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1 PROJECT CONTENT

Summary. This project will advance the capability of multiple stakeholders in California's water resources to routinely access and utilize Earth observations-based water quality products to support operational or institutional decision-making related to water management practices. Our proposal is based on the intersection between water quality parameters used in our partners' respective organizations and the data products that can be derived from remote sensing datasets. Based on this, we propose to do the following: (1) develop and/or strengthen existing algorithms from various platforms for the identified water quality products; (2) centralize and, in some cases, automate processing for, water quality products for access through the Bay Delta-Live ((BDL) baydeltalive.org) web application; and (3) iteratively work to develop a suite of decision dashboards that encompass specific use cases or management use scenarios.

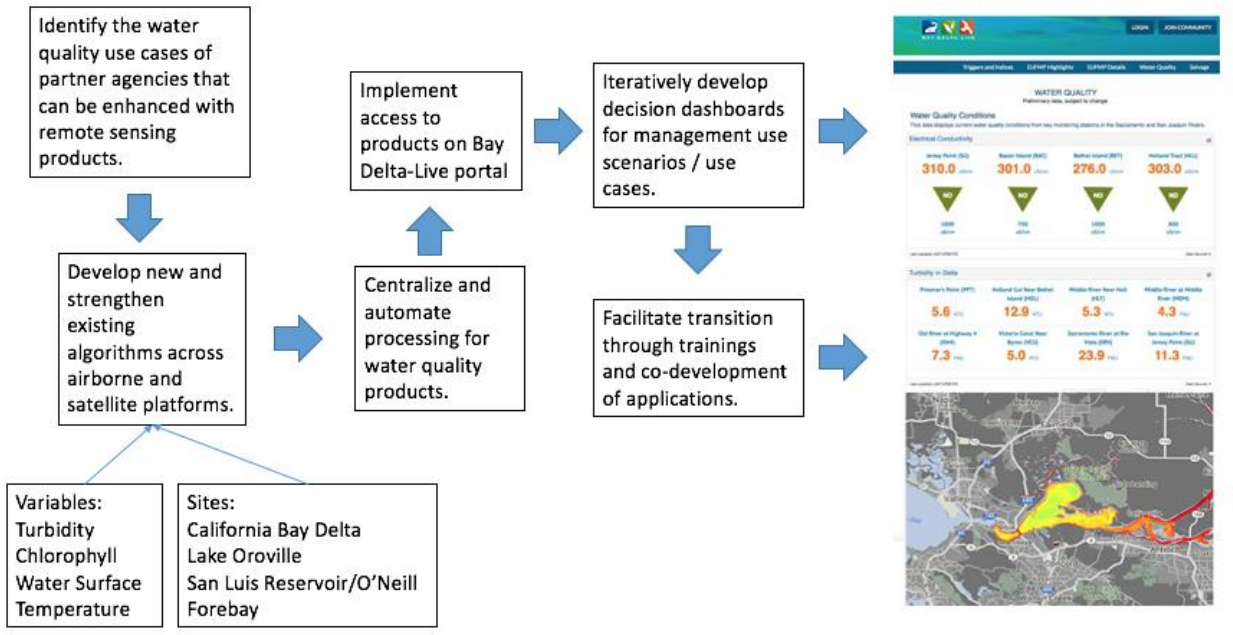

Figure 1-1. Proposed Workflow. Note that example dashboard hosted on partner-funded Bay Delta-Live (baydeltalive.org) would integrate existing datasets, such as from *in situ* monitoring stations, and remote sensing-derived water quality products.

1.1 Decision-Making Activities

Using water quality in export/release operations and water resource management decisions (based on discussions with Metropolitan Water District (MWD) and California Department of Water Resources (CDWR)). Water quality is the crucial link between public health, ecological health, and water resources. In monitoring water quality, we are able to understand the status of drinking water and source water supply (and make decisions about the type of treatment technologies need to applied), the status of recreating waters and whether they pose a health risk, and impacts on aquatic and coastal environments and the species that inhabit those systems. In this project, we identify decision use cases in which water quality is used to help balance between the competing needs between water supply uses and environmental protection as well as management of resources for restoration efforts.

Turbidity. Turbidity is a measure of the amount of suspended material in water that is scattering light, often referred to as the "cloudiness" of the water column and can be represented in Nephelometric Turbidity Units (NTU) and sometimes referred to in units of mass (μg or mg) per volume unit (L). In the Bay Delta, turbidity is an especially important water quality variable because it is associated with the endangered species (at federal and state levels) *Hypomesus transpacificus* (Feyrer et al. 2007), also known as the *Delta smelt*. This association is marked during winter months during the Delta smelt spawning cycle, whereby the "first flush" storm, accompanied by high levels of turbidity, is linked in triggering smelt migration (Sommer et al. 2011). As a result, turbidity levels during winter months, in the California Bay Delta, is an important factor driving export and release operations, which, under state and federal mandates, must work to prevent entrainment of fish in export facilities. **12 NTU is the turbidity threshold during winters months** which, when exceeded for more than 3 days at certain locations, can trigger actions on export operations, as documented in the US Fish and Wildlife Services Biological Opinion (U.S. Fish and Wildlife Service 2008).

For Lake Oroville and San Luis Reservoir/O'Neill Forebay, turbidity is monitored regularly and managed as needed. Lake Oroville's turbidity must be maintained within the range of 0.58 mg/L to 25 mg/L while San Luis Reservoir will monitor and respond on an as needed basis, if turbidity levels begin to "cause nuisance or adversely affect beneficial uses." (U.S. Bureau of Reclamation 2013).

Temperature. In the Bay Delta, during warmer months, the dominant water quality factors for operations often shift towards salinity and temperature (note that salinity is not a focus of this proposed project). This is in part because, during warmer months, saltwater intrusion and higher temperatures become a greater risk factor to smelt, and operations prioritize these variables more heavily. The thresholds for temperature are specified depending on time of year (U.S. Fish and Wildlife Service 2008) and designed to be protective of endangered fish habitats. Currently, these parameters are also monitored using stations, which are continuous temporally but very discrete spatially (one localized issue with discrete stations is that they are typically installed on the channel embankment and may not reflect distributions of conditions across the channel). In one example, if a certain temperature threshold is exceeded, restrictions on pumping may be relaxed, so that operations can proceed with pumping and reduce water temperatures.

For Lake Oroville, water temperature requirements were set by the NOAA National Marine Fisheries Service Biological Opinion and summarized in a DWR Report about Fish Species Composition in Oroville (Schwarzenegger & Chrisman 2004) and have different thresholds throughout the year, depending on season. One of the main goals of including Oroville in this study is to ensure more spatially and temporally consistent monitoring of the system. For San Luis Reservoir / O'Neill Forebay, the temperature requirements were specified in terms of not exceeding 5 degrees C between the incoming waters and the reservoir waters (U.S. Bureau of Reclamation 2013).

Chlorophyll. Chlorophyll-a is a measure of phytoplankton biomass or abundance, which is the largest living component in the Bay Delta (sfbay.wr.usgs.gov) and the ecological food base in many estuarine systems (Cloern 1996), including the Bay Delta. Phytoplankton and zooplankton have been severely impacted by changes in this highly altered system. Of note are two events that occurred in the 1980s, which included the construction of a wastewater treatment system and the introduction of an invasive clam, the *Corbula amurensis*, after which productivity in this

system plummeted (Alpine & Cloern 1992). Chlorophyll can be used to monitor the onset of phytoplankton blooms, that support the ecology of the Delta, including the Delta smelt; to this end, the Metropolitan Water District and stakeholders are interested in better understanding the conditions that allow these blooms to occur and possibly incorporate this knowledge into water management and restoration efforts.

Figure 1-2. Recent headline indicating issues with algal blooms in California waterways.

In addition to monitoring beneficial phytoplankton blooms, chlorophyll-a may potentially be used as an early indicator of an algal bloom that has detrimental impacts (Sutula et al., submitted), either as a nuisance algae that can impact water supply systems or if they are toxin-producing. The drought has also been implicated in the series of algal blooms occurring across California currently, of which there is one in San Luis Reservoir (that was harmful, and required a public warning) and one that was occurring in Lake Oroville. Algal blooms, depending on extent and severity, could trigger mitigative actions or impact downstream water treatment operations.

Tools. Water resource operators and stakeholders currently rely on *in situ* data in their decision-making processes. California DWR utilizes an Excel application that extracts station data from the California Data Exchange Center and provides some statistics calculating capabilities. This existing process could potentially be enhanced, and will be used as the basis for a data decision dashboard (to be further discussed in the Technical Approach and Methodology section).

1.2 Earth Observations and Other Data Sources.

Table 1-1. Priority water quality parameters, platform, and sites. Shaded Cells indicate airborne platforms/sensors.

Parameter	Platform/Sensor To Be Utilized	Sites
Temperature	Landsat-8 Thermal Infrared Radiometer	Bay Delta, Lake Oroville, San Luis Reservoir/O'Neill Forebay
	Suomi National Polar-Orbiting Partnership (Suomi NPP) Visible Infrared Imaging Radiometer Suite (VIIRS)	Bay Delta, Lake Oroville, San Luis Reservoir/O'Neill Forebay
	Moderate Resolution Imaging Spectrometer (MODIS) / Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Airborne Simulator	Bay Delta
Turbidity and Suspended Sediment	Landsat-8 Operational Land Imager	Bay Delta, Lake Oroville, San Luis Reservoir/O'Neill Forebay
	Sentinel 2 Multispectral Instrument (MSI) / 3 Ocean and Land Colour Instrument (OLCI)	Bay Delta, Lake Oroville, San Luis Reservoir/O'Neill Forebay
	Airborne Visible and InfraRed imaging Spectrometer (AVIRIS) - Classic (C) and Next Gen (NG)	Bay Delta
	Portable Remote Imaging SpectroMeter (PRISM)	Bay Delta
Chlorophyll-a	Landsat-8 OLI	Bay Delta, Lake Oroville, San Luis Reservoir/O'Neill Forebay
	Sentinel 2 MSI/3 OLCI	Bay Delta, Lake Oroville, San Luis Reservoir/O'Neill Forebay
	AVIRIS-C, AVIRIS-NG	Bay Delta
	PRISM	Bay Delta

Other Data Sources.

Bay Delta. In situ monitoring – station network. A combined 46 turbidity monitoring stations, operated by U.S. Geological Survey (USGS) and CDWR, are distributed throughout the Delta. These stations are typically installed at the edge of the channel; because of the heterogeneity of Delta, the existing network cannot comprehensively capture the spatial variability of these conditions. There are 144 temperature monitoring stations in the Delta, operated by a combination of US Bureau of Reclamation (USBR), CA Department of Fish and Wildlife Services, CDWR, and USGS. Lake Oroville and San Luis Reservoir/O'Neill have *in situ* stations, and it will be part of the project to fully characterize these existing data resources.

In situ monitoring – field data collection. A more detailed description of our field data collection process and algorithm development/refinement will be described in the Technical Approach section. Our proposal team members have significant experience leading different projects in the Delta and San Luis Reservoir, we will be able to leverage field data collection across all their respective works.

1.3 Project Elements

1.3.1 Description of the Water Quality Challenge and Project Sites

Water quality is a critical element of freshwater supply, particularly in times and areas of drought, in part due to less dilution in the presence of point contaminant sources (Mosley 2015). Limited water resources can be further strained if water quality is not managed properly. While there are measures in place to protect human and environmental health from poor and risky water quality conditions (US EPA, 2002), implementation of these measures are reliant on collecting physical water samples, or using station data, both of which provide a spatially and temporally incomplete understanding of water quality conditions. This consideration is especially important in environments that are highly complex and heterogeneous such as the Bay Delta, as well as in budget-constrained systems, or with sites that are remote and have limited access.

It is widely recognized that Earth observations may be valuable to improving water management (Lee et al. 2016) and has gained traction primarily in managing water supply, land use practices related to water resources, and consumptive use / agriculture water demand . There is considerable potential for application of remote sensing to specific water quality management challenges as well (Lee, Orne, and Schaeffer 2014) and represents an opportunity to supplement existing networks and datasets that collect ground-based point measurements.

In this applications project, we will leverage and demonstrate the complementary benefits across satellite, airborne, and ground-based platforms for water quality monitoring and management, as it relates to freshwater resources. We envision this multi-tiered approach because each platform has it value and its limitations: satellite missions may provide systematic measurements over years to decades for an important suite of water quality variables, including chlorophyll-a concentration (Moses et al. 2012; Keith 2014), total suspended solids, (Chen et al. 2015; Bonansea & Fernandez 2013) and colored-dissolved organic matter (Slonecker et al. 2016). However, there is a wealth of airborne imaging spectroscopy data not yet analyzed for water quality properties, that could also play a role in supporting water resource management by providing water quality estimates at greater spatial and spectral resolution needed for inland waters (e.g. phycocyanins, the diagnostic pigment of harmful cyanobacterial blooms). High resolution airborne imaging spectroscopy can also be used to map submerged and floating aquatic vegetation (Hestir et al. 2008; Khanna et al. 2011) and have been used to map

water quality parameters relevant to this project, with AVIRIS (Hoogenboom et al. 1998; Karaska et al. 2004), as well as PRISM (Fichot et al. 2016) and MASTER (Hulley et al. 2011). It should be noted that ground-based monitoring will continue to be important; field efforts, for example, can be much more flexible, with existing mechanisms in place to respond to events of importance (such as first storm events, floods) and monitoring stations enables continuous temporal monitoring of variables at certain point locations. Furthermore, analysis of collected samples can provide detail about water quality parameters that cannot be determined by existing remote sensing sensors and platforms, such as nutrient concentration or microbiological contamination.

Site Descriptions.

Bay Delta. The San Francisco Estuary (SFE) (referred to as the "Bay Delta" in this proposal) is the largest estuary on the Pacific coast of North and South America and is in a state of ecological crisis due to the numerous threats to its sustainability (Hanak et al. 2013). The upstream river Delta, formed by the confluence of the Sacramento and San Joaquin Rivers is the nexus of the CA water system. California's Delta is representative of many of the challenges facing estuary and delta ecosystems around the world. The California Delta is a critical node in the Western U.S. fresh water supply system, providing water for over 27 million users and underpinning a $27 billion USD agricultural industry (deltacouncil.ca.gov) . The Delta also provides critical habitat to several threatened and endangered fish, bird and mammalian species, and is considered a biodiversity hotspot. However, it is currently under extreme ecosystem stress from being located in a highly urbanized area, and is experiencing impacts from climate change and human disturbance (U.S. Fish and Wildlife Service 2008). The recent water shortages in the Western U.S. have only exacerbated the competing pressures for water resources and ecosystem sustainability in the Delta. To achieve the co-equal goals of maintaining water supply for the state economy and ensuring sustainability of the ecosystems, this proposal aims to link satellite and airborne remote sensing information with existing data sources to support ongoing management efforts in this system. Importantly, all the investigators on this proposal have engaged in previous work conducted in the Bay Delta; in particular, we are leveraging a recently funded NASA study, lead by Davis and Tufillaro (Figure 1-3).

