

Headquarters U.S. Air Force

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U.S. Air Force Weather Modeling: Status Update and Future Plans for New/Enhanced Model Capabilities



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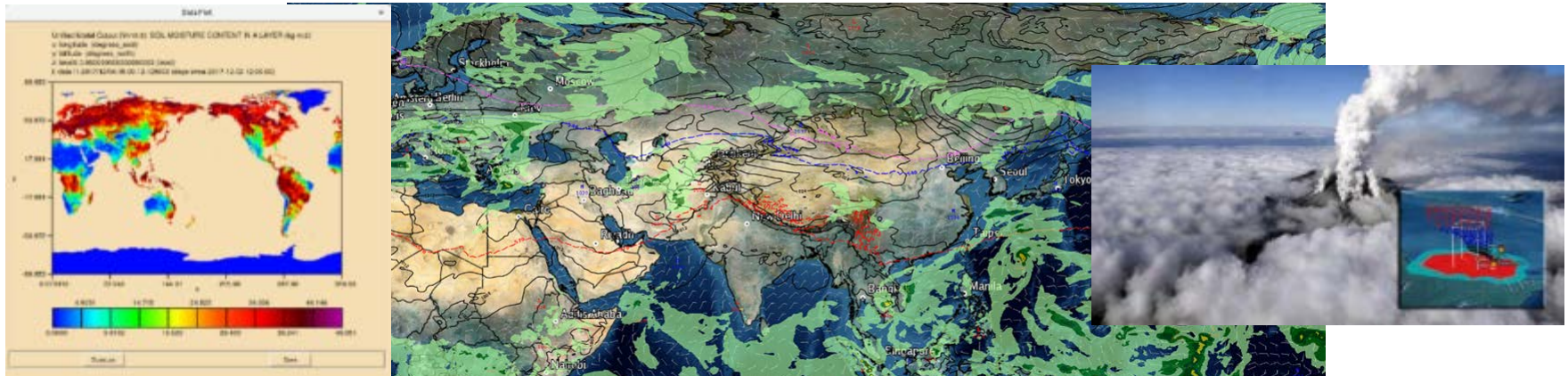
- **Global Air-Land Weather Exploitation Model (GALWEM)**
 - **Current status + upgrades planned for 2020**
 - **HPC System 11**
- **Joint projects with interagency partners**
 - **Interagency modeling partnerships**
 - **Hydrology modeling**
 - **Machine Learning/Artificial Intelligence (ML/AI)**
- **Strategy for future USAF modeling enterprise**
 - **National Defense Strategy: motivation for change**
 - **USAF modeling modernization concept**
- **Summary/final points**



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Global Air-Land Weather Exploitation Model (GALWEM)

- Primary numerical model input for all AF and Army operations
- Runs 4x/day to 240 hours at ~17 km horizontal resolution
 - *Dev/test trials for 10-km horiz res by Q2 CY2020*
- Unified Model (UM) v 10.9, fed with UK Met Office initial data
 - *DA w/557 WW organic data sched for dev/test by Q2 CY2020*
- Products/gridded data available via web services on 0.25° grid
- Land surface model collaborations w/Met Office and NASA (LIS)
- Working with UK Met Office and Cold Regions Research/Eng Lab on dust source regions to improve dust/aerosols forecast

