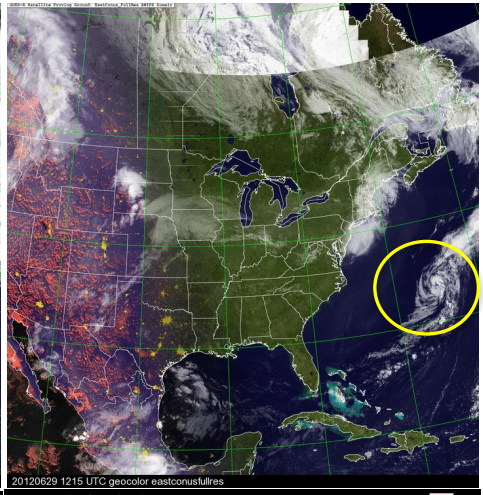
More verification (analyses and imagery)

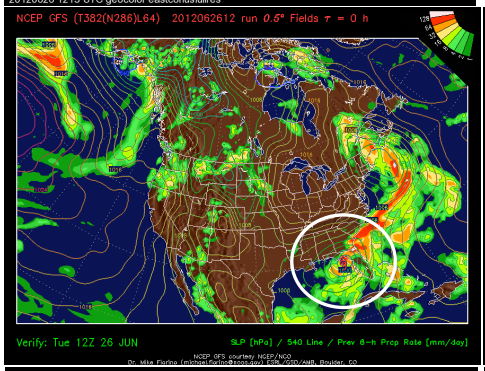
12z/26 June | 12z/27 June | 12z/28 June | 12z/29 June

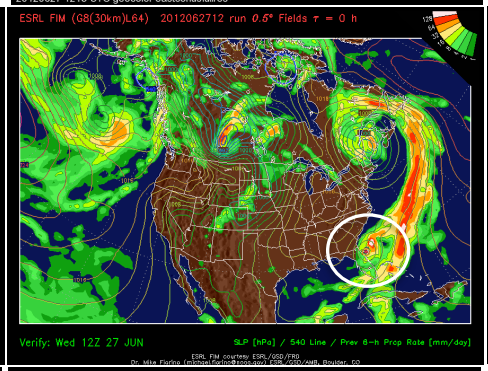


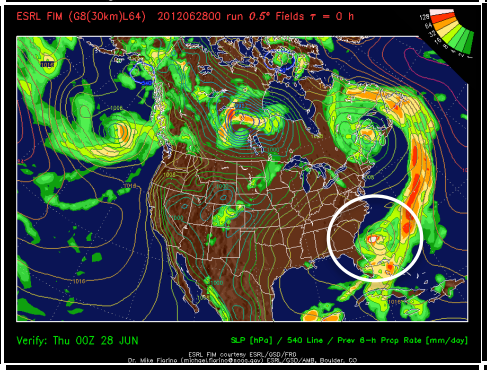


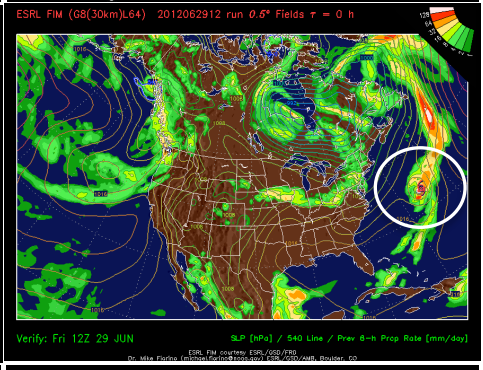


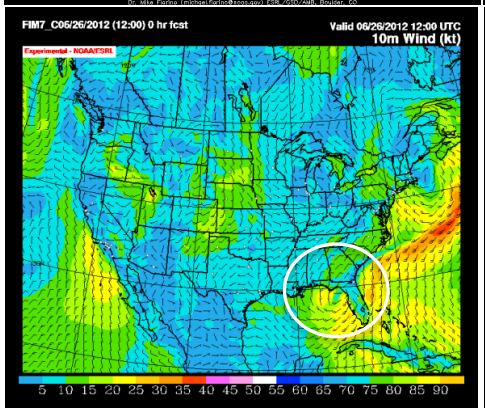


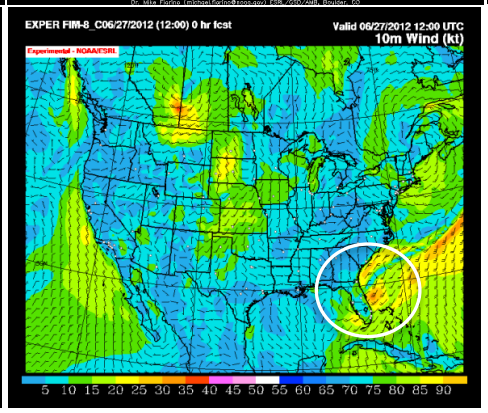


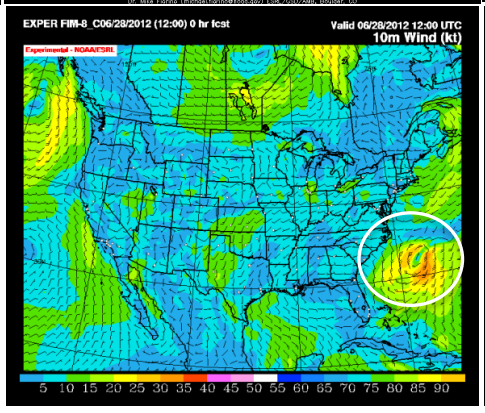


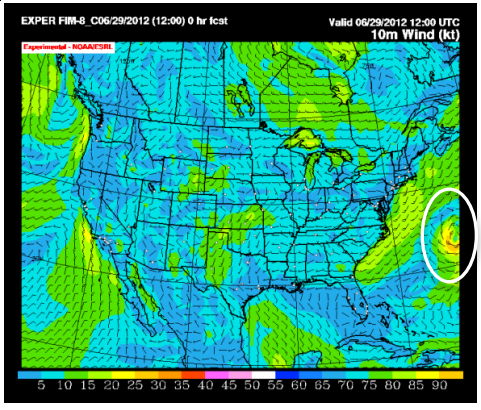




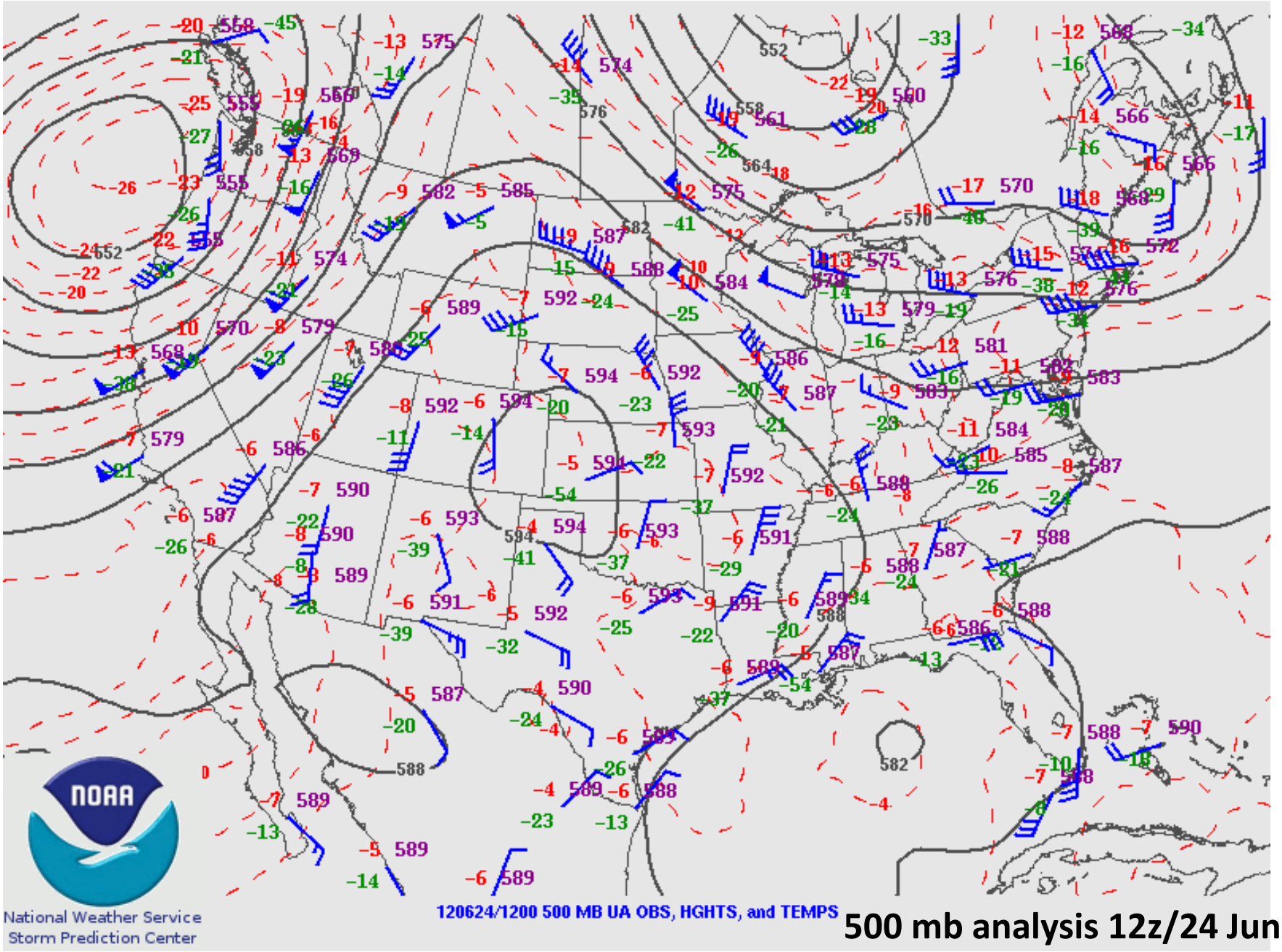








Complex situation – an upper-level low was in the Gulf



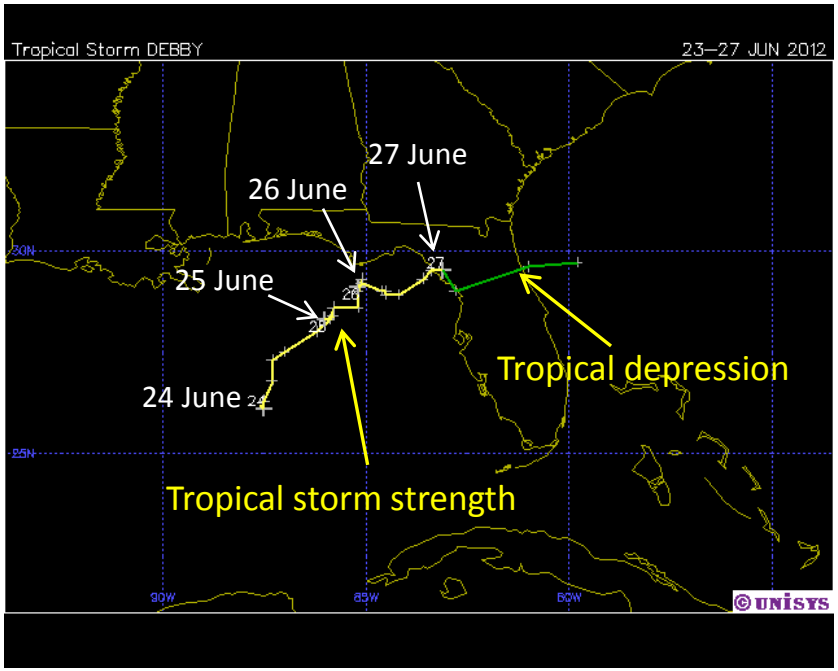
500 mb analysis 12z/24 June

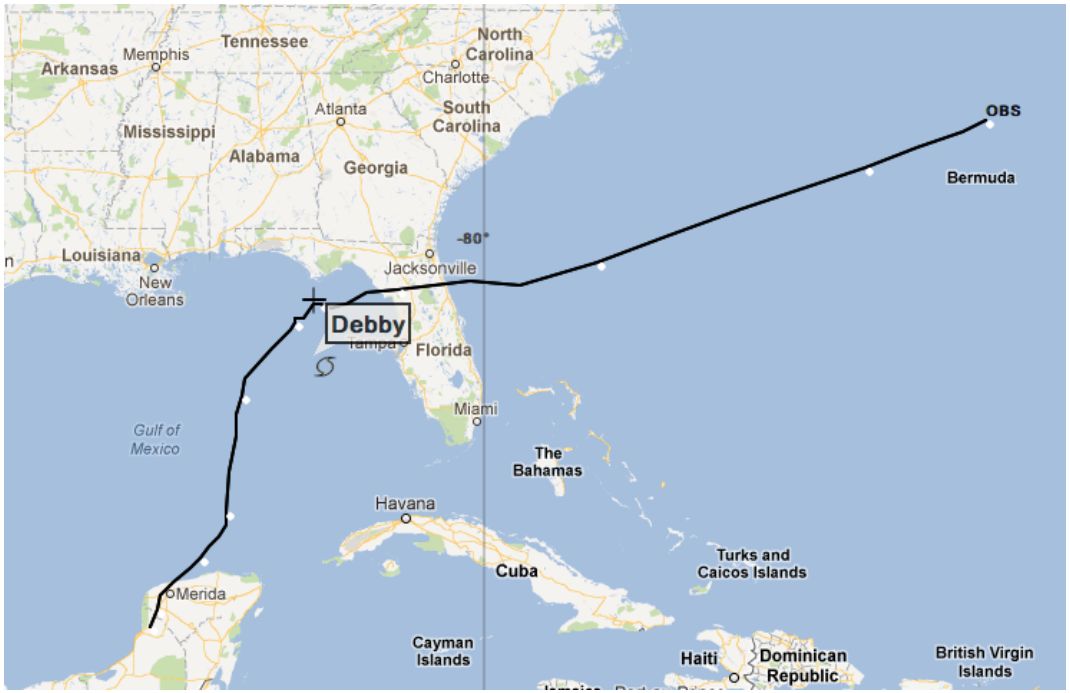
Brief summary of the *deterministic* global models examined

Model	Type	delta x (km)	Vertical	initialization
GFS	spectral	T574/~25	sigma-P	Oper GFS - Hybrid EnKF/3D-VAR GSI
UKMET	grid pt	25 km	sigma-z	Hybrid Incremental 4D-VAR
NOGAPS	spectral	T319/~41	sigma-P	NAVDAS 4D-VAR
Canadian	grid pt	33 km	sigma	4D-VAR
ECMWF	spectral	T1279/~16	sigma-P	4D-VAR
FIM8	icos	~30	sigma-isentropic	GFS oper hybrid EnKF/var
FIM7	icos	~60	sigma-isentropic	GFS oper hybrid EnKF/var
FIM9	icos	~15	sigma-isentropic	GFS oper hybrid EnKF/var
FIMChem	icos	~60	sigma-isentropic	GFS oper hybrid EnKF/var (with WRF inline chemistry in model)

Tropical Storm Debby – Late June 2012

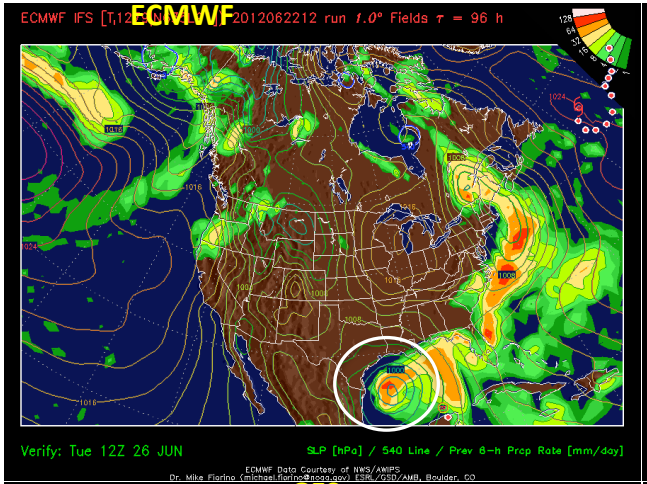
- Overview of model behavior – model-unique characteristics were consistent over several runs
  - 4D-Var init models took storm to the west (ECMWF, UKMET, NOGAPS)
  - GFS had good to excellent forecasts, best overall for this storm. FIM forecasts between GFS and EC/UKMET/NOGAPS

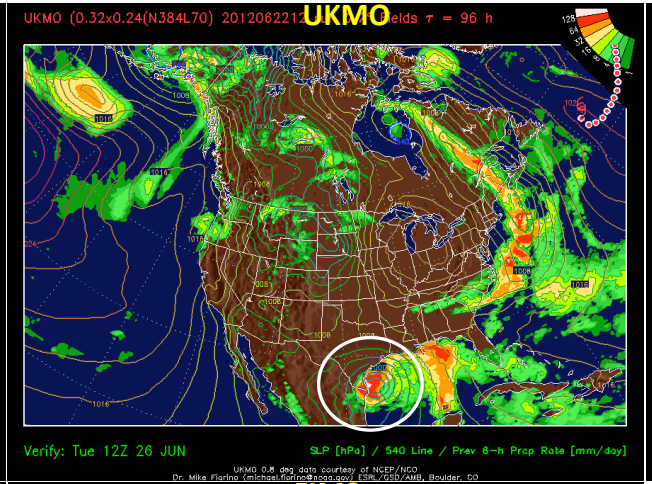


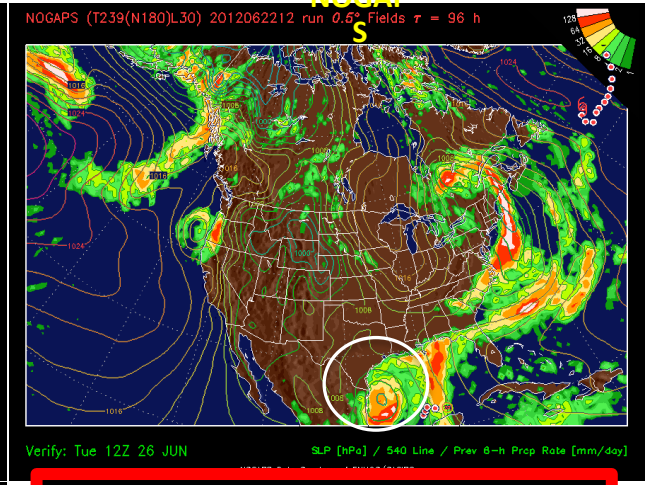


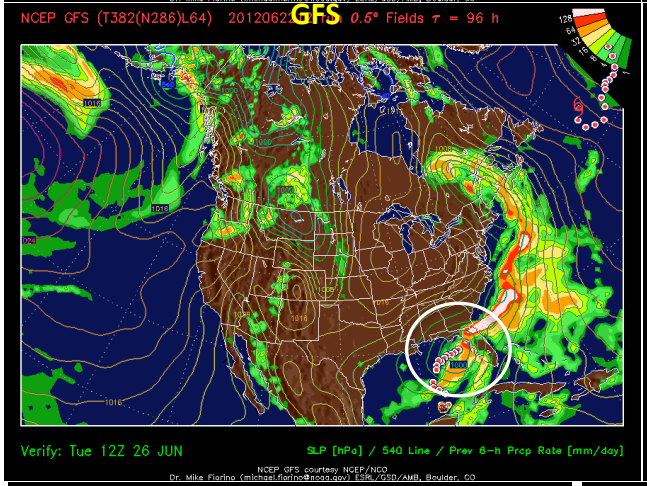
Runs from 12z/Saturday/23 June

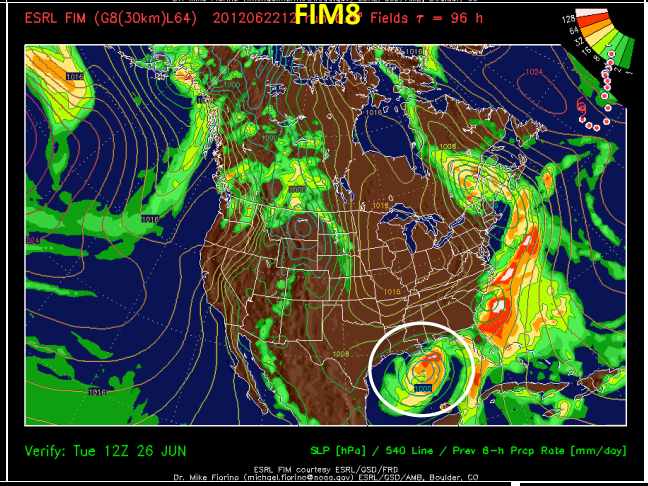
- Shown are 3 forecast times from the deterministic runs
  - 96-, 120- and 144-h forecasts
  - Accumulated precipitation forecast from most of the models
- Model summary
  - 4D-Var init models EC, NOGAPS and UK all send the storm to the west
    - Tracks are fairly close with NOGAPS having a more southern track
  - FIM9 has a more northerly track
    - Close to the other FIM runs but somewhat to the west of them (hits New Orleans)
  - All other FIM runs drift storm to the nne
  - GFS is by far the best forecast
  - Precipitation forecasts:
    - GFS has the best forecast for northern FL
    - FIM runs though are not too bad as they drop a lot of precip near or over FL
    - ECMWF underdoes FL precipitation and has big precip into se TX

