



Navy/NRL Perspectives on JCSDA

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JCSDA Associated Director for the Navy

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*Marine Meteorology Division, Monterey, CA



Science, research and infrastructure development focused on a high-resolution, modular and flexible data assimilation (DA) systems that combines adjoint- and ensemble-based solution methods to best meet Navy needs. Ongoing emphasis is on developing effective assimilation strategies for satellite, conventional and observations of opportunity. Priorities also include observation impact assessment, developing diagnostics and verification metrics appropriate for DA, and microwave satellite sensor calibration and validation.

Marine Meteorology Division Strategic Thrusts

- Science, research and infrastructure development focused on high-resolution, modular and flexible data assimilation (DA) systems to best meet Navy needs
- Emphasis on developing effective assimilation strategies for satellite, conventional and special observations
- Priorities include observation impact assessment, uncertainty quantification, and satellite calibration/ validation and sensor requirements
- Partnerships are crucial as the complexity of the DA and NWP systems increases

Observations and Remote Sensing

Global Obs. System	New Sensors & Sats
Non-conventional	Commercial
SBEM Requirements	Verification

Naval Relevance: Applications and Impacts

Obs Impacts	Cal/Val & Monitoring
Uncertainty Estimation	OSE and OSSE
Diagnostics	Infrastructure

Data Assimilation Methods (Solvers)

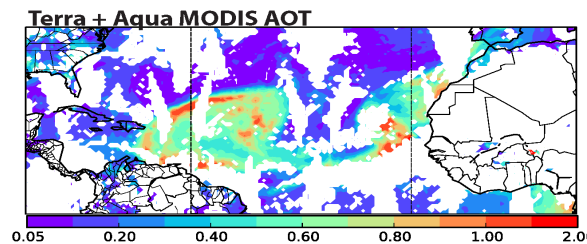
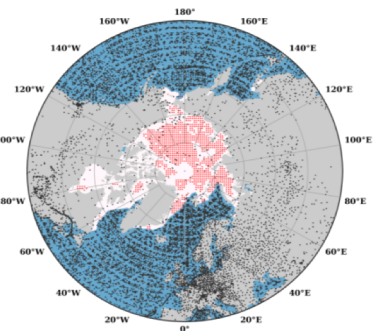
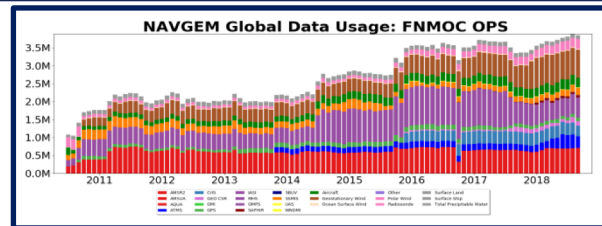
Coupled DA	NAVGEN
Ensembles & Adjoints	COAMPS
Clouds and Aerosols	NEPTUNE

Partnerships and Collaborations

JCSDA	NOAA, NASA, JPL
NCAR, Universities	ONR/DoD programs
Met Office, ECMWF	WMO programs

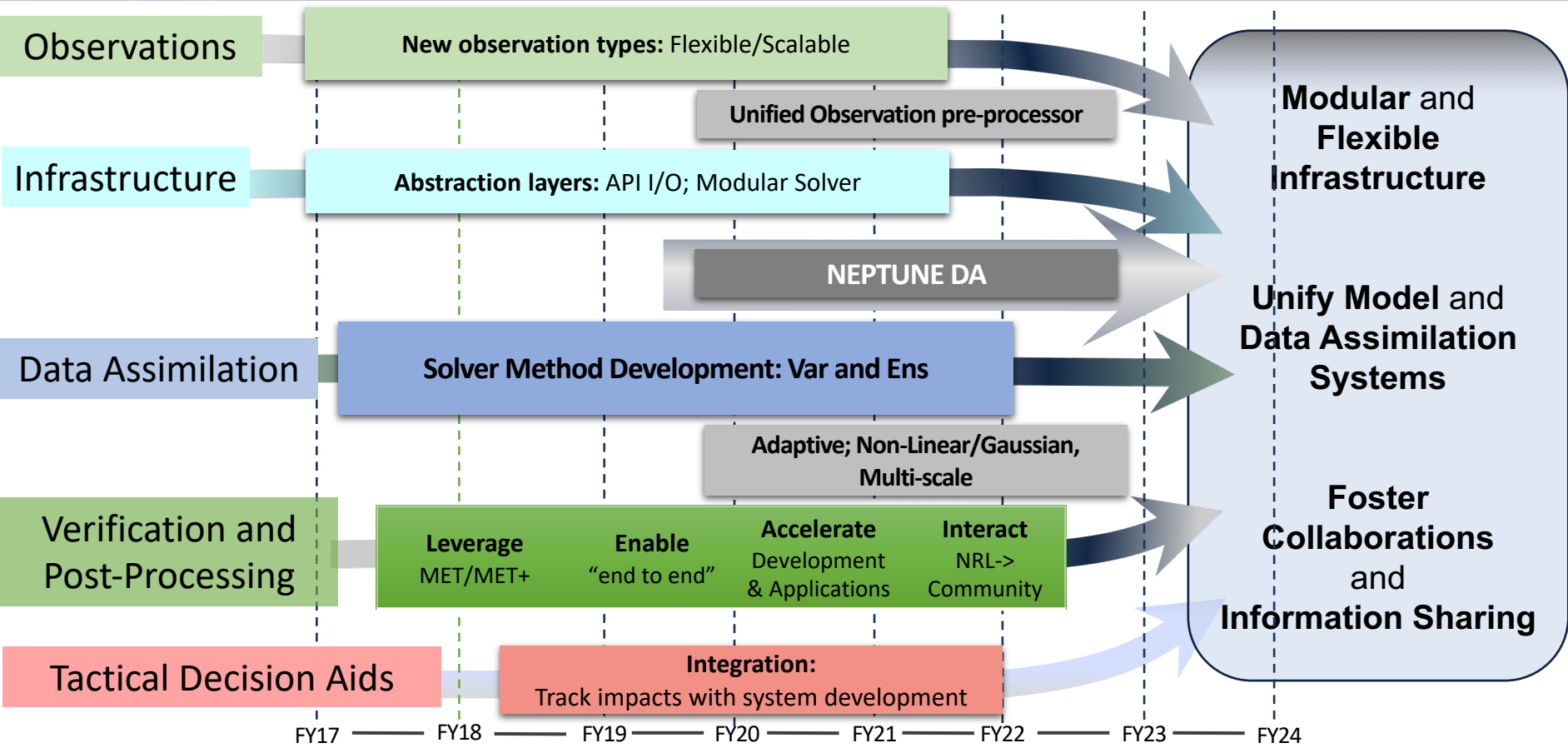
Summary of NRL Data Assimilation Capabilities

- Global (NAVGEM) Atmospheric DA: Hybrid 4DVar
- Navy ESPC – NAVGEM/HYCOM Coupled Global Atmosphere/Ocean DA: “Interface Solver”
- Global Middle Atmosphere DA: Hybrid 4DVar, LETKF
- Radar Data Assimilation: hourly 3DVar, EnKF, 4DVar
- All Sky DA (COAMPS): EnKF
- Ocean, Waves, Sea Ice DA – NCODA 3DVar & 2DVar; SWAN (4DVar)
- Coupled Regional Atmosphere/Ocean Data Assimilation: COAMPS/NCOM
- Aerosol Data Assimilation: 3DVar & EnKF
- Ensembles: Ensemble Transform (ET), LETKF, Perturbed Obs
- NEPTUNE DA with JEDI



