NWS Science and Technology Roadmap

Data Assimilation and Modeling

Team Composition

- Steve Lord, NWS—Team Leader
- Bill Lapenta, NWS—Contributor
- Roland Draxler, ARL—Contributor
- Gopalakrishnan, AOML—Contributor
- Steve Weygandt, ESRL—Contributor
- Sreela Nandi, OST—Contributor
- Nelson Seaman, OST—Contributor
- Fred Toepfer, OST —Contributor

Vision/Benefits/Impacts

- **Focus Area Team Vision:**

  A transformed and continuously improving Operational Environmental Forecast System, serving the requirements of all internal/external customers for saving life and property and enhancing economic activity, and supported by relevant innovative research, a strategically redesigned code framework, and state of the art data assimilation and models.

- **Benefits**
  - Addresses national need for more accurate, timely and actionable Earth System forecasts, including: Atmosphere, Ocean, Land surface, Seasonal/interannual climate, Air quality and atmospheric chemistry, Space Weather, Links to Ecosystems
  - Estimates and communicates uncertainty: Ensemble based, Post processed probabilistic products
  - Supports "warn on forecast" capability: Excess capacity for situational forecasts; Sufficient resolution for severe weather applications (hurricane, tornadic storms, …)

- **Impacts:**
  - Reduce aviation-related delays and hazards
  - Enhance energy planning and efficiency of consumption
  - Reduce health impacts and deaths due to poor air quality
  - Mitigation of hurricane-related damage and loss of lives
  - Enhance efficiency of surface transportation (ocean and land)
  - Improve links to ecosystems
  - Reduce risk posed to communications systems by space weather events

Goals/Targets:
Customer Needs

Goal/Target	Outstanding Issues
Build a NOAA Environmental Modeling System (NEMS) for both operations and research, based on community software (e.g. Earth System Modeling Framework)	Software development and engineering for portability and meeting requirements Gain acceptance throughout modeling community and begin training Maintain software and import additional capabilities from research
Build fully consistent weather prediction capabilities from global → North American → convective resolving scales; linking to National Unified Operational Prediction Capability (NUOPC) across federal government	Develop/acquire and test dynamics/technologies for global grid models with uniform resolution and nesting capability Develop/acquire and test dynamics and physics to ensure forecast skill is sufficient for "Warn on Forecast" (WoF) goal

Goals/Targets:
Customer Needs

Goal/Target	Outstanding Issues
Construct and implement accurate, e.g. ensemble-based probabilistic guidance for all members of the NCEP Production Suite	Develop user-oriented products in collaboration w/customers Computing resources Ensemble generation and system diversity compatible w/DA
Build, implement and operate advanced data assimilation system for global, regional, hurricane and other systems	Develop and test case-specific flow-dependent error covariance statistics in four-dimensional DA techniques; Timely observations delivery; Dropouts; unknown error sources in data assimilation
2016: < 10 km/91 L global system < 3 km/100L regional system ~ 1 km/50L local system 2025: local “on-demand, WoF” system	COMPUTER resources and scientific development (physics, grid configuration technology)

Goals/Targets:

Emerging Science & Technology

Goal	Outstanding Issues
Build a NOAA Environmental Modeling System (NEMS) for both operations and research, based on community software (e.g Earth System Modeling Framework)	Permanently supported human resources for external collaborations and future augmentations, e.g. import additional capabilities from research (R2O) and support operational systems to the research community (O2R); Software development and engineering for portability and meeting requirements; Gain acceptance throughout modeling community and begin training
Build fully consistent weather prediction capabilities from global → North American → convective resolving scales; linking to NUOPC across federal government	Develop/acquire and test to ensure forecast skill is sufficient for "Warn on Forecast"; Computing resources for testing, implementation and operational execution
Construct and implement accurate, e.g. ensemble-based probabilistic guidance for all members of the NCEP Production Suite	Computer resources; development and collaboration human resources; maintenance personnel; development of ensemble generation techniques and system diversity

Goals/Targets:

