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Strategic Area	Measure (The monitoring of ongoing progress toward pre-established goals.)	Milestone (A distinct activity planned for completion on a scheduled date)	FY16		FY17		FY18		FY19		FY20		PERFORMANCE MEASURE and MILESTONE DESCRIPTIONS
			Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	
Modeling: Integrated & Improved	Annual number of GSL peer-reviewed publications providing significant contributions to environmental prediction and understanding		20	31	13	19	20	31	20	35	20	44	Peer-reviewed publications are a recognized measure of GSL's scientific productivity, research quality, and credibility provided to NOAA, its research partners, other agencies, states, and the general public. It is an OAR GPRA (Government Performance and Results Act) performance measure reported to NOAA and DOC.
Weather: Atmospheric	FY16-17: Annual number of technologies developed to improve operational weather forecasting that are transferred to NWS, other government organizations or the private sector for operational use. FY18-20: R2A Index: Annual number of OAR R&D products transitioned to a new stage(s) (development, demonstration, or application).		2	5	0	3	3	6	2	7	5	7	GSL develops new systems, weather prediction models, technologies and techniques to improve operations. This performance measure provides the number of technologies transferred to operational entities, academic and public users. This performance measure is reported annually to NOAA and DOC.
Modeling: Integrated & Improved	Cumulative percentage improvement in accuracy (total skill score of ceiling <1000 ft) of the 3-hour cloud ceiling for operational forecasts critical for aviation safety during take-off and landing of aircraft		8%	8%	9%	11.4%	11%	13%	14%	19%			Better awareness of expected cloud ceiling over the next 3-hour period is critical to airline safety and aircraft take-offs and landings. Cumulative percentage improvements (approx. 1% per year) will be derived from operational implementation of new short-range, rapidly updated models called the Rapid Refresh (RAP) and the High Resolution Rapid Refresh (HRRR) at NWS/NCEP and continuous updates of the models.
Modeling: Integrated & Improved		Establishment (standup) of an advanced real-time experimental 3D-RTMA analysis system code at Global Systems Laboratory with improved cloud ceiling fields relative to the HRRR background field.							X	X			GSL has been working to help update the current two-dimension NCEP operational Real-Time Mesoscale Analysis (RTMA) system to a 3D version that will provide three-dimensional cloud analyses from which two-dimensional fields such as ceiling can be diagnosed. Both the 2D and 3D versions ingest short-range HRRR forecasts as background fields for their anaylses. Under this milestone, GSD will establish and run in real-time an advanced experimental 3D-RTMA, which will provide improved ceiling fields compared to the background HRRR fields.
Modeling: Improve quantitative prediction		Incorporate new variational/ensemble analysis package for the cloud analysis within the GSL real-time experimental RAP (prototype of next NCEP RAP v5.0)					X	X					Accomplishment of the milestone represents the culmination of a complex task to convert the traditional (non-variational) cloud analysis to a variational / ensemble-based cloud analysis. The variational / ensemble cloud analysis will allow the specification of auto and cross-covariances for cloud hydrometeor and water vapor fields, leading to improved retention of cloudy features in the RAP (and related HRRR) model forecasts. This work will include examination of combined methods that use both the new variational / ensemble cloud analysis and the traditional cloud analysis, as well as evaluation of relative humidity bias issues associated with the cloud analysis.