Atmospheric DA Roadmap

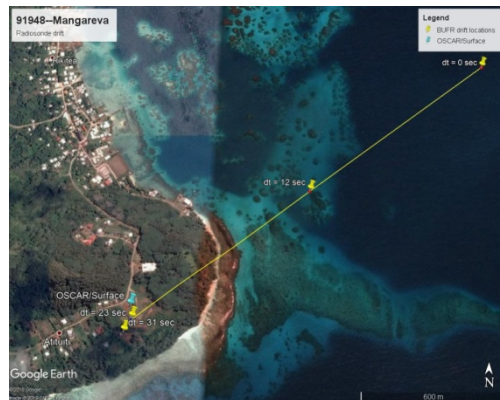
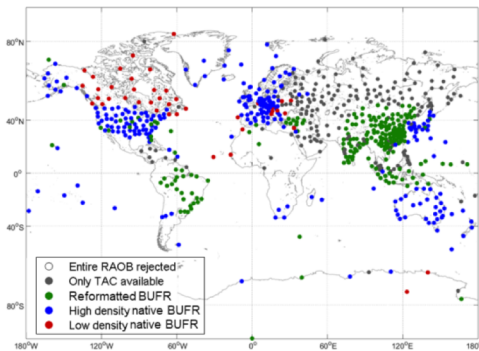
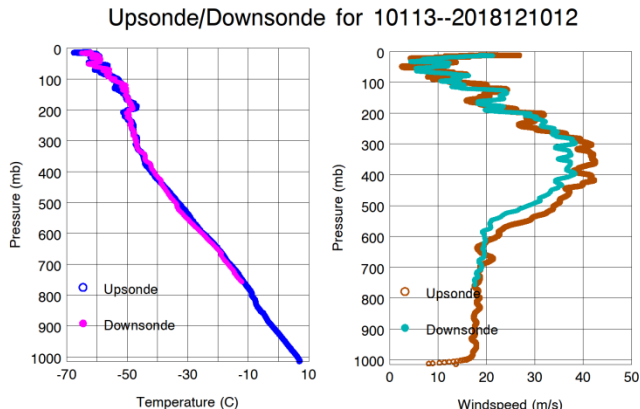
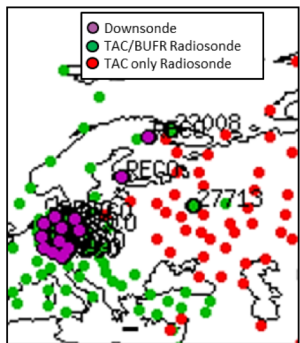
**new capabilities



FY17 — FY18 — FY19 — FY20 — FY21 — FY22 — FY23 — FY24

Observation and Data Preprocessing Updates

- Implemented BUFR dropsondes and downsondes into data preprocessing
 - Downsondes are from Vaisala RS41 sondes that transmit data after balloon burst
- Implementing radiosonde reported drift
 - BUFR formatted (red and blue stations) RAOBs transmitting radiosonde drift information
 - Use of reported drift requires new quality control routines
- GOES-17 AMVs implemented into data preprocessing
 - Waiting for update to NESDIS AMV processing to evaluate new algorithm
 - GOES-17 ABI issues a concern; if not remedied will cause significant degradation to AMV height assignments**



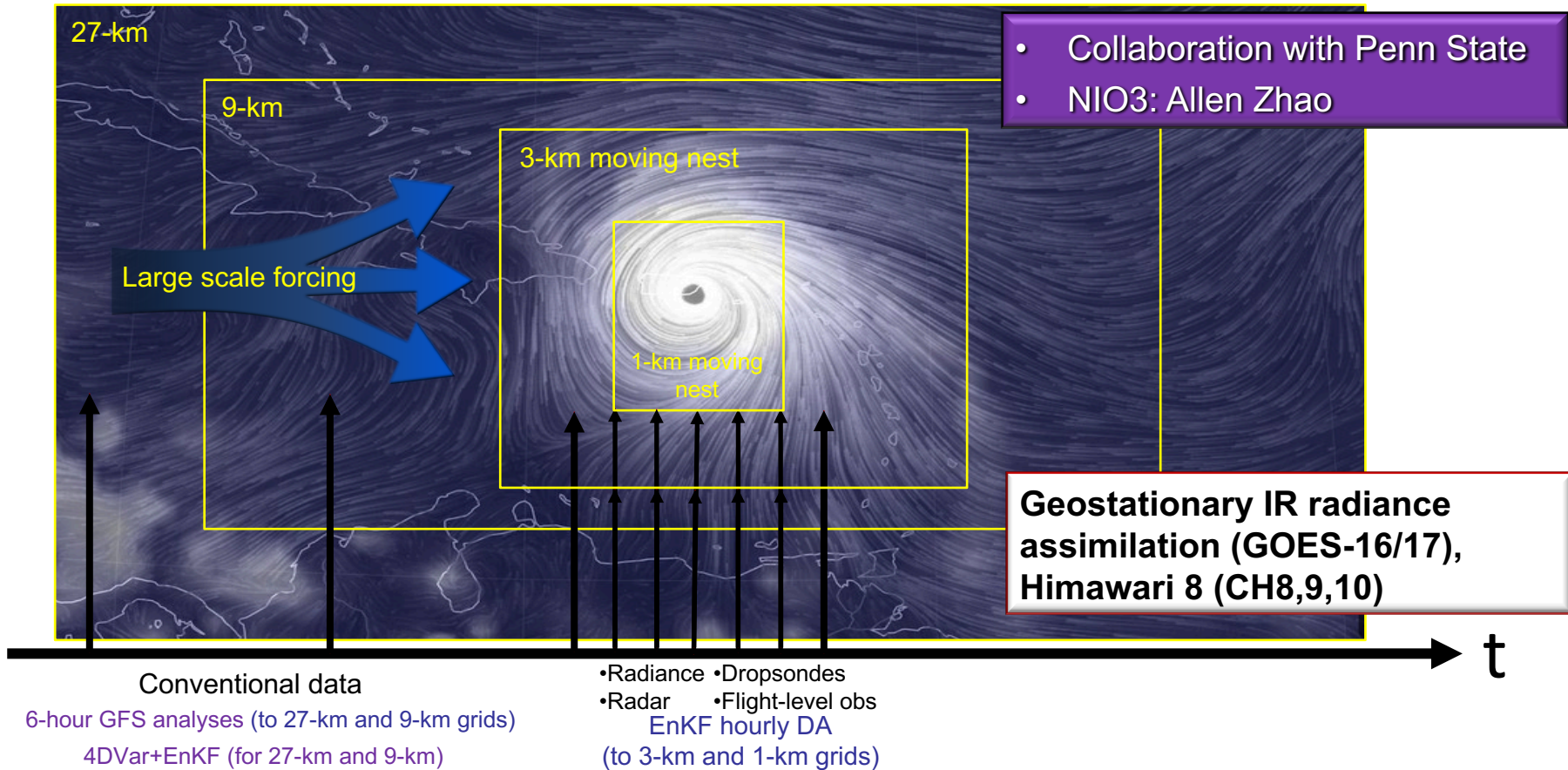
NIO1:Nancy Baker & Pat Pauley
NIO2: Rebecca Stone

- Complete testing of observation processing within ocean and atmosphere data assimilation systems
- Determine observation impacts from:
 - Saildrone observations
 - SHARC observations
 - UAS observations
 - Acoustic pressure observations
 - Acoustic Doppler current profilers
 - Velocity observations from drifters, floats, and HF radar



NIO, SOCA, IOS

All-sky Radiance DA EnKF for COAMPS® TC Intensification



Satellite Sounder Assimilation

See poster by *B. Ruston et al.*

CrIS Full Spectral Resolution (FSR)

The CrIS FSR data development is complete and ready for for transfer.

