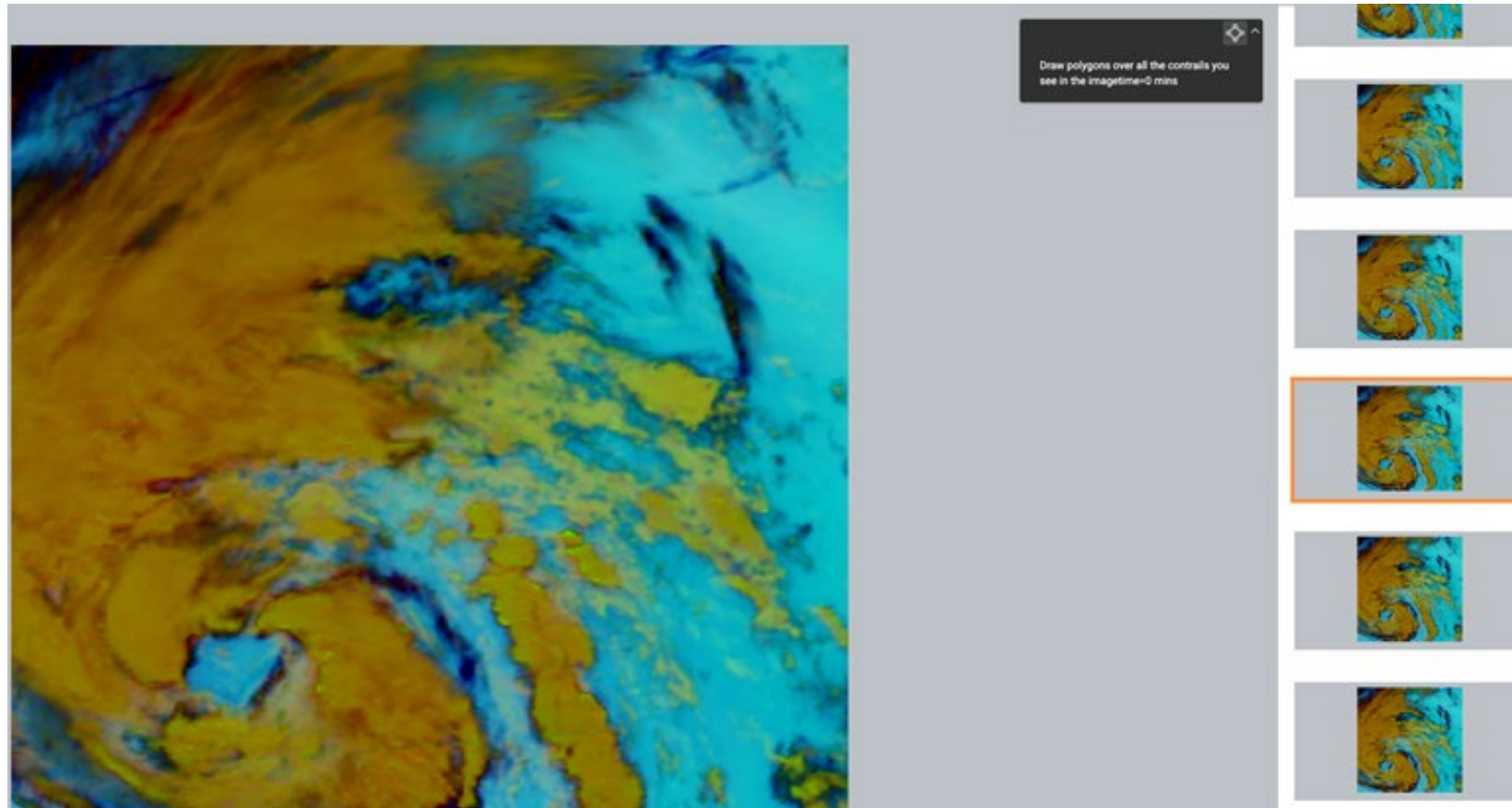


# Detecting contrails with deep learning in GOES-16 ABI

[mccloskey@google.com](mailto:mccloskey@google.com), on behalf of our team

# Creating labels

## Labeling tool

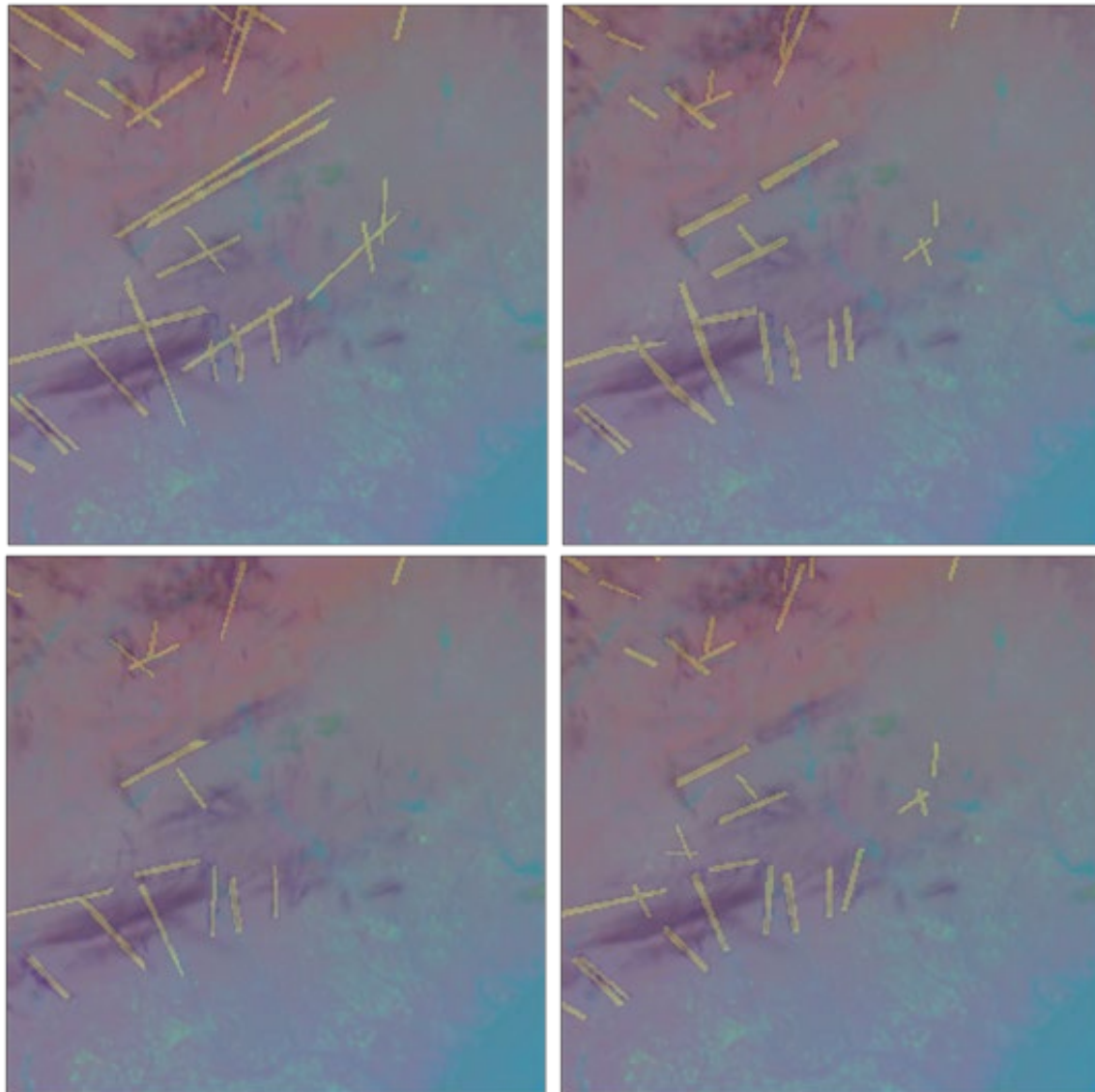