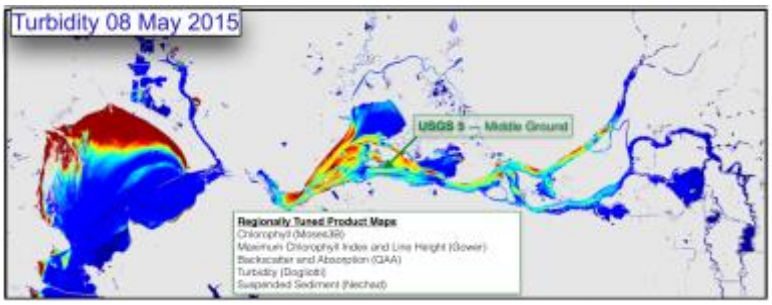

Figure 1-3. Recent Landsat-8 retrievals with turbidity distributions represented in the Bay Delta (Tufillaro et al.)

Lake Oroville is the largest reservoir in the state-managed California State Water Project (California Department of Water Resources n.d.); with a capacity of over 3.5 million acre feet (MAF), Lake Oroville is second only to Shasta Lake (~4.5 MAF) in California. Lake Oroville is a source of water supply, recreation,

hydropower generation, among other uses. Initial Landsat-8 retrievals from (April – July 2016) over this region show potential for assessing suspended particulate matter and chlorophyll using remote sensing data. Based on discussions with CDWR and other studies (California Department of Water Resources 2004; California Department of Water Resources 2009), products of potential value also include temperature, and turbidity. These water quality parameters, for example, can help inform decisions and operations that factor in risk to human health or fish habitats and sample Landast-8 retrievals show potential for resolving this reservoir in this study (Figure 1-4).

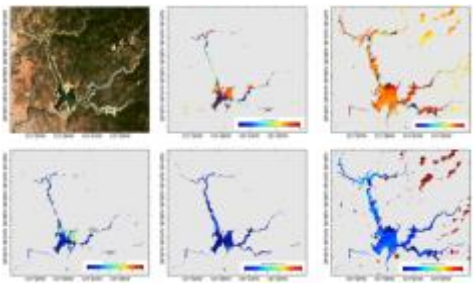

Figure 1-4. Lake Oroville sample retrievals from Landsat-8, applied suspended particulate matter and chlorophyll algorithms.

San Luis Reservoir and O'Neill Forebay. These water bodies are jointly operated by state (SWP, Central Valley Project) and federal entities (USBR) and have a holding capacity of approximately 2 MAF and 50 KAF. They hold water diverted from the Delta for subsequent delivery to federal and State water users in San Joaquin Valley, southern California, San Benito and Santa Clara counties. Water quality constituents of importance include chlorophyll-a and algal blooms, as well as dissolved organic matter, temperature and salinity. Managing agricultural runoff and native fish habitat disruption are also noted as issues in this region (U.S. Bureau of Reclamation 2013). Initial retrievals (Figure 1-5) of Landsat-8 data show promise that these water bodies can be resolved.

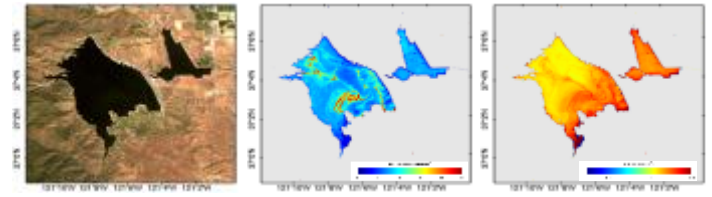

Figure 1-5. San Luis Reservoir / O'Neill Forebay Landsat-8 retrievals of suspended particular matter and chlorophyll, April 2017. Tufillaro et al.

1.3.2 Methodology and Technical Approach

1.3.2.1 Satellite and Airborne Algorithms for Water Quality Parameters

Satellite for optical water quality parameters. For the Bay Delta, we will build on a previous 3-year study of *in situ* optical parameters for the upper bay and Delta (PI Davis, Oregon State University (OSU)). During this study, our team developed a suite of algorithms that incorporated atmospheric correction using the infrared bands as described in (Vanhellemont & Ruddick 2015) and with products generated using either the regionally tuned Quasi-Analytical Algorithm (QAA) (Lee et al. 2002), or direct empirical regressions for turbid water as described in (Vanhellemont & Ruddick 2014). Products include chlorophyll-a, turbidity, and suspended sediment.

In this component of the work, we will automate the processing for these parameters utilizing Landsat-8 (60-m) and Sentinel-2 (10-60-m) and 3 (300-m) sensors, and also some continue to refine existing algorithms by collecting data from the Delta (in coordination with USGS) once per year. For new sites, Lake Oroville and San Luis Reservoir/O'Neill Forebay, we will utilize a similar approach to product development and collect *in situ* optical data on a seasonal basis

(min 3 times per year, in coordination with USGS). Landsat-8 provides an image every 16 days. Combining Landsat-8 with Sentinel-2 will allow coverage every 4 days.

Optical sampling will consist of collecting in water and above water spectrometry with a Satlantic Optical Profiler and Spectral Evolution field spectrometer, according to routines collectively developed with NOAA, NIST, and NASA (Oregon State University & NOAA 2015).

Satellite for water surface temperature. We will be deriving water surface temperature (WSTs) from the 375-m thermal infrared radiometer (TIR) channel (I5) from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on the Suomi-NPP satellite platform and the 100-m pixel Landsat-8 TIR bands (10.6-12.5 μm). With the recent release of the ASTER Global Emissivity Dataset v3 (GED) at ~100 m resolution, emissivity corrections are now possible for the VIIRS I5 band using a spectral adjustment method (Hulley et al. 2015) . For atmospheric correction we use input geophysical fields from the Modern Era Retrospective-Analysis for Research and Applications-2 (MERRA-2) reanalysis data.

Airborne for optical water quality parameters. This component of the project will be leveraging the archival airborne remote sensing datasets from AVIRIS-NG, AVIRIS-C, and PRISM (with as high as 2.5 m spatial resolution in our region of interest) with a primary focus on the Bay Delta (there are no additional flights being proposed). For water column constituents such as turbidity and chlorophyll-a, we will use bio-optical models when inherent optical property data are available for calibrating the model.

Optical water quality will be retrieved from hyperspectral using first, standard products and algorithms available in SeaDAS (image analysis package, seadas.gsfc.nasa.gov) and BEAM (software package for remote sensing data analysis). Once top priority variables are developed, we will also investigate using more advanced algorithms to produce optical water quality variables that can be used to discriminate between organic and inorganic matter, and identify useful proxies of remote-sensing derived water quality variables. For potential secondary variables, including aquatic vegetation and phycocyanin, we will use a semi-empirical approach when spectral characteristics are known. For CDOM, the slope parameter is usually fixed in inversion retrievals, and is a meaningful indicator of colored dissolved organic matter quality and serve potentially as a tracer of anthropogenic dissolved organic matter (wastewater) (Brezonik et al. 2015) and may improve estimates of dissolved organic carbon (Hestir et al. 2015).

Airborne for water surface temperature. Water surface temperature (WST) derived from MODIS/ASTER (MASTER) instrument will be delivered as part of this project over the Bay Delta region. These products were developed for inland water bodies (Hulley et al. 2011) and can be calibrated against *in situ* temperature measurements from in place sensor networks (where available). Spectral libraries from the MODIS Emissivity Library and the ASTER Reflectivity Library will be used. We will use the optical data where possible to reduce the confounding effects of surface roughness and mats of submerged and floating vegetation.

1.3.2.2 Field Sampling and Instrumentation

In situ database acquisition: The development, validation, and fine-tuning of algorithms with optimal performance at proposed sites will require building upon or collecting new databases of simultaneous *in situ* measurement of turbidity, inherent optical properties, and remote-sensing reflectance. Since this proposal will be building on previous work done in the Delta (Hestir et al. 2008; Fichot et al. 2016; Tufillaro and Davis 2016; Hestir et al. 2016), the *in situ* data collection will focus primarily on characterizations for Lake Oroville and San Luis Reservoir/O'Neill Forebay.

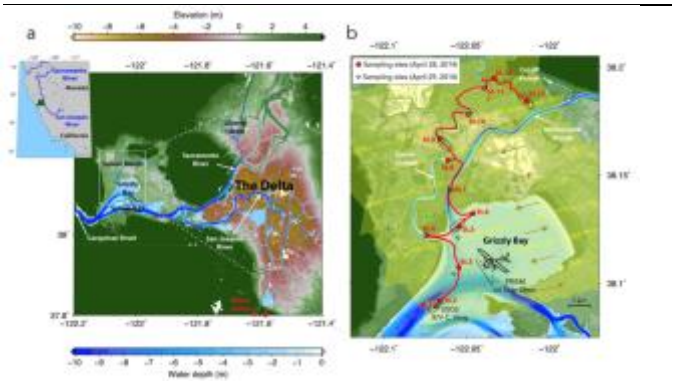

Figure 1-6. Example transact in the Delta showing underway trace and discrete sampling locations, from a study co-led by Co-Is Gierach (JPL) and Bergamaschi (USGS). Fichot et al 2016.

In situ data will be acquired seasonally to capture seasonal variations and contrasting environmental conditions (e.g., before/after rain), and will include transects within Lake Oroville and San Luis Reservoir/O'Neill Forebay and a range of conditions in the Bay Delta. *In situ* turbidity and inherent optical properties will be acquired using an underway flow-through optical and water quality system outfitted on a small watercraft and operated by the US Geological Survey of Sacramento, CA (Figure 1-6). *In situ* data collection (turbidity, chlorophyll, temperature, dissolved organic matter, total suspended solids) will be scheduled to coincide with satellite overpass and matched accordingly in time and space to the remote-sensing reflectance from the satellite sensors.

1.3.2.3 Data Pipeline for Web Services

Once the project has sample products on hand, we will be able to proceed with development of a prototype data pipeline that will ultimately prepare the products for display, access, and decision-making the Bay Delta-Live portal (baydeltalive.org), which is currently used by various water resources stakeholders to access a multitude of datasets across California's water systems (with a focus on the Bay Delta). Additional information about front end implementation and decision data dashboards will be described in the next section.

The processing pipeline to make the datasets ultimately available and open to partners and users follows a standard Geographic Information System (GIS) flow and data will be exposed through standard mapping service Application Program Interfaces (APIs). At the center of the data system is a data server and a map server. The data server is responsible for storing all the raw data in its native form, whether it is science data or user-contributed data. The map server will be used to provide the services available to Bay Delta-Live and with customized access and display for specific user-defined use cases.

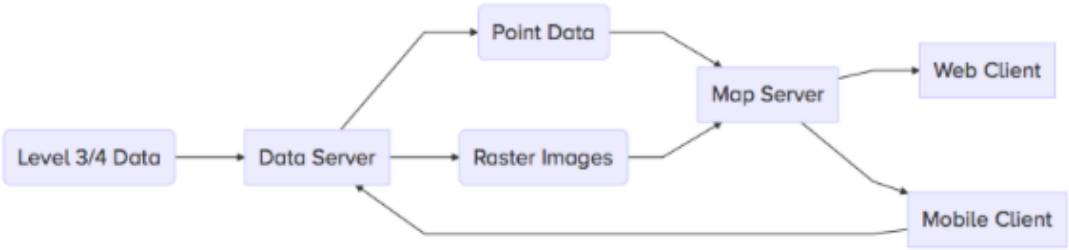

Figure 1-7. Data processing pipeline.

The higher level gridded data products will be ingested into the data server to be catalogued and organized. Once in the data server, the data will be published as point data into the map server for individual data point access. These data will also be converted into a georeferenced raster image in GeoTIFF, which will also be ingested into the map server. The map server will expose Web Mapping Service (WMS)/ Web Mapping Tile Service (WMTS) APIs for retrieving imagery as well as Web Coverage Service (WCS) APIs to access point data. The end goal is to prepare the data such that the front-end web client will enable users to visualize the data as a map as well as individual data points.

1.3.2.4 Front End Development: Implementation to Bay Delta-Live (BDL) Portal (BayDeltaLive.Org)

The objective of this project component is to leverage the existing infrastructure and community of the Bay-Delta Live web application, currently funded by various agencies at the federal, state, and local levels (CDWR, USBR, MWD), to facilitate access to remote sensing data to the water resource managers and Bay Delta stakeholders who already utilize this tool to aggregate and analyze data for their decision-making.

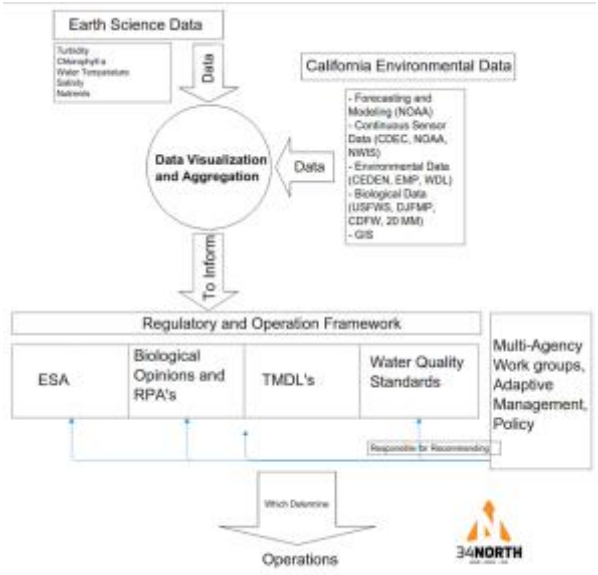

Figure 1-8. 34N Bay Delta-Live existing data-to-decisions workflow that this proposal would be leveraging. Endangered Species Act (ESA); Reasonable and Prudent Alternatives (RPA); Total Maximum Daily Load (TMDL)

The simplified Bay Delta-Live workflow (Figure 1-8) reflects the arsenal of publicly available data available is first be centralized / aggregated, and then configured into dashboards, customized by a user (i.e. stakeholder or agency). Bay Delta-Live is currently designed to support and target water resources operations or regulatory frameworks, such as the Endangered Species Act, Biological Opinions, Total Maximum Daily Loads, and Water Quality Standards. In addition to these decision frameworks, Bay Delta-Live is also very much invested in facilitating access to datasets to support scientific studies.

Figure 1-9. Data dashboards, with some elements of remote sensing products integrated, and are representative of existing dashboard formats provided by Bay Delta-Live.

Examples of use case dashboards (Figure 1-9) include representing turbidity concentrations from both *in situ* and remote sensing-derived products, alongside flow data, water surface temperature, and fish count. Another example would be mapping onset of algal blooms with water surface temperature changes with a time series functionality.

1.3.3 Organizational and Management Approach

Our project management approach to ensure that Earth science results and products are integrated into supporting existing decision-making processes centers on building a team with members from Earth science research community as well as committed and highly knowledgeable colleagues from the management and applications community. Furthermore, we have and will continue to collectively identify existing decision spaces that rely on water quality data that directly overlaps with types of products that we are proposing to develop and deliver using remote sensing datasets. Of note is the inclusion of 34N, who will be a key contributor to the success of this project, as we are leveraging a vetted framework and platform they have already developed to support this community.

