Global Ensemble Forecast System

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Acknowledgment for:
Members of Ensemble & Probabilistic Guidance Team

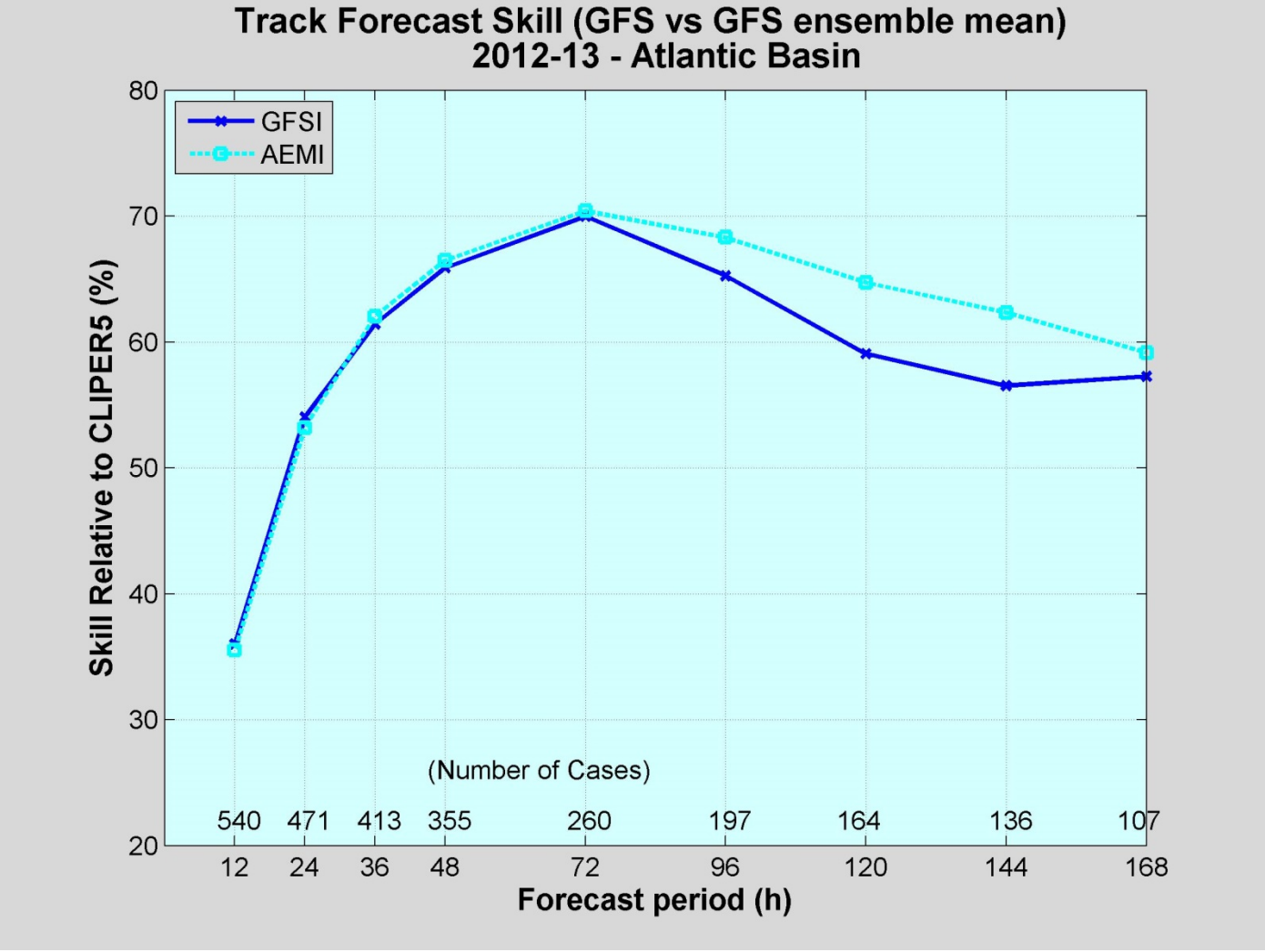
Outline

- Current Status, Performance and Concerns
- Plan for Next Implementation, FY15Q1
- Toward the Future Seamless Forecast System

Evolution of NCEP GEFS configuration

<table>
<tr><th></th><th>Initial uncertainty</th><th>TS Relocation</th><th>Model uncertainty</th><th>Resolution</th><th>Forecast length</th><th>Ensemble members</th><th>Daily frequency</th></tr>
<tr><td>1992.12</td><td rowspan="5">BV with Rescaling
(Bred Vector)</td><td rowspan="4">None</td><td rowspan="8">None</td><td>T62L18</td><td>12</td><td>2</td><td>00UTC</td></tr>
<tr><td>1994.3</td><td>T62L18</td><td rowspan="8">16</td><td>10(00UTC)
4(12UTC)</td><td rowspan="3">00,12UTC</td></tr>
<tr><td>2000.6</td><td>T126L28(0-2.5)
T62L28(2.5-16)</td><td rowspan="5">10</td></tr>
<tr><td>2001.1</td><td>T126(0-3.5)
T62L28(3.5-16)</td></tr>
<tr><td>2004.3</td><td>T126L28(0-7.5)
T62L28(7.5-16)</td><td rowspan="6">00,06,12, 18UTC</td></tr>
<tr><td>2005.8</td><td rowspan="6">TSR
(Tropical Storm Relocation)</td><td rowspan="3">T126L28</td></tr>
<tr><td>2006.5</td><td rowspan="5">BV-ETR
(Ensemble Transform with Rescaling)</td><td>14</td></tr>
<tr><td>2007.3</td><td rowspan="4">20</td></tr>
<tr><td>2010.2</td><td rowspan="3">STTP
(Stochastic Total Tendency Pert)</td><td>T190L28</td></tr>
<tr><td>2012.2</td><td>T254/190L42</td></tr>
</table>

TRACK FORECAST: GFS vs. GEFS mean

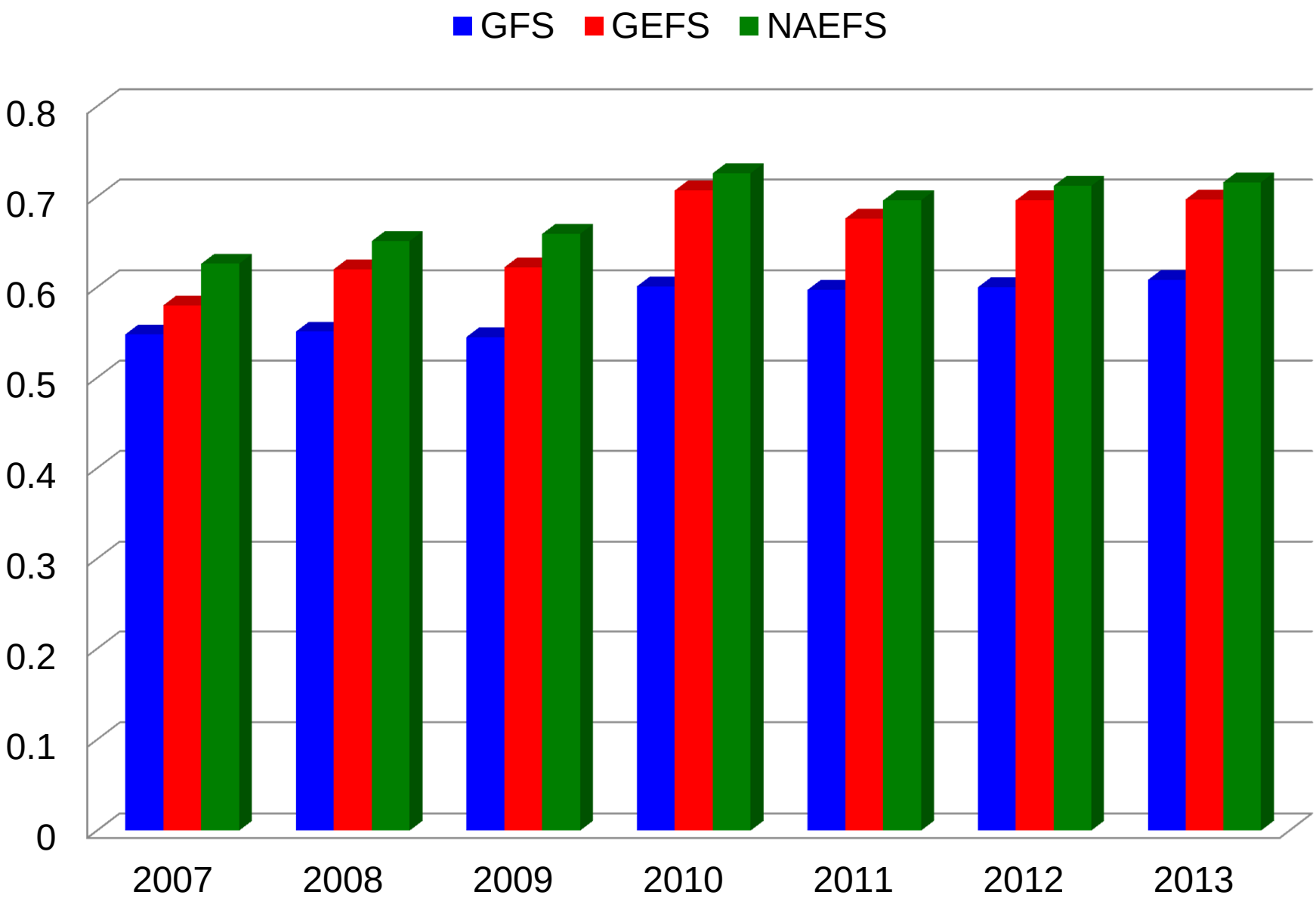


This is a 2-yr sample (2012-13)

