The Development of High Resolution Super Probabilistic Forecast

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NCEP GEFS Upgrade – February 14 2012

- Model and initialization
  - Using GFS V9.01 (current operational GFS) instead of GFS V8.00
  - Improved Ensemble Transform with Rescaling (ETR) initialization
  - Improved Stochastic Total Tendency Perturbation (STTP)
- Configurations
  - T254 (55km) horizontal resolution for 0-192 hours (from T190 – 70km)
  - T190 (70km horizontal resolution for 192-384 hours (same as current opr)
  - L42 vertical levels for 0-384 hours (from L28)
- Part of products will be delayed by approximately 20 minutes
  - Due to limit CCS resources
  - 40-42 nodes for 70 minutes (start +4:35 end: +5:45)
  - GEFS final product delivery - +6:30 hours
  - NAEFS product delivery - +9:00 hours
- Unchanged:
  - 20+1 members per cycle, 4 cycles per day
  - pgrb file output at 1*1 degree every 6 hours
  - GEFS and NAEFS post process output data format
- What do we expect from this implementation?
  - Improve general probabilistic forecast skill overall
  - Significant improvement of tropical storm tracks (especially for Atlantic basin)

NCEP SREF Upgrade – August 21 2012

- Model Change
  - Model adjustment (eliminate Eta and RSM legacy models and add new NEMS-based NMMB model)
  - Model upgrade (two existing WRF cores from v2.2 to version 3.3)
  - Resolution increase (from 32km/35km to 16km)
  - All models run with 35 levels in the vertical and 50hPa model top.
- IC diversity improvement
  - More control ICs (NDAS -> NMMB, GDAS -> NMM, RAP blended @ edges w/GFS -> ARW)
  - More IC perturbation diversity (blend of regional breeding and downscaled ETR)
  - Diversity in land surface initial states (NDAS, GFS, and RAP).
- Product information
  - 21 members and 4 times per day (03UTC, 09UTC, 15UTC and 21UTC)
  - Every 3 hours out to 87 hours
 - Product delivery time - unchanged - +4:40 hours

NAEFS Current Status – update by 2/14/2012

	NCEP	CMC	NAEFS
Model	GFS	GEM	NCEP+CMC
Initial uncertainty	ETR	EnKF	ETR + EnKF
Model uncertainty/Stochastic	Yes (Stochastic Pert)	Yes (multi-physics)	Yes
Tropical storm	Relocation	None	
Daily frequency	00,06,12 and 18UTC	00 and 12UTC	00 and 12UTC
Resolution	T254L42 (d0-d8)~55km T190L42 (d8-16)~70km	(d0-d16) – 66km	1*1 degree
Control	Yes	Yes	Yes (2)
Ensemble members	20 for each cycle	20 for each cycle	40 for each cycle
Forecast length	16 days (384 hours)	16 days (384 hours)	16 days
Post-process	Bias correction (same bias for all members)	Bias correction for each member	Yes
Last implementation	February 14th 2012	August 17th 2011	

Review of NCEP Statistical Post Process (SPP)

- Purpose
  - Improve reliability while maintaining resolution in NWP forecasts
    - Reduce systematic errors (improve reliability) while
    - Not increasing random errors (maintaining resolution)
      - Retain all useful information in NWP forecast

- Methodology
  - Use bias-free estimators of systematic error
  - Need methods with fast convergence using small sample
  - Easy implementation for frequency upgraded forecast system

- Approaches – Computational Efficiency
  - Bias Correction : remove lead-time dependent bias on model grid
    - Working on coarser model grid allows use of more complex methods
    - Feedback on systematic errors to model development
  - Downscaling: downscale bias-corrected forecast to finer grid
    - Further refinement/complexity added
      - No dependence on lead time