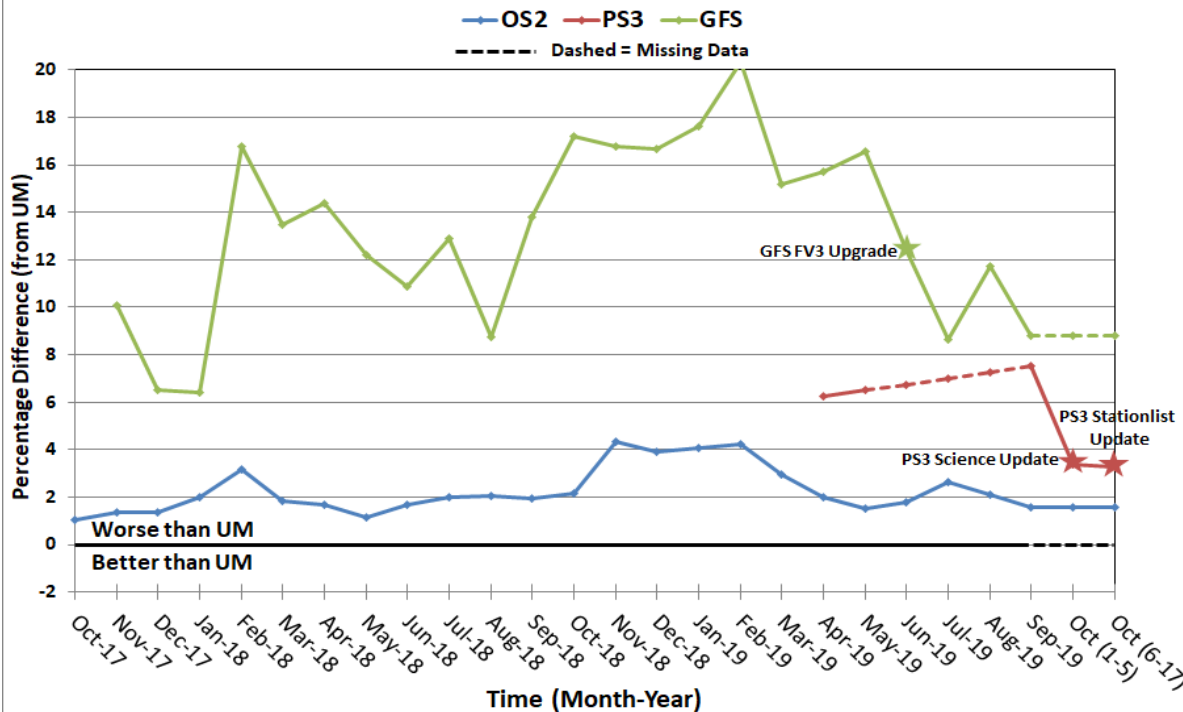




GALWEM DA: Commission for Basic Systems (CBS) Score

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CBS Global Index (201710 - 201910)



The CBS score metric is derived from variables that WMO requires all global modeling centers to provide to standardize evaluation of the major global forecast models (e.g., GFS, UM, NAVGEM). UKMOs formulation is calculated as a weighted average of the RMSEs of the WMO variables.

The Science and Stationlist upgrades in early October 2019 brought PS3's performance closer to GALWEM (OS2).

OS2 and PS3 have performed better than GFS even after the GFS FV3 upgrade in June.

OS2: GALWEM Ops Suite v2 driven by analyses created at UK Met Office

PS3: GALWEM Parallel Suite v3 driven by analyses created at 557th WW



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JTWC TC Track Consensus: Annual Evaluation for 2018

Mean head-to-head TC track forecast errors (NM)

	0	12	24	36	48	72	96	120	144	168
CONW	7.6	26.4	38.8	50.3	62.5	92.8	132.5	183.7	248.8	329.6
TES7	7.6	26.5	39.2	50.8	62.9	94.0	135.4	189.3	258.3	344.7
#CASES	1290	1252	1174	1077	980	779	600	461	325	206

2018 consensus

2018 consensus minus GALWEM

Consensus model TC vortex trackers

Numerical model	Model type	Primary parent tracker	Primary interpolated tracker
NAVGEN	Global dynamic	NVGM	NVGI
GALWEM	Global dynamic	AFUM	AFUI
GFS	Global dynamic	AVNO	AVNI
JGSM	Global dynamic	JGSM	JGSI
UK Met Office	Global dynamic	EGRR	EGRI
ECMWF	Global dynamic	ECMF	ECMI
GEFS	Ensemble	AEMN	AEMI
ECMWF Ensemble	Ensemble	EEMN	EEMI
UK Met Office Global Ensemble	Ensemble	UEMN	UEMI