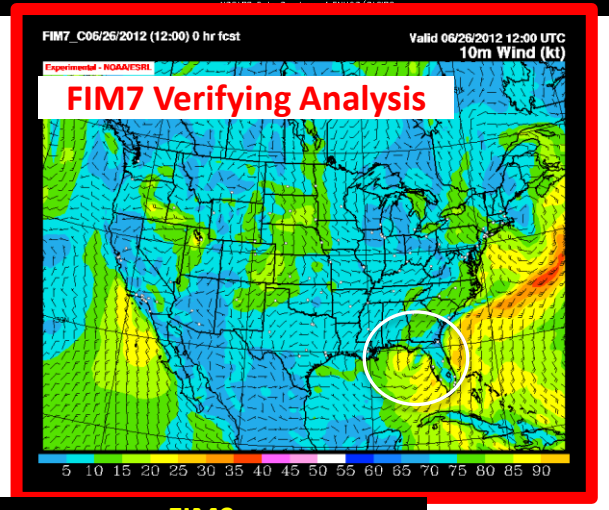


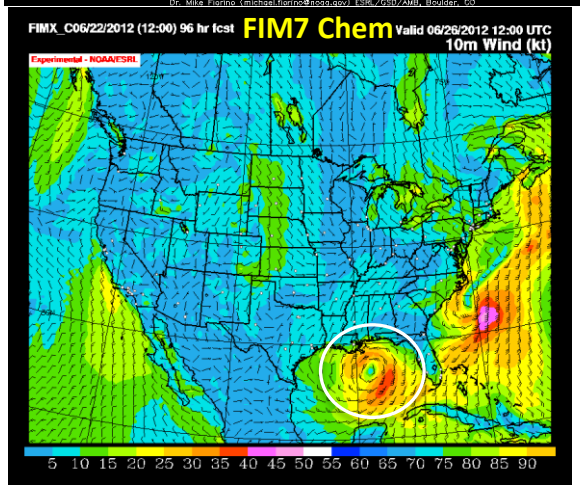


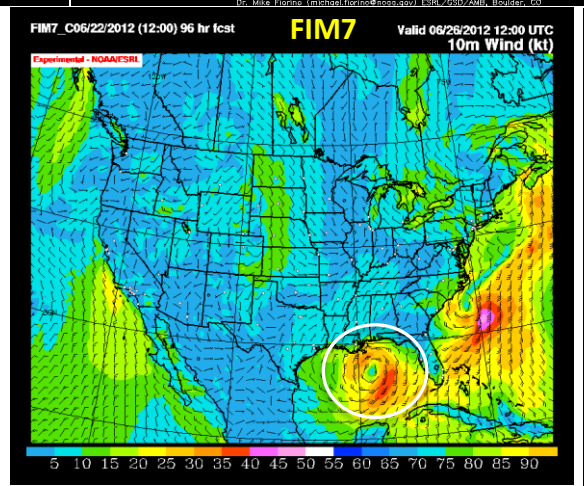


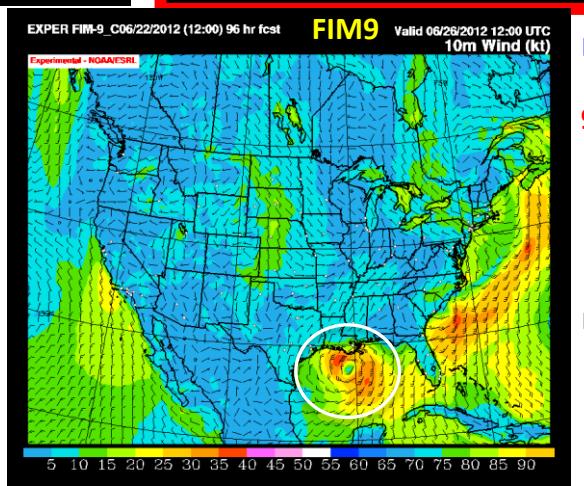






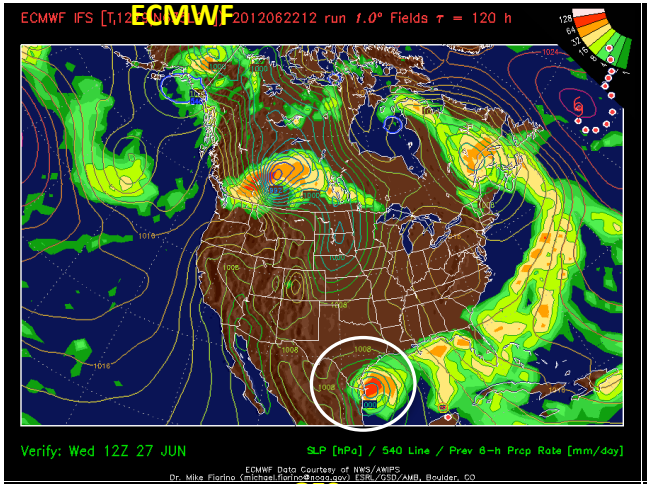


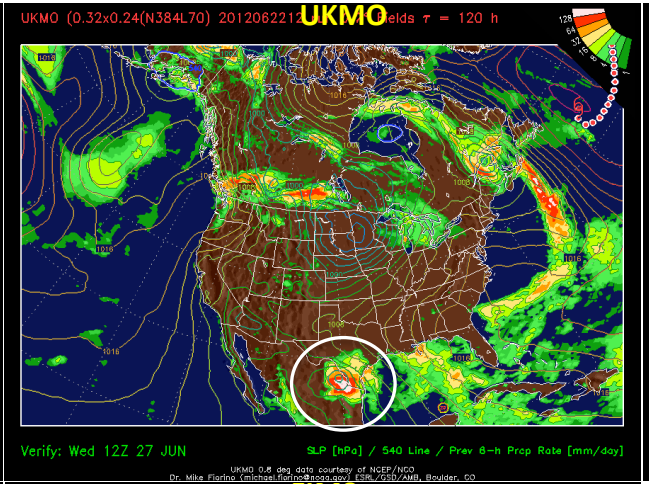


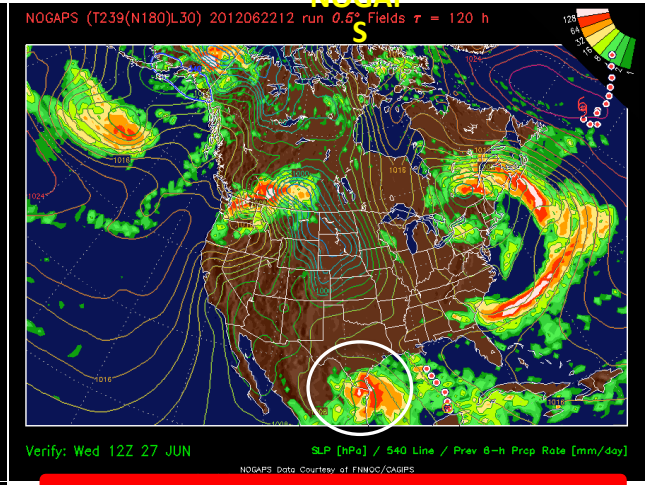


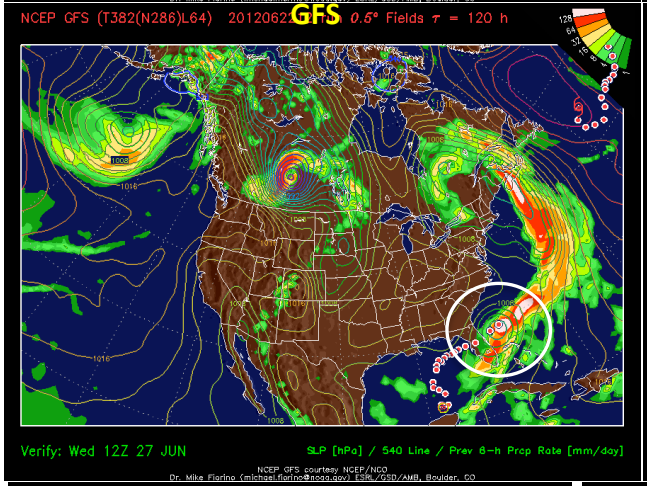
Forecasts from 12z/22 June: 96-h valid 12z 26 June.

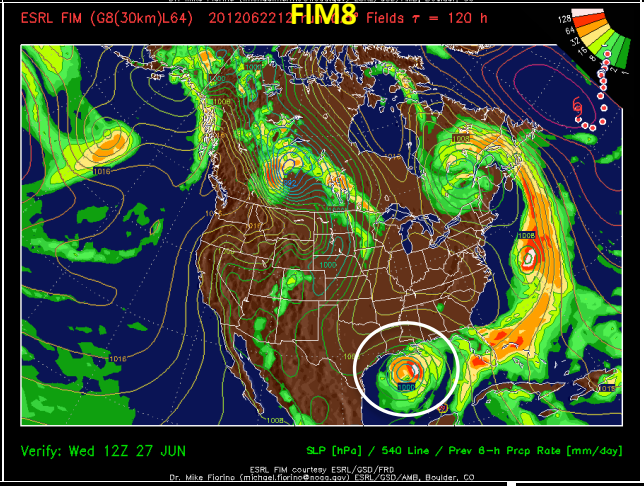
The track of Debby is w-wnw in the 4D-Var models (EC, UK, NOGAPS), ene in the GFS (correct), and more north in the FIM runs.

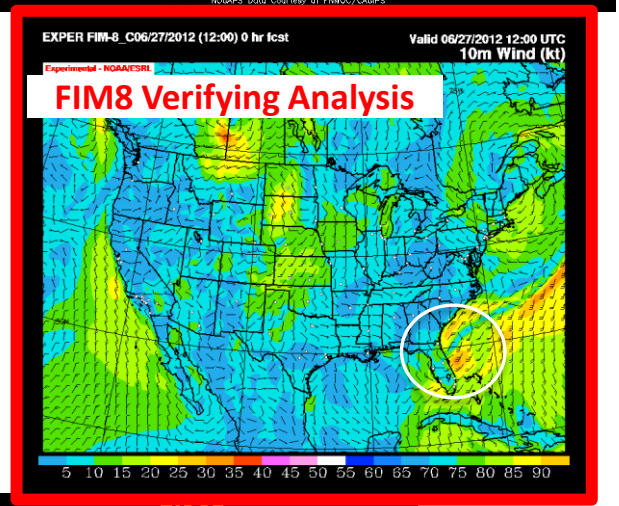


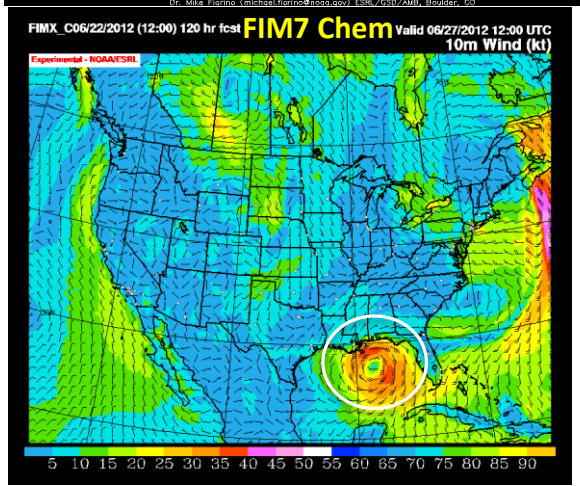


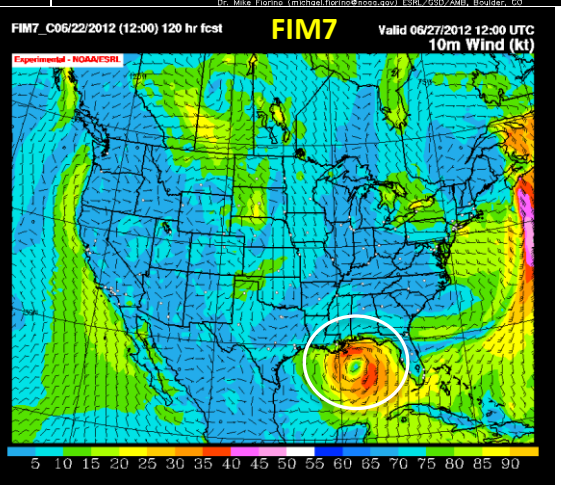


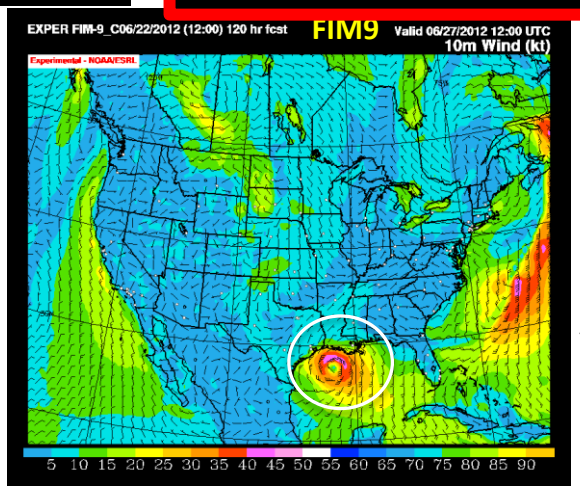




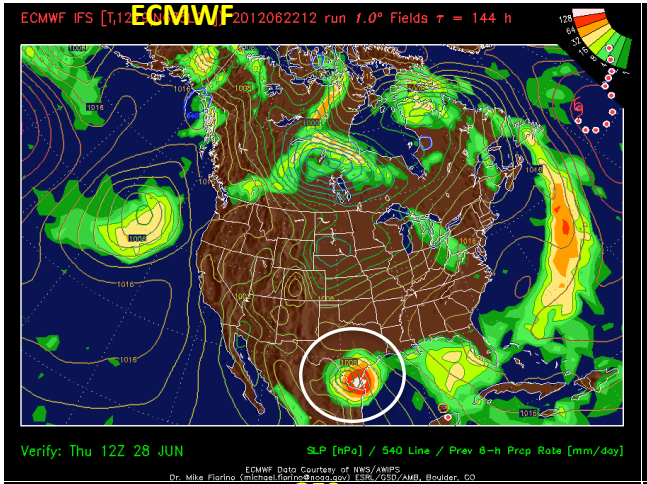


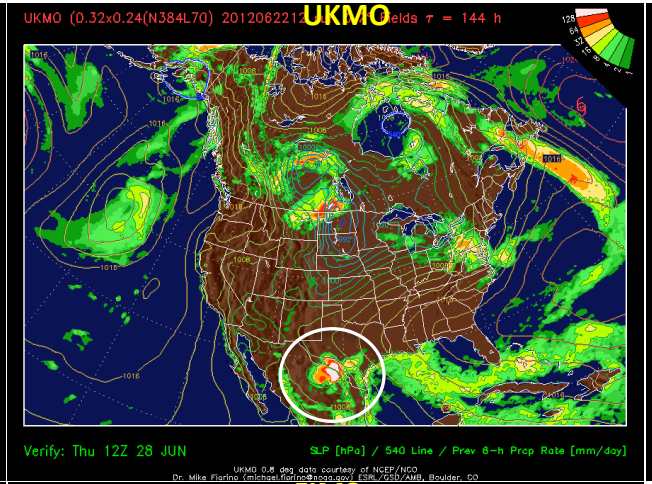


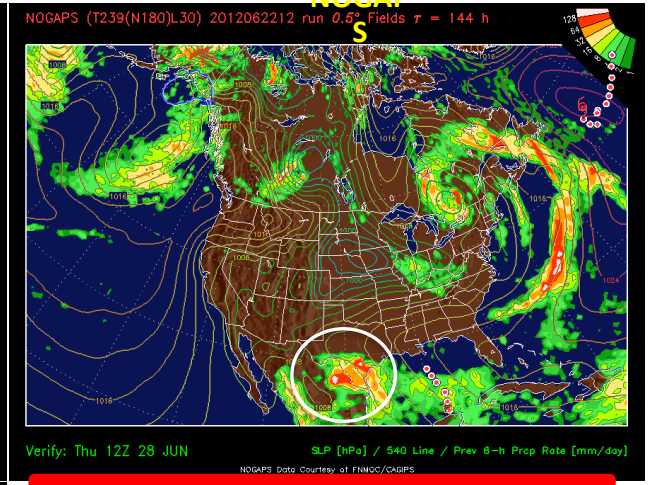


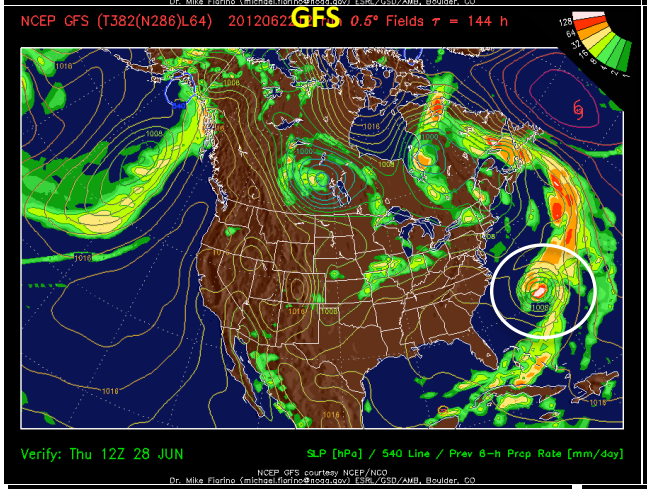


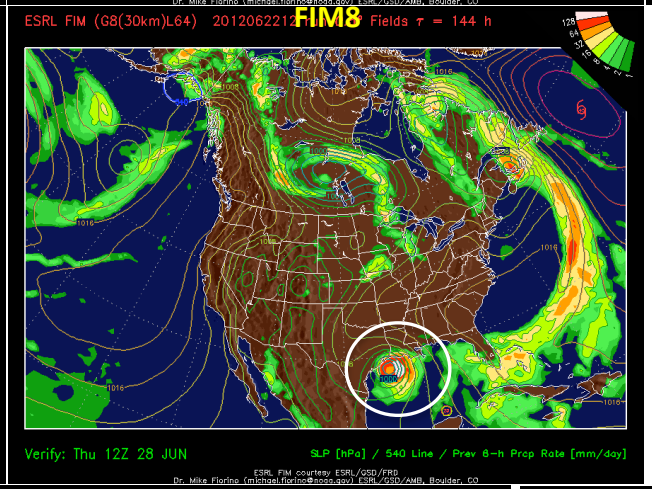
Forecasts from 12z/22 June: 120-h valid 12z 27 June. Only the GFS has the correct track to the ene across northern FL.

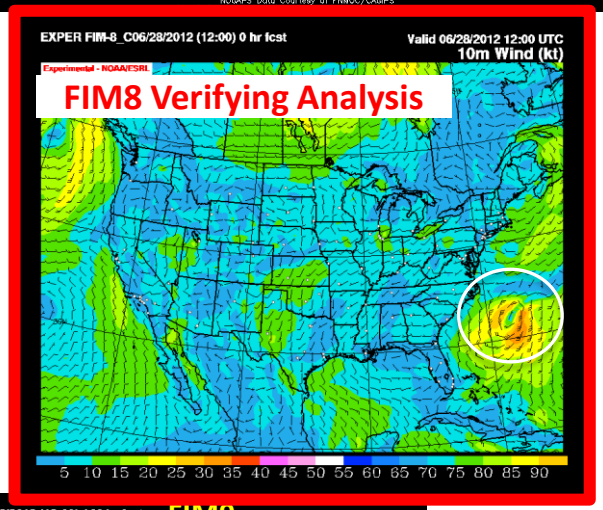


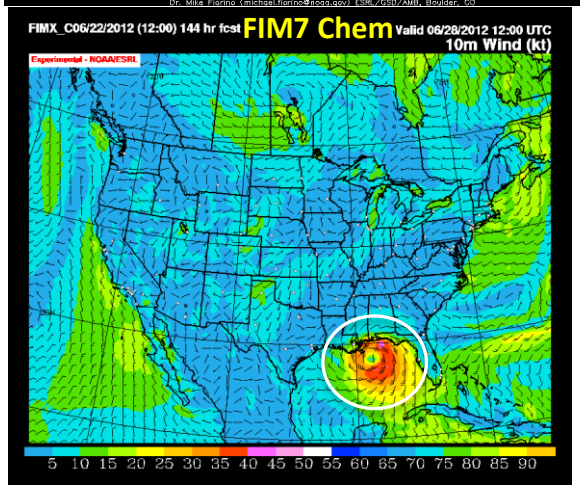


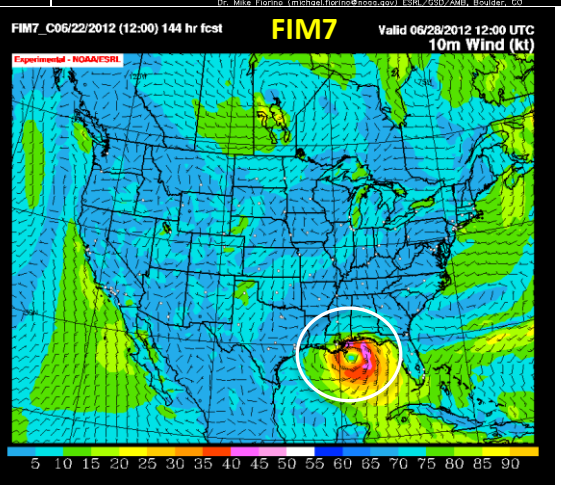


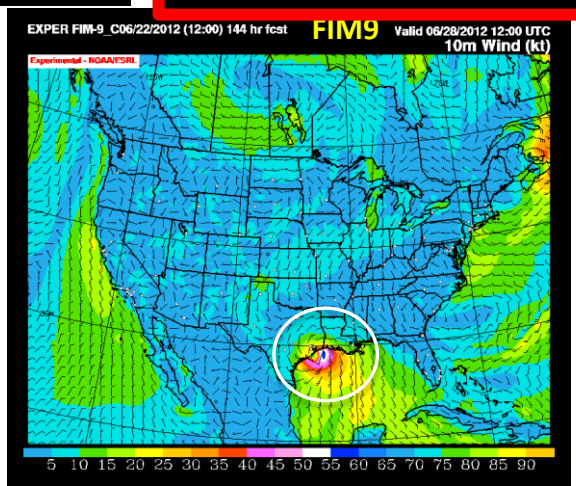






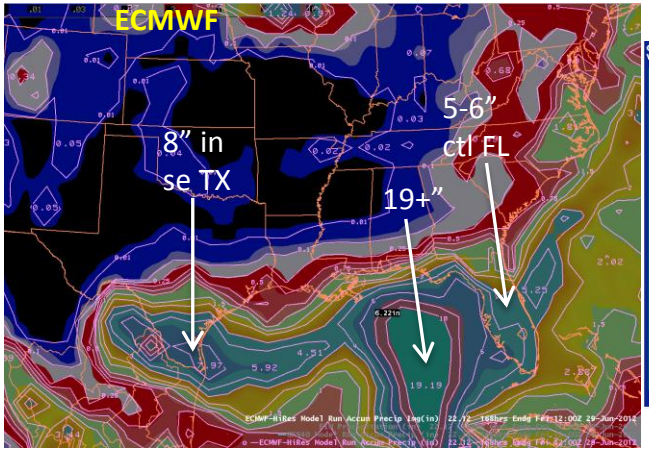




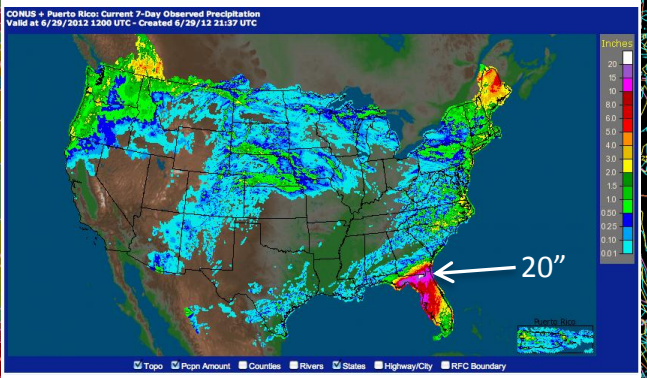


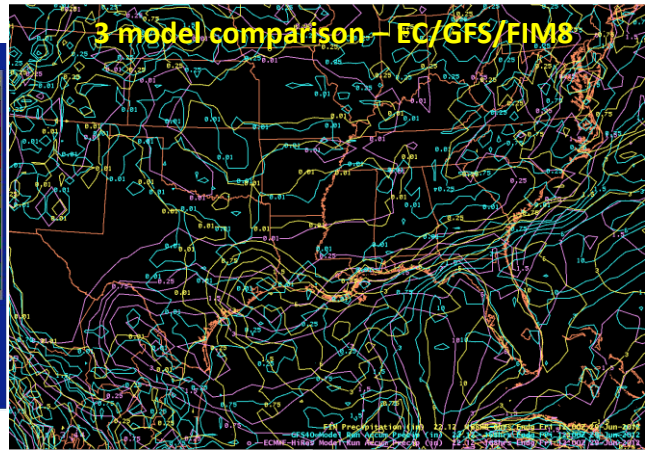
Forecasts from 12z/22 June: 144-h valid 12z 28 June.

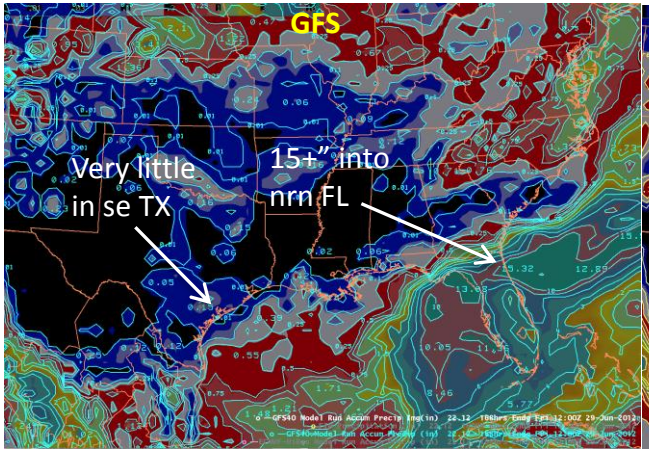
Of the FIM runs, FIM9 is stronger than FIM8 & 7. The lower resolution FIM7 runs take the storm more to the north, other FIMs are more like the EC but slower.

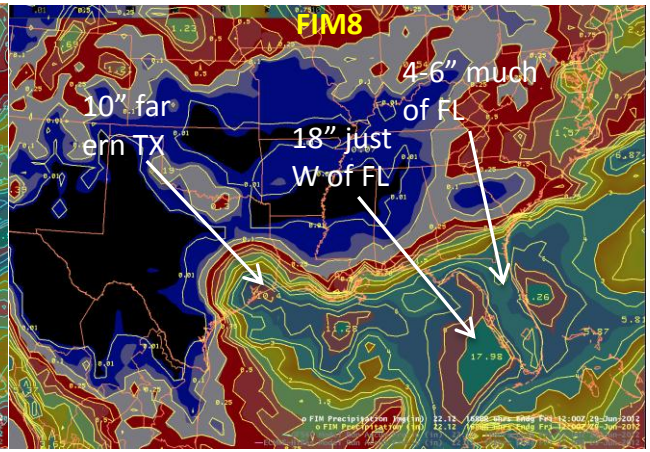


Observed 7-day precip ending 12z/29 June



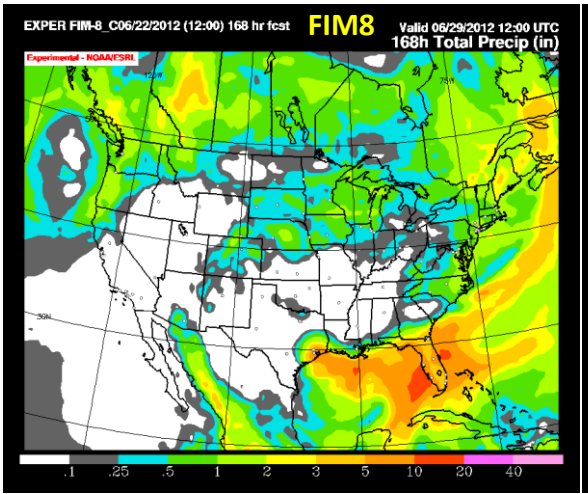


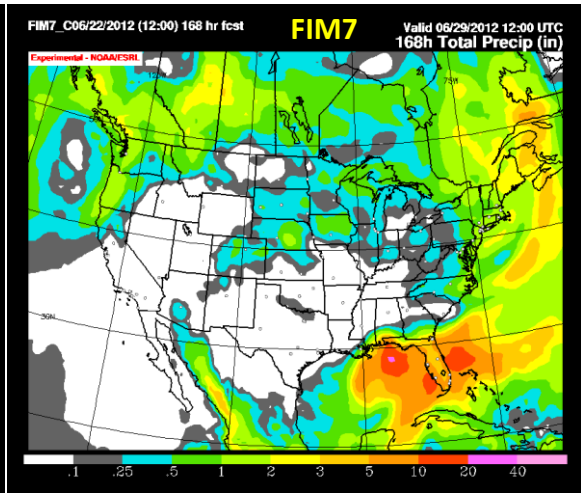


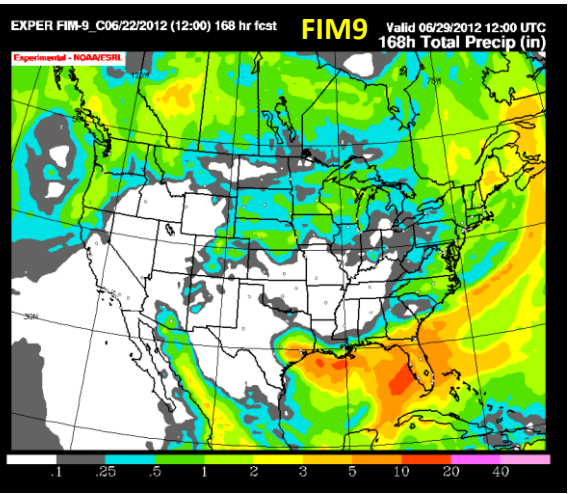


7-day Total Precip Forecasts ending 12z/29 June:

EC has 19” of precip but it is in the Gulf. Despite a more westerly track then the GFS, FIM runs brought significant precip to FL.





