NOAA
Hurricane Forecast Improvement Project

Bob Gall

NOAA HFIP Purpose

- *Unify the NOAA effort*
- *Provide the basis for NOAA co-leading with NSF, Navy and others a national effort to:*
  - *Define and coordinate National Hurricane Research Agenda*
  - *Apply new science and technology to the hurricane and storm surge warning and forecast problem*
- *Significantly improve guidance to NHC for hurricane track and intensity forecasts*

Significantly improve NOAA's forecast services
for tropical storms and hurricanes
through
improved hurricane forecast science and technology

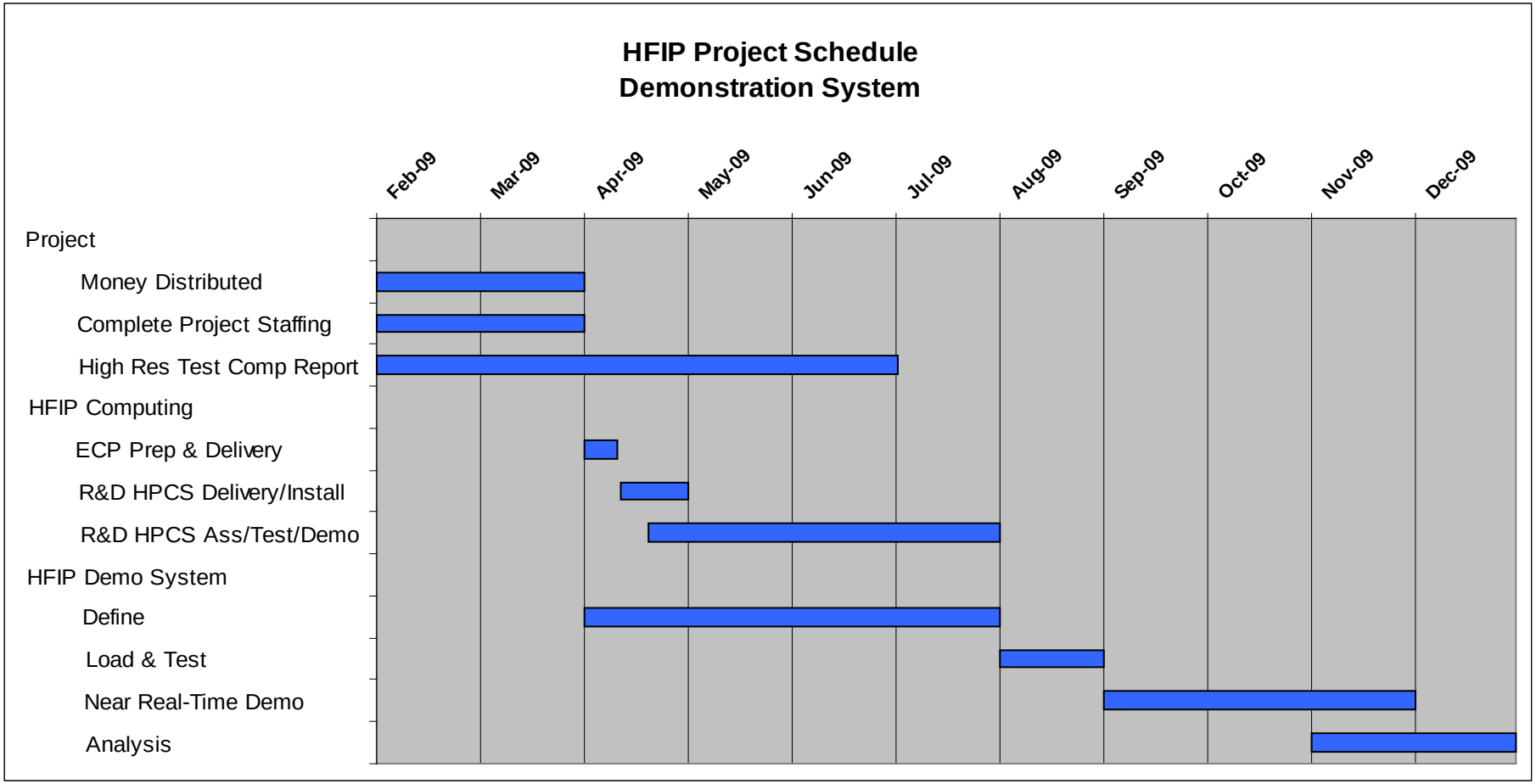
Motivation

- NOAA has been charged by OMB, and Congress, to substantially improve NOAA's Hurricane Forecast and Warning Performance
  - 20% within 5 years
  - 50% overall goal
- Specific 10 year goals:
  - Reduce average track error by 50% for Days 1 through 5.
  - Reduce average intensity error by 50% for Days 1 through 5.
  - Increase the probability of detection (POD) for rapid intensity change to 90% at Day 1 decreasing linearly to 60% at Day 5, and decrease the false alarm ratio (FAR) for rapid intensity change to 10% for Day 1 increasing linearly to 30% at Day 5.
  - Extend the lead time for hurricane forecasts out to Day 7.

