CUSTOM WORKFLOWS FOR DETECTING HYDROCARBON MICROSEEPAGE IN REMOTE SENSING IMAGERY

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BACKGROUND

Microseeps are invisible traces of light hydrocarbons that migrate to the surface from an underlying oil or gas reservoir. Alterations in soil geochemistry and vegetation health can indicate the presence of microseeps. While remote sensing cannot directly detect microseeps, it can reveal alteration patterns at a large scale that provide a starting point for further exploration. Field studies and soil samples are required to fully investigate microseeps, along with knowledge of the underlying geology and faults. This presentation focuses on remote sensing and offers ideas for image-processing workflows that can be used to investigate microseeps.

WORKFLOWS AND MODELS

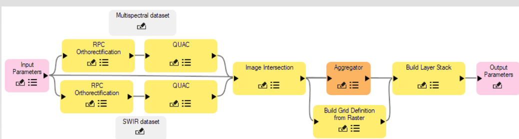
Remote sensing of hydrocarbons from airborne and satellite imagery involves preprocessing steps and spectral analysis techniques that take a significant amount of time to set up and run. Models created with a visual programming tool are one way to create custom analytic workflows without requiring any programming experience. The ENVI ® Modeler was used in this presentation to create workflows for analyzing potential areas of microseepage. Models run quickly and can be packaged and shared with colleagues or deployed to cloud environments. They also can be deployed as standalone tools to ArcGIS® software.

MINERAL ALTERATION

Common geochemical indicators of microseeps include bleached red beds, clay mineral alteration, and increased carbonates. WorldView-3 imagery from DigitalGlobe was used to create mineral indices that identify alteration zones. The indices are designed to use visible, near-infrared, and shortwave-infrared bands to look for pixels with spectral profiles that mimic those of common alteration minerals. Alteration zones do not necessarily indicate the presence of hydrocarbons, but they can be used as a starting point for further investigation.

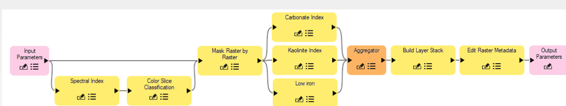
Preprocessing Workflow and ENVI Model

Read image → RPC orthorectification → Atmospheric correction and conversion to reflectance → Resample SWIR bands to 1.5 meters → Create a layer stack of VIS-NIR and SWIR bands → Manually mask out agricultural fields, water, and large man-… (Not part of the model)



Mineral Indices Workflow and ENVI Model

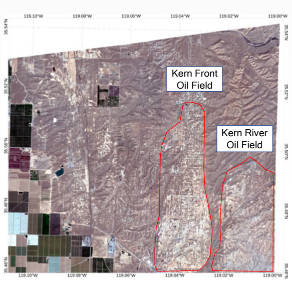
Read preprocessed image → Mask out remaining vegetation pixels → Calculate mineral indices using Band Math → Create a layer stack of indices (one per band) → Update band names



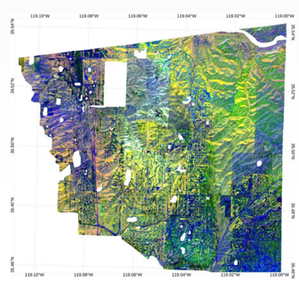
Carbonate and Kaolinite indices are from Sun, Tian, and Di (2016).

$$Carbonate\ Index = \frac{SWIR_6 * SWIR_3}{SWIR_8 * SWIR_8} \qquad Kaolinite\ Index = \frac{SWIR_3 * SWIR_8}{SWIR_5 * SWIR_6} \qquad Low\ Iron\ Index = \frac{Green}{Red}$$

Example



WorldView-3 true-color composite near Bakersfield, California, USA, 11 October 2015



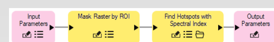
Color composite of mineral indices (Red: Carbonate Index, Green: Kaolinite Index, Blue: Low Iron). White pixels correspond to masked regions.

STRESSED VEGETATION

Vegetation occupying microseep-induced acidic soils often shows abnormal spectral signatures. Spectral indices that exploit the red-edge wavelength region can be used to indicate stressed vegetation, which can be caused by many different factors, not just the presence of hydrocarbons. The ENVI Crop Science module was used to create maps of relative crop health derived from red-edge spectral indices.

