National Aeronautics and Space Administration

Surface Reflectance Data Fusion for Current and Future JPL Missions

Principal Investigator: Margaret Johnson (398)
Co-Investigators: Gregory Halverson (329), Jouni Susiluoto (398),
Kerry Cawse-Nicholson (329), Glynn Hulley (329)

Program: FY22 R&TD Topics
Strategic Focus Area: Uncertainty Quantification

Objective:

Develop a flexible, multi-instrument data fusion methodology to produce high spatial resolution visible to shortwave infrared (VSWIR) multispectral surface reflectance products at daily temporal resolution. Specific objectives are to 1) develop statistical data fusion models and a scalable Kalman filter/smoother feasible for regional to global scale processing, 2) demonstrate and validate the methods using Visible Infrared Imaging Radiometer Suite (VIIRS) imagery, the Harmonized Landsat Sentinel (HLS) products, and auxiliary validation datasets, 3) illustrate the impact of fused surface reflectance products and uncertainty information in evapotranspiration (ET) retrieval algorithms.

Background:

Due to physical limitations on the spatial, temporal, and spectral resolutions of individual sensors, no single, non-commercial space mission can currently provide the daily, moderately high spatial resolution (<100 m) VSWIR data products needed to monitor geophysical processes that exhibit rapid changes over space and time. Multi-sensor data fusion leveraging the strengths of individual instruments presents a solution to the challenge of instrument spatial-temporal-spectral resolution tradeoffs. Additionally, quantified uncertainties associated with the fused estimates will be crucial for downstream quality assessments, sensitivity and uncertainty quantification studies, and for informed science inference and decision making.

Significance/Benefits to JPL and NASA:

The data fusion capability will increase the usability of data from current and future missions, from ECOSTRESS to SBG. Our methods will provide critical technology for the optimal use of SBG data both in data fusion across wavelength ranges (such as for ET), as well as fusion between complementary instruments, such as ESA's CHIME. Data fusion has the potential to improve the resolution (and uncertainty understanding) of ecosystem studies of phenology and carbon cycling, increasing JPL's competitiveness in NASA program calls. This project will provide new state-of-the-art data fusion methods that are currently unavailable both within and outside of JPL, further contributing to JPL's leadership in data fusion and uncertainty quantification.

Approach and Results:

Our methodology uses statistical spatiotemporal models to leverage the correlations between past, present, and/or future observations across multiple instruments to predict, *with quantified uncertainties*, spatially complete images at spatial and temporal resolutions jointly finer than capable by single instruments. We developed the statistical model and a scalable Kalman filter/smoother using near-infrared reflectance from VIIRS (daily, ~500m resolution) and HLS (~5 day, 30m resolution) in a region over the Salton Sea, CA and a region in England corresponding to a HyTES overpass.

Data fusion is performed by recursively obtaining the posterior probability distribution of the target high-resolution image using any past and current observations (filtering) or past, current, and future observations (smoothing), see Fig. 3. By leveraging statistical correlations between observations, our data fusion methods provide spatially complete estimates even on days with substantial missing data (Fig. 1). The probabilistic approach directly provides uncertainties with each fused estimate (Figs. 2 and 3).