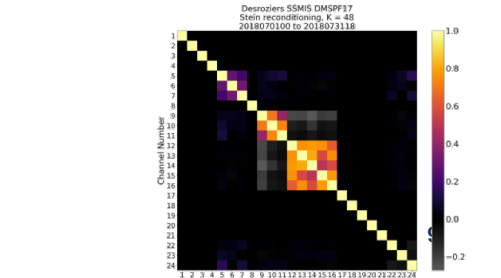
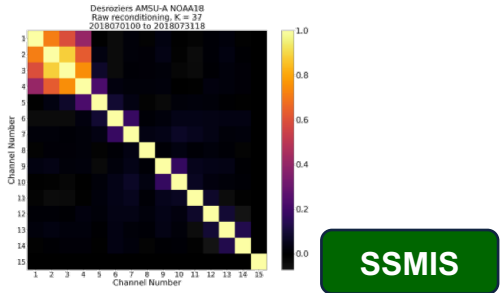
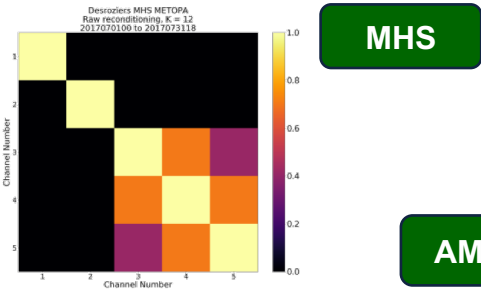
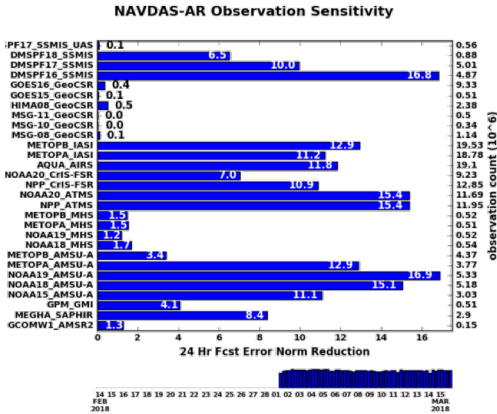
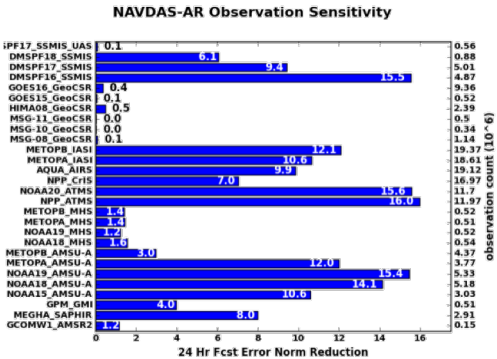
CrIS FSR has larger per observation impact than traditional CrIS data.

Observation Correlations

Observation correlation matrices account for frequency correlation and also contain signal from forward operator.

Testing ongoing but expected to complete and be ready for delivery next quarter.

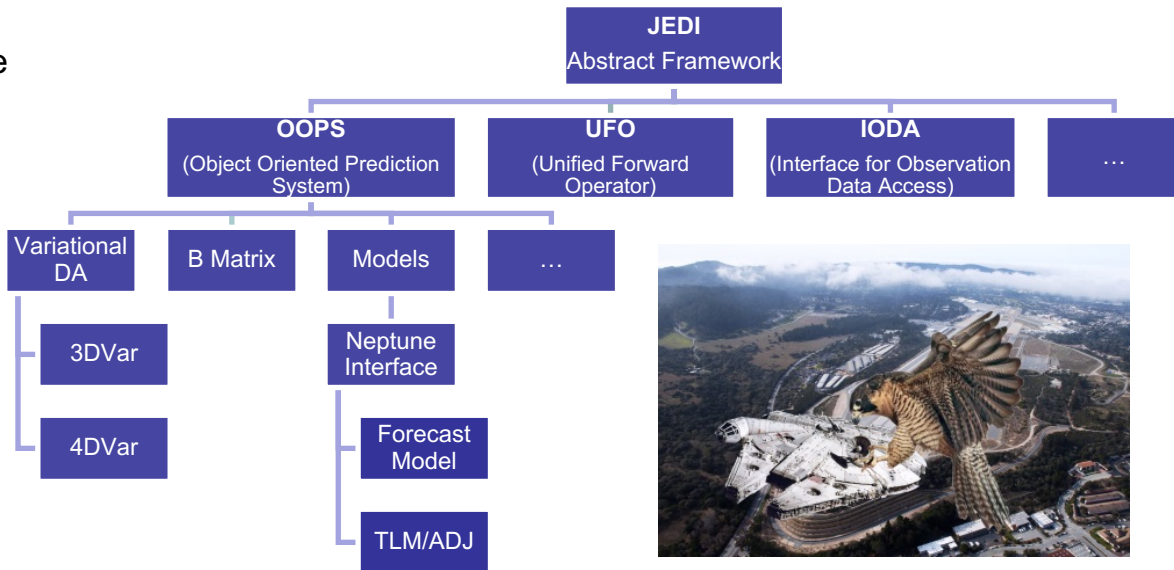
IOS1: Rolf Langland
 IOS2: Bill Campbell
 NIO2: Ben Ruston
 NIO3: Bill Campbell
 NIO4: Ben Ruston



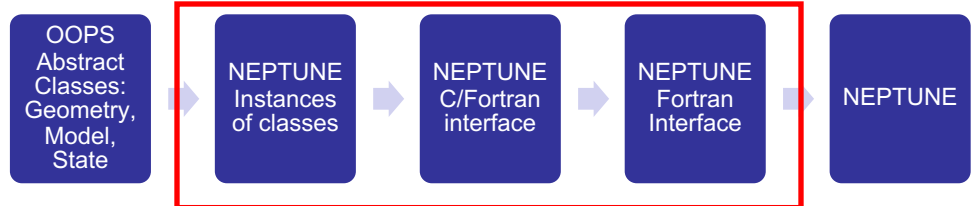
NEPTUNE Data Assimilation

Flexible Assimilation Linking Collaborations to Operations for Neptune (FALCON)

- Work with JEDI is focused on building the NEPTUNE/JEDI interface
- Created code to utilize the JEDI Unified Forward Operator (UFO) for radiosondes
- Participated in JCSDA code sprints and hosted IODA workshop
- NEPTUNE refactoring to improve functionality of the interface
- Completed NEPTUNE TLM & ADJ (dynamics only) for 4DVar and FSOI
- 3DVar → 4DVar → Hybrid 4DVar
 - Dependency on JEDI EnKF
 - EDA or NRL LETKF



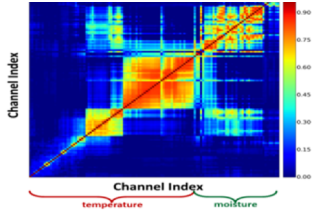
NEPTUNE Interface



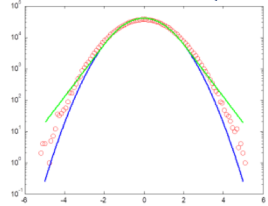
- JEDI1: Steve Lowder
- JEDI2: Patrick Flynn, Ben Ruston, NRL Liaison
- JEDI3: Flynn & Baker
- JEDI4: Sarah King, John Michalakes, NRL Liaison
- JEDI5: Dave Kuhl & Michael Herrera
- JEDI6: NRL Liaison

Unified Verification and Validation System for Navy Atmospheric Models

Estimation of Background and Observation Error Covariance



Estimation of Error Distributions for Quality Control



Leverage
MET/MET+

Enable
“end to end”

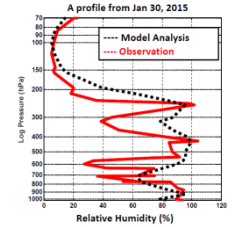
Interact
NRL->
Community

Accelerate
Development
& Applications

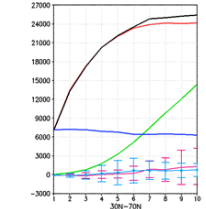
- Focus our effort on naval need
- In-house developed diagnostics can transition to MET software
- Contribute to community efforts
- Expand Partnerships