Weather: Atmospheric	**FY16-17**: Cumulative number of assessments conducted on aviation weather products to evaluate potential for transition to NWS operations supporting FAA aviation operations. **FY18-20**: Annual number of reports evaluating new aviation weather products for their potential to transition to NWS operations supporting FAA aviation operations.		24	24	26	26	2	2	2	3	4	4	Under the FAA's Aviation Weather Research Program (AWRP), new aviation weather forecast products are developed by organizations both inside and outside NOAA. FAA has an interagency agreement with GSL to conduct assessments of the products which include both en-route products (icing, turbulence, jet stream, convection, etc) and terminal aerodrome forecast (TAF) products (visibility, ceiling, fog, reflectivity, etc). These formal assessments evaluate the effectiveness of technology and tools for improving the accuracy and quality of weather information at critical decision points, thus improving aviation services to the public. FY16 assessments include: 1) the Offshore Precipitation Capability developed by MIT/Lincoln Lab (completed Q1); 2) the Graphical Turbulence Guidance- Nowcast (GTG-N) developed by NCAR (completed Q2) and 3) the forecast component of the Icing Product for Alaska-Forecast (IPA-F) also developed by NCAR (completed Q4). FY17 assessments include: 1) the CCFP (experimental CDM Convective Forecast Planning guidance) report and 2) the Icing Product for Alaska - Diagnosis (start). FY18 assessments include: 1) Icing Product for Alaska - Diagnosis (Written report completed) and 2) Ensemble Prediction of Oceanic Convective Hazards (EPOCH). FY19 assessments include: 1) Assessment of Ceiling and Visibility Analysis Products, Part 2 and 2) Graphical Turbulence Guidance - Global Version, Part 2. FY20 assessments and reports include: 1) Offshore Precipitation Capability Assessment; 2) Icing Product Alaska--Forecast (IPA-F) Implementation Assessment; 3) Rapid Refresh (RAP) Model Version 5 Assessment; and 4) High-Resolution Rapid Refresh (HRRR) Model Version 4 Impact Assessment.
Weather: Atmospheric		Complete the assessment of the Diagnosis component of the Icing Product for Alaska by FY17Q4.			X	X							The Icing Product Alaska - Diagnostic (IPA-D) combines observations with model analyses to provide a real-time picture of the risk of in-flight icing. The assessment of IPA-D compared it to both the products currently in use by the Alaska Aviation Weather Unit (Forecast Icing Potential, FIP; Forecast Icing Severity, FIS) and a two-hour forecast from the newly developed Icing Product Alaska - Forecast (IPA-F). IPA-D was found to diagnose substantially less icing across the domain, resulting in more missed events but fewer false alarms; combining these two characteristics, the skill of IPA-D was similar to IPA-F and FIP/FIS.
Weather: Atmospheric		Complete report evaluating "Ensemble Prediction of Oceanic Convective Hazards (EPOCH)"					X	X					The Federal Aviation Administration's (FAA's) Aviation Weather Research Program (AWRP) has overseen the development of the EPOCH capability, which is a global probabilistic forecast of convective weather hazardous to aviation with a focus over oceanic regions. This product was developed by AWRP's Convective Weather Product Development Team (CW PDT) at the National Center for Atmospheric Research (NCAR). Tasks are conducted in coordination with the FAA project lead and AWRP's Convective Weather PDT.

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Weather: Atmospheric		Complete "Offshore Precipitation Capability" assessment for the FAA	X	X							X	X	The FY2016 assessment of the Offshore Precipitation Capability (OPC), developed by MIT/Lincoln Labs, was conducted for the FAA. The product uses satellite and lightning data to produce a radar-like display of convection. The assessment found that the product behaved sufficiently different than radar to make it difficult to use in an operational context. A re-assessment was performed in FY2020 after significant changes were made to the OPC algorithm. Objects in OPC were larger and more circular than seen in the corresponding satellite-based radar. The new algorithm performed better in the Gulf of Mexico than in the Atlantic, but still lagged considerably from ground-based radar, as expected. Another re-assessment was performed in FY2021; this version of OPC used satellite-based lightning instead of a ground-based network. The new version with the satellite lightning slightly outperformed the previous version using ground-based lightning, except over the northern Atlantic region.
Weather: Atmospheric		Complete report evaluating "Graphical Turbulence Guidance - Global Version"							X	X			In support of the World Area Forecast System (WAFS) global turbulence forecast product, the Graphical Turbulence Guidance (GTG) algorithm was extended from RAP-based product from coverage over the United States (to be exact, CONUS) to a GFS-based global domain. The assessment of this global version of GTG (GTG-G) was compared against the operational WAFS forecast and, where they intersect, the RAP-based forecast (GTG3). GTG-G outperformed the operational WAFS forecast by reducing the number of false alarms without increasing the number of missed events. GTG-G also outperformed GTG3 over the United States. With the GFS upgrade in Spring 2021, GTG-G is included in the standard Unified Post Processor output and is included in the official WAFS global turbulence forecast.
