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Pixel-Based Smoke Detection with Neural Network

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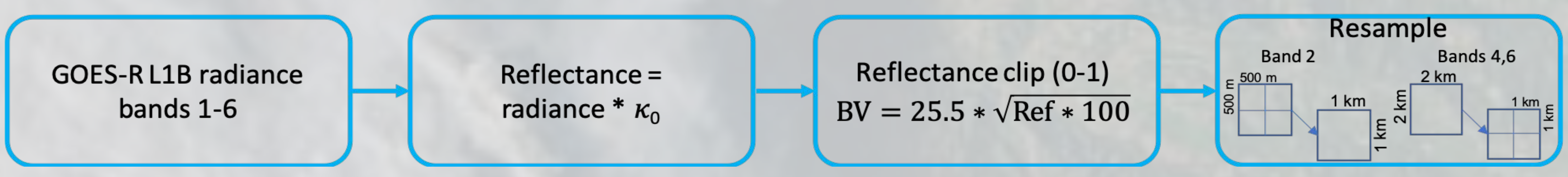
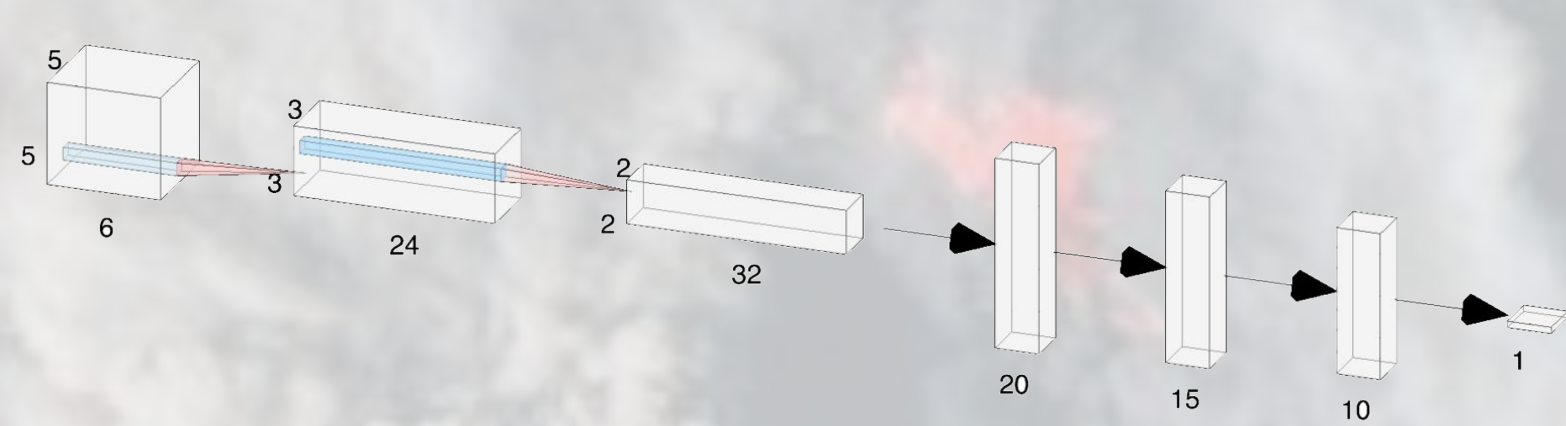
Introduction

