

Impact of tropical cyclone relocation in the operational NCEP GFS/GDAS

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Background & Motivation

- Continued improvement in TC track and intensity guidance important due to high societal impact
- Resolution and complexity of global numerical models continues to increase, making vortex initialization ever more important
 - Complicated by fact that few observations within TC region are assimilated
 - Representativeness, scattering (clouds/precipitation), etc.
- Process for initializing TCs in operational NWP suite is complicated and differs by modeling system
 - *NCEP/EMC fields many questions about the process in the GFS/GDAS*



Other Operational Centers & NCEP Models

- **NAM:** Vortex relocation to be implemented for 12km domain with Nam.v4 this week
- **HWRP:** Combination of relocation, vitals minimum sea level pressure, intensity and structure adjustments, and inner core assimilation
- **HMON:** Combination of relocation, vitals minimum sea level pressure, intensity and structure adjustments
- **ECMWF:** Assimilation of real observations only (no vitals), no bogus vortex or relocation
- **UK Met Office:** Assimilation of *hourly* vitals minimum sea level pressure, no bogus vortex or relocation
- **US Navy (NAVGEM):** Full TC bogusing
- **Canadian GEM:** No TC bogus



TC Initialization for GDAS/GFS

- There is always some component external to assimilation of real observations involved:
 1. “Tracker” is run on GDAS forecast
 - a. If storm found in forecast/background, ***mechanical relocation*** of vortex
 - b. If not found, ***bogus observations*** are generated (winds are assimilated)
 2. Advisory minimum sea-level pressure observations are then assimilated with other observations regardless of (1)



Mechanical Relocation

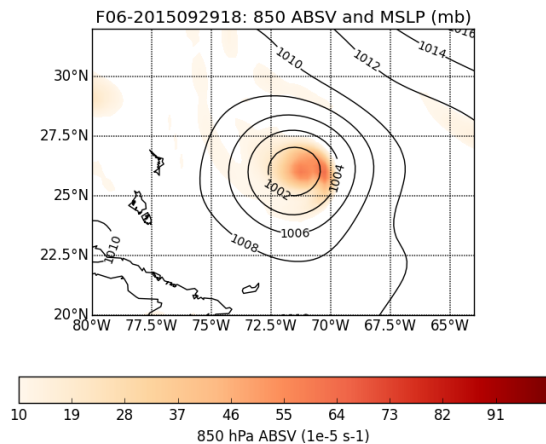
- Locate tropical cyclone vortex in short forecast/background
 - Automated tracker on post-processed regular grid (grib files)
 - Abort process if storm center over major land mass, if terrain $>500\text{m}$, or if relocation distance is too large
- Separate vortex from environment
- Move vortex to advisory position
 - This then serves as background for assimilation
- Assimilate observations including advisory minSLP



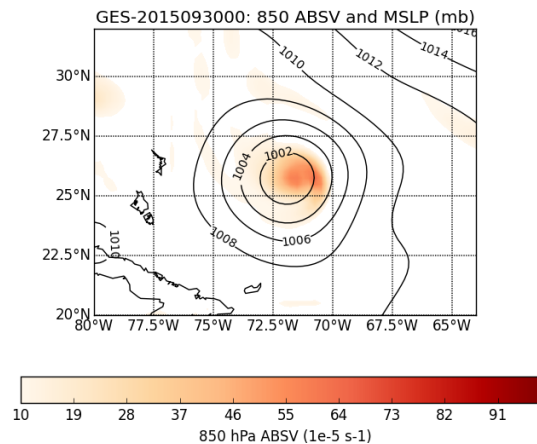
Impact of Relocation (2015093000)

