Upgrades to the GFDL/GFDN Operational Hurricane Models Planned for 2015

(A JHT Funded Project)

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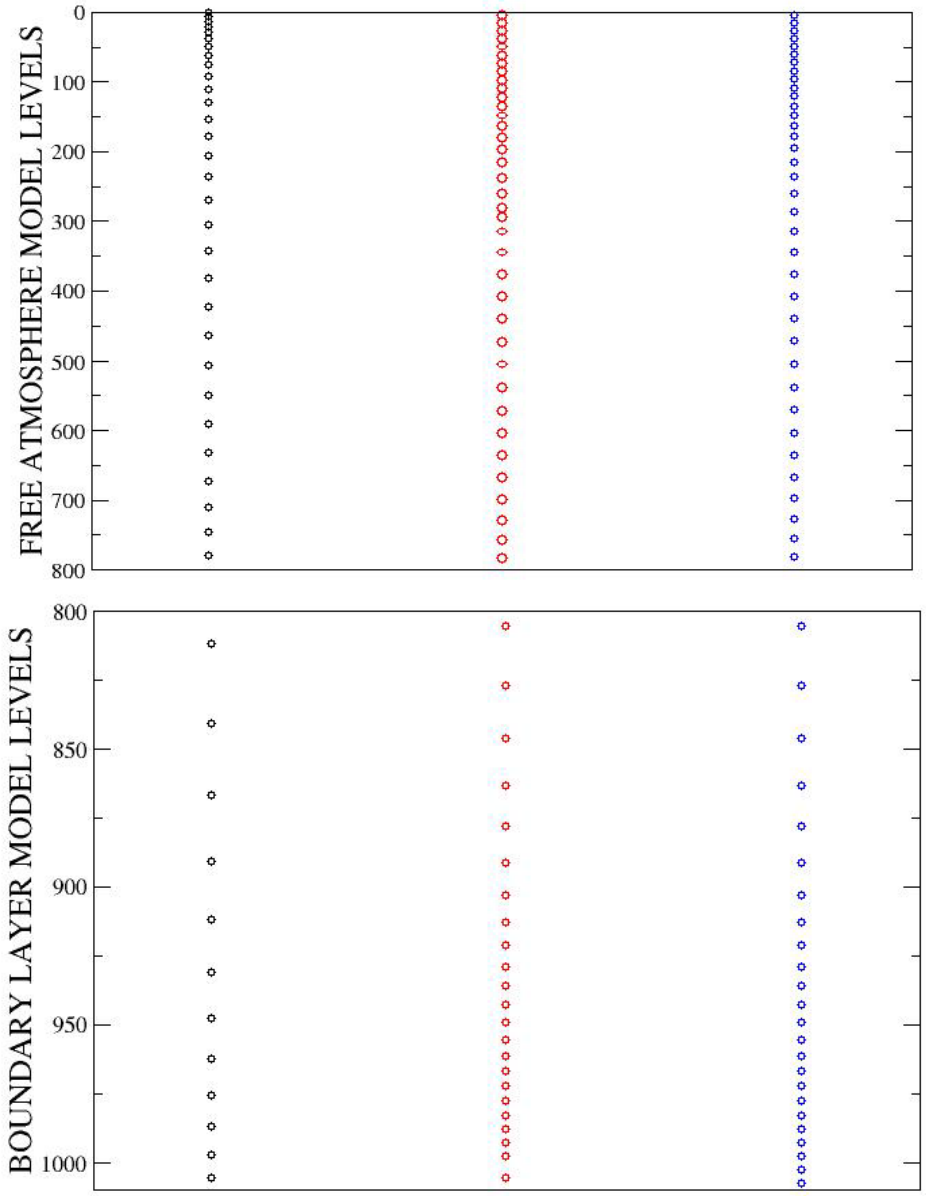
Summary of Proposed Upgrades

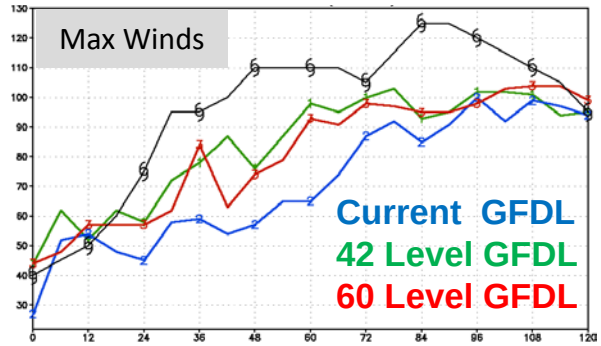
- **Upgraded version of GFS**
- **Increase of vertical sigma levels from 42 to 60**
  Similar Configuration to HWRF levels
- **Improved Initialization of Moisture Field (r)**
- **Using improved moisture specification: reintroduction of Vortex Specification for all storms (e.g. TD, and weak TS) except Nameless systems**
- **New Specification of Storm size (Rb)**
- **Modified filter depth in vortex specification**
  (Tested, but rejected due to unfavorable impact)
- **Modified criterion for large-scale condensation**
- **Bug Fix in GFDL coupler**
- **Bug Fix in Surface Current Specification**

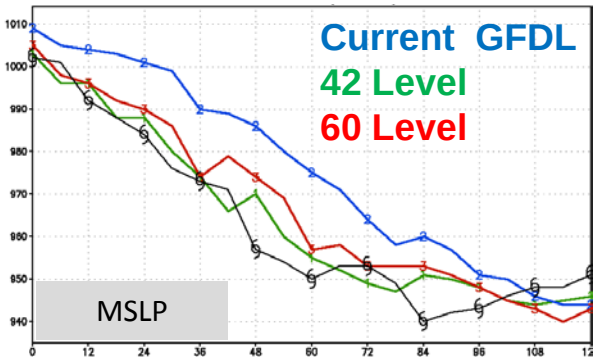
VERTICAL LEVEL CONFIGURATION

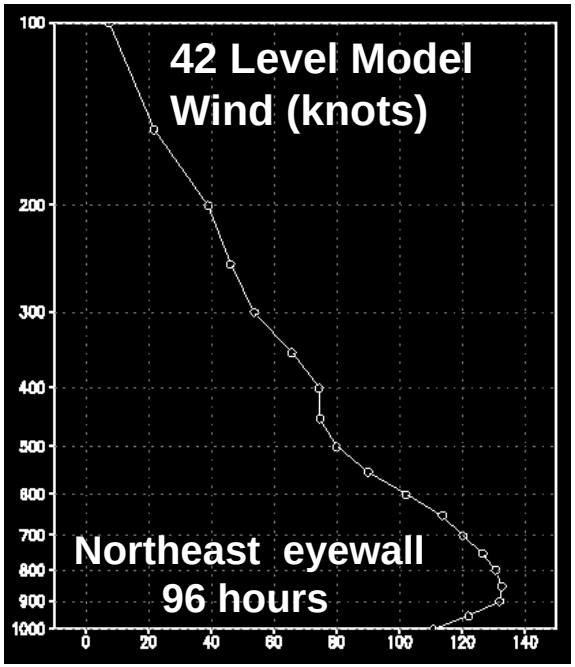
42 Level GFDL 60 Level GFDL 60 Level HWRF

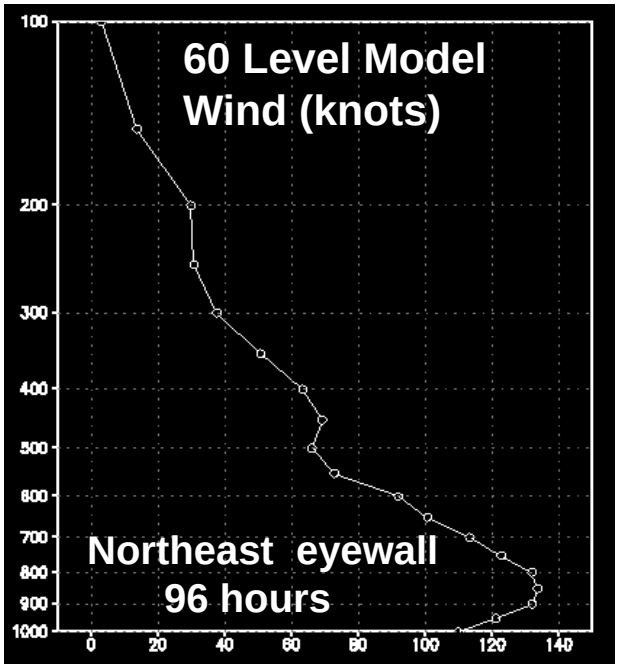


Hurricane Gonzalo (0000 UTC 13 October)