IOS1: Rolf Langland
IOS2: Liz Satterfield, Bill Campbell

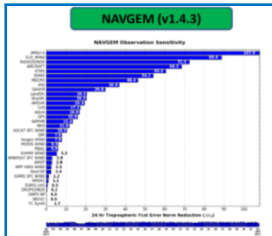
Representativeness Error



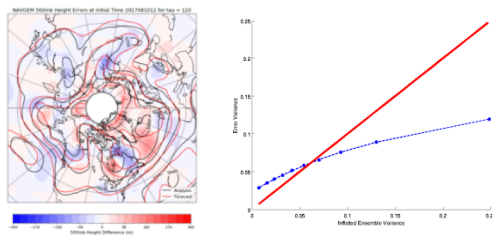
Activity Diagnostics and Tendencies



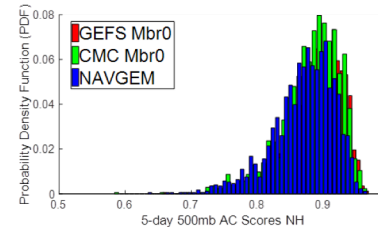
Observation Impact



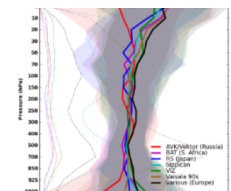
Ensemble Diagnostics for DA Windows



Comparison with Other Centers



Innovations, Analysis Increments and Residuals



SSMIS Constellation Status and NAVGEM Impact

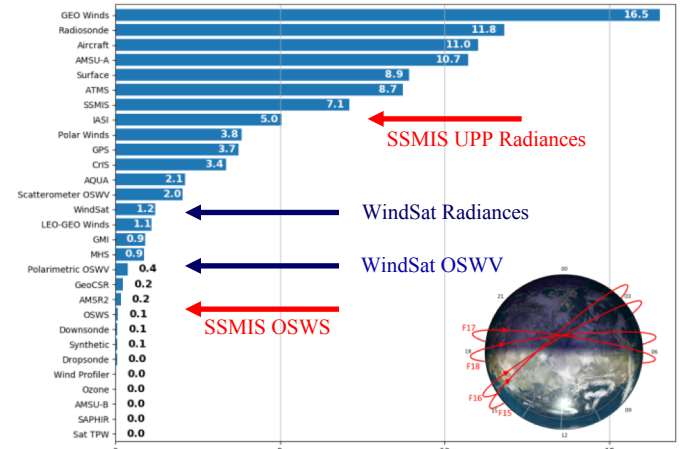
Current SSMIS Channel Status Stoplight Chart Date: 1 March 2019

		SSMIS Channel																								
	LTAN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
F16	15:55	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
F17	18:38	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
F18	17:33	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
F19	N/A	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
F20	TBD	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
		LAS Temperature						LAS Humidity						Surface Imaging, Water vapor, Clouds						UAS Temperature						
Rain Rate																										
OSWS																										
TVAP																										
CLW																										
Sfc.Type																										
LST																										
API																										
Snow Depth (Holl. Alg)																										
Snow Water (M/C Alg)																										
Ice Conc.																										
Ice Age																										
Direct Radiance Assimilation																										

- Fully functional channel. NEDT within requirement.
- Functional LAS channels for Direct Radiance Assimilation (Sweeping PLO). NEDT within requirement.
- Bias issues with channel. Functional capability requires Bias correction for DA.
- NEDT issues. Seasonal anomalies and strict QC required
- Loss of channel. No functional capability.
- Channel required for retrieval algorithm or used in Direct Radiance Assimilation

The two highest peaking SSMIS channels (19,20) require higher model top

NAVGEM Observation Sensitivity (% of total)



NAVGEM assimilates 5 "imager" channels. The 91 and 150 GHz channels are used as a Scattering Index QC parameter.

SSMIS Imagery used for TC-Web Apps, center fixes, TC!; Sea Ice Age and Concentration used at FNMOC and NAVO, Snow Depth used at NIC

CRTM2: E. Simon & S. Swadley, NIO2

Toward Future Navy Modeling

Navy METOC mission, basic and applied research, National ESPC, future coordinated national modeling

2020s

Bridge to NEPTUNE

- Further development, evaluation, and integration of NUOPC/ESMF-compliant community physical parameterization suites and additional coupled components.
- Emphasize performance for next-generation compute platforms
- Committed to partnerships

2019

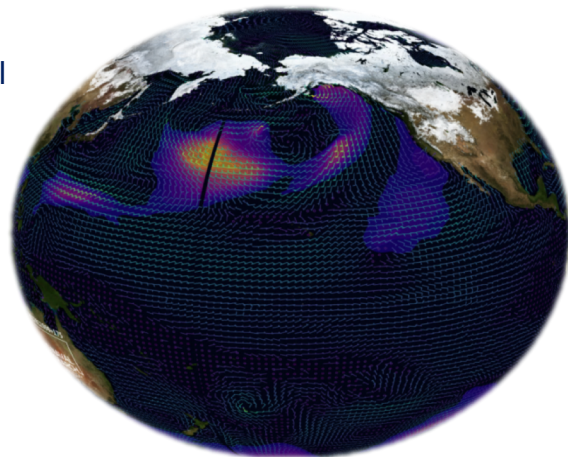
NAVGEN 3.x

- ~13km resolution with new physics-dynamics coupling with NUOPC interoperable physics driver and limited coupling to fit within operational time constraints

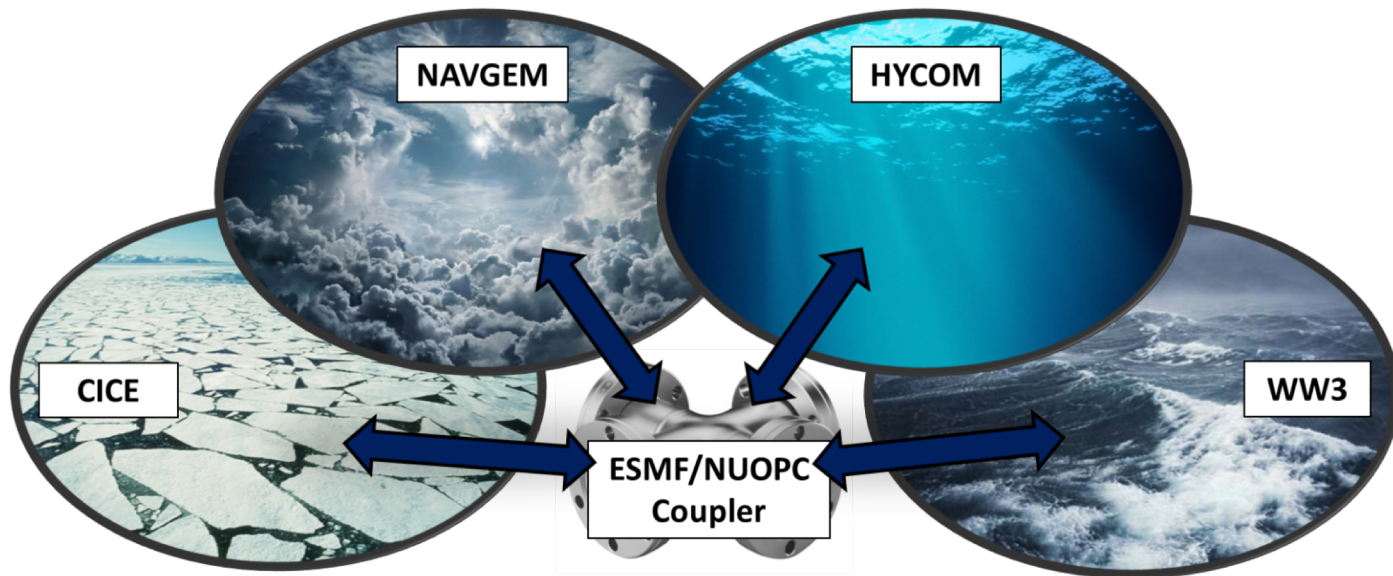
2018

NAVGEN 2.x

- ~19km resolution with new scalable infrastructure for improved efficiency and scalability on current DoD computational platforms.
- New TLM/Adjoint models for 4D-Var, FSOI, and sensitivity studies.

