National Aeronautics and Space Administration

Planning Observations for Systematic Science Experimentation (POSSE)

Principal Investigator: Peyman Tavallali (398); Co-Investigators: Yuliya Marchetti (398), Margaret Johnson (398), James Montgomery (398), Steve Chien (397), Andrew Branch (397), Hui Su (329), Longtao Wu (398)

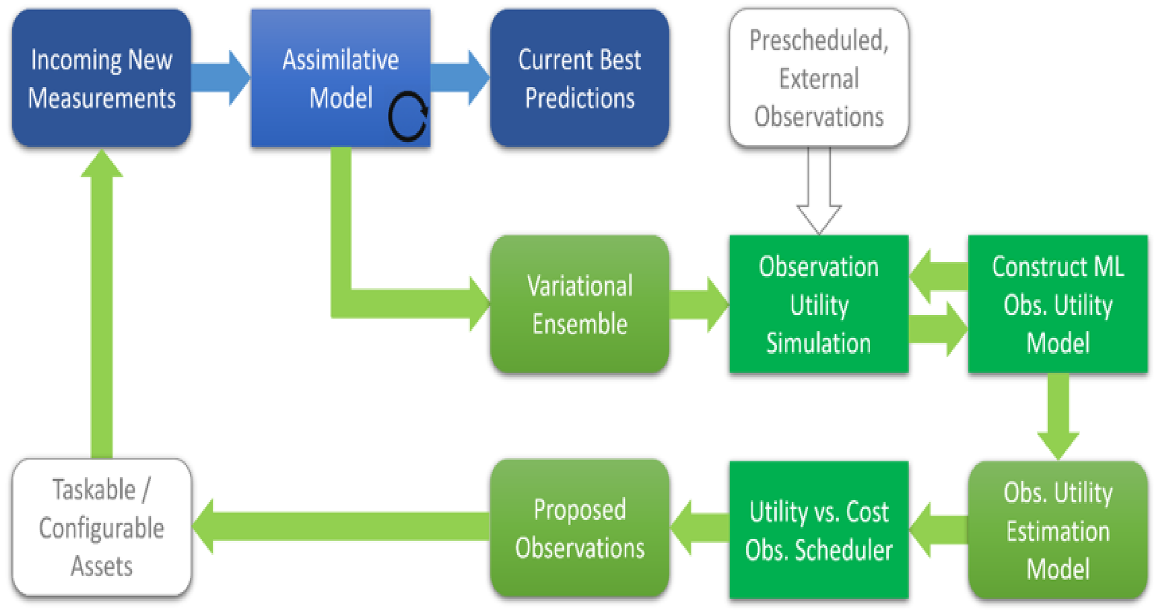
Program: FY21 R&TD **Strategic Focus Area: Intelligent Adaptive Observing System**

Objectives: Year 1: Conduct a study to determine the upper-bound metrics improvement in prediction of a single hurricane track based on the observation utility estimation. Develop a multi-observational utility estimation framework to efficiently evaluate a set of proposed observations. Design for a preliminary aerial route planning problem specification and algorithms and provide a scheduling algorithm prototype that is utility sensitive. **Year 2:** Construct an adaptive observation planning prototype to maximize model understanding and prediction based on a single hurricane track based on a single observation utility estimation. This includes ensemble model generation, machine learning estimation of observation utility, and constraint-based scheduling/tasking of target instruments. **Year 3:** Expand the results from Year 1 to incorporate a diversity of past hurricanes and identify the relevant subset for a current hurricane target. **Year 4:** Extend the integrated observation system to incorporate dependencies between sequential observations. Perform OSSE evaluation of adaptive policies with agile observations and cost constraint scenarios. Define optimal abstract instruments selected by POSSE for current and future JPL instruments.

Background: Currently, data-assisted physical model systems only ingest the passive observations impeding their accuracy and reliability (see Figure 1). Coordination between the physical models and the constellation of measurement instruments is challenging due to the involvement of many active and complex assets. However, the ability to take coordinated observations across assets in an observing system, and to target those observations on the most scientific relevant areas will enhance the accuracy of state estimation and maximally inform the scientific understanding of the system dynamics. Having a smart data collection system will also reduce the operational costs due to its optimal target monitoring which in turn allows the allocation of the measurement assets to other tasks. Executing those observation goals in an intelligent observation network will enable a broader and more powerful set of observations, with commensurate increase in science understanding. Observing assets are spatially and temporally distributed, and have different kinds of instruments and capabilities, all of which can be exploited to satisfy observation goals. POSSE further amplifies that observing power by being able to react to events.

Approach and Results: Traditional assimilative systems have a single algorithmic element that combines current state understanding, a physics-based forward model, and fresh observations to produce an optimal nowcast and forecast.

POSSE extends this very successful architecture to incorporate the concept of proposing optimal sets of desired observations that would maximally improve state estimation.