- Applications:
  - GEFS and NAEFS was implemented since 2006
  - SREF was implemented in 2012
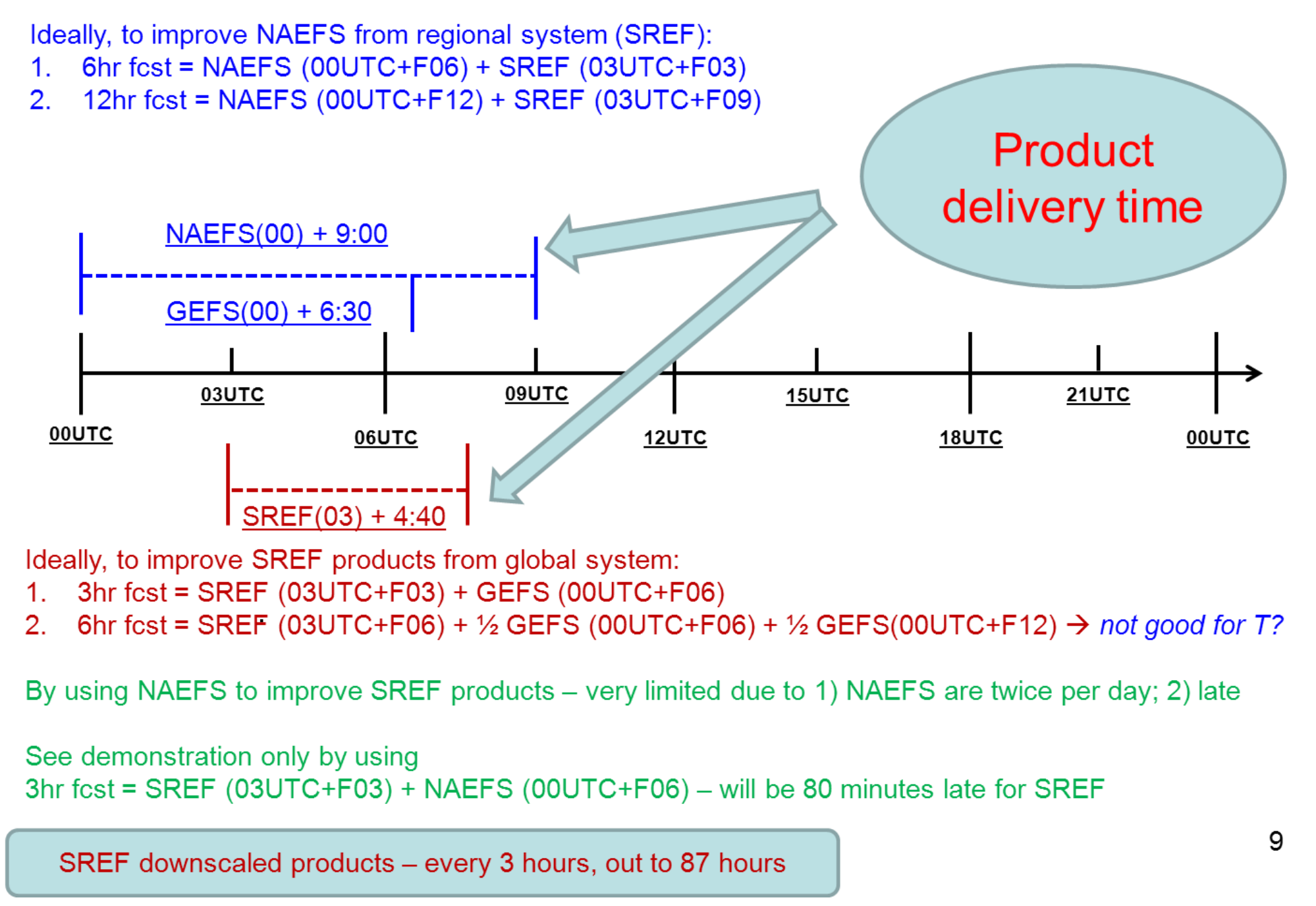
Current NAEFS SPP System
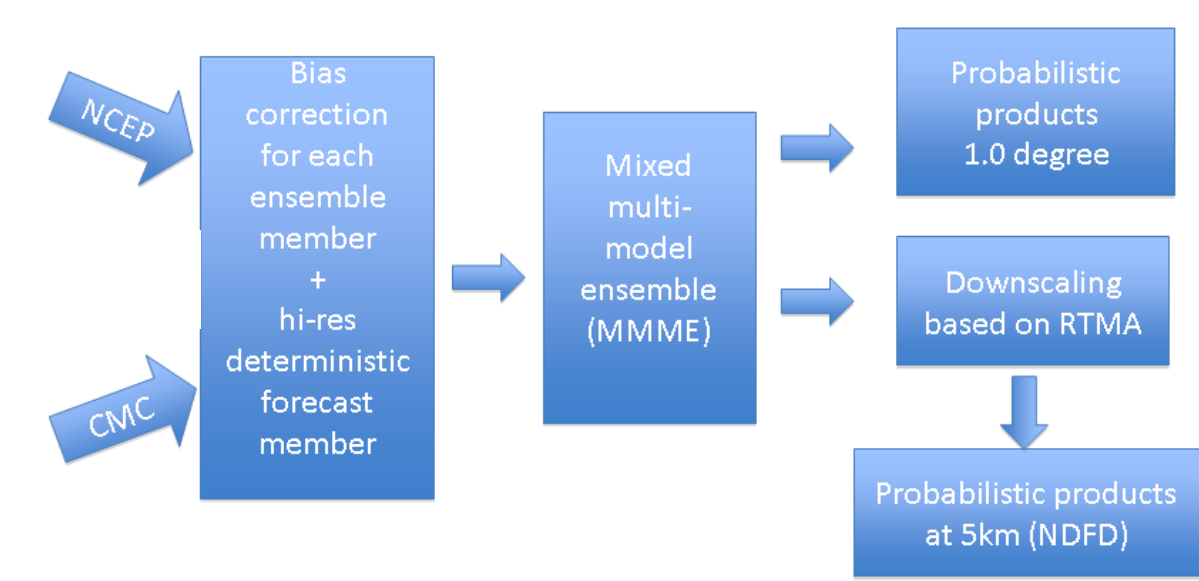
- Bias corrected NCEP/CMC GEFS and NCEP/GFS forecast (up to 180 hours), same bias correction algorithm
  - Combine bias corrected NCEP/GFS and NCEP/GEFS ensemble forecasts
  - Dual resolution ensemble approach for short lead time
  - NCEP/GFS has higher weights at short lead time