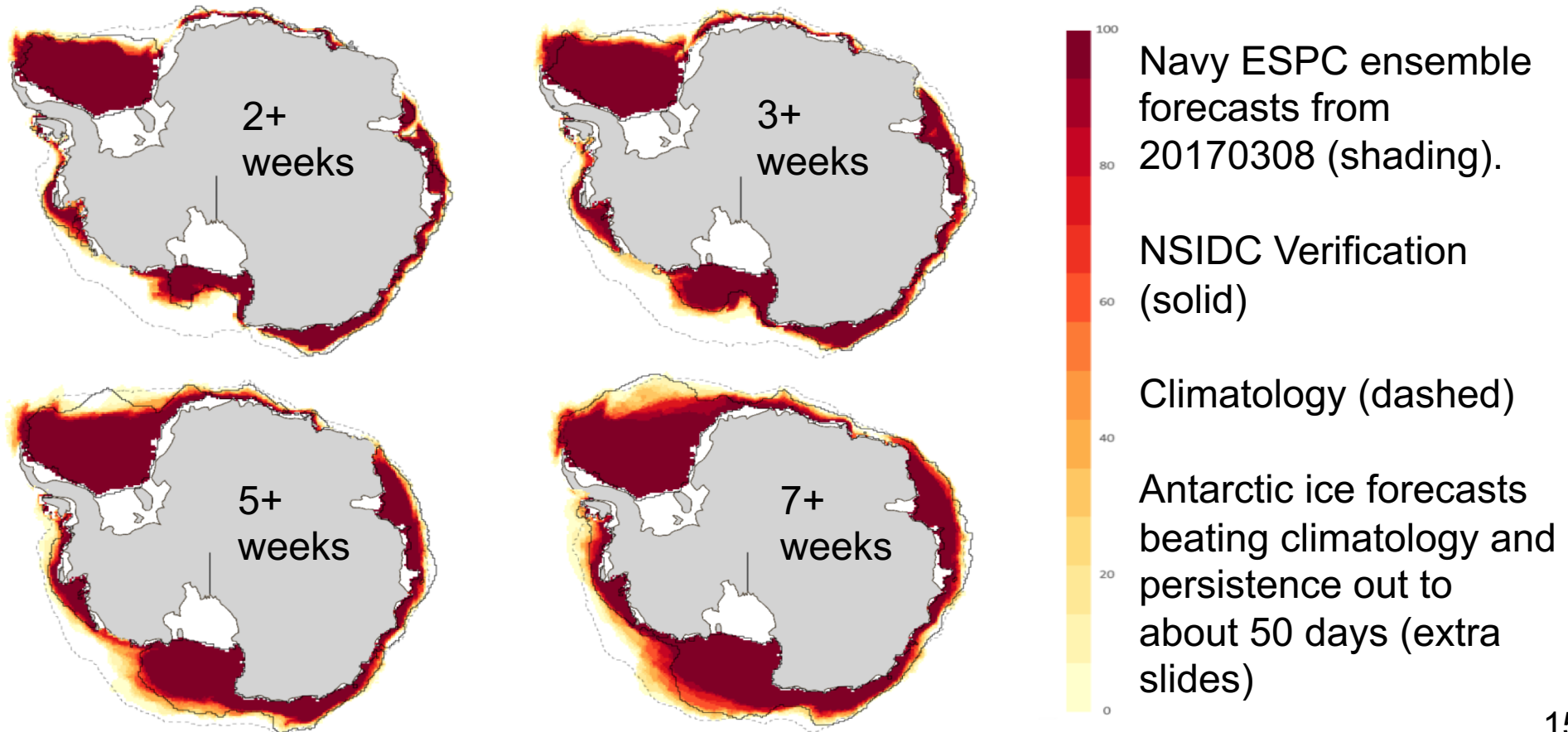


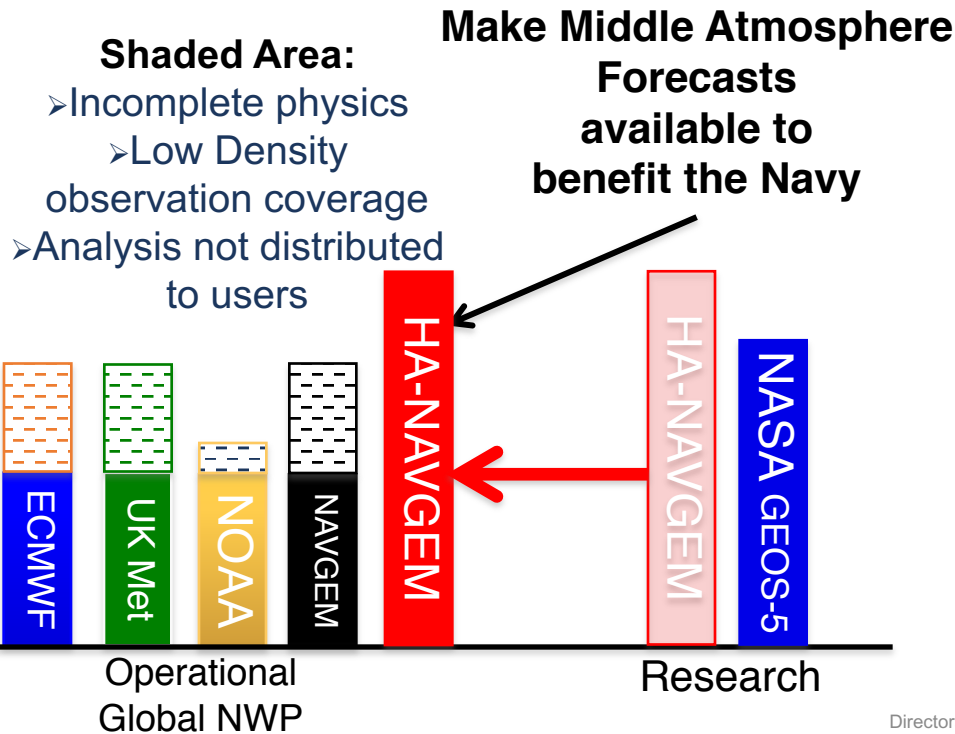
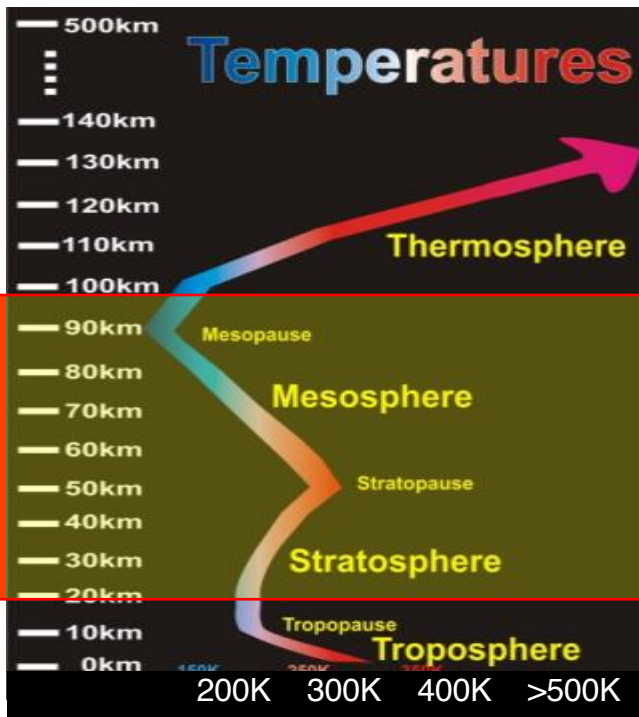
Common Challenges: Improve Coupling



- Developed to meet Navy needs for global earth system forecasts from days to months.
- High-resolution ocean and ice distinguish us from other centers.
- ESMF/NUOPC framework designed for flexibility.
- Participation in NOAA SubX program allows for robust evaluation, real-time use by NIC.
- Transition to operational partners scheduled for spring 2019.