Tested TC track consensus permutations

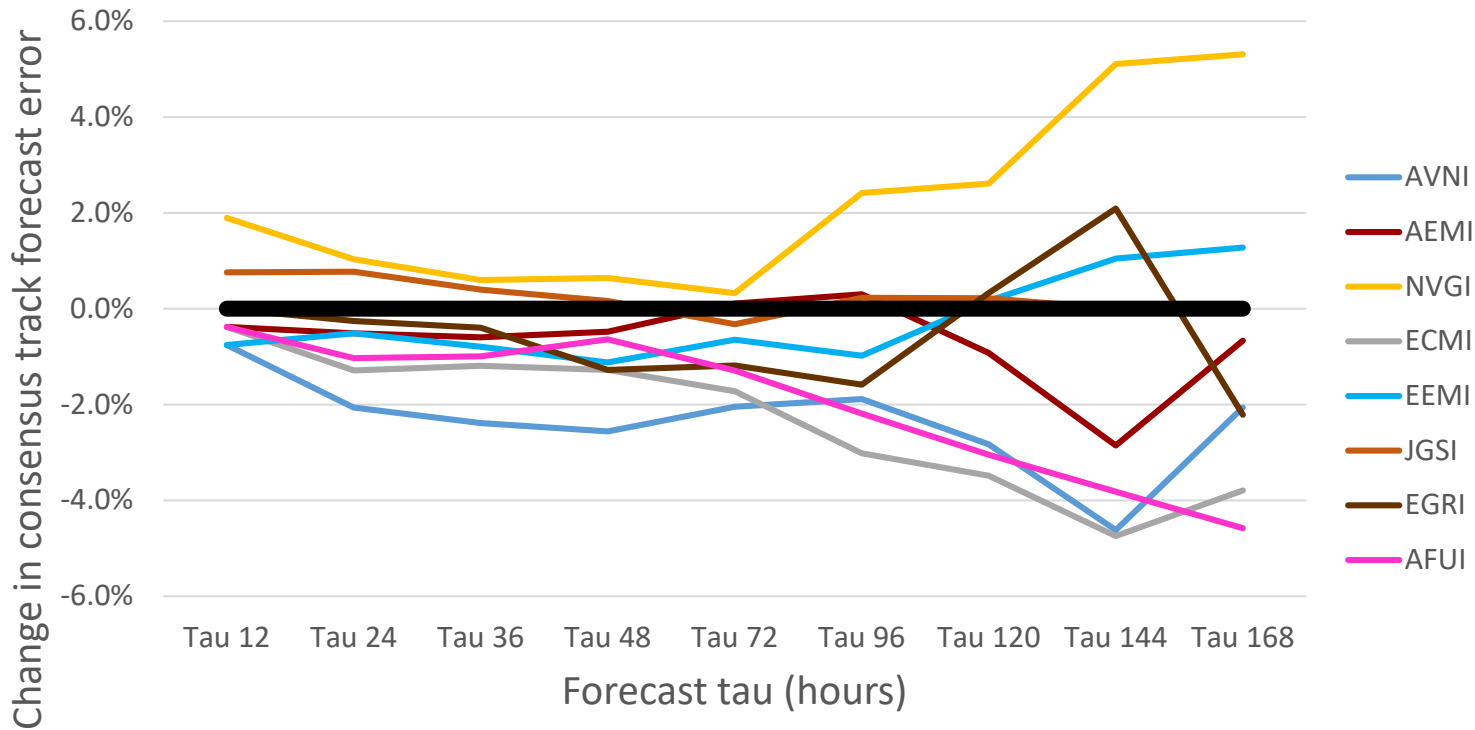
CONW=EGRI+JGSI+AVNI+ECMI+AEMI+EEMI+AFUI+NVGI	2018 consensus
TES1 = JGSI+AVNI+ECMI+AEMI+EEMI+AFUI+NVGI	
TES2 = EGRI+ AVNI+ECMI+AEMI+EEMI+AFUI+NVGI	
TES3 = EGRI+JGSI+ ECMI+AEMI+EEMI+AFUI+NVGI	
TES4 = EGRI+JGSI+AVNI+ AEMI+EEMI+AFUI+NVGI	
TES5 = EGRI+JGSI+AVNI+ECMI+ EEMI+AFUI+NVGI	
TES6 = EGRI+ JGSI+AVNI+ECMI+AEMI +AFUI+NVGI	
TES7 = EGRI+JGSI+AVNI+ECMI+AEMI+EEMI +NVGI	2018 consensus minus GALWEM
TES8 = EGRI+JGSI+AVNI+ECMI+AEMI+EEMI+AFUI	
TES9 = EGRI+JGSI+AVNI+ECMI+AEMI+EEMI+AFUI+NVGI+HWFI	
TE10 = EGRI+JGSI+AVNI+ECMI+AEMI+EEMI+AFUI+NVGI+CTCI	
TE11 = 10*ECMI+10*EGRI+NVGI+JGSI+GFNI+AVNI+COTI+HWFI+AEMI+EEMI	
TE12 = UKMI/EGRI+JGSI+AVNI+ECMI+AEMI+EEMI+AFUI+NVGI	
TE13 = EGRI+JGSI+AVNI+ECMI+AEMI+EEMI+AFUI+UEMI	