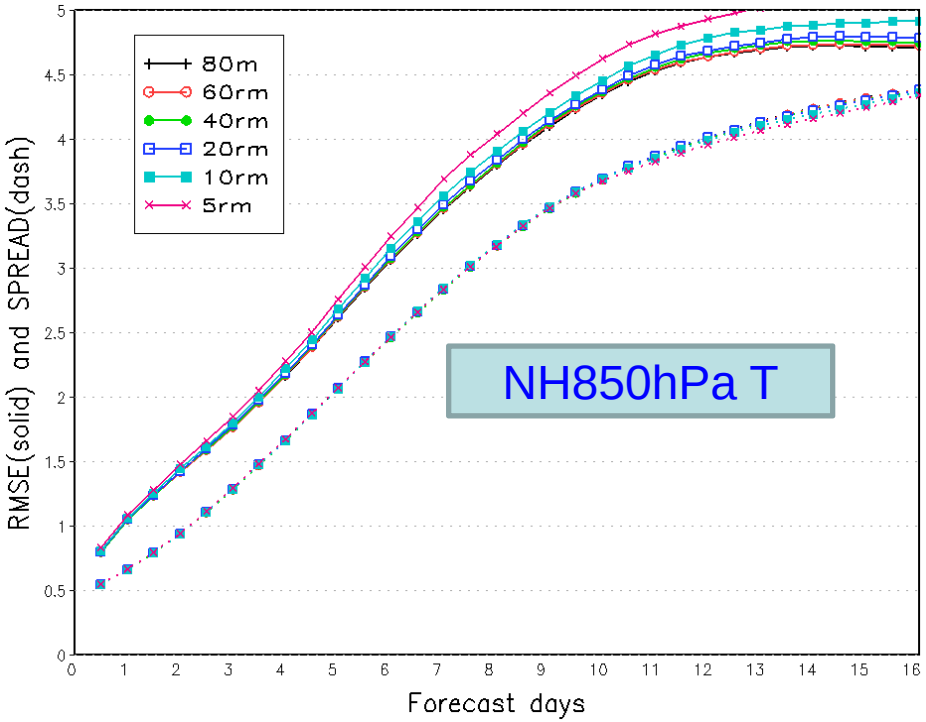
The skill of GFS and AEMI are very similar through 72 h. After that, AEMI is more skillful.

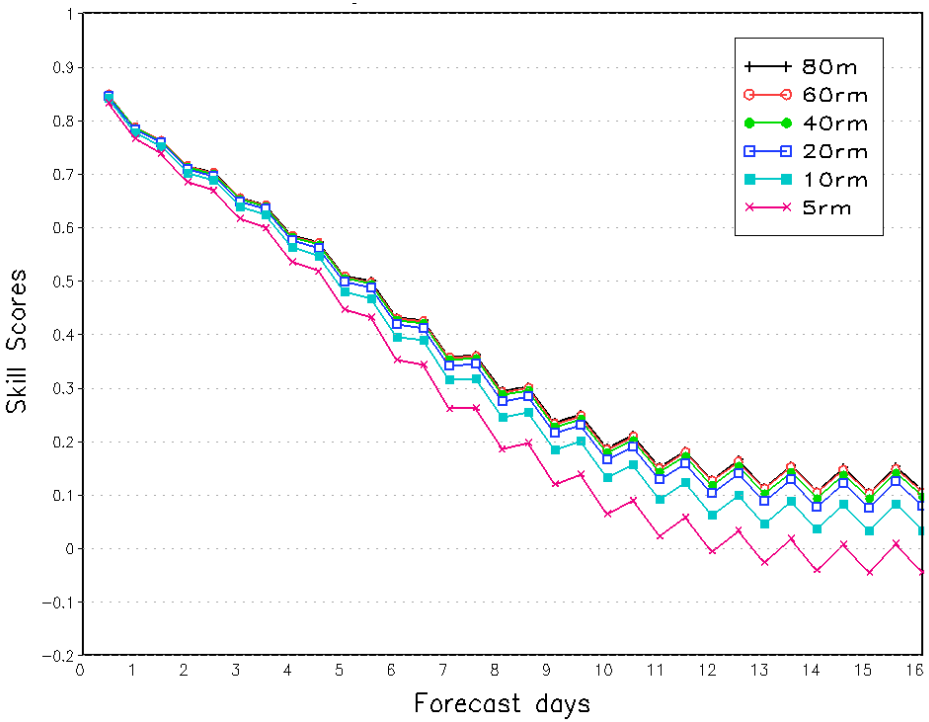
Courtesy of James Franklin (NHC)

NH 500hPa height AC for day-8 of calendar year



Ensemble Size .vs Resolution





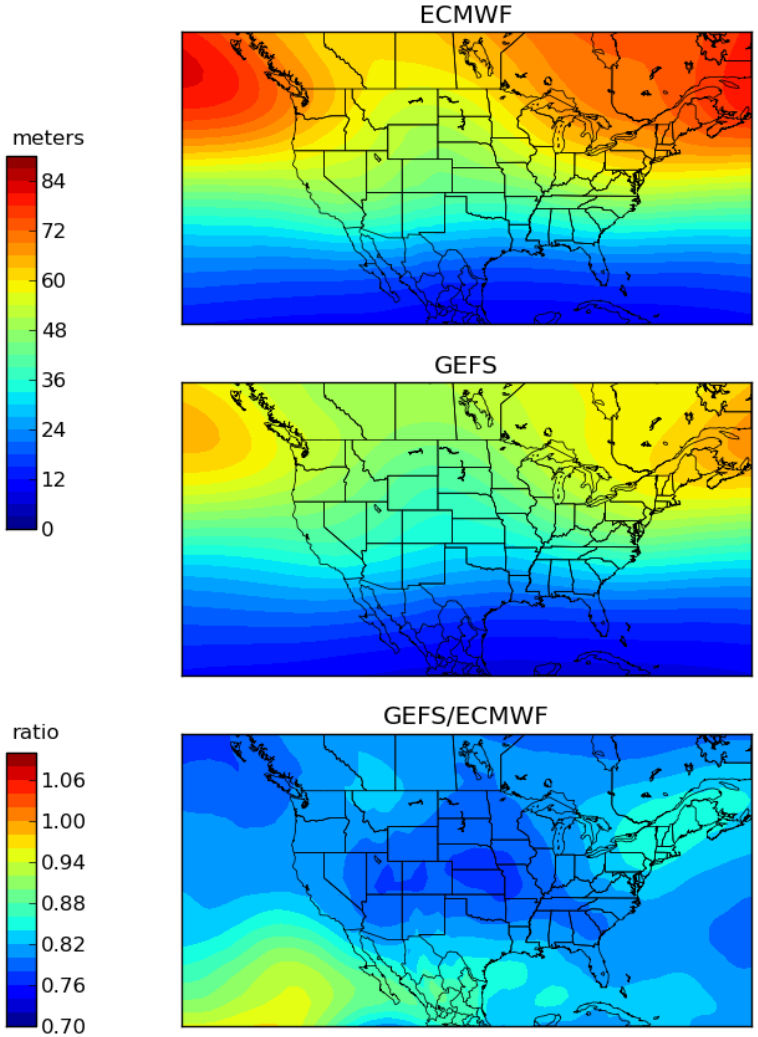
	RMSE	AC	CRPSS
20T190	1-5d		3-5d
80T126	12-16d	13-16d	11-16d

Reference: Ma and et al, 2012: *"An Effective Configuration of Ensemble Size and Horizontal Resolution for the NCEP GEFS"*, AAS Vol. 29 p782-794