- NAEFS products
  - Combine NCEP/GEFS (20m) and CMC/GEFS (20m), FNMOC ens. will be in soon
  - Produce Ensemble mean, spread, mode, 10% 50%(median) and 90% probability forecast at 1*1 degree resolution
  - Climate anomaly (percentile) forecasts also generated for ens. Mean

- Statistical downscaling
  - Use RTMA as reference – NDGD resolution (5km/6km), CONUS and Alaska
  - Generate mean, mode, 10%, 50%(median) and 90% probability forecasts

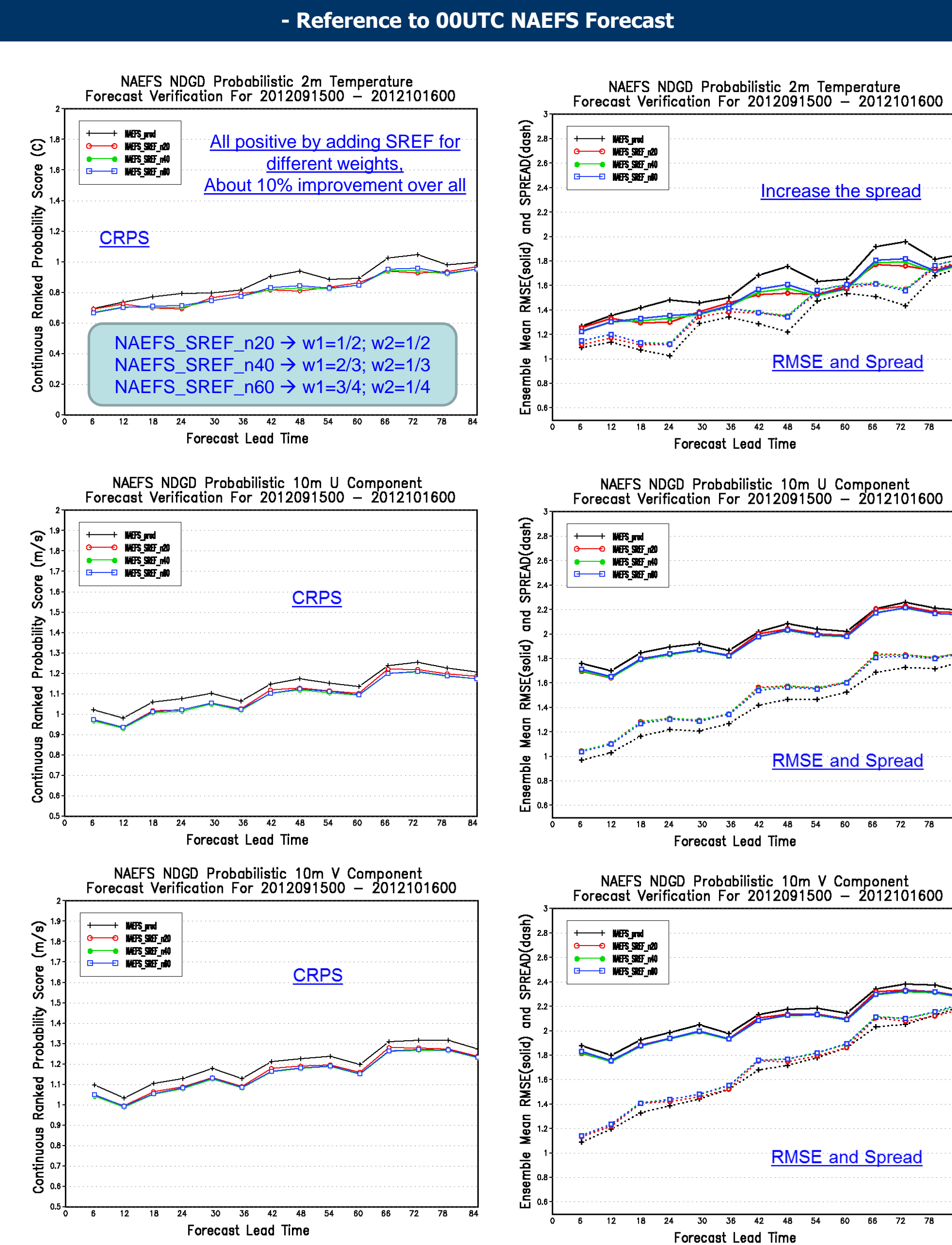## GEFS, SREF and NAEFS at 5km resolution for CONUS

- NCEP GEFS:
  - 5km NDGD resolution
  - Every 6 hours, out to 16 days
  - 4 times per day (00UTC, 06UTC, 12UTC and 18UTC)
  - Surface variables
- NAEFS:
  - 5km NDGD resolution
  - Every 6 hours, out to 16 days
  - 2 times per day (00UTC and 12UTC)
  - Surface variables
- NCEP SREF:
  - 5km NDGD resolution
  - Every 3 hours, out to 87 hours
  - 4 times per day (03UTC, 09UTC, 15UTC and 21UTC)
  - Surface variables
- Product service for:
  - All NCEP service centers – HPC, OPC, SPC, TPC and etc…
  - NWS regionals, WFOs and RFCs.
  - All public users.
- Combinations for Super Probabilistic Products (for example):
  - Add SREF (03UTC forecasts) to NAEFS (00UTC forecasts)
  - Add GEFS (00UTC forecasts) to SREF (03UTC forecasts)
  - Add NAEFS (00UTC forecasts) to SREF (03UTC forecasts) – SREF will be 80 minutes delay
  - A function (or weight) we need to use (compare): NAEFS*w1+SREF*w2 or SREF*w1+GEFS*w2
  - w1 and w2 is function of lead time ? (Further study)
- Property of initial time:
  - All GEFS, SREF and NAEFS are using RTMA as proxy truth for downscaling process, so initial states are consistent
- Limitation:
  - Only testing the variables which have normal distribution (assumption).