We expect the process of refining the data decision dashboards to be a highly iterative process that will occur over the full 3-year project terms. However, we have initiated discussions about potential use cases, which will serve as the starting point for these conversations and to allow MWD, CADWR, and USGS to figure out how to fully utilize the data for their respective needs.

1.3.4 Application Readiness Level

Table 1-2. Summary of Application Readiness Levels of Priority Variables.

Parameter	Platform/Sensor	Current ARL Levels	Anticipated end ARL Level	Lead
Temperature	Landsat-8 TIR	2	7/8	Hulley
	NPP VIIRS	1	7/8	Hulley
	MASTER	2	7	Hulley
Turbidity and Suspended	Landsat-8 OLI	3	8	Tufillaro
	Sentinel 2 MSI/3 OLCI	3	8	Tufillaro

Sediment	AVIRIS-C, AVIRIS-NG	1	7	Hestir
	PRISM	2	7	Gierach
Chlorophyll-a	Landsat-8 OLI	2	7	Tufillaro
	Sentinel 2 MSI/3 OLCI	2	7	Tufillaro
	AVIRIS-C, AVIRIS-NG	1	7	Hestir
	PRISM	2	7	Gierach

1.3.5 Transition Plan and Evidence of Partner Commitment

Partner Commitment. Partners on our project are highly committed to this project. The Metropolitan Water District (see letter of support) will be committing in-kind (for 0.25 FTE total) to participate in this project as well as direct funds to support the work. USGS and CDWR have also provided letters of support; CDWR plans to provide in-kind support to participate in our science team meetings and discuss the prototype applications; they have also provided critical insight into current decision processes and provided an example tool that they currently use to assess turbidity conditions and determine the appropriate response in operations.

Transition Plan Development. The proposal is crafted with sustainability and transition as one of its highest priorities. This is largely reflected through the involvement and integration of the 34N organization, who has a track record of working with California water stakeholders and connecting them with decision support and data access through the Bay Delta-Live web application. 34N's Bay Delta-Live infrastructure and activities are currently funded by a joint working group between US Bureau of Reclamation, California Department of Water Resources, and the Metropolitan Water District, **independently of this proposal**; that is, there is a mechanism already in place for hosting our project outputs beyond the 3-year lifecycle. We have also discussed with project team members the need to automate processing, which is relevant for the satellite products to tie this to displays / outputs on the Bay Delta-Live. Also of note is that 34N has included in their project plan training workshops with partners, to support the iteration process of developing data dashboards and training on data access through the Bay Delta-Live site.

In addition to 34N's critical role in this project, we have also requested funds for a 1-year postdoc to join the project team in the third year, whose main contribution will be to help transition the project and support training/integrating activities. We will plan for the postdoc to be based at JPL for 3-6 months, and at our partner agencies' offices for other portions of the year.

It is important to note, however, that we will continue to have discussions to refine and finalize the transition plan and to ensure that we are finding the most efficient and sustainable process for maintaining access to remote sensing water quality products long-term to agency managers.

1.3.6 Challenges/Risks to Project Success, Adoption, Transition, and Use

Technical. One technical challenge/risk we face is the development of algorithms from archival airborne datasets (AVIRIS-C and AVIRIS-NG) because we will be relying on existing *in situ* data from field cruises or from monitoring stations. We are proposing to investigate these existing datasets, but we may not always have the coincident observations needed to develop a robust algorithm for the proposed products. This is one reason why we have proposed a

multiplatform approach, to ensure that we are able to leverage what is available across satellite, airborne, and ground-based resources.

Management / Operational and Training. Another challenge that we have is team size; because we are looking across various platforms and data resources, we have built a team that spans various entities and organizations. To mitigate this challenge, we have identified very specific roles and deliverables for each investigator and team member, with JPL functioning to provide overall coordination and management.

Building the capacity for partner organizations to efficiently utilize these data products is also an important challenge and concern. 34N's role in this project will also help mitigate this, as their team has considerable experience working with agency partners in building capacity and data access capability for stakeholders in the Bay Delta region.

Transition. There will also be challenges associated with transition, which we have worked to address and mitigate in two ways: (1) we have budgeted for a postdoc in the third year specifically to support transition; this person is envisioned to be based in part at JPL and at partner organizations and (2) we are working with an existing infrastructure and community that has been spearheaded by 34N. Their local knowledge of stakeholder communities and water quality issues will be key to facilitating transition.

1.4 Anticipated Results

We anticipate that remote sensing water quality data products will become easily accessible through data dashboards, and on an on-going basis, through the Bay Delta-Live portal and application. We have identified specific decision points that utilize water quality variables to trigger a specific action or response, for turbidity and temperature. For chlorophyll, we have identified that this variable can be used to support overall management or restoration efforts, or can support management of water supply (treatment) in the event that an algal bloom is toxin-producing.

For Metropolitan Water District, we hypothesize that this project will greatly benefit decisions related to resource allocation by providing a more comprehensive understanding of water quality parameters in the Bay Delta. MWD also anticipates being able to utilize chlorophyll-a and temperature time series maps to help inform ecological restoration efforts for endangered species. MWD also anticipates being able to use the turbidity products to calibrate and validate independently developed turbidity models.

For California Department of Water Resources, there is the potential for this project to be highly beneficial; however, we hypothesize that in the near term the benefits from this project will be modest until we can help demonstrate the increased utility of a spatially comprehensive and temporally consistent datasets and continue to develop case studies for Lake Oroville and San Luis Reservoir / O'Neill Forebay. Possible benefits (that have been articulated by CDWR) have been the use of satellite data to help trigger sampling events, or as an independent comparison to a station monitor that is reading data in an unexpected or possibly erroneous way). For other sites, we anticipate that Earth science datasets can serve as a beneficial complement to the discrete sampling or monitoring stations.

1.5 Project Management

Christine Lee will serve as the principal investigator for this project and will coordinate across the team members, including facilitating discussions with partner agencies. David Fullerton (Co-PI) is responsible for providing and delivering input from partner agency Metropolitan Water District, and will coordinate feedback from Shawn Acuna (Co-I, MWD), and Russell Ryan (Co-I, MWD). Russell will also help oversee the Bay Delta-Live component. Nicholas Tufillaro (Co-I, OSU) will be responsible for delivering satellite-based algorithms for water quality products, for chlorophyll-a and turbidity. Erin Hestir (Co-I, NCSU) will be responsible for delivering airborne-based from AVIRIS-C/AVIRIS-NG algorithms for water quality products, chlorophyll-a and turbidity. Amye Osti (Co-I, 34N) will be responsible for implementation of products into Bay Delta-Live. Glynn Hulley and Nabin Malakar (Co-I, JPL) will be responsible for delivering water surface temperature products from both satellite and airborne platforms. Michelle Gierach(Co-I, JPL) will be responsible for delivering water quality products from PRISM (turbidity, chlorophyll-a, colored dissolved organic matter). George Chang (Co-I, JPL) will be responsible for the data pipeline from L3 products to web services. Brian Bergamaschi (Co-I, USGS) will be responsible for delivering in situ data and coordinating field campaigns. John Leahigh (Collaborator, CDWR) will provide partner feedback into our products and applications. Cedric Fichot (Collaborator, Boston U) will serve in an advisory role and have access to provide comments on products. Sustin Ustin (Collaborator, UC Davis) will serve in an advisory role and share /coordinate laboratory resources when appropriate. Curtiss Davis (Collaborator, Oregon State University) will serve in an advisory role.

1.6 Schedule with Milestones

Table 1-3. Summary of Schedule.

	Year 1				Year 2				Year 3			
Task	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Delivery of satellite optical and thermal water quality products and algorithms				X				X				X
Delivery of all in situ data collected in research cruises				X				X				X
Delivery of software for automated processing of satellite data										X		
Delivery of airborne optical and thermal water quality products				X				X				X
Development of data pipeline to transfer products to web services							X					
Visualization and access of data products in BDL								X				
Refinement of partner use cases and customizing data dashboards									X			
Finalize transition plan									X			
MWD, CDWR, USGS access and utilize data dashboards												X

1.7 Changes in Team Structure Since Step-1

Table 1-4. Summary of Changes in Team Structure Since Step-1

Change	Justification
Cedric Fichot Co-I to collaborator	Fichot was interested in methylmercury applications, which were de-emphasized in the scope in Step 2.
Shruti Khanna Co-I removed	Khanna since accepted a position at CA FWS, so will not be able to commit to the project as initially planned.
Susan Ustin Co-I changed to collaborator	Ustin will be contributing primarily as an advisor and collaborator; initially, she was also going to help supervise Khanna, who is no longer on the project. As collaborator, Ustin has agreed to share existing datasets and allow access to her lab/facilities as appropriate.
Russell Ryan added as a Co-I	Ryan will be contributing (with in-kind funds from MWD) up to 0.1FTE as an investigator who manages the Bay Delta-Live portal from the MWD side.
Amye Osti added as a Co-I	Osti from 34N will be contributing to the project as an investigator managing implementation of data products into Bay Delta-Live and building data dashboard.
Glynn Hulley added as Co-I	Hulley is contributing by developing and delivering water surface temperature products.
Nabin Malakar added as a no cost Co-I	Malakar is a no cost Co-I and fully funded postdoc who will be supporting Hulley in temperature product development.
Erin Hestir added as a Co-I	Hestir is taking on the role originally intended for Khanna.

2 PERFORMANCE MEASURES

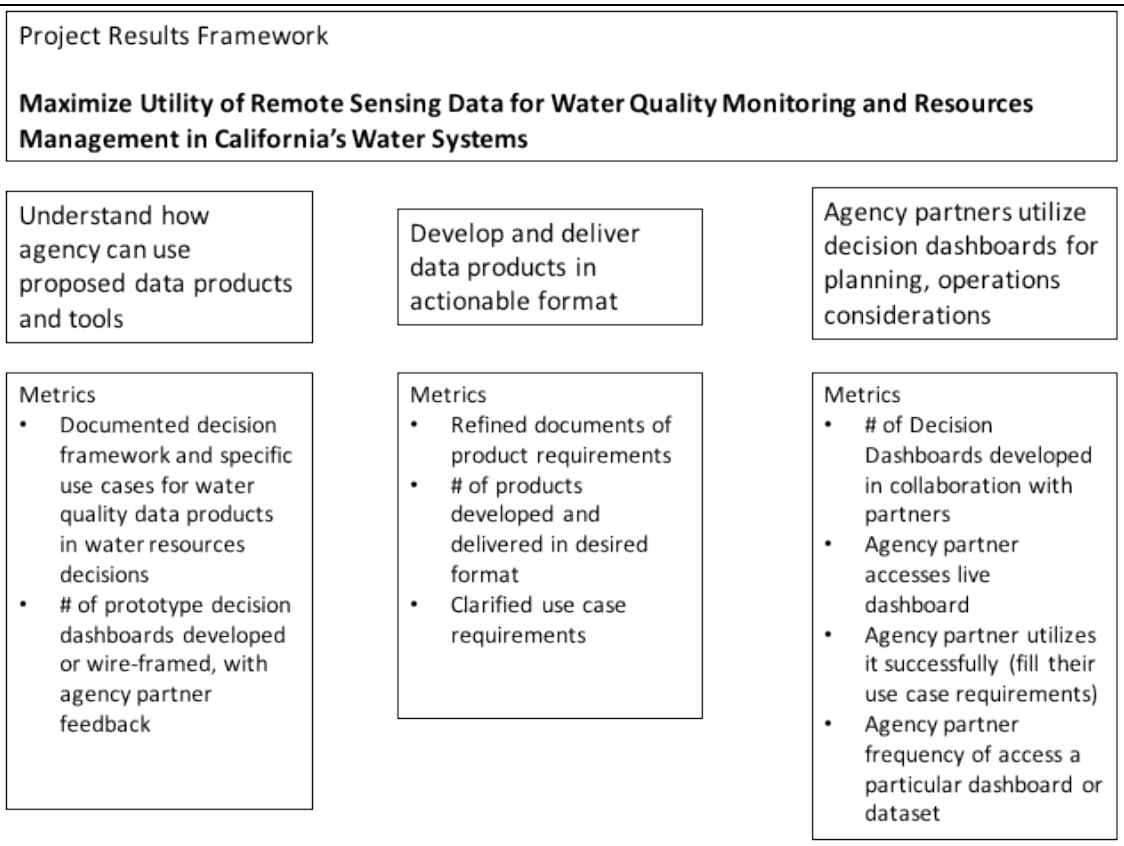

Figure 2-1. This schematic represents the first iteration on performance metrics for the proposed projects. The metrics listed will help us track the overall performance and whether the project is able to meet intermediate goals, in support of the overall objective.

3 STATEMENTS OF COMMITMENT – CO-INVESTIGATORS

OSU Oregon State University

Office for Sponsored Research and Award Administration
Oregon State University, 308 Kerr Administration Building, Corvallis, Oregon 97331-2140
Tel 541-737-4933 | **Fax** 541-737-3093 | sponsored.programs@oregonstate.edu

August 19, 2016

To Whom It May Concern,

Oregon State University is pleased to cooperate with the Jet Propulsion Lab on the project titled "Maximizing Utility of Remote Sensing Data for Water Quality Monitoring and Resources Management in California's Water Systems." We understand that you will be submitting this proposal to the National Aeronautics and Space Administration with Oregon State University as a subcontractor to your organization.

The appropriate programmatic and administrative officials have reviewed and approved this proposal in the amount of $304,050 for the project duration of January 1, 2017 through December 31, 2019. The authorized institutional official's signature below indicates institutional approval for the proposed project.

Oregon State University is prepared to perform the work as outlined in the proposal, subject to the State of Oregon – Oregon State University regulations. Dr. Nicholas Tufillaro will serve as Oregon State University's Principal Investigator for this project.

