National Aeronautics and Space Administration

Planning Observations for Intelligent Science Experimentation

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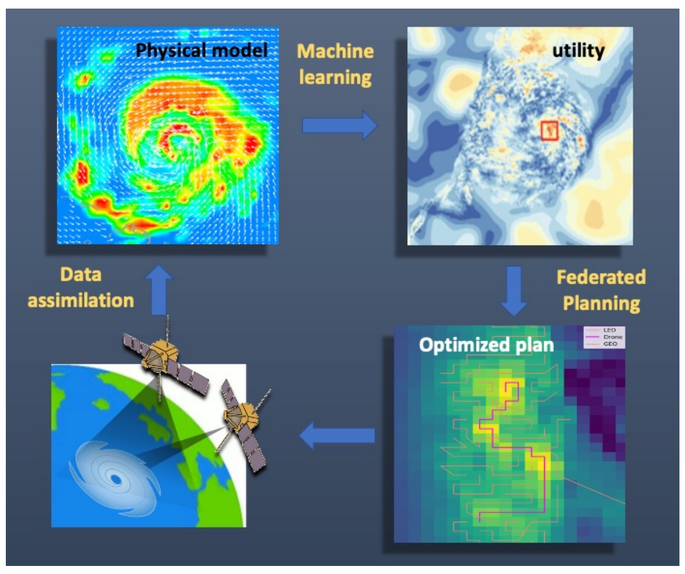
Program: FY22 R&TD Strategic Initiative
Strategic Focus Area: Intelligent Adaptive Observing System
Strategic Initiative Leader: Benjamin Smith

Objectives

Planning Observations for Intelligent Science Experimentation (POISE) develops autonomous technologies that enable coordinated, targeted, adaptive observations across multiple observing systems guided by the estimated improvement to our model-based understanding, predictive skills, and scientific understanding of highest priority Earth processes in the Earth Science Decadal Survey.

Adaptive Observing Concept



Background

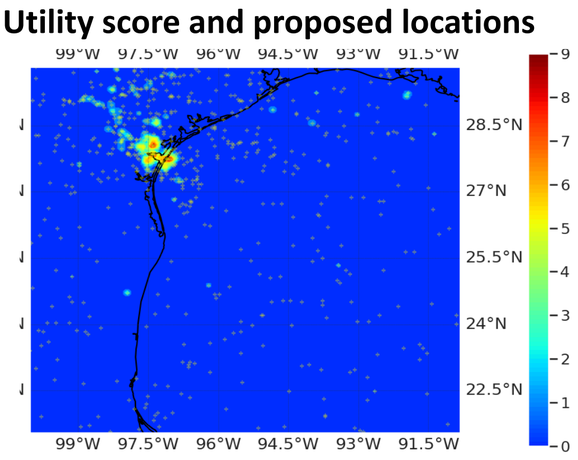
- Current systems observe based on instrument configurations
- Simple triggers used
- Model and predictions have no impact on observations (“blind observations”)
- Assets not coordinated

- ***Identification*** *of observations that are most useful to a physical model with machine learning.*
- ***Coordination*** *across observing assets to schedule targeted measurements.*
- ***Assimilation*** *of obtained observations back into the forecast model.*
- *Hurricane intensification as a case study.*

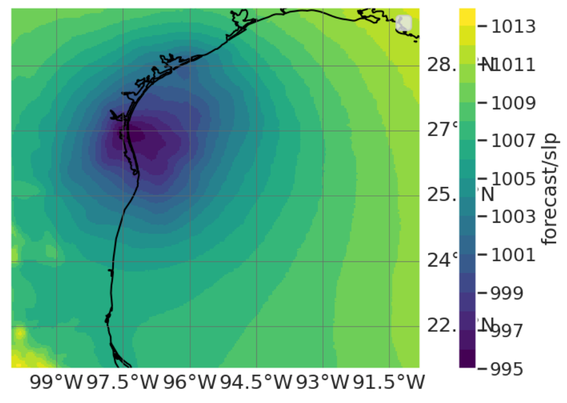
Utility

- Utility measures reduction in variance (RIV) of a forecast ensemble
- ML model (ensemble trees): 1) predicts forecast at a locations based on any number of other locations, 2) extracts only impactful locations and types of observations, 3) computes RIV as pseudo coefficient of determination.