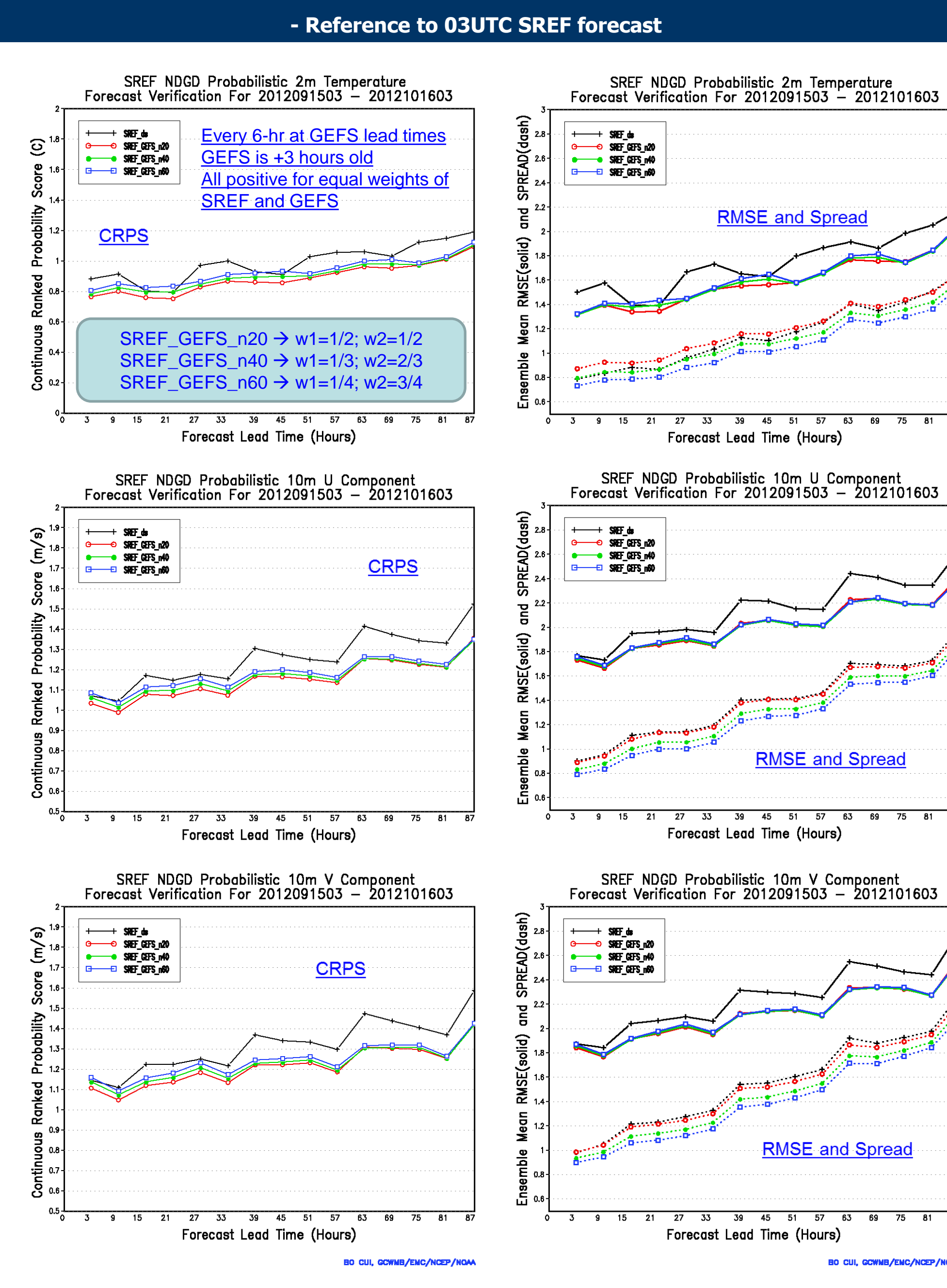## Process to Downscale Wind Speed and Direction