Ensemble Spread

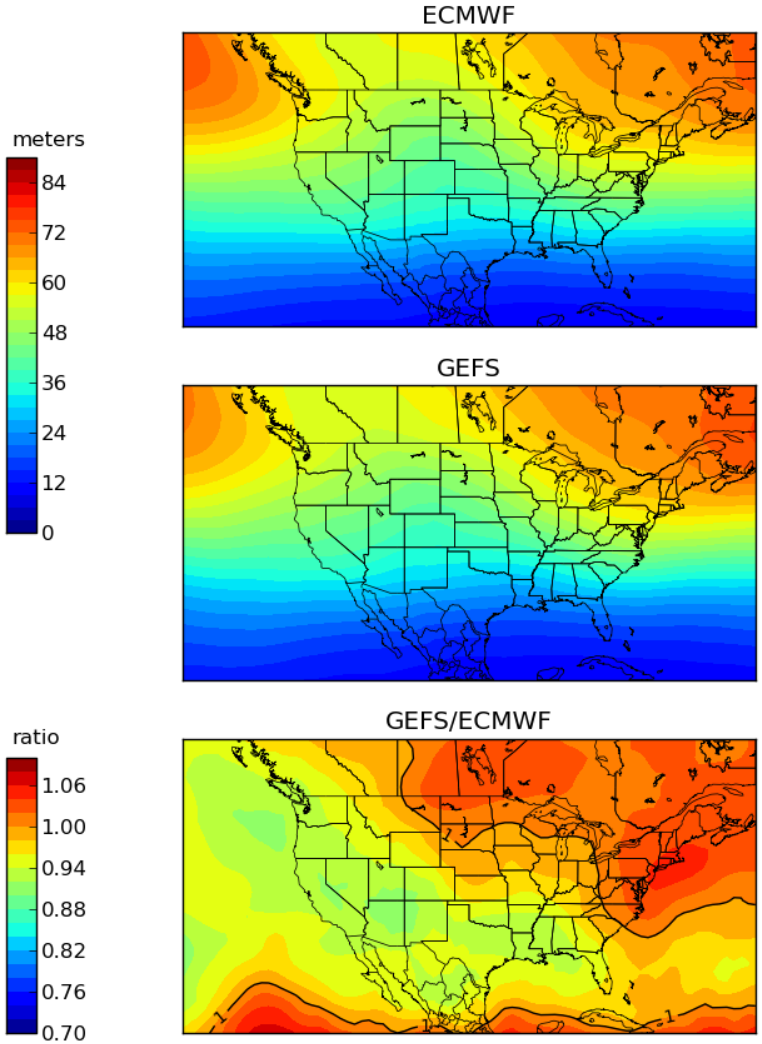
Then

Average 00Z Ensemble Spread (Mar 2007 - Mar 2009)
168-h Forecasts of 500-mb Geopotential Height (n=745)



Now

Average 00Z Ensemble Spread (Mar 2012 - Mar 2013)
168-h Forecasts of 500-mb Geopotential Height (n=360)



[Courtesy of Dr. Trevor Alcott]

Next GEFS configuration

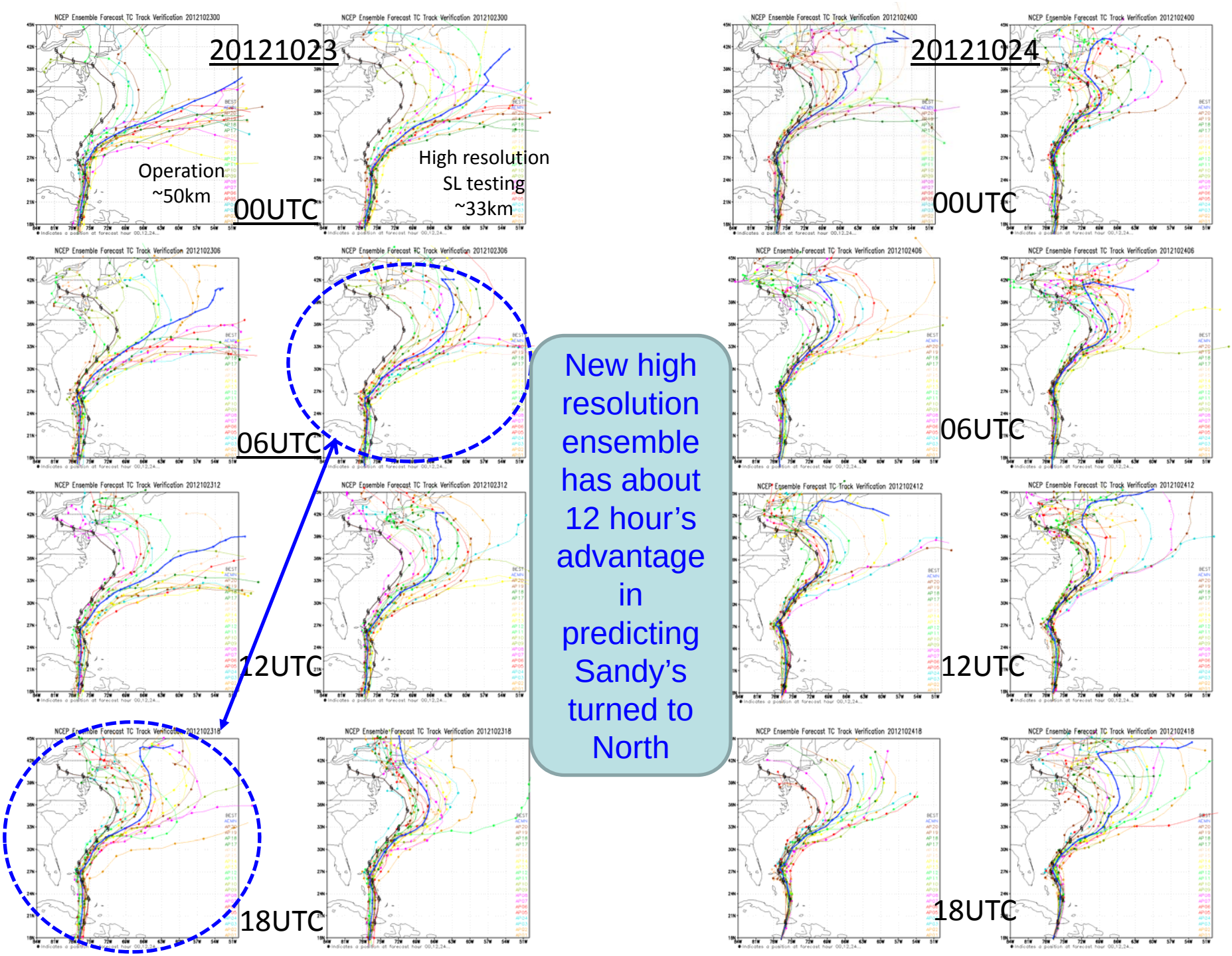
- Model
  - Current: GFS Euler model
  - Plan: GFS Semi-Lagrangian model
- Horizontal resolution
  - Current: T254 (55km for 0-192 hours), T190 (73km for 192-384 hours)
  - Plan
    - Option 1: T574 (T382 physics – 34km for 0-384 hours)
    - Option 2: T574 (T382 physics - 34km for 0-168 hours), T382(T254 physics – 55km for 168-384 hours)
- Vertical resolution
  - Current: L42 hybrid levels
  - Plan:
    - Option 1: L42 hybrid levels to use less resources
    - Option 2: L64 hybrid levels to use match with GFS and DA
- Computation cost:
  - Current: 84 nodes (+ post process) for 55 minutes
  - Plan: 300 nodes (first 30 minutes), 250 nodes (2nd 30 minutes)
- Output:
  - Current: every 6-hr for 1*1 degree pgrb files
  - Plan: every 3-hr for 0.5*0.5 degree pgrb files
- Challenges:
  - T574L64 configuration will cost 250-300 nodes for one hour
  - Option: T574L42 configuration will use less resources, but the forecast quality will be degraded.