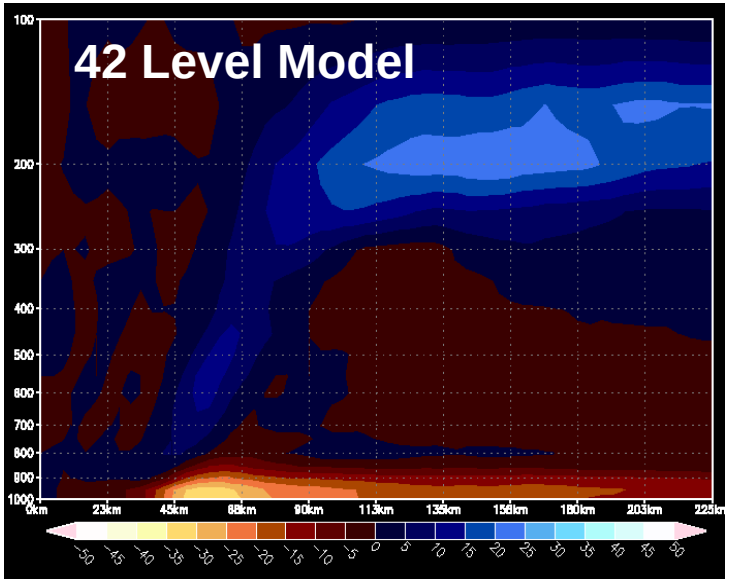


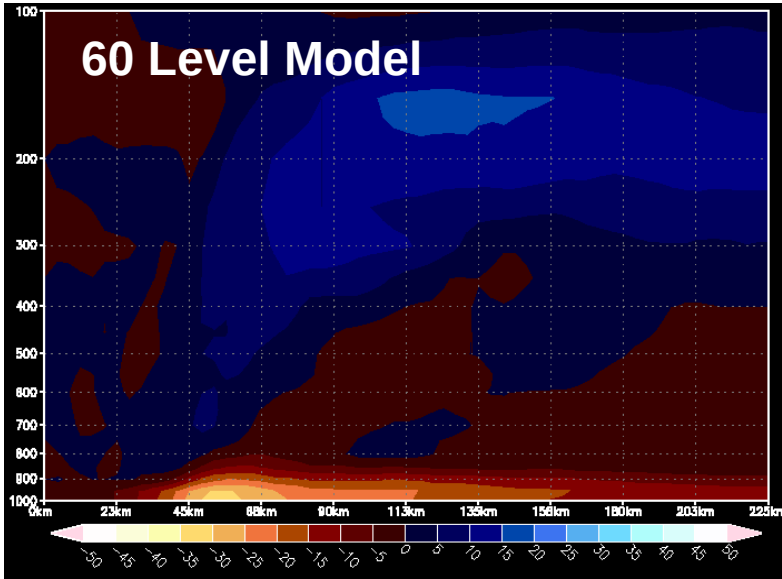




Circular Averaged Radial Wind (96 hours)

42 level model enhanced secondary circulation





Improved Moisture Initialization

Current Scheme :

$(U, V, T, r, p^*) = (U, V, T, r, p^*)_{Envr} + (U, V, T, r, p^*)_{axi\text{-}sym\ vortex}$

$r_{axi\text{-}sym\ vortex}$ defined with respect to the Environmental moisture field

(Environment is determined by moisture field outside the filter radius)

Lead to Unrealistic drying in middle troposphere

(Limited RI for weak, developing systems)

Revised Scheme :

$(U, V, T, p^*) = (U, V, T, p^*)_{Envr} + (U, V, T, p^*)_{axi\text{-}sym\ vortex}$

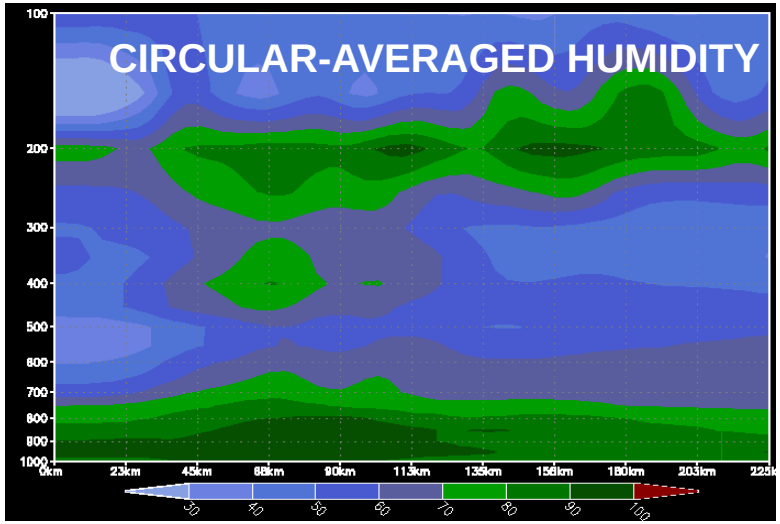
$r = r_{gfs} + r_{vortex}$

More realistic Initial Moisture lead to significantly Improved Intensification in RI situations

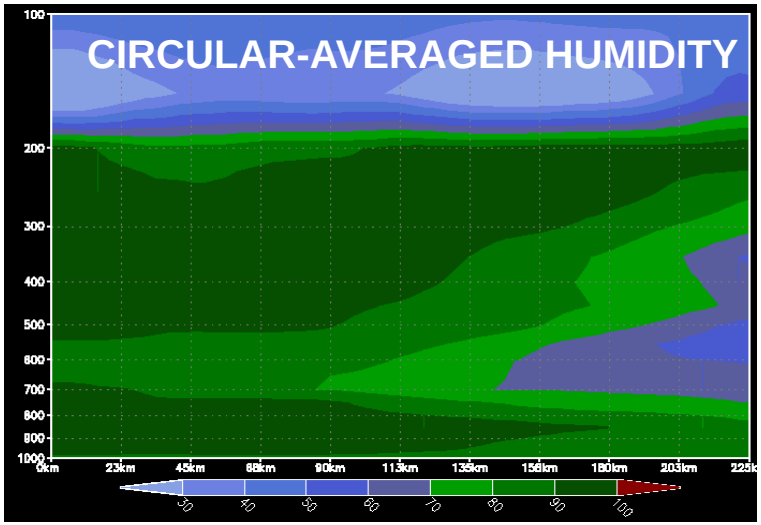
Impact of Improved Moisture Initialization

Hurricane Earl (Initial time: 0000 UTC 27 August, 2010)

