**NASA DEVELOP National Program**

**2020 Fall Project Proposal**

**California – JPL**

**Central Valley Water Resources II**

*Improving Groundwater Assessments in the Central Valley using Remotely Sensed Groundwater Storage Change and Land Subsidence Measurements for Water Resource Management*

**Project Overview**

***Project Synopsis*:** The objective of this project is to continue to assist the California Department of Water Resources (CA DWR) by providing high-resolution estimates of terrestrial water storage change and land subsidence in the Central Valley region of California. The first term used GRACE and GRACE-FO data to identify and quantify groundwater depletion and used Interferometric Synthetic Aperture Radar (InSAR) datasets to identify and quantify land subsidence. The proposed work will increase data coverage to include additional partner-specified critically over-drafted subbasins of the Central Valley. Geospatial maps of the increased study area, along with a more robust and accessible web tool, will benefit end users with groundwater management initiatives by allowing them to identify areas across the entire Central Valley experiencing the most groundwater depletion and subsidence.

***Community Concern:*** Over the past two decades, California’s Central Valley has been acutely affected by widespread droughts. The most recent drought was one of the most intense in California’s history, lasting from December 27, 2011 to March 5, 2019. Droughts, coupled with California’s agricultural and residential reliance on groundwater, have resulted in the pumping of Central Valley aquifers at unsustainable levels – exceeding the rate of recharge from precipitation and runoff. California’s Sustainable Groundwater Management Act (SGMA), passed in 2014, requires governments and water agencies of high and medium priority sub-basins to have a Groundwater Sustainability Plan (GSP) in place by 2024 and to bring groundwater storage into balanced levels of pumping and recharge by 2042. State-level agencies need ways to assess the veracity of GSP sustainability claims to determine if groundwater is being managed sustainably, as monitoring well data are often sparse or unreliable.

***Source of Project Idea:*** Following the spring 2020 term, the CA DWR showed interest in the project’s continuation. Although the team was able to fulfill the initial needs of the end user, they were only able to analyze a small percentage of the Central Valley in 10 weeks. The partners requested another term to increase the study area to additional subbasins and to further develop the Visualization of In-situ and Remotely sensed Observations (VIRGO) tool into a more robust product that they can use to compare InSAR subsidence measurements and GRACE groundwater depletion measurements to *in situ* well data across the study area.

***National Application Area Addressed:*** Water Resources

***Study Location:*** Central Valley, CA

***Study Period:*** January 2003 – August 2020

***Advisors:*** John T. Reager (NASA Jet Propulsion Laboratory, California Institute of Technology), Zhen Liu (NASA Jet Propulsion Laboratory, California Institute of Technology), Kyra Kim (NASA Jet Propulsion Laboratory, California Institute of Technology)

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **California Department of Water Resources** | Bill Brewster, Senior Engineering Geologist, North Central Region Office Section Lead; Mike McKenzie, Senior Engineering Geologist, South Central Region Office Section Lead; Jack Tung, Water Resources Specialist Research Scientist, Southern Region Office | End User | Yes |
| **California State University, Los Angeles** | Dr. Charles Hays, Professor | Collaborator | No |

***End User Overview***

***End User’s Current Decision-Making Process:***SGMA requires governments and water agencies that regulate high and medium priority groundwater basins to halt overdraft and bring groundwater basins into balanced levels of pumping and recharge. Under SGMA, these basins should reach sustainability within 20 years of implementing their sustainability plans. SGMA requires that critically overdrafted basins follow a sustainable plan by 2040. High and medium priority basins face a 2042 deadline. The CA DWR regional offices assist local California groundwater management agencies in meeting SGMA requirements by housing and serving useful data sets for evaluation of groundwater basin hydrological properties. The partner currently hosts data from InSAR that displays subsidence in select areas of the Central Valley on their data viewer webpage, although they lack a method to reliably cross-examine remotely sensed and *in situ* groundwater and subsidence measurements.

***End User’s Capacity to Use NASA Earth Observations:***

*California Department of Water Resources –* The Southern (SRO), North Central (NCRO), and South Central (SCRO) region offices all have experience using remote sensing data products, along with the application of these data into a website platform that is openly accessible to local governments and the general public. Although they are familiar with and host remote sensing data products, this project will build their capacity to examine subsidence and groundwater depletion measurements as they relate to *in situ* measurements.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*California State University, Los Angeles* – Professor Hays has a long history working at JPL as a Senior Member of the Technical Staff (2001 - 2013) and has worked with the JPL Project Advisors. In addition, Hays connected the SRO to the DEVELOP team as the end user. Hays will provide regional knowledge and scientific support throughout the project.

***Dissemination by Boundary Organizations*:**

*California Department of Water Resources –* The SRO, NCRO, and SCRO will disseminate the project results to other CA state agencies and partners. All three regional offices are in regular contact with the SGMA Program Office in Sacramento, CA, and have been fully approved to support this project and provide ongoing support to local agencies. They assist local agencies and groundwater sustainability agencies, and they foresee posting the end products on their SGMA Dataviewer.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The DEVELOP Fellow and science advisors will initiate the first partner meeting, and the Project Lead will be the main POC for the project throughout the term. Biweekly calls will be conducted to discuss the project’s status and receive feedback from partners. Email exchanges will occur as needed.

***Transition Plan*:** An early handoff will be conducted in Week 8 of the term in order to demonstrate the tool to the project partners and collect any feedback that can be incorporated before the end of the term. The team will showcase the end products and discuss considerations for future work, and the partners will be given an opportunity to use the end products. The project deliverables and end products will be sent via NASA Large File Transfer (LFT).