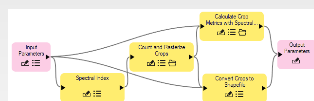
Hotspot Analysis Workflow and ENVI Model

Read image → Isolate a single field using ROI → Create hotspot image based on Modified Red Edge Simple Ratio

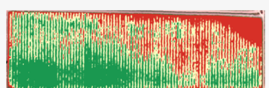


Crop Health Workflow and ENVI Model

Read image → Create an image that provides high contrast between crops and background → Count crops and identify their locations and sizes → Calculate mean Red Edge NDVI values for each crop → Create a classification image showing relative health for each crop



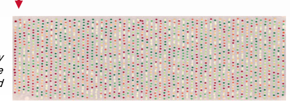
Example



Hotspot image indicating variations in crop health. Green pixels correspond to statistically significant positive values in a vegetation index. Red pixels correspond to statistically significant negative values.

True-color composite of a hyperspectral image acquired from a Cessna aircraft on 31 July 2014 near Sacramento, California, USA. Image courtesy of Corning.

Image showing individual crop locations and their relative health according to a Red Edge Normalized Difference Vegetation Index. Green polygons indicate relatively healthy crops. Yellow polygons indicate crops that are statistically insignificant with respect to crop health. Red polygons indicate relatively unhealthy crops.

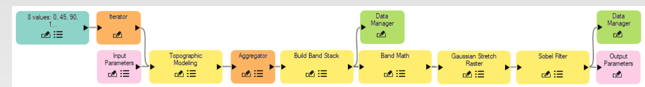


TOPOGRAPHY

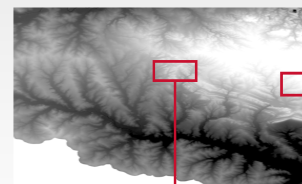
Local topography plays a critical role in discovering new areas for hydrocarbon exploration. While gravity and seismic data are typically required to confirm the presence of an underlying reservoir, visualizing the terrain at a detailed resolution can help identify unknown faults and vertical migration paths. Hillshade images are commonly used, but they are typically derived from a single solar illumination angle. A multi-directional hillshade image can reveal more subtleties in the relief. A Sobel filter can further help to draw out lineaments and edges.

Topographic Workflow and ENVI Model

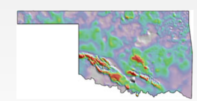
Read DEM → Create 8 hillshade images, each using a different solar azimuth value → Create a band stack of hillshade images → Average them to create a multi-directional hillshade image → Apply a Sobel filter to emphasize edges in all directions



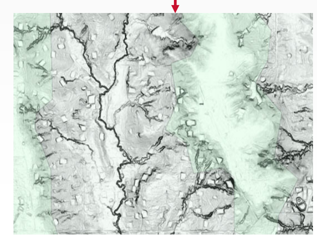
Example



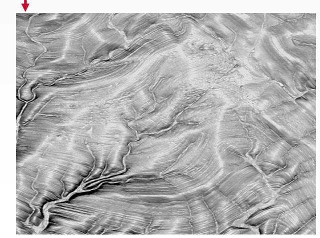
USGS 1/9-arc-second DEM, Washita River Basin, Oklahoma, USA



USGS magnetic anomaly image, Oklahoma, 1 km resolution



Multi-directional hillshade image overlaid with geologic units



Multi-directional hillshade image with Sobel filter applied

ACKNOWLEDGEMENTS

Digital data grids for the magnetic anomaly map of North America, available from the U.S. Geological Survey at https://mrdata.usgs.gov/magnetic/.

Digital elevation data available from the U.S. Geological Survey *National Map* at https://viewer.nationalmap.gov/basic/.

Hyperspectral imagery used with permission from Corning Incorporated.

WorldView-3 imagery used with permission from DigitalGlobe.

Sun, Y., S. Tian, and B. Di. “Extracting Mineral Alteration Information Using WorldView-3 Data.” *Geoscience Frontiers* 9 (2017): 1051-1062.