Move Storm SW by ~0.5 degrees

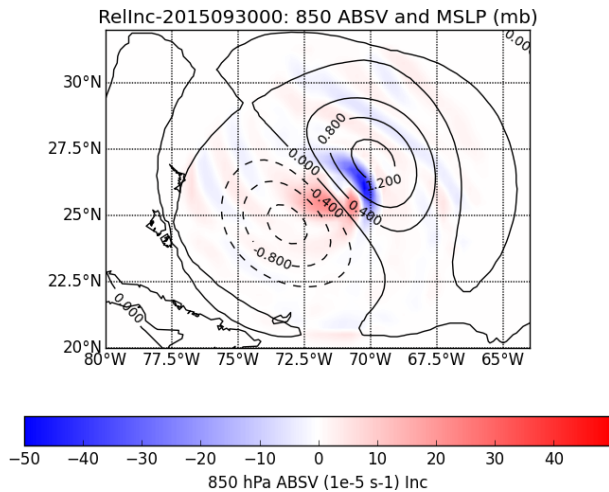
Original
F06



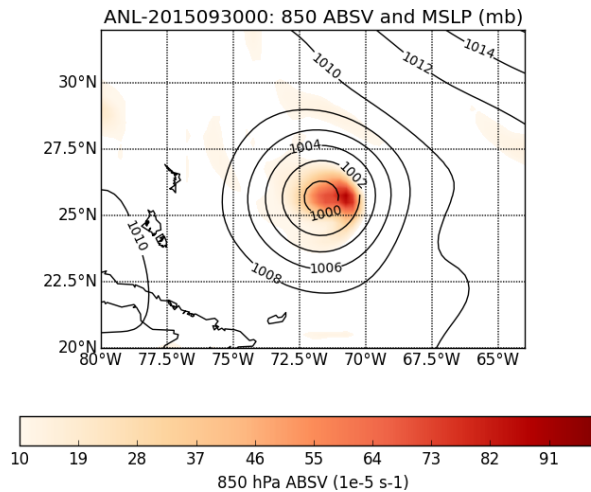
Relocated
F06
(Background)



Relocation
Increment



Final Analysis

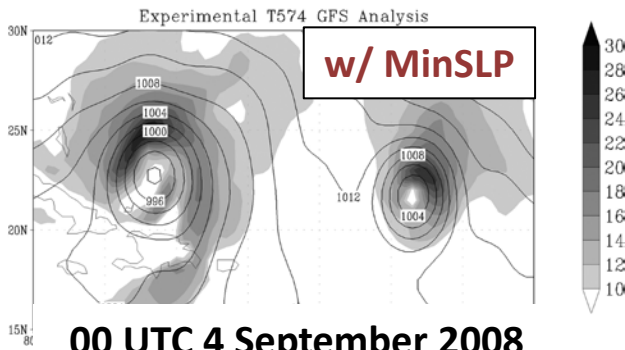
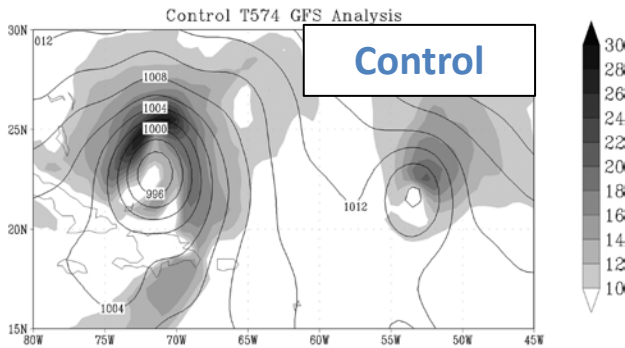
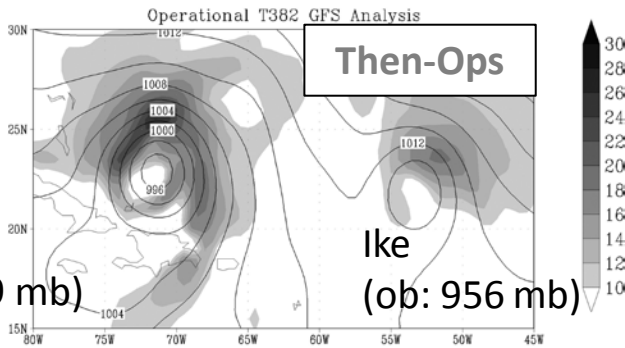


Advisory MinSLP in GDAS/GFS (Kleist 2011)

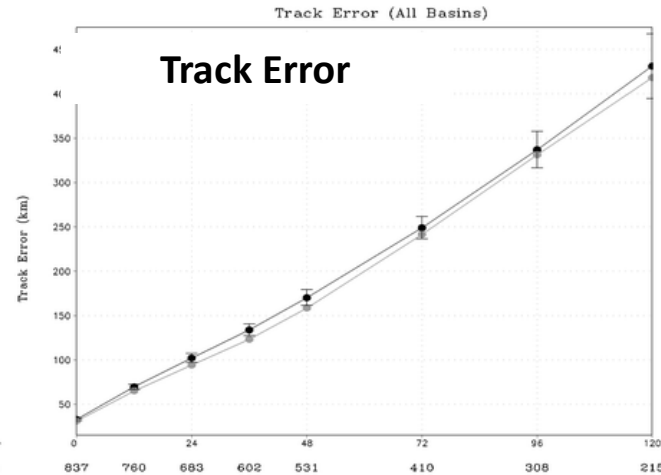
Hanna
(ob: 989 mb)