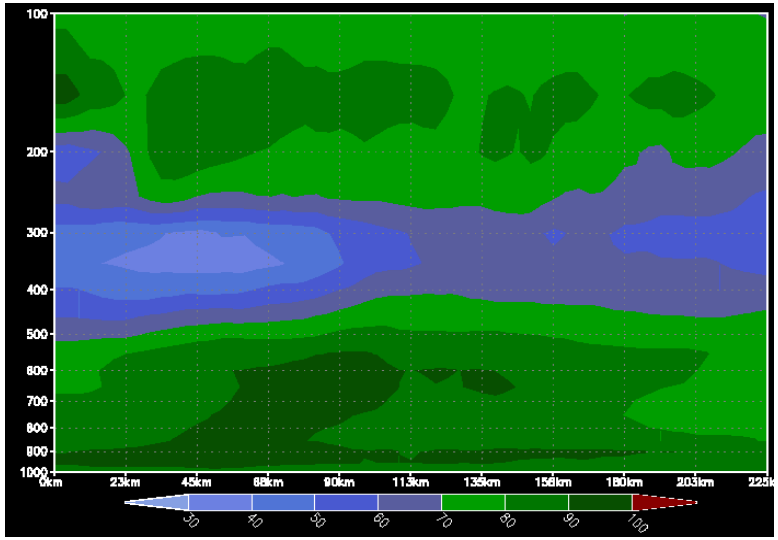
OLD MOISTURE INITIALIZATION



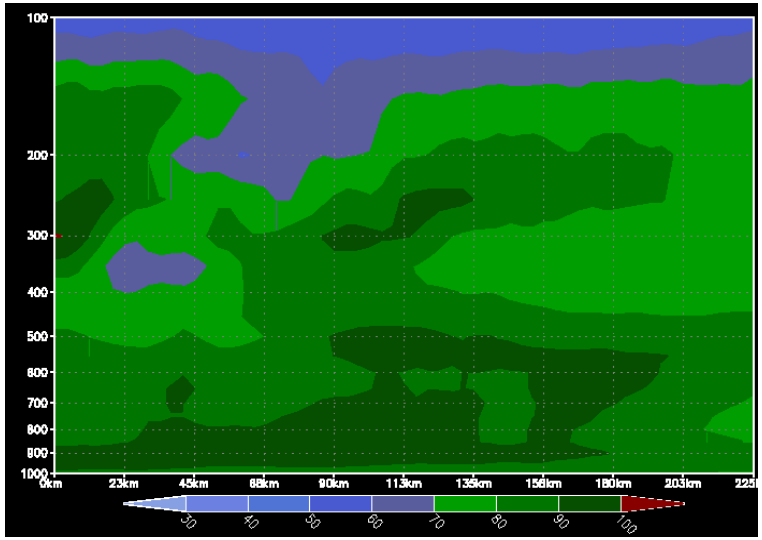
NEW MOISTURE INITIALIZATION



HOUR 0

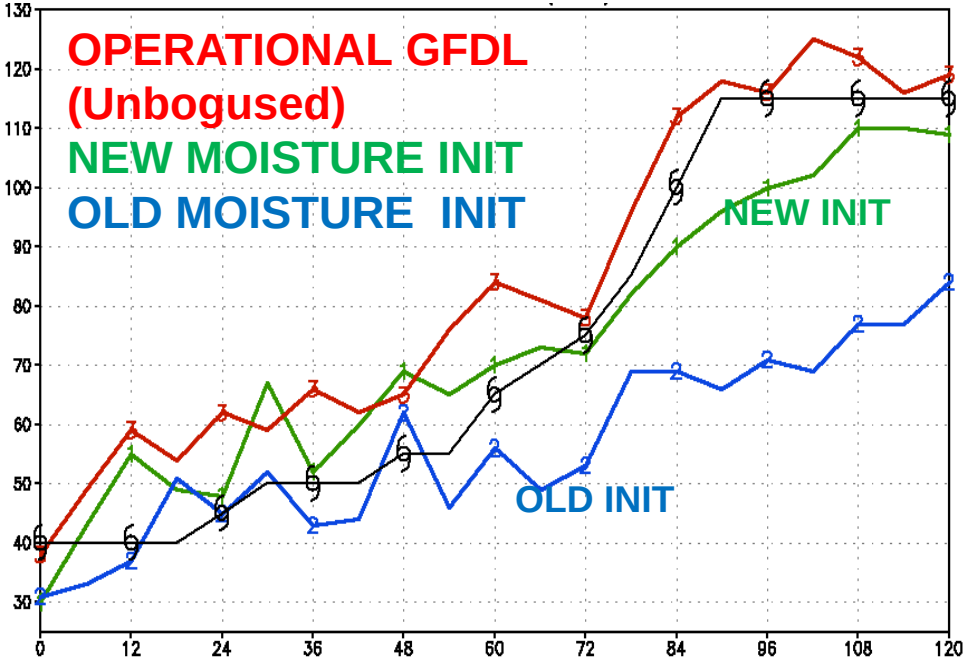


FORECAST HOUR 42

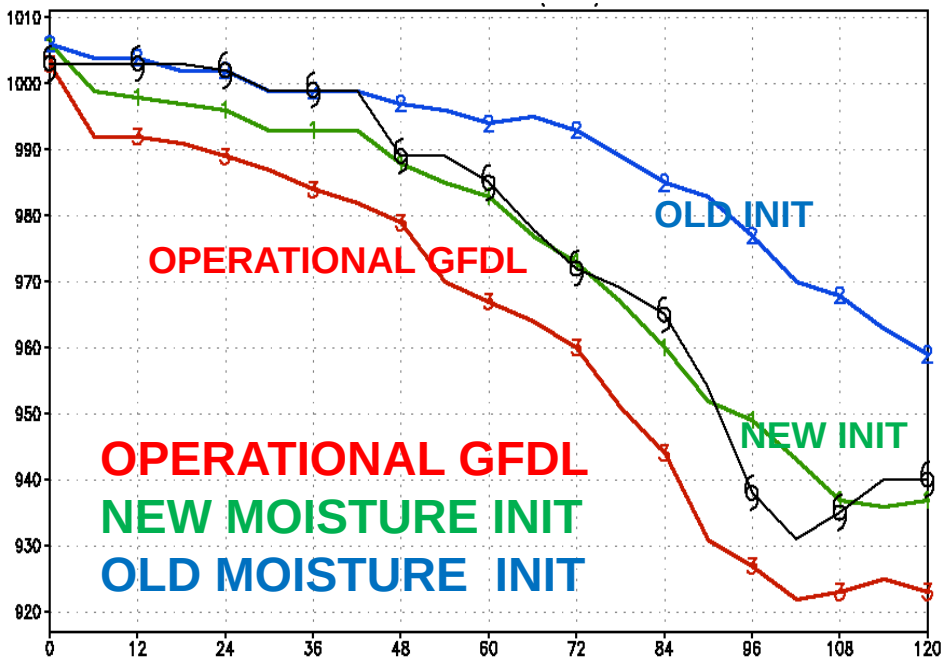


Impact of Improved Moisture Initialization

MAXIMUM SURFACE WINDS (KTS)



CENTRAL PRESSURE (hPa)



HURRICANE EARL (INITIAL TIME: 000 UTC 27 AUGUST, 2010)

Formulation of New Storm Size (R_b)

(radius where the tangential wind of specified vortex goes to 0)

In current vortex initialization we assume R_b is a simple function of the Radius of the Last closed Isobar (RLCI) from the tcvitals file (R_b = 1.5 * RLCI)

Assume the Absolute Angular Momentum M(r)

$M(r) = rv + \frac{1}{2}$ f r^2 *is roughly conserved for*

A parcel of air moving radially inwardly toward the storm center

$$V(r)_{tan} = \frac{M(p)}{r^x} - \frac{1}{2} f r \qquad Carr\ and\ Elsberry,\ MWR\ (1997)$$

Where: **(x = .4)** $M(p) = M(r)/r^{(1-x)}$

$$M(p) = \frac{1}{2} f (R_b)^{(1+x)}$$

Assuming R_b = Radius where tangential wind vanishes

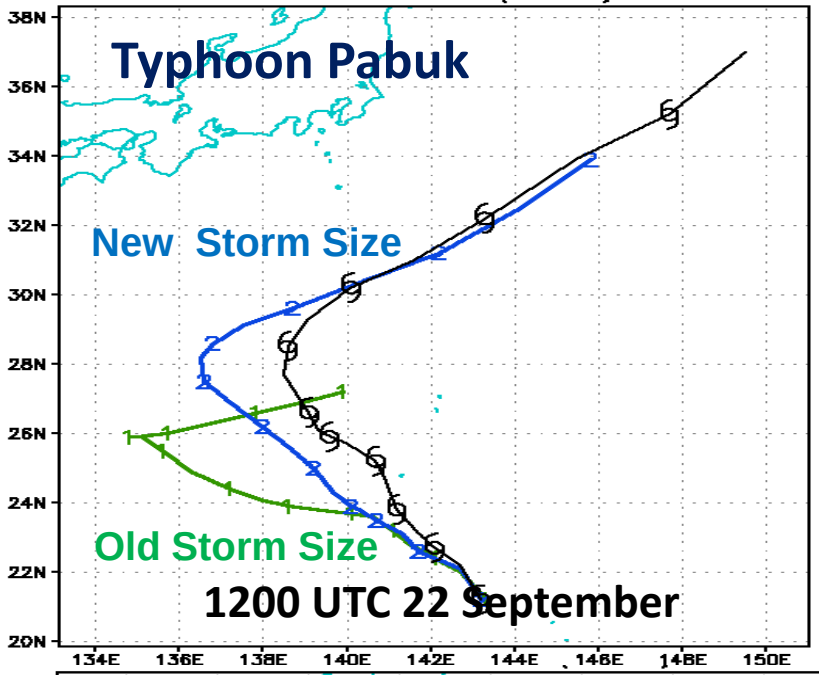
The Absolute Angular Momentum (M_{gale}) at the radius of Gale winds can be determined from the tcvitals :