Next GEFS science

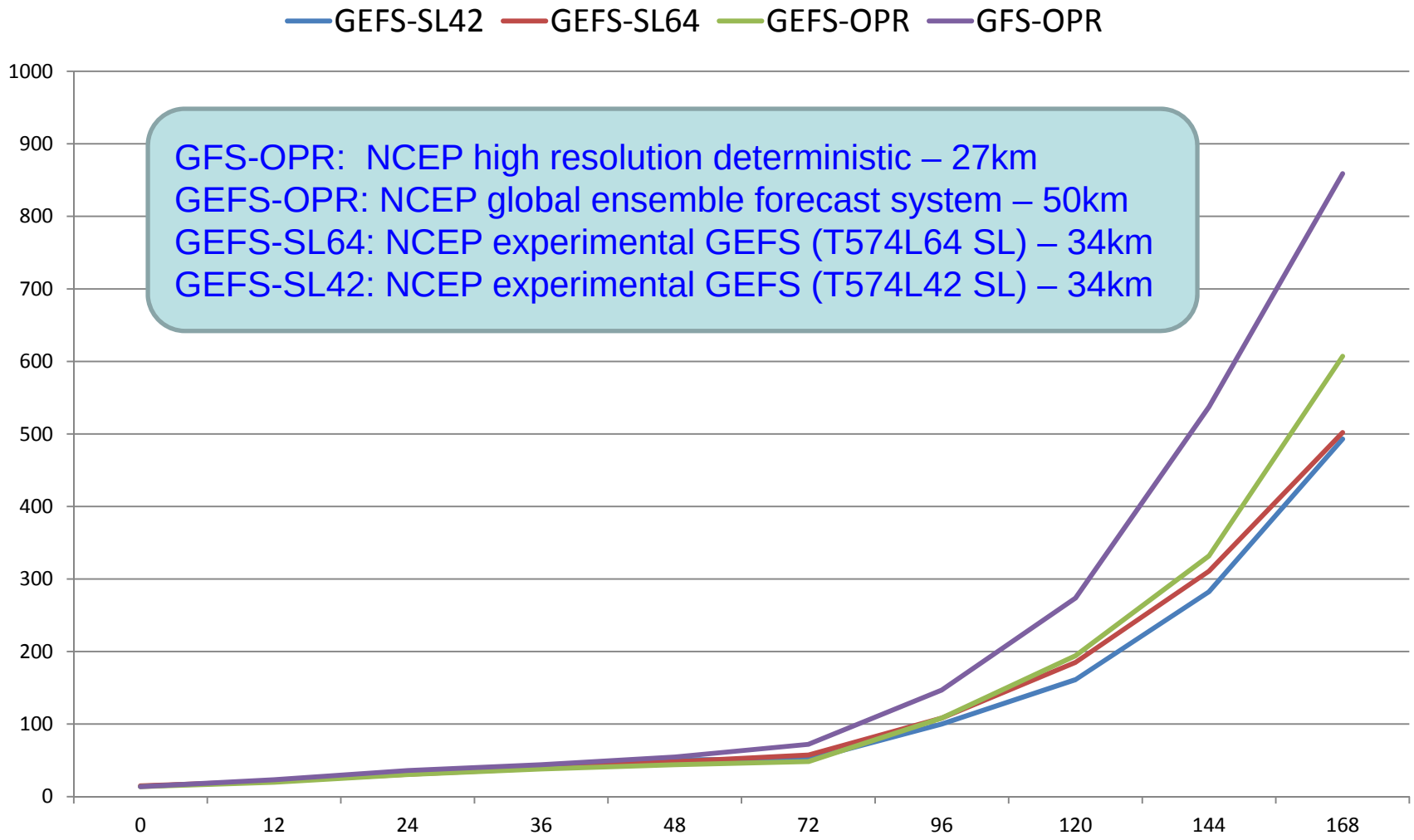
- Initial perturbations
  - Base: EnKF 6hr forecast
  - TS relocation – Yochrio's modification version (simplify the process)
    - Is testing the effect of perturbed TS intensity
  - Ensemble transform (ET) from 80 vectors
    - ET will apply to 80 EnKF f06 vectors
    - Centering for 20 selected perturbations for integration
    - Theoretically, this design will lost the advantage of lag ensemble
      - No continuation of perturbed vectors from cycle to cycle
  - 3 dimensional rescaling (3DR)
    - Building analysis error variance (total energy norm)
    - Monthly average from past years EnKF analysis (less inflated one)
    - Rescaling 6hr forecast perturbations by applying 3DR
- Stochastic perturbations
  - Tune STTP for model change and initial perturbation changes
  - Turn off stochastic perturbations for surface pressure in STTP
- Expectations
  - Improve hurricane track forecast
  - Improve probabilistic forecast guidance
  - Improve predictability of HIW and extreme weather event

Sandy case set up and experiments

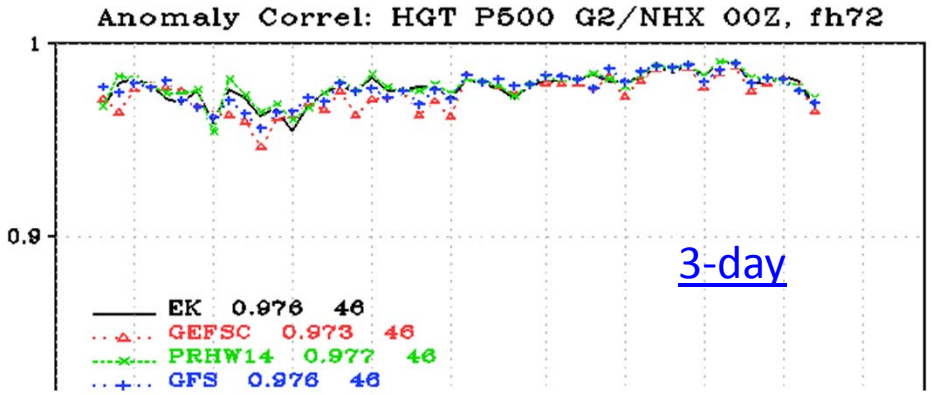
- Early developed GFS semi-Lagrangian model version (Early 2013)
- T574L42/T574L64 resolutions
- No updated initial condition, still use operational hybrid initial condition.
- No STTP to assimilate model uncertainty
- No ETR cycling for new model, high resolution
- No tuning for initial perturbations

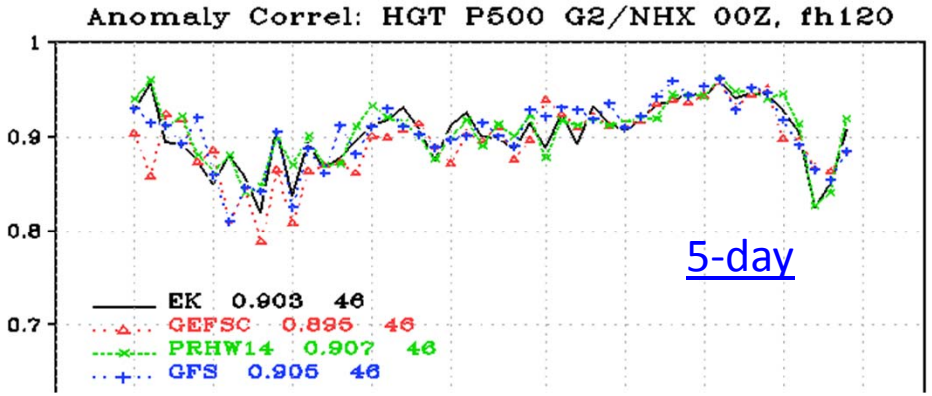

20121023
20121024
Operation
~50km
High resolution
SL testing
~33km
00UTC
00UTC
06UTC
06UTC
12UTC
12UTC
18UTC
18UTC
New high resolution ensemble has about 12 hour's advantage in predicting Sandy's turned to North

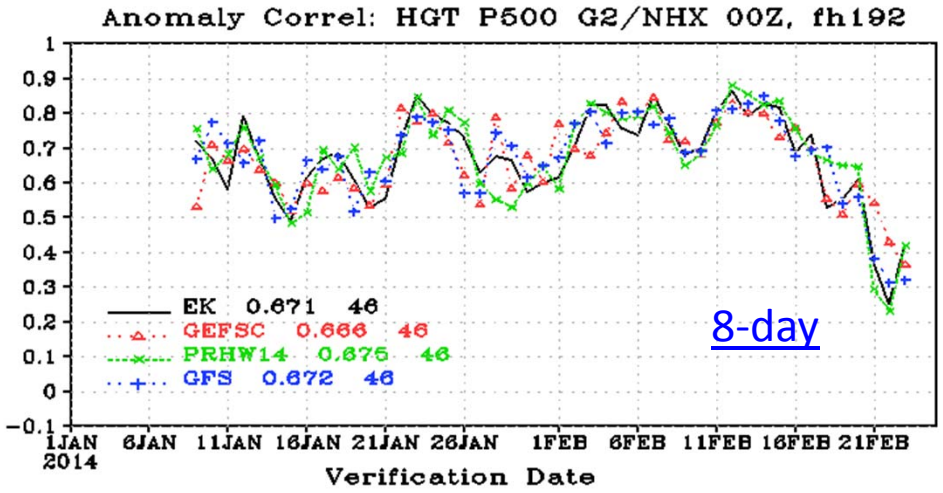
Sandy Case study for new GEFS
Statistics of Track Error Forecast



CASES	33	33	33	31	29	25	21	17	13	9





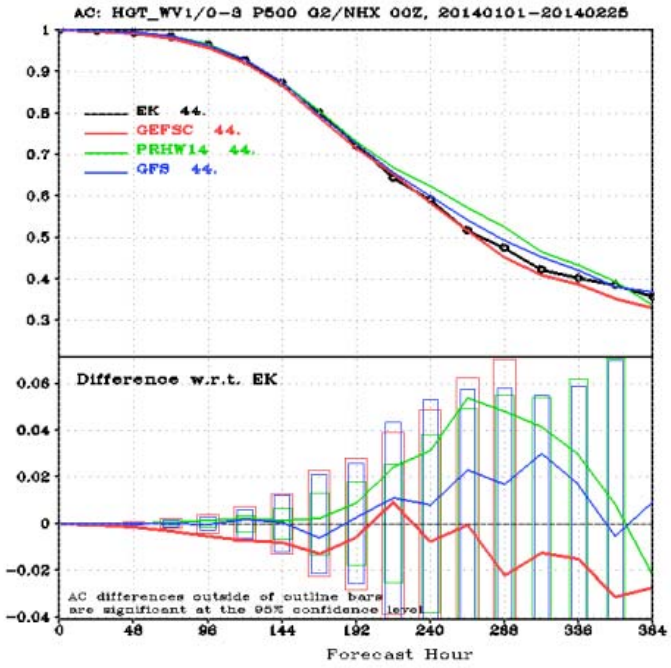


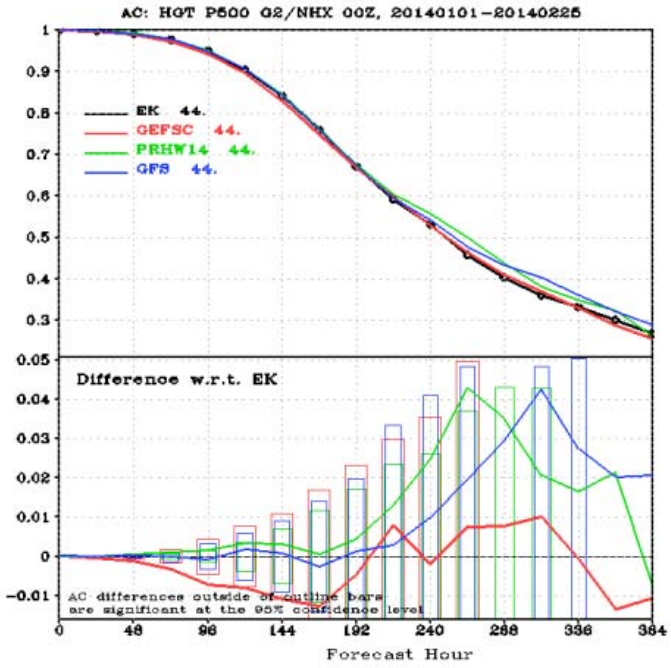
Comparison of new GFS model (latest version) against the operational For deterministic Forecast

