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A novel spectral index for ocean oil spill detection

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Abstract

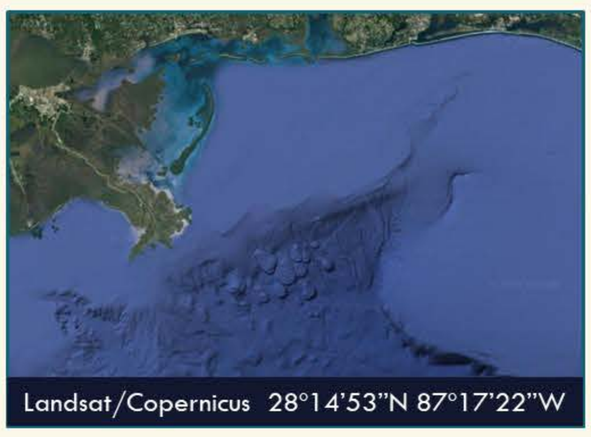
In this work, the authors propose a new spectral index for oil spill detection, the **Normalized Difference Oil Index** (NDOI). Its main characteristic is that it obviates suspended sand in the sea, making it ideal for the detection of spills in coastal areas. A comparison is made of the 10 most important spectral indices used to detect spills in the specific case of the **Deep Water Horizon** (DWH). An assessment is made based on confusion matrices, accuracy and F1-score metrics resulting from the kNN classification. The results obtained present NDOI as a good candidate for future coastal spill monitoring due to its balanced tradeoff among the different error metrics and its performance.

Study area

The DWH accident occurred on April 20th, 2010, in the Gulf of Mexico and discharged $780.000\ m^3$ of oil.

To evaluate the performance of the spectral indices, data acquired by these sensors will be used:

- AVIRIS
- HICO



Source: *Google earth V*9.147.0.2

Spectral indices

By paying special attention to the spectral profiles of the different thicknesses of the spill, the Normalized Difference Oil Index (NDOI) is proposed:

$$NDOI = \frac{R_{599} - R_{870}}{R_{599} + R_{870}}$$

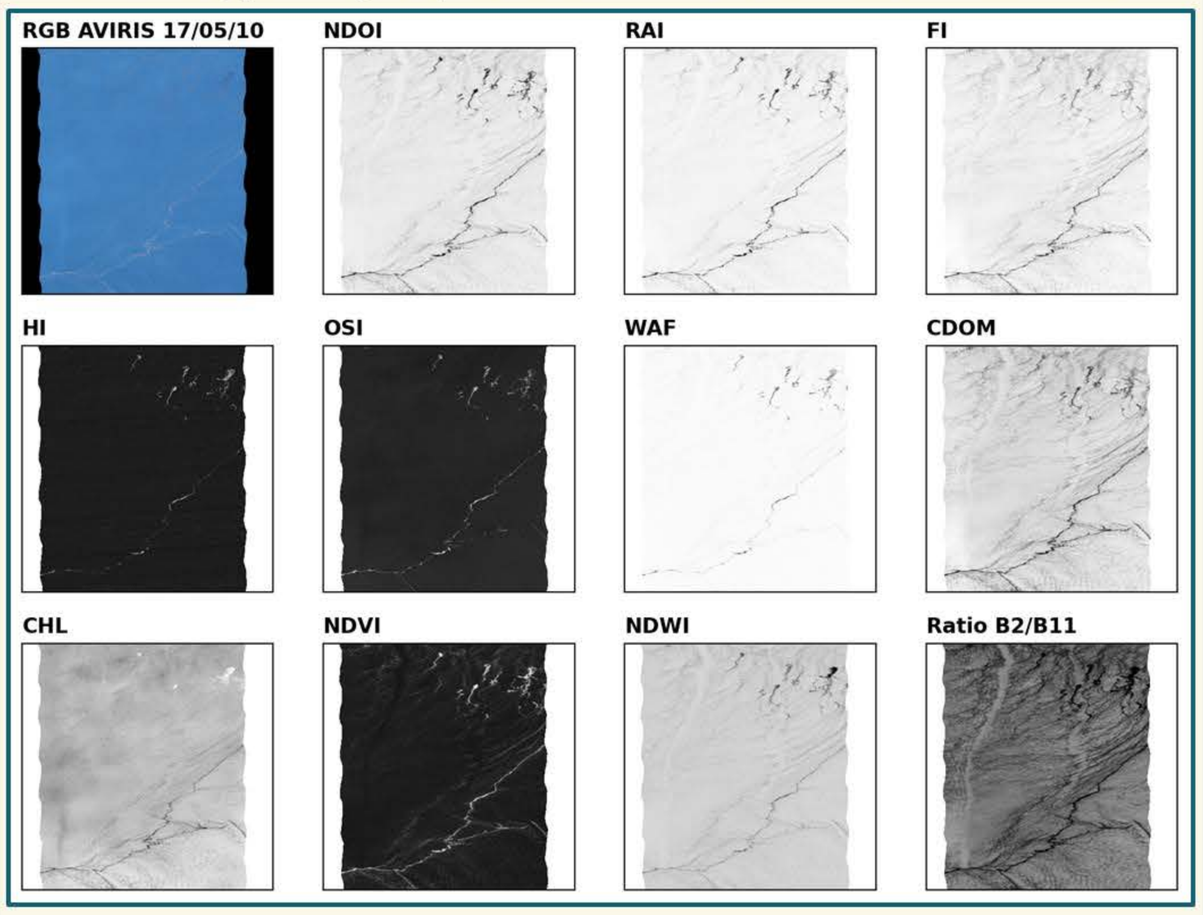
which will be able to distinguish spill thickness.