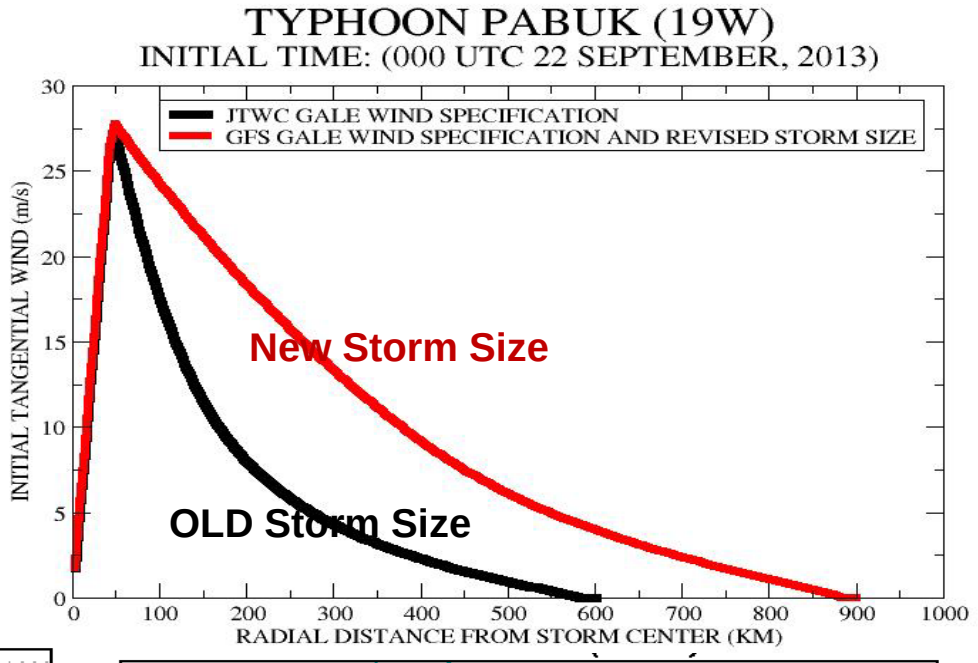
$$M(r)_{gale} = r_{gale} v_{gale} + \frac{1}{2} f\ r_{gale}^2$$

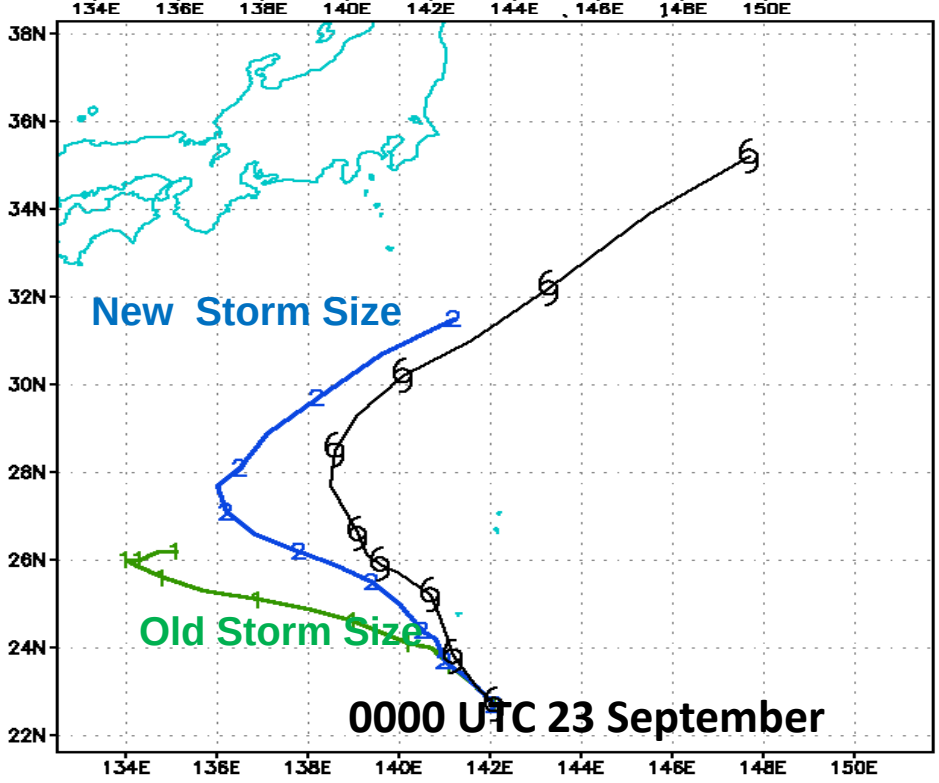
$$MLG = log\ (2(M(r))_{gale}/f\ r_{gale}^{(1-x)}$$

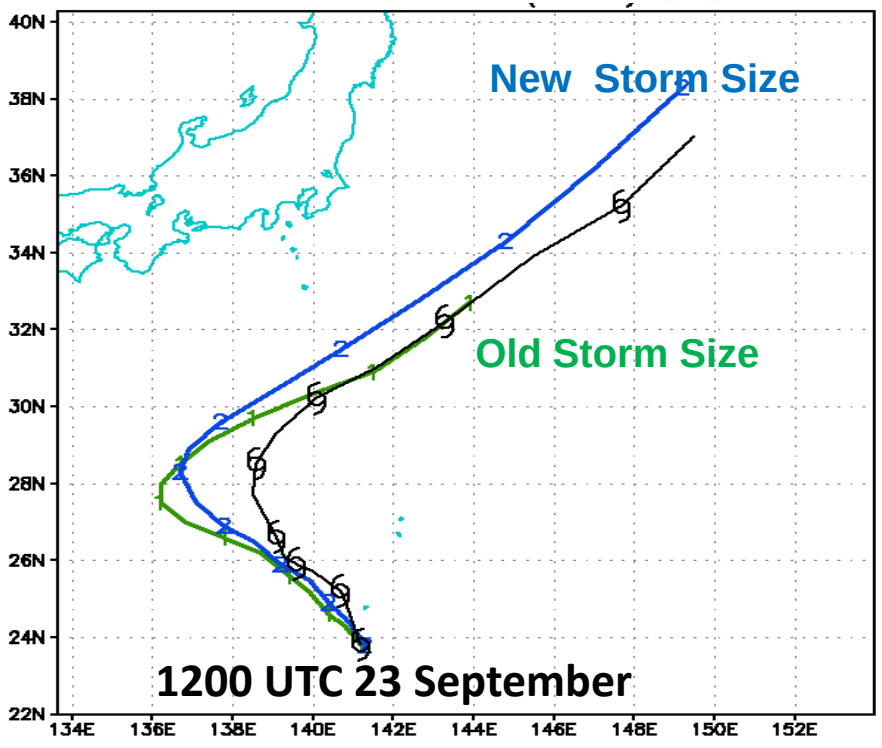
r_{gale} *averaged sum of* radli of gale winds v_{gale} at each of the 4 storm quadrants