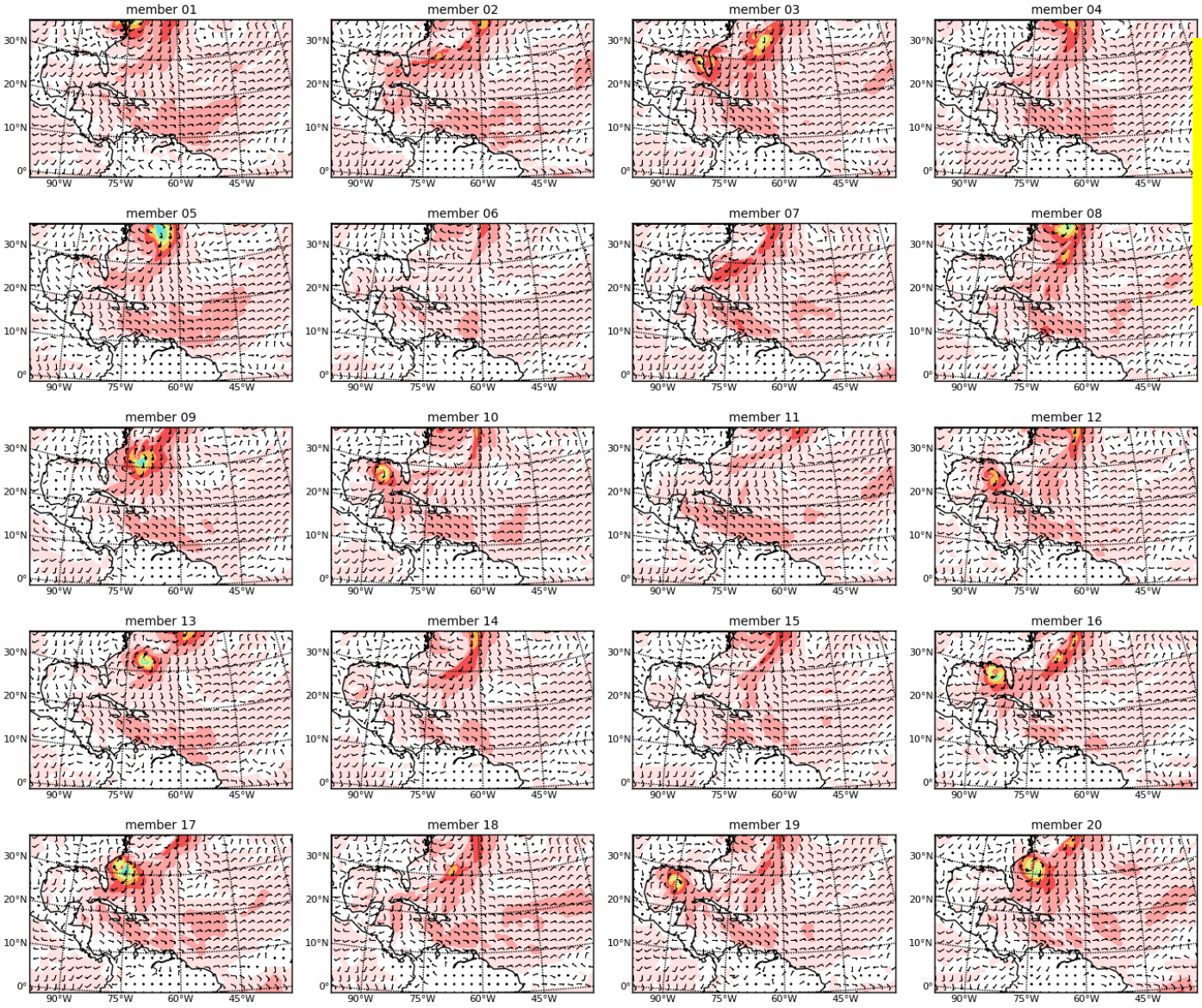


Brief summary of the global model ***ENSEMBLES*** examined for TS Debby

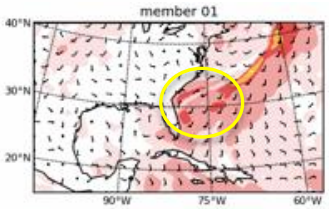
Model	Type	delta x (km)	Vertical	initialization
GFS	spectral	T254/~60	sigma-P	Hybrid EnKF/3D-VAR GSI – **NCEP oper**
GFS	spectral	T382/~40	sigma-P	Hybrid EnKF/3D-VAR GSI – **ESRL/Whitaker**
UKMET	grid pt	60 km	sigma-z	24-member ETKF perturbations
Canadian	grid pt	33 km	sigma	EnKF
ECMWF	spectral	T1279/~16	sigma-P	4D-VAR

T382 GFS/EnKF 10-m wind ens 120-hr fcst for ATL from 2012062212

ESRL GFS/EnKF ensemble members: 22 June/12z run, 120-h 10-m wind valid 27 June/12z



There are only 3 members that keep the storm in the Gulf of Mexico.



Verifying T382 analysis

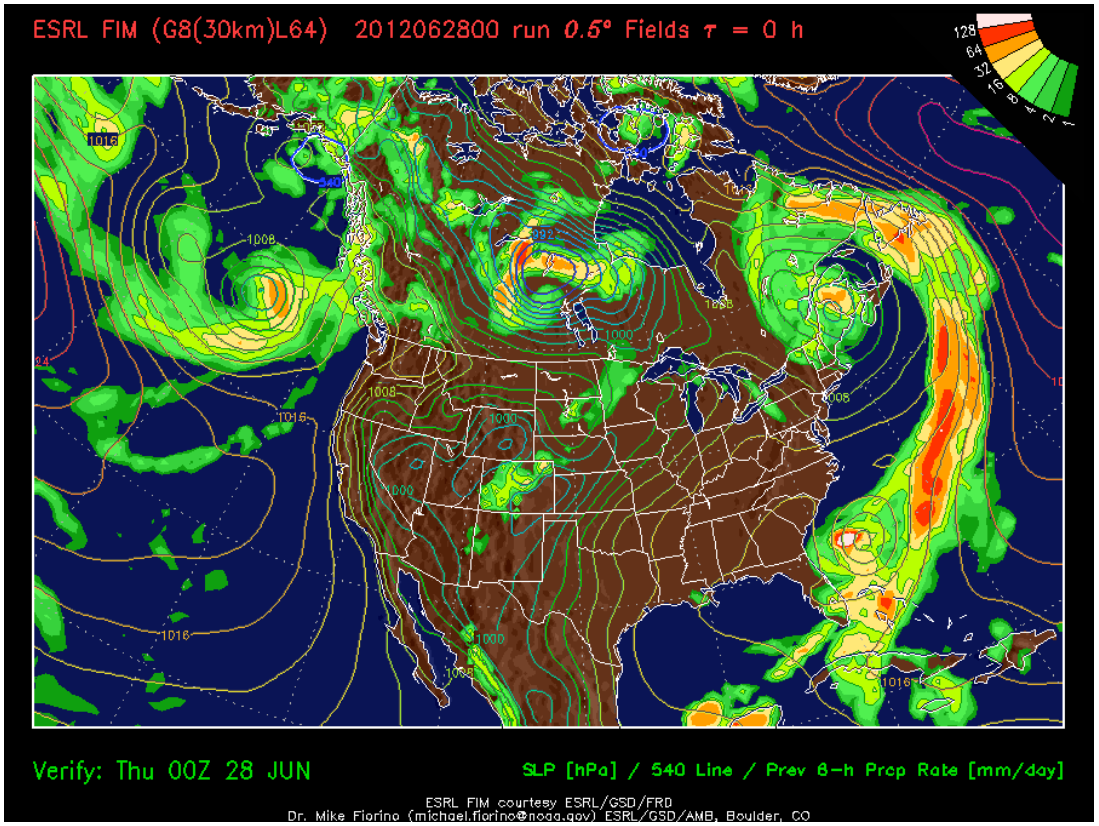
Runs from 00z/Saturday/23 June

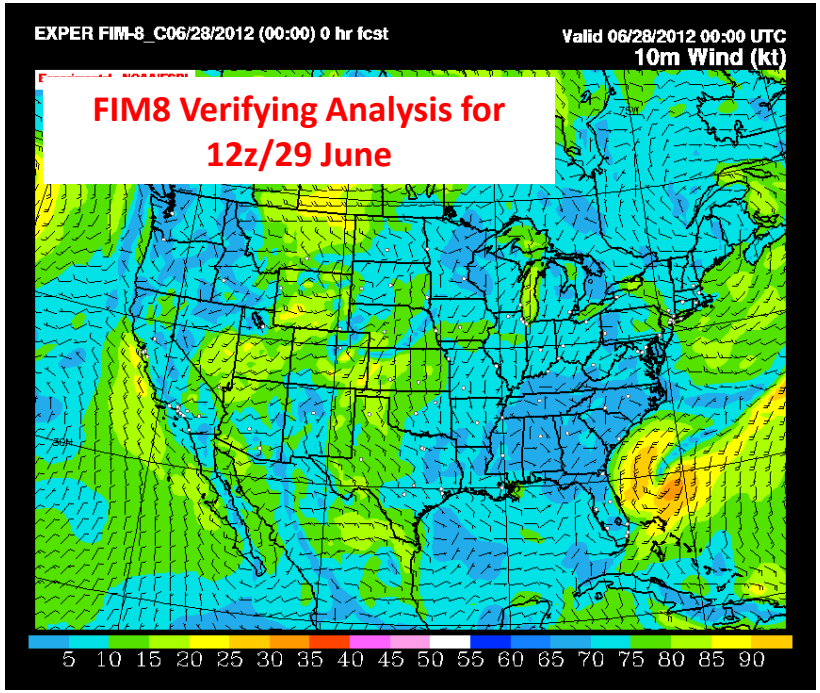
- Shown are 2 slides
  - 168-h forecast with track
    - Or a shorter length forecast if that is all that is available
  - Accumulated precipitation forecast from most of the models
- Model summary
  - Again 4D-Var models EC, NOGAPS and UK all send the storm to the west
    - Tracks remain close with NOGAPS having the more southern track
  - GFS remains the best forecast
  - EnKF FIM9 has a more northerly track
    - Close to the other FIM runs but somewhat to the west of them (hits New Orleans)
  - All other FIM runs drift storm to the nne
  - Precipitation forecasts:
    - GFS has the best forecast for northern FL
    - FIM runs though are not too bad as they drop a lot of precip near or over FL
    - ECMWF underdoes FL precipitation and has big precip into se TX

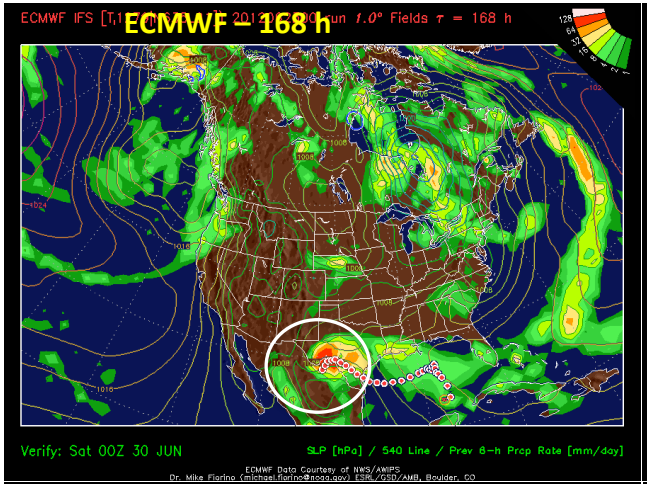
Runs from 00z/Friday/23 June

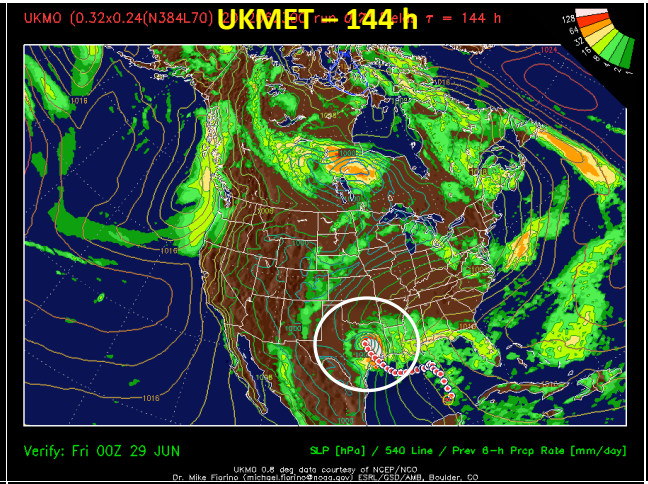
- Shown are:
  - Snapshot of deterministic forecasts (hours vary)
  - ESRL GFS/EnKF ensemble members 120-h forecast
  - No ensemble tracks available yet

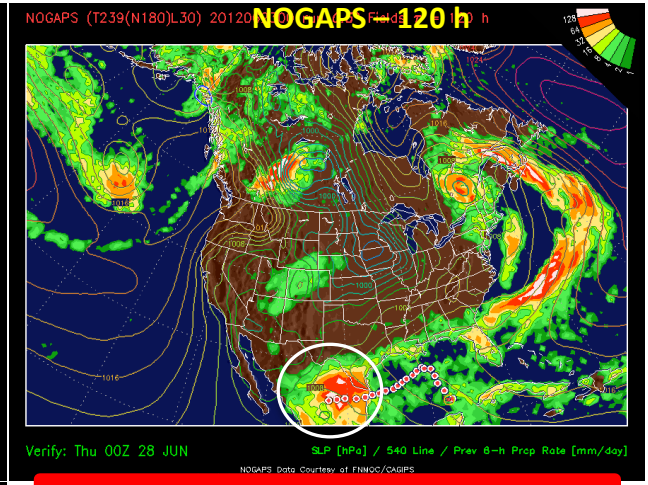
Verification for 120-h forecasts that are valid at 00z/28 June

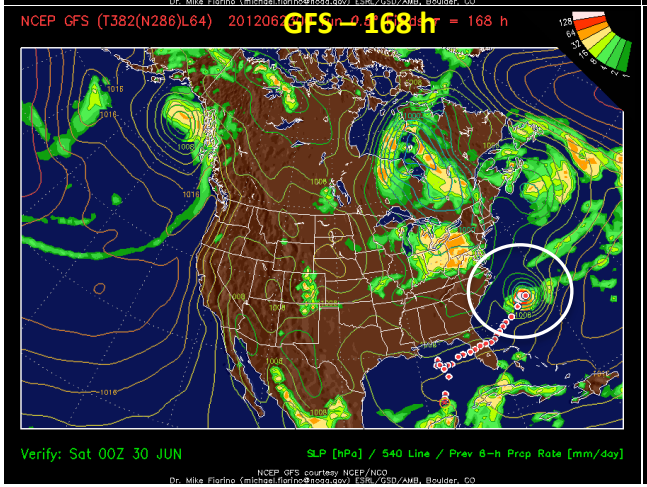


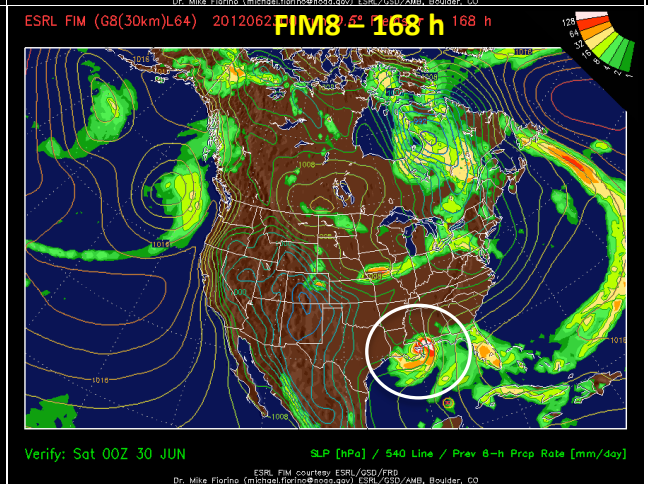


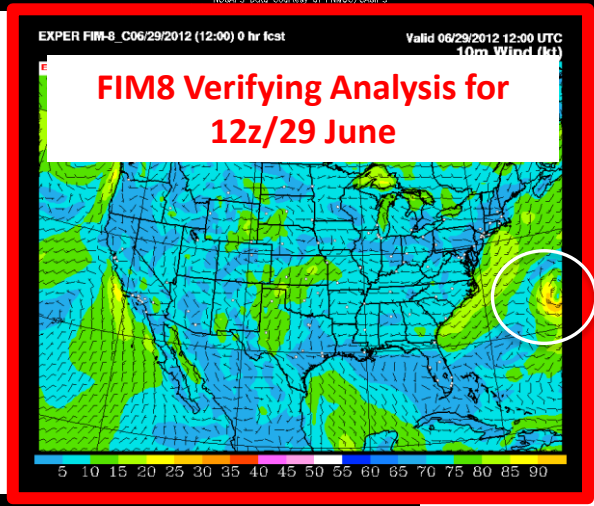


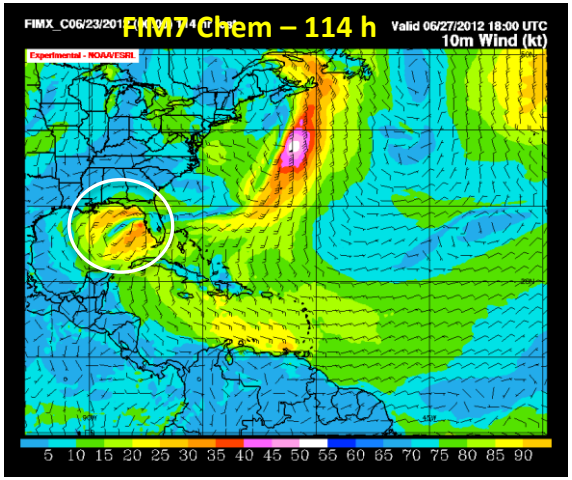


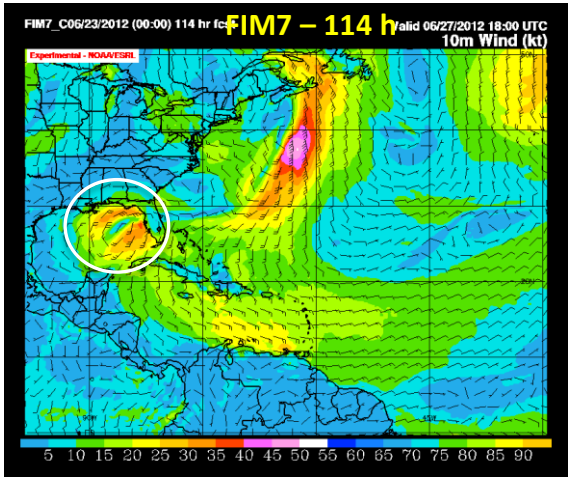


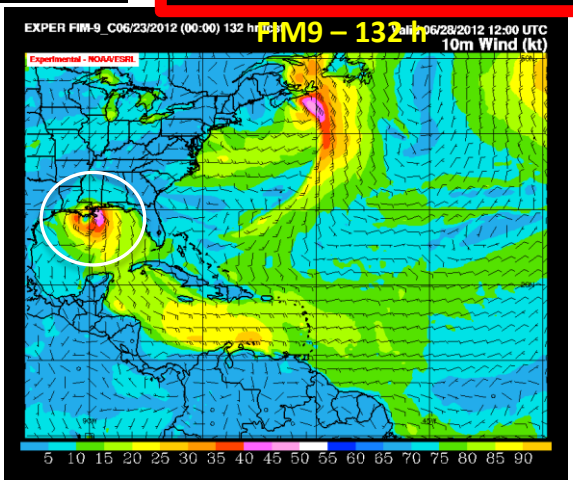




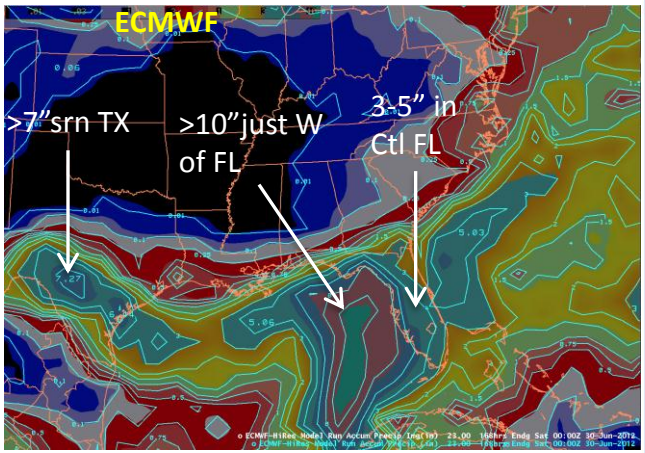


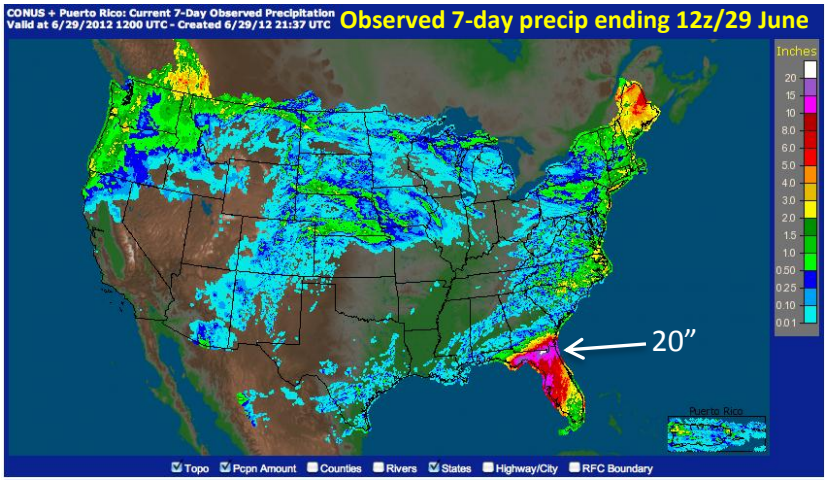


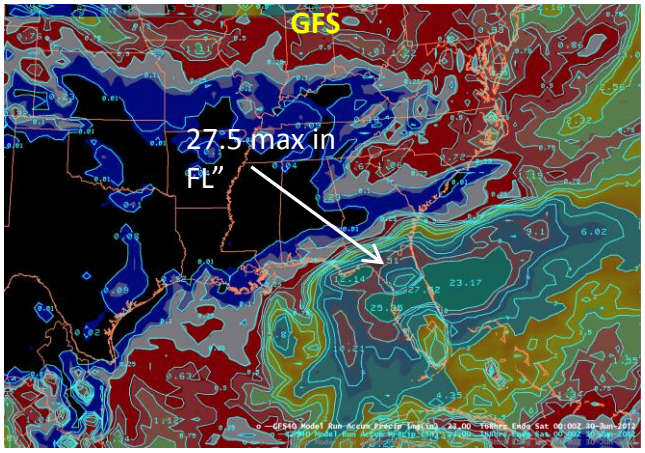


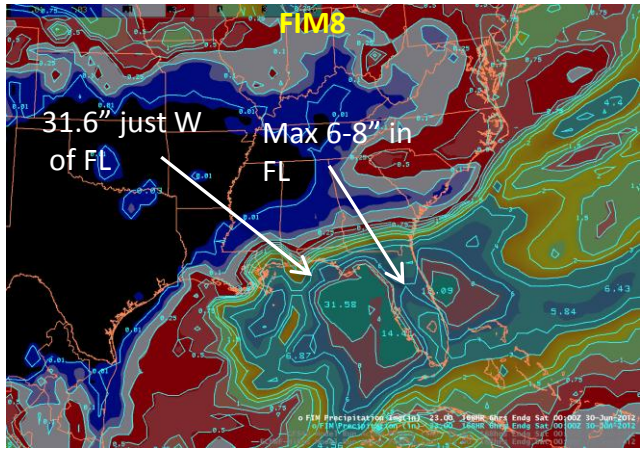


Forecasts from 00z/23 June: forecast hour varies. The GFS forecast clearly remains the best. Note that all three 4D-Var models (top row) take Debby to the west. Of the FIMs, FIM9 (EnKF run) is the most west.

