**NASA DEVELOP National Program**

**2020 Spring Project Proposal**

**California – JPL**

**Great Lakes Water Resources II**

*Improving Wetland Change Mapping Using Optical and Radar Satellite Sensors to Assess Wetland Gain and Loss in the Great Lakes Region*

**Project Overview**

***Project Synopsis*:** This continuation project will further develop the Wetland Extent Tool (WET) to aid partners in the Great Lakes basin in automating the mapping of wetland extent and change. WET is hosted in the Google Earth Engine platform and utilizes the optical sensors Landsat 8 OLI and Sentinel-2 MSI, as well as the radar sensor Sentinel-1 C-SAR. The NASA DEVELOP team will continue to partner with end users including 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), as well as a number of collaborators and academic partners in the United States and Canada. This work will build the partners’ capacities to use a coding platform with optical and radar imagery which may help reduce the costs to maintain up-to-date wetland maps.

***Community Concern:*** Wetlands are dynamic ecosystems that change every day. They are a critical and vulnerable feature of our landscape, providing important ecosystem services such as controlling water quality, mitigating erosion, and bolstering the economy through recreation. Wetlands are also one of the most difficult and expensive features to map, due to factors such as some inundated areas being difficult to discern by ground-based means, or the need to identify wetlands manually through aerial photographs. 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.

***Source of Project Idea:*** Brian Huberty, from USFWS NWI, contacted Natasha Stavros, JPL scientist, and expressed an interest in pursuing this idea for a NASA DEVELOP project. The project developed out of a discussion between Brian and the JPL DEVELOP node leadership group, as radar applications for wetland mapping would be a natural fit. Brian suggested a Google Earth Engine tool as it may make it more feasible to use from an operational standpoint.

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

***Study Location:*** Great Lakes Basin: MN, WI, MI, Ontario

***Study Period:*** 2017 – 2019 (May – September)

***Advisors:*** Bruce Chapman (NASA Jet Propulsion Laboratory, California Institute of Technology), Benjamin Holt (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** | Megan Lang, Chief Scientist | End User | Yes |
| **Minnesota Department of Natural Resources** | Jennifer Corcoran, Remote Sensing Program Consultant | End User | Yes |
| **US Environmental Protection Agency, Office of Research and Development** | Tom Hollenhorst, Ecologist | End User | No |
| **Ducks Unlimited** | Robb Macleod, National GIS Coordinator | End User | Yes |
| **University of Minnesota** | Joe Knight, Associate Professor | Collaborator | Yes |
| **NOAA, Office for Coastal Management** | Brandon Krumwiede, Remote Sensing Specialist and Great Lakes Geospatial Coordinator | Collaborator | Yes |
| **Michigan Technological University** | Laura Borgeau-Chavez, Research Scientist/Adjunct Associate Professor | Collaborator | Yes |
| **Natural Resources Canada, Canada Centre for Mapping and Earth Observation, Canada Centre for Remote Sensing** | Brian Brisco, Senior Research Scientist | Collaborator | No |

***End-User Overview***

***End User’s Current Decision-Making Process:***The NWI, the MN DNR, EPA, and DU all have field managers who repeatedly ask for current wetland map products. They all are continually making daily decisions on where to send field biologists for conservation and scientific related work. This could include waterfowl counts tied to wetland types, wetland restoration projects, and invasive species eradication. Although outdated wetland maps are used, incorporating new remotely sensed imagery will provide more accurate, current wetland maps.

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

*US Fish and Wildlife Service, National Wetlands Inventory –* The NWI is familiar with remote sensing, specifically aerial imagery such as the National Agriculture Imagery Program (NAIP), which is the main data source for their online Wetlands Mapper. The group does not currently use NASA Earth observations in its decision-making, but recently initiated a research & development program that is investigating the feasibility of using coarser spatial resolution data to support targeting, production, and updates. This project will help build their capacity to use NASA Earth observation data for wetland mapping for the Great Lakes Basin.

*Minnesota Department of Natural Resources –* The MN DNR uses a variety of 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. The purpose of this imagery is for both land and habitat management. This specific project will help build their capacity to use remote sensing data for water and wetland change mapping.

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

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

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*University of Minnesota –* The UMN is very familiar with NASA Earth observations since they have used remote sensing data since the 1970s. Their Remote Sensing and Geospatial Analysis Laboratory has worked with NASA satellite data and has been building capacity among their staff and students. This project will allow them to build their capacity to include radar data for their wetland mapping efforts. The UMN will provide the team with the new statewide image object landcover map and wetland map determination methodologies. They will also provide access to DigitalGlobe’s WorldView and RADARSAT-2 satellite imagery if needed.