Then-Ops

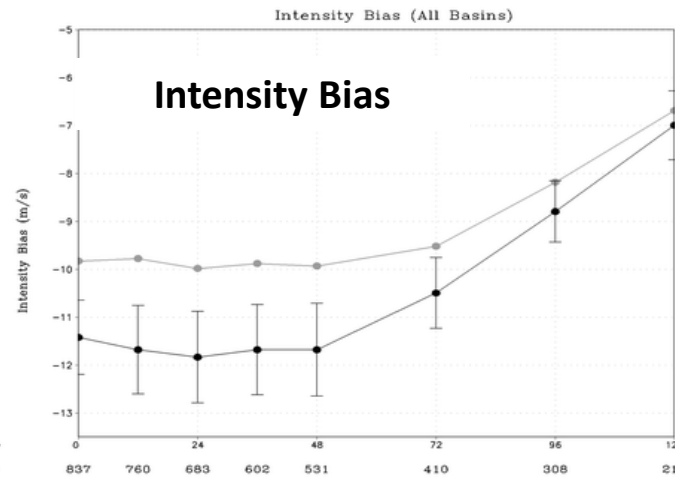
Ike
(ob: 956 mb)



00 UTC 4 September 2008



Control
MinSLP

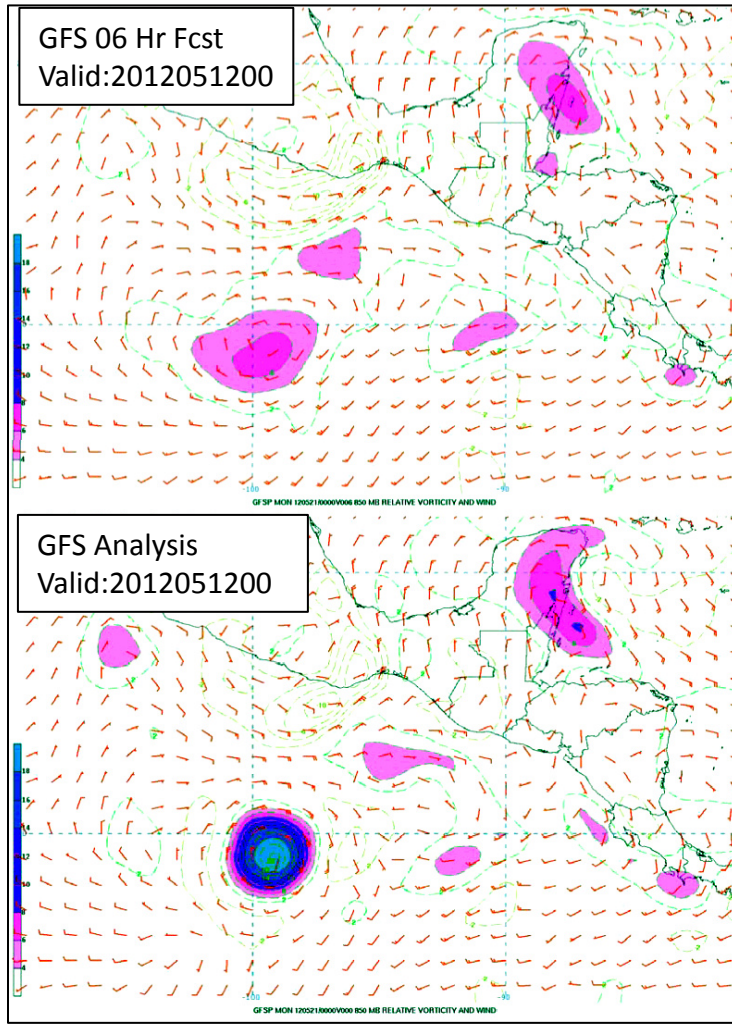


Control
MinSLP



Example of Bogus Wind Assimilation

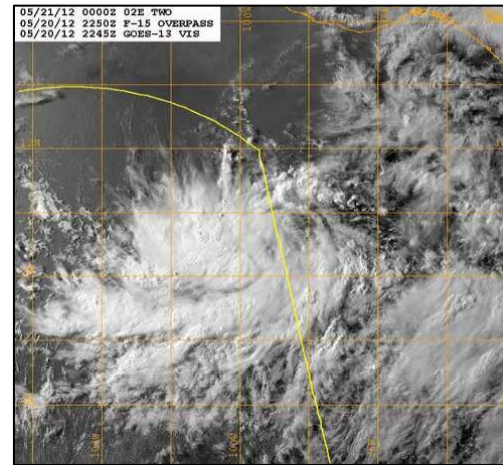
Generally rare in operations, Occurs mainly in genesis situation



