**NASA DEVELOP National Program**

**2019 Spring Project Proposal**

**California – JPL**

**Great Lakes Water Resources**

*Improving Wetland Change Mapping by using Optical and Radar Satellite Sensors to Assess Wetland Gain and Loss Metrics in Minnesota*

**Project Overview**

***Project Synopsis*:** This project will use Landsat 8 OLI, Sentinel-1 C-SAR, Sentinel-2 MSI, RADARSAT-2, and WorldView data to aid partners in Minnesota by creating an automated tool that maps wetland extent and change. The NASA DEVELOP team will partner with end users at the US Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI), Minnesota Department of Natural Resources (MN DNR), Environmental Protection Agency (EPA), Ducks Unlimited (DU), and University of Minnesota (UMN). The team will be provided with ancillary data to integrate with optical and radar image sets to create an automated wetland change map tool. This work builds the partners’ capacities to use a coding platform and radar imagery and can also help reduce the costs to make up-to-date wetland maps by using change metrics to remap changes instead of traditional coverage approaches.

***Community Concern:*** Wetlands are dynamic features that change every day. The Intergovernmental Panel on Climate Change declared wetlands to be the most vulnerable landscape feature on the planet. Wetlands are also one of the most difficult and expensive features to map. Wetland managers, homeowners, highway engineers, and farmers all need current and accurate wetland maps to plan for conservation, home development, transportation infrastructure, and agriculture management. The state of Minnesota spent a decade and $8 million dollars to remap the 1982 state wetland map.

***Source of Project Idea:*** In recent years, the project partners have discussed the need for an automated, satellite-based, seasonal approach for wetland mapping that can efficiently account for change. Brian Huberty from the USFWS NWI contacted Natasha Stavros, JPL scientist, and expressed interest in pursuing this idea for a NASA DEVELOP project. The project developed out of a discussion between Brian and the California – JPL node leadership group since radar applications for wetland mapping would be a natural fit. Brian requested a Google Earth Engine tool as it may make it more feasible to use from an operational standpoint.

***National Application Areas Addressed:*** Water Resources, Ecological Forecasting

***Study Location:*** MN

***Study Period:*** October2017 – January 2019

***Advisor:*** Bruce Chapman (NASA Jet Propulsion Laboratory, California Institute of Technology)

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **US Fish and Wildlife Service, National Wetlands Inventory** | Brian Huberty, Regional NWI and USFWS Remote Sensing Coordinator | End User | Yes |
| **Minnesota Department of Natural Resources** | Steve Kloiber, Wetland Monitoring Coordinator | End User | Yes |
| **US Environmental Protection Agency, Office of Research and Development** | Tom Hollenhorst, Ecologist | End User | Yes |
| **Ducks Unlimited** | Robb Macleod, National GIS Coordinator | End User | Yes |
| **University of Minnesota** | Joe Knight, Associate Professor | End User | Yes |

***End-User Overview***

***End User’s Current Decision-Making Process:***The USFWS, MN DNR, EPA, UMN, and DU all have field managers who repeatedly ask for current wetland map products. Each agency and research university is continually making daily decisions on where to send field biologists for conservation-related work. This includes waterfowl counts tied to wetland types, wetland restoration projects, and invasive species eradication. The UMN has used the NWI map to help refine the statewide land cover map in the past. Although outdated wetland maps are used, incorporating new remote sensing imagery will provide more accurate and current wetland maps.

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

*US Fish and Wildlife Service, National Wetlands Inventory –* The USFWS NWI has used NASA Earth observation systems in the past, as illustrated in each annual NASA Aeronautics and Space Report of the President. The USFWS acquires historic and current views of the landscape across North America for a variety of USFWS applications. This project will help build the organization’s capacity to use radar data for wetland mapping since it has not applied radar data in its mapping efforts in the Great Lakes region.

*Minnesota Department of Natural Resources –* The MN DNR helped create MapServer as part of the NASA-funded 1994 FORNET project to deliver Landsat and aerial imagery to field foresters. The MN DNR uses various sources from internal GIS and remote sensing resources to a variety of online maps with image backgrounds, such as MapServer, Google Earth, ArcGIS Online, MN DNR Landview, and others. This project will help build the MN DNR’s capacity to use radar data for wetland mapping.