Approved:

Acting for: Lydia Peng
Patricia A. Hawk
Institutional Authorizing Official

NC STATE UNIVERSITY

College of Sciences
Office of the Associate Dean for Research

sciences.ncsu.edu

Campus Box 8209
2700 Stinson Drive, 312 Cox Hall
Raleigh, NC 27695-8209
P: 919.515.7865

August 17, 2016

Christine M. Lee
Scientific Applications Engineer
NASA Jet Propulsion Laboratory (JPL)
4800 Oak Groove Drive
Pasadena, CA 91109
Tel: 818-354-3343 Email: Christine.M.Lee@jpl.nasa.gov

Proposal Title: "Maximizing Utility of Remote Sensing Data for Water Quality Monitoring and Resources Management in California's Water Systems"
NCSU Reference No. 75913
NCSU Principal Investigator: Erin Hestir
JPL Principal Investigator: Christine M. Lee
Start Date: 12/01/2016 End Date: 11/30/2019

Dear Dr. Lee:

This letter transmits the subcontract referenced above from North Carolina State University (NCSU) to your organization on behalf of NCSU's Principal Investigator Erin Hestir. Included with this letter, you will find a statement of work, budget, and any other documentation required to accompany the proposal. Please forward this letter and proposal to the appropriate administrative officer within your organization to inform them that the appropriate administrative officials at NCSU support this proposal and are prepared to negotiate an agreement if said proposal is selected for funding. If you need any additional information regarding this proposal or NCSU's public service, research or educational missions, please contact the NCSU Sponsored Programs office at:

North Carolina State University
ATTN: Sherrie Settle or other Authorized Organizational Representative
Sponsored Programs & Regulatory Compliance Services
2701 Sullivan Drive, Suite 240, Campus Box 7514
Raleigh, NC 27695-7514

Phone: 919-515-2444, Fax: 919-515-7721, Email: sps@ncsu.edu

Various NCSU business information useful during a proposal's review and the preparation of an agreement may be found on the attached NCSU Info Sheet or online at: http://www.ncsu.edu/sparcs/proposal/project_info.php. From this site you can access and print documents such as NCSU's A-133 Audit report, F&A Agreement, etc. For informational purposes, please note that NCSU is not delinquent on any federal debt and is not presently debarred, proposed for debarment, declared ineligible or voluntarily excluded from covered transactions by a Federal department or agency. On behalf of the University, please accept my gratitude for your organization's review and consideration to fund this important work.

For North Carolina State University,

Attachments: Proposal and budget, NCSU Information Sheet

Copied: College Research Office

Note: This is a fundamental research or scholarly project and, as such, the University shall be free to publish or disseminate the results of this research or otherwise treat such results as in the public domain, and it will conduct the research in an open forum consistent with the University's mission of research, instruction and public service.

United States Department of the Interior
U. S. GEOLOGICAL SURVEY
California Water Science Center
6000 J Street, Placer Hall
California State University
Sacramento, California 95819-6129
Phone: (916) 278-3000 Fax: (916) 278-3071

April 29, 2016

Christine M. Lee
California Institute of Technology
Jet Propulsion Laboratory
4800 Oak Grove Dr.
M/S: 183-401
Pasadena, CA 91109

Dear Dr. Lee:

I am writing to express support for our joint proposal, "Maximizing Utility of Remote Sensing Data for Water Quality Monitoring and Resources Management in California's Water Systems."

My research group at the USGS conducts applied science and research studies in support of management actions. In the Bay Delta and elsewhere in California we have conducted and are currently conducting research in support of management efforts of, for example, the California Department of Water Resources, the US Bureau of Reclamation, the State and Federal Water Contractors, California State and Regional Water Quality Control Boards, the Bay-Delta Science Program, the Interagency Ecological Program and others.

Much of our current research portfolio involves field studies of water quality conditions and biogeochemical dynamics, with a component of the studies typically focused on bio-optics. In the past, we have conducted such studies in support of cal/val efforts for remote sensing measurements. We have available to us the boats and instruments necessary to support the field activities in this proposal.

We are looking forward to partnering on the proposed activity and being able to strengthen the use of remote sensing capabilities in our investigations and in support of water resource management agencies.

If you have any questions, please feel free to contact me.

Best Regards,

Brian A. Bergamaschi, Ph.D.
bbergama@usgs.gov

4 LETTERS FROM PARTNER ORGANIZATIONS

THE METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA

Date: April 29, 2016

To: Review Committee of the NASA Applied Sciences Water Resources Proposal Solicitation

From: Shawn C Acuña, Senior Resource Specialist, Bay-Delta Initiatives
1121 L Street, Suite 900
Sacramento, CA 95814

Subject: Letter of Support for JPL Joint proposal

This letter is to express my support for Christine Lee and the Jet Propulsion Laboratory (JPL) for our joint proposal for the NASA Earth Science Division, Applied Sciences Water Resources Proposal Solicitation, entitled "Maximizing Utility of Remote Sensing Data for Water Quality Monitoring and Resources Management in California's Water Systems." The Metropolitan Water District of Southern California (MWD) is prepared to help support the study with direct funds (to both JPL and partner USGS) and through in-kind services over the three years if the proposal is selected.

MWD is the largest distributor of treated drinking water in the United States and is a regional wholesaler of water to 26 member agencies. Through this consortium of agencies, MWD helps to provide water for over 19 million people in more than 300 cities and unincorporated areas in Southern California. MWD supports the co-equal goals of supplying reliable high-quality water to meet present and future needs and sustaining, restoring, and protecting the Delta ecosystem in an environmentally and economically responsible manner.

The JPL-led study workplan will significantly enhance how MWD's can use current remote sensing tools to increase our understanding of water quality dynamics that affect water management in the San Francisco Bay-Delta Estuary. The proposed workplan will also leverage partner and field data to improve communication and dissemination of the data to water managers in the Sacramento-San Joaquin Watershed. In addition, the workplan will offer an application that will centralize and automate data generation that is critical for decisions in water management in California. Furthermore, this study will be important in assessing dynamics of multiple factors including temperature, turbidity, sediment, and chlorophyll in support of water management operations.

I am confident that the JPL's proposed study will be highly valuable to the California water resources and Bay-Delta communities and improve how we are able to access and use remote sensing water quality data.

Shawn C Acuña,
Senior Resource Specialist, Bay-Delta Initiatives

STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY EDMUND G. BROWN JR., Governor
DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

April 29, 2016

Christine M. Lee, Ph.D.
NASA Jet Propulsion Laboratory
4800 Oak Grove Dr., MS 168-200
Pasadena, California 91109

Dear Dr. Lee:

I support your proposal that relates remote sensing data for water quality monitoring with resources management in California's water supply systems. If funded, we commit to providing input and feedback into the data product and application development activities that would be conducted as part of this proposal effort.

Water quality is a high priority area of interest of ours especially in the Sacramento-San Joaquin Delta portion of the San Francisco Bay Estuary, as it is tied to multiple beneficial uses, including water supply and ecosystem drivers. Our team regularly utilizes and relies upon water quality parameter information (for turbidity, temperature, colored dissolved organic matter, and salinity) as part of water resources operations considerations.

I see remote sensing technologies as having potential to greatly advance our ability to monitor water quality in this region with more consistent temporal and spatial coverage. I look forward to collaborating on this effort.

Sincerely,

John Leahigh, Chief
SWP Water Operations Office
Division of Operations and Maintenance

5 BUDGET JUSTIFICATION: NARRATIVE AND DETAILS

The proposed budget for the three-year project is based on analysis of the resources required to execute the project scope. This project involves costs for labor, travel, compute resources, and equipment maintenance. Labor hours were determined based on assessment of the time required to develop each set of products, field campaigns, software for automated processing, data pipeline, and implementation of the data into a public-facing web services application. Estimates were approved by the respective organizations' management and determined to be suitable for each investigator's designated scope of work. Travel costs were estimated using a combination of commercial and government travel rates for airfare and meals and incidental expenses (MI&E). Airfare rates were for domestic trips and dependent on the originating airport (Eugene, OR for OSU; Raleigh, NC for NCSU, LA, CA for JPL, and SAC, CA for USGS)

Table 5-1. Project travel pricing details. Extended costs rounded to three significant figures.

FY	Date	Purpose	Duration	Traveler	Airfare	Daily Cost	TOTAL
2017	Feb 2017	Field Campaign	6 days	N.Tufillaro	$400 R/T	$267	$2,000
2017	May 2017	Team Meeting	3 days	N. Tufillaro	$400 R/T	$533	$2,000
2017	Sept 2017	Field Campaign	6 days	N. Tufillaro	$400 R/T	$267	$2,000
2017	Dec 2017	Field Campaign	6 days	N. Tufillaro	$400 R/T	$267	$2,000
2017	Feb 2017	Field Campaign	5 days	B. Bergamaschi	N/A	$100	$500
2017	May 2017	Team Meeting	3 days	B. Bergamaschi	$200	$100	$500
2017	Sept 2017	Field Campaign	5 days	B. Bergamaschi	N/A	$100	$500
2017	Dec 2017	Field Campaign	5 days	B. Bergamaschi	N/A	$100	$500
2017	Sept 2017	Field Campaign	5 days	C. Lee	$200	$249	$1,445
2017	Dec 2017	Science Conference	5 days	C. Lee	$200	$249	$1,445
2017	May 2017	Team Meeting	4 days	E. Hestir	$900	$249	$1,898
TOTAL YEAR 1 TRAVEL BUDGET (3 significant digits)							$14,800
2018	Feb 2018	Field Campaign	6 days	N.Tufillaro	$400 R/T	$267	$2,000
2018	May 2018	Team Meeting	3 days	N. Tufillaro	$400 R/T	$533	$2,000
2018	Sept 2018	Field Campaign	6 days	N. Tufillaro	$400 R/T	$267	$2,000
2018	Dec 2018	Field Campaign	6 days	N. Tufillaro	$400 R/T	$267	$2,000
2018	Feb 2018	Field Campaign	5 days	B. Bergamaschi	N/A	$100	$500
2018	May 2018	Team Meeting	3 days	B. Bergamaschi	$200	$100	$500
2018	Sept 2018	Field Campaign	5 days	B. Bergamaschi	N/A	$100	$500
2018	Dec 2018	Field Campaign	5 days	B. Bergamaschi	N/A	$100	$500
2018	Sept 2018	Field Campaign	5 days	C. Lee	$200	$249	$1,445
2018	Dec 2018	Science Conference	5 days	C. Lee	$200	$249	$1,445
2018	May 2018	Team Meeting	4 days	E. Hestir	$900	$249	$1,898
TOTAL YEAR 2 TRAVEL BUDGET (3 significant digits)							$14,800
2019	Dec 2019	Field Campaign	6 days	N. Tufillaro	$400 R/T	$267	$2,000
2019	Feb 2019	Field Campaign	6 days	N.Tufillaro	$400 R/T	$267	$2,000
2019	May 2019	Team Meeting	3 days	N. Tufillaro	$400 R/T	$533	$2,000
2019	Sept 2019	Field Campaign	6 days	N. Tufillaro	$400 R/T	$267	$2,000
2019	Feb 2019	Field Campaign	5 days	B. Bergamaschi	N/A	$100	$500
2019	May 2019	Team Meeting	3 days	B. Bergamaschi	$200	$100	$500
2019	Sept 2019	Field Campaign	5 days	B. Bergamaschi	N/A	$100	$500
2019	Dec 2019	Field Campaign	5 days	B. Bergamaschi	N/A	$100	$500
2019	Sept 2019	Field Campaign	5 days	C. Lee	$200	$249	$1,445
2019	Dec 2019	Science Conference	5 days	C. Lee	$200	$249	$1,445
2019	May 2019	Team Meeting	4 days	E. Hestir	$900	$249	$1,898
2019	Dec 2019	Science Conference	6 days	E. Hestir	$900	$317	$2,800
TOTAL YEAR 3 TRAVEL BUDGET (3 significant figures)							**$15,800**

NOTE: Daily cost includes rental car and per diem (lodging, meals, and incidentals)
[1] Location for Science Team Meeting will be at JPL
[2] Location for Science Conference is San Francisco, CA

Table 5-2. Table of personnel work effort in full time equivalents (FTE) for the CA Water Quality Project.

Name	Organization	Role	Work Commitment		
			Year 1	Year 2	Year 3
Dr. Christine Lee	JPL	PI (Management)	0.20	0.20	0.20
Postdoc, TBD	JPL	Technical Staff/Facilitate Application/Product Use and Transition	0	0	1
Dr. Nicholas Tufillaro	OSU	Co-I (Satellite Data Product Development for Optical Water Quality Products)	0.25	0.25	0.25
Postdoc, Tufillaro Lab[1]	OSU	Technical Staff/Postdoc	0.17	0.17	0.17
Dr. Erin Hestir	NCSU	Co-I (Airborne Data Product Development for Optical Water Quality Products)	0.083	0.083	0.083
Student, Hestir Lab[2]	NCSU	Technical Staff/Graduate Student	0.5	0.5	0.5
Dr. Glynn Hulley	JPL	Co-I (Product Delivery/Development for Water Surface Temperature from Satellite and Airborne)	0.19	0.19	0.19
Dr. Nabin Malakar[3]	JPL	Co-I (No funds requested) (Support Water Surface Temperature Product Delivery)	0.10	0.05	0.05
Dr. Michelle Gierach	JPL	Co-I (Delivery of PRISM water quality products)	0.01	0.01	0.05
George Chang	JPL	Co-I (Data pipeline lead from L3 to web services format)	0.12	0.12	0.17
Brian Bergamaschi	USGS	Co-I (Delivery of In Situ Data and Coordination of Research Cruises)	0.06	0.06	0.06
Amye Osti	34N	Co-I (Implementation of water quality products into BDL)	0.10	0.10	0.10
Co-investigators and Collaborators fully funded by agency partners (no budget requested from NASA)					
Dr. David Fullerton[4]	MWD	Co-PI (Management of MWD input into project and use of data products in case studies)	0.10	0.10	0.10
Shawn Acuna[5]	MWD	Co-I (MWD scientist contributing to / providing case studies)	0.05	0.05	0.05
Russell Ryan[6]	MWD	Co-I (MWD lead for BDL)	0.10	0.10	0.10
John Leahigh[7]	CADWR	Collaborator (participation in group discussions and provide feedback on value / utility of products)	0.02	0.02	0.02

[1] Dr. Tufillaro will be responsible for deliverables and will have part time support from a postdoc.
[2] Dr. Hestir will be responsible for deliverables and a fulltime graduate student will be dedicated to this project.
[3] Dr. Malakar is a full time postdoc at JPL whose FTE is fully covered. No funds are requested for his contributions.
[4,5,6] Contributions from MWD personnel are in-kind and no funds are being requested to NASA for their participation or commitment in the project.
[7] Contributions from CADWR personnel are in-kind and no funds are being requested to NASA for their participation or commitment in the project.

Rationale and Basis of Estimate

The cost proposal for *Maximizing Utility of Remote Sensing Data for Water Quality Monitoring and Resources Management in California's Water Systems* was prepared using JPL's pricing/accounting system, which has been reviewed and approved by the DCAA. The rates applied in this proposal are JPL's current published rate set (version FY15-02), dated November 2014.

The derivation of the cost estimate is a grassroots methodology based on the expert judgment from a team of experienced individuals who have performed similar work. The team provides the necessary relevant experience to develop a credible and realistic cost estimate. The cognizant individuals identify and define the products and the schedule needed to complete the tasks for each work element. The team developed the grassroots estimate using estimating methods and techniques (analogy, vendor quotes, historical experience) appropriate for each element of work. These methods are used to generate the detailed schedule and resource estimates for labor, procurements, travel, and other direct costs for each work element. The resource estimates are aggregated and priced using JPL's pricing/accounting system. JPL's process assures that lower level estimates are developed and reviewed by the performing organizations and their management who will be accountable for successfully completing the proposed work scope within their estimated cost.