Automated tracker “failed” to find coherent vortex to relocate

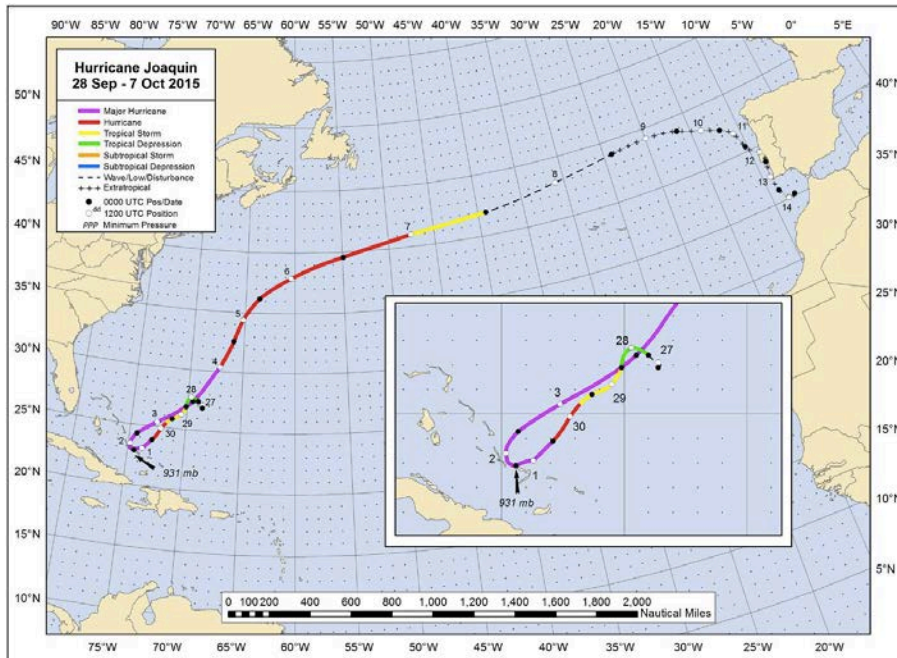
This can happen because:

- Distance from observation too large
- Too much tilt
- Parameters used to find position misaligned
- Nothing there

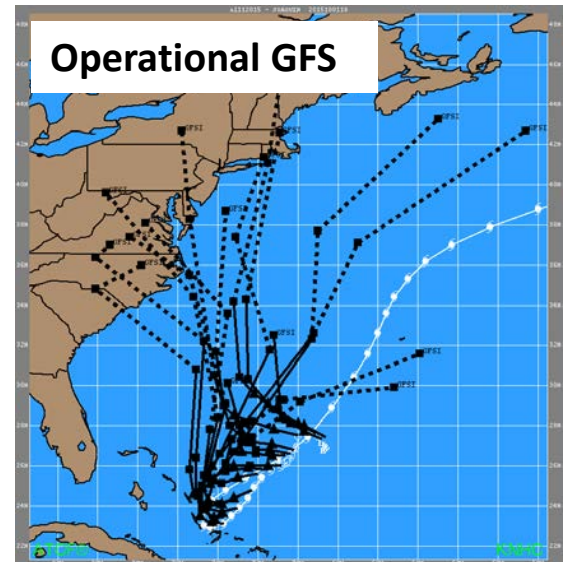


For Bud, tracker “failed” and resultant analysis had radically different vortex due to assimilation of bogus winds (and advisory minSLP)

Hurricane Joaquin (2015)



- High Impact in Bahamas
- Some guidance (GFS/HWRF) during early cycles advertised potential U.S. coastal impacts