Period: 1/1 -2/24/2014

EK – GEFS control (para) - T574L64 EU
GEFSC – GEFS control – T254/190L42 SLG
PRHW15 – GFS (para) – T1534L64 SLG
GFS – GFS (opr) – T574/382L64 EU

Conclusion:
3-, 5-, 8-day NH 500hPa AC scores of GEFS control parallel are about 0.5% better than current operation, close to operational GFS, but not as good as GFS parallel.


AC: HGT_WV1/0-3 P500 G2/NHX 00Z, 20140101-20140225
EK 44.
GEFSC 44.
PRHW14 44.
GFS 44.
Difference w.r.t. EK
AC differences outside of outline bars
are significant at the 95% confidence level
Forecast Hour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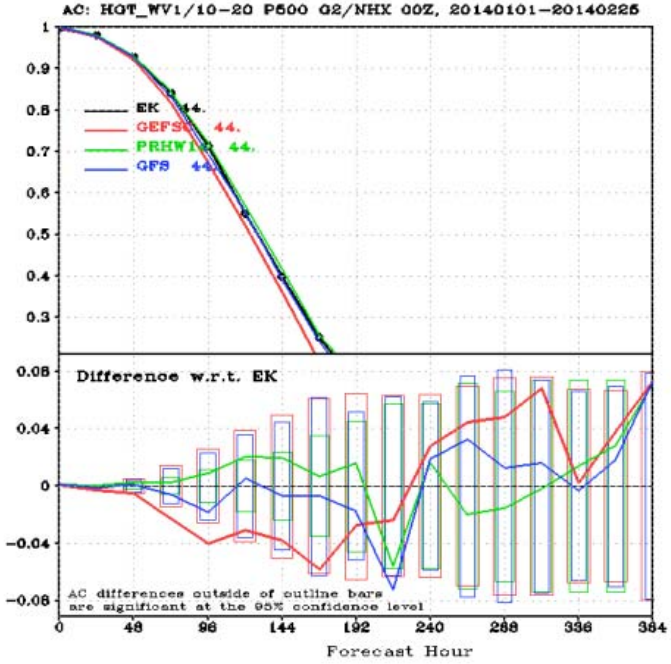
AC: HGT_WV1/10-20 P500 G2/NHX 00Z, 20140101-20140225
EK 44.
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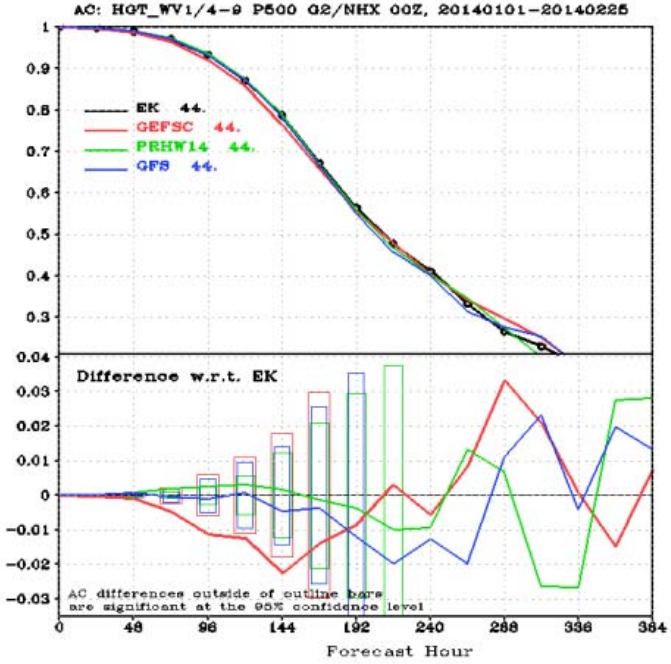
AC: HGT_WV1/4-9 P500 G2/NHX 00Z, 20140101-20140225
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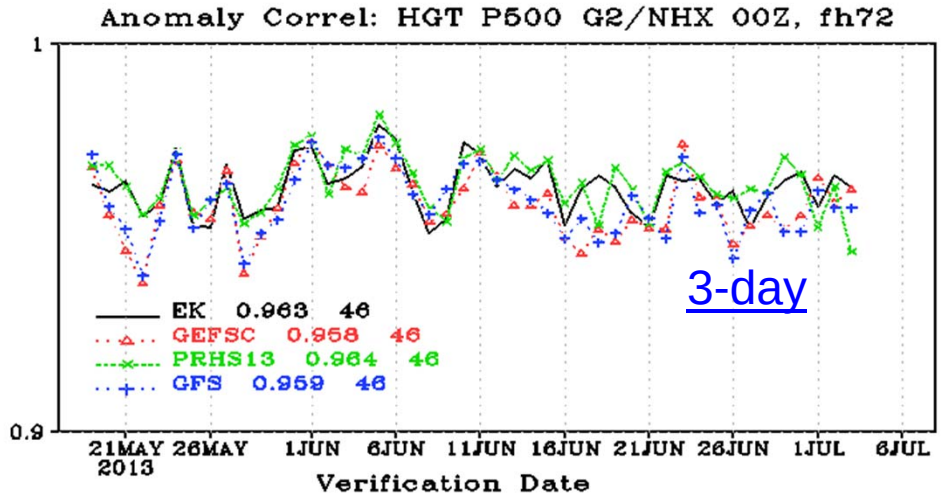

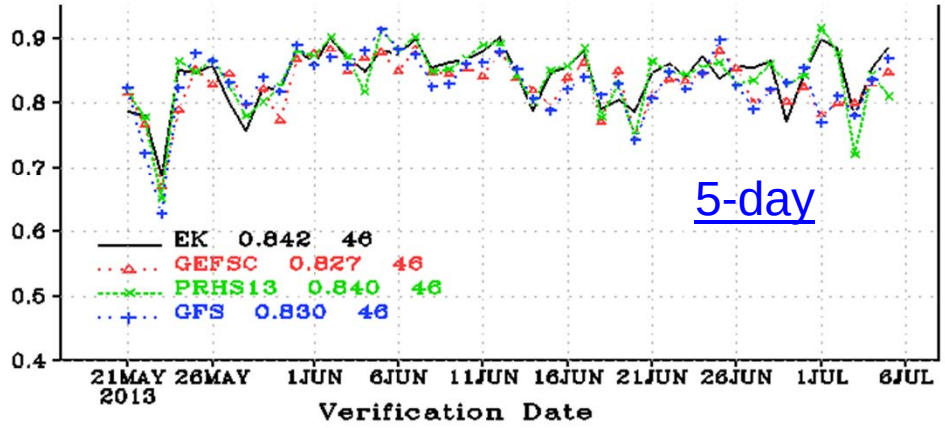

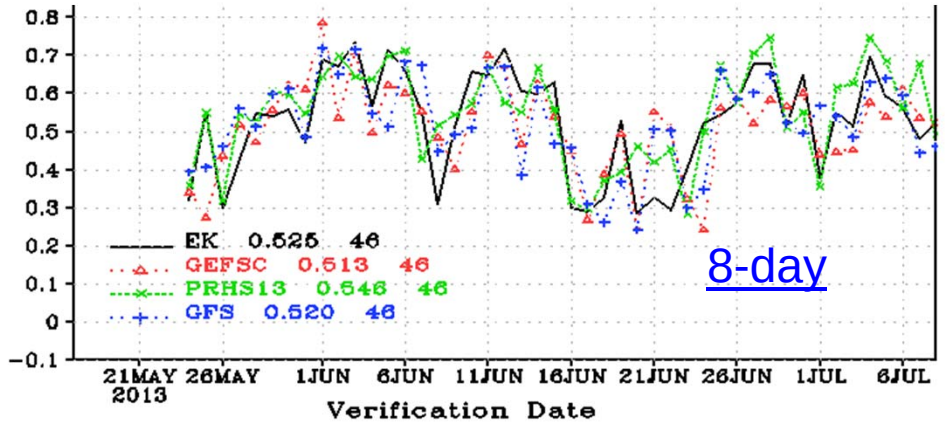

Comparison of new GFS model (latest version) against the operational For deterministic Forecast