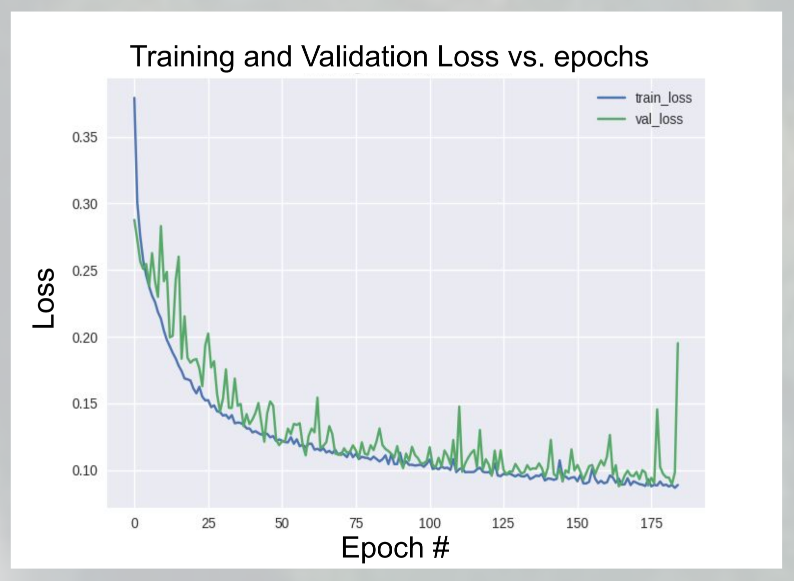
Exposure to biomass burning has been linked to respiratory and cardiovascular illnesses in humans. Traditional satellite based visual and multispectral smoke detection methods are not scalable to capabilities of new generations of remote sensing platforms. We develop a scalable, deep learning based detection model capable of identifying smoke pixels using GOES-16 shortwave reflectance data and present a operational web-based tool to visualize smoke predictions.

Methodology

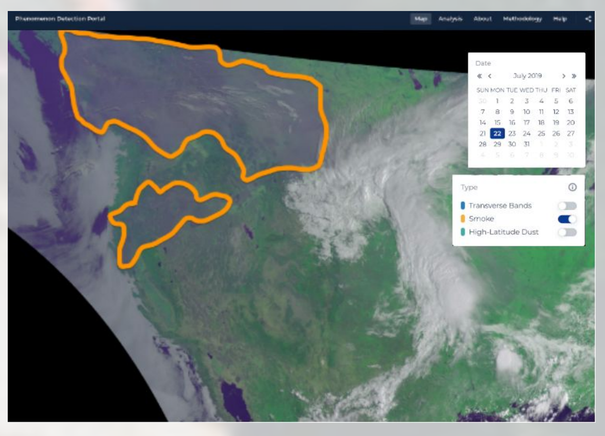


Training data developed by manually labeling boundaries of smoke in GOES 16 imagery. For training the model, GOES L1B radiance data is downloaded from NOAA-AWS repository. Radiance values are then converted to reflectance and bands 2, 4 and 6 are resampled to 1 km pixels.



