4. Final prioritized requirements list

Requirements from all groups were combined into a single list, duplication was removed, and the full list was reviewed to assign priorities to each requirement. Priorities range from 1 for the highest, or most immediate, priority to 4 for the priorities to be addressed in Phase 2, and are based on goals of the NGGPS V&V team, guidance provided by EMC managers, and, to some extent, based on time and resources required for implementation.

Note that requirements for coupled components and process-oriented metrics will be further refined and documented in a follow-on document.
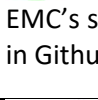
4.1   Functional Requirements

The following prioritized list of functional requirements is the result of the current evaluation. To list the group which indicated during our discussions a need for the requirement, the following abbreviations are used, in addition to other common organizational abbreviations:

AllEMC   All branches and groups within EMC
GlobalDet   Global Deterministic
GlobalEns   Global Ensemble
MMDet   Mesoscale Modeling Deterministic
MMEns   Mesoscale Modeling Ensemble
Cyclones   Tropical and Extratropical Cyclones
Procs   Process-Oriented Metrics
Ocns&Wvs   Oceans and Waves
UGCS   Unified Global Coupled System

Req Num	Group/s	Prior-ity	Description	Funding for completion
1	GlobalDet	1	System must have all functionality currently available on Fanglin Yang's main websites, both for the operational global model, and for the comparison between the operational and parallel models. This requirement is an overriding requirement for any details not captured elsewhere in this document.	Submitted for install in operations 09/18

2	GlobalDet	1	Must include simple-to-use scripting to support an end-to-end system that can produce output as defined in requirement 1.	Submitted for install in operations 9/18
3	GlobalDet	1	Must compute Anomaly Correlation, Bias, RMS Error, Murphy's MSE Skill Score, Ratio of Standard Deviation, RMSE from Mean Difference and RMSE from Pattern Variation.	✔
4	GlobalDet	1	Must include features like the use of cosine-latitude weighting and 2.5 degree climatologies for global (large domain) scores, where appropriate.	✔
5	Cyclones	1	Must match cases to provide homogeneous dataset. Implicit in Requirement 1.	✔
6	GlobalDet	1	Must produce plots as produced by fit2obs for radiosondes and aircraft. This may initially be implemented by a link to output from the Fit2Obs package.	NGGPS-YR2-3 if still required
7	GlobalDet	1	Must produce a scorecard as currently produced by Fanglin, shown in Figure D-1.	✔
8	GlobalDet	1	Must produce plots for a forecast sounding with lead time on the x-axis, pressure level on the y-axis and a contour of the selected statistical values (e.g. RMSE) See Figure D-2	✔ EMC's scripts in Github
9	GlobalDet	1	Must produce plots of T-p maps, which have color-coded anomaly correlation values with date of initialization times on the vertical axis and lead time on the horizontal axis as shown in Figure D-3	✔ EMC's scripts in Github
10	GlobalDet	1	Must produce plots of die-off curves of anomaly correlation with Fourier decomposition, including a differences plot with error bars as shown in Figure D-4. This implies a requirement to be able to use Fourier transform to decompose fields and computer scores, especially for wavenumbers 10-20.	✔ EMC's scripts in Github

11	GlobalDet	1	Must read ATCF file format and produce plots of hurricane track and intensity errors over defined basins.	✓
12	GlobalDet	1	Must include ability to display confidence intervals generated either with student-t or bootstrapping	✓
13	GlobalDet	1	Must include ability to compute level of significance with user-specified alpha values.	✓
14	GlobalDet	1	Must include option to remove auto-correlation	✓
15	GlobalDet	1	Must produce a plot of mean ETS or Bias scores for 24-hour accumulated rainfall against a range of threshold values, including differences between 2 models. This is implied from Requirement 1.	✓
16	GlobalDet	1	Must produce a contoured plot of either ETS or Bias with forecast hour on y-axis and threshold on x-axis. This is implied from Requirement 1.	✓ EMC's scripts in Github
17	GlobalDet	1	Must produce a plot of time series of ETS or Bias over defined time range with defined threshold value, including plot of obs count. This is implied from Requirement 1.	✓
18	CPC	1	Must be easy to add new models and forecasts. Implicit in the Requirement 1 for parallel model comparisons.	✓
19	GlobalDet, MMDet	1	Must produce a plot of mean ETS or Bias scores against threshold values, including differences between 2 models. This is implied from Requirement 1.	✓
20	GlobalDet, MMDet	1	Must be able to calculate all precipitation scores currently available on Ying Lin's website, including Bias, Equitable Threat Score, ETS with bias adjustments, Fractional Skill Score (FSS), Probability of Detection (POD) and False Alarm Ratio (FAR)	✓

