In October 1978, the U.S. NASA launched the Nimbus-7 spacecraft, carrying with it the first proof-of-concept satellite ocean color sensor. Less than a month later, the Coastal Zone Colour Scanner (CZCS) captured an image of a red tide bloom on the West Florida Shelf (Steidinger and Haddad, 1981). This observation helped spark decades of research aimed at advancing remote sensing technology and developing bloom detection algorithms in the Gulf of Mexico and beyond.

Today, satellite ocean color data is collected with more than a dozen sensors by several international space agencies. Many of these sensors are suitable for monitoring red tides in the Gulf of Mexico.

Sensor	Satellite	Agency	Swath (km)	Spatial resolution (m)	Temporal resolution (days)	Spectral resolution (# visible/NIR bands)
MODIS	Terra (2000-), Aqua (2002-)	NASA (USA)	2330	250-1000	1-2	13
VIIRS	Suomi-NPP (2011-), JPSS-1/NOAA-20 (2017-)	NOAA/NASA (USA)	3000	750	1-2	7
OLCI	Sentinel-3A (2016-), Sentinel-3B (2018-)	ESA/EUMETSAT (Europe)	1270	300	1-2	21
MSI	Sentinel-2A (2015-), Sentinel-2B (2017-)	ESA (Europe)	290	10-60	10	10

Numerous remote sensing algorithms also exist that are capable of transforming surface reflectance signals measured by these sensors into useful data products for tracking blooms.

In 2015, the USF Optical Oceanography Lab (OOL) collaborated with FWC-FWRI and the USF Ocean Circulation Group to establish an Integrated Red tide Information System (IRIS). IRIS was designed to integrate satellite observations, numerical models, and water sampling to provide information on the location, intensity, spatial extent, and surface transport of red tides and other types of discolored waters for the eastern Gulf of Mexico. The information is updated daily through a user-friendly web portal, where a user can bring all data layers to Google Earth for navigation and adding other layers.

As part of this current project, we aim to:

a) **Maintain/upgrade our existing remote sensing infrastructure for near real-time monitoring and service**
   In addition to performing the necessary tasks required for maintaining existing services offered by IRIS, several system upgrades have been planned. IRIS originally offered satellite ocean color data collected by MODIS and VIIRS only. With support from this project, we expanded these offerings to include OLCI data, and are currently working towards adding MSI data. Compared to MODIS and VIIRS, the spatial resolutions of OLCI (300m) and MSI (10-60m) are finer, allowing for the detection of smaller bloom features and blooms located closer to shore. HAB trajectory maps generated by the USF/Ocean Circulation Group are also now being

downloaded daily and integrated with imagery, and then made available online with Google Earth compatibility for comparison with existing data products.

b) **Develop improved remote sensing algorithms for quantifying red tides**
To date, despite significant amount of work from the research community, satellite remote sensing maps often fail to distinguish between red tide and non-red tide blooms, and contain artifacts and uncertainties that require a human analyst to correct. We aim to build upon prior research by developing and validating improved semi-analytical or machine learning algorithms (e.g., neural network, forest tree, deep learning) to derive *K. brevis* cell abundances using satellite data alone.

c) **Examine long- and short-term variability of red tides on the West Florida Shelf**
Finally, once equipped with satellite ocean color data collected by multiple sensors and improved bloom detection algorithms, we will begin examining how various environmental, physical, and chemical factors affect long-term (decadal) and short-term (sub-daily) red tide patterns through collaborations with project partners.

Reference
Steidinger, K. A., & Haddad, K. (1981). Biologic and hydrographic aspects of red tides. Bioscience, 31(11), 814-819.