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **GRACE-FO** | Land water storage change | GRACE-FO Tellus Level-3 Monthly Land Water Mass Anomaly data will be used to measure terrestrial water storage changes. A downscaled GRACE-FO product created by NASA Goddard Space Flight Center will be used where available. |
| **GRACE** | Land water storage change | GRACE Tellus Level-3 Monthly Mass Grids data will be used to measure terrestrial water storage changes. A downscaled GRACE product created by NASA Goddard Space Flight Center will be used where available. |
| **Sentinel-1 C-SAR** | Interferometric synthetic aperture radar | Sentinel-1 C-SAR was used by JPL to create InSAR. This InSAR data will be used to measure land subsidence. |
| **ALOS-2 PALSAR-2** | Interferometric synthetic aperture radar | ALOS-2 PALSAR-2 was used by JPL to create InSAR data. This InSAR data will be used to measure land subsidence. |

***Ancillary Datasets:***

* NASA Goddard Space Flight Center downscaled GRACE product – provides downscaled GRACE data at a level appropriate for regional and local analysis
* US Geological Survey National Water Information System – *in situ* well data used to compare to GRACE measurements
* CA Department of Water Resources Periodic Groundwater Level Measurements – *in situ* well data used to compare to GRACE measurements
* CA Department of Water Resources Continuous Groundwater Level Measurements – *in situ* well data used to compare to GRACE measurements

***Software & Scripting:***

* Esri ArcGIS – manipulate data and create visuals
* QGIS – manipulate data and create visuals
* Python – additional InSAR and GRACE processing, tool development

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Groundwater Storage Change Maps** | This geospatial map will identify areas in the Central Valley experiencing groundwater depletion. Quantifying the severity of groundwater depletion will help end users better allocate resources to the areas most in need. | This map will incorporate groundwater storage change measurements derived from GRACE and GRACE-FO data. GRACE and GRACE-FO data downscaled by researchers at NASA Goddard Space Flight Center will be used as available. | N/A |
| **Land Subsidence Maps** | This geospatial map will identify areas in the Central Valley experiencing land subsidence. Quantifying the severity of land subsidence will help end users better allocate resources to the area’s most in need. | This map will incorporate land subsidence measurements using Sentinel-1 C-SAR and ALOS-2 PALSAR-2 InSAR datasets. | N/A |
| **Groundwater – Subsidence Time Series** | These time series will be used to compare *in situ* groundwater measurements, remotely sensed groundwater estimates, and land subsidence over time. The end users can use this end product to find trends and correlations between these three measurements over time. | These time series utilize monitoring well *in situ* data, GRACE and GRACE-FO groundwater measurements, and Sentinel-1 C-SAR and ALOS-2 PALSAR-2 interferometry. | N/A |
| **Visualization of In-situ and Remotely sensed Observations (VIRGO)** | This tool, created by the first term, will be given a more robust user interface, a larger study area, and will be designed with transfer to the CA DWR in mind. | This tool takes inputs from GRACE, GRACE-FO, Sentinel-1 C-SAR, and ALOS-2 PALSAR-2 to create groundwater depletion and land subsidence products. | IV |
| **VIRGO User Guide/Tutorial** | This end product will describe the methods used to create the product and contain a detailed tutorial of how to utilize the VIRGO tool. | N/A | N/A |

***End User Benefit*:** This project could build extensive terrestrial water storage change results for the CA DWR, especially for outlying rural areas, where there is a paucity of *in situ* data measured from groundwater monitoring wells. The CA DWR will be able to use the project’s end products to aid in verifying claims made by Groundwater Sustainability Agencies, helping to ensure that groundwater sustainability rules set forth by the state of California are being adhered to. The VIRGO tool will enable the partners to conduct additional analyses as more data becomes available.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2020 Spring & 2020 Fall

***Multi-Term Objectives:***

* **Term 1:** 2020 Spring (JPL) – Central Valley Water Resources
  + This term began developing a tool that can assess groundwater depletion and subsidence based on *in situ* groundwater measurements, remotely sensed groundwater measurements, and remotely sensed land subsidence. The team was only able to analyze these factors for a subset of the Central Valley. The end users were satisfied but were interested in expanding the study area.
* **Term 2 (Proposed Term):** 2020 Fall (JPL) – Central Valley Water Resources II
  + The second term will focus on conducting detailed analyses of findings, improving upon the tool created by the first term, and increasing partner involvement in the project. In addition to increasing coverage to additional subbasins of the Central Valley, the team will conduct analyses on a local level as opposed to regional by utilizing point analysis as opposed to zonal analysis. The team will emphasize improving the VIRGO tool by developing a user interface, making it easy for even inexperienced water managers to assess subsidence and groundwater depletion using Earth observations.

***Previous Terms:***

2020 Spring (JPL) – Central Valley Water Resources: Improving California Groundwater Assessments using GRACE and InSAR Datasets for Water Resource Management

***Related DEVELOP Work:***

2017 Spring (ID & WC) – Southeastern Idaho Water Resources II: Utilizing NASA Earth Observations to Identify Existing Surface Water Features and Improve Water Management and Resource Allocation in Southeastern Idaho

2015 Fall (GA) – Georgia Water Resources: Assessing Groundwater Storage Change and Contamination Risk in Southwest Georgia

2014 Spring (MSFC) – Southeast US Water Resources: Development of an Alternative Drought Monitoring System using NASA Earth Observation-Derived Drought Indices and Groundwater Storage Estimates for Improved Water Resource Monitoring in the Southeastern United States

**Notes & References:**

***Notes*:**

The SGMA Data Viewer provides agencies with information on groundwater basin boundaries, critically overdrafted basins, water quality, land subsidence, agricultural crops, well locations and climate change data: <https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels>

***References:***

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