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HyperCoast: A Python Package for Visualizing and Analyzing Hyperspectral Data in Coastal Environments

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Summary

HyperCoast is a Python package designed to provide an accessible and comprehensive set of tools for visualizing and analyzing hyperspectral data in coastal environments. Hyperspectral data refers to the information collected by sensors that capture light across a wide range of wavelengths, beyond what the human eye can see. This data allows scientists to detect and analyze various materials and conditions on the Earth's surface with great detail. Unlike multispectral data, which captures light in a limited number of broad wavelength bands (typically 3 to 10), hyperspectral data captures light in many narrow, contiguous wavelength bands, often numbering in the hundreds. This provides much more detailed spectral information. Leveraging the capabilities of popular packages like Leafmap (Wu, 2021) and PyVista (Sullivan & Kaszynski, 2019), HyperCoast streamlines the exploration and interpretation of complex hyperspectral remote sensing data from existing spaceborne and airborne missions. It is also poised to support future hyperspectral missions, such as NASA's SBG and GLIMR (Dierssen et al., 2021).

HyperCoast supports the reading and visualization of hyperspectral data from various missions, including the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) (Green et al., 1998), the National Ecological Observatory Network (NEON) Airborne Observation Platform (AOP) (Kampe et al., 2010), the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission (Gorman et al., 2019), the Earth Surface Mineral Dust Source Investigation (EMIT) (Green et al., 2021), and the German Aerospace Center (DLR) Earth Sensing Imaging Spectrometer (DESIS) (Alonso et al., 2019), along with other datasets like the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) (Fisher et al., 2020). Users can interactively explore hyperspectral data, extract spectral signatures, change band combinations and colormaps, visualize data in 3D, and perform interactive slicing and thresholding operations (see Figure 1). Additionally, by leveraging the `earthaccess` (Barrett et al., 2024) package, HyperCoast provides tools for interactively searching NASA's hyperspectral data. This makes HyperCoast a versatile and powerful tool for working with hyperspectral data globally, with a particular focus on coastal regions.

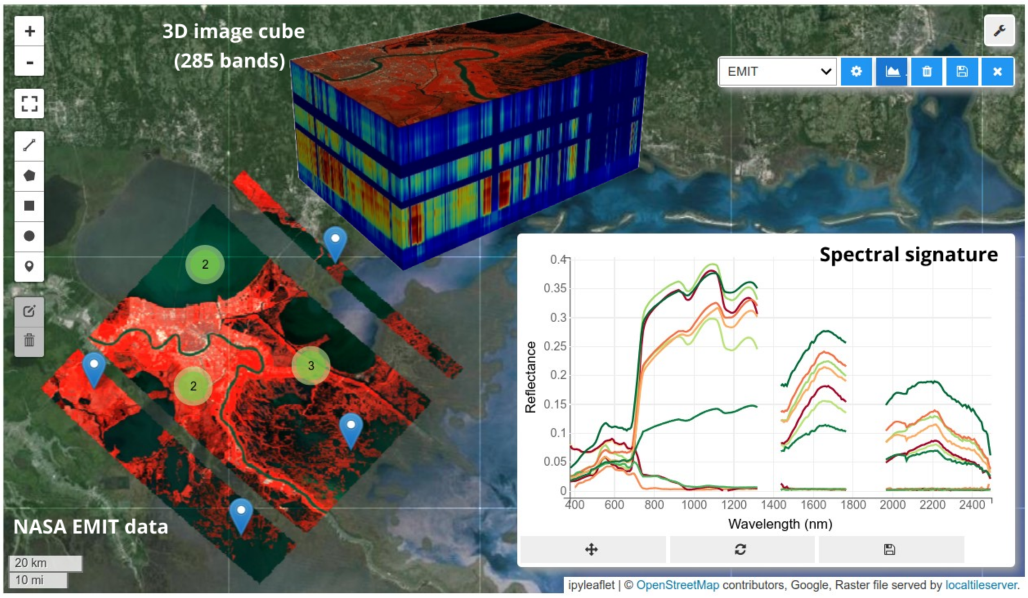

Figure 1. An example of visualizing NASA EMIT hyperspectral data using HyperCoast.