NOAA HFIP Vision

- **A National Hurricane Forecast System** (NHFS) focused on providing accurate and reliable forecast guidance to NHC out to 5-7 days
  - Multi-component global and storm scale atmospheric, wave and oceanic modeling system -- to accurately and reliably model both the hurricane and intensity and the environmental controls on storm evolution over time
  - Managed ensemble diversity to:
    - Provide ‘Most Probable” forecast
    - Quantify, bound and reduce forecast uncertainty
  - Optimal use of existing and planned observing systems
  - Advanced forecast techniques for forecaster use

High Level Performance/Project Schedule



HFIP Teams

1.	*Global Modeling Development Team*	**Stan Benjamin (ESRL)**
2.	*Regional Model Development Team*	**Morris Bender (GFDL)**
3.	*Hurricane Data Assimilation Team*	**Steve Lord (EMC)**
4.	*Non-hydro Meso. Model Physics Team*	**Young Kwon (EMC)**
5.	*Global Model Physics Team*	**John Brown (ESRL)**
6.	*Verification Team*	**Tim Marchok (GFDL)**
7.	*Model Diagnostics Team*	**Mark DeMaria (NESDIS)**
8.	*Post Processing / Applic. Develop. Team*	**Ed Rappaport (NHC)**
9.	*Ensemble Systems Development Team*	**Carolyn Reynolds (NRL)**
10.	*Hurricane Observations Team*	**Sim Aberson (HRD** **Nick Shay (RSMAS)**
11.	*Coupled Ocean/Wave model Team*	**Hendrik Tolman (EMC)**

Design Issues

- Global Modeling System
- “hurricane” data assimilation
  - Technical Approach
  - Data
- Physics Package/Resolution
- Ocean Interaction
- Ensemble System
  - Global
  - Regional
- Business Case Development

Organization HFIP Missions

- ***AOML***
  Stream 2 regional model and data assimilation development. Physics package development
- ***EMC***
  Stream 1 regional and global model development. Physics package development. HWRF operational system maintenance.
- ***ESRL***
  Stream 2 global model, ensemble system development. Physics package development
- ***NRL***
  Stream 2 Ensemble system development, physics package development.
- ***GFDL***
  Stream 2 global model development. Stream 1 ocean coupling
- ***DTC***
  HFIP research code repository maintenance. Verification system development.
- ***NHC***
  Lead post processing development.
- ***AOC***
  HFIP related aircraft observations
- ***URI***
  Stream 1 ocean coupling
- ***NESDIS/CIRA***
  Verification toolkit development. Ensemble post processing applications

Two Stream Approach

HFIP has a two stream development plan which includes:

- Stream 1: Development and maintenance of the operational hurricane model system.
- Stream 2: Development of a Demonstration System that will go beyond what is currently available operationally using various computer resources including the recently acquired HFIP HPCC computers at Boulder and Gaithersburg.

Two Stream Development

- **Stream 1:** Operational system
  - Current plan outlined by the operational centers
  - Uses currently projected operational computing capability
  - ***(the sure thing)***
- **Stream 2: Development**
  - Assumes possibility of acquiring 3-5 times the computing beyond what is currently projected.
  - Development in this stream is to demonstrate added value of increased computing in operations.
  - **(possible step function improvements)**
- **Stream 2: Demonstration System:** We will run a demonstration forecast system with higher resolution/more ensemble members than is available in operations.
  - Using dedicated HFIP computers (ESRL, TACC, Oak Ridge)
  - System would be improved each year based on new development and results from the previous season.
  - Would be run in real time -- results made available to NHC.
  - Transition of components of demo system to operations when benefits are verified

Demonstration Forecast System

- **HFIP will create a major dedicated computer resource where real-time (not operational) forecasts will be conducted each hurricane season.**
  - Other times of the year this system will be available for HFIP development
- **Since the system is dedicated we will be able to run forecasts that will not be possible for several on the operational systems**
  - Higher resolution
  - More ensemble members
  - More elaborate physics parameterizations
  - More elaborate data assimilation systems