21	MMDet	1	Must be able to run neighborhood method to compute FSS for multiple neighborhoods. Implicit in Requirement 19	✓
22	GlobalDet	4	Must be able to verify forecasts against NCEP/CPC gauge analysis.	✓
23	GlobalDet, MMDet	1	Must be able to compute 3-, 6- and 24 -hour accumulated QPF and QPE values	✓
24	AllEMC	1	Must produce 2-D maps of forecasted values. This is implied from Requirement 1. This requirement may initially be met with links to maps generated elsewhere.	✓ EMC's scripts in Github
25	GlobalDet, GlobalEns, MMDet, MMEns, MEG	1	Must have ability to produce standardized, pre-generated graphical images	✓
26	AllEMC	1	Must have ability to compare against multiple analyses and obs sets	✓
27	GlobalEns	1	Must have ability to verify against CCPA for precipitation	✓
28	GlobalDet, GlobalEns, MMDet, Fit2Obs	1	Must be able to read data in PrepBUFR format.	✓
29	AllEMC, WPC	1	Must be able to read all standard NCEP grids	✓
30	AllEMC	1	Must have flexible masking to define regions; should be able to at a minimum define 1) regions that are over land or over ocean, and 2) regions defined by lat, long corner points	✓
31	GlobalEns, MMEns	1	Must be able to read GRIB variants from NCEP, UKM, ECM, CMC, FNO, JMA, NCMRWF and German models	Just need to confirm last 2

32	GlobalEns	1	Must produce output that can be used by a plotting package to create plan-view for model data.	✔
33	GlobalEns	1	Must be able to produce stats in ASCII, in a format that is easy for human to view.	✔ 4/17
34	AllEMC	2	Must be able to read disparate datasets and place into uniform formats	Ongoing as needs identified
35	MMDet	2	Must be able to apply verification measures differently to different models and grids (e.g. continuous stats are computed for 12 and 40km grids but categorical are computed for 12, 40 and 80km grids)	✔
36	GlobalDet	2	Must include ability to select a vertical or horizontal cross-section to generate a plot.	✔ EMC's scripts in Github
37	MEG, MMDet, UGCS, CPC, WPC	2	Must have ability to compute scores for individual cases, specific case specifications (e.g. synoptic conditions, sky condition or climate indices), as well as monthly averages.	✔ specific applications ongoing
38	MMDet, MMEns	2	Must be able to read CMORPH QPE, URMA, WWMCA, GOES satellite and Stage IV radar mosaic data. Need to confirm if readable by MET	✔
39	MMDet	2	Must be able to produce box and whisker plots	✔
40	GlobalEns, MMEns, Cyclones	2	Must be able to compute ensemble member relative fields and scores: mean of entire ensemble or sub-group, spread across members or envelop of time, rank histograms, relative position, economic value	Time-Spread need more specification
41	GlobalEns, MMEns, Cyclone	2	Must be able to compute spread and produce spread/skill plots	✔

42	MEG	2	Must have ability to aggregate over multiple regions	✓
43	GlobalEns	2	Must have ability to normalize spread and skill values using 1 degree climatology	✓
44	GlobalEns, MMEns, Fit2Obs	2	Must be able to use climatology expressed either as 1) mean and std. dev., or 2) empirical distribution of values to be sampled every nth point	✓
45	MMEns, WPC, CPC	2	Must compute probability statistics including Ranked Probability Score, and Brier Score	RPS - 03/19
46	GlobalDet, MEG, WPC	2	Must be able to run MODE systematically out to 10 days	✓
47	MMEns	2	Must be able to compute and plot ensemble outliers (obs that fall outside a range of ensemble values) and extremes (top and bottom 10% of distribution)	TBD 03/19
48	MMDet	2	Must compute less used scores like ODDS ratio and SEEPS	TBD 03/19
49	GlobalEns, CPC	2	Must be able to compare stats from multiple projects or years, likely from different databases	✓
50	Cyclones	2	Must be able to read ExTC-modified ATCF file formats	✓
51	MMDet	2	Must be able to read operational mesoscale model fields (e.g. from NAM, RAP, HRRR etc.) and CMAQ fields	✓
52	MMEns	2	Must be able to apply verification measures differently to different models and grids (e.g. SREF there is only 24hr QPF evaluation and FSS not applied)	✓
53	MMEns	2	Must be able to evaluate probability products as well as members	✓
54	MEG	3	Would like a streamlined, centralized, well-organized web layout to make it easy to find	✓