New Estimate for R_b : $(R_b) = e^{(MLG/(1+x))}$

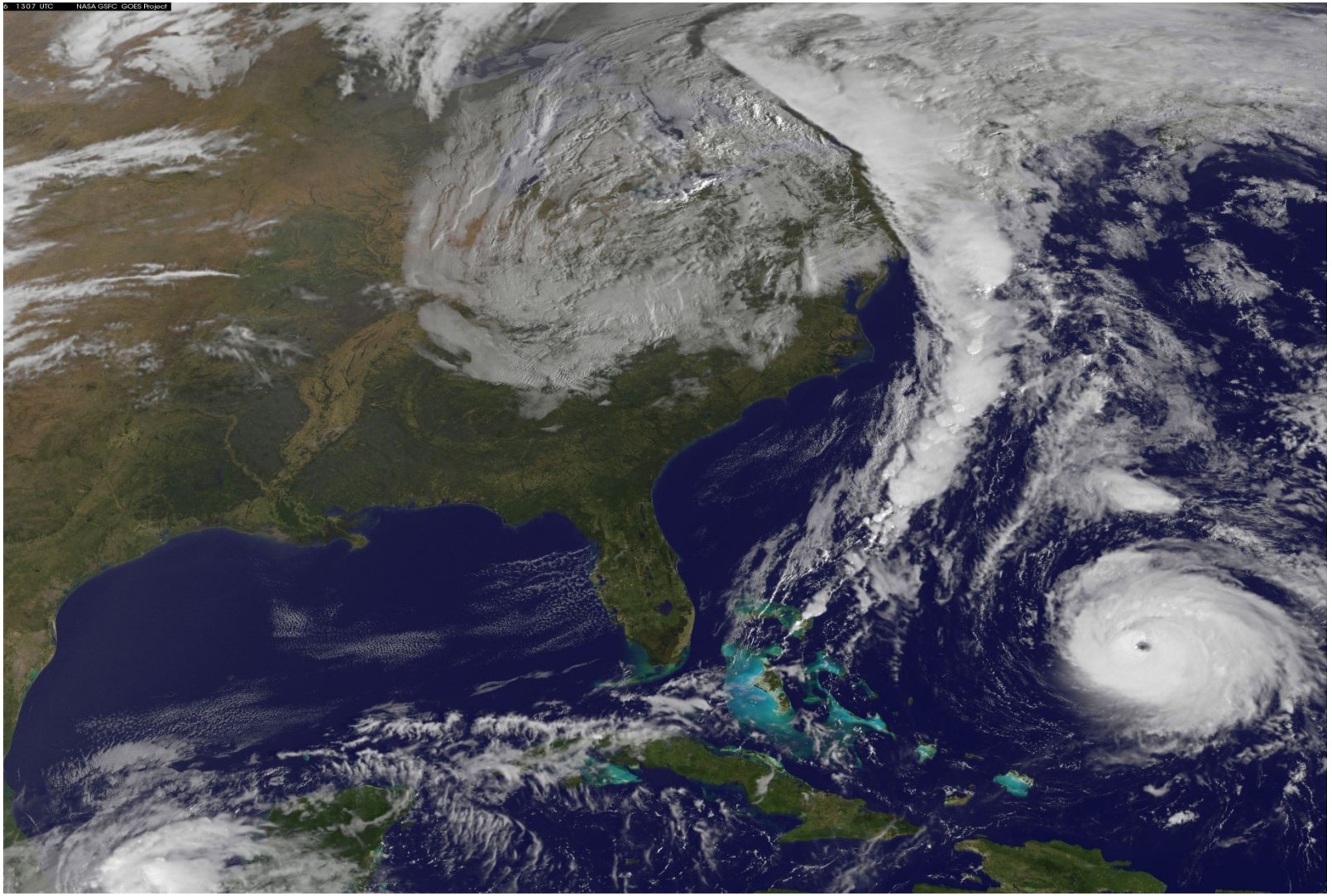

Typhoon Pabuk
New Storm Size
Old Storm Size
1200 UTC 22 September


TYPHOON PABUK (19W)
INITIAL TIME: (000 UTC 22 SEPTEMBER, 2013)
JTWC GALE WIND SPECIFICATION
GFS GALE WIND SPECIFICATION AND REVISED STORM SIZE
New Storm Size
OLD Storm Size
INITIAL TANGENTIAL WIND (m/s)
RADIAL DISTANCE FROM STORM CENTER (KM)


New Storm Size
Old Storm Size
0000 UTC 23 September

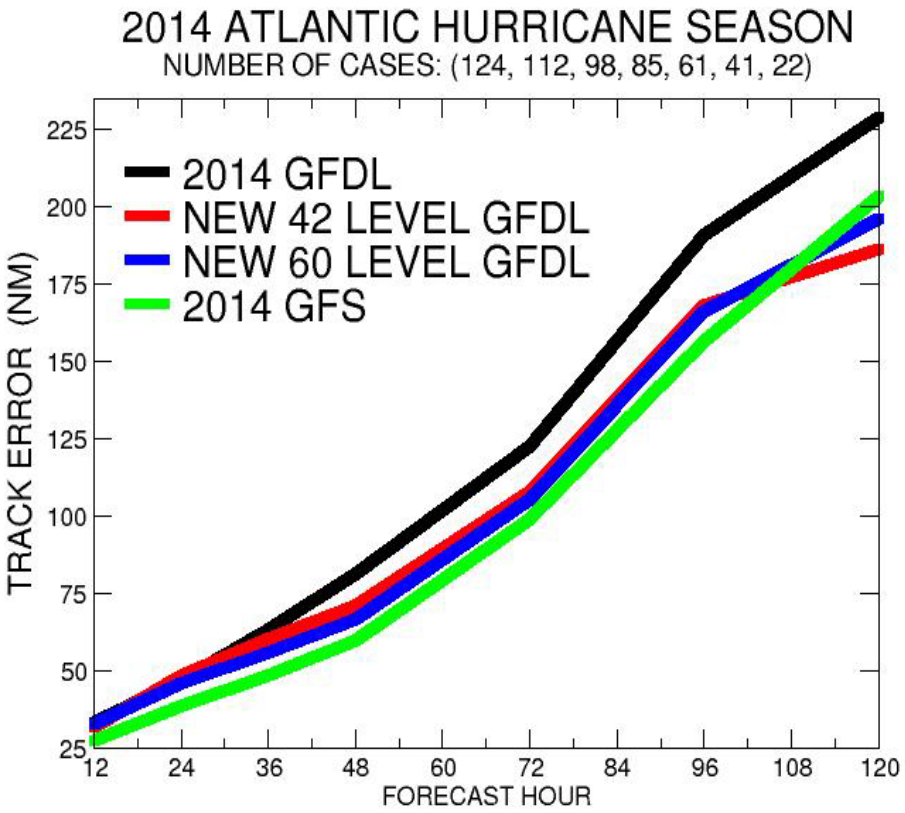

New Storm Size
Old Storm Size
1200 UTC 23 September

Performance Evaluation of Upgraded Model with Previous GFS



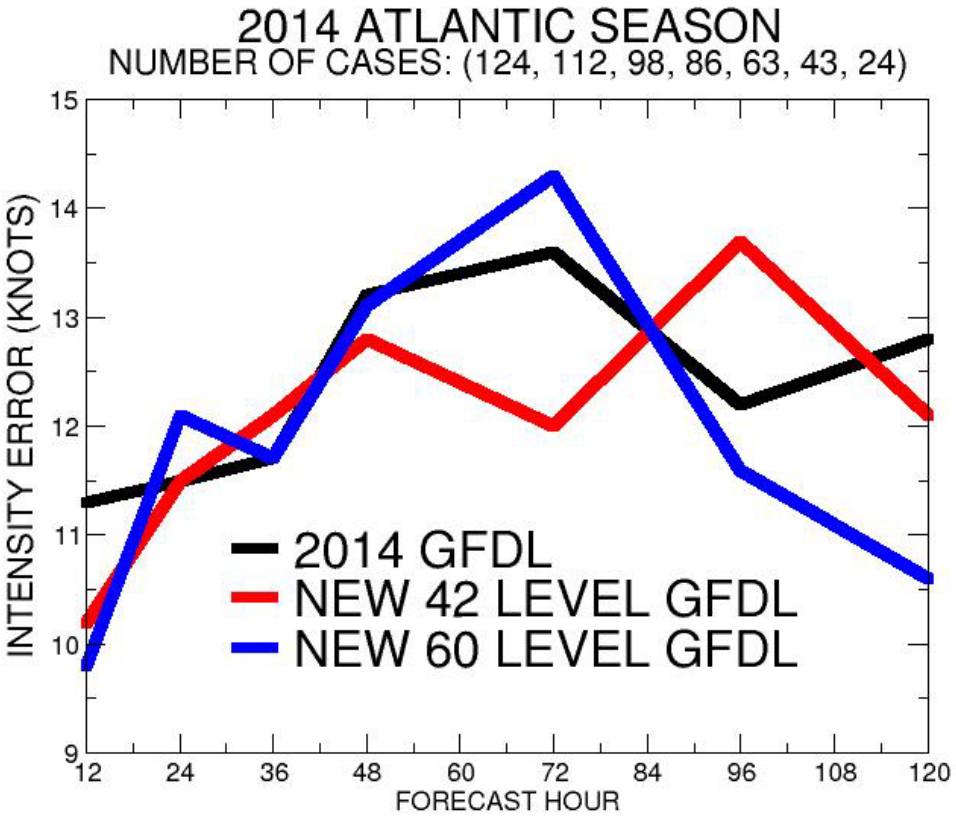
2014 Atlantic Season with 2014 GFS

TRACK ERROR (NM)



16-18% Reduced Track Error for 2-5 Days for Both Upgraded Models
New Models Comparable to GFS