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JTWC TC Track Consensus: Individual Model Impacts (2018)

CONW Improvement/Degradation by Model
(Negative value = % Improvement; Positive value = % Degradation)

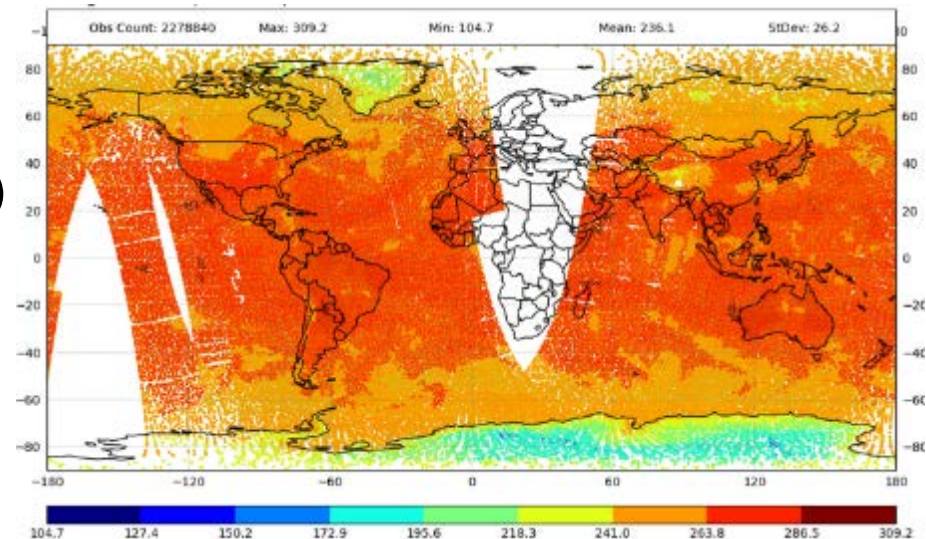




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GALWEM Data Assimilation

- GALWEM Operational Suite v3 (OS3), **implemented 29 Oct 2019**
 - Runs 4x/day to 240 hrs at ~17 km resolution, UM v. 10.9
 - UKMO collects data, pre-processes and ships to 557WW
 - 557 WW thins/QCs data, runs hybrid 4DVAR DA to create analysis, and then runs the model
 - Important incremental step to full organic/indep DA
- Dev Suite for organic DA
 - Start DA w/557 WW organic database (fully indep system)
 - **Operational Q2 CY2020**