			statistics, with ability to drill down (could look at ECMWF as a good example)	
55	DA, Ocns&Wvs	3	Must be able to include observation error/uncertainty	✔
56	DA	3	Must be able to look at first guess departures (o-b) and (o-a) for all GSI diagnostic observation types and write out summary files	✔
57	MMEns	3	Must be able to substitute observation/analysis with a single member to compute performance (e.g. control)	✔
58	Cyclones	3	Must be able to compute both consensus track and consensus variance.	✔
59	MMDet, MEG	3	Must be able to derive fields (e.g. PBL depth, Best CAPE, CAPE, etc.) from prepBUFR data or leverage prepFits module	Single variate capability available Rest expected 12/18
60	GlobalEns, MMDet	3	Must have option to use topography for interpolating when verifying point locations	TBD 03/19
61	CPC, UGCS	3	Must be able to read CDAS Reanalysis	✔
62	CPC	3	Must be able to use CPC analysis of temp, precip, unified gauge analysis, 500 hgt	TBD 03/19
63	MMDet, Aerosols, Ocns&Wvs	3	Must be able to read BUFR format (e.g. for Aerosol Optical Depth)	✔
64	MMDet, Aerosols, Sea Ice, Ocns&Wvs	3	Must be able to read multiple satellite, radar and precipitation files from CLAVIR, MODIS, JASON, CRYOSAT, ALTIKA, MRMS and RFC precipitation gauge, IMERG precipitation analysis	✔
65	CPC, WPC	3	Must be able to read Grib1, Grib2, NetCDF, GrADS format	✔

66	GlobalEns, MMDet	3	Must provide comparison of annual performance for different years	✓
67	MEG	3	Must be able to replicate current web pages produced by Eric Rogers for T-2m, Td, and Winds, and by Ying Lin for precipitation case studies, including threat and bias scores	✓
68	MEG	3	Must be able to plot meteograms	TBD 03/19
69	MMDet	3	Must be able to do multi-panel plotting (e.g. 4 plots on a page)	✓ EMC's scripts in Github
70	GlobalEns	3	Must be easy to use in both real-time and retrospective modes	✓
71	MEG	4	Must be able to verify on runs (both operational and parallel) managed by NCO, and also for internal EMC runs; need ability to switch between EMC parallel and NCO parallel as if it were a single model and identify which is used	✓
72	AllEMC	4	Must include flexible scorecard capability that can be applied to areas beyond Global Deterministic (e.g. Global and Mesoscale Ensembles, Mesoscale Deterministic, Climate, etc.)	✓
73	CPC, UGCS	4	Must be able to evaluate basic coupled system including: Fluxes, ocean, ice, chemistry, LSM	FY20
74	CPC	4	Must handle evaluation of ensembles that predict climate signals (e.g. ENSO, MJO etc.) and anomalies	FY19-20
75	CPC, UGCS	4	Must provide computation of lagged-correlations – need better definition of how many lags	FY19
76	DA	4	Must replicate scores generated by DA system for verification – need better definition	FY20
77	Procs, Sea Ice, Ocns&Wvs	4	Must be able to evaluate fluxes (movement of a physical species or atmospheric properties, i.e. moisture flux or radiation flux)	73 and 77 seems redundant - This may be