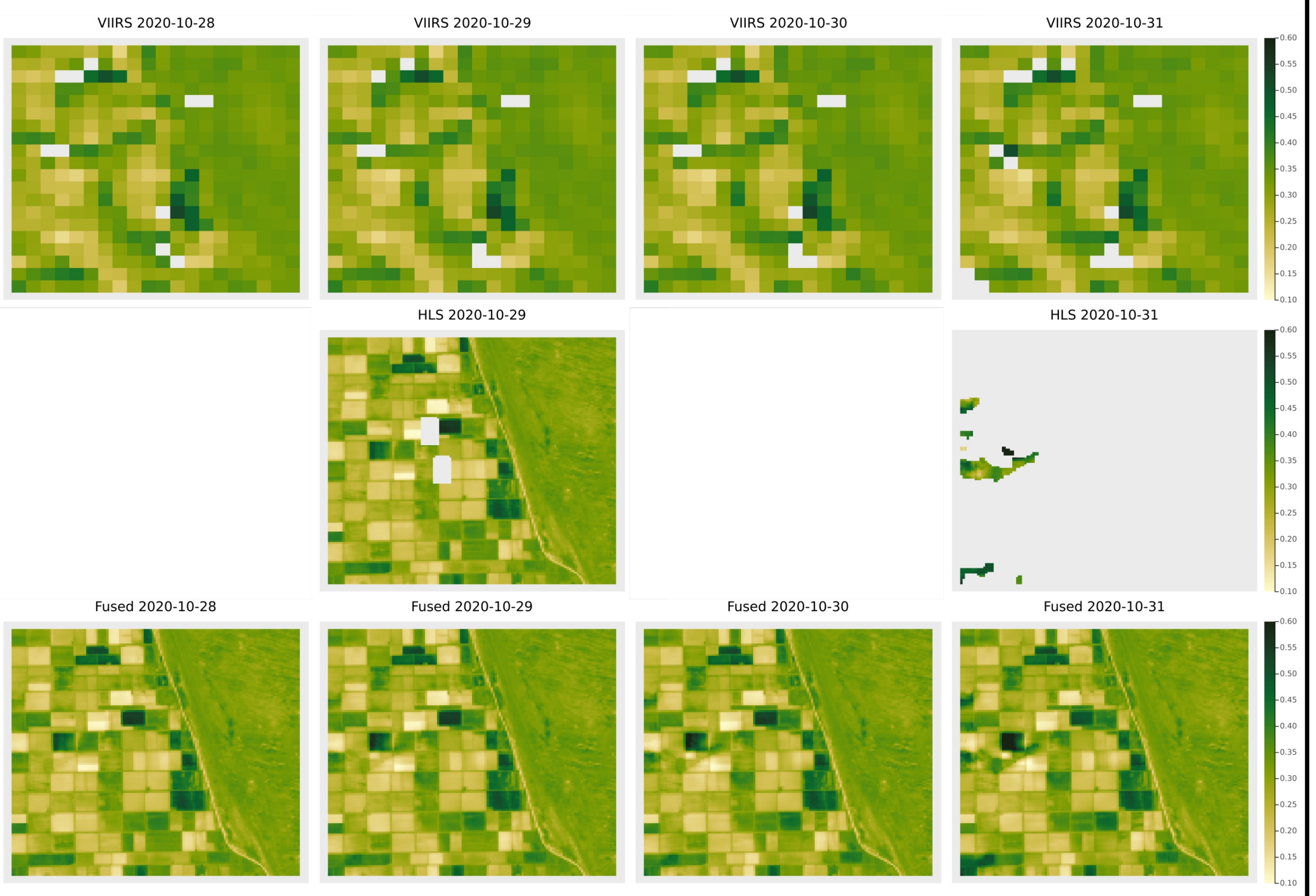


Figure 1: *Near-infrared reflectance 70m fusion results (bottom) near Salton Sea, CA. The fusion method leverages the temporal information from VIIRS coarse resolution imagery (top) while maintaining the fine-scale structure learned from recent HLS imagery (middle) to make complete predictions when fine imagery is missing due to temporal resolution or cloud contamination.*

To achieve scalability to regional and global scales, we developed a computationally-efficient, moving-window Kalman filter/smoother. The method breaks the spatial domain up into small, overlapping blocks that are fused independently (spatially) and then stitched back together to produce complete imagery. This method is highly parallelizable and the overlap between blocks results in minimal spatial artifacts (Figs. 1 and 2).