Emerging Science & Technology

Goal	Outstanding Issues
Build, implement and operate advanced hybrid data assimilation system for global, regional, hurricane and other systems	Computing resources, development and collaboration human resources; maintenance personnel; Develop and test four-dimensional DA techniques; Dropouts; unknown error sources in data assimilation
Prepare for, implement and operate software for advanced NPOESS & GOES-R instruments, next-generation radar, aircraft and surface observations	Computing resources, development and collaboration human resources; maintenance personnel; Timely observations delivery; Data utilization and QC
Advance tropical cyclone intensity and track forecasts by 50% by 2019	Operational computing resources; human resources for transition of community research into operations and maintenance of complex coupled system and multi-model ensemble
2016: < 10 km/91 L global system < 3 km/100L regional system ~ 1 km/50L local system	Computing resources, human resources for scientific development and collaboration; maintenance personnel

Key Information Gaps

Gap	Solution Alternative	Impact
1. Inadequate DAM resolution hinders predictive skill	1.1 Increase R&D for hi-res. physics, 4-D DA methods, and ingest of new data types	Enables 10-km global / 1-km regional resolution and better accuracy for all weather, ocean & climate DAM activities, ops. and res.
2. Incompatible dynamics at global → regional scales feeds forecast error growth	2.1 Acquire/develop global and regional grid model capabilities with consistent dynamics, physics and nesting	Enables accelerated implementation of advanced interscale-compatible software capabilities, more accurate forecasts and uncertainty predictions.
3. Current 3-D DA techniques inadequate to support DAM activities in NPOESS era; observations planning and impacts insufficient	3.1 R&D on 4-D hybrid data assimilation techniques with case-specific flow-dependent error covariance statistics; execute program for OSEs and OSSEs	Enables implementation of advanced ensemble DA software capabilities, quality control techniques and science for using new data sources (NPOESS satellite, radar, aircraft, surface) and planning for future generation instruments