5.1 Budget Details – Year 1

Direct Labor – Year 1

- Dr. Christine Lee is the PI and will oversee all aspects of the proposed work. Time Commitment is 0.20 work years.
- George Chang will serve as a Co-Investigator for this effort. George will work at 0.12 work years and will set up a prototype data pipeline during Year 1.
- Dr. Glynn Hulley will serve as Co-Investigator on this project. During year 1, he will develop algorithms to extract water surface temperature data from VIIRS and Landsat. Glynn will work at 0.18 work years.
- Dr. Michelle Gierach will serve as Co-Investigator on this project. During year 1, she will provide existing PRISM data products to use in testing of the prototype data pipeline. Time Commitment is 0.01 work years.
- Dr. Nabin Malakar will serve as a no-cost Co-Investigator on the project. During year 1, he will support Dr. Hulley in Landsat-8 retrievals for water surface temperature. Time Commitment is 0.1 work years.

Other Direct Costs – Year 1

Subcontracts/Subawards

- Subcontract to Oregon State University to develop and deliver satellite optical water quality products, participate in field campaigns, and time for a postdoc to support project (0.17 wy) who will work with Co-I Tufillaro (20.0K).
- Subcontract to North Carolina State University to develop and deliver airborne optical water quality products and time for a Graduate Student Researcher (0.5 wy and tuition) to work with Co-I Hestir (11.3K)
- Subcontract to 34N to design implementation plan for remote sensing products in the BDL portal, includes user experience/user interface meetings with working groups, includes time for staff (up to 0.25 wy) to support Co-I Osti (9.6K).
- Desktop Network Chargebacks (calculated at $6.73/hr.): All JPL computers are subject to a monthly service charge that includes hardware, software, and technical support. ($6.1K)

Consultants – There are no consultants required for this project.

Equipment – There are no major equipment purchases necessary for this project.

Services – There are no service costs required for this project.

Supplies and Publications –.

Travel -- Christine Lee will travel twice a year once for a Science Conference (targeting Bay Delta / CA Water Resources stakeholders) and once for field campaign ($2.9K)

Other

Facilities and Administrative (F&A) Costs – Year 1

Other Applicable Costs – Year 1

- Subcontract to U.S. Geological Survey to coordinate field campaigns and use of research equipment / boat and to deliver in situ data from campaigns, includes time for support staff (0.15 wy) to support Co-I Bergamaschi (11.2K)

5.2 Budget Details – Year 2

Direct Labor – Year 2

- Dr. Christine Lee is the PI and will oversee all aspects of the proposed work. Time Commitment is 0.19 work years.
- George Chang will serve as a Co-Investigator for this effort. George will work at 0.12 work years and will set up a prototype data pipeline during Year 1.
- Dr. Glynn Hulley will serve as Co-Investigator on this project. During year 1, he will develop algorithms to extract water surface temperature data from VIIRS and Landsat. Glynn will work at 0.18 work years.
- Dr. Michelle Gierach will serve as Co-Investigator on this project. During year 1, she will provide existing PRISM data products to use in testing of the prototype data pipeline. Time Commitment is 0.01 work years.
- Dr. Nabin Malakar will serve as a no-cost Co-Investigator on the project. During year 1, he will support Dr. Hulley in Landsat-8 retrievals for water surface temperature. Time Commitment is 0.05 work years.

Other Direct Costs – Year 2

Subcontracts/Subawards

- Subcontract to Oregon State University to continue to develop and deliver satellite optical water quality products, participate in field campaigns, and time for a postdoc to support project (0.17 wy) who will work with Co-I Tufillaro (16.5K)
- Subcontract to North Carolina State University to develop and deliver airborne optical water quality products and time for a Graduate Student Researcher (0.5 wy and tuition) to work with Co-I Hestir (21.2K)
- Subcontract to 34N to design implementation plan for remote sensing products in the BDL portal, includes user experience/user interface meetings with working groups, includes time for staff (up to 0.25 wy) to support Co-I Osti (9.6K)
- Desktop Network Chargebacks (calculated at $6.73/hr.): All JPL computers are subject to a monthly service charge that includes hardware, software, and technical support. ($5,950)

Consultants – There are no consultants required for this project.

Equipment – There are no major equipment purchases necessary for this project.

Services – There are no service costs required for this project.

Supplies and Publications – There are no supplies / publication costs required for this project.

Travel

- Christine Lee will travel twice a year once for a Science Conference (targeting Bay Delta / CA Water Resources stakeholders) and once for field campaign ($2.9K)

Other

Facilities and Administrative (F&A) Costs – Year 2

Other Applicable Costs – Year 2

- Subcontract to U.S. Geological Survey to coordinate field campaigns and use of research equipment / boat and to deliver in situ data from campaigns, includes time for support staff (0.15 wy) to support Co-I Bergamaschi (11.6K)

5.3 Budget Details – Year 3

Direct Labor – Year 3

- Dr. Christine Lee is the PI and will oversee all aspects of the proposed work. Time Commitment is 0.20 work years.
- George Chang will serve as a Co-Investigator for this effort. George will work at 0.17 work years and will finalize data pipeline for remote sensing products to web.
- Dr. Glynn Hulley will serve as Co-Investigator on this project. He will finalize product delivery for water surface temperature data from VIIRS and Landsat to ingest into data pipeline. Glynn will work at 0.18 work years.
- Dr. Michelle Gierach will serve as Co-Investigator on this project. She will finish packaging PRISM data products to ingest into data pipeline. Time Commitment is 0.05 work years.
- Dr. Nabin Malakar will serve as a no-cost Co-Investigator on the project., he will support Dr. Hulley in Landsat-8 retrievals for water surface temperature. Time Commitment is 0.05 work years.

Other Direct Costs – Year 3

Subcontracts/Subawards

- Subcontract to Oregon State University to finalize development and delivery of satellite optical water quality products, software to automate processing of data, participate in field campaigns, and time for a postdoc to support project (0.17 wy) who will work with Co-I Tufillaro. (19.2K)
- Subcontract to North Carolina State University to participate in team meetings and discussions with Co-I Hestir (7.7K)
- Subcontract to 34N to finalize implementation of remote sensing products in the BDL portal, includes user experience/user interface meetings with working groups and conduct training to use decision dashboards, includes time for staff (up to 0.06 wy) to support Co-I Osti (9.6K).
- Desktop Network Chargebacks (calculated at $6.73/hr.): All JPL computers are subject to a monthly service charge that includes hardware, software, and technical support. ($7,170)

Consultants – There are no consultants required for this project.

Equipment – There are no major equipment purchases necessary for this project.

Services

- Caltech Postdoc will be funded in year 3 (1 wy) to support project transition and training.

Supplies and Publications

- The Caltech Postdoc has an associated materials and supplies cost for chargebacks (9.6K).

Travel

- Christine Lee will travel twice a year once for a Science Conference (targeting Bay Delta / CA Water Resources stakeholders) and once for field campaign ($2.9K)

Other

Facilities and Administrative (F&A) Costs – Year 2

Other Applicable Costs – Year 2

- Subcontract to U.S. Geological Survey to coordinate field campaigns and use of research equipment / boat and to deliver in situ data from campaigns, includes time for support staff (0.15 wy) to support Co-I Bergamaschi (11.6K)

6 FACILITIES AND EQUIPMENT

JPL has 903,000 square feet of laboratories, fabrication, and other development and test facility space. JPL is the lead USA center for robotic exploration of the solar system and develops advanced robotic capabilities for future space missions. JPL's expertise in system engineering, mission design, autonomous robotic systems, and instrument integration and test will be essential during execution of the MSF project. For the data processing pipeline, we will access a high-end desktop workstation with Redhat Linux 7 Server, Dual Intel Xeon Processors running at 2.4GHz, with 32 GBs of RAM and 2.5TB of local storage to ingest, stage, process, and deliver science data.

OSU operates a Satlantic Free Falling Optical Profiler II for in water radiance measurements, as well as handheld above water radiance and reflectivity measurements with a Spectral Evolution Field Spectrometer, PSR-1100-F. The Optical Profiler is also equipped with an Wetlabs ECO PUCK with scattering at 470 and 700 nm, and chlorophyll fluorescence at 470/695 nm. For computing resources, OSU will have use a dedicated Macintosh Workstation (64GB RAM, 24 TB storage) and for storage, will use 4 Linux / Dell Servers (40TB).

USGS facilities include a fully instrumented powered watercraft (USGS R/V Landsteiner) that will be used for underway sampling and discrete sample collection. This vessel is outfitted with a ¾ inch diameter stainless steel sample pick-up tube attached to the keel at the transom, 0.5 m below the water surface. Tygon tubing will be used to direct flow from the pick-up tube to a 12 volt DC, Viton diaphragm pump (SHURflo, Cypress, CA, USA) fitted with a 178 micron in-line strainer (Cole Parmer; EW-29595-47). Additionally, there wil a sampling system comprising of a Seabird model SB45 thermosalinograph, Satlantic model ISUS V3 nitrate analyzer, and a YSI ECO2 fitted with sensors for conductivity, turbidity, pH, dissolved oxygen, fDOM, fCHLA, and a phycocyanin fluorometer as a proxy for blue green algae. Instruments in the flow-through system include a Campbell Scientific model CR1000 measurement-and-control-system datalogger, and GPS. Pigment analysis will be completed at the USGS National Water Quality Laboratory as needed (http://nwql.usgs.gov).

NCSU will be using an existing application server that is 128GB, Intel Xeon 20 core environment for remote sensing datasets. Data will need to be locally accessible for efficient processing. The attached storage data server will be assembled at NCSU and completely devoted to research. Software includes programs for web conferencing, data analysis, software development, secure network and office productivity software as well as software license and maintenance fees (e.g. for IDL, Adobe). Computer supplies include data archival media.

34N facilities on-site includes compute resources that consists of 7 iMac Computers with comprehensive software suites for data management; 2 onsite GIS Machines running ArcServer, ArcMap and QGIS, large demonstration screens for data analysis and visualization and OpenNRM Software Suite. **34N also utilizes off-site equipment (network operating server)** includes a raster processing server for NASA imagery – a high performance dedicated 32GB RAM, 350GB storage, and 7TB bandwidth server, BDL database server, BDL web server, BDL GIS server, and a back up server.

7 RESUME/CV: PRINCIPAL INVESTIGATOR

Christine M. Lee
NASA Jet Propulsion Laboratory
168-200, 4800 Oak Grove Dr., Pasadena, CA 91109
+1(818) 354-3343 | christine.m.lee@jpl.nasa.gov

Proposed Role in the Investigation

Christine Lee will serve as the principal investigator for the proposed work, serving to coordinate across the team and responsible for project deliverables.

Experience Related to the Investigation

Christine Lee has a background in water quality and experience working in applied sciences, in particular developing partnerships with end user organizations and understanding their priorities and data needs.

2014-Present	Science Applications Software Engineer, JPL Data Interaction and Science Applications Group
2014-Present	Research Affiliate, UCLA Institute of the Environment and Sustainability and the Center for Environmental Research and Community Engagement (2016-)
2012-2014	AAAS Science and Technology Policy Fellow, NASA Headquarters, Applied Sciences Program (Capacity Building, Water Resources)
2010-2012	Postdoctoral Research Scientist, JPL Planetary Science
2006-2010	Graduate Student Researcher, UCLA, Coastal Water Quality, Method Development and Monitoring

Education

- Ph.D., Environmental Engineering, UCLA, 2010
- M.S., Environmental Engineering, UCLA, 2006
- B.S., Chemical Engineering, UCLA, 2005

Honors/Awards

2012-2014 American Association for the Advancement of Science, Science and Technology Policy Fellow

Related Publications

Lee CM, Serrat-Capdevila A, Iqbal N, Ashraf M, Zaitchik B, Bolten J, Melton F, Doorn B.. Applying Earth Observations for Water Resources Challenges, Ch 6. *Earth Science Satellite Applications,* Springer Remote Sensing/Photogrammetry, 2016.

Hossain F, Serrat-Capdevila, Granger S, Thomas A, Saah D, Ganz D, Mugo R, Murthy MSR, Ramos VH, Anderson E, Schumann G, Lewison R, Kirschbaum D, Escobar V, Srinivasan M, **Lee CM,** et al. A Global Capacity Building Vision for Societal Applications of Earth Observation Systems and Data: Key Questions and Recommendations, *Bulletin in American Meteorological Society,* 2016.

Bolten JB, **Lee CM**, Houser P. Satellite Data for Water Resources Management. *American Geophysical Union Eos Transactions,* 2015.

Lee CM, Cable ML, Hook SJ, Green RO, Ustin SL, Mandl DJ, Middleton EM. An introduction to the NASA Hyperspectral InfraRed Imager (HyspIRI) mission and preparatory activities, *Remote Sensing of Environment,* 2015.

Lee CM, Orne T., Schaeffer B. How can remote sensing be used for water quality? Bridging the operational and applications communities to address water quality challenges. *American Geophysical Union Eos transactions*, 2014.

Noell AC, Greenwood A, **Lee CM,** Ponce A. High Density, Homogeneous Endospore Monolayer Deposition on Test Surface, *Journal of Microbiological Methods,* 2013.

Lee CM, Hemmings SN, Searby ND. Using Earth observations to enhance water resources decision-making and disaster assessment processes in the U.S. and in the developing world. *IEEE Global Humanitarian Technology Conference*, 2013.

Ros-Giralt J, Launglucknavalai K,Massaguer D, Casanova J, **Maxwell CM**. Using Labdoo to Bridge the Digital Divide: A New Form of International Cooperation. *Service Learning in the Computer and Information Sciences: Practical Applications in Engineering Education,* Ch 18 © 2012.

Lee CM, Covalently-linked immunomagnetic separation/adenosine triphosphate technique is a rapid and field-portable method for measuring *E. coli* and *Enterococcus* spp., in fresh and marine water environments. *Journal of Applied Microbiology.* 2010.

Mika KB, Imamura G, Chang C, Conway V, Fernandez G, Griffith J, Kampalath R, **Lee CM,** Lin C, Moreno R, Thompson S, Whitman R, Jay JA. Pilot and bench-scale testing of fecal indicator bacteria survival in marine beach sand near point sources. *Jounral of Applied Microbiology.* 2009.

Ramanathan N, **Lee CM,** Lin T, Neumann R, Rothenberg S, Harvey C, Harmon T, Kohler E, Estrin D, Jay JA. Sensor-based investigation of biogeochemical control on arsenic mobilization in rural Bangladesh. Conference Proceedings, *American Chemical Society*. 2007.