Weather: Atmospheric	**FY16-17**: Cumulative number of major tests and evaluations of numerical weather prediction forecast system components to inform decisions for NWS operational systems **FY18-20**: Annual number of reports documenting results of major tests and evaluations of numerical weather prediction forecast system components to inform decisions for NWS operational systems		31	31	36	37	5	5	3	3	2	2	The multi-agency Developmental Testbed Center conducts major tests and evaluations of improvements to numerical weather prediction (NWP) forecast system components provided by the NWP research and operational communities. These tests and evaluations are critical for selecting proposed changes that need to be transitioned to operational centers. For example, DTC tests and evaluations will be critical for selection of the optimal physics packages, data assimilation strategies, and ensemble configurations used in the Hurricane Weather Research and Forecast (HWRF) model, the Rapid Update Cycle (RAP) model, and by the Next-Generation Global Prediction System (NGGPS).
Make Forecasts Better		Complete report on baseline asssessment of the performance of physics suites at different model resolutions.									X	X	Results presented on findings of testing that will provide a baseline assessment of the performance of several physics suites at different model resolutions. Physics suites already available in the Common Community Physics Package (CCPP) framework will be considered for this evaluation with future suites (e.g. HWT, HWRF) added as they become available.
Weather: Atmospheric		Complete evaluations using the High Resolution Rapid Refresh Ensemble (HRRRE) to address model uncertainty through stochastic parameter perturbations.					X	X					For the purpose of designing a unified storm-scale ensemble forecasting system, the utilization of a single dynamic core with a single physics suite and stochastic approaches would be beneficial to the use of computing resources. The evaluations will attempt to find realistic approaches to represent sources of model uncertainty in a single-dycore ensemble system. Using the HRRR-based ensemble (HRRRE), tests will be conducted of an alternative option for creating desirable spread and reliability by perturbing the members stochastically.
Weather: Atmospheric		Release next version (v4.0a) of the Hurricane Weather Research and Forecasting (HWRF) model to the research and development community							X	X			The HWRF is an operational modeling system run by NOAA's National Center for Environmental Prediction (NCEP) to generate numerical guidance for topical cyclone forecasting worldwide. This public release will contain the end-to-end HWRF modeling, including the WRF atmospheric model, the Princeton Ocean Model, the HWRF coupler, the WRF Preprocessing System (WPS), the Gridpoint Statistical Interpolation (GSI) data assimilation system, the Unified Post Processor (UPP), the GFDL Vortex Tracker, and all necessary libraries and scripts to run the system in a number of supported platforms. This release does not include a few aspects of the operational HWRF, such as the HYCOM ocean model and the HWRF high-resolution dual ensemble capability. This release enables researchers and developers of HWRF to run, develop, and contribute to the operational HWRF system. This release will contain the following capabilities transitioned with DTC contribution: upgrades to the cloud overlap specification in the radiation parameterization, inclusion of SFMR and GIV-TDR data in the initial conditions, and incorporation of dropsonde drift in the DA.
Modeling: Integrated & Improved	Annual number of retrospective multi-week experiments of the atmospheric Flow-following finite-volume Icosahedral Model (FIM) to support development of the National Multi-Model Ensemble (NMME) which will be implemented in the NWS operational suite of models.		20	20									FIM began producing real-time forecasts based on initial conditions from NCEP's Global Forecast System in 2009. Since then, the FIM has been substantially upgraded both in its numerical procedures and in its use of the latest operational version of the GFS. Moreover, an icosahedral version of the ocean model HYCOM (called i-HYCOM) has been constructed and coupled to FIM. Model development requires assessments with objective information verifying the improvement of new forecast software vs current models. Retrospective cases can be verified using observation systems deployed. Retrospective experiments of FIM are necessary to determine which, if any, components are best suited for development of the National Multi-Model Ensemble (NMME) for subseasonal weather forecasts.