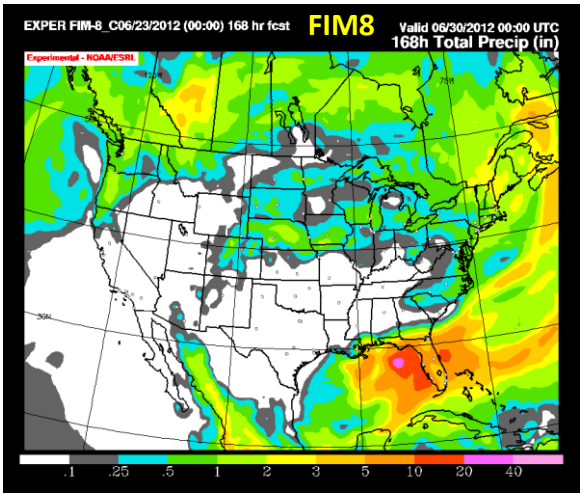


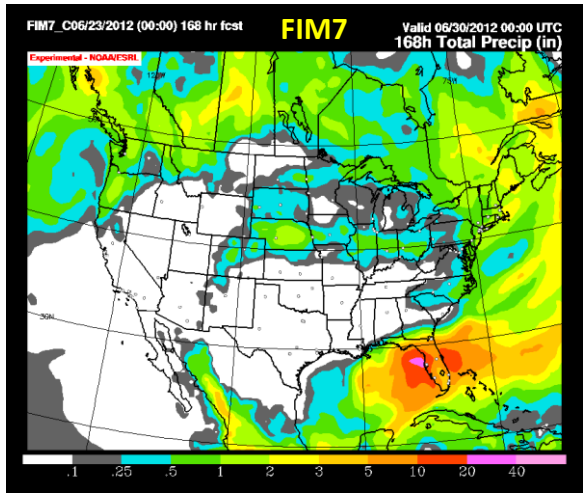


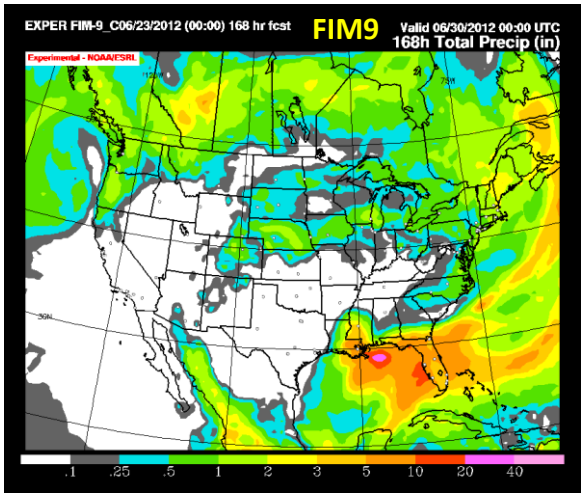




7-day Total Precip Forecasts ending 00z/30 June: Precip swatch nicely shows the tracks as well. GFS a little too far south with max but did the best over FL. Maybe 30+” did fall in the Gulf of Mexico!

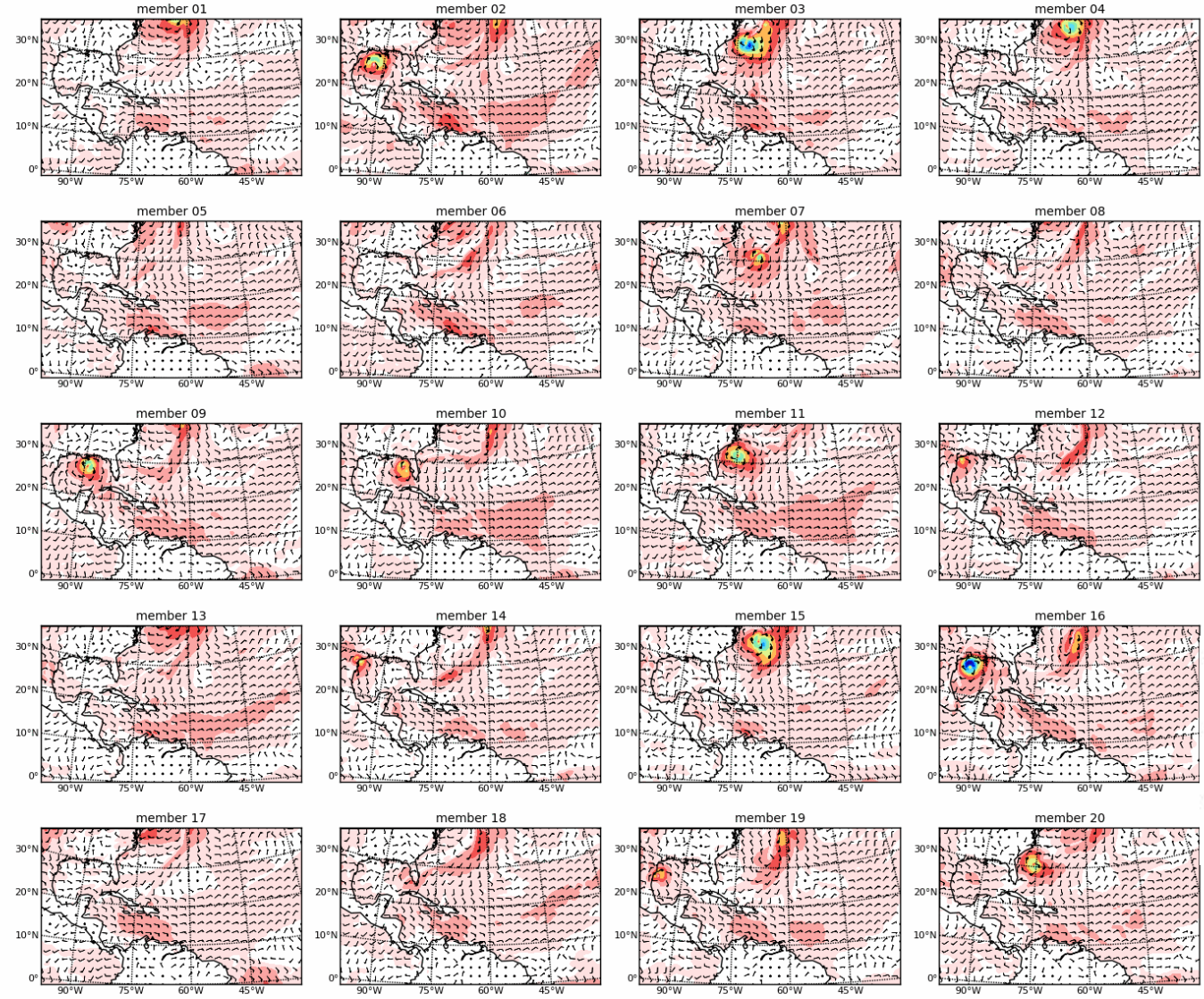




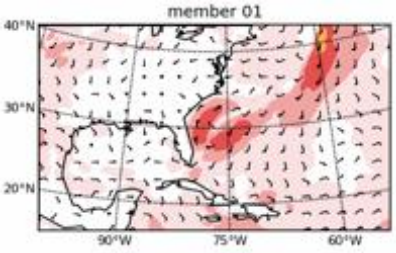


T382 GFS/EnKF 10-m wind ens 120-hr fcst for ATL from 2012062300

GFS/EnKF ensemble members: 23 June/00z run, 120-h 10-m wind valid 28 June/00z



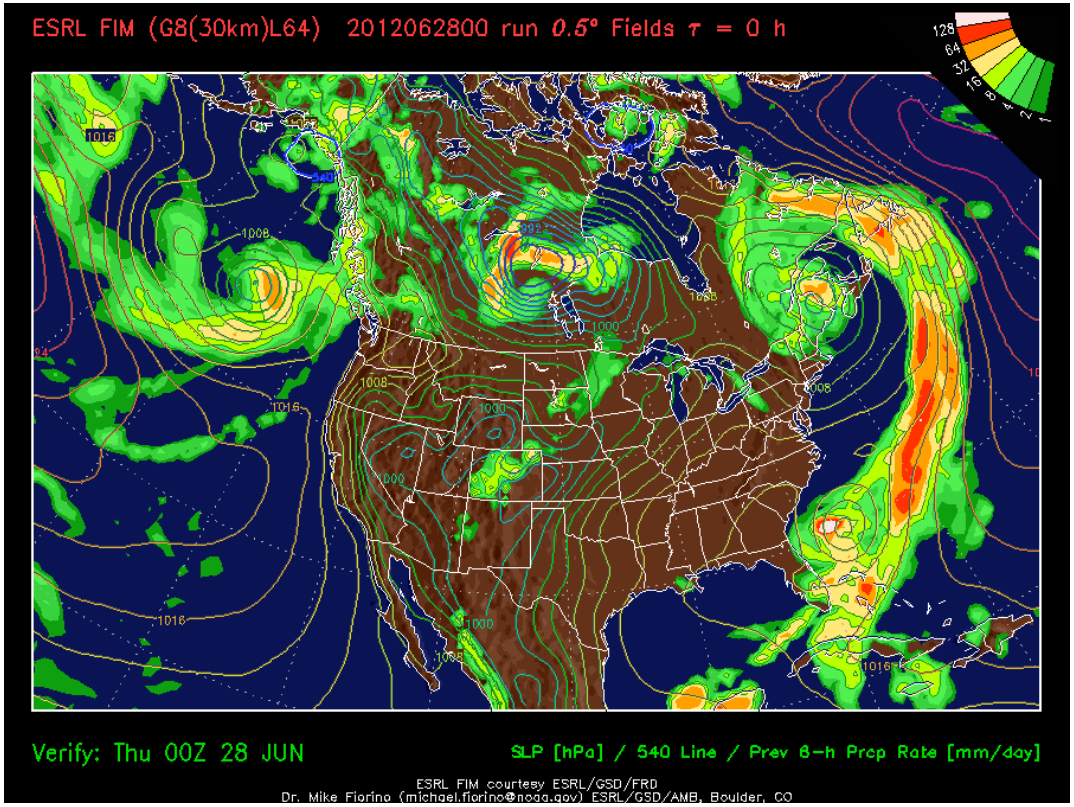
Now there are actually 6 members that keep the storm in the Gulf of Mexico. Two of these have a distinct westward track.



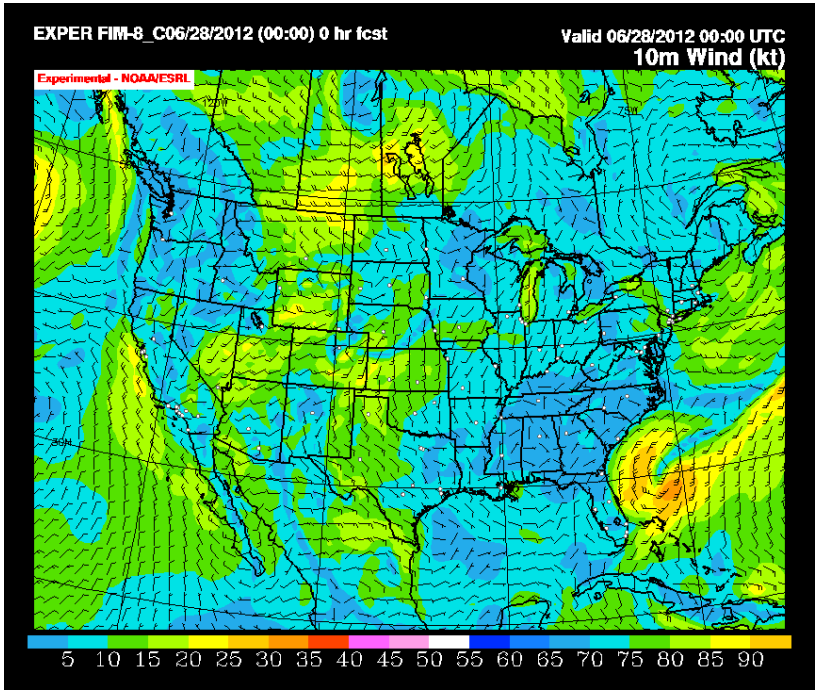
Verifying T382 analysis

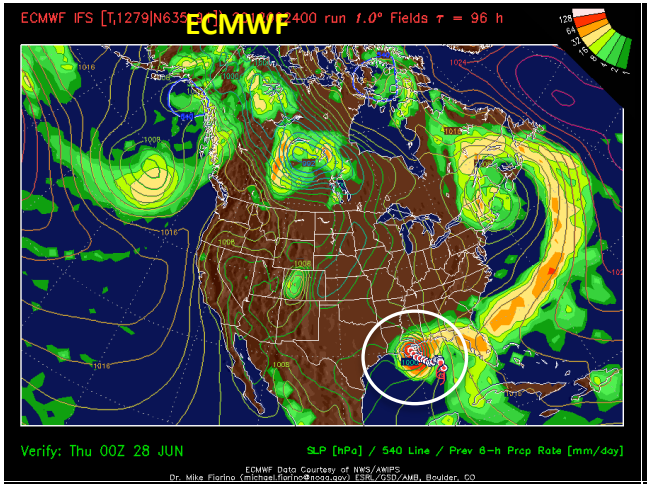
Runs from 00z/Sunday/24 June

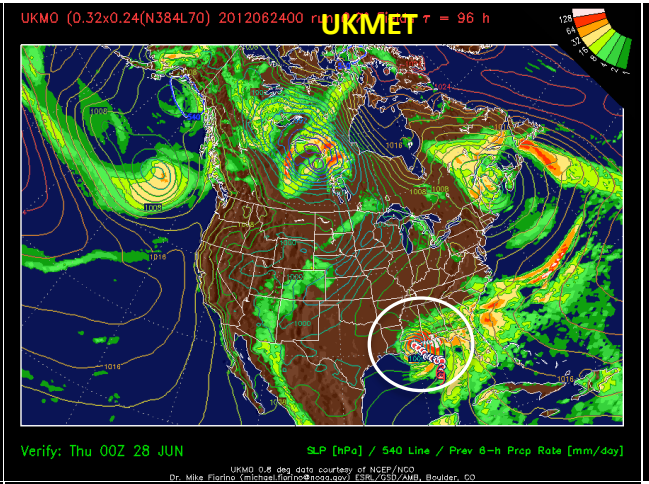
- Shown are
- 96-h & 144-h forecasts from each model
- Forecast tracks for ensembles from GFS, ECMWF and CMC
  - Strike probability graphic for ECMWF ensembles
  - 96-h forecast of GFS/EnKF ensemble members (10-m wind)
  - NHC Advisory 5-day forecast
    - Takes Debby to the west and strengthens to a hurricane, cone does not include FL

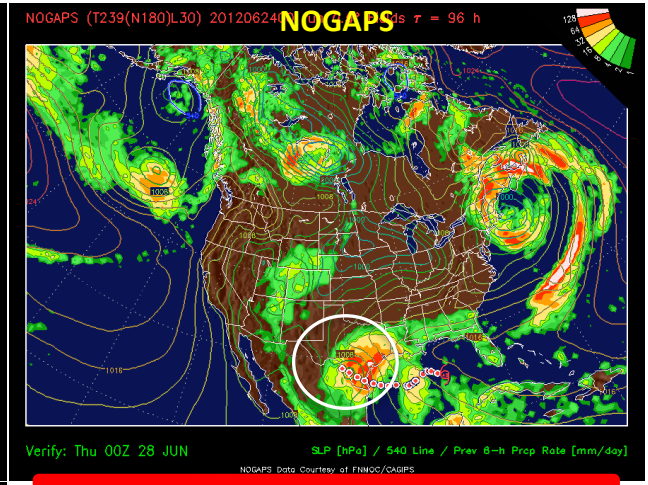


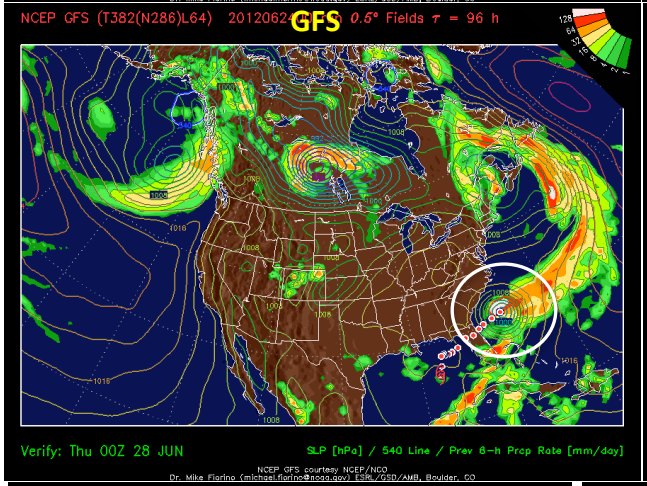
Verification for 96-h forecasts

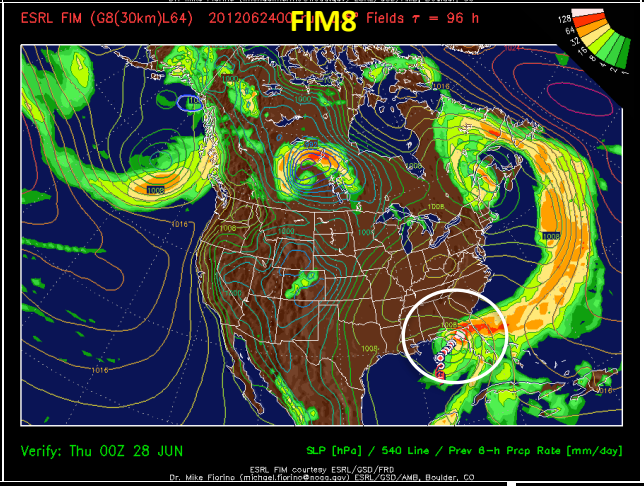


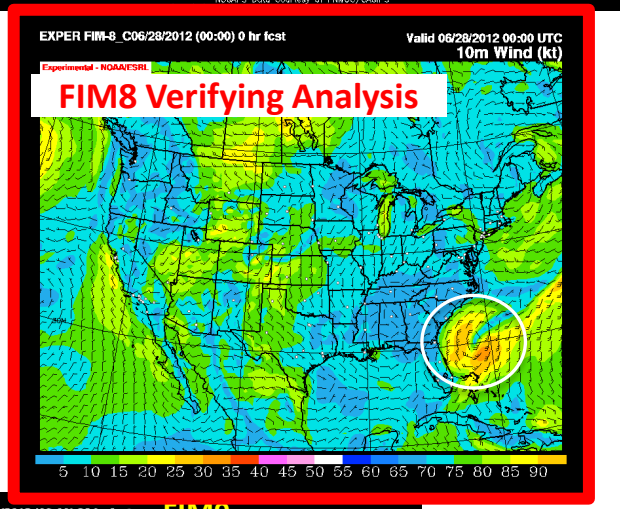


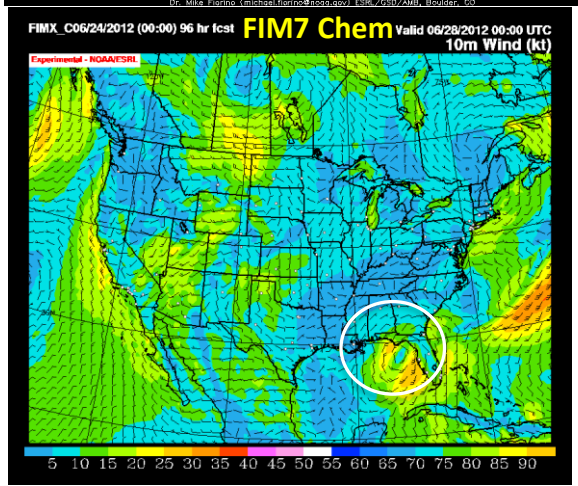


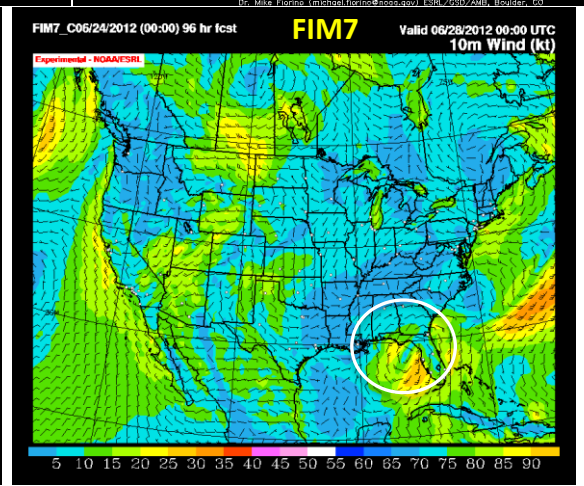


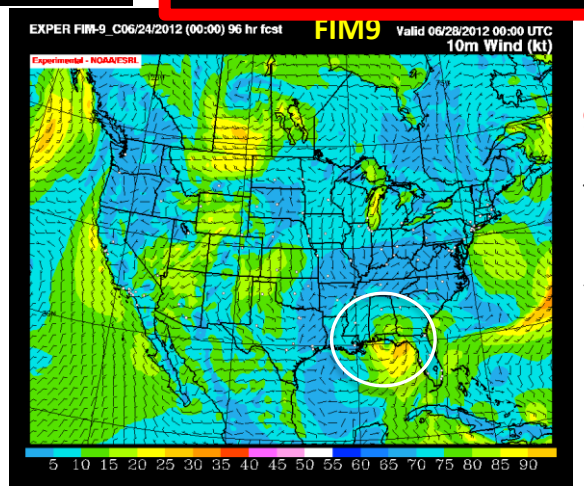






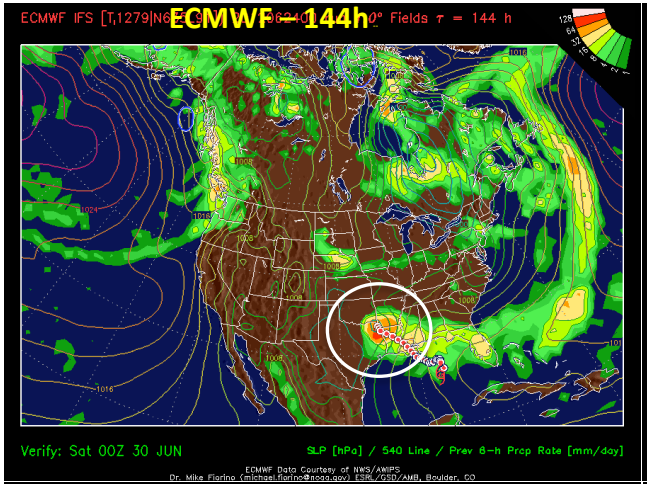


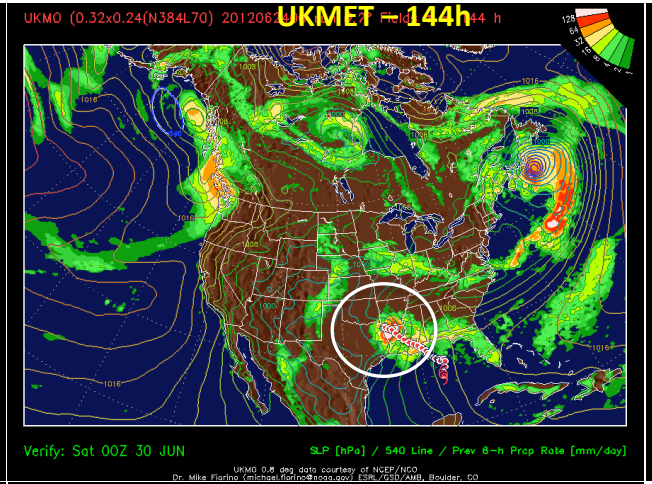


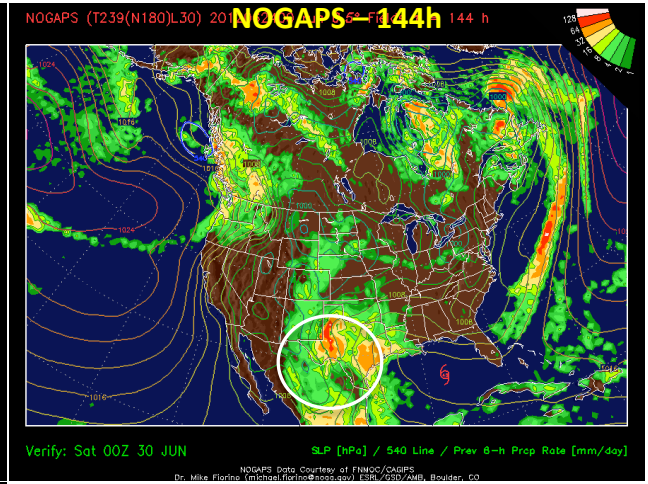


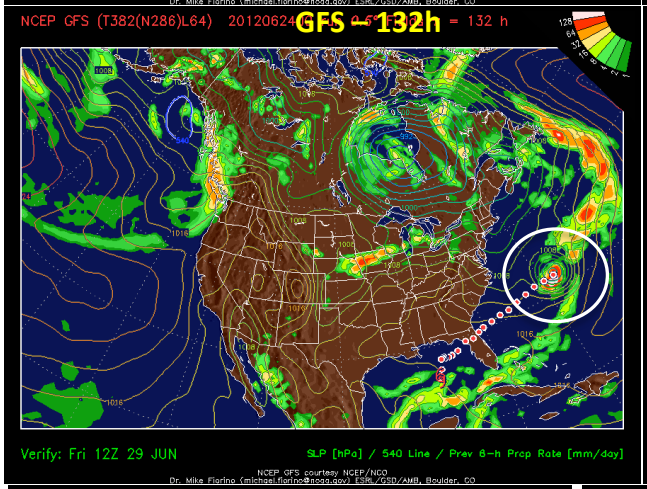
Forecasts from 00z/24 June: 96-h valid 00z 28 June.