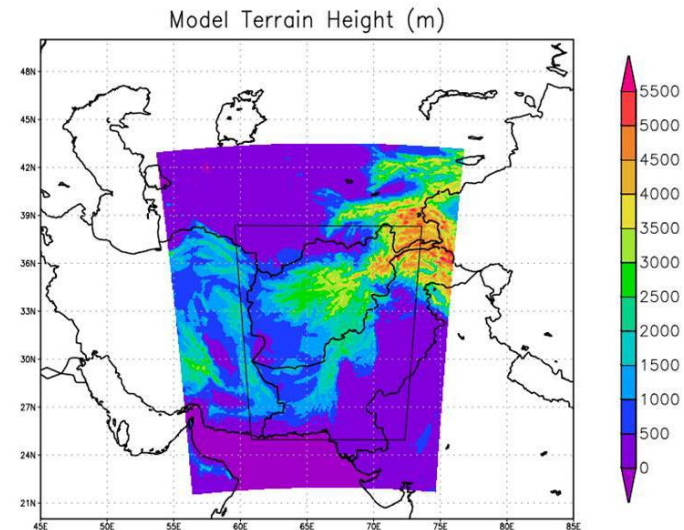
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GALWEM

New Capabilities in Dev/Test

- **GALWEM Global Ensemble run in dev/test by Q1 CY2020**
 - 21 members
 - 40 km horizontal res
 - 70 vertical levels
 - Forecast to 16 days

- **GALWEM Regional Deterministic runs**
 - First domains: SW Asia and Korea
 - Dev/test complete; Ops implementation **TBD**
 - Next planned domains are Baltics and Taiwan straights
 - *Note: Large data volume for high-res windows present challenges for our data/comm infrastructure*





HPC System 11

- Cray SHASTA selected as the AF Weather's HPC 11
 - Cray's latest technology with AMD Rome Chipset
- Provides >5x compute & storage capacity of current system
 - Exceeded AF Weather's objective requirements
- Dual compute halls & file systems provide full back up
 - Dynamic load balancing across halls allows surges of Production runs to deliver more products to users faster
 - System names: *Fawbush* and *Miller*
- Both compute and storage easily scalable
 - Accelerator chips (e.g. GPUs) can be easily added to develop/test next generation models & algorithms
- Racks & infrastructure designed to last 10 years
 - Next system could just involve an upgrade of blades



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HPC System 11 Schedule

- Contract with Cray signed **29 Jul 2019**
- Delivery of System at ORNL began **Dec 2019**
- ORNL system acceptance **May 2020**
- Operations anticipated to begin **Oct 2020**





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Partnerships

- AF Weather will continue to partner with Interagency organizations, Academia and Labs to improve our modeling capabilities





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Interagency Modeling Partnerships

- **National Earth System Prediction Capability**
 - AF Weather currently chairs Executive Steering Group
 - Principal partner w/NWS, Navy, NASA, NSF, & DOE
 - *GALWEM planned to be added to ESPC ensemble in 2020*
- **Joint Center for Satellite Data Assimilation (JCSDA)**
 - Participating in all governance boards and AOP development
 - Contributing resources for cloud data assimilation
 - *Growing challenges for DA of smallsat & commercial data*
- **Developmental Testbed Center (DTC)**
 - Funds research & participates in government boards/oversight
 - Supports MET tools efforts to improve verification capabilities
- **Environmental Prediction Innovation Center (EPIC): TBD**