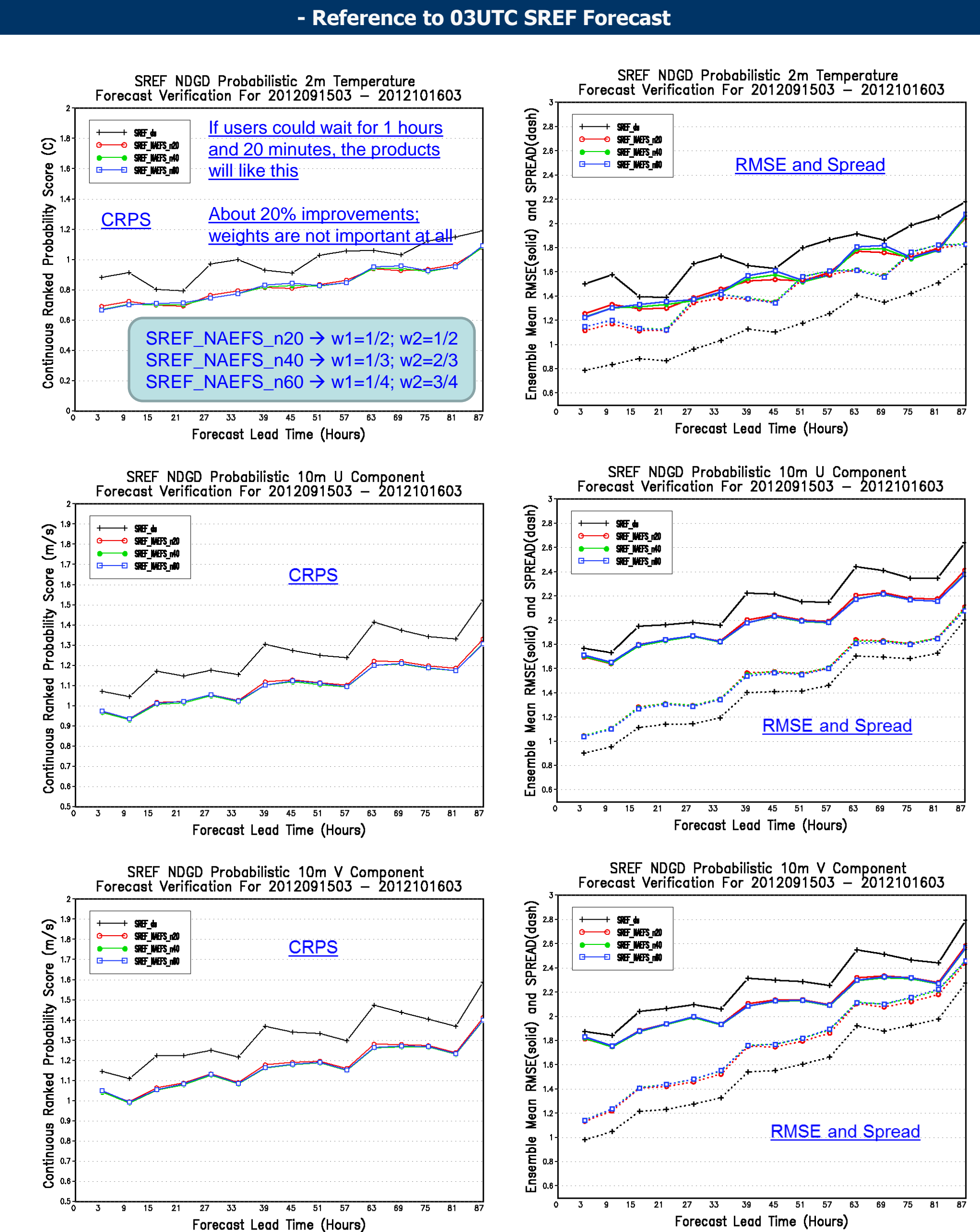GEFS/NAEFS downscaled products – every 6 hours, out to 16 days