TABLE I
MOST CITED INDICES FOR IDENTIFYING SPILLS.

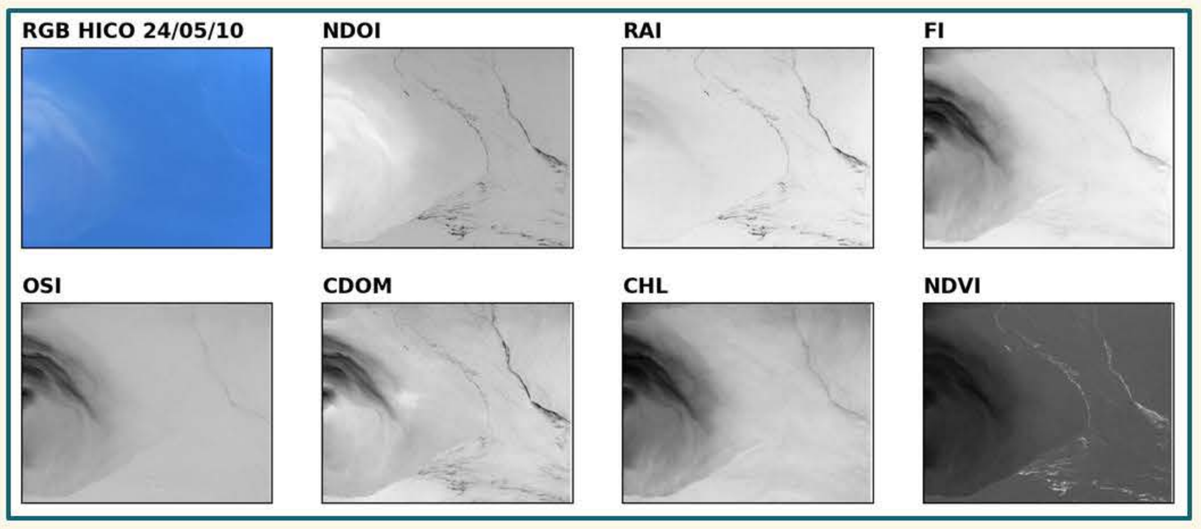
Index	Equation	Measured property
RAI	(Blue - IR) / (Blue + IR) $\sqrt{\sum_{i=1}^{N} b_i^2}$	Oil fluorescent characteristics
FI	(Blue - Red) / (Blue + Red)	Oil fluorescent characteristics
HI	$(\lambda_{1729} - \lambda_{1705})\frac{R_{1741} - R_{1705}}{\lambda_{1741} - \lambda_{1705}} + (R_{1705} - R_{1729})$	Oil-affected soils
OSI	$(DN_{\lambda_{Red}} - DN_{\lambda_{Yellow}})/(\lambda_{Red} - \lambda_{Yellow})$	Existence of crude oil
WAF	$(R_{1343} + R_{1563})/2 - R_{1453}$	Seawater characteristics
CDOM	R_{565}/R_{660}	Seawater characteristics
CHL	$log(max(R_{433,490,510})/R_{555})$	Surface chlorophyll *a*
NDVI	(NIR - Red) / (NIR + Red)	Live green vegetation
NDWI	$(R_{860} - R_{1240})/(R_{860} + R_{1240})$	Vegetation liquid water
Ratio B_2/B_{11}	Blue / SWIR	Oil presence