*NOAA, Office for Coastal Management –* Through the Coastal Change Analysis Program (C-CAP), NOAA has developed a more detailed land cover and wetland map using Landsat for many years (1975 to 2016 in some locations). They are now embarking on a more detailed, 1-meter spatial resolution, land cover classification using NAIP aerial imagery which may be useful for further verification as the project area expands throughout the Great Lakes Basin.

*Michigan Technological University –* MTU continues to research and development of a large variety of remote sensing applications over the Great Lakes region. This includes a wealth of remote sensing derived products along with corresponding field verification that they can share with the team.

*Natural Resources Canada, Canada Center for Remote Sensing –* The CCRS is a very large and historic producer of Earth observation products. This project will bring in their radar mapping expertise with Radarsat 1&2 as well as creating a direct access bridge to the Radarsat Constellation Mission.

***Dissemination by Boundary Organizations*:**

*US Fish and Wildlife Service, National Wetlands Inventory –* As one of the first federal agencies to serve mapped data over the internet decades ago, the USFWS National Standards and Support Team (NSST) will distribute data, results, and methodologies which meets the need of supporting the Federal Geographic Data Committee (FGDC) standard on the USFWS NWI website as appropriate. A NWI representative will also present results at local, national and international wetland conferences such as MN GIS/LIS, International Association of Great Lakes Researchers, the Canadian Remote Sensing Society and the American Society for Photogrammetry and Remote Sensing – national & regional technical conferences.

*Minnesota Department of Natural Resources –* Data, results, and methodologies from this project may be distributed on the DNR’s website as well as through the MNGEO Geospatial Commons. The MN DNR will 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, MN GIS/LIS Consortium, and MN Waters Annual Conference.

*University of Minnesota –* As part of the Big Ten GeoPortal Alliance, the UMN library and U-spatial provide the distribution of a variety of geospatial products that are open to the public.

*National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management –* NOAA will use its Digital Coastal portal to make project results publicly available for U.S. Coastal Regions.

*Michigan Technological University –* MTU may also share results as part of their on-going research over the Great Lakes Basin, and they regularly disseminate project results to the International Association of Great Lakes Researchers and the American Geophysical Union.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The team will communicate with the partners biweekly during the term via teleconference or by email. The main POCs will be the Project Lead and Megan Lang from the USFWS NWI.

***Transition Plan*:** Software release is anticipated to be in its final stages for approval, so we plan to share the Wetland Extent Tool (WET) to the partners and give a tutorial on how to use it after the end of the second term or after the code is approved by NASA legal. The partners will be able to use the tool to create their own wetland change maps. Other project related deliverables will be handed off by NASA Large File Transfer and the team will give their final presentation and tutorial via video conference.

**Earth Observations Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Surface reflectance,  Modified Normalized Difference Water Index (MNDWI), Tasseled Cap Greenness Wetness Index (TCGW), Dynamic Surface Water Extent (DSWE) | Spectral signatures and indices will be used to classify wetland areas at a 30 m resolution. More importantly, the detection of spectral variation will indicate significant change categories in different wetland cover types. |
| **Sentinel-1 C-SAR** | Backscatter, vertical polarization (VV), horizontal polarization (VH) | Radar data will be used to identify inundated areas to help classify wetland extent. |
| **Sentinel-2 MSI** | Surface reflectance,  Modified Normalized Difference Water Index (MNDWI)  Tasseled Cap Greenness Wetness Index (TCGW) | Spectral signatures and indices will be used to classify wetland areas at a 20 m resolution. More importantly, the detection of spectral variation will indicate significant change categories in different wetland cover types. |
| **DigitalGlobe WorldView 1,2,3** | Vegetation surface canopy | Ancillary 2 m multi-temporal optical data will be used to compare the results with Landsat 8 OLI and Sentinel-1 C-SAR. |
| **RADARSAT-2** | Backscatter | Ancillary radar data will be used to delineate wetland water extent and flooded vegetation. |

***Ancillary Datasets:***

* National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management 2016 C-CAP Regional Land Cover Data – Use as a land cover type verification dataset and new 1 m test sites
* Minnesota Department of Natural Resources Wetland Monitoring Sample Plots and Validation Points – Test the accuracy of wetland extent generated by the tool
* Michigan Technological University Coastal Wetland Cover Data – Use as a land cover type verification dataset
* Great LakeS Restoration Initiative Pilot Sites (UMN, MTU, SharedGeo, USFWS, MN DNR) - Very detailed wetland and water extent classifications