Ideally, to improve NAEFS from regional system (SREF):
1. 6hr fcst = NAEFS (00UTC+F06) + SREF (03UTC+F03)
2. 12hr fcst = NAEFS (00UTC+F12) + SREF (03UTC+F09)

NAEFS(00) + 9:00
GEFS(00) + 6:30

Product delivery time

SREF(03) + 4:40

Ideally, to improve SREF products from global system:
1. 3hr fcst = SREF (03UTC+F03) + GEFS (00UTC+F06)
2. 6hr fcst = SREF (03UTC+F06) + ½ GEFS (00UTC+F06) + ½ GEFS(00UTC+F12) → not good for T?

By using NAEFS to improve SREF products – very limited due to 1) NAEFS are twice per day; 2) late

See demonstration only by using
3hr fcst = SREF (03UTC+F03) + NAEFS (00UTC+F06) – will be 80 minutes late for SREF

SREF downscaled products – every 3 hours, out to 87 hours

1. Use SREF to Enhance NAEFS Products
- Reference to 00UTC NAEFS Forecast

- All positive by adding SREF for different weights, About 10% improvement over all
- Increase the spread
- CRPS
- RMSE and Spread
- NAEFS_SREF_n20 → w1=1/2; w2=1/2
- NAEFS_SREF_n40 → w1=2/3; w2=1/3
- NAEFS_SREF_n60 → w1=3/4; w2=1/4

2. Use GEFS to Enhance SREF Products
- Reference to 03UTC SREF forecast

- Every 6-hr at GEFS lead times GEFS is +3 hours old All positive for equal weights of SREF and GEFS
- CRPS
- RMSE and Spread
- SREF_GEFS_n20 → w1=1/2; w2=1/2
- SREF_GEFS_n40 → w1=1/3; w2=2/3
- SREF_GEFS_n60 → w1=1/4; w2=3/4

3. Use NAEFS to Enhance SREF Products
- Reference to 03UTC SREF Forecast

- If users could wait for 1 hours and 20 minutes, the products will like this
- About 20% improvements; weights are not important at all
- CRPS
- RMSE and Spread
- SREF_NAEFS_n20 → w1=1/2; w2=1/2
- SREF_NAEFS_n40 → w1=1/3; w2=2/3
- SREF_NAEFS_n60 → w1=1/4; w2=3/4

Product Application Notes

- The forecast lengths are different for GEFS/NAEFS and SREF
  - GEFS/NAEFS – out to 16 days
  - SREF – out to 87 hours
  - How to make forecast continuation after 87 hours if using SREF to help NAEFS?
- The forecast output frequencies are different for GEFS/NAEFS and SREF
  - GEFS/NAEFS – every 6 hours (will plan to have every 3 hours out to 3 days)
  - How to help SREF by using GEFS/NAEFS?
- The product delivery times are different for GEFS, NAEFS and SREF
  - The example demonstrated in this study have already considered product delivery time.
  - Product delivery time is very important to our costumers

Summary and Future Plan

- There are significant extra values by adding:
  - SREF to NAEFS
  - GEFS to SREF
  - NAEFS to SREF
- It is very cheaper process since all sources are on board
- Weights for each model are not so critical in mostly – may use equal weights for simply application.
- Test other variables (non-Gaussian distribution variables – such as precipitation)
- Test to include downscaled ECMWF ensemble forecast into NCEP multi-model operational ensemble system
- Test higher resolution – NDGD at 2.5km for CONUS

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