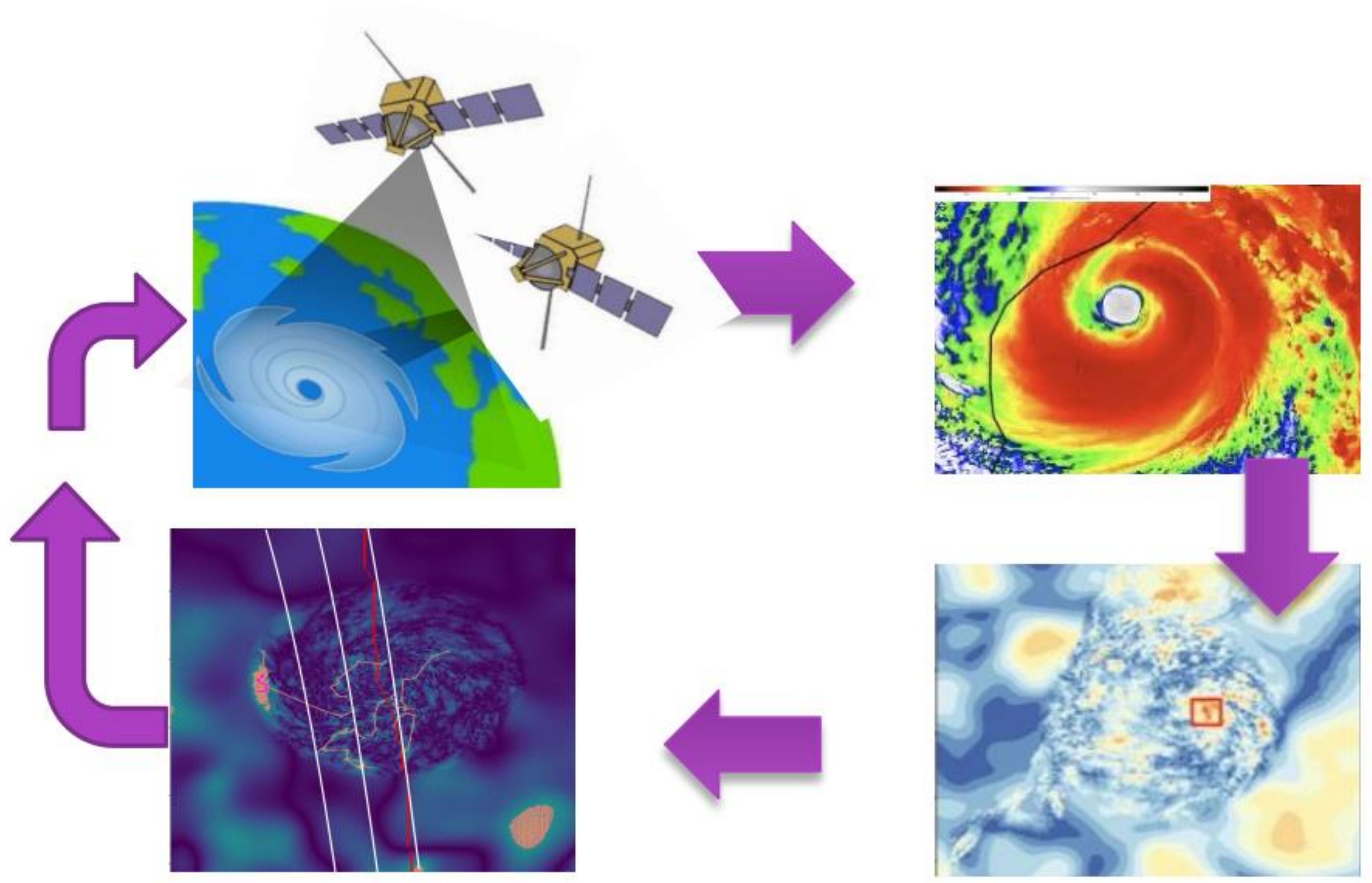
Significance/Benefits to JPL and NASA: The ability to take coordinated observations across assets in an observing system, and to target those observations on the events that are most scientifically informative, will advance JPL's capabilities in intelligent instruments and autonomy, and improve our science understanding and predictive capabilities in areas of high societal impacts. The kinds of targeted, coordinated observations that can be acquired by such a system will enable new classes of science missions such as direct hypothesis testing of the system. It will enable first-of-kind adaptive sampling strategies driven by specific science goals such as overall model or specific parameter uncertainty reduction, ensuring coverage over recognized science regions of interest, and provides strategies conditioned on already scheduled observations from other observing systems. This proposal will construct a general framework and learning system applicable to problems beyond hurricanes. It will bring major applicability to all systems where strong assimilative models are present. This proposal is a significant step in developing collaborative novel data-driven approaches and traditional model-based inference. As an outcome, this proposal will enable OSSE-like exploration of alternative instruments, tuned instrument reconfiguration, or new mission concepts including small-sat constellations. In general, our approach will bring strong support for JPL mission proposal competitiveness.