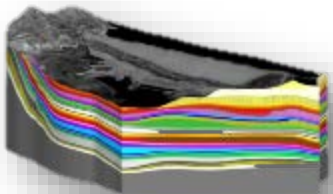


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Modeling Partnerships

Hydrology Modeling

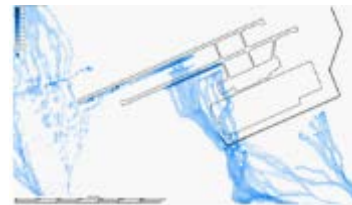
- Working to develop global, medium-range hydrological forecast capability to support multiple needs:
 - Mission Planning and mobility constraints for DoD ops
 - Base/site selection and resource protection
 - Humanitarian assistance and disaster response
- Team effort to dev/test/deploy complete system
 - **UKMO**: UM/GALWEM for medium-range precip
 - **NASA/GSFC**: Land surface modeling (LIS)
 - **USACE/ERDC**: global Streamflow Prediction Tool
 - **DOE/ORNL**: HPC optimization + inundation mapping



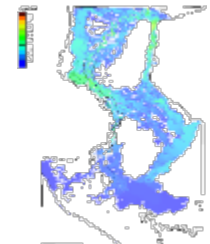
Mosul Dam



Sava River '95



Airfield Inundation



Pakistan Flood '10



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Machine Learning / Artificial Intelligence (ML/AI) Initiatives

- **Global Synthetic Weather Radar (GSWR)**
 - Machine learning implemented by MIT Lincoln Laboratory
 - Leverage strengths of various sensors to fuse existing traditional & non-traditional data sets
 - Horizontal resolution < 5 km, data update every 5 min
 - 0-12 hrs forecast blended with GALWEM
 - *Operational global & regional output in AFW cloud in 2020*





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Air Force Weather Operations Vision 2019

Based on Department of Defense's
2018 National Defense Strategy's Lines of Effort



- **Lethality and Readiness**
 - *Improve Integration*
 - *Enhance Resiliency*
 - *Realign Our Force*

- **Alliances & Partnering**
 - *DoD & Government Agencies*
 - *Allies & Trusted Coalition Partners*
 - *Industry & Academia*

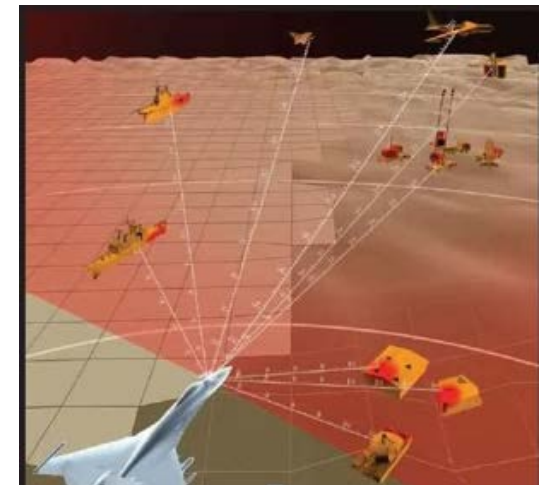
- **Reform for Performance & Affordability**
 - *Attack our inefficiencies*
 - *Rapidly Modernize*
 - *Redesign our Force*



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National Defense Strategy: Modeling Challenges

- Improvements needed to meet challenges posed by:
 - Reemergence of near-peer adversaries (counter-terrorism focus since 9/11/2001)
 - Needs of future weapons systems to compete with near-peer adversaries
- Reevaluate entire modeling system; develop strategy to meet future needs
 - Improve resilience and enhance lethality and agility of military ops
 - Distributed computing, expanding partnerships, diverse data sources





AF Weather Vision for Modeling

- **USAF undergoing comprehensive review of entire modeling system in order to:**
 - **Optimize usage of new HPC System 11, and**
 - **Address needs of National Defense Strategy**
- **Modeling Modernization Concept identifies options/courses of action (COAs) that require further study; COAs explores improvements in 3 areas:**
 - **Improve/Sustain Existing Capability to Meet Current Needs**
 - **Provide Modeling Capability to Meet Gaps**
 - **Add Resilience To Our Modeling System**
- ***Modernization Concept identifies COAs and areas for deep dive evaluation, which drive final decisions; once made, Implementation Plans will be developed***