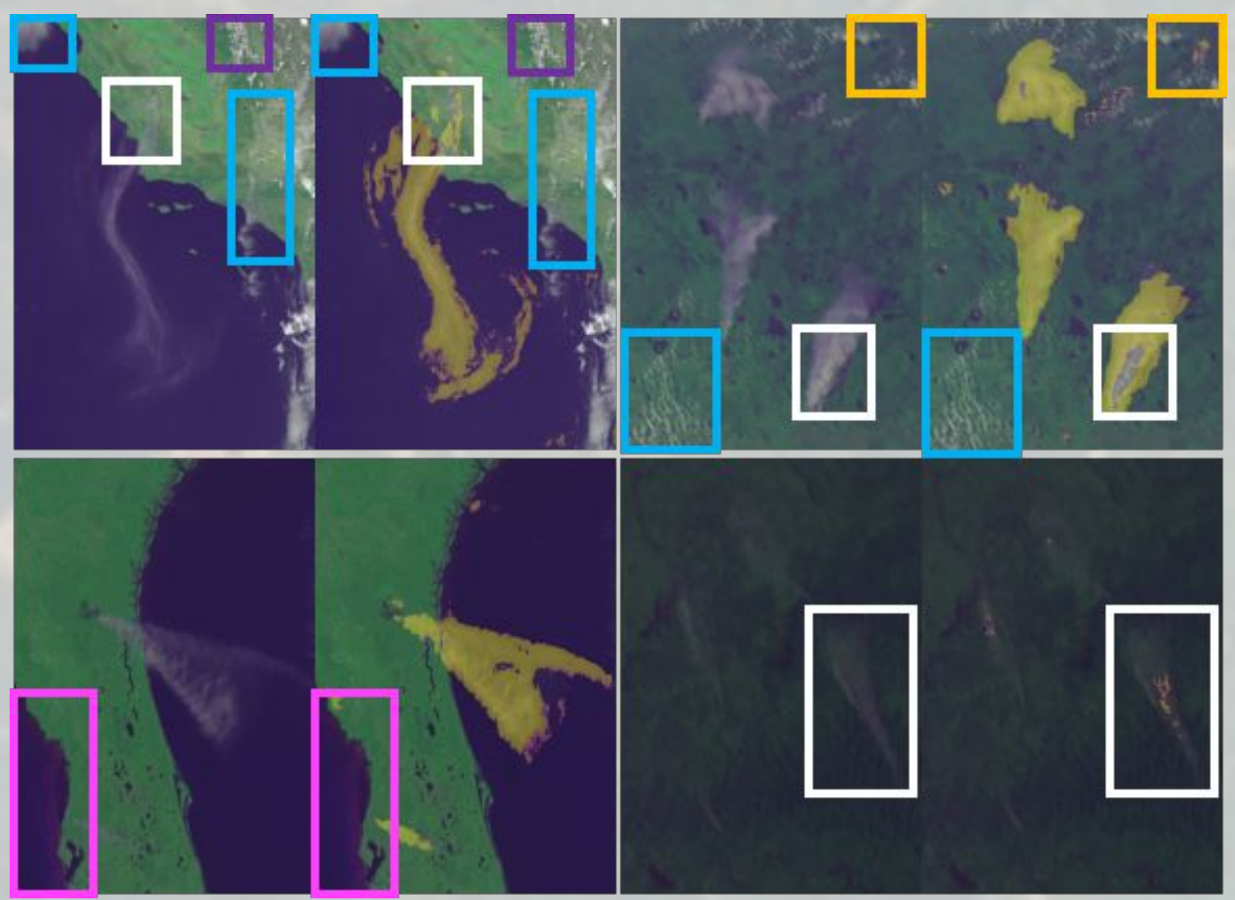


Labeled smoke plumes are defined as truth labels for training a Convolutional Neural Network. The input to the network is a neighborhood of reflectance values around pixel to be classified, and neighborhood size (N) is optimally determined by analysing multiple trained models with varying N. The picture in the right shows the training and validation loss curves over time for N=7, which we found to be optimal N value.



Model predicts the probability (p) that a pixel is smoke. A bitmap of the predictions (p > 0.5) are then geotagged and converted to shapefiles. These files are rendered and visualized in an online web portal for each day, and is also available through an API in GeoJSON format.

Results



The 4 sets of image pairs showing GOES 16 pseudo RGB image (left) and predictions overlain (right) demonstrates the model's capability to predict smoke ranging from low to high optical thicknesses, over a variety of high and low reflectance surfaces (land and ocean). The model is able to successfully discriminate smoke from common phenomena including:

- Cumulus, cirrus and coastal stratocumulus clouds (blue)
- Chlorophyll widely found along the coastal Gulf of Mexico (magenta)
- Land surface ice and snow (purples)

Areas for which model prediction improvement remain needed include:

- Identifying thin smoke over arid regions (high background surface reflectance)
- Identifying pyrocumulus clouds, which take on the characteristics of clouds
- Identifying smoke at very low sun angles when smoke reflectance is also low
- the incorrect predictions of cloud boundaries as smoke (orange)

Conclusion

Major contributions of this work includes:

- Scalable smoke detection model using GOES-R satellite reflectance data instead of computationally intensive multispectral analysis
- Well curated smoke plume extent dataset
- Integration of model into an operational visualization and analysis platform for real-time detection

Acknowledgements

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