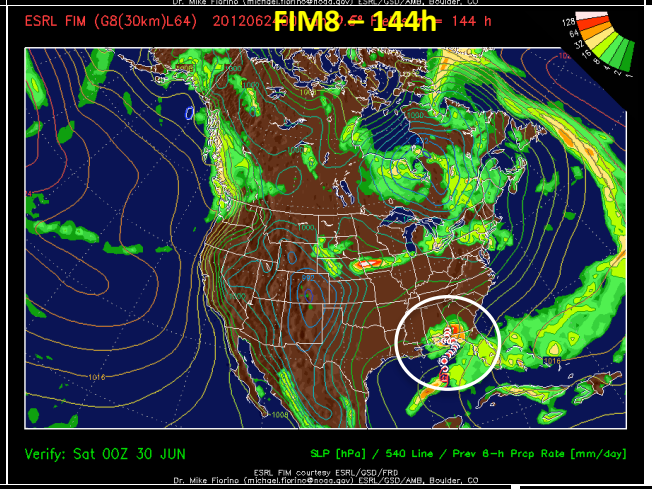
The FIM runs are trying to curve the storm more to the east (least so the FIM9), while all the 4D-VAR runs still take it to the west.

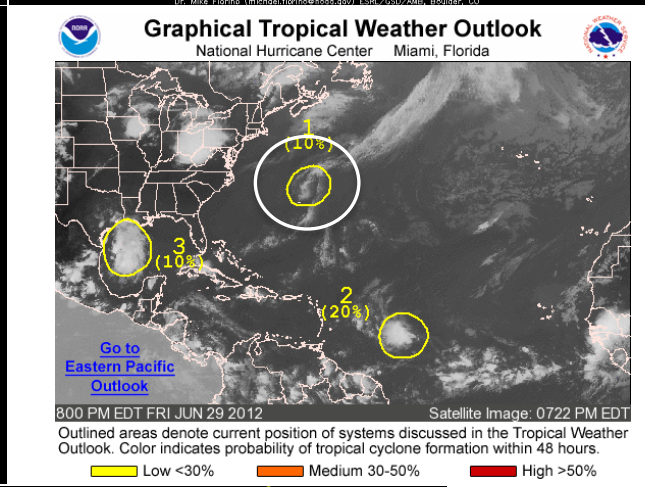


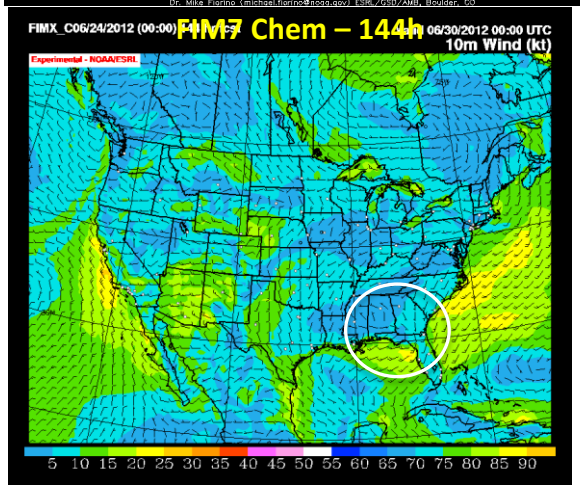


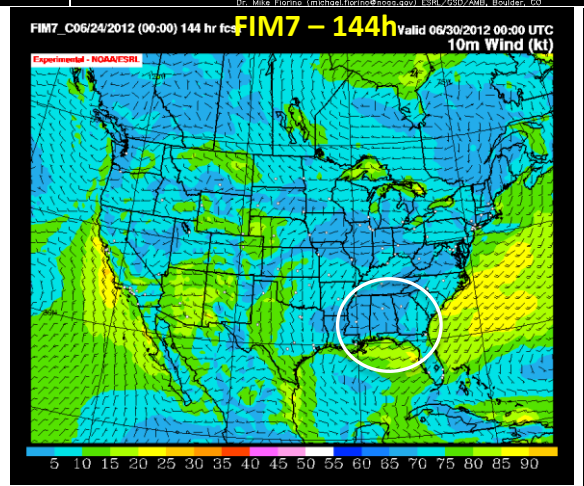


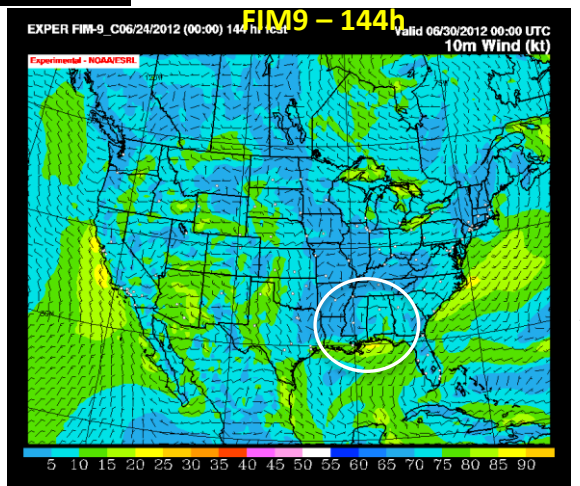






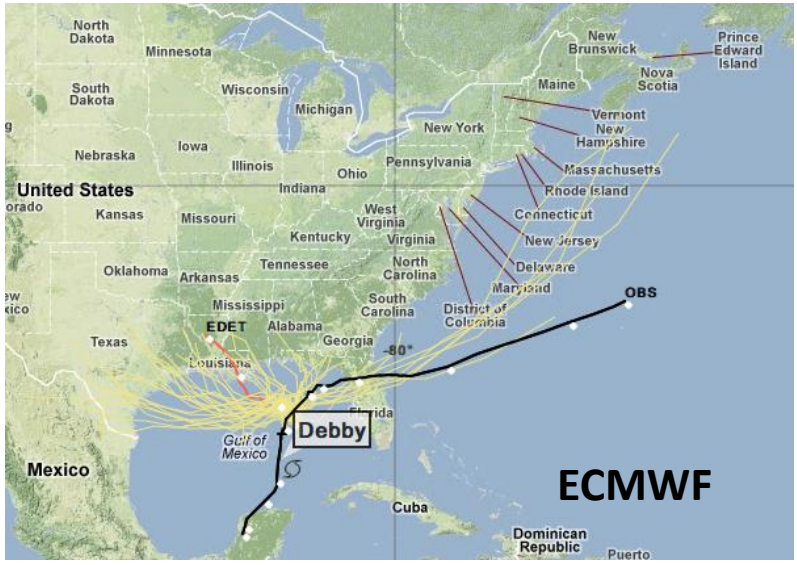


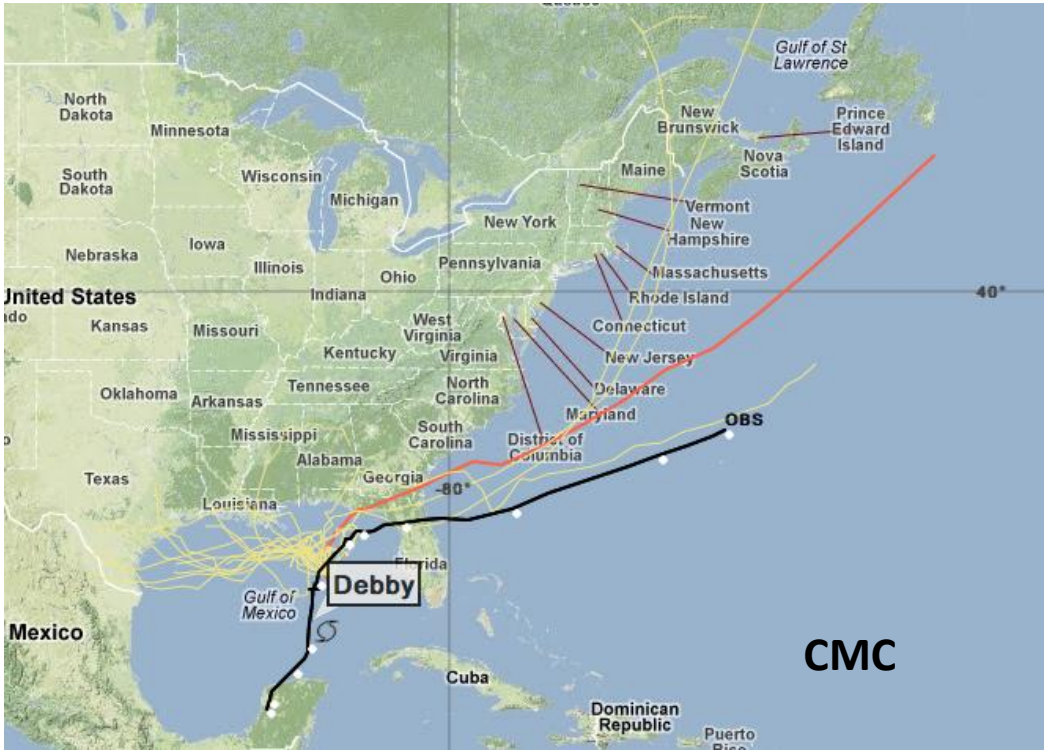




Forecasts from 00z/24 June: 144-h valid 00z 30 June (except GFS).

Same comments as at 96-h, with FIM runs trending more to the east but EC, UK and NOGAPS still go to the west.

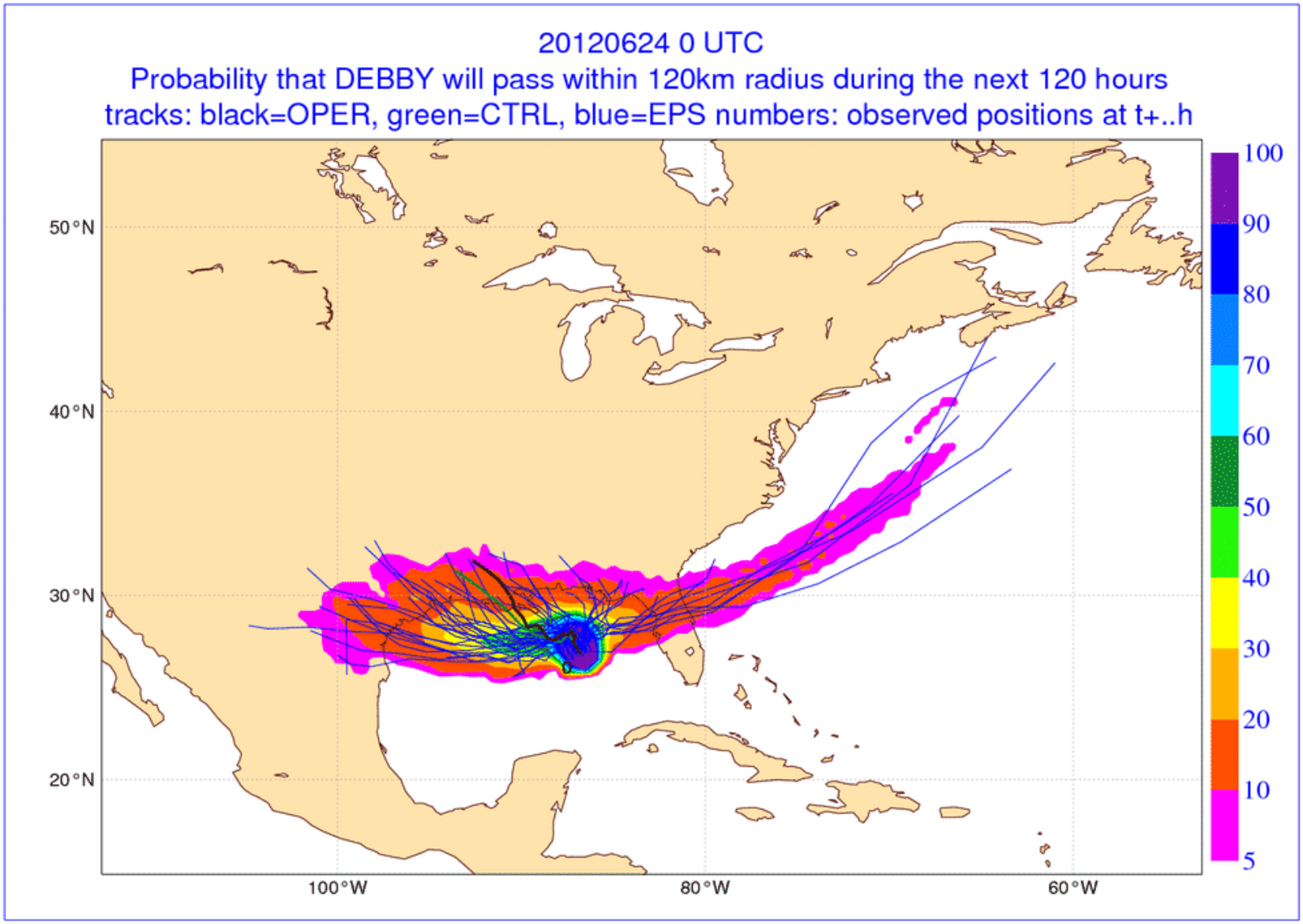




Comparison of global ensemble forecasts for 00z/24 June runs

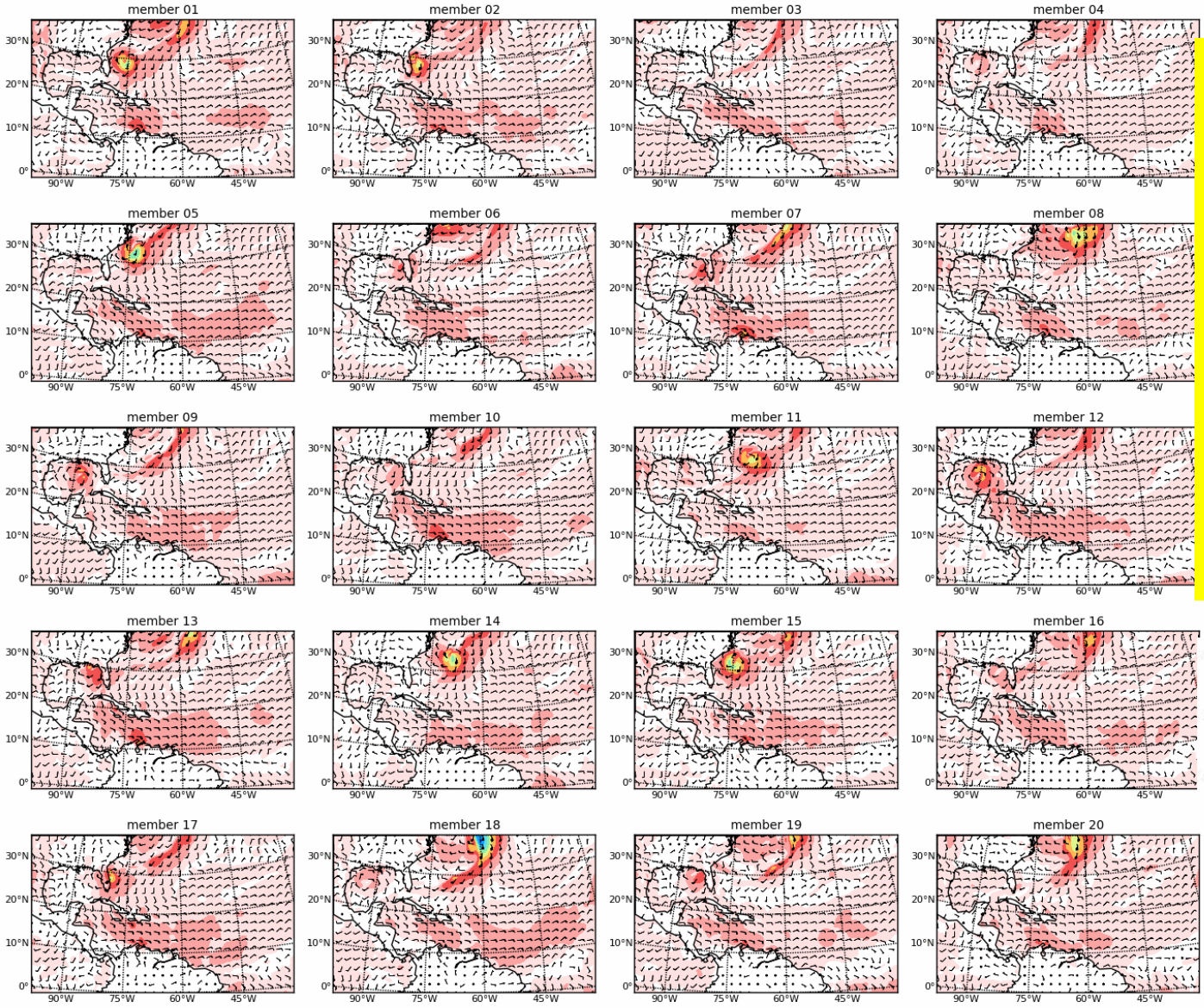
Note that most members of the ECMWF and CMC global ensembles take Debby to the west. The deterministic CMC run has a better track like the observed. The operational GFS ensemble has a few members going to the west, but more to the ene, and the majority lingering in the Gulf of Mexico.

Bonus – alternative depiction of ECMWF ensemble

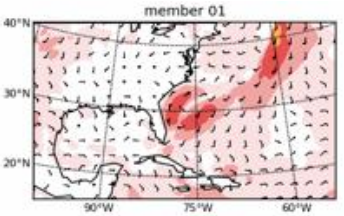


T382 GFS/EnKF 10-m wind ens 096-hr fcst for ATL from 2012062400

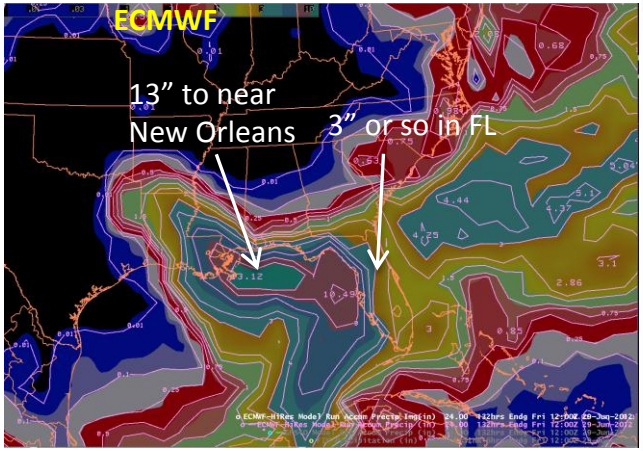
GFS/EnKF ensemble members: 24 June/00z run, 96-h 10-m wind valid 28 June/00z

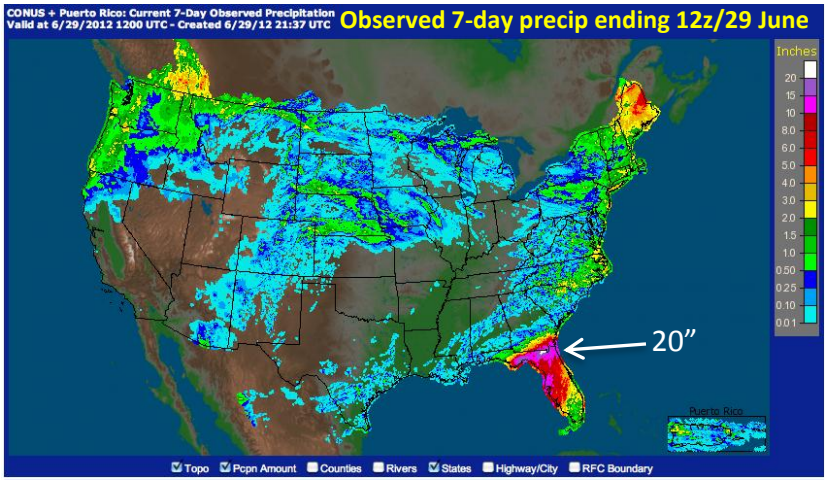


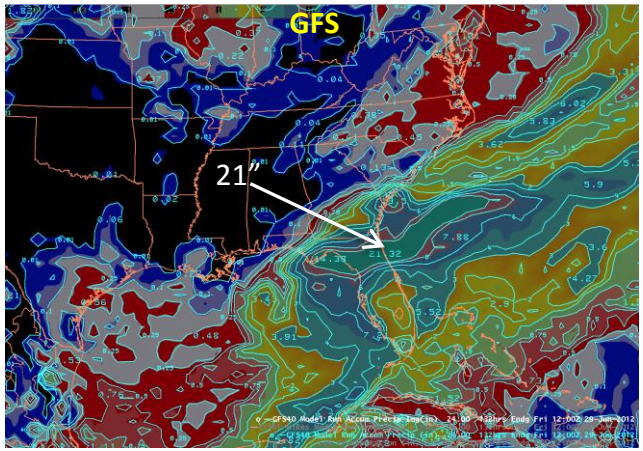
Two members keep a storm in the Gulf of Mexico. For both of these there was a piece of energy that did move off to the east-northeast. Some of the members barely show a storm because it has moved out of the limited domain already.

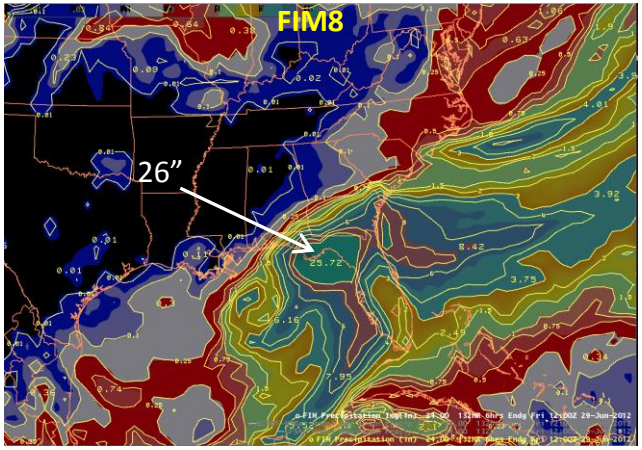


Verifying T382 analysis



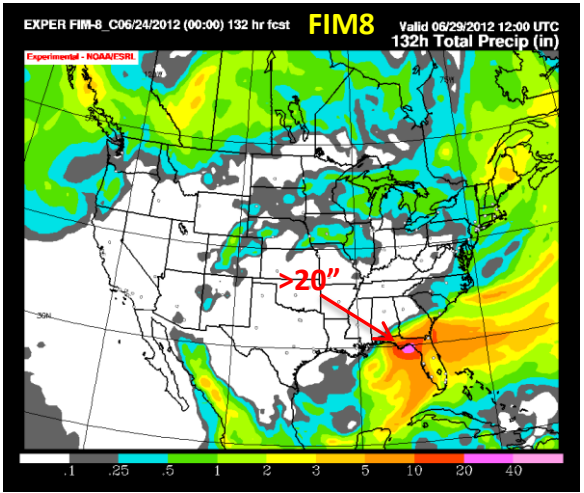


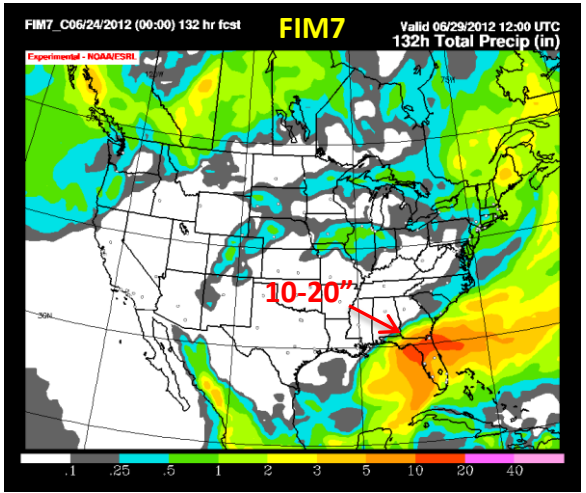


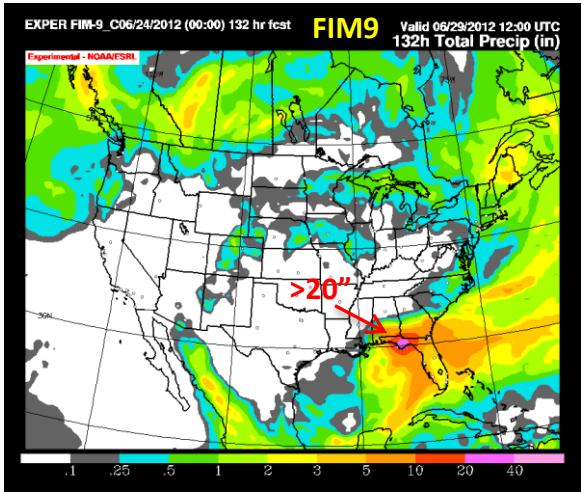


7-day Total Precip 132-h forecasts from 00z/24 June runs ending 00z/30 June:

The precip forecast confirms that the FIM tracks Debby better then in previous runs, and while the EC takes the storm to the west it is not as far to the west as in earlier runs.