Period: 5/15 -7/1/2013

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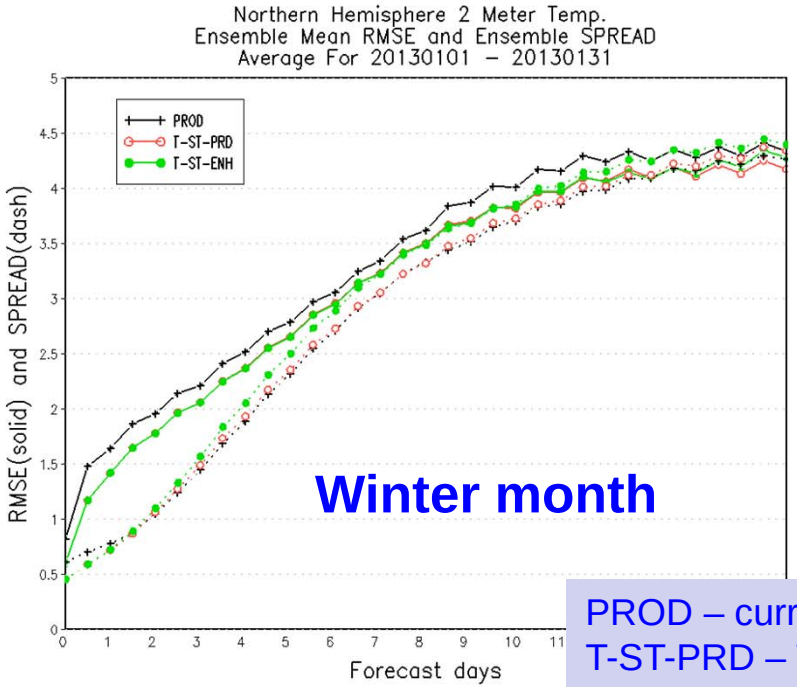
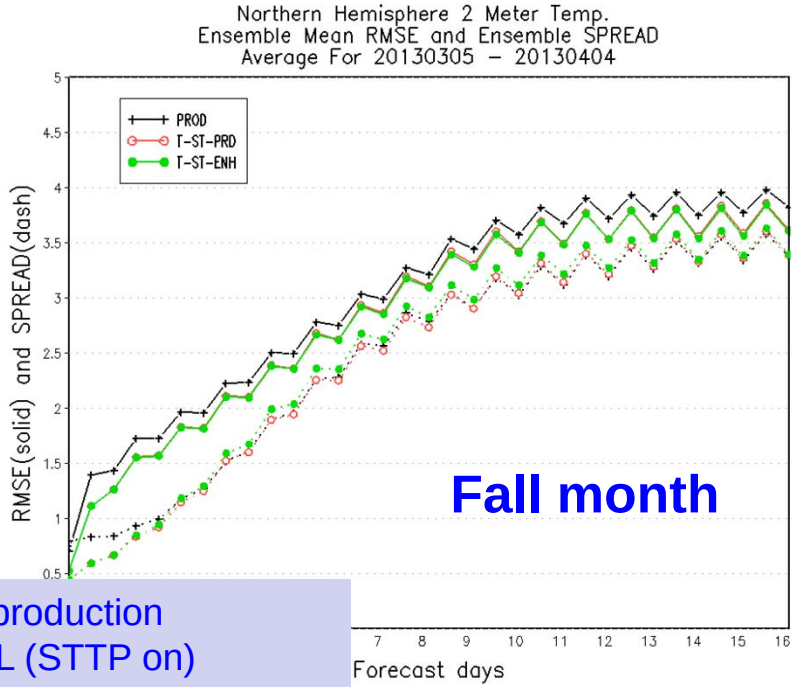
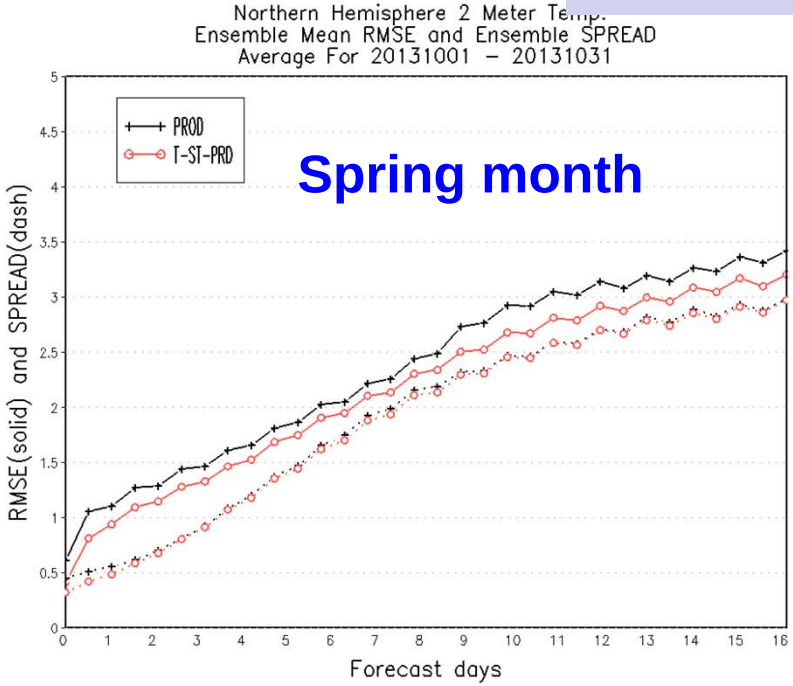
GFS – GFS (opr) – T574/382L64 EU

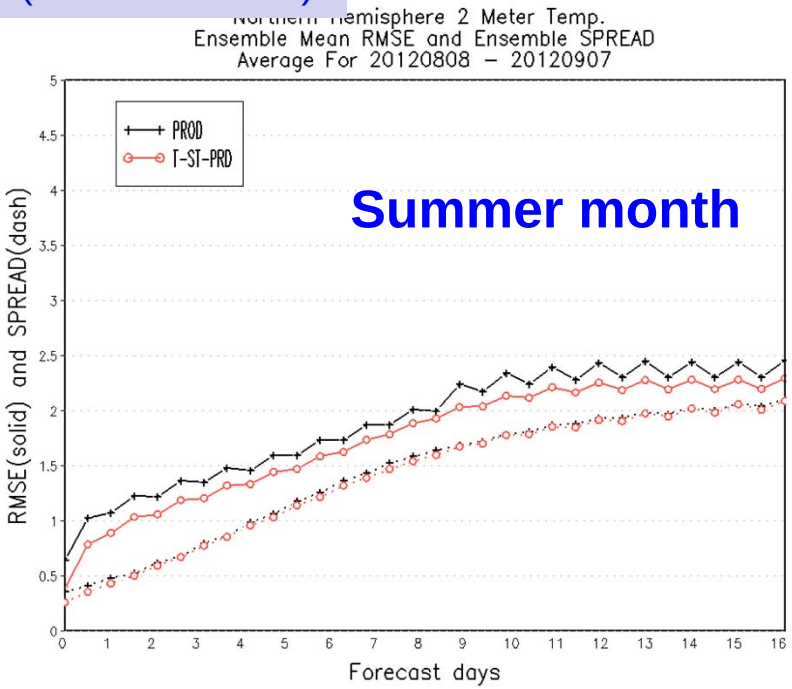
Conclusion:
3-, 5-, 8-day NH 500hPa AC scores of GEFS control parallel are about 1-1.5% better than current operation (5d and 8d lead time), closer to or better than operational GFS.





PROD – current GEFS production
T-ST-PRD – T574L42 SL (STTP on)
T-ST-ENH – T574L42 SL (enhanced STTP)





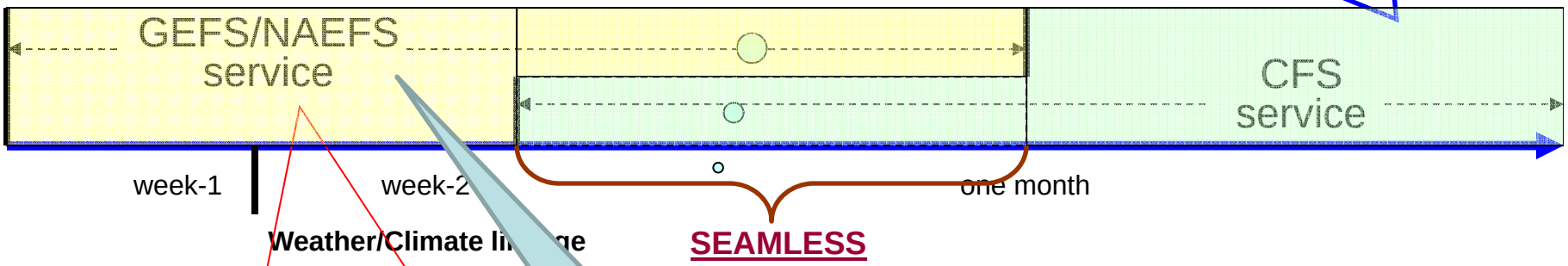
Future Seamless Forecast System

NCEP/GEFS is running on T254L42 (GFS 9.0 version) resolution with tuned ETR initial perturbations and adjusted STTP scheme for 21 ensemble members, forecast out to 16 days and 4 cycles per day. **Extended to 45 days at T126L28/42 resolution, 00UTC only (uncoupled)**
NAEFS will consider to include FNMOC ensemble with improving post process which include bias correction, dual resolution and down scaling

Main products:

ENSO predictions???
Seasonal forecast???