Figures courtesy NHC TC Report

Kleist et al. – Relocation for NCEP GFS
2017 TCORF, 71st IHC
14-16 March 2017



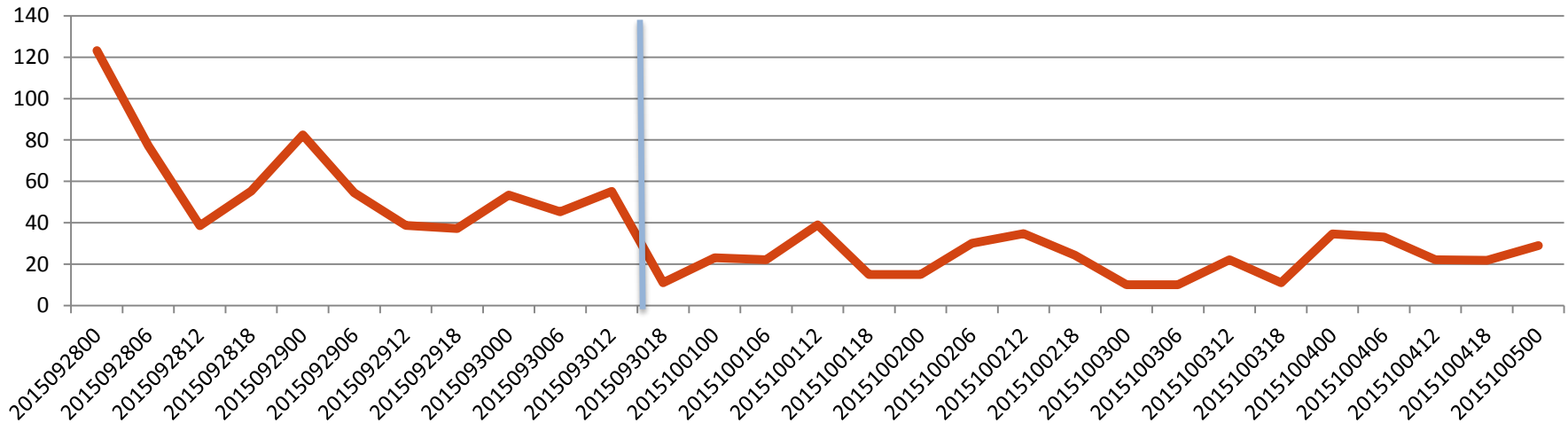
Pilot Study: Joaquin (2015) Experiment

- Fully-cycled (early and late cut-off) T1534L64 GFS with 80 member EnKF-based ensemble for hybrid data assimilation (3D EnVar)
- Control (with relocation) and Experiment (without) started prior to classification of Joaquin as depression
 - For experiment without relocation the effect is cumulative – we are not evaluating the impact of relocation on any individual operational forecast
- Bogus winds were never generated in operations, control, or experiment
- Advisory MinSLP assimilated into hybrid and EnKF for control and experiment



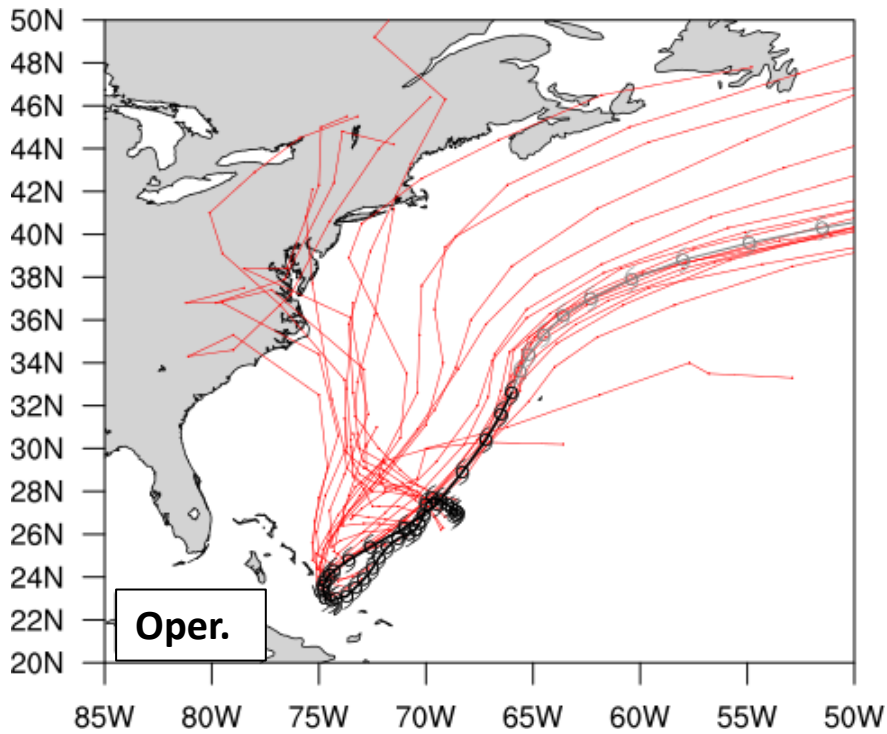
Relocation Distance in Control for Joaquin

Control GFS Relocation Distance for Joaquin by Cycle (km)