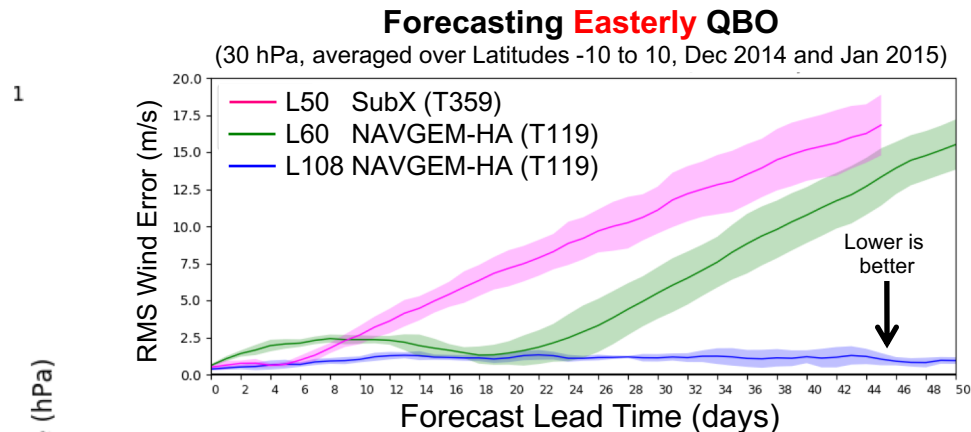
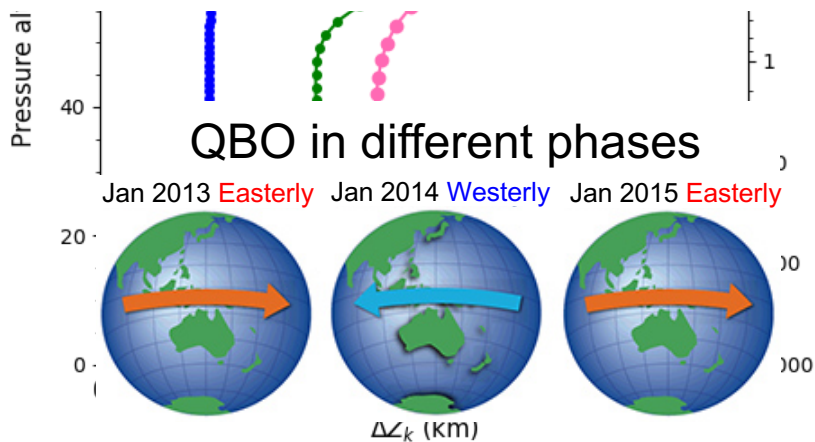
Probability of Sea Ice > 15%



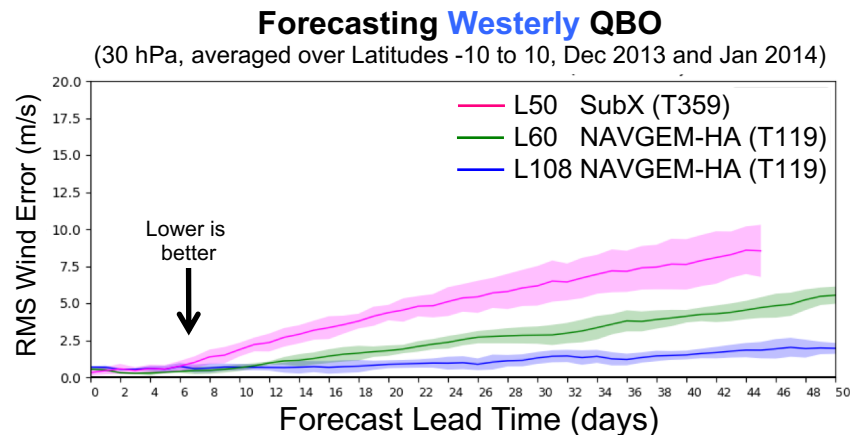


Middle Atmosphere Numerical Weather Prediction Seasonal Forecasts of QBO

- **Teleconnections:** causal connection or correlation between meteorological or other environmental phenomena that occur a long distance apart and on long time scales
- **Quasi-Biennial Oscillation (QBO),** which describes the wind direction in the tropical stratosphere, is a phenomena that impacts weather all over the globe on seasonal time scales (teleconnection)
- **Being able to forecast the QBO is important for atmospheric seasonal forecasting**



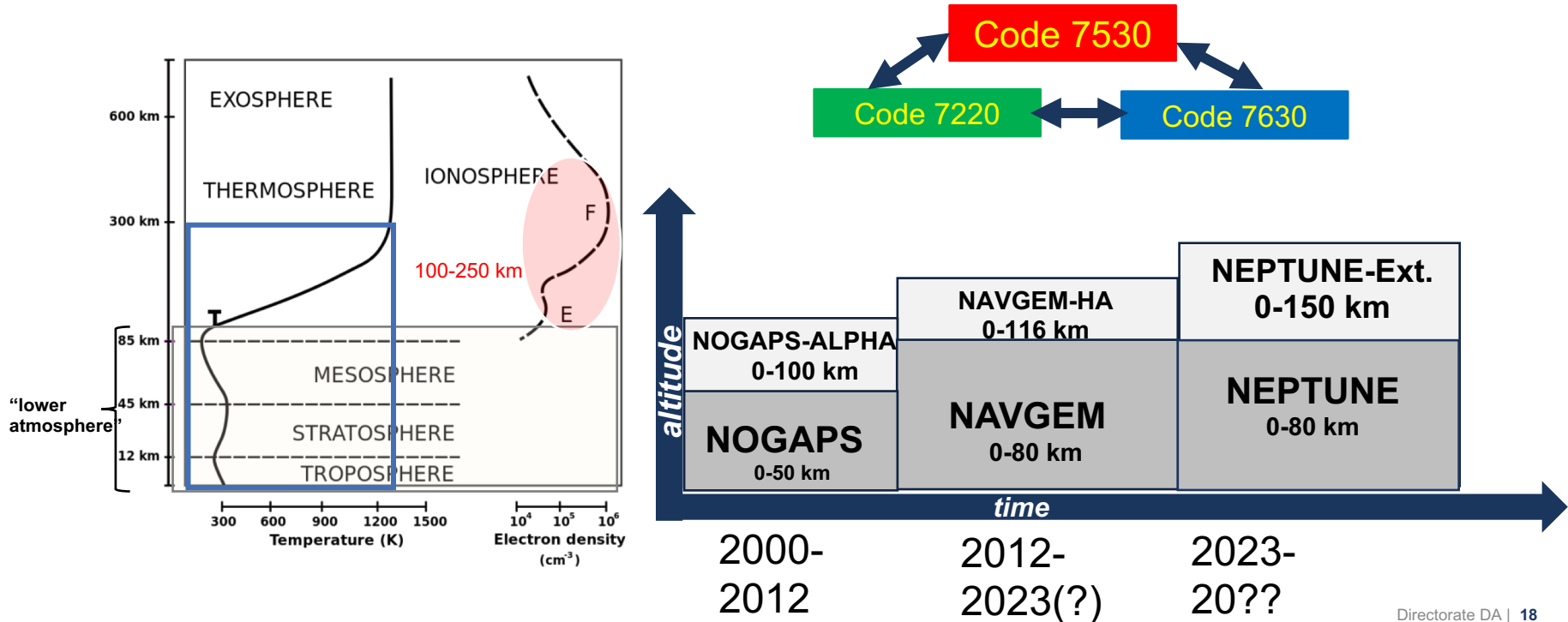
Pressure (hPa)