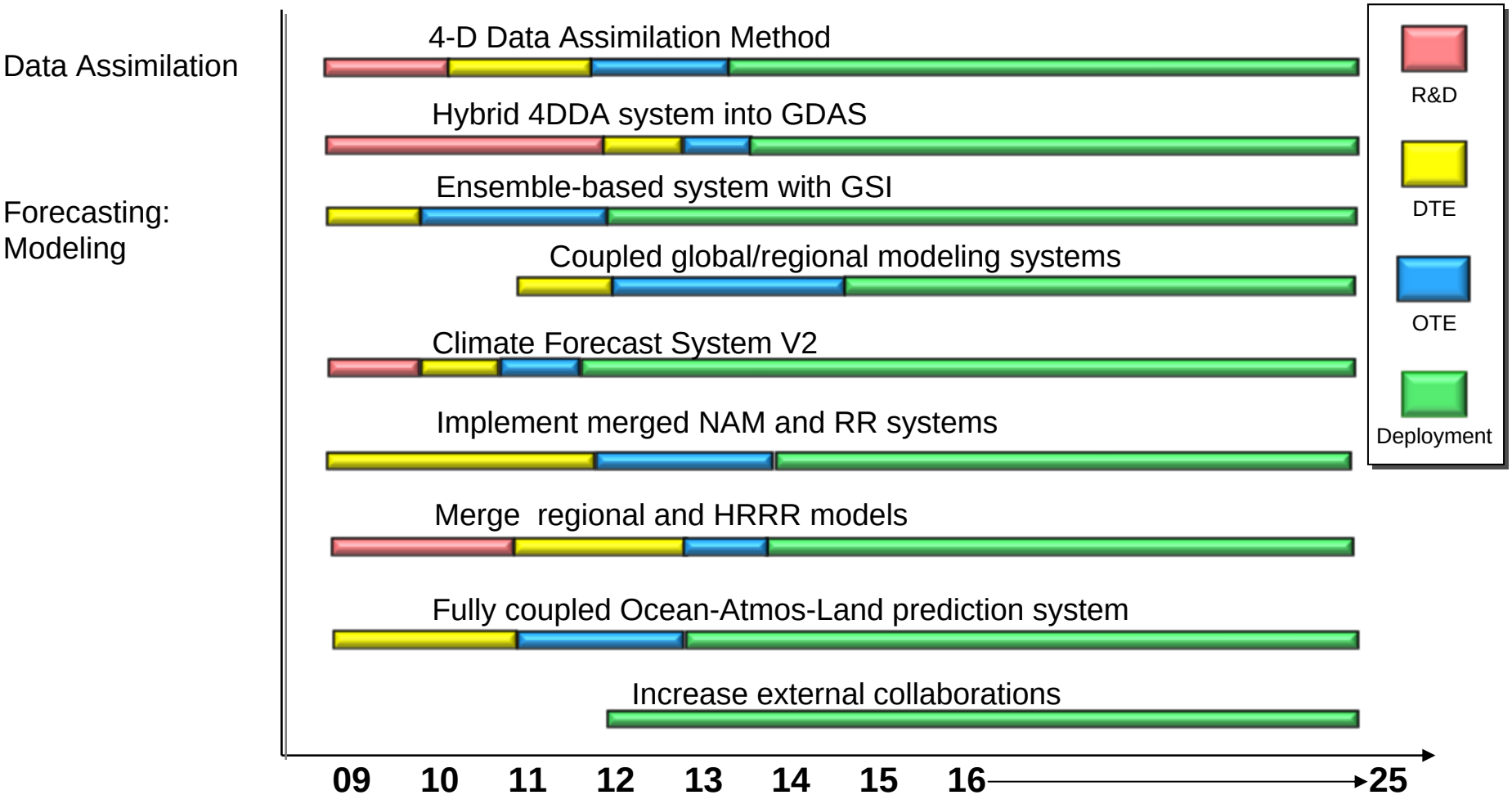
Key Information Gaps

Gap	Solution Alternative	Impact
4. Inadequate rate of external research advancements flowing into operations codes (R2O), including insufficient leveraging of investments by NOAA partners.	4.1 Accelerate transfer of ops codes/frameworks to res community (O2R) and R2O; increase NWS-OAR and tri-agency collab-orations; Visiting Scientist Program	Facilitates relevant research and increases pot- ential number of improvements acquired from external community; accelerates incorporation and testing of new science and technologies into operations; enables training for new users.
5. Insufficient real-time access to DAM outputs: growing volumes, rising use	5.1 NOMADS → 4d-data cube (WIDB)	Enables users to choose their information and selectively download it
6. Legacy "stovepipe" environmental model architectures	6.1 Develop integrated/coupled modeling systems in ESMF	Enables interactively coupled DAM systems, including integrated ensembles, with better accuracy for all wx, ocean, climate forecasts
Inadequate probabilistic information	Characterize pdf with ensembles: in Post Processing Roadmap	