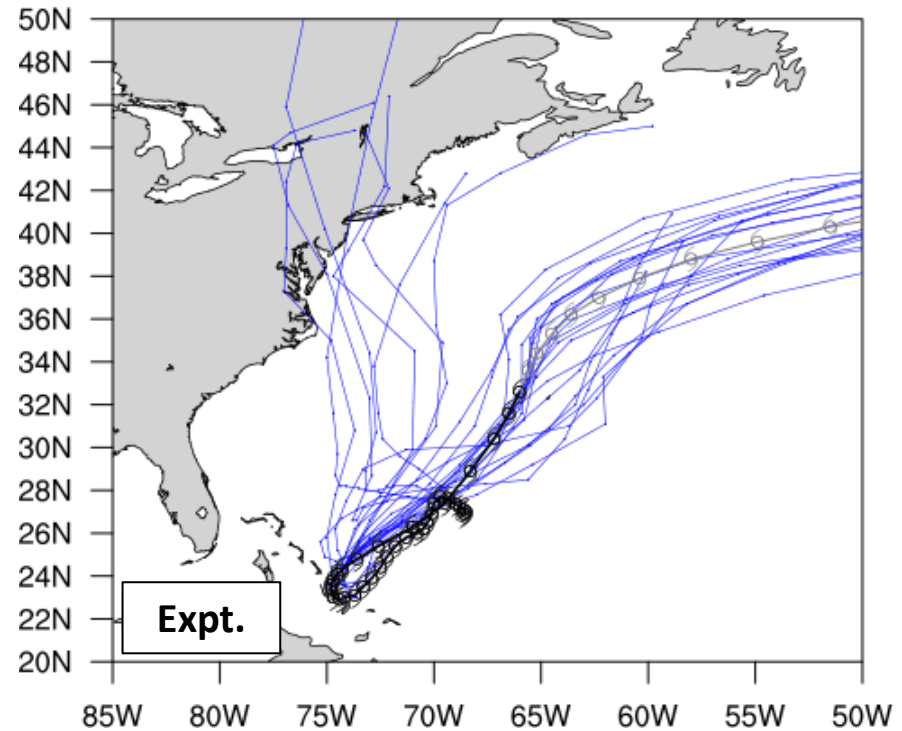


- During depression and TS phase, relocation distance larger than when storm reached hurricane status
- These are approximate – the tracker operates on quarter degree output and relocation is estimated to precision of tenths of degrees
- Also important to keep in mind that advisory position has uncertainty

Track Summary for Experimental Period



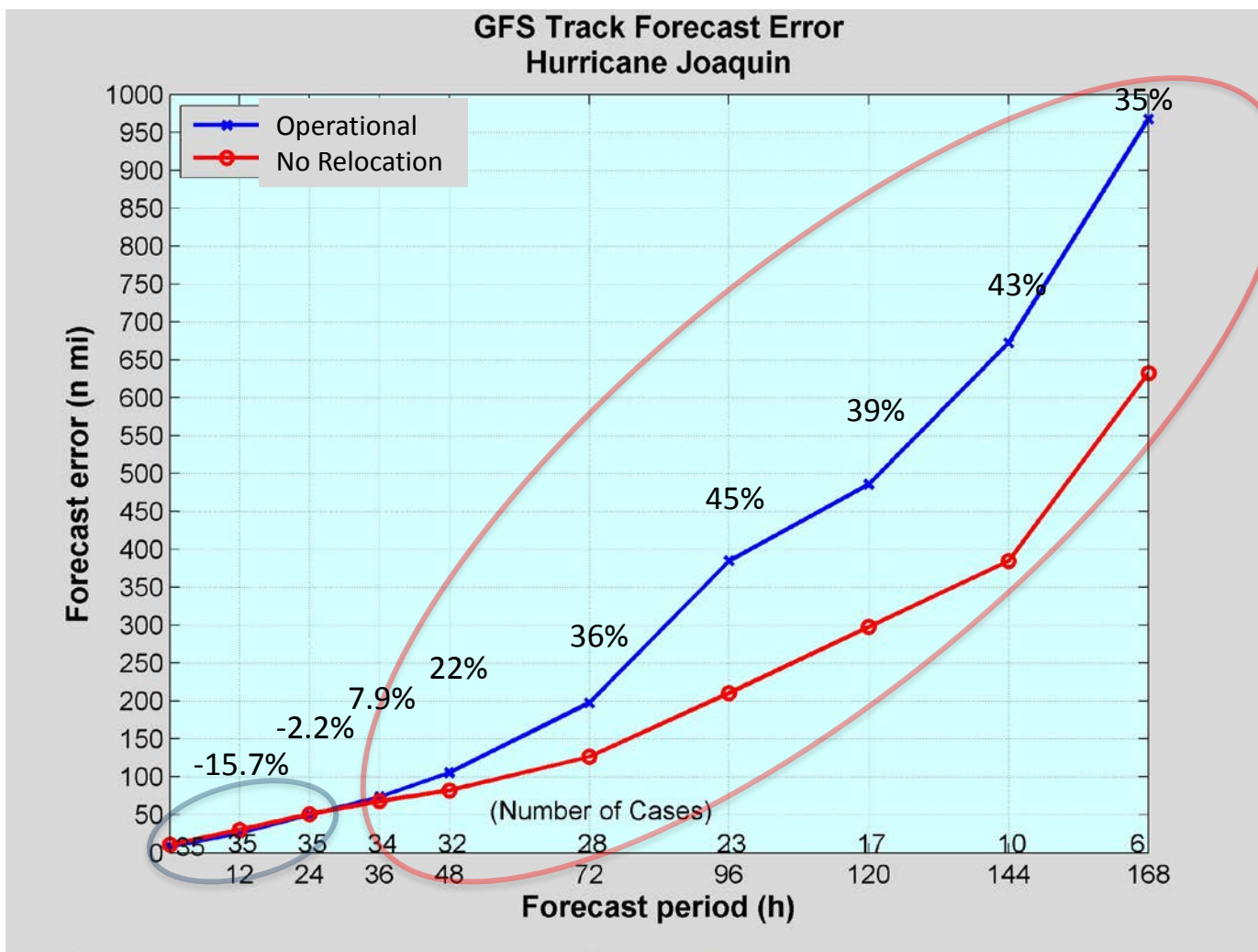
With Relocation



Without Relocation

Figures courtesy Andrew Penny/NHC

Joaquin Mean Track Errors w/ and w/out relocation



Kleist et al. – Relocation for NCEP GFS
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Full season at full resolution (June-October 2015)