Utility score and proposed locations

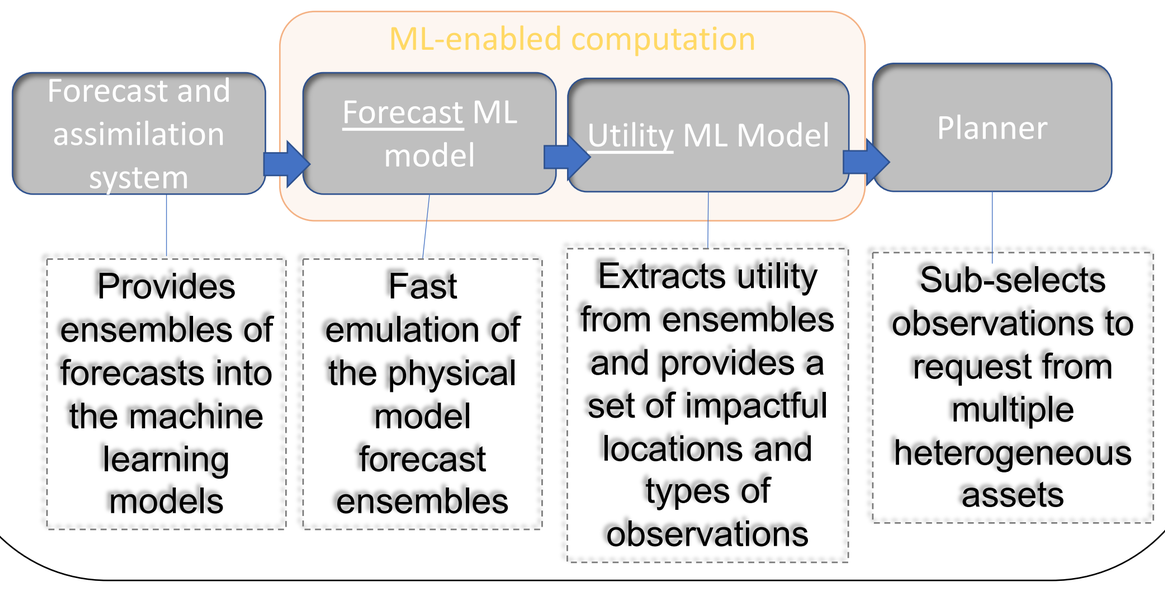


Example forecast of sea level pressure



Approach

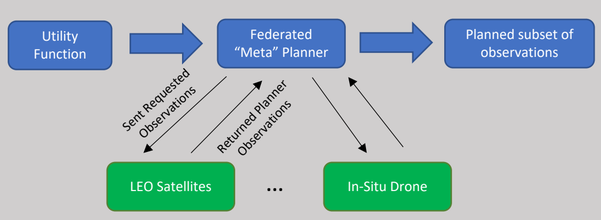
New technologies include 1) variational ensemble generation for many hurricane cases and dates, 2) machine learning model to accelerate forecast, 3) observational utility metric and machine learning (ML) utility model, 4) utility-based observation scheduling:



Planning

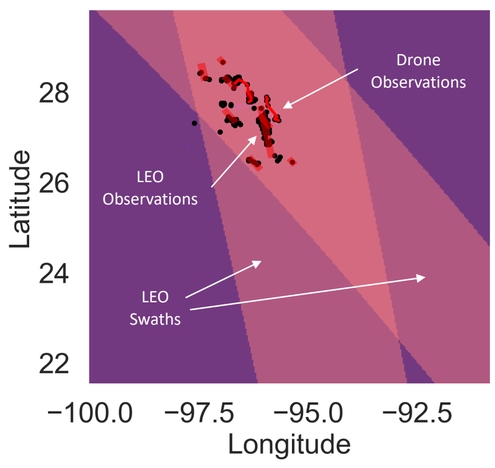
- Select observation requests to maximize utility while obeying operational constraints of multiple heterogeneous assets.
- Utilizes combinatorial optimization (i.e. simulated annealing) to allocate requests to individual assets.

A new automated federated observation planning strategy developed, motivated by the adaptive observing system:

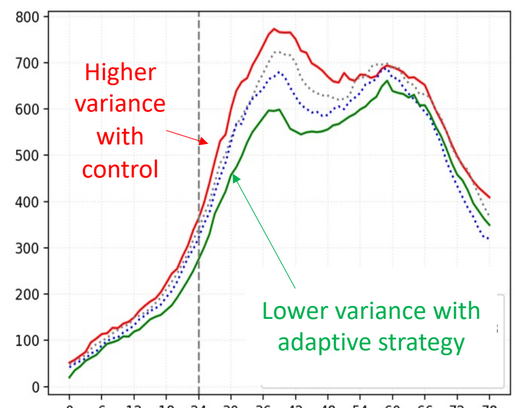


- Combines observations from independent heterogenous assets to maximize utility
- Decouples utility from low-level planning, easier integration with existing asset operational systems.

Planned Observations



Variance of the forecast ensembles



Significance/Benefits to JPL and NASA

- Maximizes science return of observations from multiple assets
- Improve science understanding and predictive capabilities
- Applicability to systems with strong assimilative models
- Strong support for mission proposal competitiveness

Results

- Demonstrate a **~25%** reduction in sea level pressure forecast ensemble variance in OSSE-type simulation experiments over “blind” observations.
- Tropical cyclone intensity projections closer to the true state
- Improved numerical model stability

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Publications:

Branch, A.; Chien, S.; Marchetti, Y.; Su, H.; Wu, L.; Montgomery, J.; Johnson, M.; Smith, B.; Mandrake, L.; and Tavallali, P., “Federated Scheduling of Model-Driven Observations for Earth Science”, *In International Workshop on Planning & Scheduling for Space (IWPSS),* July 2021.

Tavallali, P., Chien, S.; Mandrake, L.; Marchetti, Y.; Su, H.; Wu, L.; Smith, B.; Branch, A.; Mason, J.; and Swope, J., “Adaptive, Model-Driven Observations for Earth Science”, *In Proceedings of the International Symposium on Artificial Intelligence, Robotics and Automation in Space (i-SAIRAS 2020),* January 2020.

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