				included as separate pkg
78	Procs, Aerosols	4	Must be able to evaluate point forecasts (e.g. single column, surface station location, AERONET station, etc.) using point observations	FY19
79	Procs	4	Must include evaluation of cloud properties like liquid cloud water, ice concentration, etc.	FY19-20
80	Fit2Obs, MEG, CPC, WPC	4	Metrics must be able to be disseminated to users such as MEG, Climate Prediction Center and Weather Prediction Center	✓
81	Fit2Obs	4	Must be able to read CFSR and NCI climatologies	✓
82	Cyclones	4	Must be able to evaluate probability of rapid intensification	✓
83	Cyclones	4	Must include community version of ExTC track-matching algorithm	This needs to be discussed further
84	Cyclones	4	Must include ensemble verification for TCs	✓
85	MMDet	4	Must include NWP Index	✓
86	Cyclones	4	Must include option to include genesis phase in evaluation	FY19-20
87	Cyclones	4	Must be able to stratify statistics by conditions such as strength (e.g. Category 1 and Category 2 storms)	✓
88	MEG	4	Would like regime-dependent diagnostics	✓ but would like to add automated ways of doing this

89	MEG	4	Would like to have interactive capability to generate customized verification output as needed	FY19
90	Fit2Obs	4	Must be able to do linear in log-p vertical interpolation	FY19
91	WPC, CPC	4	Must be able to read human generated forecasts in VGF format	FY19
92	Aerosols, Procs, Ocns&Wvs	4	Must preprocess a neighborhood of observations for use in verification including the computation of min/max/mean in neighborhood and "best match".	✅
93	CPC, Fit2Obs, Ocean and Waves	4	Must be able to read component specific formats such as tripolar geometry, TOGATAU, PIRATA, RAMA, Buoys, RTOFS, HYCOM and GSM sigma files	Reading GSM Sigma (i.e. raw) files requires a major overhaul
94	Fit2Obs, GlobalEns	4	Would like to be able to develop and use climatologies of surface observations and soundings	FY19-20
95	CPC	4	Must be able to use band-pass filtering to compute diagnostic indices (e.g. drought, MJO, ENSO, etc.)	FY19-20
96	Procs, Fit2Obs, Sea Ice, Ocns&Wvs	4	Must be able to handle special data from field projects (e.g. self-describing ASCII or NetCDF files that do not comply with current verification package standards)	FY19 through python embedding
97	DA	4	Must be able to evaluate fraction of beneficial observation - how many improve and how many degrade	Uncertain how to approach so difficult to size
98	Cyclones, MMDet, WPC	4	Must be able to evaluate model performance using storm-relative methods	✅
99	MMDet, Sea Ice	4	Must be able to validate trajectory forecasts, such as Hysplit and sea ice drift	FY 19-20

4.2 Non-Functional Requirements

Non-functional requirements were also identified which apply across all functional requirements. These have not been prioritized, but all are considered essential.

1. Must run automatically daily to aggregate monthly scores and quarterly scores
2. Software must be able to complete auto-generated plots within 2 hour after completion of model runs.
3. Code must be maintained in a software repository, using either SVN or git, and accessible both internally to NOAA and externally to partners.
4. For Phase 1, software must be able to be installed and run on EMC servers or IDP development servers.
5. For Phase 2, software must be able to be installed and run on IDP production servers and conform to all NCO operational software requirements.
6. Must be able to run on WCOSS, Theia, or Yellowstone systems to generate statistics.
7. Must be able to run from cron.
8. Software must be able to run under Red Hat Enterprise Linux.
9. Software must be able to run within a workflow system, including Rocoto and/or ECflow in a batch mode.
10. Software must conform to all organizational security requirements.
11. Software must support additions or changes from NCEP or NGGPS verification developers.
12. Web applications must not use Java Applets, and initial versions for 2016/2017 should be based on html5 technology.
13. Database access must be able to support at least 20 concurrent users with response times within 30 secs.
14. Database must be scalable to support all metrics for current global operational models and models in a parallel evaluation.
15. Database should be scalable to allow the addition of regional models or future new models to be verified.
16. A helpdesk must be provided for support.
17. Operational users should receive initial response to issues/questions sent to the helpdesk within 2 hours during business hours within resource constraints defined by NCEP.
18. Training should be available if needed.
19. Documentation for use of the software must be provided and kept updated.
    a. It should provide many examples of how to configure the system.
    b. It should include a description of how statistical significance is calculated.