Statement of Need

Coastal systems, characterized by complex physical, chemical, and bio-optical processes (Liu et al., 2019), play a crucial role in connecting terrestrial landscapes with marine ecosystems (Pringle, 2001). These systems have undergone significant anthropogenic modifications (Elliott & Quintino, 2007) and are particularly vulnerable to the impacts of climate change (Junk et al., 2013). This diverse array of stressors underscores the increasing need to enhance monitoring techniques and capabilities. Hyperspectral views of coastal systems provide significantly greater spectral details for characterizing biodiversity, habitats, water quality, and both natural and anthropogenic hazards, such as oil spills and harmful algal blooms (HABs).

The launch of new hyperspectral sensors, such as NASA's Ocean Color Instrument (OCI) aboard the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission (Gorman et al., 2019), marks a transformative era in global hyperspectral data acquisition. These sensors feature narrow spectral bands ranging from ultraviolet to near-infrared and offer 2-day global coverage. Focusing on inland-coastal applications, the Earth Surface Mineral Dust Source Investigation (EMIT) instrument serves as a precursor to the Surface Biology Geology (SBG) mission, combining high spectral resolution (380-2500 nm with a spectral resolution of 7.4 nm) and spatial resolution (60 m). EMIT provides significant hyperspectral advantages for monitoring water quality and biodiversity across diverse habitats (see Figure 1) (Green et al., 2021; Thompson et al., 2020).

However, effectively working with and visualizing diverse hyperspectral data, such as PACE's swath data, poses significant challenges, especially for non-expert users. Currently, there are few Python packages dedicated to hyperspectral data visualization and analysis. HyperSpy (De La Peña et al., 2017), for example, is widely used for such analysis but is not tailored for new hyperspectral data (e.g., PACE, EMIT). Additionally, it does not leverage the latest advances in the Jupyter Widget ecosystem and 3D visualization.

HyperCoast fills this gap by providing a comprehensive set of tools tailored to the unique needs of researchers and environmental managers working in coastal regions. By integrating advanced visualization techniques and interactive tools, HyperCoast enables users to effectively analyze hyperspectral data, facilitating a better understanding and management of coastal ecosystems (see Figure 2).

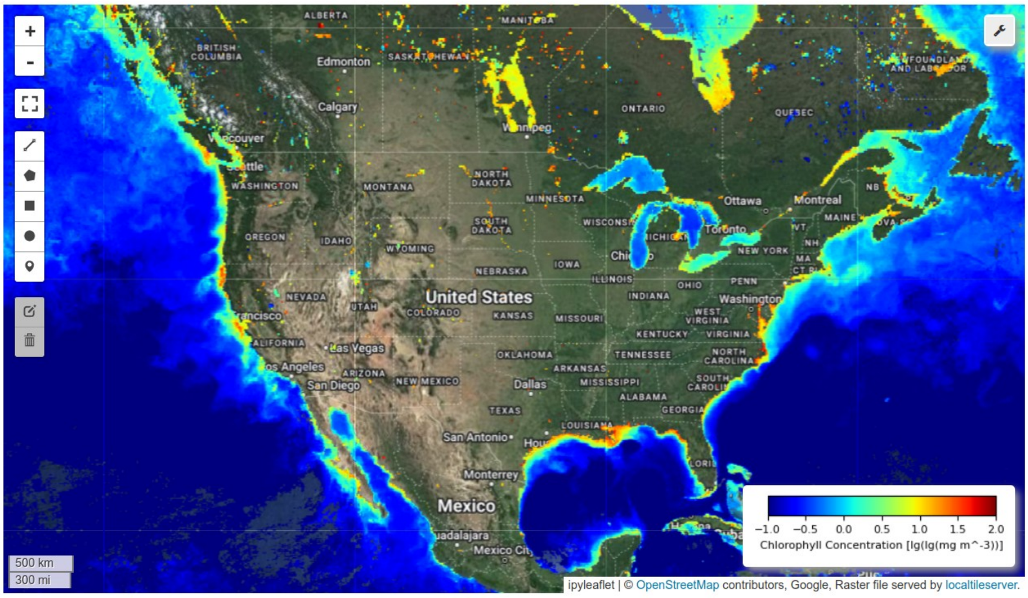

Figure 2. An example of mapping chlorophyll-a concentration using NASA PACE hyperspectral data with HyperCoast.

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