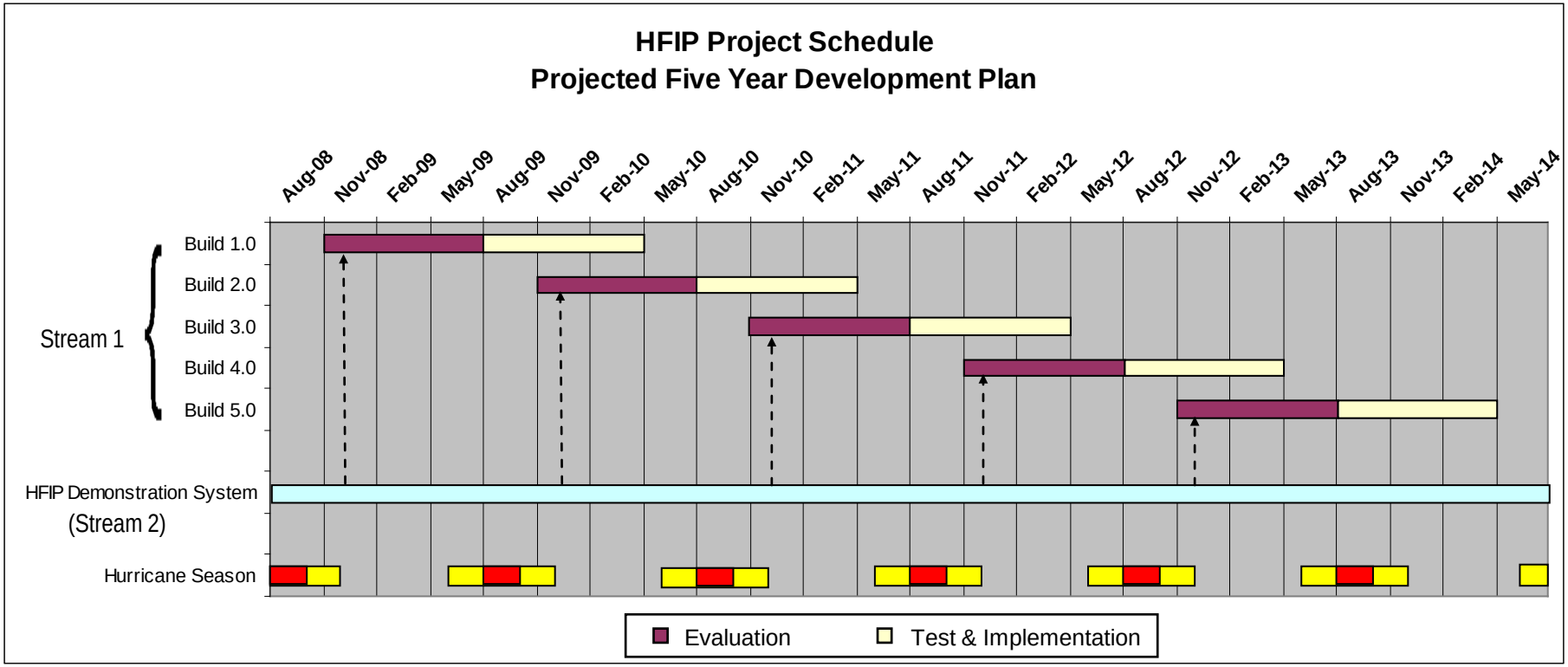
Hurricane Forecast System Comparisons: 2009 Season

Operational Model Suite	Demonstration System
• **Global model:** GFS T382 (~35km), 64 layers	• **Global Model:** FIM 15 km, 64 layers
• **Global ensemble:** GFS T126 (100km), 28 layers, 20 members (40 with NAEFS); FIM will be tested at 60km when ported	• **Global ensemble:** FIM 20km, 64 layers, 15 members (depends on available computing)
• **Regional model:** HWRF 9km, 69 levels, coupled ocean (POM)	• **Regional Model:** ARW 1km, 34 layers, 1-D ocean
• **Regional Ensemble:** 35-45km, 28-51 layers, multi-member ensemble (ARW, NMM, RSM, ETA) 21 members (non-hurricane model fixed domain)	• **Regional Ensemble:** 5-10km, up to 43 layers, multi-member ensemble (ARW, HWRF, COAMPS-TC, GFDL, MM5), 5 members
• **NHC Consensus Ensemble: Track (GFSI, EGRI, NGPI, GFMI, HWFI); Intensity (DHSP, LGEM, GHMI, HWFI, GFNI)**	
• **Data assimilation, Global:** GSI	• **Data assimilation global:** GSI
• **Data assimilation regional:** GSI	• **Data assimilation regional:** EnsKF (with Tail Doppler data when available)

Transition to Operations Implementation

- Transition to operations is accomplished through a movement of functionality from Development stream 2 to Stream 1
- Transition is dependent upon
  - Expected impact on operational stream 1 forecast performance
  - Available operational Computing
- Experimental operational demonstration of new functionality is maintained in Stream 2.