INTENSITY ERROR (KNOTS)

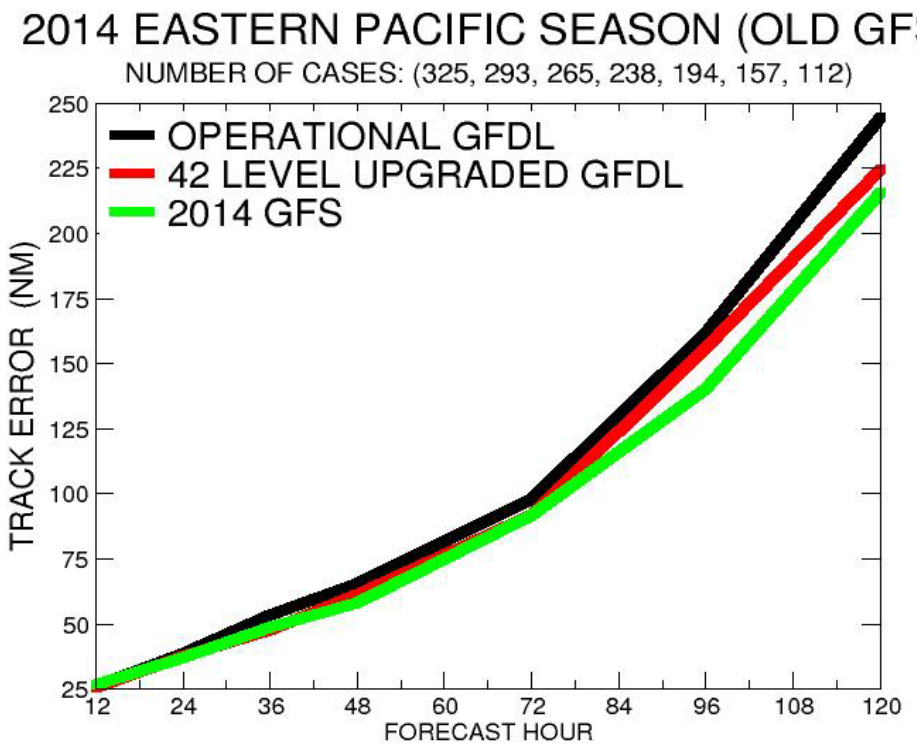


INTENSITY PERFORMANCE MIXED
42 LEVEL IMPROVED EARLY TIME
60 LEVEL IMPROVED LATER TIME

2014 Eastern Pacific Season with 2014 GFS

Only 42 Level Upgrade Run

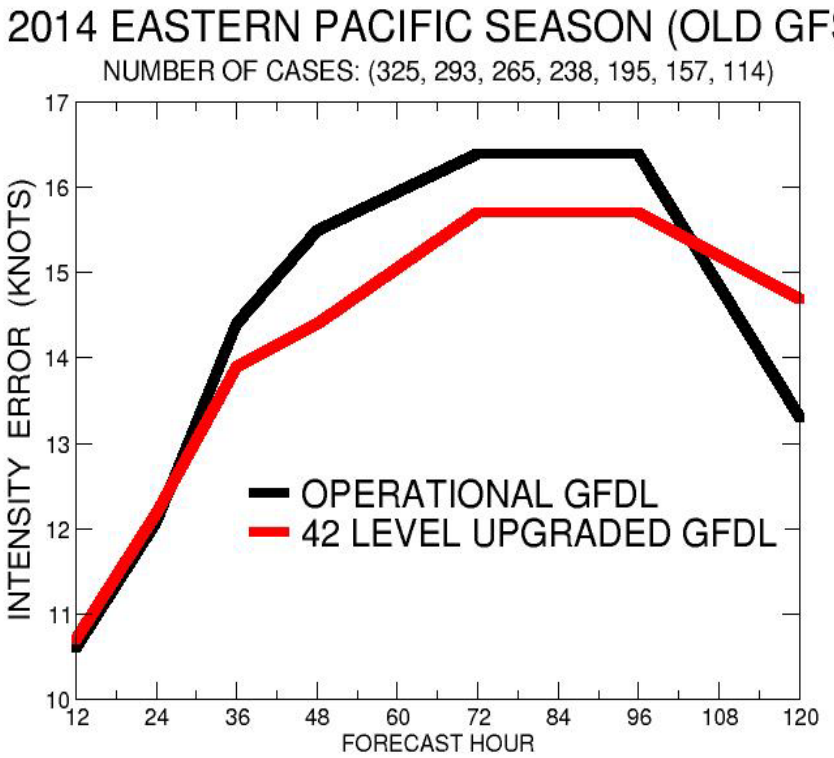
TRACK ERROR (NM)



7% Reduced Track Error for 42 level model 2-5 Days

New 42 Level Model Comparable to GFS through day 3 and at day 5

INTENSITY ERROR (KNOTS)