Comparative study of spectral indices

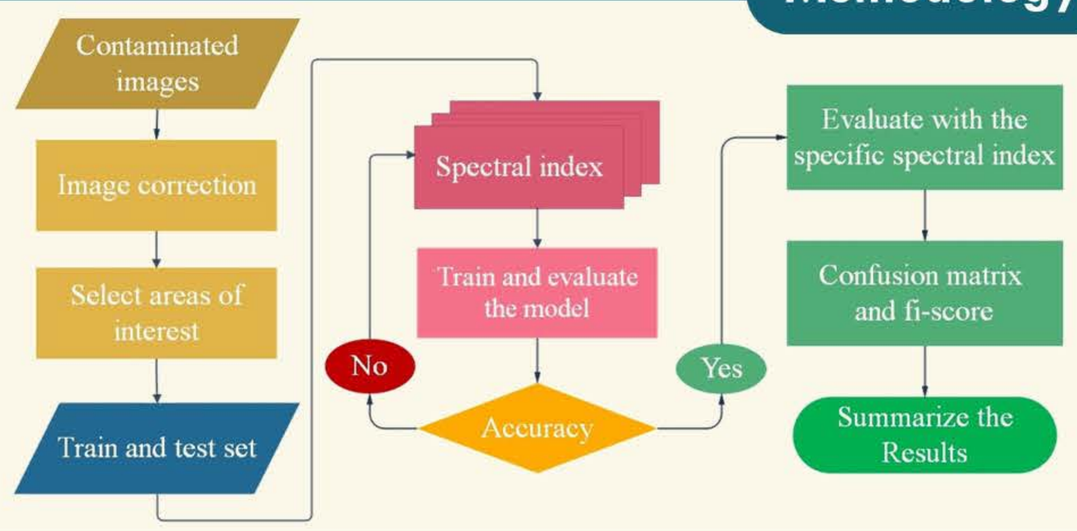
In AVIRIS image NDOI shows similar behavior to other spectral indices in the literature, pointing to spills thicker than 50 microns and emulsions[1].



The HICO image shows on the left the trail of sand in suspension coming from the Mississippi River mouth and the spill is nearly undetectable in the RGB composition. NDOI is the index that most clearly highlights the spill lines and also completely disregards the suspended sand from the delta. Most indices erroneously accentuate the sand as if it were oil, and in many of them the two spill lines are not properly distinguishable.



Methodology

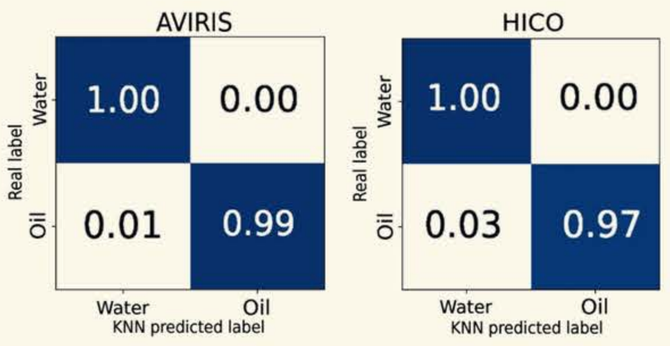


Validation

Since spills are dynamic phenomena, ground truth is usually not available. To validate NDOI, pixels are manually selected from the true-color image, labeling them and constructing a training and a test dataset. Secondly, the kNN algorithm is trained with NDOI pixels and the classification confusion matrices are obtained, as well as the overall accuracy and the F1-score.

TABLE II
ERROR METRICS FOR ASSESSING NDOI.

Metric	AVIRIS	HICO
Accuracy	0.9994	0.9919
Water F1-score	0.9996	0.9951
Oil F1-score	1.0000	0.9872



Conclusions

Optical sensors instead of radar

- Shorter revisit period.
- Composition information.

Advantages of spectral indices.

- Low computational cost.
- Simple mathematical equations.
- Easy parallelization to accelerate its computation.

Why NDOI?

- Significant improvement with coastal spills since it reduces false detections due to suspended sand.
- Correctly detects spills thicker than 50 microns and thickness estimation is possible.
- Uses bands common in commercial sensors.

[1]D. Zhao, X. Cheng, H. Zhang, Y. Niu, Y. Qi, and H. Zhang, "Evaluation of the ability of spectral indices of hydrocarbons and seawater for identifying oil slicks utilizing hyperspectral images", Remote Sensing, vol. 10, no. 3, 2018. [Online]. Available: https://www.mdpi.com/2072-4292/10/3/421

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