Schedule Development and Technology Transfer Plan



NOAA HFIP
Expected Out year Budgets

- Total Expected HFIP Budget in FY10 – FY13
  - $3M PAC for HPC
  - $20M ORF (Includes $6M in OAR Base)
- Additional research/operational computing in NOAA-wide HPC Initiative
- NOAA budget has assured that $13M in FY10 President's Budget

NWS Budget Breakdown Participating Organization

	AOML	EMC	ESRL	GFDL	NRL	NCAR/UNIV	NHC	AOC	PO	MDL	NESDIS	NOS/CSDL	Total
HWRF/SLOSH O&M	0	740	0	0	0	0	150	0	0	150	0	0	1040
NAEFS Transition	0	200	200	0	0	0	0	0	0	0	0	0	**400**
Total	**0**	**940**	**200**	**0**	**0**	**0**	**150**	**0**	**0**	**150**	**0**	**0**	**1440**
Stream 2													
Team 1 Global Model	0	130	200	100	100	0	0	0	0	0	0	0	530
Team 2 Regional Model	250	300	0	0	100	200	0	0	0	0	0	0	850
Real Time Evaluation	0	0	0	0	0	0	180	0	0	0	0	0	180
Team 9 Ensembles	175	200	150	0	250	0	0	0	0	0	0	0	775
Development code repository maint.	0	0	0	0	0	500	0	0	0	0	0	0	500
Demo system	200	180	200	0	150	0	0	0	0	0	0	0	730
Total	**625**	**810**	**550**	**100**	**600**	**700**	**180**	**0**	**0**	**0**	**0**	**0**	**3565**
General development													
Team 3 Assimilation	270	290	100	0	0	0	0	0	0	0	300	0	960
Team 4 Non-Hydro Phy	240	150	100	130	150	0	0	0	0	0	0	0	770
Team 5 Global Physics	0	150	180	100	100	0	0	0	0	0	0	0	530
Team 6 Verification	0	0	0	70	0	100	0	0	0	0	50	0	220
Team 7 Model Diag	200	0	0	0	0	0	0	0	0	0	100	0	300
Team 8 PPAD	135	0	0	0	0	0	500	0	0	0	0	0	635
Team 10 Obs	0	0	0	0	0	0	0	1500	0	0	0	0	1500
Team 11 Coupled Ocn (including Storm Surge)	150	1000	0	0	150	0	0	0	0	0	0	500	1800
Other													
Carribean RAOBS/fixig Gulf data bouys	0	0	0	0	0	0	0	0	850	0	0	0	850
DTC	0	0	200	0	0	400	0	0	0	0	0	0	600
Software Engineering	0	0	0	0	0	0	0	0	500	0	0	0	500
Hi res test	0	0	0	0	0	300	0	0	0	0	0	0	300
Hi res test	0	0	0	0	0	200	0	0	0	0	0	0	200
Project Office	0	0	0	0	0	0	0	0	650	0	0	0	650
NUOPC	0	0	0	0	0	0	0	0	520	0	0	0	520
Total	**995**	**1590**	**580**	**300**	**400**	**1000**	**500**	**1500**	**2520**	**0**	**450**	**500**	**10335**
Grand Total	**1620**	**3340**	**1330**	**400**	**1000**	**1700**	**830**	**1500**	**2520**	**150**	**450**	**500**	**15340**
Component before taxes in blue	**4040**												
AOML base budget	6000	0	0	0	0	0	0	0	0	0	0	0	6000
HFIP Computing	0	0	0	0	0	0	0	0	5700	0	0	0	5700
HFIP total	**7620**	**3340**	**1330**	**400**	**1000**	**1700**	**830**	**1500**	**8220**	**150**	**450**	**500**	**27040**

Budget by Development Topics

Topic	Budget
Stream 1: HWRF operations and maintenance	$1.4M
Stream 2: Global, regional models and their ensembles for the Demonstration System	$3.1M
General development (data assimilation, physics package, model products, and verification development)	$3.4M
Observations (Caribbean raobs, expendables, flight hours)	$2.4M
Ocean coupling including storm surge	$1.8M
HFIP code repository maintenance/community interactions	$1.4M
Software engineering for demo system	$0.6M
Project office	$1.2M
Total	**$15.3M**