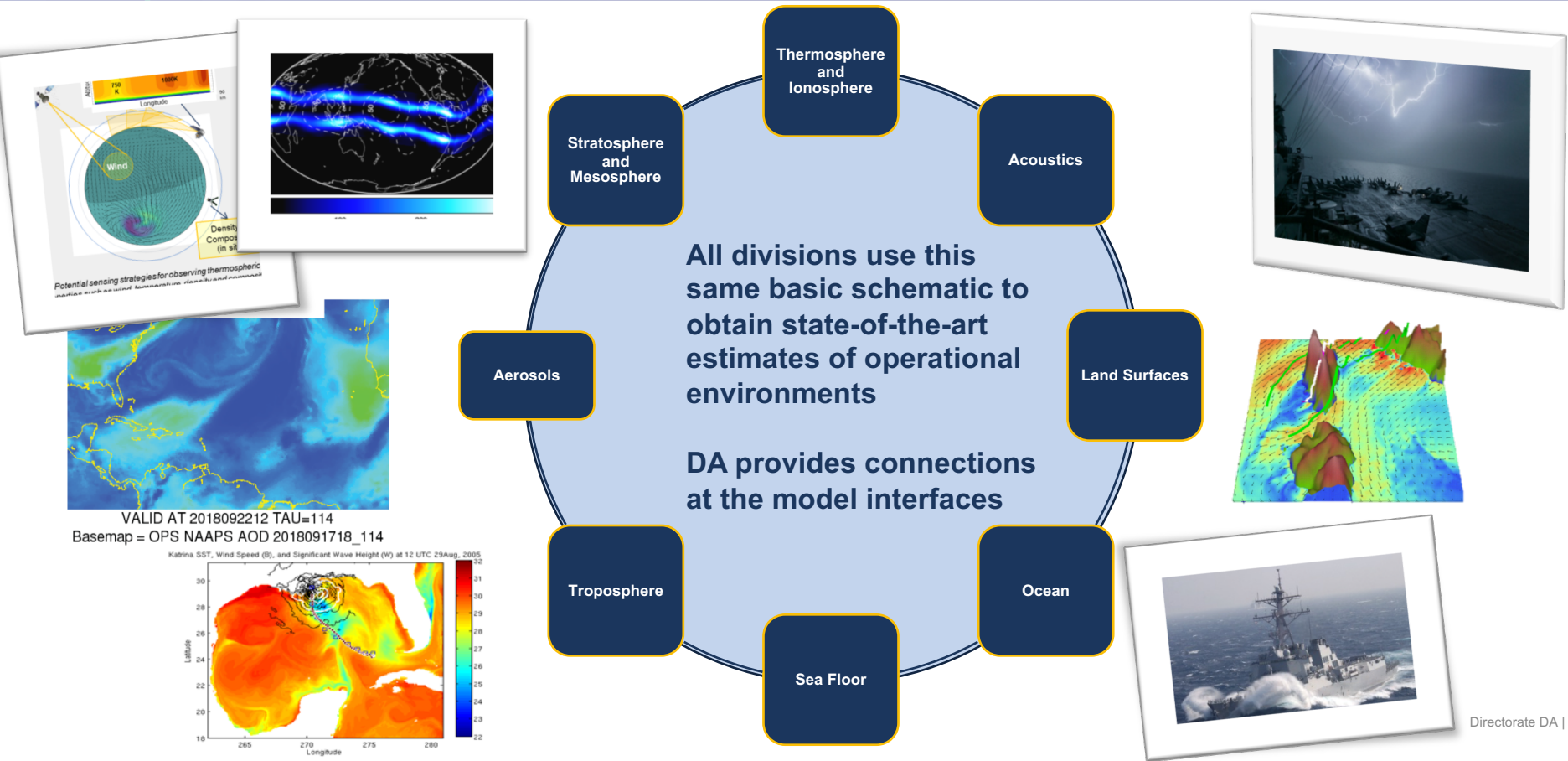
NRL Space Science, Remote Sensing and Marine Meteorology Divisions

What does Geospace SR&T do now?

Improve representation of stratosphere, mesosphere, thermospheric physics in Navy NWP models to enable high altitude NWP



Where Do We Excel?



Common Needs and Challenges

Methods

- ▣ *Flexibility enables application-specific methods*

Naval Need

- ▣ *Operate in forward deployed and communications limited environments*

- ▣ **Modular Infrastructure**

- ▣ **Accelerate progress in new DA efforts (e.g. Acoustic, Ionosphere)**

- ▣ **Collaborate on basic research (e.g. multi-scale, non-linear, non-Gaussian)**

- ▣ **Improve error estimation and quality control (correlations, flow dependence)**