*US Environmental Protection Agency, Office of Research and Development –* The EPA has created and used NASA Earth observations for decades. Algae bloom monitoring of the Great Lakes is one current example. This project will help build the EPA’s capacity to use radar data for wetland mapping.

*Ducks Unlimited –* DU pioneered the use of Landsat imagery for wetland mapping of the United States starting in the early 1980s. The organization continues to use Landsat as part of the Canadian Wetland Inventory. This project will help build DU’s capacity to use radar data for wetland mapping.

*University of Minnesota –* The UMN is very familiar with NASA Earth observations as they have used remote sensing data since the 1970s. The Remote Sensing and Geospatial Analysis Laboratory has worked with NASA satellite data and has been building capacity among its staff and students. This project will allow the UMN to build capacity to include radar data in its wetland mapping efforts.

***Collaborator & Boundary Organization Overview***

***Dissemination by Boundary Organizations*:**

*US Fish and Wildlife Service, National Wetlands Inventory –* Brian Huberty will distribute data, results, and methodologies on the organization’s website. If the products meet the needs of stakeholders, such as hunters, fishermen, and landowners, for example, the data could be used to develop new wetland maps as well as refine existing NWI wetland maps. USFWS personnel also present results at local, national, and international wetland conferences. More specifically, they will likely present results at the Association for State Wetland Managers annual conference, the MN GIS/LIS Consortium, the MN Waters Annual Conference, and the American Society for Photogrammetry and Remote Sensing – national and regional technical conferences.

*Minnesota Department of Natural Resources –* Dr. Steve Kloiber and John Jerezek will distribute data, results, and methodologies on the MN DNR website. They also present results at local, national and international wetland conferences. More specifically, they will likely present results at the Association for State Wetland Managers annual conference, the MN GIS/LIS Consortium, the MN Waters Annual Conference, and the American Society for Photogrammetry and Remote Sensing – national and regional technical conferences.

*US Environmental Protection Agency, Office of Research and Development –* The EPA has been providing environmental data for decades. The EPA’s EnviroAtlas data server is an example. The EPA will distribute the results to other Great Lakes researchers and collaborators, including the EPA Great Lakes National Program Office (GLNPO).

*Ducks Unlimited –* Robb Macleod will distribute data, results, and methodologies on the DU website. DU affiliates also present results at local, national, and international wetland conferences. More specifically, they would likely present results at the Association for State Wetland Managers annual conference, the MN GIS/LIS Consortium, the MN Waters Annual Conference, and the American Society for Photogrammetry and Remote Sensing – national and regional technical conferences. Robb will also distribute the results to DU offices in Canada and Mexico.

*University of Minnesota –* The UMN Polar Geospatial Center leads the deployment of geospatial products for the Polar Regions for NSF. The UMN also hosts U-spatial, which provides the distribution of a variety of geospatial products. Partners at the UMN will distribute the results on these websites, which are open to the public.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The team will communicate with the partners weekly or biweekly during the term via teleconference or by email. The main POCs will be the Project Lead and Brian Huberty from the USFWS when other partners are unavailable to meet in a given week.

***Transition Plan*:** The Google Earth Engine tool will be handed off to the partners for further development and implementation. Software release will be required. The partners will receive the code after it is completed by the team and approved by NASA legal. After getting access to the code and testing its development, the MN DNR, USFWS, and DU may host the wetland change data on their websites. The source data may be hosted at the UMN U-Spatial Center where they can also serve up the data through Open Geospatial Consortium - Web Mapping Services and ESRI Representational State Transfer Services.

***Letters of Support*:** Brian Huberty, Regional NWI and USFWS Remote Sensing Coordinator, US Fish and Wildlife Service, Midwest Region, National Wetlands Inventory. Steve Kloiber, Wetland Monitoring Coordinator, Minnesota Department of Natural Resources. Robb Macleod, National GIS Coordinator, Ducks Unlimited. Joseph Knight, Associate Professor, University of Minnesota. Tom Hollenhorst, Ecologist, Environmental Protection Agency.