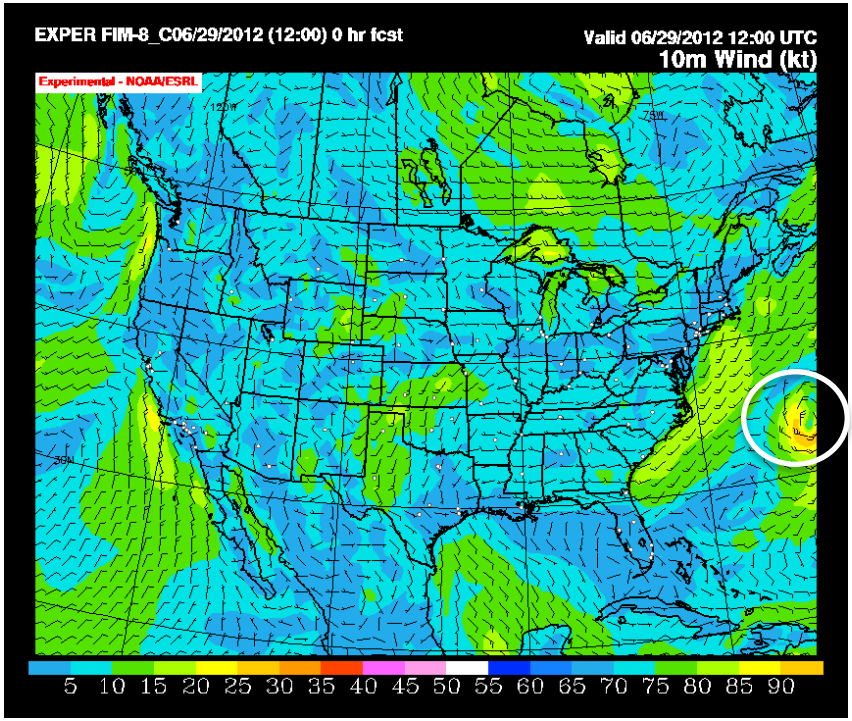


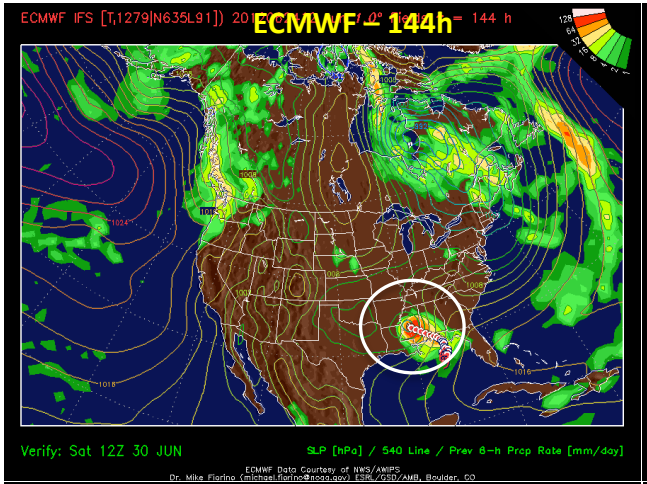


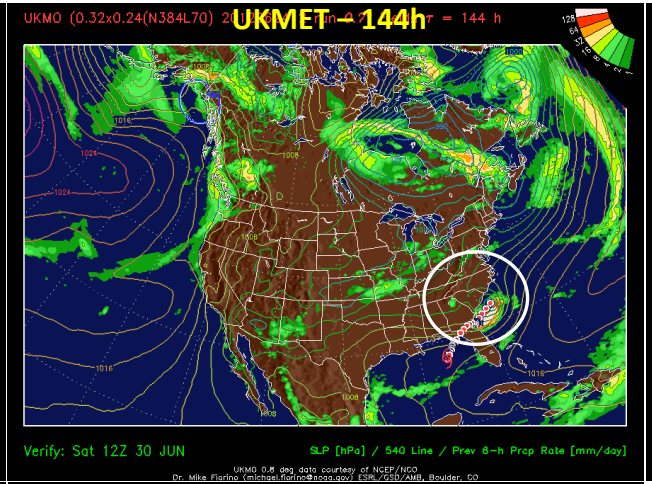
Runs from 12z/Sunday/24 June

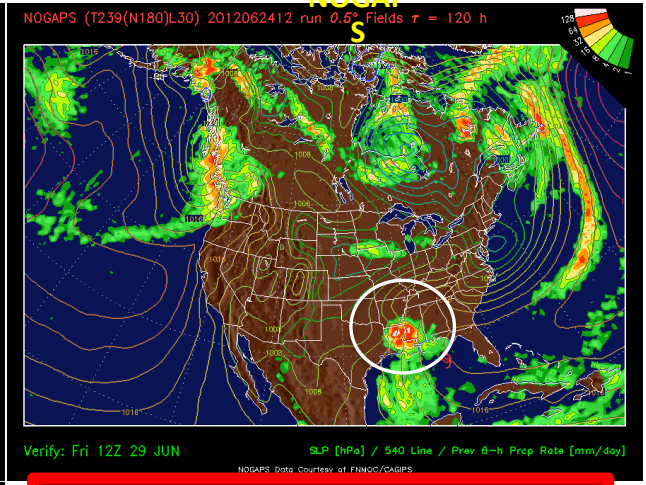
- Shown are:
  - 120-h deterministic forecasts from each model
  - 120-h ESRL GFS/EnKF ensemble forecasts of 10-m wind & ellipses
    - Also 60-h forecasts to illustrate how some runs move a system out of the Gulf of Mexico *and* leave one behind
  - Track forecasts from ECMWF, CMC and GFS ensembles
  - NHC 5-day forecast
    - Now takes Debby north as a weaker system but “cone” barely has Florida in it

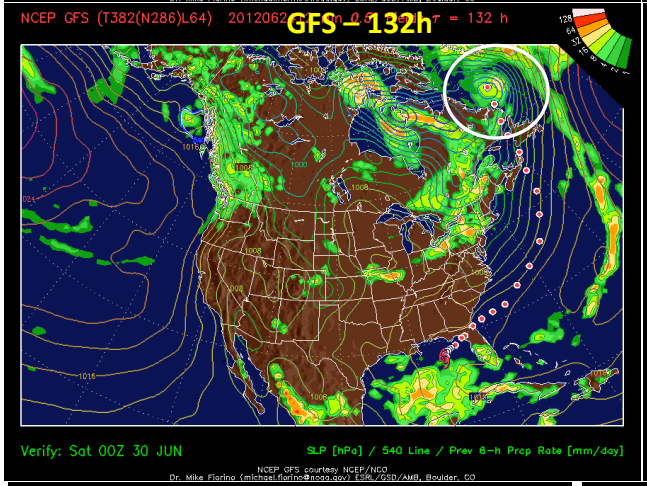
Verification ----->

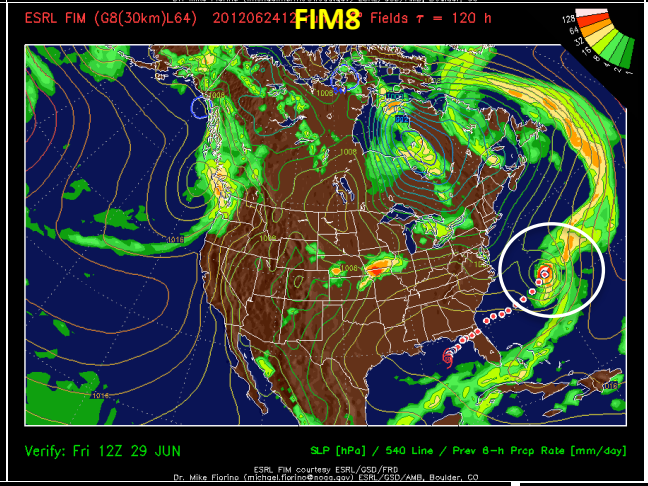


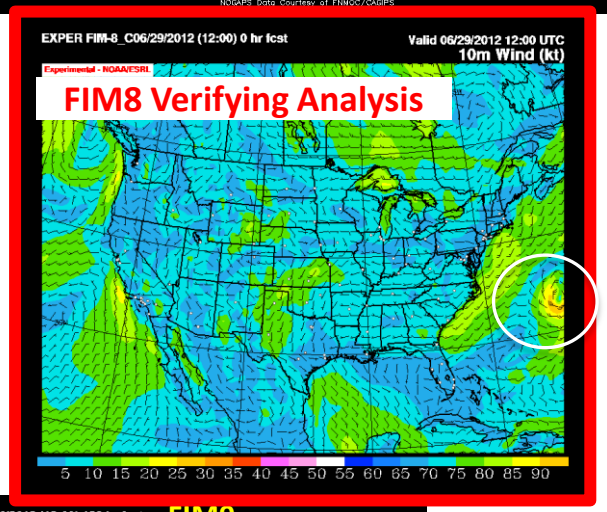


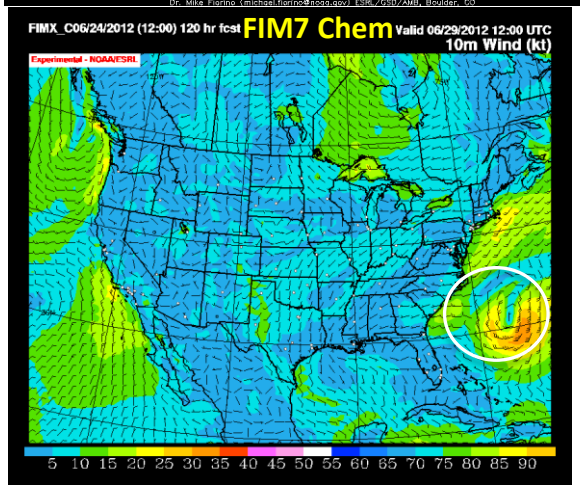


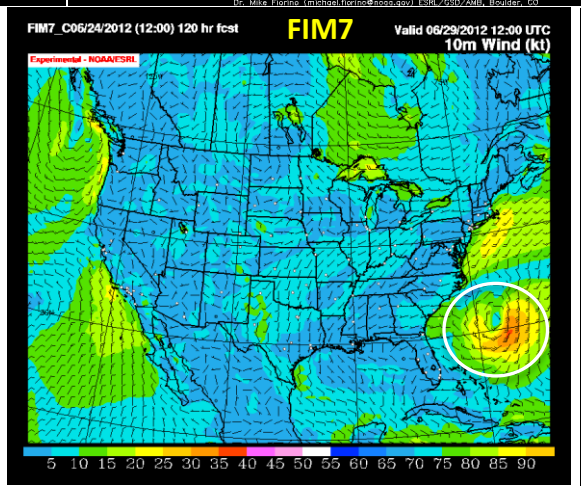


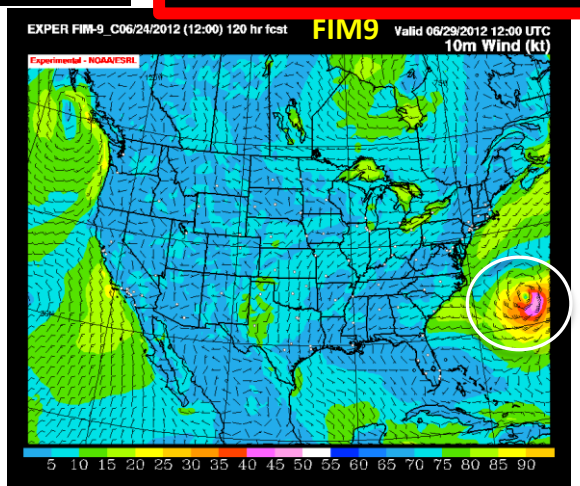












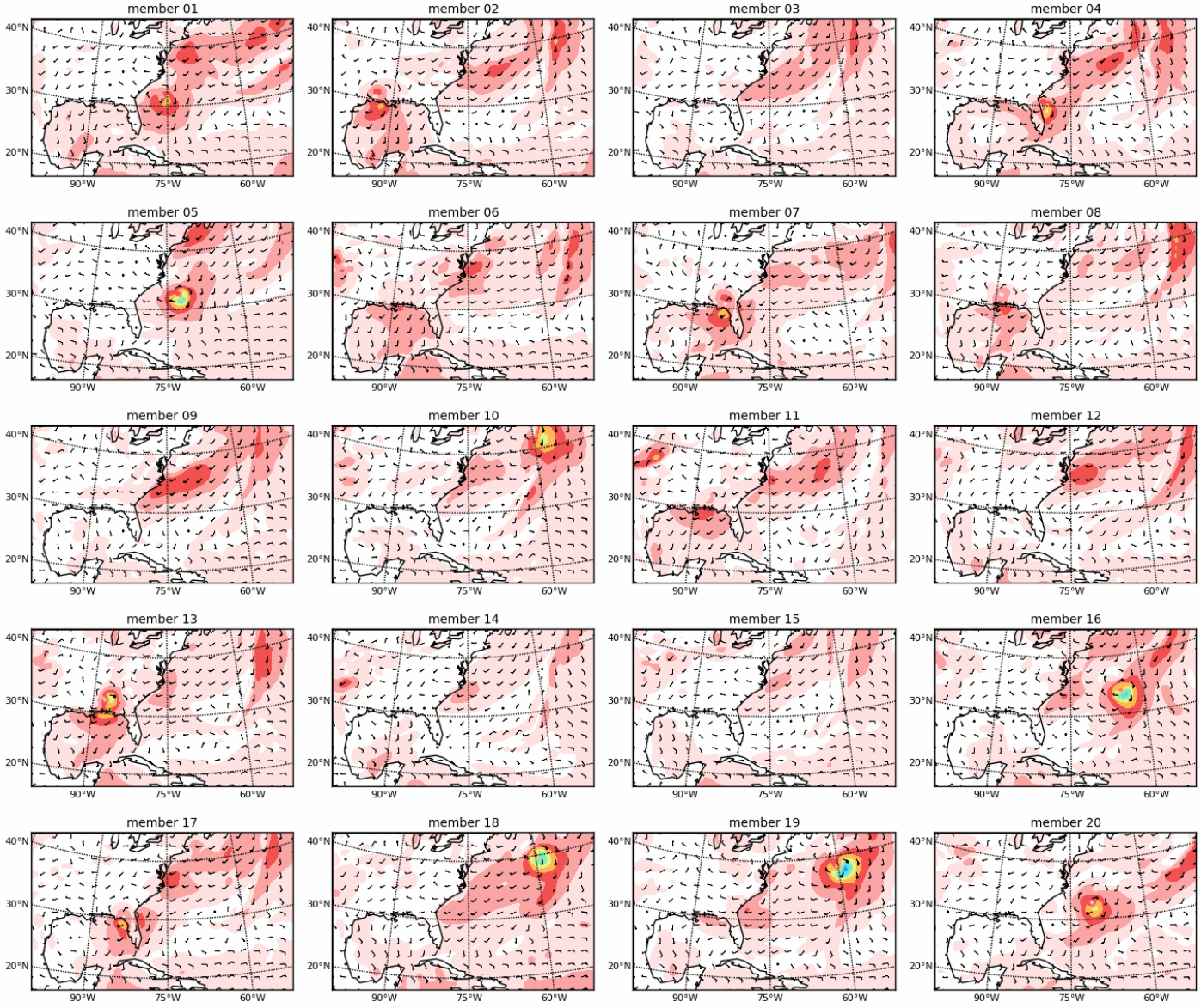
Forecasts from 12z/24 June:

120-h (except as indicated) valid 12z 29 June.

The EC and NOGAPS still hold onto a more west-oriented track, but UK has changed. FIM runs are good, GFS too fast now.

T382 GFS/EnKF 10-m wind ens 120-hr fcst for 04L from 2012062412

GFS/EnKF ensemble members: 24 June/12z run, 120-h 10-m wind valid 29 June/12z



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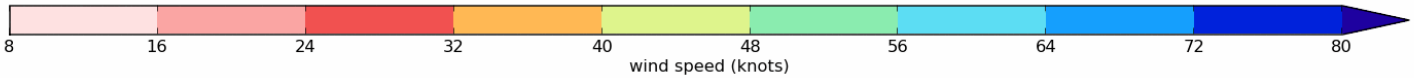
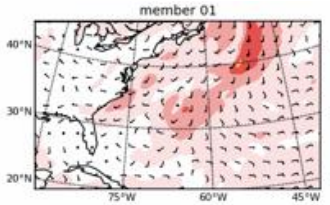


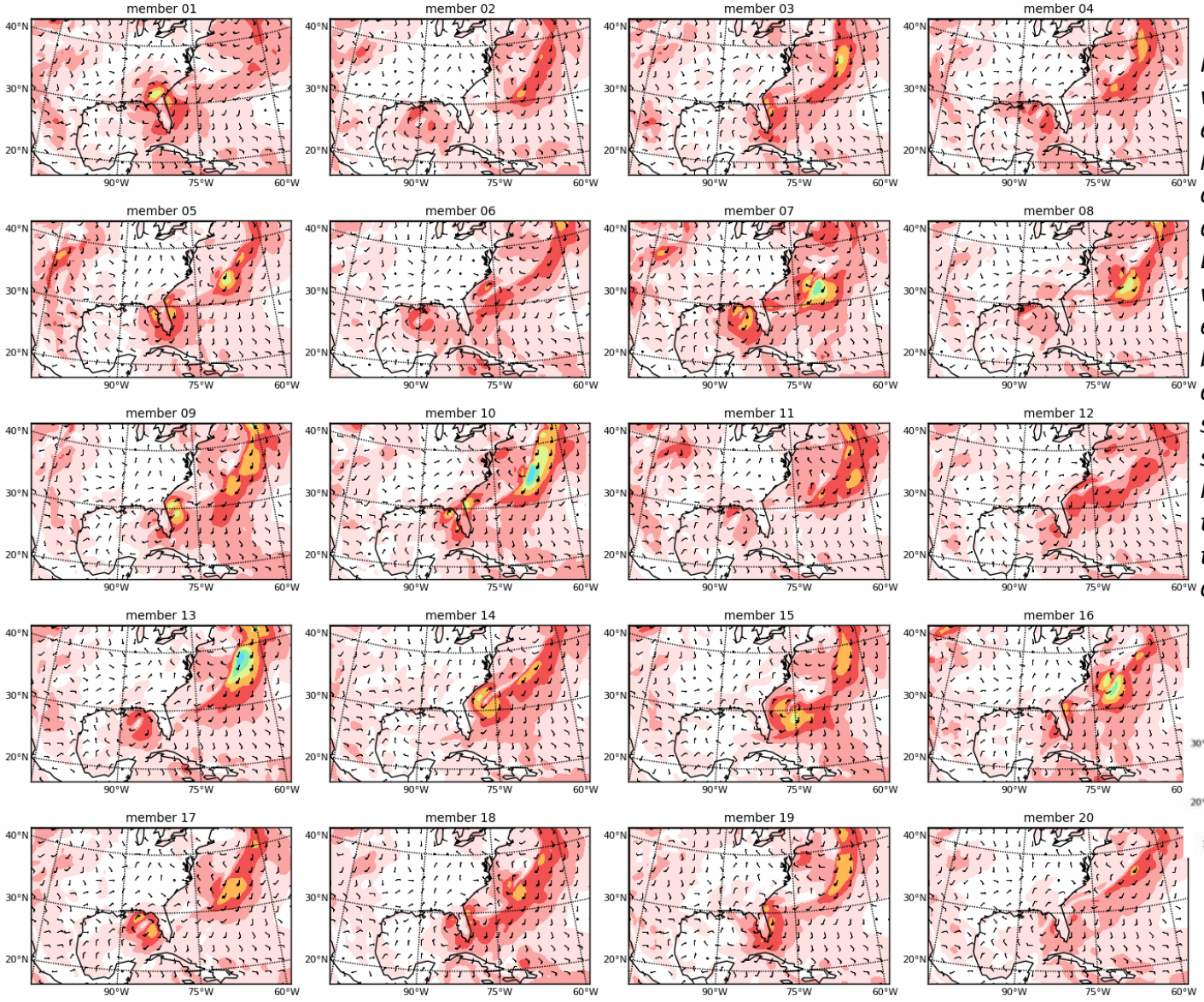
It appears that there are still some members that keep a storm in the Gulf of Mexico. But it appears that all runs sent at least a piece of the system off to the east-northeast. With this in mind, have included an earlier (60-h) forecast from this ensemble to illustrate this point.



Verifying T382 analysis

T382 GFS/EnKF 10-m wind ens 060-hr fcst for 04L from 2012062412

GFS/EnKF ensemble members: 24 June/12z run, 60-h 10-m wind valid 27 June/00z



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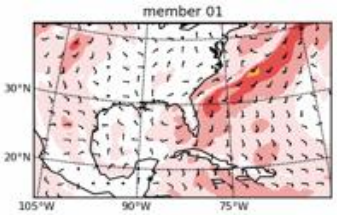
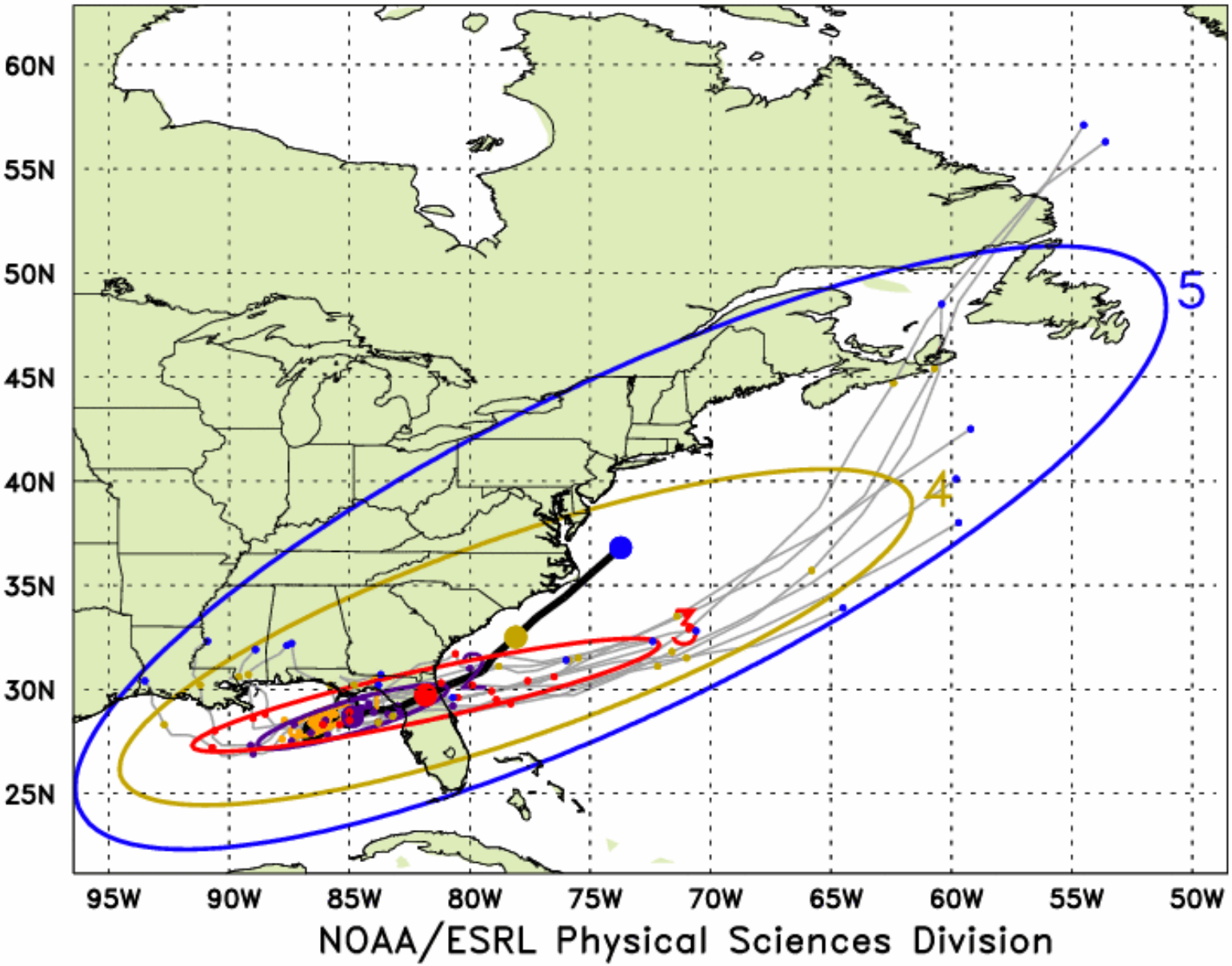
Here is a 60-h forecast where we can see that even with runs that still have a storm in the Gulf of Mexico there is another system off the East Coast. In other words, a piece of energy seems to be left behind in a fair number of these forecasts but in such cases a separate storm did track across FL and out to sea. I think the bottom line is that this is a complicated situation!