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AF Weather Modeling Modernization

Major decisions/areas in evaluation

- **UNCLASSIFIED/CLASSIFIED PROCESSING**
 - **Pursue prototyping to determine our future classified production capability**
- **BLENDED MODELING**
 - **Pursue a blended modeling capability to increase accuracy and resiliency in partnership with UK Met Office**
- **RAPID REFRESH FORECASTING**
 - **Pursue global rapid refresh modeling to increase operational effectiveness**
- **CLOUD MODELING**
 - **Continue ongoing work with NCAR to develop explicit cloud forecasts and exploit ML/AI techniques**
- **SUBSEASONAL-TO-SEASONAL (S2S)**
 - **Acquire S2S data sets and tailor them to the defense mission. Running independent S2S model not planned.**



- **USAF on track for significant model and system improvements in 2020**
 - **Continued evolution of GALWEM**
 - **Stand-up of System 11 HPC system at ORNL**
 - **Begin long-term evolution of modeling enterprise in accordance with AF Weather Ops Vision 2019**
- **Continuing to exploit and grow our modeling collaboration and partnering opportunities**



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Q&A

If you'd like to follow up on any item, feel free to contact me via LinkedIn, Twitter ([@MikeFarrar_Wx](#)), or email: michael.r.farrar2.civ@mail.mil



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Back-up slides



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AF Weather Vision for Modeling

- **Improve/Evolve/Sustain Existing Capability to Fully Meet Current User Needs**
 - **Global Numerical Weather Prediction (NWP) Model**
 - **Regional NWP Model**
 - **Cloud Modeling**
 - **Land Modeling**
 - **Dust/Volcanic Ash Modeling**
 - **Stochastic Modeling Approaches**
 - **Post Processing**
 - **Machine-to-Machine Applications**
 - **Stochastic post-processing**
 - **Verification**



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AF Weather Vision for Modeling

- **Provide Modeling Capability to Meet Gaps**
 - **Specialized Models (e.g., Polar)**
 - **Global/Regional Hydrology Model**
 - **Sub-seasonal-to-Seasonal (S2S) Model**
 - **NWP Model Extending to the High Altitude Neutral Atmosphere (for ionosphere coupling for space wx)**
 - **Surrogate Models Machine Learning/AI**
 - **Aerosol/Chemistry Modeling**



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AF Weather Vision for Modeling

- **Add Resilience To Our Modeling System**
 - **Modular Hardware and Software**
 - **Distributed Computing**
 - **Non-Traditional Data Sources**
 - **Modeling Operations with Limited Data Sets**
 - **Operational Back Up**
 - **Multiple Model Ingest for Model Blending**
 - **Multiple data sources**



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AF Weather Vision for Modeling Lines of Effort

- **Data Assimilation**
 - **Operationalize Organic DA**
- **Non-Traditional Observations**
 - **Resiliency**
 - **Our edge**
- **Modeling Operations with Limited Data Sets**
 - **We must understand the minimum required data set to run our forecast models**



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AF Weather Vision for Modeling Lines of Effort

- **Storage**
 - Pressing need
 - Required for verification, AI/ML, hydrology, S2S
- **Tactical Modeling**
 - Expeditionary CONOPs
 - Mobile forces in data degraded/denied conds.
 - Reachback architecture breaks down
- **Coupling**
 - Terrestrial and Space
 - Earth system (atmos, oceans, waves, cryosphere, aerosols/chemistry, etc.)



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AF Weather Vision for Modeling Lines of Effort

- **Polar Modeling Capability**
 - **Understand GALWEM weaknesses**
 - **Partner to gain capability or pursue AFWO model**
- **High Altitude**
 - **Critical for evolving missions (hypersonics, Directed Energy, etc.)**
 - **Needed for coupling with space models**