**Earth Observations Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 8 OLI** | Surface reflectance | Spectral signatures and indices will be used to classify wetland areas at a 30-m resolution. More importantly, detection of spectral variation will indicate significant change categories, such as surface water vs saturated soil (mudflats). |
| **Sentinel-2 MSI** | Surface reflectance | Spectral signatures and indices will be used to classify the wetland areas at a 10-m resolution.  The data will also be used for further identification of wetland water quality parameters. |
| **Sentinel-1 C-SAR** | Backscatter | Radar data will be used to delineate wetland types and the extent of saturated soils in the imagery. |
| **DigitalGlobe WorldView 1,2,3** | Vegetation surface canopy | This dataset includes 2-m multi-temporal vegetation surface canopy change products over the entire state where there is optical coverage from DigitalGlobe. The intention is to use the data to validate the approach developed by the team. |
| **RADARSAT-2** | Backscatter | Ancillary radar data will be used to delineate wetland water extent and flooded vegetation throughout Duluth, MN. |

***Ancillary Datasets:***

Minnesota Department of Natural Resources National Wetland Inventory Update for Minnesota – The new MN NWI statewide map (completed fall 2018) will be used as a comparison against the end products

Minnesota Department of Natural Resources Wetland Monitoring Sample Plots and Validation Points – The 5000 1-mile2 sample plots will be used to assess gain and loss of wetland acres from the past decade and the 7000 field validation points will be used to test for accuracy

Minnesota Department of Natural Resources LiDAR Elevation data – These will be used to detect surface features on Earth and interpret wetland features

Minnesota Department of Natural Resources Spring Aerial Imagery Program dataset – Higher resolution aerial imagery collected from 2009-2014 will be used to compare past extents of wetlands

USFWS National Wetlands Inventory Wetlands Mapper database – Data will be used to assess the historical wetland cover types

USGS National Land Cover Database (NLCD) 2016 – This dataset will be used to compare wetlands to classified wetland change imagery

***Software & Scripting:***

Google Earth Engine API – Manipulate data, create the project methodology, and create a user-friendly tool

Esri ArcGIS – Manipulate data and create visuals

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Wetland Change Maps** | Wetland change maps are needed to help the partner agencies target where to apply their map updates as well as to address wetland changes on the ground. The maps created from the tool below will help get these maps more frequently to the agencies. | The Landsat 8 OLI, Sentinel-1 C-SAR, Sentinel-2 MSI, RADARSAT-2, and WorldView historic record will be used to document wetland change trends to create change maps. Results will be compared to the new MN NWI statewide map, 5000 1-mile2 sample plots, and 7000 field validation points. | I |
| **Wetland Change Decision Support Tool** | A wetland change tool will aid in more refined mapping and inform on-the-ground conservation practices. Areas are flagged by potential disturbance to help focus managers’ monitoring efforts. | Landsat 8 OLI, Sentinel-1 C-SAR, Sentinel-2 MSI, RADARSAT-2, and WorldView imagery will be the main inputs into the tool to map wetland change (by differencing two pre- and post-images) and will be validated with the ancillary data mentioned above. | IV |

***End-User Benefit*:** The benefits for the partners include gaining better wetland loss and gain metrics, lowering their costs to keep the statewide inventory up-to-date, creating seasonal wetland maps that they have not created before, and providing time savings for landowners, wetland managers, and farmers for more accurate wetland determinations. A tool that will map wetland change will be a valuable addition to the partners’ efforts to maintain their wetland inventories.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 3 Terms: 2019 Spring to 2019 Fall