Research Needs and Opportunities

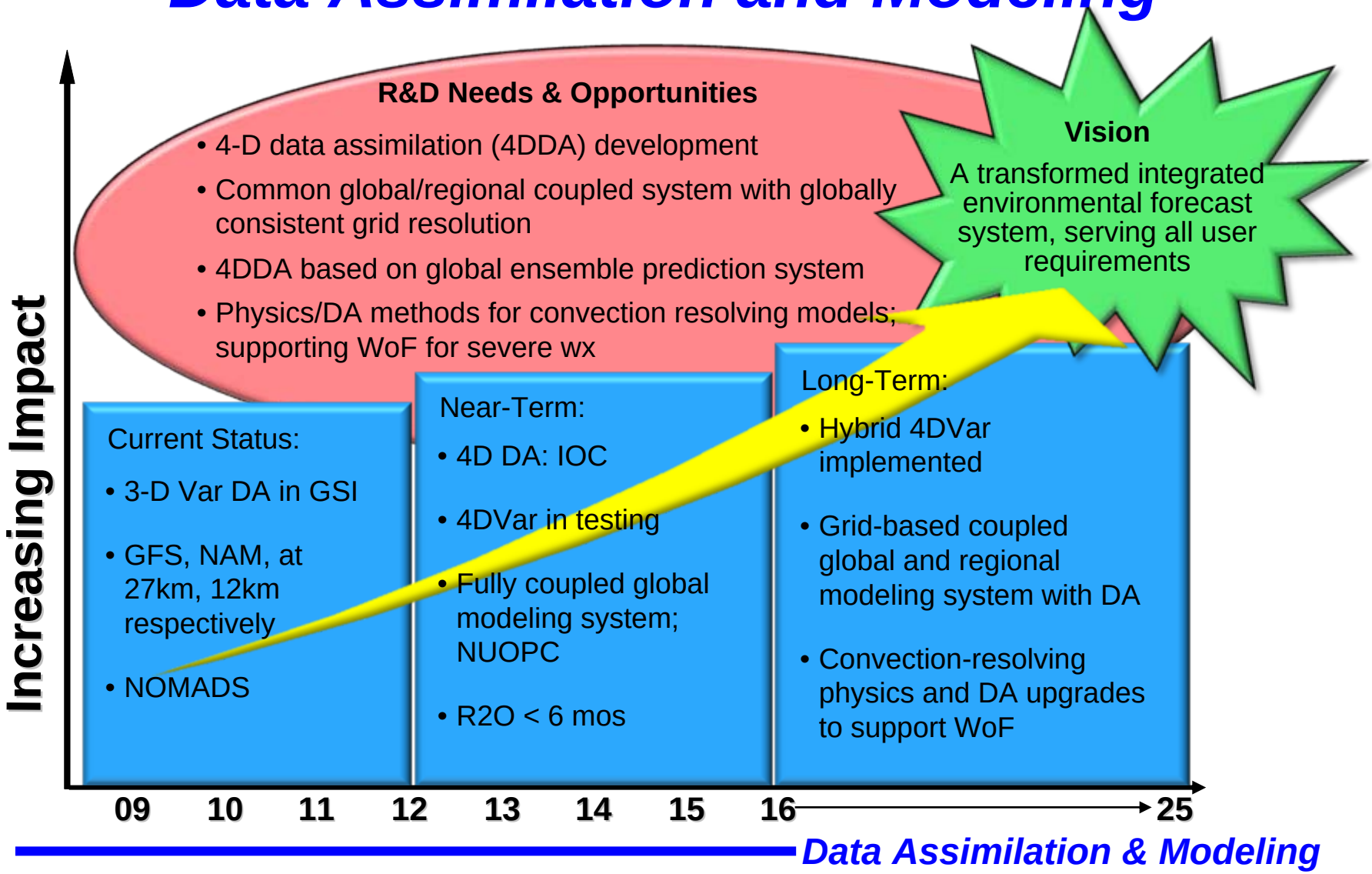
- **Short-term**
  - 4-D data assimilation development
  - Global grid models with globally consistent resolution
  - Case-specific flow-dependent error covariance statistics for 4-D DA
- **Long-term**
  - Mitigate explosive growth in observations available for data assimilation: NPOESS, GOES-R, next-generation radar data exploitation
  - Common global/regional coupled grid system
  - 4-D DA based on information from global ensemble prediction system
- **Additional outstanding research needed**
  - Physics and DA methods for convection resolving (Dx<4 km) regional models supporting warn-on-forecast for severe wx