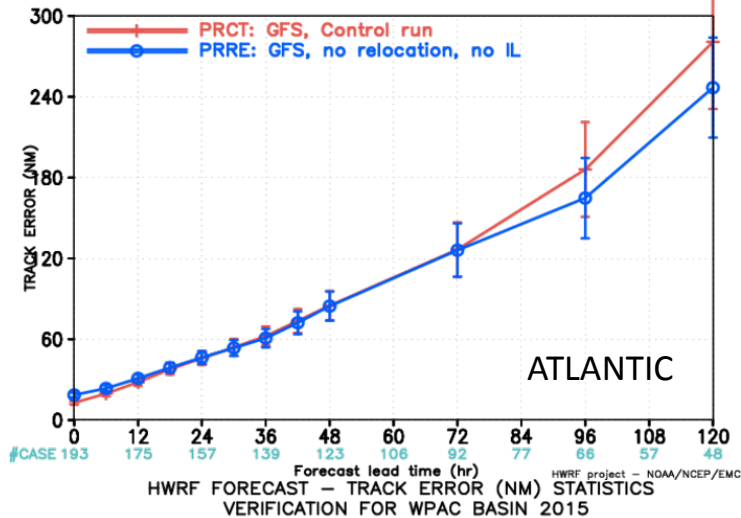
- This sensitivity has prompted a further evaluation with full season cycling
- Fully-cycled (early and late cut-off) T1534L64 GFS with 80 member T574L64 EnKF-based ensemble for hybrid data assimilation (4D EnVar)
- Control (with relocation) and Experiment (without)
 - Experiment is simply turning off mechanical relocation **and** bogus vortex wind assimilation
- ***Advisory MinSLP assimilated into hybrid and EnKF for control and experiment***



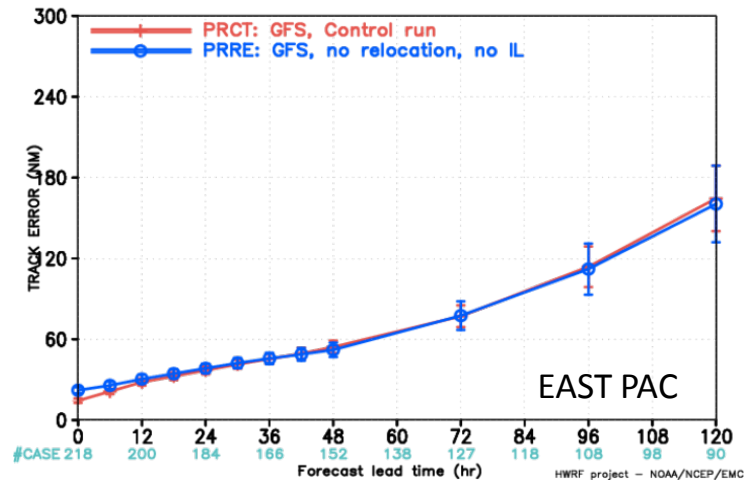
Summary of Results: Mean Track Error

Control v. Experiment

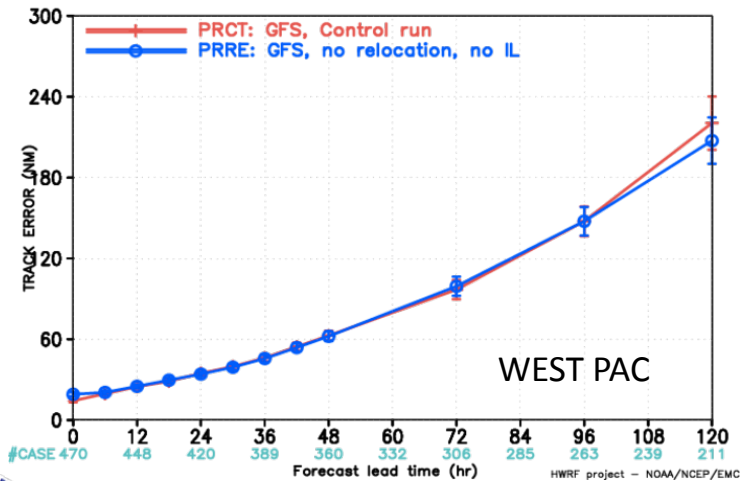
HWRP FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION FOR NATL BASIN 2015



HWRP FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION FOR EPAC BASIN 2015