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Modeling: Integrated & Improved		Complete evaluation of the NMME subseasonal forecast performance out through week 4	X	X									The preliminary results from the multi-year hindcast experiments of global FIM-iHYCOM coupled model show it has comparable skills comparing the operational NCEP Climate Forecast System Version 2 (CFSv2). Due to its unique design in numerics, FIM-iHYCOM would be a great addtion to model diversity and model ensemble in NMME. This evaluation he performance of the NMME is being evaluated out to 4 weeks. The goal of the NMME (National Multi-Model Ensemble) expansion task is to evaluate and establish the prediction capabilities of high-impact weather extremes out to several months by leveraging and enhancing the existing NMME system and data.
Modeling: Integrated & Improved		Determine if FIM-iHYCOM coupled model will be a member of the NWS NMME providing subseasonal forecasts	X	X									NWS/NCEP/Climate Prediction Center has not yet decided if the coupled FIM-iHYCOM model results will contribute to the National Multi-Model Ensemble (NMME) which will run at NWS. Both FIM and HYCOM use a unique dycore structure (unstructured horizontal grid and hybrid vertical grid), quite different from the rest of NMME models, which would make it a very attractive ensemble member. The NMME aims to improve operational forecast skill on intraseasonal to interannual time scales and to provide more information about forecast uncertainty.
Modeling: Integrated & Improved	Annual number of 7-day parallel tests of experimental High Resolution Rapid Refresh (HRRR) model upgrades at 3-km for future incorporation into NWS/NCEP suite of operational models		5	5	5	5							Real-time tests comparing the High Resolution Rapid Refresh increase in skill with the Rapid Refresh model. These assessments are used to validate the HRRR using observations and provide feedback on the HRRR skill.
Modeling: Integrated & Improved		Implement HRRRv2 into NWS/NCEP operations	X	X									High Resolution Rapid Refresh Model v.2 was implemented into NCEP suite of operational models on August 23, 2016.
Modeling: Integrated & Improved		Ready HRRRv3 model code handoff to NWS/EMC in FY17Q4.			X	X							High Resolution Rapid Refresh Model v.3 was implemented into NCEP suite of operational models on July 12, 2018.
Modeling: Integrated & Improved	Cumulative improvement in accuracy of wind forecasts (speed,direction,timing, amplitude, duration) to optimize energy generation from wind		4%	4%	5%	5%	6%	6%					The skill of a forecast is measured by the error, most often by the root mean square error (RMSE). The RMSE is a standard term in statistics that measures the differences between values predicted by a model and the values actually observed. Improvements to the RAP and HRRR models specifically for wind energy generation are expected to reduce the forecast error and increase wind forecast accuracy. This will assist the renewable energy industry to be more effective and efficient.
Weather: Atmospheric		Complete Wind Forecast Improvement Project 2 (WFIP2) report and submit to U.S. Department of Energy					X	X					WFIP2 is a public-private partnership effort led by the U.S. Department of Energy and National Oceanic and Atmospheric Administration's Earth System Reserach Laboratory. On March 31, 2017, the Wind Forecast Improvement Project 2 (WFIP-2) wrapped up 18 months of collecting atmospheric observations in the Columbia River Gorge that will be used to improve wind forecasts in areas of complex terrain. The project successfully leveraged resources, instruments, and researchers across all Earth System Research Laboratory (ESRL) Divisions, the Air Resources Laboratory Field Research Division, other federal agencies, private companies, and universities to collect an unprecedented and valuable dataset that will pay off for years to come.
Make Forecasts Better	Annual number of retrospective runs using the HRRRv4 model for the Wind Forecast Improvement Project 2 (WFIP-2) time period.										2	2	Conducting retrospective runs of the Wind Forecast Improvement Project 2 (WFIP-2) timeframe (October 2015-March 2017) provides a comparison to evaluate how well the changes made to the HRRRv4 model have improved the wind turbine-height wind forecasts in the complex terrain of the WFIP-2 domain (Columbia River Gorge and Columbia Basin in eastern Washington and Oregon)
Make Forecasts Better		Complete a 10-day spring and 10-day fall reforecast over the Wind Forecast Improvement Project-2 field campaign time period using the HRRRv4 model.									X	X	This milestone contributes to the performance measure "Annual number of retrospective runs using the HRRRv4 model for the Wind Forecast Improvement Project 2 time period."