DA and Modeling
Alternative Solution Advances



Data Assimilation & Modeling

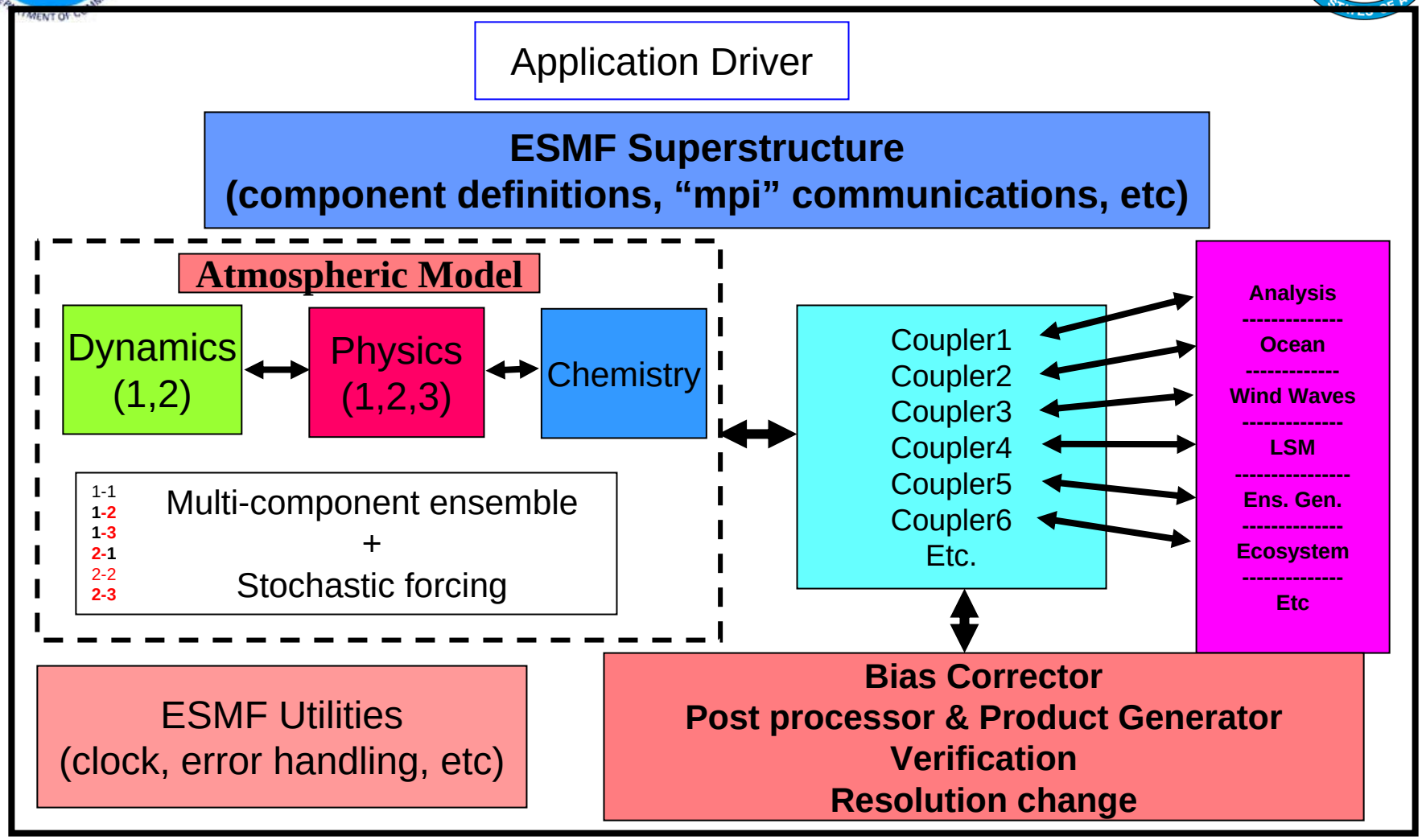
Focus Area Team Summary: Data Assimilation and Modeling



NWS Science and Technology Roadmap

Data Assimilation and Modeling Additional Information

NOAA Environmental Modeling System (NEMS)
(uses standard ESMF compliant software)



* Earth System Modeling Framework (NCAR/CISL, NASA/GMAO, Navy (NRL), NCEP/EMC), NOAA/GFDL

2, 3 etc: NCEP supported thru NUOPC, NASA, NCAR or NOAA institutional commitments

Components are: Dynamics (spectral, FV, NMM, FIM, ARW, FISL, COAMPS…)/Physics (GFS, NRL, NCAR, GMAO, ESRL…)

Target Performance Measures: DA and Modeling

Proposed	Current (2009)	FY 2016 Target Example	FY 2025 Target Example
Global Forecast Accuracy:			
ETS for precip	~0.25 @ 2 days	0.30 @ 2 days	0.30 @ 3 days
NH and SH 500-hPa anomaly correlations	~0.85 @ 5 days	0.90 @ 5 days	0.90 @ 7 days
Hurricane Forecast Accuracy:			
Intensity error	14 kts error @ 48 h	7 kts error @ 48 h	7 kts error @ 72-96 h
Regional Fcst Accuracy:			
ETS for precip	~0.25 @ 2 days	0.30 @ 2 days	0.40 @ 2 days
Tornado warning avg. lead-time → warn on fcst	~20 min.	~25 min	~40 min