Main event MJO



Main products:

1. Probabilistic forecasts for every 6-hr out to 16 days, 4 times per day: 10%, 50%, 90%, ensemble mean, mode and spread.
2. D6-10, week-2 temperature and precipitation probabilistic mean forecasts for above, below normal and normal forecast
3. **MJO forecast (week 3 & 4 …)**
4. **Blocking ……**

The quality of NAEFS week-2 forecast

CPC has reviewed it

Operational CFS has been implemented in 2011 with T126L64 atmospheric model resolution (CFSv2, 2010version) which is fully coupled with land, ocean and atmosphere (GFS+MOM4+NOAH), 4 members per day (using CFS reanalysis as initial conditions, one day older?), integrate out to 9 months.

IMME and NMME - ???

GEFS extension to 30 days

- Two important science issues
  - Coupled GEFS
  - GEFS reforecast
- Why GEFS for monthly forecast?
  - GEFS demonstrated excellent skills for week-2 temperature & precipitation forecasts
- How does GEFS differs from CFSv2?
  - Latest state-of-art numerical model/Data Assimilation Systems
  - Higher model resolution
  - Best initial perturbations with cycling to represent obs/ana uncertainties
  - Best physics perturbations (STTP and others) to represent model uncertainties
- Advantage:
  - Will provide upgraded numerical guidance more frequently along with associated hindcasts
  - Less expensive for extended range GEFS forecast beyond 16 days (lower resolution)
- Disadvantage:
  - Hindcasts need to be upgraded frequently
  - Hindcasts length will rely on computer resources
- Cost:
  - Additional 10% computer resources

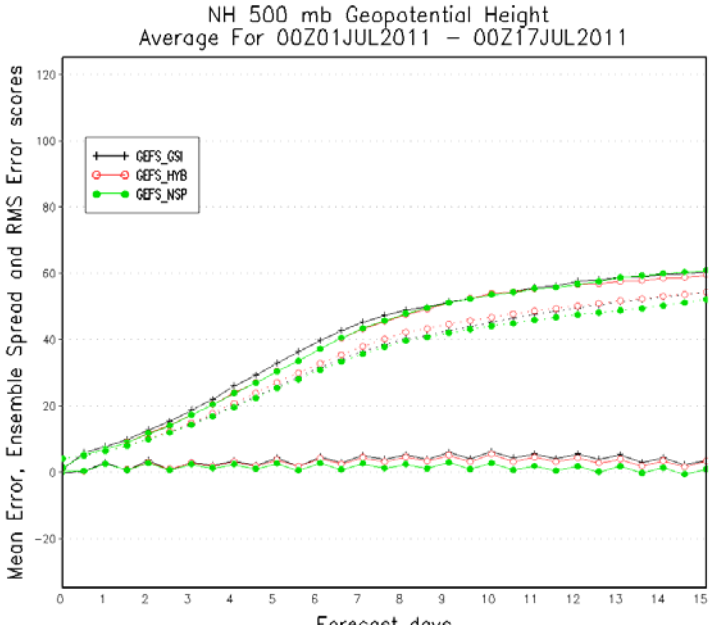
Background!!!

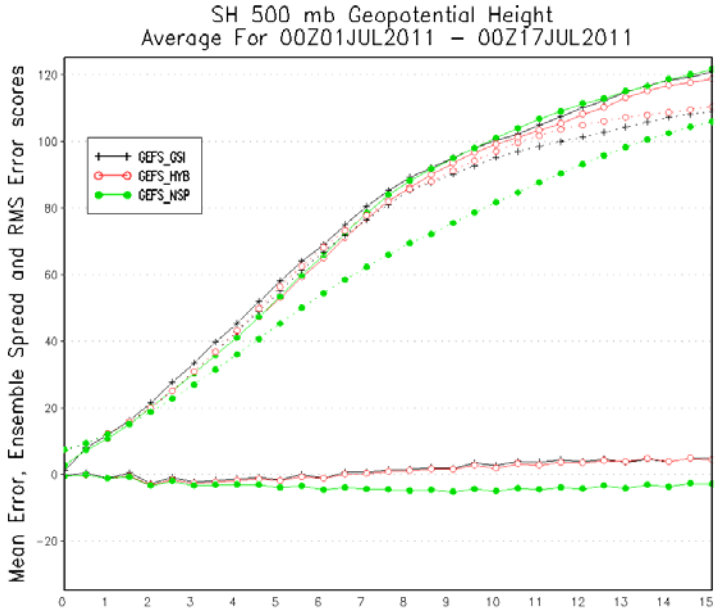
Responsibilities of Ensemble Forecast

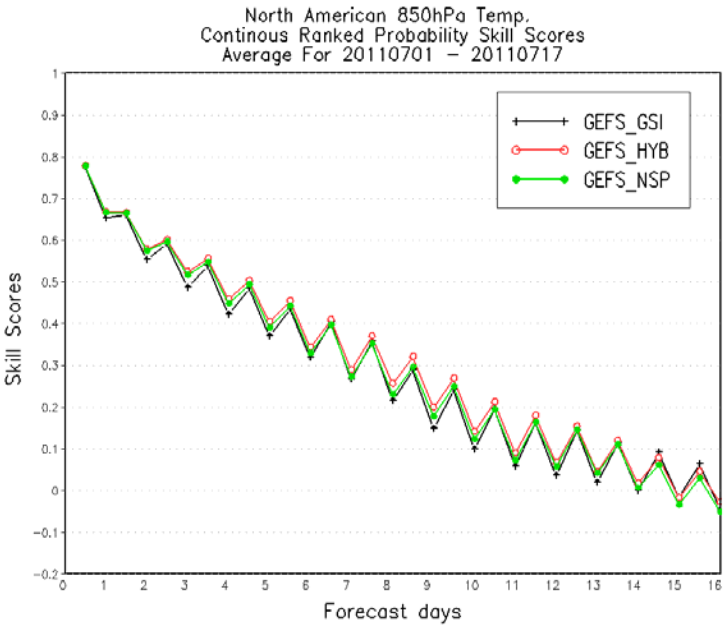
- Assess, model, communicate uncertainty in numerical forecasts

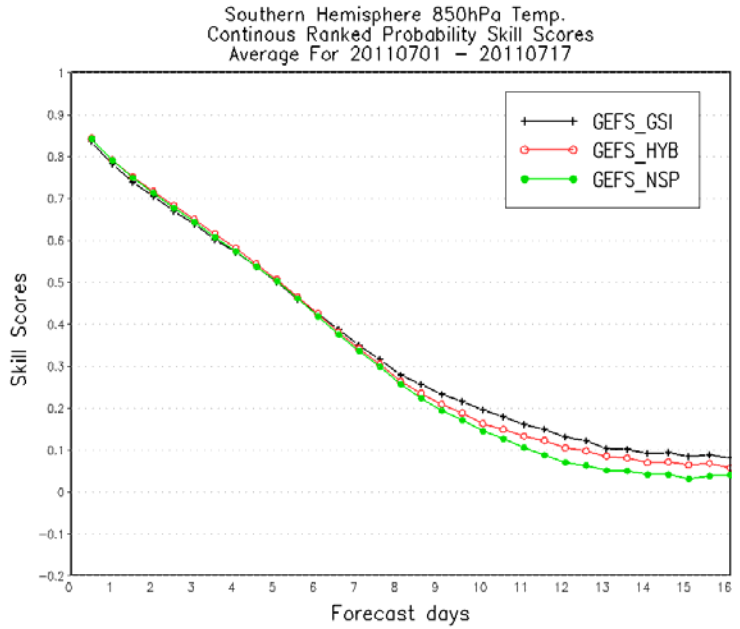
- Present uncertainty in numerical forecasting
  - Tasks
    - Design, implement, maintain, and continuously improve ensemble systems
  - Presents
    - Initial value related uncertainty
    - Model related forecast uncertainty
  - Ensemble systems
    - Regional – SREF / HREF / NARRE-TL / HWAF ensemble
    - Global – GEFS/NAEFS/NUOPC
    - Climate – CFS, IMME and NMME
    - Ocean wave ensemble (MMA/EMC)
- Statistical correction of ensemble forecasts
  - Tasks
    - Correct for systematic errors on model grid
    - Downscale information to fine resolution grid (NDFD)
    - Combine all forecast info into single ensemble/probabilistic guidance
- Probabilistic product generation / user applications
  - Contribute to design of probabilistic products
  - Support use of ensembles by
    - Internal users (NCEP Service Center, WFOs, OHD/RFC forecasters and et al.)
    - External users (research, development, and applications)