***Multi-Term Objectives:***

* **Term 1 (Proposed Term):** 2019 Spring (California – JPL) – Great Lakes Water Resources
  + The first term will focus on Minnesota wetlands given that statewide there are 5000 1-mile2 wetland change plots and 7000 field validation points for accuracy assessment. Data from Landsat 8 OLI, WorldView, RADARSAT-2, Sentinel-1 C-SAR, and Sentinel-2 MSI will be used for a multi-frequency, multi-sensor, multi-temporal approach to wetland mapping. The proposed primary end product is a preliminary tool derived from Google Earth Engine that would automate the creation of change maps. The city of Duluth, MN, may be surveyed to gauge and refine the products for expansion to the Great Lakes Region in future terms.
* **Term 2:** 2019 Summer (California – JPL) – Great Lakes Water Resources II
  + The second term objective is to further expand the approach developed in Minnesota to the bordering states of Wisconsin and Michigan. Recent wetland mapping work in these states completed by Ducks Unlimited will be used for validation. The validated methods used on MN will have the same output for WI and MI. Further adjustments to the tool will be fine-tuned so it can work in the other two states. Results will be compared to seasonal, sub-meter optical DigitalGlobe and monthly RADARSAT-2 imagery that has been acquired over 10 pilot sites across the Great Lakes since 2016. The team will be able to use the Wisconsin and Michigan pilot sites for further comparison and evaluation. Software release is anticipated to begin during this term.
* **Term 3:** 2019 Fall (California – JPL) – Great Lakes Water Resources III
  + The goals of the third term are to expand the study area to the other states bordering the Great Lakes and possibly Canada and provide a robust handoff and a webinar. The project may expand to include a few more partners or boundary organizations such as Natural Resources Canada, the Great Lakes and St. Lawrence Cities Initiative, Great Lakes tribes and other natural resource departments where the tool and results will be disseminated. Partners are expected to help the team by providing more validation datasets. A software release is expected for this updated tool, and hopefully, the tool from the prior term is ready to be shared with the partners by this term.

***Related DEVELOP Work:***

2017 Spring (UGA) – Eastern India Ecological Forecasting II: A Multi-Sensor Approach to Enhance the Prediction of Mangrove Biophysical Characteristics in Chilika Lagoon and Bhitarkanika Wildlife Sanctuary, Odisha, India

2016 Fall (LaRC) – Everglades Ecological Forecasting II: Utilizing NASA Earth Observations to Enhance the Capabilities of Everglades National Park to Monitor and Predict Mangrove Extent to Aid Current Restoration Efforts

2014 Fall (LaRC) – Great Lakes Climate: Monitoring the Impacts of Climate Change and Decreasing Water Levels on Wetlands in the Great Lakes Region of North America

**Notes & References:**

***Notes*:**

* A multiple term project is requested from the partners and the goal will be to get a functioning tool by the end of the second term. The third term may not be necessary depending on this status.
* Past approaches from decades ago required the use of stereo aerial photography and intensive photo interpretation. Minnesota has led the way over the last eight years towards automating the traditional process using LIDAR, derived DEM products, multi-seasonal aerial imagery, and image object processing.  However, the project still took about eight years to complete. There is a need to isolate smaller areas with changing wetlands to keep the maps up-to-date without resorting to spending another eight million dollars to do another statewide wetland inventory update.
* The NASA DEVELOP team may approach this in three stages: 1) processing optical data through the Google Earth Engine, 2) processing radar data through the ESA Sandbox, 3) then merge the results in an image object approach using the ancillary datasets to derive wetland change products.
* The existing MN DNR NWI/DU image object model may be used as a base template approach.
* The UMN will provide the team with the new statewide image object land cover map and wetland map determination methodologies. They will also provide access to DigitalGlobe’s WorldView and RADARSAT-2 satellite imagery if needed.
* DU will also help provide insight into how they create their wetland maps.
* EPA EnviroAtlas: <https://www.epa.gov/enviroatlas>
* Minnesota Department of Natural Resources National Wetland Inventory Update for Minnesota: <https://gisdata.mn.gov/dataset/water-nat-wetlands-inv-2009-2014>
* Minnesota Department of Natural Resources Wetland Monitoring Sample Plots: <https://www.dnr.state.mn.us/wetlands/monitoring.html>
* Minnesota Department of Natural Resources LiDAR Elevation data: <http://www.mngeo.state.mn.us/chouse/elevation/lidar.html>
* Minnesota Department of Natural Resources Spring Aerial Imagery Program dataset: <http://www.mngeo.state.mn.us/chouse/airphoto/spring2009-2015.html>
* Minnesota Department of Natural Resources Landview: https://www.dnr.state.mn.us/maps/landview/index.html
* Minnesota NWI Website: <https://www.dnr.state.mn.us/wetlands/index.html>
* US Fish & Wildlife NWI Mapper: <https://www.fws.gov/wetlands/data/mapper.html>

***References:***

Kloiber, S. M., Macleod, R. D., Smith, A. J., Knight, J. F., & Huberty, B. J. (2015). A semi-automated, multi-source data fusion update of a wetland inventory for east-central Minnesota, USA. *Wetlands, 35*(2), 335-348. https://doi.org/10.1007/s13157-014-0621-3