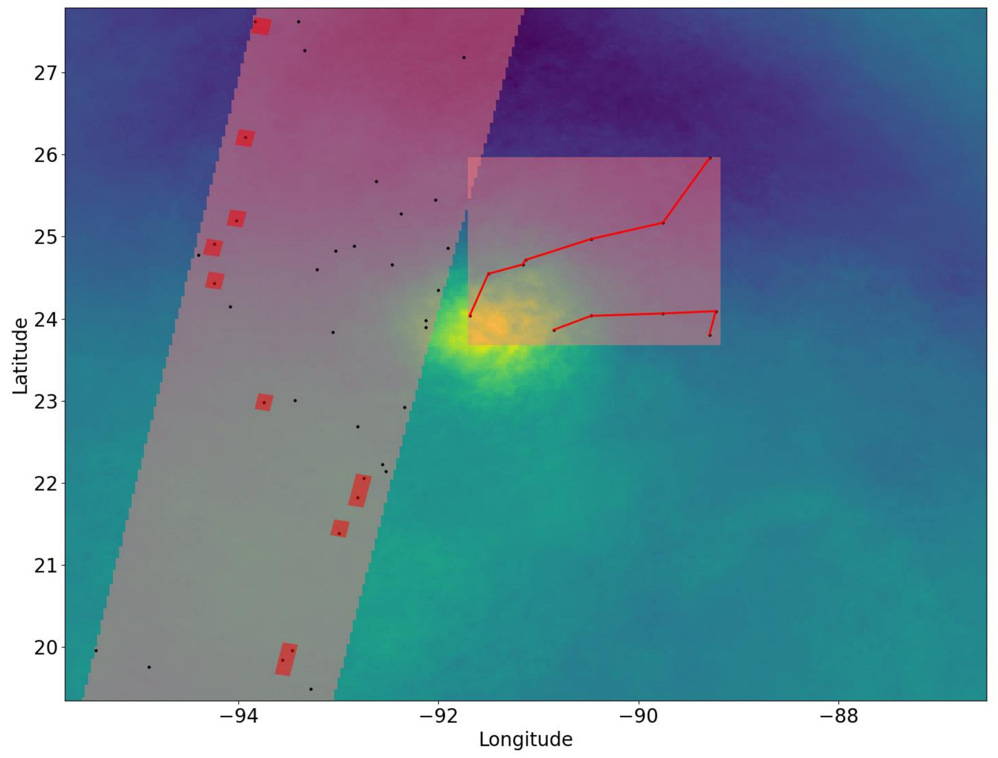
Publications:

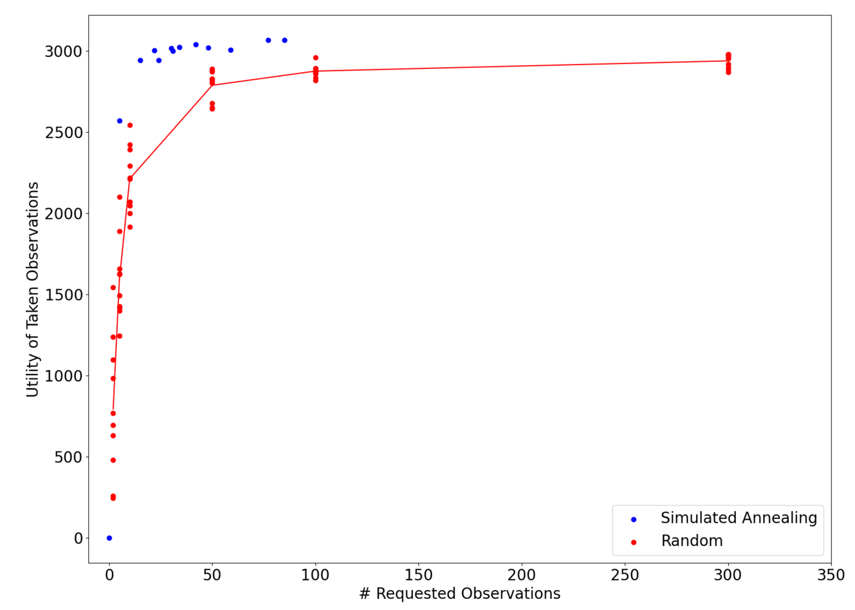
Tavallali, P.; Chien, S.; Mandrake, L.; Marchetti, Y.; Su, H.; Wu, L.; Smith, B.; Branch, A.; Mason, J.; and Swope, J. Adaptive Model-driven Observation for Earth Science. In Proceedings of the International Symposium on Artificial Intelligence, Robotics and Automation for Space (i-SAIRAS'2020), Virtual, 2020. European Space Agency;

Tavallali, P.; Chien, S.; Mandrake, L.; Marchetti, Y.; Su, H.; Wu, L.; Smith, B.; Branch, A.; Mason, J.; and Swope, J. Adaptive Model-driven Observation for Earth Science. In Proceedings of the Fall Meeting of the American Geophysical Union, Washington, DC, USA, 2020. American Geophysical Union;

P. Tavallali, S. Chien, L. Mandrake, Y. Marchetti, H. Su, L. Wu, B. Smith, A. Branch, J. Mason, J. Swope, Adaptive Model-driven Observations for Earth Science, 101st Annual Meeting of the American Meteorological Society, 2021.







National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

PI/Task Mgr Contact
Email: peyman.tavallali@jpl.nasa.gov

Poster No.
Clearance No.
JPLTask#R20037