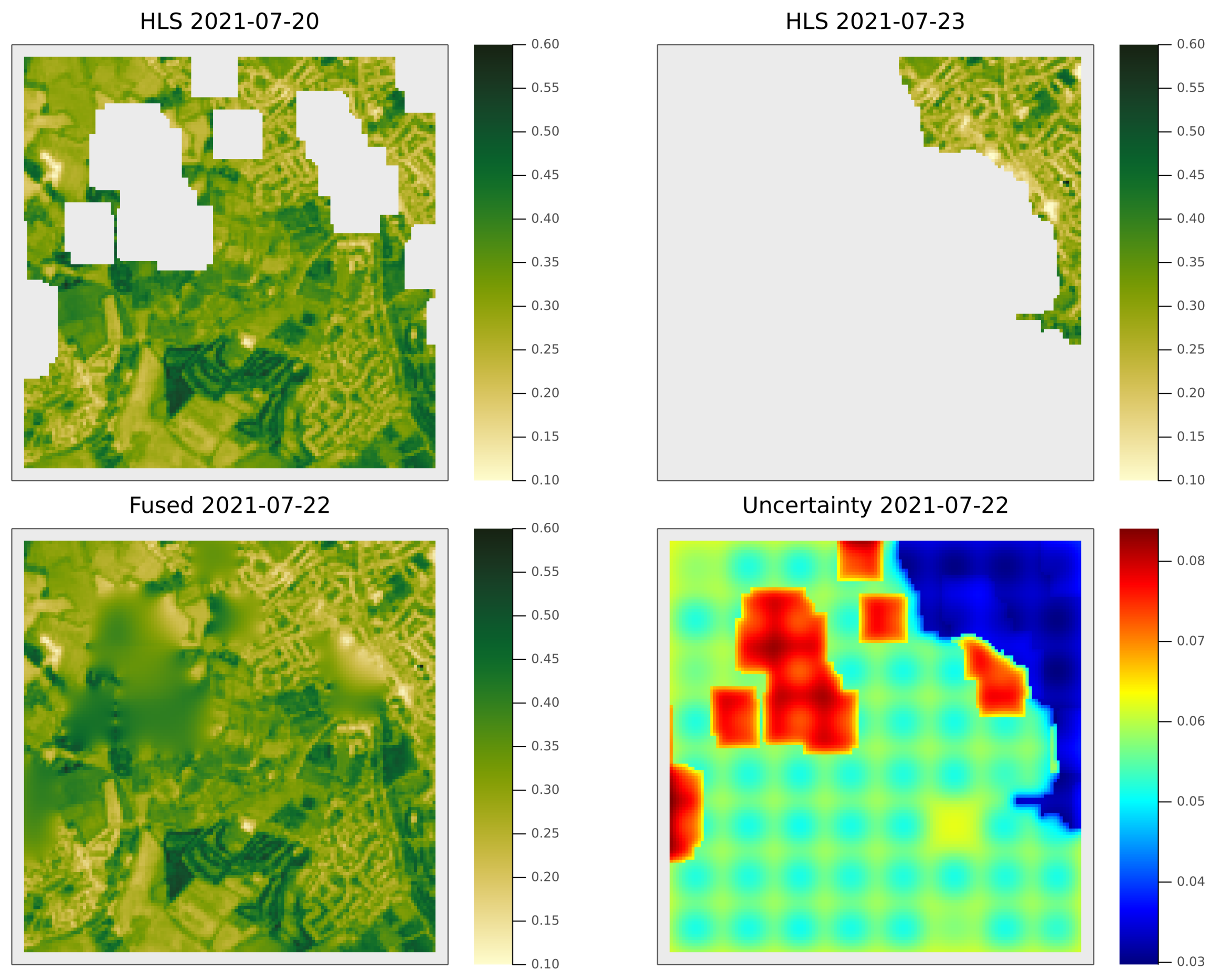
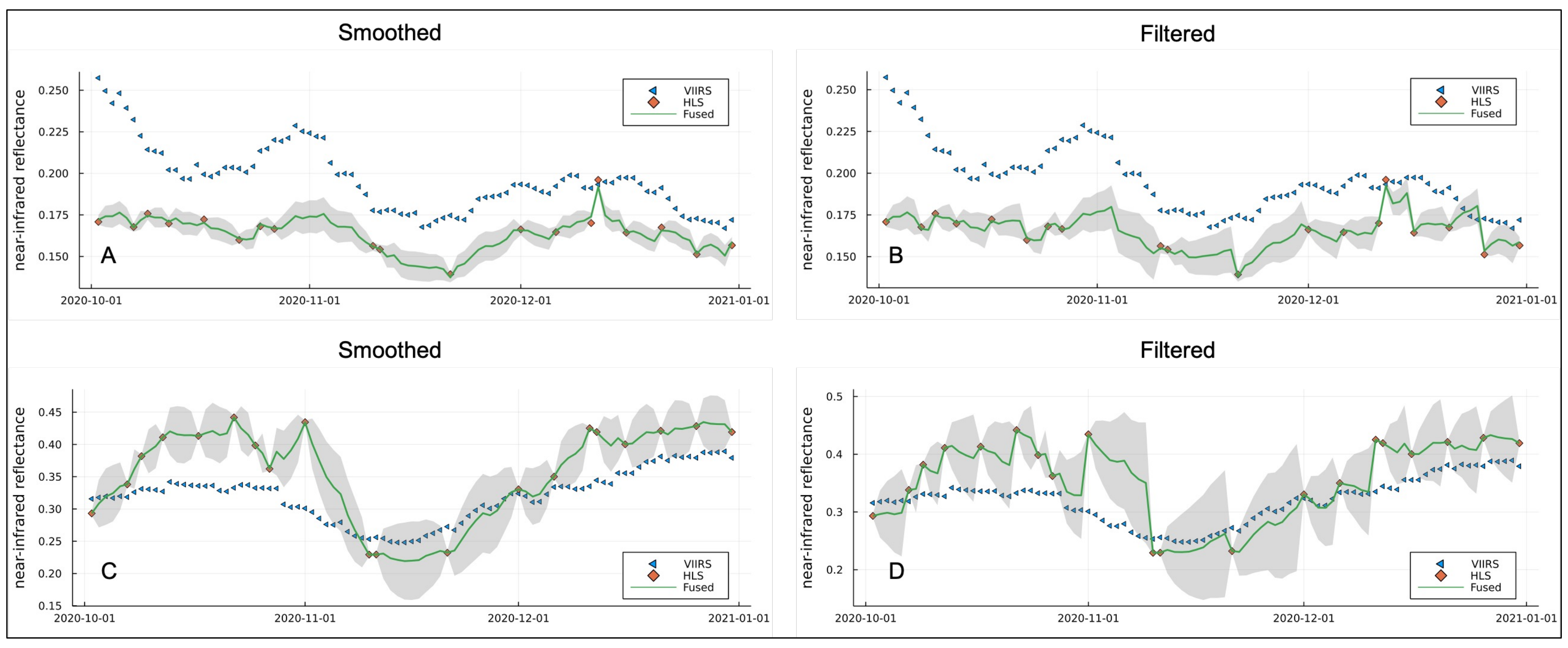


Figure 2 (Left): *Example 30m fusion results of near-infrared reflectance on July 22, 2021 over the HyTES region. (Top) Most recently available 30m HLS imagery on July 20, 2021 and July 23, 2021. (Bottom) 30m resolution fused imagery (left) with pixel-level uncertainties (right) using all available HLS/VIIRS data from July 5 – August 4, 2021. Due to the cloudiness in the region over the time period, fine scale structure is never observed in certain parts of the image but crucially, this lack of fine-scale information is quantified by larger uncertainty in the fused estimate (bottom right).*

Figure 3 (Below): *(A) and (C) show example daily, 70m fused time series of near-infrared reflectance (green) with uncertainty intervals (grey) at two 70m pixels, using both past and future (smoothing) coarse VIIRS and fine HLS near-infrared measurements. (B) and (D) show fusion results for the same pixels but now using only past and current observations (filtering/streaming) at each time point. Higher uncertainty in filtering results is reflected in the increasing uncertainty envelopes until new HLS (red) measurements are observed.*



National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#22-5234
Poster Number: RPC#R22126

PI/Task Mgr. Contact Information:

Email: maggie.johnson@jpl.nasa.gov