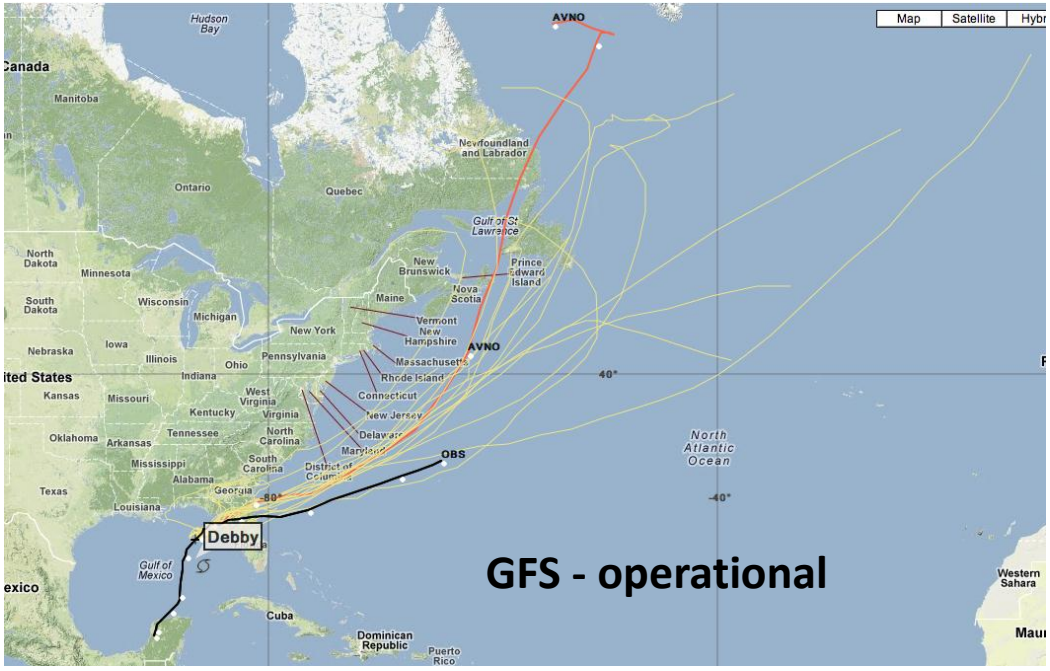


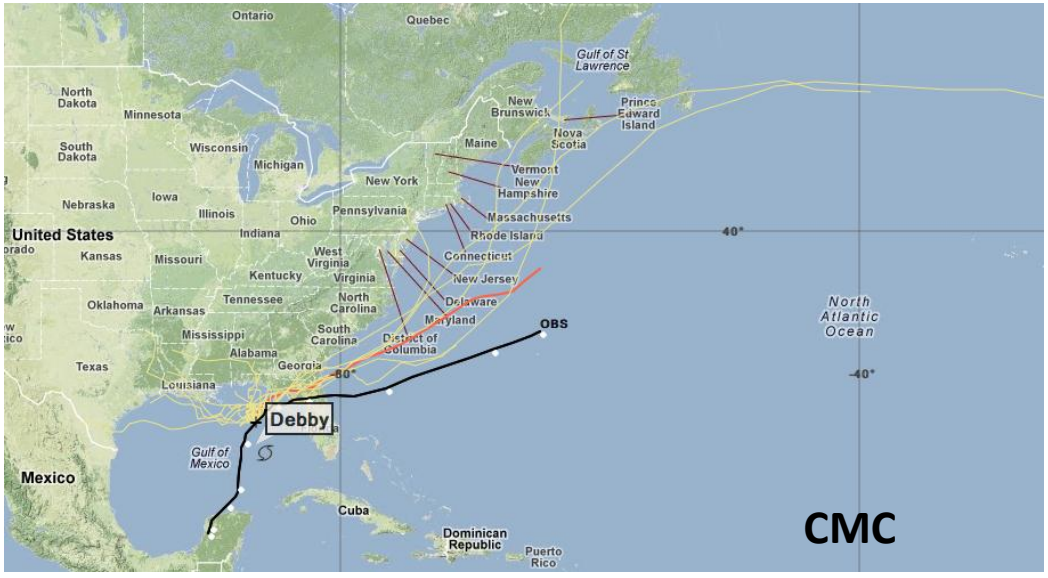
Verifying T382 analysis

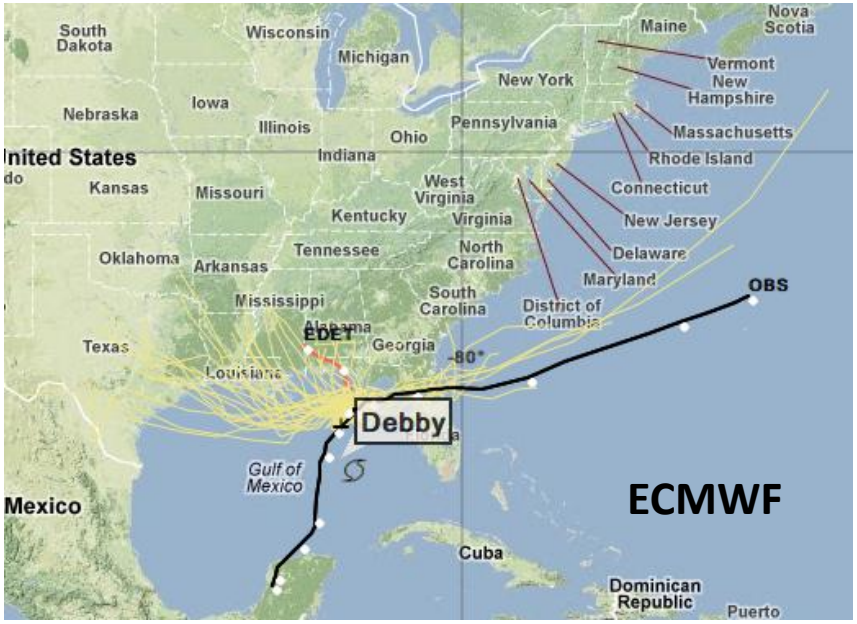

GFS/EnKF ensembles and ellipses,IC=2012062412
for storm number 04 in the AL basin
60N
55N
50N
45N
40N
35N
30N
25N
95W
90W
85W
80W
75W
70W
65W
60W
55W
50W
5
4
3
NOAA/ESRL Physical Sciences Division

Comparison of ensemble forecasts for 12z/24 June runs

All we show for this initialization time is the set of ensemble tracks.. Many of the EC and CMC members still take it w to wnw.

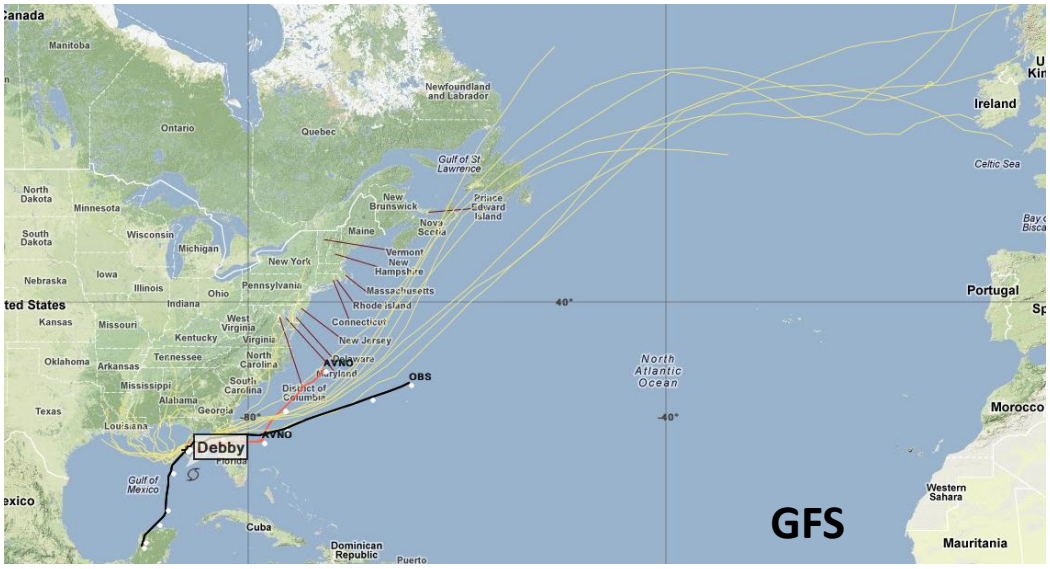


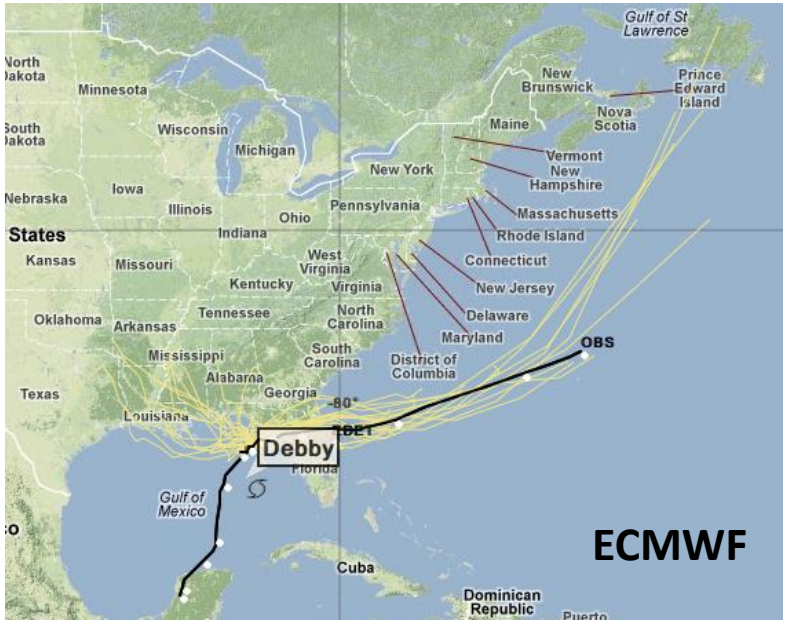


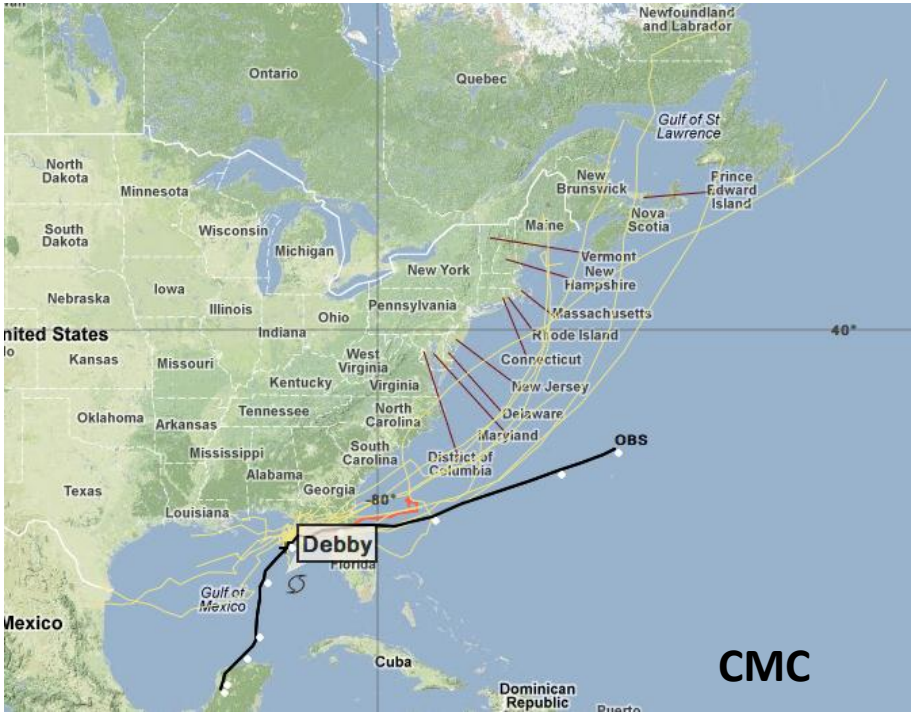


Comparison of ensemble forecasts for 00z/25 June runs

Many of the EC and CMC members still take it w to wnw.

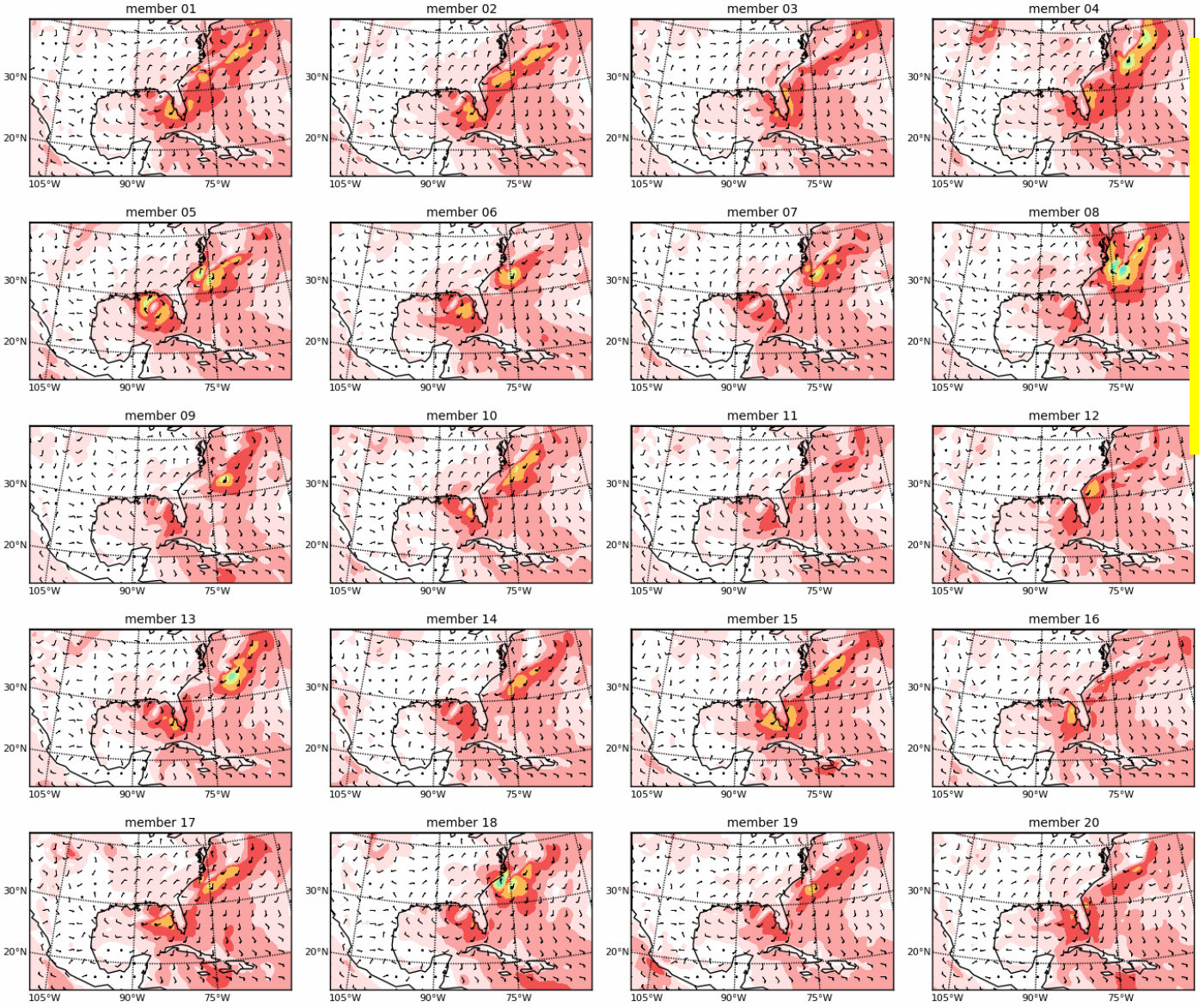




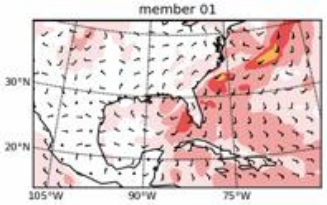


T382 GFS/EnKF 10-m wind ens 036-hr fcst for 04L from 2012062500

GFS/EnKF ensemble members: 25 June/00z run, 36-h 10-m wind valid 26 June/12z



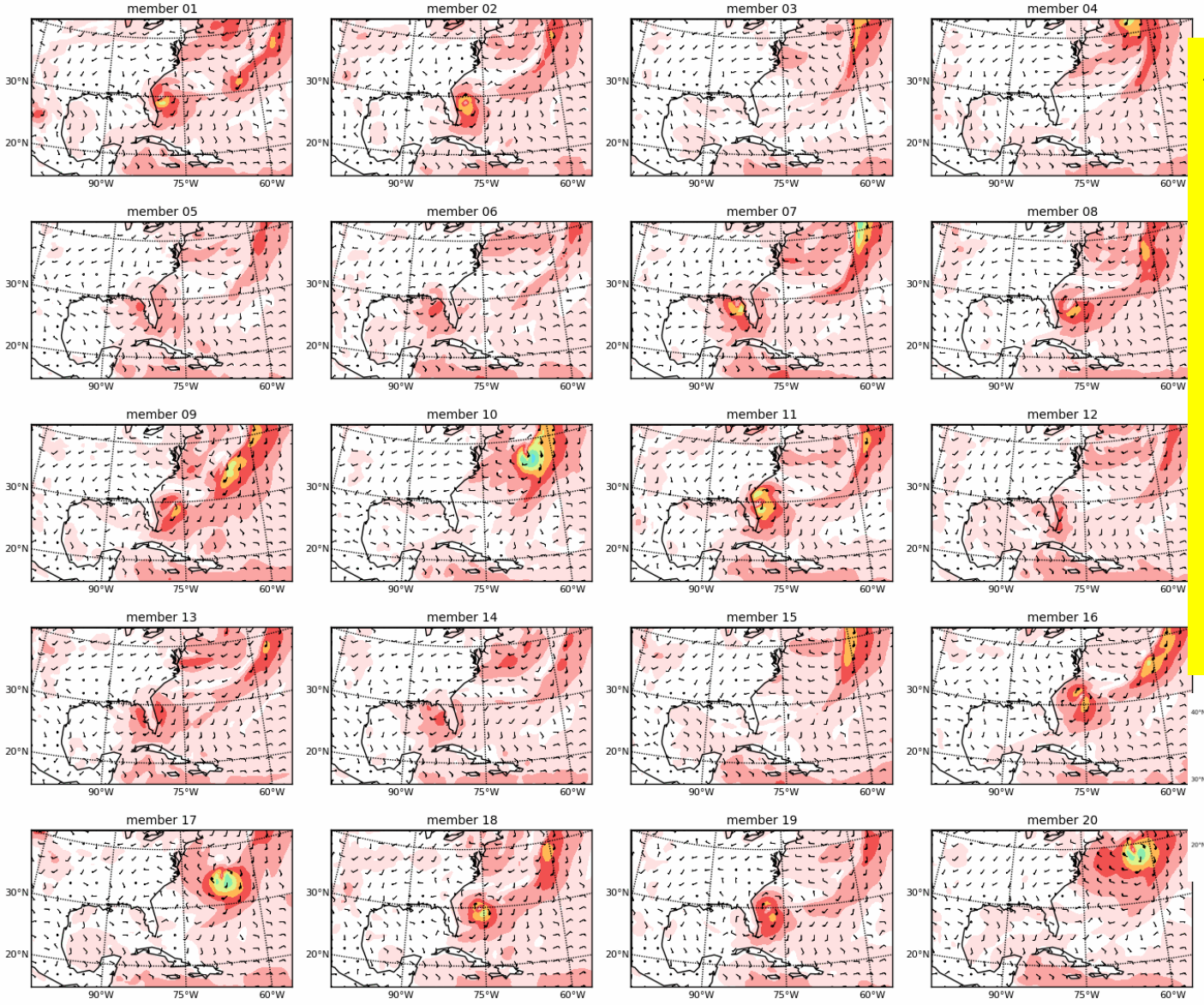
Same ideas as before; some members keep more of a system in the Gulf of Mexico but have still moved a system into the western Atlantic.



Verifying T382 analysis

T382 GFS/EnKF 10-m wind ens 084-hr fcst for 04L from 2012062500

GFS/EnKF ensemble members: 25 June/00z run, 84-h 10-m wind valid 28 June/12z



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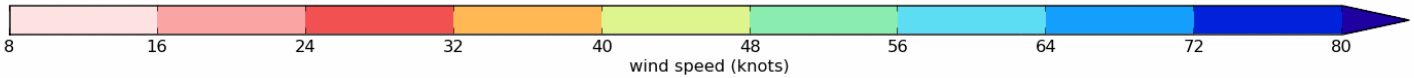
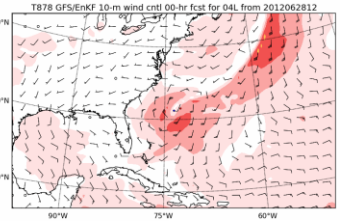
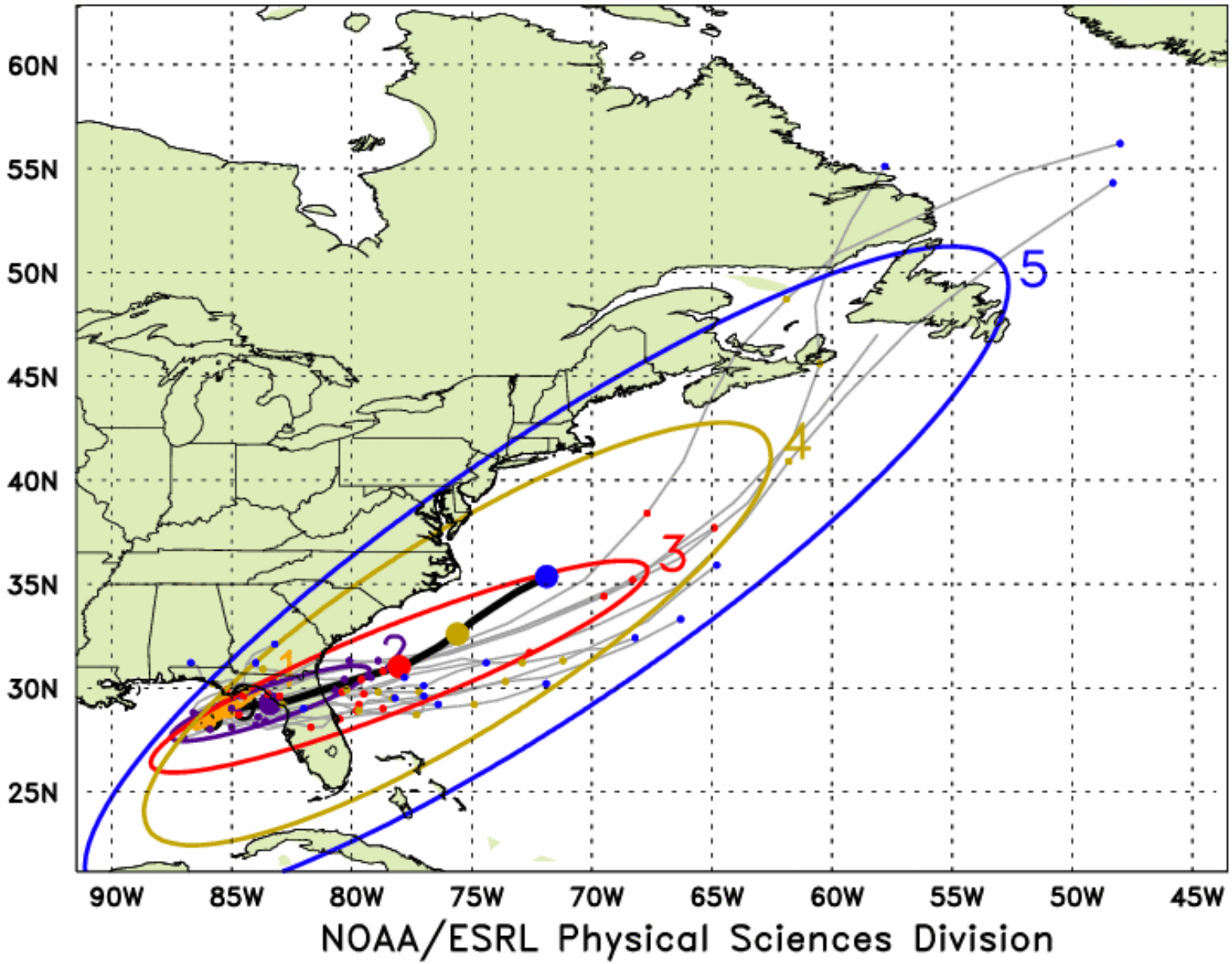


At 84-h even the runs that left a system in the Gulf of Mexico have moved it off, for the most part. The verification is shown below (with the same wind scale), where we see the system has gone well east of FL at this point.