HWRP FORECAST – TRACK ERROR (NM) STATISTICS
VERIFICATION FOR WPAC BASIN 2015



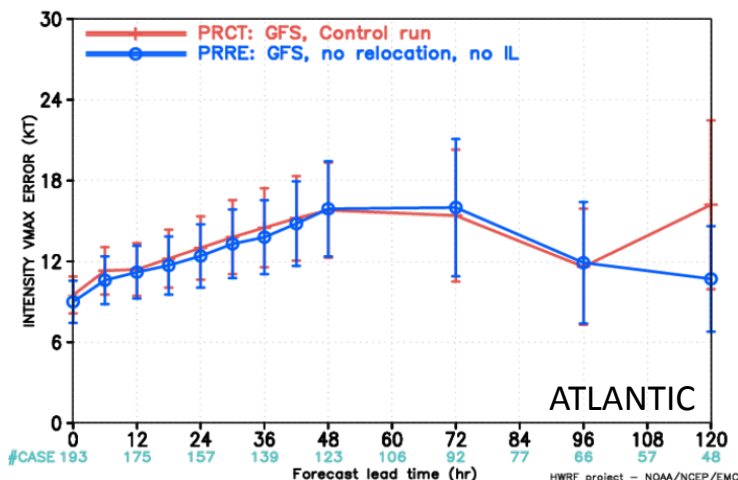
- Slight degradation < 12h
- Neutral 12h-72h
- Neutral to slight improvement > 72h



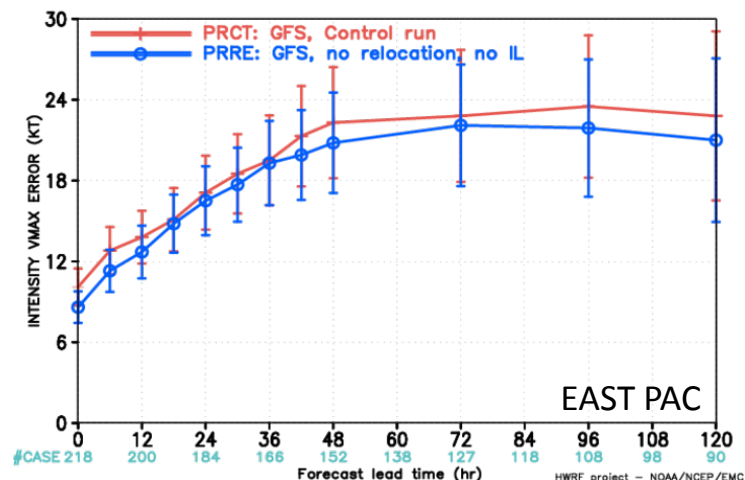
Summary of Results: Max Wind Intensity Error

Control v. Experiment

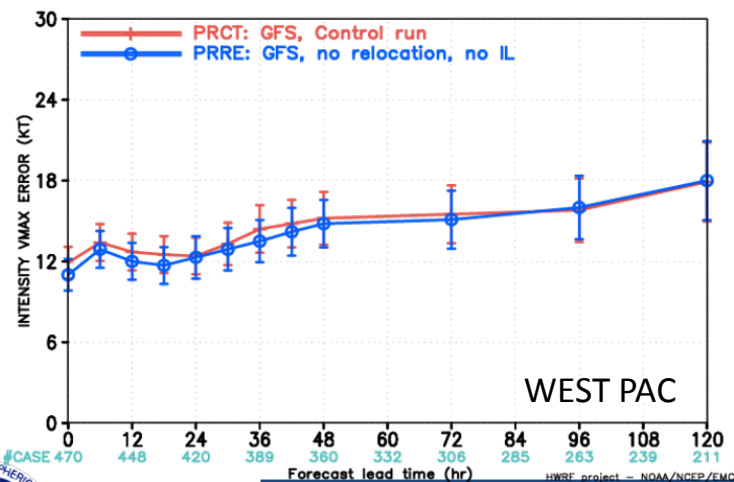
HWRP FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION FOR NATL BASIN 2015



HWRP FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION FOR EPAC BASIN 2015



HWRP FORECAST – INTENSITY VMAX ERROR (KT) STATISTICS
VERIFICATION FOR WPAC BASIN 2015



- Slight, systematic improvements to intensity forecasts (winds)
- Central pressure verification similar in Atlantic and East Pacific
 - Slightly worst for Western Pacific



Next Steps for Relocation

- Continue to investigate individual cases
 - Want to understand reasons for degradation
 - Look into impact of other forecast tools that rely on GFS
- Recommendations for operations
 - Turn off relocation and bogus generation schemes in future implementation (?)
 - Increase threshold for minimum distance for performing relocation
 - Perform some form of relocation on ensemble component only (for ensemble covariance)
- Fixes to current relocation scheme
 - Apply on the model native grid (tracker and relocation)
 - Filtering and interpolation options
- ***Alternatives within the data assimilation itself***
 - Explore use of 3 hourly or hourly vitals (as in UKMO) to anchor 4D solver
 - Position assimilation directly in the hybrid-variational solver (underway by PhD student at UMD)
 - Position assimilation in the EnKF to improve covariance representation
 - Feature Calibration and Alignment (FCA) in GSI
 - Cloudy radiances, radar, dropsondes



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