Lee CM, Lin TY, Lin CC, Kohbodi G., Bhatt A, Lee R, Jay JA. Persistence of fecal indicator bacteria in Santa Monica Bay beach sediments. *Water Research*. 2006

8 RESUME/CV: CO-INVESTIGATORS (REQUESTED FUNDS TO NASA)

George W. Chang
California Institute of Technology - Jet Propulsion Laboratory
4800 Oak Grove Dr. MS 168-200 Pasadena, CA 91109
george.w.chang@jpl.nasa.gov

Education

M.B.A, Anderson School of Business, UCLA, Los Angeles, CA., 2011
M.S. Computer Science, Columbia University, New York, NY., 2003
B.S. Computer Science, Cornell University, Ithaca, NY., 2001

Experience

Current Positions:

2012 – current Technical Group Supervisor, Science Applications and Data Interaction
Instrument Software and Science Data Systems Section, NASA/JPL
2012 – current Software Development Lead/Product Delivery Manager
Physical Oceanography Distributed Active Archive Center (PO.DAAC), NASA/JPL

Previous Positions:

2009 – 2012 Development Lead, *Lunar Mapping and Modeling Portal Project, NASA/JPL*
2009 – 2012 Co-Investigator, *ROSES/CMAC – Cloud-enabled, Collaborative Software Platform for Radio Science, NASA/JPL*
2006 – 2009 Software Configuration Manager, *Service Preparation Subsystem (SPS) in the Deep Space Network, NASA/JPL*
2003 – 2006 Associate Software Engineer, *Deep Space Network, NASA/JPL*
1999 – 2000 Co-op Intern, *Deep Space Network, NASA/JPL*

Selected Papers and Presentations

G. Chang. Lunar Mapping and Modeling Portal, Cloud Infrastructure Design. Book chapter in *"Software Engineering Frameworks for Cloud Computing Paradigm"*, Springer Publishing, 2013.

G. Chang. Lunar Mapping and Modeling Portal System Design and Demonstration. In Proceedings of *Planetary Data Workshop*, Flagstaff, AZ, June 2012.

G. Chang, K. Shams, J. Callas, and A. Kern, A Novel Approach to Automated, Secure, Reliable, and Distributed Backup of MER Tactical Data on Cloud. In Proceedings of *IEEE Aerospace Conference*, Big Sky, MT, March 2012.

G. Chang, E. Law, and S. Malhotra, Demonstration of LMMP Automated Performance Testing Using Cloud Computing Architecture, In Proceedings of *ACM Conference on Software Engineering*, Honolulu, HI, May 2011.

G. Chang, S. Malhotra, and P. Wolgast, Leveraging the Cloud for Robust and Efficient Lunar Image Processing, In Proceedings of *IEEE Aerospace Conference*, Big Sky, MT, March 2011.

Michelle Gierach

Jet Propulsion Laboratory, 4800 Oak Grove Drive, M/S 300-323, Pasadena, CA 91109
Tel: +1 818-354-1933, Fax: +1 818-354-0966, Email: michelle.gierach@jpl.nasa.gov

RELEVANT EXPERIENCE

I have extensive experience in the analysis and application of satellite and airborne observations, in-situ data, and model simulations to study synoptic to decadal changes in the ocean, with specific focus on biophysical interactions, ecosystem dynamics, and carbon fluxes. My current research ranges in scale from the equatorial Pacific, investigating the ocean response to ENSO diversity, to the coasts of California, using the airborne PRISM instrument to study water quality.

EDUCATION

Ph.D., Marine Science, University of South Carolina, 2009
M.S., Meteorology, Florida State University, 2006
B.S., Meteorology, Florida State University, 2004

PROFESSIONAL EXPERIENCE

Scientist in Oceans and Ice Group, Jet Propulsion Laboratory, 2011 – present
Project Scientist for PO.DAAC, Jet Propulsion Laboratory, 2011 – present
Postdoctoral Associate, Applied Marine Physics, RSMAS, University of Miami, 2009 – 2011

FELLOWSHIPS AND HONORS

Caltech / JPL Lew Allen Award for Excellence, 2015
NASA Early Career Achievement Medal, 2013

SELECTED PUBLICATIONS

Fichot, C. G., B. Downing, B. Bergamaschi, L. Windham-Myers, M. Marvin-DiPasquale, D. R. Thompson, and **M. M. Gierach**, 2015: High-resolution remote sensing of water quality in the San Francisco Bay-Delta Estuary, *Environmental Science and Technology*, 50(2), 573–583, doi:10.1021/acs.est.5b03518.

Thompson, D. R., F. C. Seidel, B. C. Gao, **M. M. Gierach**, R. O. Green, R. M. Kudela, and P. Mouroulis, 2015: Optimizing irradiance estimates for coastal and inland water imaging spectroscopy. *Geophys. Res. Lett.*, 42, doi:10.1002/2015GL063287.

Gierach, M. M., B. Holt, R. Trinh, B. Pan, and C. Rains, 2014: Satellite detection of wastewater diversion plumes in southern California. *Estuarine, Coastal and Shelf Science*, in review.

Gierach, M.M., M. Messié, T. Lee, K.B. Karnauskas, and M.-H. Radenac, 2013: Biophysical Responses near Equatorial Islands in the Western Equatorial Pacific Ocean during El Niño/La Niña Transitions. *Geophys. Res. Lett.*, 40(20), 5473-5479, doi:10.1002/2013GL057828.

Gierach, M.M., T. Lee, D. Turk, and M.J. McPhaden, 2012: Biological response to the 1997-98 and 2009-10 El Niño events in the equatorial Pacific Ocean. *Geophys. Res. Lett.*, 39, L10602, doi:10.10.29/2012GL051103.

Gierach, M.M., B. Subrahmanyam, and P.G. Thoppil, 2009: Physical and biological responses to Hurricane Katrina (2005) in a 1/25° nested Gulf of Mexico HYCOM. *J. Mar. Syst.,* 78, 168-179.

Gierach, M.M., B. Subrahmanyam, A. Samuelsen, and K. Ueyoshi, 2009: Hurricane-driven alteration in plankton community size structure in the Gulf of Mexico: A modeling study. *Geophys. Res. Lett.*, 36, L07604, doi:10.1029/2009GL037414.

Gierach, M.M., and B. Subrahmanyam, 2008: Biophysical responses of the upper ocean to major Gulf of Mexico hurricanes in 2005. *J. Geophys. Res. Oceans*, 113, C04029, doi:10.1029/2007JC004419.

Gierach, M.M., and B. Subrahmanyam, 2007: Satellite data analysis of the upper ocean response to Hurricanes Katrina and Rita (2005) in the Gulf of Mexico. *IEEE Geosci. Remote Sens. Lett.*, 4, 132-136.

Dr. Glynn Hulley
U.S. Resident
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NASA Jet Propulsion Laboratory (JPL)
California Institute of Technology (Caltech)
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USA

Research Experience:

Glynn is a member of the Carbon Cycle and Ecosystems group at the Jet Propulsion Laboratory. His research is focused on improving our understanding of Earth surface properties, ecosystem and hydrological processes. Glynn is an expert on thermal infrared spectroscopy, and is a member of several instrument teams including ECOSTRESS, ASTER, MODIS, S-NPP, and Landsat. A key aspect of Glynn's research is the development of new techniques to analyze and extract land surface temperature and emissivity from thermal remotely sensed data. Techniques and algorithms developed by Glynn are widely used by researchers and he has developed science products (ASTER GEDv3, MOD21, VNP21, http://emissivity.jpl.nasa.gov) that have been incorporated into commercial packages by NASA.

He is currently leading an effort to produce thermal infrared products from the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS), which will offer clues about how Earth's water and carbon cycles affect plant growth and how ecosystems adapt to changes in climate by measuring the loss of water from leaves and soil over the diurnal cycle. He is also leading an effort to develop algorithms and science objectives for the thermal infrared sensor on the HyspIRI Satellite Mission recommended by the National Research Council (NRC) Decadal Survey for Earth Science.

Education:

- Ph.D., University of Maryland Baltimore County, Baltimore, MD, USA (2007)
  Atmospheric Physics
- M.Sc., University of Maryland Baltimore County, Baltimore, MD, USA (2004)
  Atmospheric Physics
- B.Sc., Francis Marion University, Florence, SC, USA (2001)
  Physics and Mathematics.

Selected Publications:

- **Hulley, G. C.**, Duren, R. M., Hopkins, F. M., Hook, S. J., Vance, N., Guillevic, P., Johnson, W. R., Eng, B. T., Mihaly, J. M., Jovanovic, V. M., Chazanoff, S. L., Staniszewski, Z. K., Kuai, L., Worden, J., Frankenberg, C., Rivera, G., Aubrey, A. D., Miller, C. E., Malakar, N. K., Sánchez Tomás, J. M., and Holmes, K. T.: High spatial resolution imaging of methane and other trace gases with the airborne Hyperspectral Thermal Emission Spectrometer (HyTES), Atmos. Meas. Tech., 9, 2393-2408, 2016.
- **Hulley, G.**, Hook S.J, Abbott, E., Malakar, N., Islam, T., Abrams, M., (2015), The ASTER Global Emissivity Database (ASTER GED): Mapping Earth's emissivity at 100 meter spatial resolution, *Geophysical Research Letters*, 42, doi:10.1002/2015GL065564.
- **Hulley, G.,** S. Veraverbeke, S. Hook, (2014), Thermal-based techniques for land cover change detection using a new dynamic MODIS multispectral emissivity product (MOD21), *Rem. Sens. Environ*, 140, p755-765
- **Hulley, G. C.**, T. Hughes, and S. J. Hook (2012), Quantifying Uncertainties in Land Surface Temperature (LST) and Emissivity Retrievals from ASTER and MODIS Thermal Infrared Data, J. Geophys. Res. Lett, 117, D23113, doi:10.1029/2012JD018506.
- **Hulley, G. C.**, and S. J. Hook (2012), A radiance-based method for estimating uncertainties in the Atmospheric Infrared Sounder (AIRS) land surface temperature product, J. Geophys. Res. Lett, 117, D20117, doi:10.1029/2012JD019102.

Nicholas B. Tufillaro
College of Earth, Ocean and Atmospheric Sciences,
Oregon State University, Corvallis, OR 97331

Dr. Nicholas Tufillaro is Associate Professor, Senior Research in the College of Earth, Ocean, and Atmospheric Sciences (CEOAS) at Oregon State University. He received his Bachelor's degree in Physics from the Reed College, Portland, Oregon in 1982, and his Ph.D. in Physics from Bryn Mawr College in 1990. He pursued postdoctoral work at the Woods Hole Oceanographic Institution in 1991, and was also the recipient of both NSF and Fulbright fellowships to pursue studies in Europe and New Zealand respectively. From 1995 to 2008 he was as senior researcher and member of the technical staff at HP/Agilent working on the development of new high speed electronic and optical test instrumentation. Nick is also the author of three books in nonlinear physics, and more than 50 research articles in physics, electronic engineering, optics, and ocean sciences. In 2009 Nick began working with Curt Davis on research and operational support for calibration and validation activities with HICO, MERIS, and VIIRS, and in-situ data using instruments such as the Satlantic HyperPRO. Current projects include the development of the test plan for a prototype multi-slit ocean viewing spectrometer, the creation of a web portal for automated ocean color product validation, and the invention of novel signal processing algorithms for hyperspectral sensors using techniques such as optical flow and sparse signal processing.

Special Interests: Optical remote sensing of the coastal ocean using multispectral and hyperspectral data. Signal processing and algorithms for the creation of new products from remote sensing, in particular the identification of case II waters constituents such as different types of sediments and microbiology species.

SELECTED RECENT PUBLICATIONS:

Saldias, Sherman, Barth, & Tufillaro, 2016, Optics of the offshore Columbia River plume from glider observations and satellite imagery, J. Geophysical Research.

Ryan, Davis, Tufillaro, Kudela, & Gao, 2014, Application of the Hyperspectral Imager for the Coastal Ocean to Phytoplankton Ecology Studies in Monterey Bay, CA, USA, Remote Sensing.

Davis & Tufillaro, 22 July 2013, Remotely sensing the complexity of rivers and estuaries, SPIE Newsroom article.

Tufillaro, N., 2012, "The shape of ocean color," book chapter in From Laser Dynamics to the Topology of Chaos, R. Gilmore and C. Letellier eds., World Scientific.

Luttman, A., E. Bollt, R. Basnayake, S. Kramer, and N. Tufillaro, 2012, A framework for estimating potential fluid flow from digital imagery, Physica D.

Valle, T. C. Hardesty, C. O. Davis, N. Tufillaro, M. Stephens, W. Good, and P. Spuhler, 2012, Multi-Slit Optimized Spectrometer: An innovative design for geostationary hyperspectral imaging, Proc. of OSA Optical Remote Sensing of the Environment 2012.

Thomas, C. T., A. Kennedy, J. Selker, A. Moretti, M. Schroth, A. Smoot, N. Tufillaro, and M.Zeeman, 2011, High-resolution fiber optics: A new tool to study 2-D thermal structure of near-surface atmospheric boundary layer flows, Boundary-Layer Meteorology 142 (2)

Erin Lee Hestir

Professional Preparation

University of California, Berkeley, CA	Geography	B.A.	2004
University of California, Davis, CA	Geography	Ph.D.	2010

Appointments

2014-present	Assistant Professor, Marine, Earth & Atmospheric Sciences, NCSU Raleigh, NC
2014-present	Visiting Scientist, Land and Water Flagship, CSIRO, Canberra, AU
2013-present	Adjunct Sr. Lecturer, Civil Eng. & Survey., U. South. Qld., Toowoomba, AU
2011-2014	Postdoc Environmental Earth Observation, CSIRO, Canberra, AU
2010-2011	Postdoc Land, Air & Water Resources, University of California Davis, CA

Relevant Publications

Hestir, E.L., Schoellhamer, D.H., Greenberg, J., Morgan-King, T., & Ustin, S.L. (2016). The Effect of Submerged Aquatic Vegetation Expansion on a Declining Turbidity Trend in the Sacramento-San Joaquin River Delta. Estuaries and Coasts, 39, 1100-1112

Santos, M.J., Khanna, S., Hestir, E.L., Greenberg, J.A., & Ustin, S.L. (2016). Measuring landscape-scale spread and persistence of an invaded submerged plant community from airborne remote sensing. Ecological Applications. In press

Lymburner, L., Botha, E., Hestir, E., Anstee, J., Sagar, S., Dekker, A., & Malthus, T. (2016). Landsat 8: Providing continuity and increased precision for measuring multi-decadal time series of total suspended matter. Remote Sensing of Environment. In press.

Hestir, E.L., Brando, V.E., Bresciani, M., Giardino, C., Matta, E., Villa, P., & Dekker, A.G. (2015a). Measuring freshwater aquatic ecosystems: The need for a hyperspectral global mapping satellite mission. Remote Sensing of Environment, 167, 181-195

Hestir, E.L., Brando, V.E., Campbell, G., Dekker, A.G., & Malthus, T.J. (2015b). The relationship between dissolved organic matter absorption and dissolved organic carbon in reservoirs along a temperate to tropical gradient. Remote Sensing of Environment, 156, 395-402

Hestir, E.L., Schoellhamer, D.H., Morgan-King, T., & Ustin, S.L. (2013). A step decrease in sediment concentration in a highly modified tidal river delta following the 1983 El Niño floods. Marine Geology, 345, 304-313

Hestir, E.L., Greenberg, J.A., & Ustin, S.L. (2012). Classification Trees for Aquatic Vegetation Community Prediction From Imaging Spectroscopy. Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of, 5, 1572-1584

Santos, M.J., Hestir, E.L., Khanna, S., & Ustin, S.L. (2012). Image spectroscopy and stable isotopes elucidate functional dissimilarity between native and nonnative plant species in the aquatic environment. New Phytologist, 193, 683-695

Santos, M.J., Khanna, S., Hestir, E.L., Andrew, M.E., Rajapakse, S.S., Greenberg, J.A., Anderson, L.W.J., & Ustin, S.L. (2009). Use of Hyperspectral Remote Sensing to Evaluate Efficacy of Aquatic Plant Management. Invasive Plant Science and Management, 2, 216-229

Hestir, E.L., Khanna, S., Andrew, M.E., Santos, M.J., Viers, J.H., Greenberg, J.A., Rajapakse, S.S., & Ustin, S.L. (2008). Identification of invasive vegetation using hyperspectral remote sensing in the California Delta ecosystem. Remote Sensing of Environment, 112, 4034-4047

Synergistic activities.