- ▣ **Promote verification designed for DA**

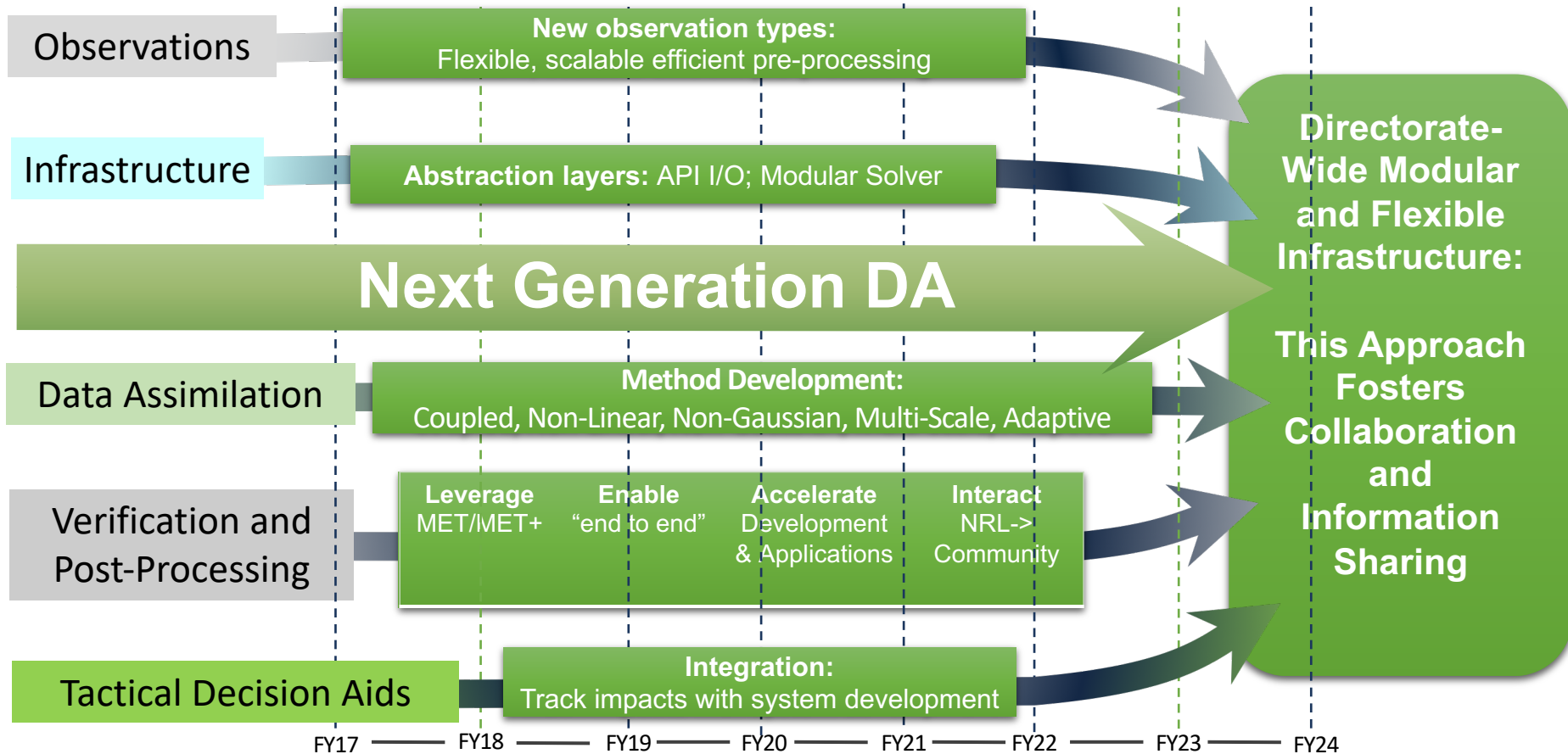
Observing Systems

- ▣ **Easy integration of new observations**

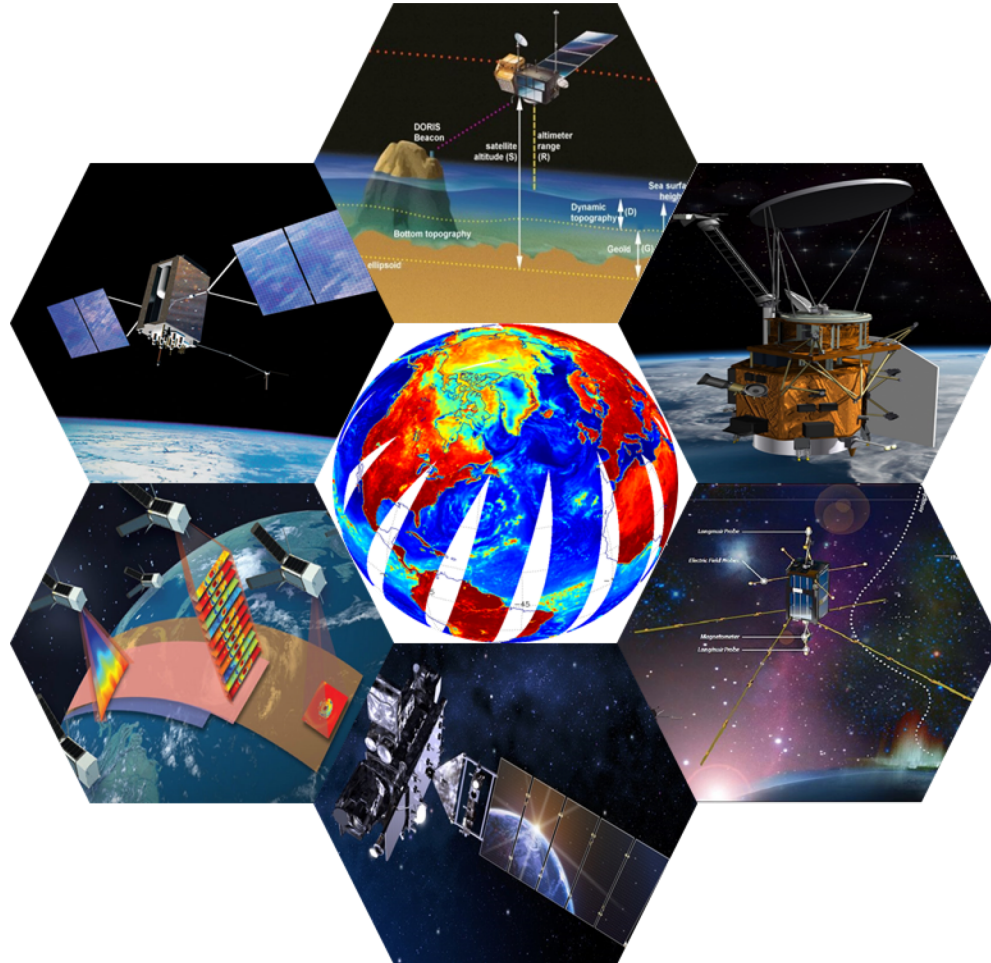
Next Generation Models

- ▣ **Improve model boundary prediction**

Common Challenges: Next Generation



Thank You



“Examination of GOES-16 ABI; MeteoSat-11 SEVIRI; ATMS and CrIS from NOAA20; and KOMPSAT-5 in a Global NWP System”

Benjamin Ruston, Nancy Baker, William Campbell, Bryan Karpowicz, Rolf Langland, Steve Swadley and Song Yang

“A New Channel Selection Method for Satellite Instruments with Correlated Observation Error”

Bill Campbell, Song Yang, Ben Ruston, Liz Satterfield and Nancy Baker

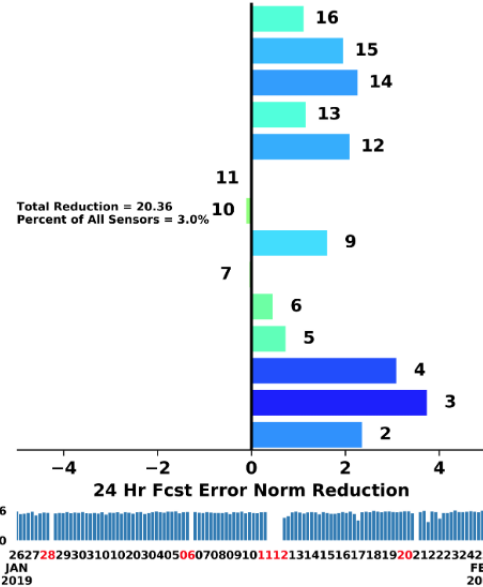
DA Focus Areas

- **Observations and Remote Sensing**
 - Making the most of observations in data sparse regions (observing in the gaps)
 - Identifying observation gaps (SBEM requirements), and local non-conventional observations
 - Adapting to changes in the global observing system
 - Dealing with large increases in new satellite observations (new sensors, small satellites, commercial sats)
 - Quality assurance, quality control and calibration/validation
- **Data Assimilation Methods (solvers)**
 - Efficient and effective DA solution methods (solvers)
 - Coupling for atmosphere, ocean, sea-ice, waves, land, aerosols and clouds
 - DA for high resolution cloud resolving models (NEPTUNE), ESPC and Whole Atmosphere Model
 - Ensemble generation and post-processing for Hybrid DA and ensemble forecasts
- **Applications and Impacts**
 - Diagnostics, Verification and Validation
 - Estimating analysis and observation errors, and assessing model skill (including for TDAs)
 - Observation impact assessment, Observing System Experiments (OSE and OSSE)
- **Partnerships and Collaborations**
 - Shared infrastructure to support the best solution for an application (JCSDA/JEDI) and tools (MET+)
 - Data providers and observation coordination (NASA, NOAA, NESDIS, EUMETSAT, JMA)
 - International partners (e.g., UK MetOffice, ECWMF, WMO) and University partners

MW SSMIS CalVal SSMIS UPP NAVGEM Impacts

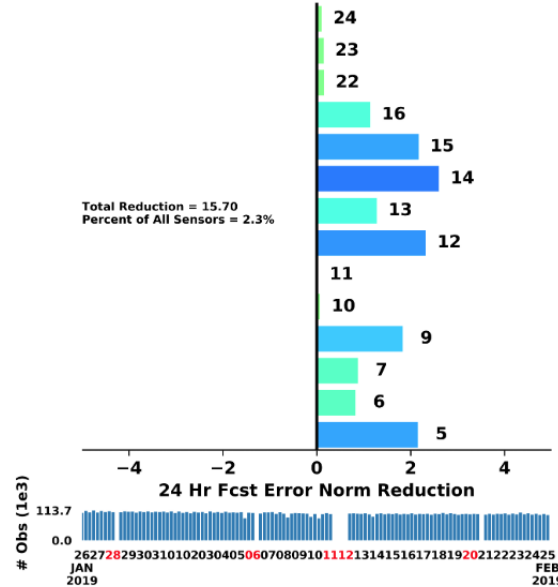
NAVDAS-AR Observation Sensitivity

DMSPF16_SSMIS



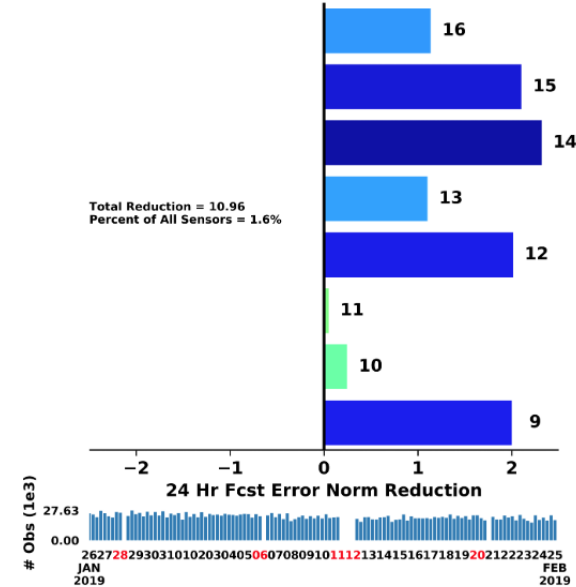
NAVDAS-AR Observation Sensitivity

DMSPF17_SSMIS



NAVDAS-AR Observation Sensitivity

DMSPF18_SSMIS



In addition to the F16, F17 (T,q) and F18 (q) available channels, NAVGEM is now assimilating 5 “imager” channels from F16, F17 and F18. The 91 and 150 GHz channels are not being assimilated but are used as a Scattering Index (SI) parameter for QC.