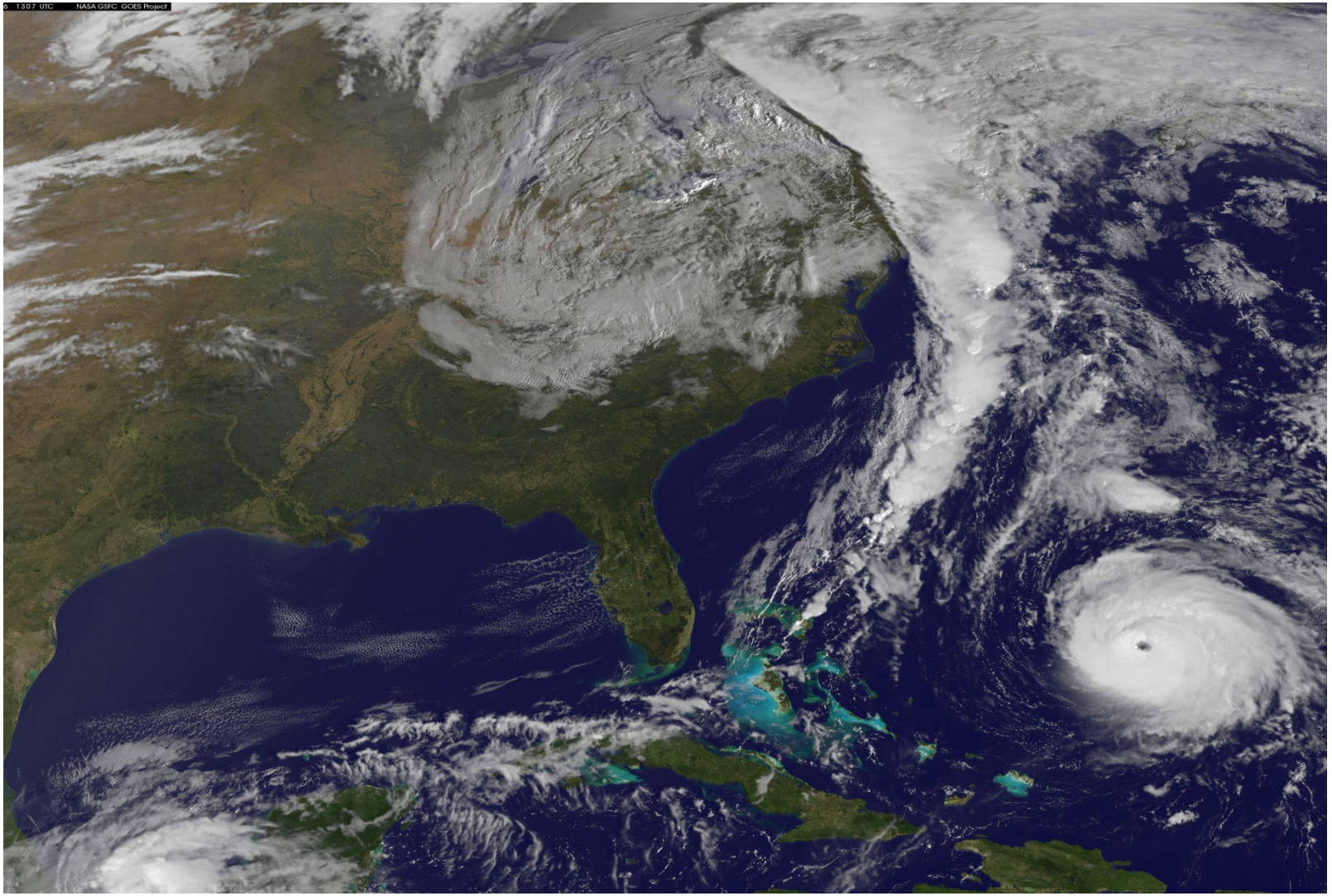


7% Reduced Intensity Error Days 1-4

Degraded Day 5

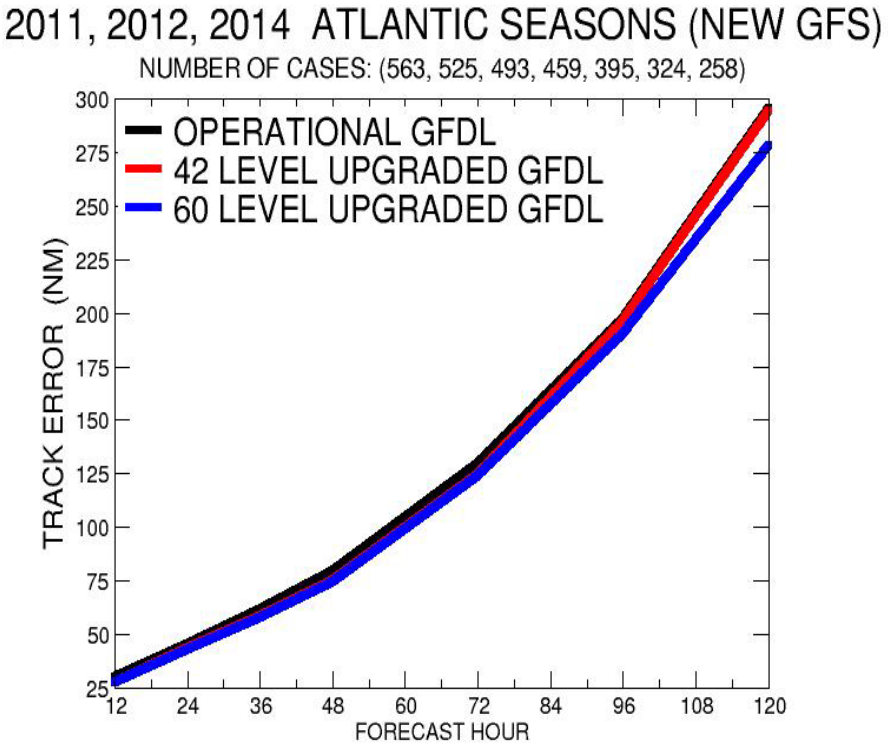
Preliminary Performance Evaluation With New GFS

(sample size in East Pacific limited by major Jet outage and not included)



2011, 2012, 2014 Atlantic Seasons

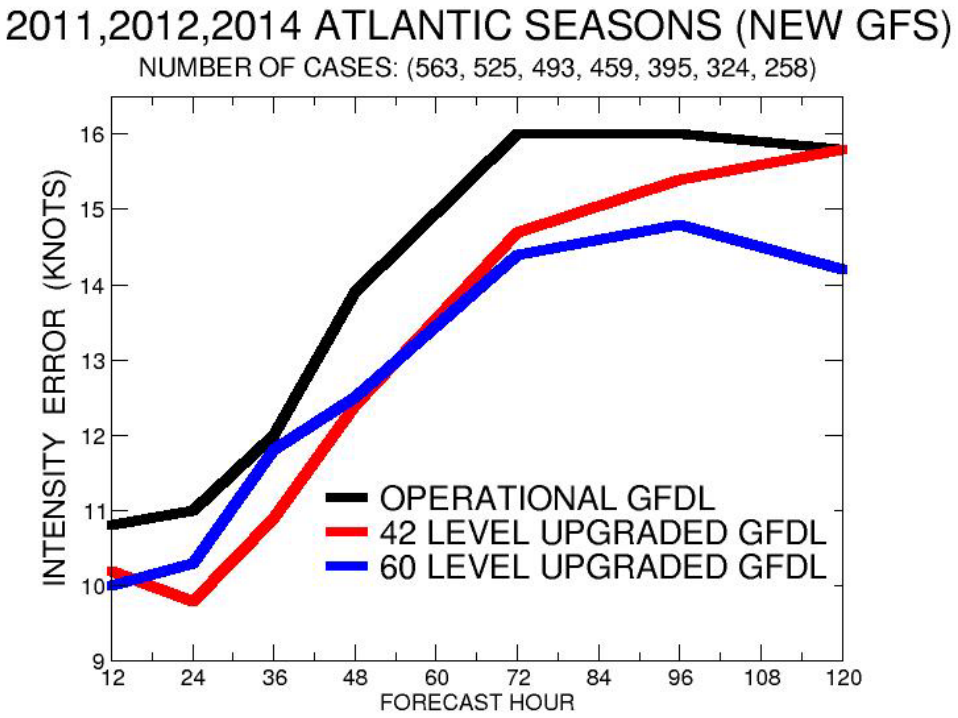
TRACK ERROR (NM)



60 Level Model performed best all time periods

(6% reduced track error compared to Current GFDL model)

INTENSITY ERROR (KNOTS)

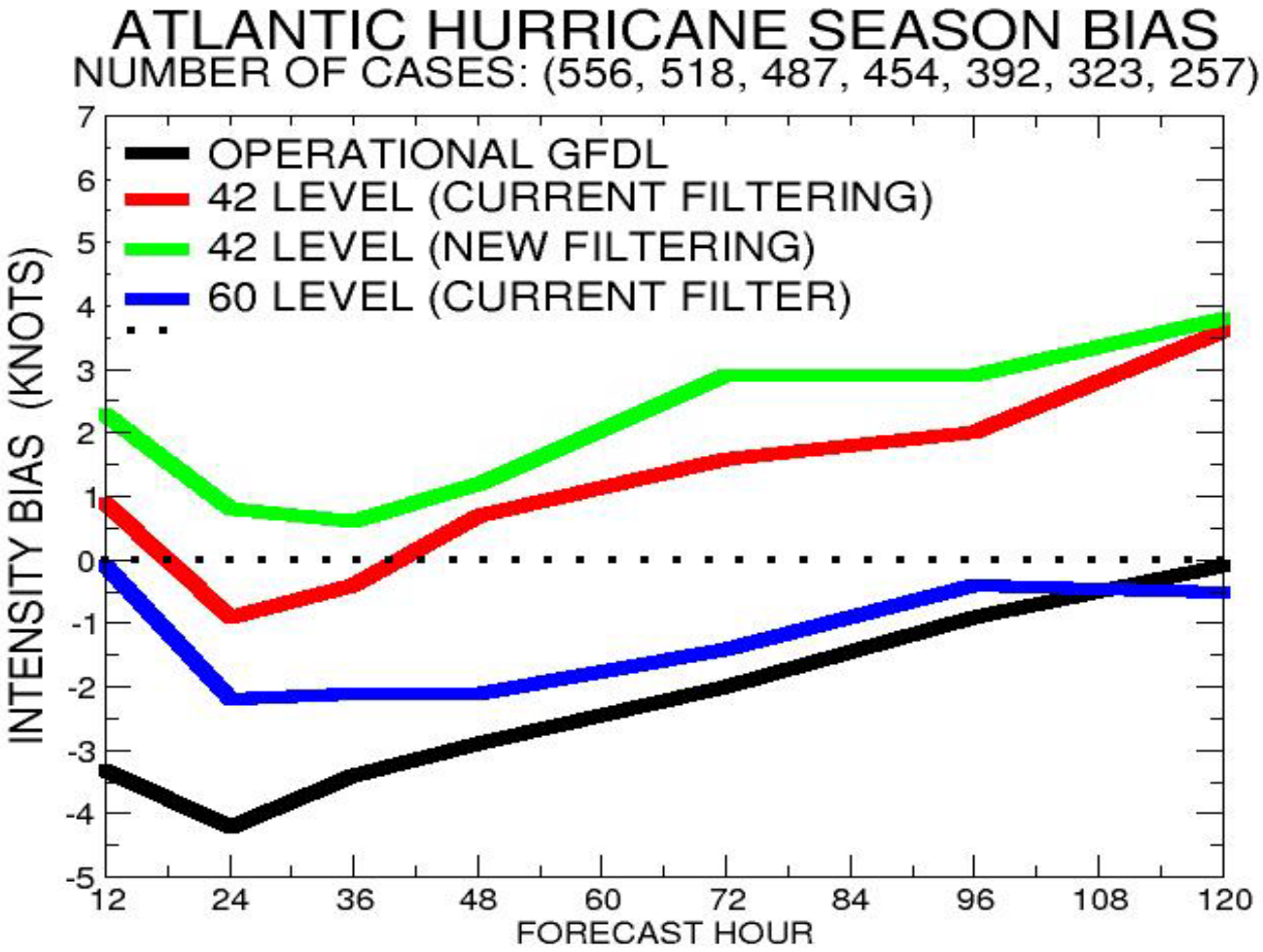


42 Level Model performed slightly better then 60 Level Model through 36 hours.

(9% reduced intensity error compared to current model)