1. NCSU Chancellor's Faculty Excellence Fellow in Geospatial Analytics
2. GEO Biodiversity Observation Network, Freshwater Biodiversity Working Group.
3. GEO Integrated Water Information Task, AquaWatch Community of Practice
4. IOCCG Earth Observations in Support of Global Water Quality Monitoring Working Group

BRIAN A. BERGAMASCHI

USGS California Water Science Center, Sacramento

California State University, 6000 J Street, Sacramento CA

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EDUCATION:

George Washington University: B.Sc. 1983; Major emphasis, zoology; minor emphasis, biochemistry.

University of Washington; Ph.D. January 1995; Major emphasis, organic geochemistry/chemical oceanography; minor emphasis, biological oceanography

Carnegie Geophysical Institute: Postdoctoral Fellow, 1995; Measurement of carbon isotopic ratios of individual carbohydrates in environmental samples.

APPOINTMENTS:

2008-Present; Adjunct Professor, California State University, Sacramento

1997-Present; Research Organic Geochemist, USGS, Sacramento, CA,

1995-1997; Organic Geochemist, C.S.U.S.

1995; Postdoctoral Fellow, Carnegie Geophysical Laboratory, Washington D.C.

RECENT PUBLICATIONS:

Fichot, C. G., B. D. Downing, B. A. Bergamaschi, L. Windham-Myers, M. Marvin-DiPasquale, D. R. Thompson, and M. M. Gierach (2015), High-Resolution Remote Sensing of Water Quality in the San Francisco Bay–Delta Estuary, Environmental Science & Technology, doi:10.1021/acs.est.5b03518.

Bergamaschi, B. A., Krabbenhoft, D. P., Aiken, G. R., Patino, E., Rumbold, D. G., and Orem, W. H., 2012, Tidally driven export of dissolved organic carbon, total mercury, and methylmercury from a mangrove-dominated estuary: Environmental science & technology, v. 46, no. 3, p. 1371-1378.

Bergamaschi, B. A., Smith, R. A., Sauer, M. J., Shih, J.-S., and Ji, L., 2014, Terrestrial Fluxes of Nutrients and Sediment to Coastal Waters and Their Effects on Coastal Carbon Storage in the Eastern United States, in Zhu, Z., and Reed, B. C., eds., Baseline and projected future carbon storage and greenhouse-gas fluxes in ecosystems of the eastern United States, Volume U.S. Geological Survey Professional Paper 1804, US Geological Survey, p. 85-114.

Downing, B. D., Pellerin, B. A., Bergamaschi, B. A., Saraceno, J. F., and Kraus, T. E. C., 2012, Seeing the light: The effects of particles, dissolved materials, and temperature on in situ measurements of DOM fluorescence in rivers and streams: Limnology and Oceanography: Methods, v. 10, no. OCTOBER, p. 767-775.

Pellerin, B. A., Bergamaschi, B. A., Gilliom, R. J., Crawford, C. G., Saraceno, J., Frederick, C. P., Downing, B. D., and Murphy, J. C., 2014, Mississippi river nitrate loads from high frequency sensor measurements and regression-based load estimation: Environmental Science and Technology, v. 48, no. 21, p. 12612-12619.

Pellerin, B. A., Bergamaschi, B.A., Downing, B.D., Saraceno, J.F., Garrett, J.A., Olsen, L.D., 2013, Optical techniques for the determination of nitrate in environmental waters: Guidelines for instrument selection, operation, deployment, maintenance, quality assurance, and data reporting U.S. Geological Survey Techniques and Methods 1–D5, 37 p.:

RECENT ACADEMIC COLLABORATORS:

Alexander Parker (California Maritime Academy); Cedric Fichot (JPL); Frances Wilkerson (Romberg Tiburon Center, SFSU); Julien Moderan (Romberg Tiburon Center, SFSU); Peter Hernes (UCDavis); Richard Dugdale (Romberg Tiburon Center, SFSU); Thomas Harter (UCDavis,); William Horwath (UCDavis); Wim Kimmerer (Romberg Tiburon Center, SFSU).

Amye Rita Osti

Chief Executive Officer, 34 North

Education: Amye Osti holds a B. A. in Political Science International Relations and Spanish from University of California, Santa Barbara and a Masters in Business and Computer Science from California Polytechnic State University, San Luis Obispo

Amye Osti, CEO and Founder 34 North, is responsible for bringing OPENNRM collaborative natural resource management data platform to market as well as build a vibrant open data community. OPENNRM Enterprise is currently used to manage large scale multi-agency efforts between USGS, USFWS, USBR, USACE, MWD, DWR, CASWRCB, EPA and many others in the California Delta, San Joaquin River and Sacramento River Watersheds. Before joining 34 North in 2007, Amye was an executive producer of entertainment websites for Paramount Pictures, Warner Brothers, Artisan, Sundance and Cartoon Network. Other positions include Dega, Director of Product Development for Ford Motor Company, Acura, GM and Trane as well a serving 3 years with the State Department in Germany and Spain analyzing emerging technologies and their effect on American industry.

About 34 North

34 North develops powerful data solutions for the environmental services industry. By using a fast and iterative agile development process our client's websites and software applications can grow and change with the needs of the marketplace. We are committed to creating software that can be managed by our clients using fully integrated content management systems. We are experts in web and mobile technologies, GIS, data management (including open data initiatives), analytics and visualization. In most cases we bring all of these tools and solutions together. Everything we build is focused on helping our customers to engage and collaborate with their communities, stakeholders and constituents.

9 RESUME/CV: CO-INVESTIGATORS (SUPPORTED WITH IN-KIND FUNDS)

David Fullerton, Metropolitan Water District of Southern California

David Fullerton has been a Principal Resource Specialist with the Metropolitan Water District of Southern California since 2002. At Metropolitan, Mr. Fullerton has been active on numerous programs, including expansion of permitted State Water Project Delta pumping capacity, MWD's water transfer program, water quality exchanges in the San Joaquin Valley, development of a long-term Environmental Water Account, and analysis of the factors driving the catch and the abundance of various ESA fish species.

Mr. Fullerton has been involved in California water policy for some thirty years. Prior to joining MWD, Mr. Fullerton was a Senior Staff Scientist at the Natural Heritage Institute, a non-profit environmental consulting firm. In the early 1990's he helped negotiate the Urban Water Conservation Best Management Practices and was the first Convener of the California Urban Water Conservation Council. He also helped to establish the Three Way Process, the precursor to the CALFED Process. Mr. Fullerton was a prime architect of the Environmental Water Account and coordinated its operations during 2001. More recently Mr. Fullerton has studied the relationship between fish catchability and various environmental factors such as turbidity.

Mr. Fullerton has degrees in Physics, Electrical Engineering and Classical Studies from Stanford University and a degree in Ancient History from UC Berkeley.

Publications

Patricia M. Glibert, David Fullerton, Joann M. Burkholder, Jeffrey C. Cornwell & Todd M. Kana (2011): Ecological Stoichiometry, Biogeochemical Cycling, Invasive Species, and Aquatic Food Webs: San Francisco Estuary and Comparative Systems, Reviews in Fisheries Science, 19:4, 358-417

Miller, William J, Bryan Manly, Dennis D Murphy, David Fullerton, & Rob R Ramey. An Investigation of Factors Affecting the Decline of Delta Smelt (Hypomesus transpacificus) in the Sacramento-San Joaquin Estuary. Reviews in Fisheries Science, 20(1):1–19, 2012

Manly, B.F.J., Fullerton, D., Hendrix, A.N. et al. Estuaries and Coasts (2015) 38: 1815. doi:10.1007/s12237-014-9905-3. Comments on Feyrer et al. "Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish"

Shawn C. Acuña

Bay-Delta Initiatives
Metropolitan Water District of Southern California
(916) 650-2664 office
E-mail: sacuna@mwdh2o.com

1121 L Street, Suite 900
Sacramento, CA 95814
(310) 938-7966 cell

Education

Ph. D, Ecology, University of California, Davis, June 2011.
Dissertation: Effects of *Microcystis aeruginosa* on Sacramento splittail, *Pogonichthys macrolepidotus*, and threadfin shad, *Dorosoma petenense*.
Master of Science, Animal Biology, University of California, Davis, April 2007.
Thesis: Inducing compensatory growth in California halibut, *Paralichthys californicus*.
Bachelor of Science, Aquatic Biology, University of California, Santa Barbara, June 1998.

Goal

To become an awardee for the Proposition 1 Grant Program Solicitation.

Work Experience

Senior Resource Specialist. Metropolitan Water District 12/13-present
Develop, manage and conduct research on the aquatic sciences in the San Francisco Estuary. Conducting ongoing researching regarding the genetic and status of listed species, and evaluating impacts of predation, entrainment, habitat quality, and contaminants on listed species in the San Francisco Estuary.

Postdoctocal Research. University of California, Davis 6/11 - 12/13
Collected, prepared and statistically evaluated data for ongoing studies on the Delta smelt, *Hypomesus transpacificus* (Fall Low Salinity Habitat study), splittail, *Pogonichthys macrolepidotus* (Splittail Habitat Survey), and largemouth bass, *Micropterus salmoides* (Largemouth Bass Salinity Survey).

Community College Lecturer. The New Plagues, Sacramento City College, 1/07-5/07.
Gave lectures, prepared lesson plans and graded tests for students with a variety of backgrounds the microbiology, history, and emergence of new pathogens.

Research Assistant: University of California, Davis, 9/04- 6/11.
Collected, maintained and statistically evaluated data for ongoing studies on fish from California. Studies included the evaluation of different culturing techniques, the effects of different habitats and the effects of toxicity from microcystin, pyrethroids, plastic, ammonia, turbidity, salinity and metals.

Larval systems manager. Scientific Hatcheries 6/03-06/04.
Care and maintenance of a fish hatchery for ornamental fish; zebra danios (*Danio rerio*), cherry barbs (*Puntius titteya*), feeder guppies (*Poecilia reticulata*), and bloodfin tetras (*Aphycoharax anisitis*) with an emphasis in larval production. Duties included system maintenance of a commercial hatchery, live feed production and management of the staff.

Laboratory Analyst: EMAX Laboratories, Inc., 8/00 – 06/03
Analyzed soil and water for dissolved gasses, fuels and oils. Prepared reports, developed methods for gas chromatography and prepared training files for audits.

Publications

Acuña, SC. 2016. Insights into factors affecting long term fish surveys in the San Francisco Estuary, for Longfin smelt. *In progress*.
Acuña, SC, Baxa, D, Deng, DF, Lehman, P, Teh, SJ. 2016. Assessing the potential impacts of *Microcystis* on threadfin shad (*Dorosoma pentenese*) in the San Francisco Estuary. Harmful Algal Blooms. *In progress*.
Acuña, SC, Slater, S, Javidmehr, A, Teh, S. 2016. Patterns of prey use and nutritional status of subadult and adult Delta smelt. San Francisco Estuary Science. *In progress*.
Hammock, B, Hobbs, J, Slater, S, Acuña, S, Teh, S. 2015. Contaminant and food limitations stress in an endangered estuarine fish. Science of the Total Environment. 532: 316-326.

Russell E. Ryan, P.E.

B.S. Civil Engineering, Loyola Marymount University, 1984

Relevant Experiment

Metropolitan Water District of Southern California, Project Management, 1990 - Present

- Ensuring reliable water supply for Southern CA, dry-year supply programs, system analyses of conveyance infrastructure, regional needs for seawater desalination
- Bay Delta Initiatives Program

Previous Experience

U.S. Army Corps of Engineers

City of Los Angeles, Department of Public Works

Los Angeles Department of Water and Power

Professional Societies

American Society of Civil Engineers 1993 -

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URL: http://www.nabinkm.com

NASA Jet Propulsion Laboratory (JPL)
California Institute of Technology (Caltech)
4800 Oak Grove Dr., MS 183-501
Pasadena, CA 91109, USA

Education

- **Ph.D.**, Physics — December 2011
  University at Albany, State University of New York (SUNY), Albany, NY
- **M.S.**, Physics — May 2008
  University at Albany, SUNY, Albany, NY

Appointments

- **Postdoctoral Research Scientist** — Aug 2014- Present
  NASA JPL/ Caltech, Pasadena, CA
- **Postdoctoral Researcher** — 2013- 2014
  NOAA-CREST, City College of New York, CUNY.
- **Part-time Lecturer, Physics** — Fall 2012
  University of Texas at Dallas
- **Research Associate** — 2011 –2013
  University of Texas at Dallas
- **Graduate Research/Teaching Assistant** — 2006 - 2010
  Department of Physics, University at Albany, SUNY

Relevant Publications

1. **N. Malakar** and G. C. Hulley, (2016), "A Water Vapor Scaling Model for Improved Land Surface Temperature and Emissivity Separation of MODIS Thermal Infrared Data", Remote Sensing of Environment, 182, 252-264. DOI: 10.1016/j.rse.2016.04.023
2. T. Islam, G. C. Hulley, **N. Malakar**, R. Radocinski, S. Hook (2016), "A physics-based algorithm for the simultaneous retrieval of land surface temperature and emissivity from VIIRS thermal infrared data", IEEE TGARS, in press.
3. G. C. Hulley, R. M. Duren, F. M. Hopkins, S. J. Hook, N. Vance, P. Guillevic, W. R. Johnson, B. T. Eng, J. M. Mihaly, V. M. Jovanovic, S. L. Chazanoff, Z. K. Staniszewski, L. Kuai, J. Worden, C. Frankenberg, G. Rivera, A. D. Aubrey, C. E. Miller, **N. Malakar**, J. M. Sánchez Tomás, and K. T. Holmes, (2016) "High spatial resolution imaging of methane and other trace gases with the airborne Hyperspectral Thermal Emission Spectrometer (HyTES)", Atmos. Meas. Tech., doi:10.5194/amt-2016-8, 2016.
4. G. C. Hulley, S. J. Hook, E. Abbott, **N. Malakar**, T. Islam, M. Abrams (2015), "The ASTER Global Emissivity Dataset (ASTER GED): Mapping Earth's emissivity at 100 meter spatial scale", Geophysical Research Letters, 42, doi:10.1002/2015GL065564.
5. K. H. Knuth, M. Habeck, **N. Malakar**, A.M. Mubeen, B. Placek, "Bayesian Evidence and Model Selection", Digital signal Processing, 4, (3), 2015.
6. D. J. Lary, F. S. Faruque, **N. Malakar**, A. Moore, B. Roscoe, Z. Adams, Y. Eggelston, "Estimating the global abundance of ground level presence of particulate matter (PM2. 5)", Geospatial health 8 (3), 611-630, 2014.
7. L. Cordero, **N. Malakar**, Y. Wu, B. Gross, and F. Moshary, "Assessing PM2.5 Estimates using Data Fusion of Active and Passive Remote Sensing Methods", Special Issue of British Journal of Environment and Climate Change, 3 (4), 2013.
8. **N. Malakar**, D. Gladkov, and K. H. Knuth, (2013), "Modeling a Sensor to Improve Its Efficacy", Journal of Sensors, vol. 2013. doi:10.1155/2013/481054.