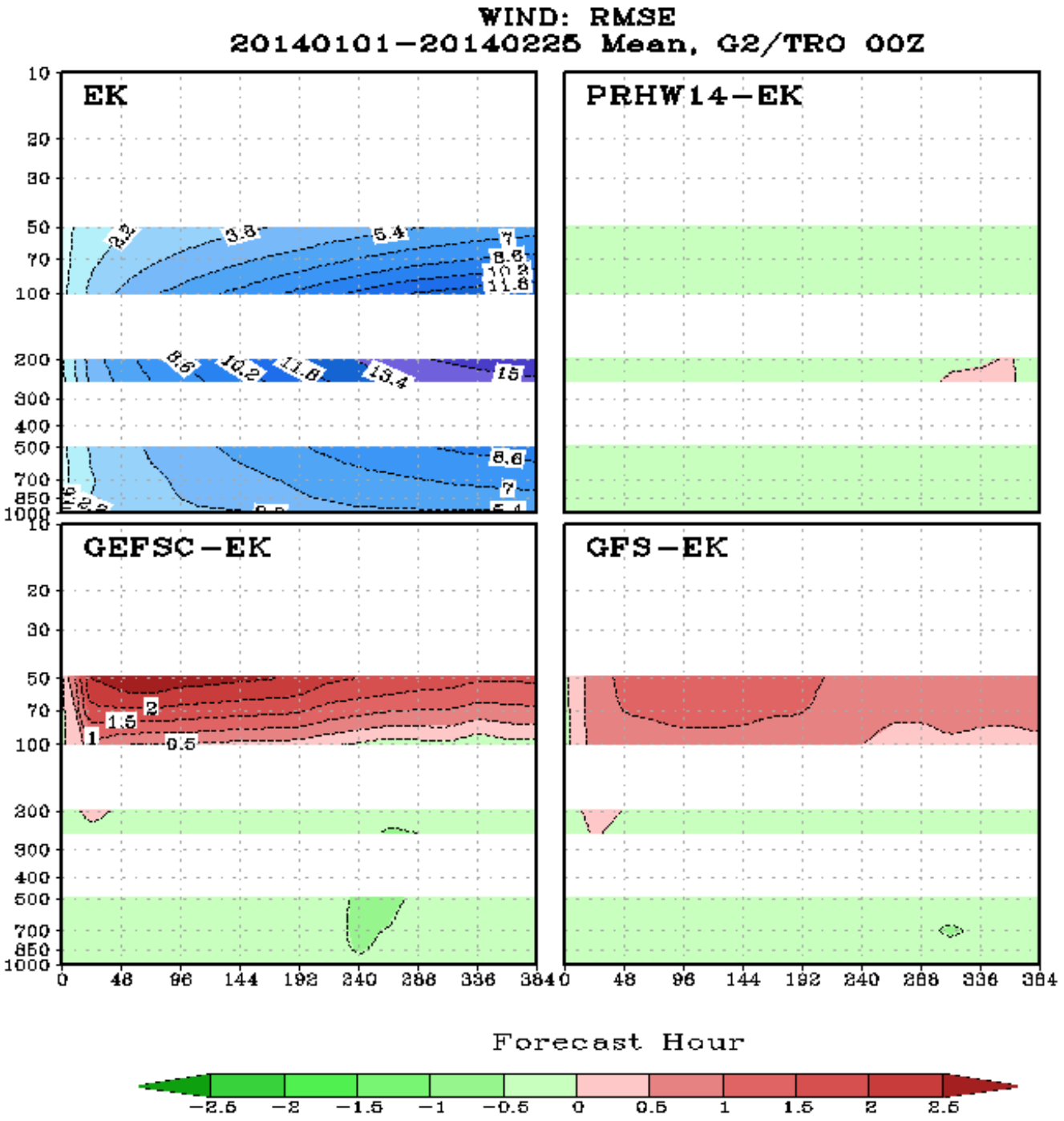
Impact of STTP: Improved Spread and Probabilistic Forecast











Tropical wind

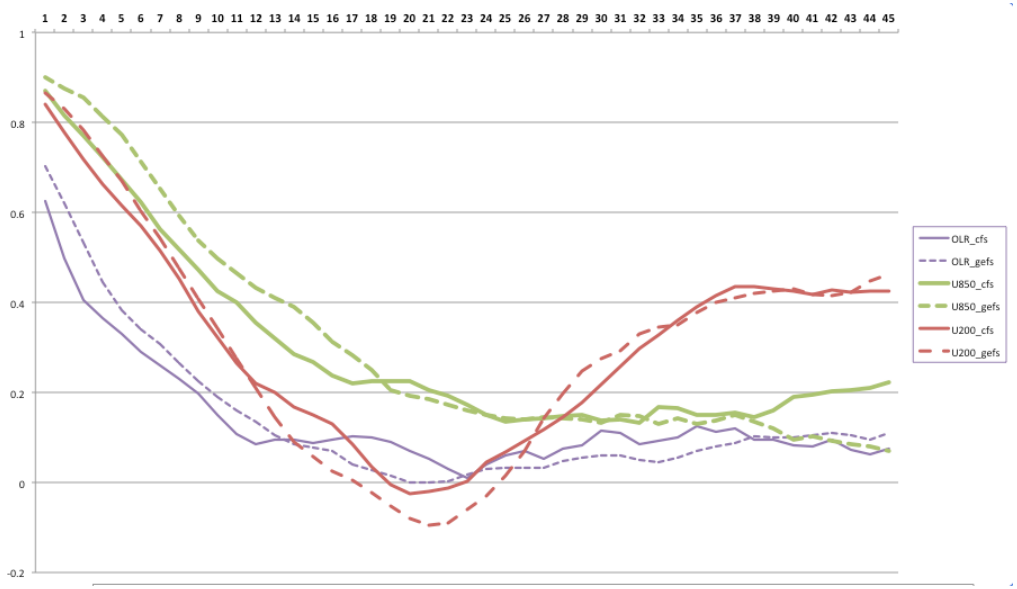
1. Not as good as high resolution GFS parallel
2. Better than GFS-opr and GEFS-opr for stratosphere.
3. Worse than GFS-opr and GEFS-opr for lower troposphere.
4. This may affect the skills for MJO prediction, and future coupling for extended forecast

Extended GEFS

- Algorithms
  - Setup algorithms to run GEFS out to 32 days
  - Forecast integrations for Summer 2011, Winter 2011-2012 and Winter 2012-2013
- Developments
  - 500hPa and MJO signal comparisons with CFSv2 benchmark (75% progress)
  - Retrospective GEFS generation for bias correction (10% progress)
  - Generation of Breeding perturbations in the coupled GFS-MOM (20% progress)
  - Development into prescribing realistic SST in the GEFS (5%)

Selected Results

For typical atmospheric variables the GEFS outperforms the operational CFS during the first two weeks

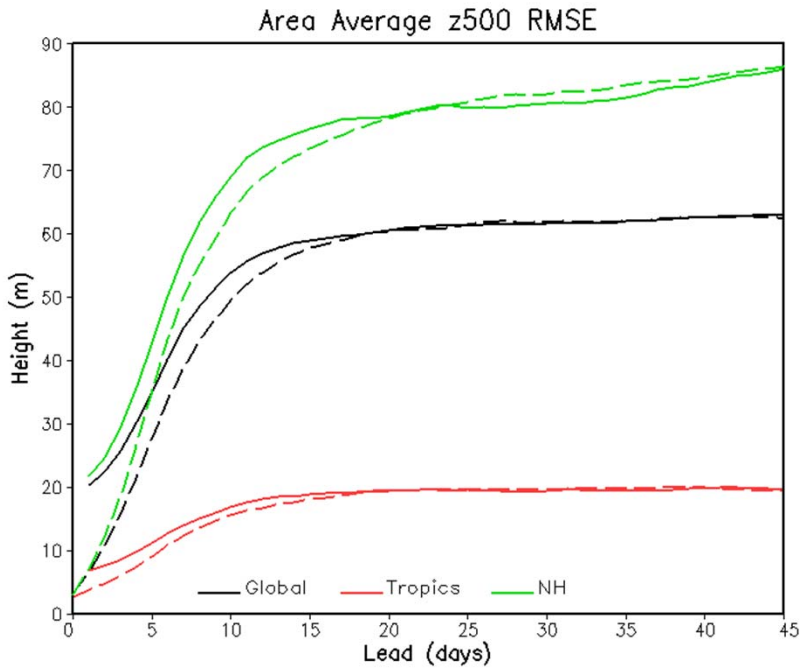


Dashed lines: GEFS T254&190L42, 21 members
Continuous lines: CFSv2 T126L64, 16 members

Beyond 3 weeks. The GEFS shows strong systematic errors. SST errors in the GEFS deteriorates skill of MJO and low-level variables.

Steps to make to improve the system:

- Implement systematic error correction strategy through hindcast
- Prescribe realistic SSTs or perform coupled GEFS



Next GEFS Implementation (Q1FY15)

- Initial perturbations
  - Base: EnKF 6hr forecast
  - TS relocation – modified version by Yoichiro Ota
  - Ensemble Transform (ET) and Centralization
    - ET will apply to EnKF f06 vectors
    - Centered for 20 initial perturbations
  - 3 dimensional rescaling (3DR) - option
    - Based on accumulated (EnKF) analysis error variance (total energy norm)
    - Rescaling EnKF f06 perturbations
- Stochastic perturbations
  - Tuning STTP for model change and initial perturbation changes
- What do we expect from this upgrade?
  - Improve probabilistic forecast?
  - Improve TS forecast?

L64 vs L42 Comparison