Verification (T878 analysis here)


GFS/EnKF ensembles and ellipses,IC=2012062500
for storm number 04 in the AL basin
60N
55N
50N
45N
40N
35N
30N
25N
90W
85W
80W
75W
70W
65W
60W
55W
50W
45W
1
2
3
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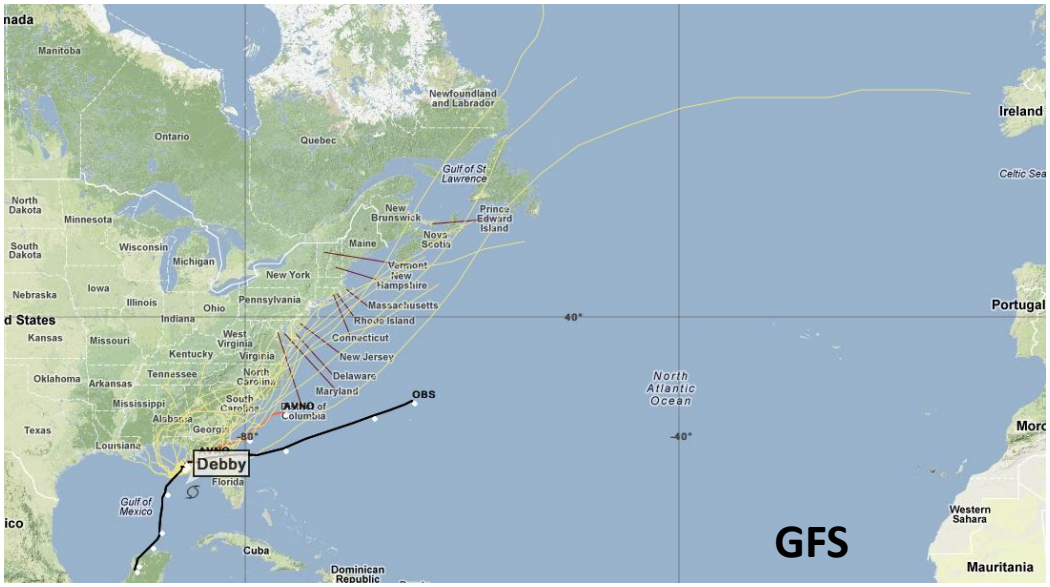
5
NOAA/ESRL Physical Sciences Division

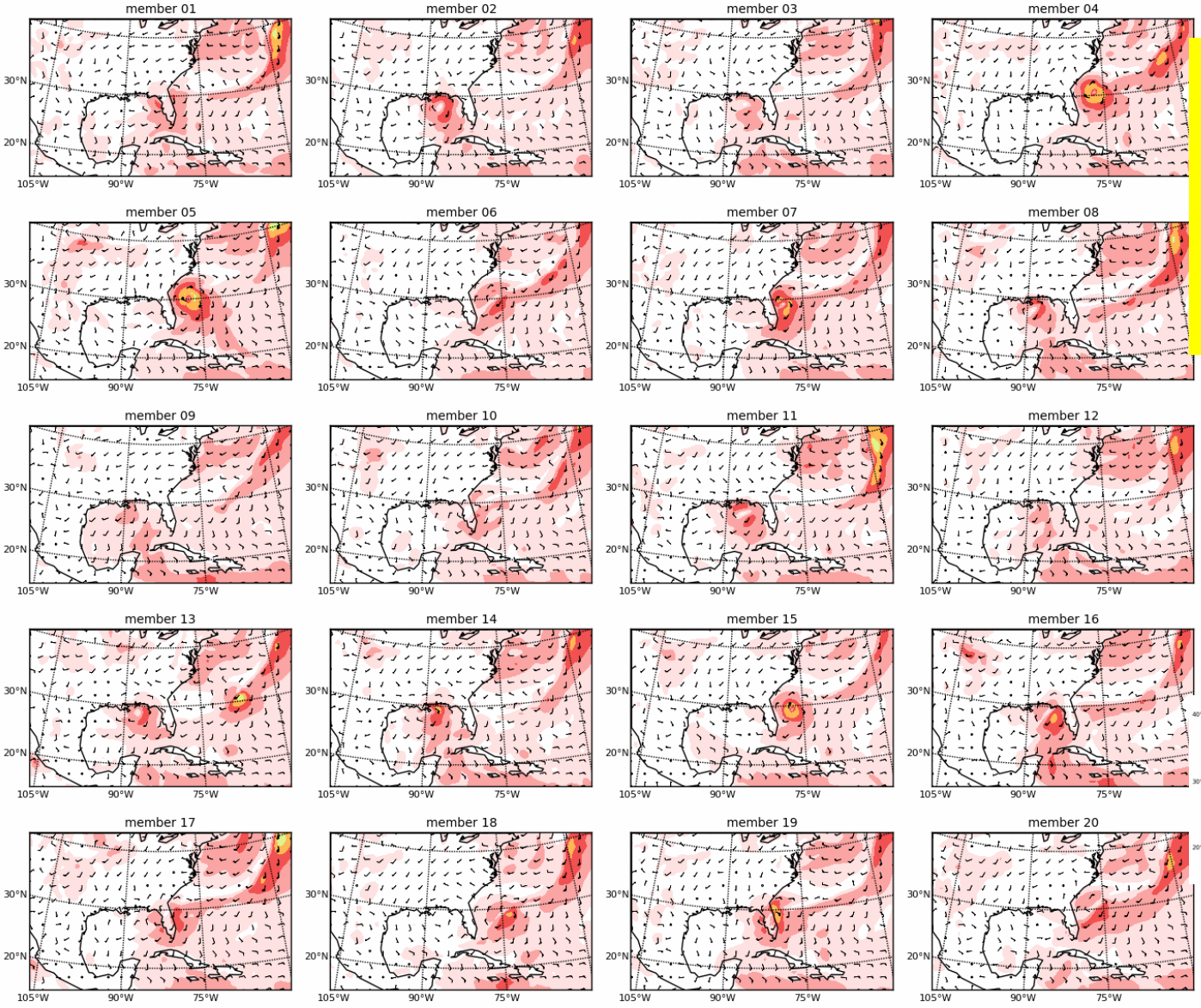
Comparison of ensemble forecasts for 12z/25 June runs

The EC and CMC still have the most members drifting a system to the wnw, but even the UK and GFS also have a few.

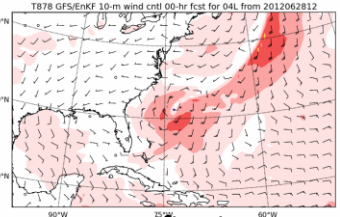


T382 GFS/EnKF 10-m wind ens 072-hr fcst for 04L from 2012062512

GFS/EnKF ensemble members: 25 June/12z run, 72-h 10-m wind valid 28 June/12z



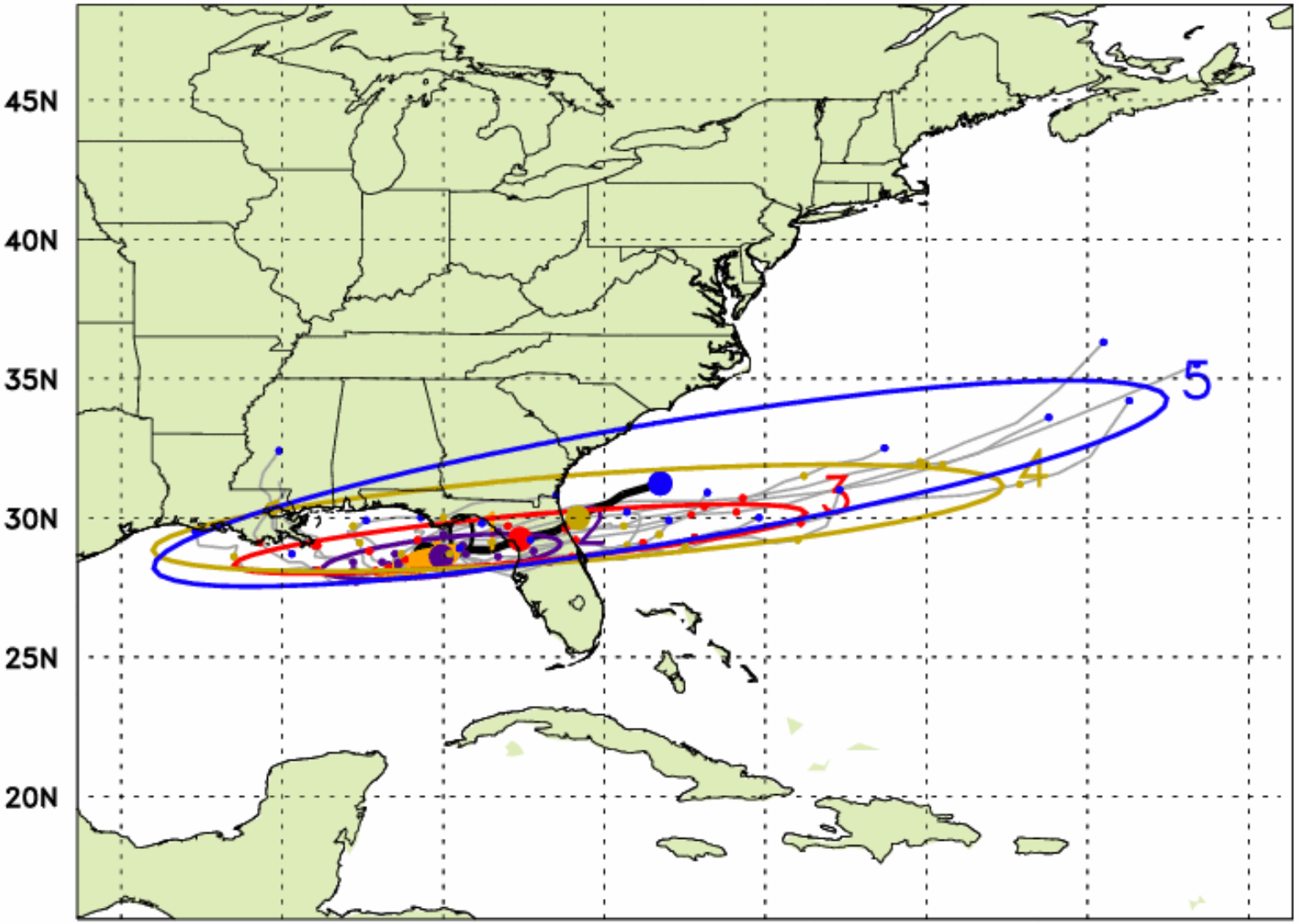
There is quite a bit of variation seen here even though this is only a 72-h forecast.



verification

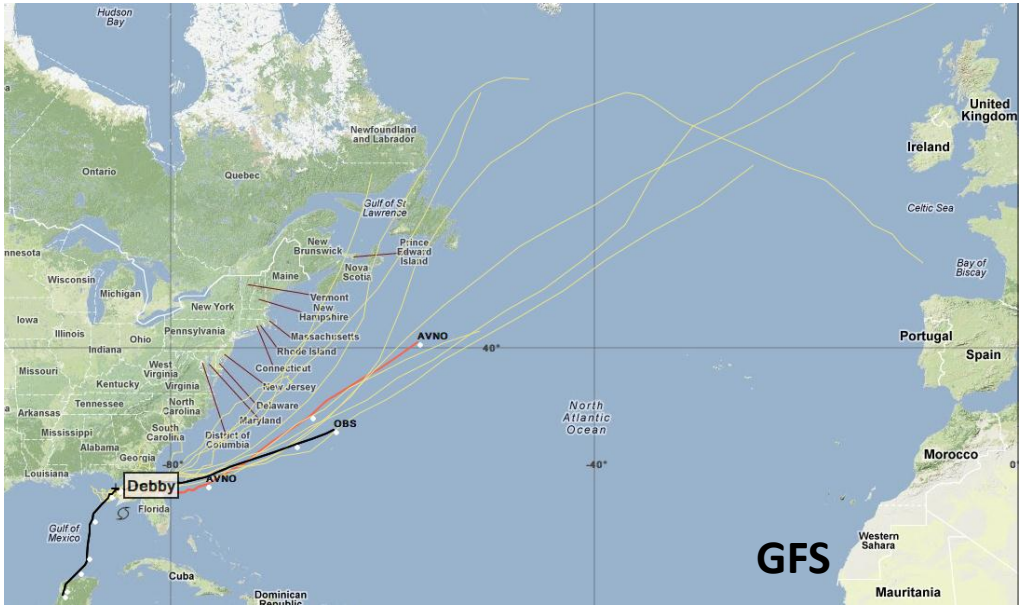
NOAA/ESRL Physical Sciences Division

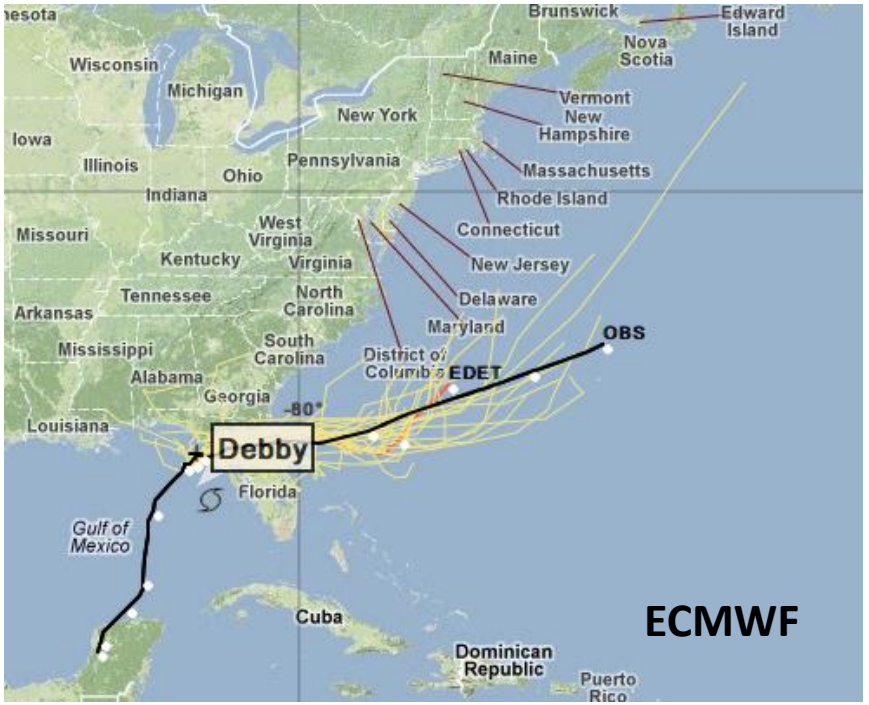
GFS/EnKF ensembles and ellipses,IC=2012062512
for storm number 04 in the AL basin

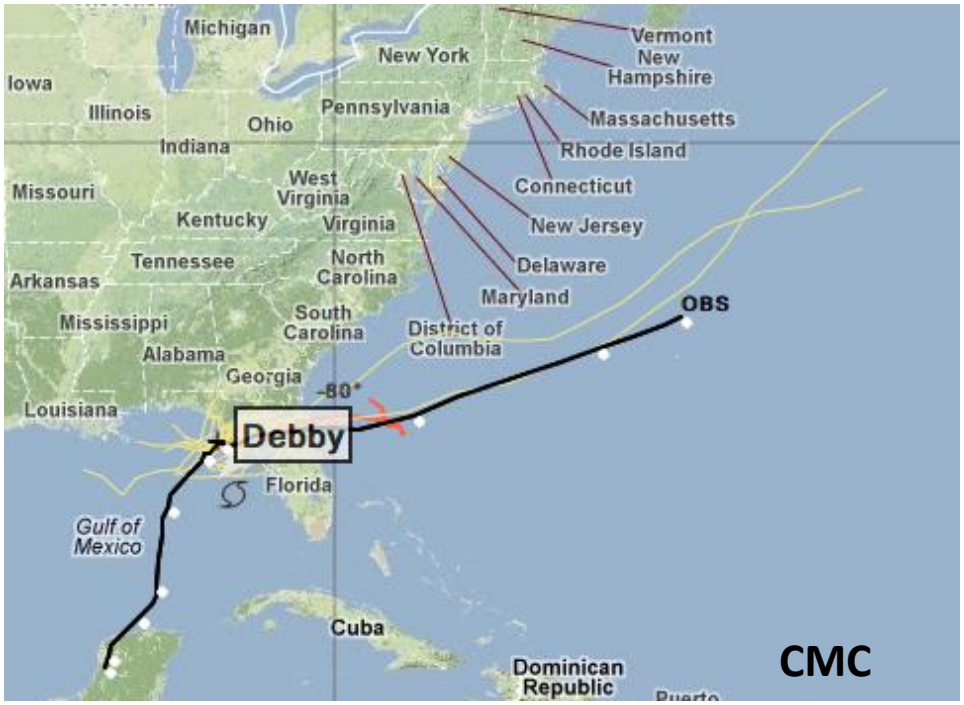


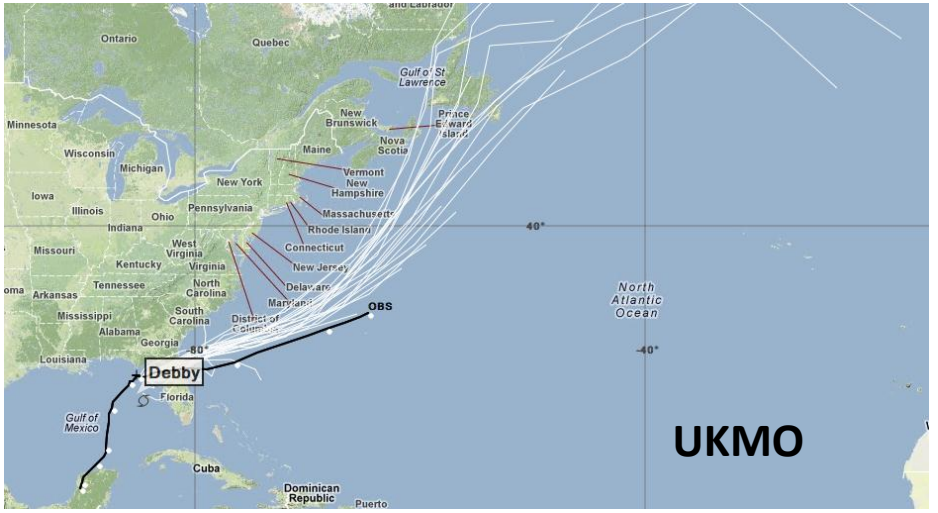
Comparison of ensemble forecasts for 00z/26 June runs

Still a few members of the EC and CMC drifting a system to the wnw, but pretty much most members of each model's ensemble now predict a correct track.



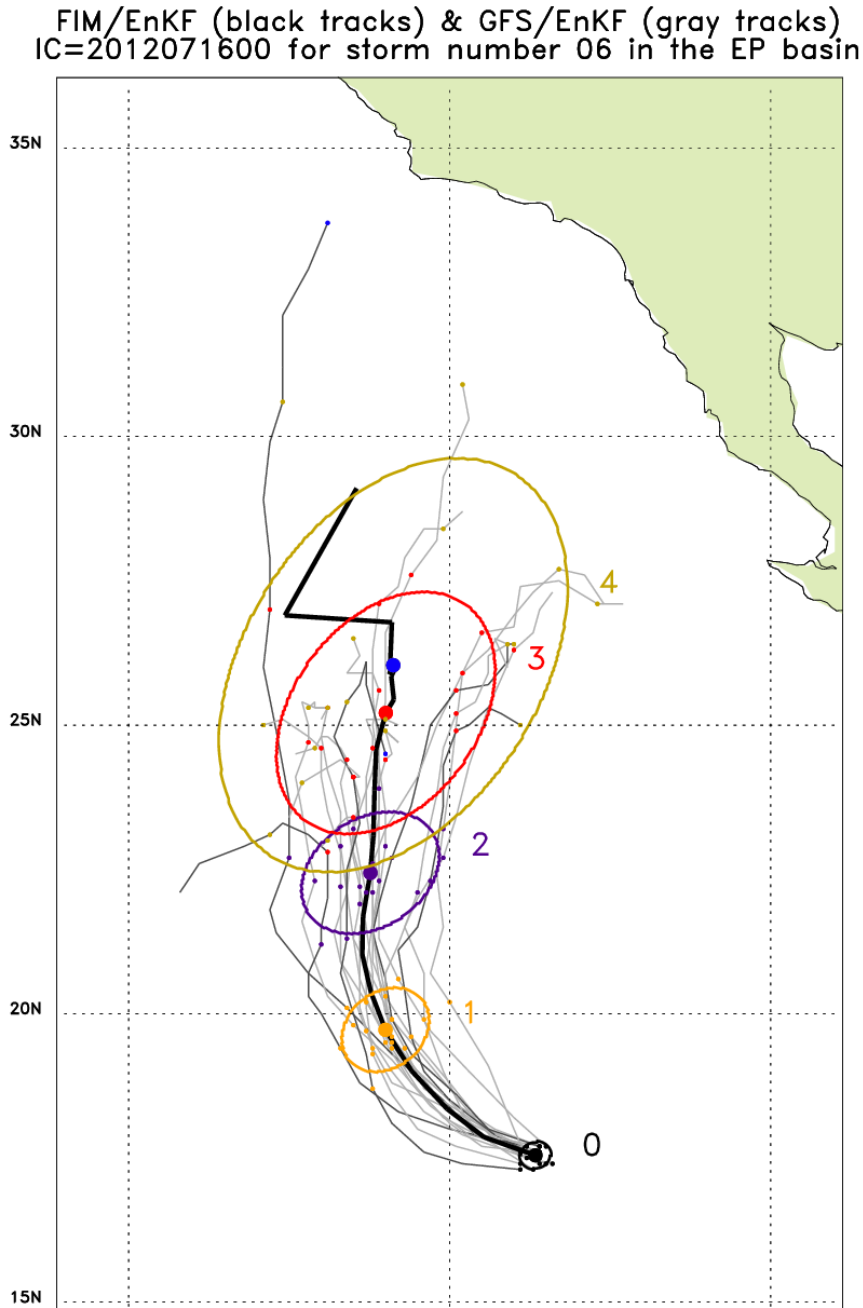






ESRL global deterministic and ensemble runs

	resolution	Deterministic runs prior to 8/1	HFIP deterministic runs post 8/1	Ensemble
FIM8	30km	GFS oper hybrid	GFS oper hybrid	ESRL GFS hybrid (Whitaker) – 20 members
FIM9	15km	GFS oper hybrid	GFS oper hybrid	N/A
GFS	T382 – 40km			ESRL GFS hybrid (Whitaker) – 10 members



Combined FIM/GFS ensemble (10 members each)

Fabio

- Initial time 00z 16 July 2012

Conclusions / 2012 HFIP experimental global models

- Difficult forecast situation with TS Debby
  - Debby not an isolated vortex but related to frontal zone linked to mid-latitude flow/PV structure
  - GFS generally better forecasts than EC, CMC, or UKMO
  - FIM partially follows GFS success presumably due to use of GFS EnKF init conds
- HFIP global experimental models from ESRL - 2012
  - ESRL GFS higher-res hybrid/EnKF/var (dual-res T878/T382)
  - Ensemble forecasts initialized by ESRL hybrid EnKF/var
    - GFS T382 (20 members) and FIM-30km (10 members)
    - mixed GFS/FIM ensemble output products also produced (20 members, 10 FIM members, 10 GFS members)
  - FIM9-15km deterministic run initialized by GFS operational hybrid EnKF/var (Stream 1.5 products)