R. Stoneback, **N. Malakar**, D. Lary, R. Heelis, "Specifying the Equatorial Ionosphere using CINDI on C/NOFS, COSMIC, and DINEOFs", Journal of Geophysical Research, 2013.

10 CURRENT/PENDING SUPPORT

Current (requesting funds from NASA)

Dr. Christine M. Lee, JPL (PI)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

George Chang, JPL (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Robert D. Toaz	Earth Observing System Data and Information System	EOSDIS/NASA Kevin Murphy (202-358-3042) kevin.j.murphy@nasa.gov	10/05/15 – 09/30/16 $9.5M	5
Emily Law	Lunar Mapping and Modeling Project	NASA	10/5/15 – 09/30/16 $700K	2

Dr. Glynn Hulley, JPL (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Glynn Hulley	A New MODIS Land Surface Temperature and Spectral Emissivity Product (MOD21) for Earth Science Research	Science of Terra & Aqua NASA: Diane E. Wickland diane.e.wickland@nasa.gov (202) 358-0245	01/2014 – 12/2016 $750 K	1
Glynn Hulley	A Unified VIIRS Land Surface Temperature and Emissivity (LST&E) Product for Earth Science Research and MODIS Continuity	NASA-NPP Diane E. Wickland diane.e.wickland@nasa.gov (202) 358-0245	06/2014 – 05/2017 $804 K	1
Simon J. Hook	The Ecosystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)	Earth Ventures Instrument-2 NASA: Kenneth Jucks Kenneth.W.Jucks@nasa.gov (202) 358-0476	07/2014 – 03/2020 $30 M	5
Simon J. Hook	A Unified and Coherent Land Surface Temperature and Emissivity (LST&E) Earth System Data Record (ESDR) for Earth Science	Measures Program NASA Martha E. Maiden ((202) 358-1078 martha.e.maiden@nasa.gov	1/1/2013-12-31-2017 $4 M	2

Dr. Michelle Gierach, JPL (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Michelle Gierach	Rapid Response to the ORCAS Campaign	Rapid Response; Paula Bontempi, (202) 358-1508, paula.s.bontempi@nasa.gov	10/2014–9/2017 $615K	0.5
Eric Hochberg	CORAL: COral Reef Airborne Laboratory	Earth System Science Pathfinder (ESSP) Venture-Class Science Investigations: Earth Venture Suborbital-2 (EVS2); Hal Maring, (202) 358-1679, hal.maring@nasa.gov	7/2015-09/2018 $15,000K	6.0
Dave Schimel	Operations and data products for carbon-climate feedbacks using OCO-2	Science Team for the OCO Mission; Kenneth W. Jucks, (202) 358-0476, kenneth.w.jucks@ nasa.gov	10/2015-9/2018 $300K	2.0

Dr. Nicholas Tufillaro, OSU (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Curtiss Davis	Impacts of Population Growth on the San Francisco Bay and Delta Ecosystem	NASA-IDS/ NASA / Paula Bontempi, paula.bontempi@nasa.gov	2013-2016 / $1,960,134	3 months per year
Curtiss Davis	Validation of VIIRS Ocean Color products for West Coast and Hawaiian Water	NOAA / JPSS Support / Mengu Wang, menghua.wang@noaa.gov	2015-2016 / $74,830	3 months per year
Nicholas Tufillaro	Analysis of GEO-TASO and MOS-Polar data for the Measurement of Ocean	NASA-GEOCAPE Program; Manager: Antonio Mannino, antonio.mannino-1@nasa.gov	2016-2017 / $80,910	3 months per year

Dr. Erin Hestir, NCSU (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Dr. Brian Bergamaschi, USGS (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Brian Bergamaschi	USGS LandCarbon project – Coastal Carbon Sequestration	U.S. Geological Survey LandCarbon Project, Zhiliang Zhu, 703-648-4243, zzhu@usgs.gov	Award Period: 10/1/2016 – 9/30/2017; Total Award: $100,000	4 months per year
Bryan Downing	Assessment of Aquatic Habitat Conditions in the Sacramento-San Joaquin Delta	US BoR, Dr. Erwin Van Nieuwenhuyse, (916) 476-5053; evannieuwenhuyse@usbr.gov	Award Period: 1/1/2015 – 9/30/2017; Total Award: $1,150,000	4 months per year
Bryan Downing	Interactions between physical processes and suspended sediment quality in relation to spawning migrations of delta smelt	US Fish and Wildlife Service, Bay-Delta Fish and Wildlife Office, Sacramento, Mike Chotkowski	Award Period: 9-1-2015 – 12-31-2016; Total Award $100,000	2 months per year
Wim Kimmerer	Dynamics of zooplankton in the Cache Slough Complex	State and Federal Contractors Water Agency, Dr. Val Connor, (916) 476-5053; vconnor@sfcwa	Award Period: 6/1/2015 – 12/31/2016; Total Award: $247,000	2

Amye Osti (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Amye Osti	Continued development of Real time intelligence data dashboards for Baydeltalive.com to allow stakeholders to better understand real time conditions. BDL real time operations, salinity, turbidity, fish survey and current river conditions data dashboards provide managers and scientists with critical information required to make key decisions.	Metropolitan Water District / Russell Ryan	2016-2018	1.2*
Amye Osti	Development of 1641 Water Quality Interactive Report Online for the California State Resources Control Board. The development of real time data dashboards and data visualizations to report on all water quality conditions in the Sacramento San Joaquin Bay-Delta.	California Department of Water Resources	2015-2018	1.2*
Amye Osti	The Sacramento River Watershed Data Portal built on the OpenNRM enterprise platform provides users with quick and easy access to extensive watershed data and information including the real time sensor networks, monitoring data, maps, studies, reports, images and	The Sacramento River Watershed Data Portal (Multi-stakeholder collaboration including the Sacramento River Watershed	2016-2018	1.2*

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
	GIS. Users can organize data spatially, compile maps, create project, wiki libraries and analytics to better visualize data collection results and answer questions about watershed conditions and health.	Program, CalFire, Sierra Nevada Conservance, CSWRCB, DWR)		
Amye Osti	Real Time Salinity and Nutrient Management in the San Joaquin River Basin. Data management and visualization using OpenNRM Enterprise data portal.	United States Bureau of Reclamation	2017-2018	1.2*
* Estimate. 34N has a staff of 12-15 people plus subcontractors.				

Current (in-kind team members, no funds requested from NASA)

David Fullerton, MWD (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Dr. Shawn Acuna, MWD (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Russ Ryan, MWD (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Dr. Nabin Malakar, JPL (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Pending

Dr. Christine M. Lee, JPL (PI)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

George Chang, JPL (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Dr. Glynn Hulley, JPL (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Dr. Michelle Gierach, JPL (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Dr. Nicholas Tufillaro, OSU (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Curtiss Davis	Properties during KORUS-OC Support to JPSS Data Products & Algorithms: Validation of VIIRS Ocean Color products for the coastal and open ocean	JPSS Support; Manager: Menghu Wang, NOAA, menghua.wang@noaa.gov	2017-2018 / $121,478	3 months per year
Erik Bollt	Remote Sensing and Data Fusion from Multi-Attribute Systems	NGA-NURI	2017-2019 / $160,166	2 months per year

Dr. Erin Hestir, NCSU (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Katherine Jennings	Utility of Remote Sensing Imagery for Weed Identification and Implementation of Site Specific Weed Management in Annual Cropping Systems	Crop Protection and Pest Management Competitive Grants Program / USDA National Institute of Food and Agriculture / Mr. Herbert Bolton (202-401-5062, hbolton@nifa.usda.gov)	01/01/2017 – 12/31/2020 / $295,013	0.09 academic months
Erin Hestir	From Arboreal to Benthic Communities: the ABCs of Land to Ocean Biodiversity Observations	A.6 Biodiversity / NASA / Mr. Woody Turner (202-358-1662, woody.turner@nasa.gov)	05/01/2016 – 11/30/2017 / $185,885	0.25 summer months per year
Robert Mickler, Erin Hestir	The Role of Blue Carbon in Coastal Resilience of Wetland Forests and Marshes to Climate Change and Sea Level Rise	A.5 Carbon Cycle Science / NASA / Ms. Paula Bontempi (202-358-1508 / paula.s.bontempi@nasa.gov)	01/01/2017 – 12/31/2019	1 summer months per year
Frank Muller-Karger, Erin Hestir	Phenology Imaging Spectrometer for Coastal Ecology Studies (PISCES)	Earth Venture Mission – 2 Earth Systems Science Pathfinder Program / NASA / Dr. Ramesh Kakar (202-358-0240 / Ramesh.k.kakar@nasa.gov)	01/01/2017-12-31-2023 / 804,350	0.5 summer months per year
Erin Hestir	Foliar Pigment Analysis Methods Test: Supporting NEON Foliar Physical and Chemical Properties Procedures (Option 1)	Methods Test, Foliar Pigment Analysis, NEON / Mr. Steve McCormick (702-330-1668, smccormick@neoninc.org)	08/22/2016-08/21/2017 / $78,496	0.09 academic months
Erin Hestir	Foliar Pigment Analysis Methods Test: Supporting NEON Foliar Physical and Chemical Properties Procedures (Option 2)	Methods Test, Foliar Pigment Analysis, NEON / Mr. Steve McCormick (702-330-1668, smccormick@neoninc.org)	08/22/2017-08/21/2017 / $61,523	0.09 academic months

Dr. Brian Bergamaschi (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Bryan Downing	Particle Quality on the Fly	USGS, Eric Reichard, (916) 278-3000, egreich@usgs.gov	Award Period: 10/1/2016 – 9/30/2017; Total Award: $70,000	2 months per year

Amye Osti, 34N (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Pending – (in-kind team members)

David Fullerton, MWD (Co-PI)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Dr. Shawn Acuna, MWD (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Russ Ryan, MWD (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

Dr. Nabin Malakar, JPL (Co-I)

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)

11 REFERENCES/CITATIONS

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Brezonik, P.L. et al., 2015. Factors affecting the measurement of CDOM by remote sensing of optically complex inland waters. *Remote Sensing of Environment*, 157, pp.199–215. Available at: http://www.sciencedirect.com/science/article/pii/S0034425714002326.

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California Department of Water Resources, 2004. *EFFECTS OF PROJECT OPERATIONS ON GEOMORPHIC PROCESSES DOWNSTREAM OF OROVILLE DAM*,

California Department of Water Resources, 2009. *Water Quality in the State Water Project, 2004 and 2005*,

Chen, S. et al., 2015. Estimating wide range Total Suspended Solids concentrations from MODIS 250-m imageries: An improved method. *ISPRS Journal of Photogrammetry and Remote Sensing*, 99, pp.58–69.

Cloern, J.E., 1996. Phytoplankton bloom dynamics in coastal ecosystems: A review with some general lessons from sustained investigation of San Francisco Bay, California. *Reviews of Geophysics*, 34(2), pp.127–168. Available at: http://doi.wiley.com/10.1029/96RG00986.

Deltacouncil.ca.gov, WATER SUPPLY | Delta Stewardship Council. Available at: http://deltacouncil.ca.gov/water-supply.

Feyrer, F., Nobriga, M.L. & Sommer, T.R., 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. *Canadian Journal of Fisheries and Aquatic Sciences*, 64(4), pp.723–734. Available at: http://www.nrcresearchpress.com/doi/abs/10.1139/f07-048.

Fichot, C.G. et al., 2016. High-Resolution Remote Sensing of Water Quality in the San Francisco Bay-Delta Estuary. *Environmental science & technology*, 50(2), pp.573–83. Available at: http://dx.doi.org/10.1021/acs.est.5b03518.

Hanak, E. et al., 2013. Stress Relief: Prescriptions for a Healthier Delta Ecosystem. Available at: www.ppic.org.

Hestir, E.L. et al., 2008. Identification of invasive vegetation using hyperspectral remote sensing in the California Delta ecosystem. *Remote Sensing of Environment*, 112(11), pp.4034–4047. Available at: http://www.sciencedirect.com/science/article/pii/S0034425708002046.

Hestir, E.L. et al., 2016. The Effect of Submerged Aquatic Vegetation Expansion on a Declining Turbidity Trend in the Sacramento-San Joaquin River Delta. *Estuaries and Coasts*, 39(4), pp.1100–1112. Available at: http://link.springer.com/10.1007/s12237-015-0055-z.

Hestir, E.L. et al., 2015. The relationship between dissolved organic matter absorption and dissolved organic carbon in reservoirs along a temperate to tropical gradient. *Remote Sensing of Environment*, 156, pp.395–402.

Hoogenboom, H.J., Dekker, A.G. & Althuis, I.A., 1998. Simulation of AVIRIS Sensitivity for Detecting Chlorophyll over Coastal and Inland Waters. *Remote Sensing of Environment*, 65(3), pp.333–340.

Hulley, G.C. et al., 2015. The ASTER Global Emissivity Dataset (ASTER GED): Mapping Earth's emissivity at 100 meter spatial scale. *Geophysical Research Letters*, 42(19), pp.7966–7976. Available at: http://doi.wiley.com/10.1002/2015GL065564.

Hulley, G.C., Hook, S.J. & Schneider, P., 2011. Optimized split-window coefficients for deriving surface temperatures from inland water bodies. *Remote Sensing of Environment*, 115(12), pp.3758–3769.

Karaska, M.A. et al., 2004. AVIRIS Measurements of Chlorophyll, Suspended Minerals, Dissolved Organic Carbon, and Turbidity in the Neuse River, North Carolina. *Photogrammetric Engineering and Remote Sensing*, pp.125–133.

Keith, D.J., 2014. Satellite remote sensing of chlorophyll a in support of nutrient management in the Neuse and Tar–Pamlico River (North Carolina) estuaries. *Remote Sensing of Environment*, 153, pp.61–78. Available at: http://www.sciencedirect.com/science/article/pii/S0034425714002077.

Khanna, S. et al., 2011. Plant community dynamics relative to the changing distribution of a highly invasive species, Eichhornia crassipes: a remote sensing perspective. *Biological Invasions*, 14(3), pp.717–733. Available at: http://link.springer.com/10.1007/s10530-011-0112-x.

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