60 Level Model performed best for 3-5 Days

(11% reduced intensity error)



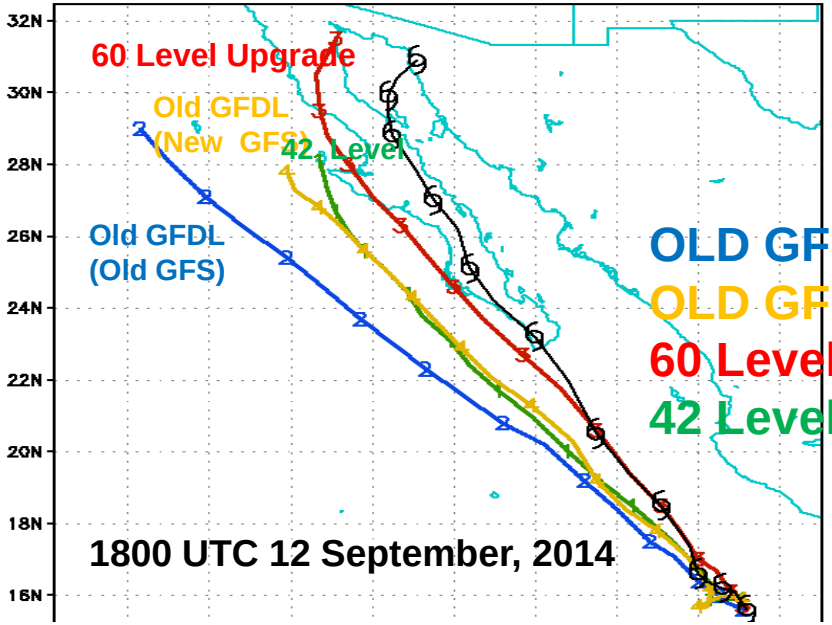
1. Improved Moisture initialization had large impact on early negative Intensity bias of current model.

2. 60 level model much improved overall bias while 42 level model has large positive bias beyond 48 hours

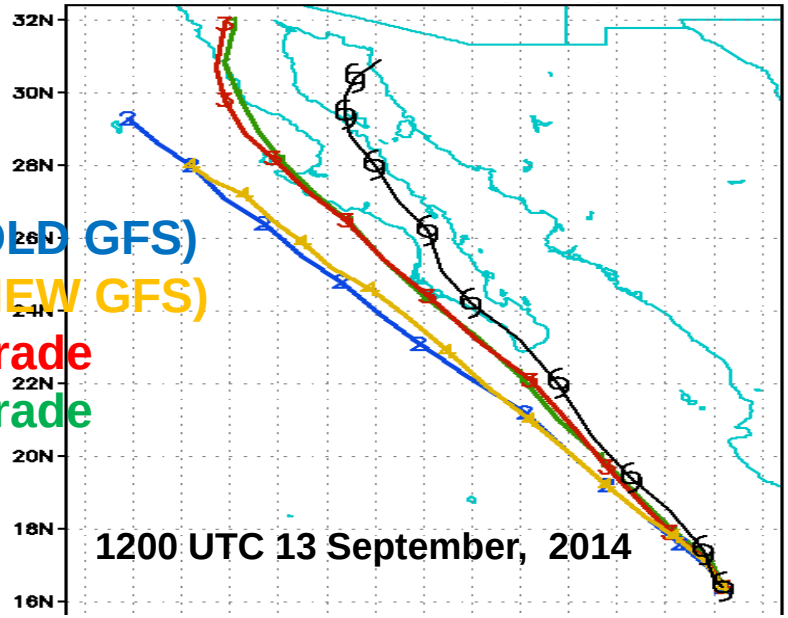
3. Modified filter increased positive bias in 42 level model by retaining too much of the GFS outflow and enhancing the secondary circulation

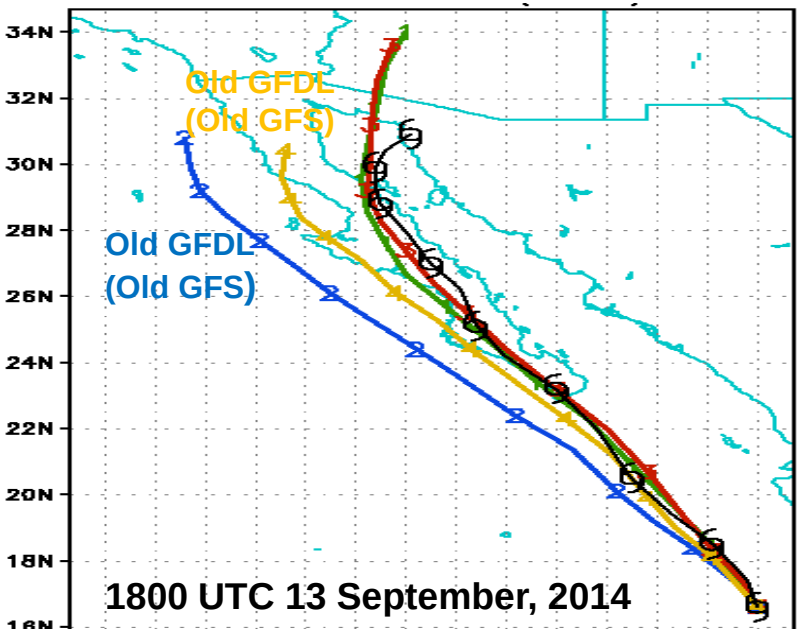
New GFS had modest positive impact on Track of Hurricane Odile

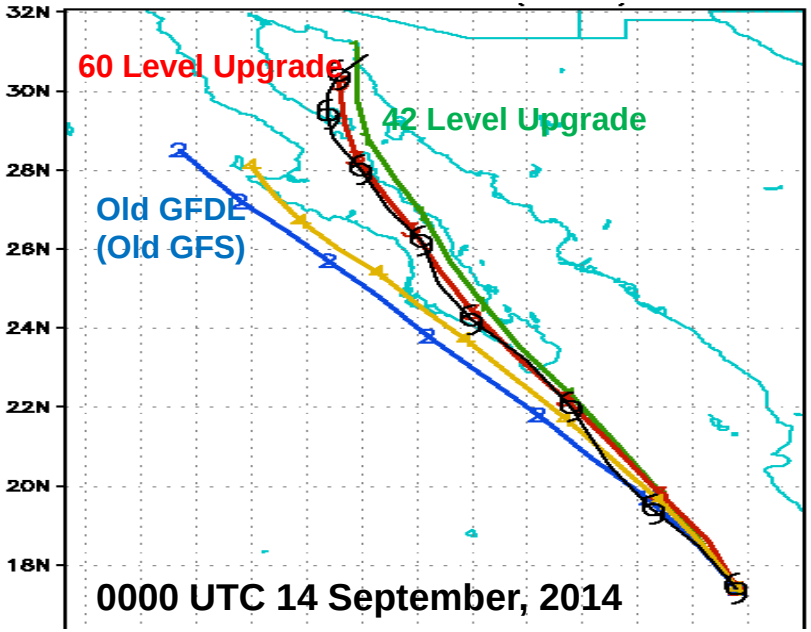
Combination with GFDL Upgrades had much improved tracks



OLD GFDL (OLD GFS)
OLD GFDL (NEW GFS)
60 Level Upgrade
42 Level Upgrade







Summary of GFDL upgrade

- **GFDL model upgrade demonstrates improved track and intensity guidance with both old and upgraded version of GFS for 2011, 2012 and 2014 Atlantic Hurricane Seasons.**
- **Upgraded version with increased vertical resolution (60 vertical levels) performed best.**
- **60 level version demonstrated smallest intensity bias compared to current and 42 level model.**
- **EastPac sample size still too small with new GFS to be included in preliminary evaluation.**