Modeling: Integrated & Improved	Cumulative improvement in surface solar radiation forecast accuracy by 20% in the developmental High Resolution Rapid Refresh (HRRR) v4 model.								20%	20%			The energy community requires forecasts of the anticipated solar radiation at the surface and wind speeds at 100m above the surface in order to optimatlly include renewable energy derived from these sources with more traiditional forms of energy. Because solar radiation and wind are quite variable, the energy community relies heavily on numberical weather prediction models such as the High Resolution Rapid Refresh (HRRR) model to forecast these variables and enable their energy resources management planning. The operational version of the HRRR v3, and previous versions before it, have significant errors in the solar radiation at the surface due to inadequacies in cloud properties within the model. The Atmospheric Science in Renewable Energy program is focusing effort on improving the accuracy of this forecast, which will benefit the energy community.

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Modeling: Integrated & Improved	Number of 1-week retrospective tests of the North American Rapid Refresh ensemble (NARRE) to improve operational charaterization of forecast uncertainty.		2	2									The North American Rapid Refresh Ensemble (NARRE)-Time Lagged improvements provide a foundation for a new 3-kim high resolution rapid refresh ensemble (HRRR-TLE) that employs a stochastic physics approach rather than using multiple models and physics components. The NARRE tests were concluded in March 2016 and the research results will be presented in a manuscript to be submitted for journal publication by September 30, 2016. NCEP/EMC may be interested in adding the stochastic physics package to the current SREF. Tests of the HRRR-Time Lagged Ensemble (HRRR-TLE) have produce alpha versions of 35 products. A direct outcome of the project will be improved ensemble hazard guidance products for operational forecasters that will reduce the ensemble information overload problem and enable a more efficient and accurate characterization of forecast uncertainty. The goal is for the high-resolution ensemble to be implemented at NWS/NCEP by end of FY18Q4.
Modeling: Integrated & Improved	Cumulative number of model components that are re-coded for fine-grain computing systems (Graphics Processing units and Many Integrated Cores) to run faster and better than on current CPU systems.		5	6	7	7							OAR is methodically translating core functions of community and experimental models to run on reduced cost/performance enhanced processors based on 3-D gaming technologies (Graphical Processor Units) and Many Integrated Core (MIC) processores. This activity will lead to savings in future high performance computer puchases. This involves a rigorous process of re-hosting software to a new platform and verification testing to track model skill. In FY2016, GSL's Advanced Technologies group completed the re-coding of the Non-Hydrostatic Icosahedral Model (NIM) for fine-grain computing to increase the cumulative number of model components re-coded from 5 to 6.
Modeling: Improve quantitative prediction		Employ Machine Learning to demonstrate ability to use latest Advanced Baseline Imager (ABI) data from GOES-16 to generate soil moisture products for assimilation in weather forecast models.							X	deferred to 2020			By employing a Machine Learning algorithm, the large sets of observations can be used to make the initial soil moisture field in the Rapid Refresh/High Resolution Rapid Refresh (RAP/HRRR) model systems more efficient and potentially more accurate. Machine Learning capabilities will be used to produce high frequency (hourly) soil moisture (temperature) fields for HRRR model initialization. (Project canceled in FY20 due to lack of funding).
Make Forecasts Better		Develop a Machine Learned Tropical Cyclone Identification tool									X	X	By employing a Machine Learning algorithm, this experimental tool will be used to analyze and extract the most important information from GOES satellite observations to be used in data assimilation systems for numerical weather prediction models. This initial work focused on feature or object detection to identify typhoons or hurricanes.
Data: Environmental Data	Annual number of stations/unique sites (by lattitude/longitude points) added to feed observations data to developmental MADIS (Meteorological Assimilation Data Ingest System) before being transferred to NWS MADIS to improve accuracy of operational weather prediction models		500	3395	20000	15000	1900	1900					GSL will continue to add new networks of unique sites (formerly referred to as stations) providing atmospheric observations such as mobile surface obs, radiometers, sodars, new mesonet networks, flood warning stations, aircraft-based observations, etc. to the developmental MADIS system for transition to NWS operational MADIS. At the end of March 2018, developmental MADIS contains approximately 80,000 unique ground-reporting sites and 727,000 aircraft-reporting sites. By the end of FY18, developmental MADIS will be the front-end ingesting and processing observations directly from over 100,000 unique sites. Transitioning these unique reporting sites to the operational MADIS at NWS will be completed FY2019-20.