***Software & Scripting:***

* Google Earth Engine API – Create a tool for remote sensing data collection, preprocessing, and delineation of wetlands
* Harris Corporation ENVI – Perform accuracy assessment of products from the tool
* Esri ArcMap – Create visuals of products from the tool

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Wetland Change Maps** | These maps will be essential to identify wetland areas and quantify changes in wetland extent. They will also be used by partners to update map inventories such as the NWI. | Landsat 8 OLI, Sentinel-1 C-SAR, Sentinel-2 MSI, WorldView-1,2,3, and Radarsat-2 imagery will be used to document wetland change trends to create change maps. | I |
| **Wetland Extent Tool (WET)** | A wetland change tool automates and streamlines wetland delineation for end users as well as for on-the-ground conservation. Areas are flagged by potential disturbance to allow for wetland change detection to inform the partners’ wetland management efforts. | Landsat 8 OLI, Sentinel-1 C-SAR, and Sentinel-2 MSI will be the main inputs in the tool to map wetland change (by differencing two pre- and post-images) and will be validated with validation points. The tool will be adjusted from the prior term so it can be useable across the Great Lakes region. | IV |
| **WET Video Tutorial** | Due to the technical nature of the end products, the team will create a video tutorial demonstrating the tool in detail, ensuring reproducibility. The partners will be able to share this tutorial with anyone interested in the tool, even if their technical knowledge is limited. | N/A | I |

***End-User Benefit*:** The major end product of this project is a tool derived from GEE that automates the creation of wetland change maps. This tool will benefit our various partners by giving them accurate and current wetland maps that can inform their daily decisions regarding conservation and restoration work. It also builds their capacities to use the GEE platform, radar imagery, and NASA Earth observation data. Ultimately, this automated tool will save time and resources that would otherwise be spent on field surveying and traditional remote sensing approaches.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2019 Spring to 2020 Spring

***Multi-Term Objectives:***

* **Term 1:** 2019 Spring (California – JPL) – Great Lakes Water Resources
  + The first term focused on Minnesota wetlands given that there are 5000 mi2 wetland change statewide plots and 7,000 field validated points for accuracy assessment. Data from Landsat 8 OLI and Sentinel-1 C-SAR were used for mapping wetlands extent and change for the growing seasons (May through September) at 30m resolution. The team worked on a preliminary tool derived from Google Earth Engine that automates the creation of change maps using a multi-temporal, object-based random forest classification approach. Software release documentation was prepared for the Wetland Extent Tool (WET), which maps wetland change. The development of this tool has set the stage to expand the work to neighboring states to further calibrate the tool.
* **Term 2 (Proposed Term):** 2020 Spring (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, Michigan, and other regions in the Great Lakes. Ducks Unlimited’s recent wetland mapping work in these states will be used for validation along with Great Lake Restoration Initiative pilot sites. The validated methods used in Minnesota will have the same output for the extended study region. This term will add an additional Earth observation, Sentinel-2 MSI. The team will use the Wisconsin and Michigan pilot sites for further comparison and evaluation. Software release is expected to be near-complete and it is planned to have an interactive handoff in which the team can give a detailed tutorial in how to use WET (with no code showing if software release is not approved yet).

***Previous Terms:***

2019 Spring (JPL) – Great Lakes Water Resources: Improving Wetland Change Mapping using Optical and Radar Satellite Sensors to Assess Wetland Gain and Loss Metrics in Minnesota

***Related DEVELOP Work:***

2019 Spring (JPL) – Alaska Ecological Forecasting II: Semi-Automated Mapping of Alaskan Wetland Inundation by Integrating Synthetic Aperture Radar and Optical Satellite Imagery

2018 Fall (JPL) – Alaska Ecological Forecasting: Automated Wetland Hydroperiod Mapping by Integrating Optical Satellite Imagery and Synthetic Aperture Radar

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*:**

* DU will also help provide insight into how they create their wetland maps.
* 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>
* NOAA 2016 C-CAP Regional Land Cover: <https://coast.noaa.gov/digitalcoast/data/>
* Michigan Technological University Coastal Wetland Cover Map Data: <https://geodjango.mtri.org/coastal-wetlands/>

***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.