Data: Management		Attain a total of 100,000 unique sites (by latitude/longitude points) feeding observations data to developmental Meteorological Assimilation Data Ingest System (MADIS) by end of FY2018					X	X					This milestone appears in the NOAA FY18 Congressional Submission Budget under Deliverable Highlights: Laboratories & Cooperative Institutes PPA: A total of 100,000 stations feeding observations data to the Meteorological Assimilation Data Ingest System (MADIS). As of March 31, 2018, developmental MADIS is on track to exceed 100,000 stations (unique sites by lat/lon points) by end of September 2018.
Stakeholder: Communicating science	Cumulative number of domestic and international Science On a Sphere® (SOS) systems installed in science museums and also featured in traveling exhibits for education through visualization of science data		145	149	155	158	165	168	170	170	175	176	Science On a Sphere, SOS, was developed by NOAA/GSL as a means to share the science of NOAA and other partners with a broad, general audience. This is achieved through the installation of SOS in science museums, visitor's centers, universities, schools, and many other facilities worldwide. SOS also is a traveling exhibit supporting many science and technology conferences.
Stakeholder: Communicating science		Complete and release Science On a Sphere® v5.3 software to customers					X	X					SOS v5.3 software application for customers will provide improved software security, better playback of videos, featured and timely datasets that automatically sync to all sites, better installation process, and a new high resolution library.
Stakeholder: Communicating science		Install domestic and international Science on a Sphere systems for education exhibits in science museums and other venues for a cumulative total of 185 systems by end of FY2022					X	X	X	X	X	X	This milestone appears in the NOAA FY18 Congressional Submission Budget under Schedule and Milestone Highlights: FY2018-2022. At the end of FY2020, there were 177 installations that had been completed.

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Make Forecasts Better	Annual number of code packages (developed, evaluated and tested) for the Hazard Services components checked into the NWS AWIPS Baseline Repository										2	1	AWIPS applications WarnGen, Graphical Hazards Generator (GHG), and RiverPro assist forecasters to produce hazard watch, warning, and advisory products and deliver services. These applications are critical to NWS Weather Forecast Office (WFO) operations, demanding high performance and dependability at times of high usage. While capable, the applications are difficult to operate, maintain, and adapt to the evolving digital forecast paradigm; new tools are needed to meet these operational challenges. The goal of the Hazard Services project is to unify the three current applications into one improved hazardous weather forecast application and add new functionalities to enable the public and NWS partners to make timelier and better-informed decisions in advance of expected hazards. GSD will develop, evaluate and test the multiple code packages comprisingf the Hazard Services application being rolled out incrementally through FY2023 to address hazards from Winter Weather, Long Duration Marine, Non-precipitation, Converctive, Short Duration Marine, Tropical, Fire Weather and other weather events.
Make Forecasts Better		Complete code modifications to the Boulder Weather Forecast Office's Probabilistic Snow Accumulation product to better meet the needs of decision makers at Denver International Airport.									X	X	GSL, NWS WFO Boulder, NCAR, and Denver International Airport operations managers collaborated to evaluate the performance of winter weather forecast ensembles in an Impact-based Decision Support Services (IDSS) effort.
Make Forecasts Better		Conduct Functional Forcaster Assessment Tests and System Forecaster Assessment Tests of Hazard Services application components									X	X	This milestone contribute to "Annual number of code packages (developed, evaluated and tested) for the Hazard Services components checked into the NWS AWIPS Baseline Repository". Functional Forecast Assessment Tests (FFATs) led by GSL provide a way for NWS WFO forecasters to learn new Hazard Services watch/warning/advisory applications and also provide feedback to the GSL developers so that changes can be made to make the applications more effective and user friendly.