Temporal context provided

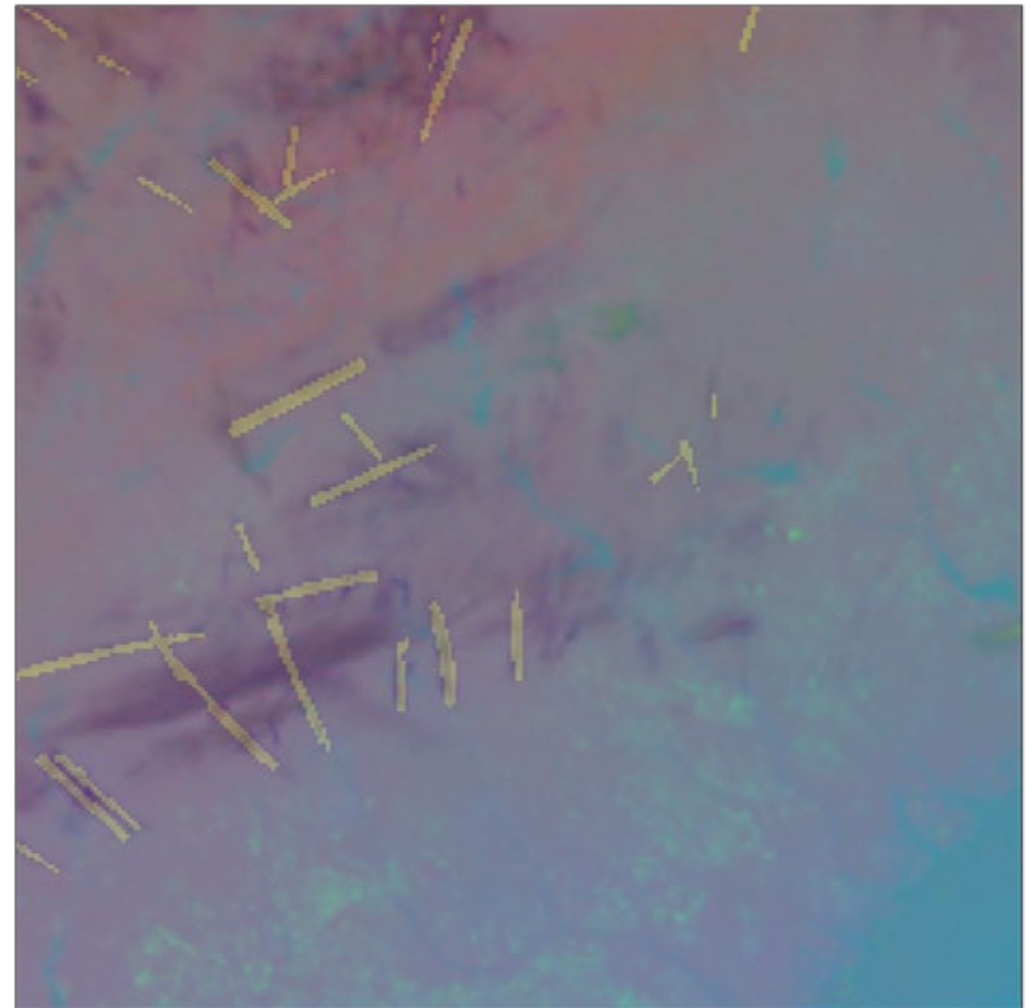
- before (60mins)
- and after (20mins)

# Majority-decision from least 4 labels

(Polygon labels shown here rasterized as a mask)

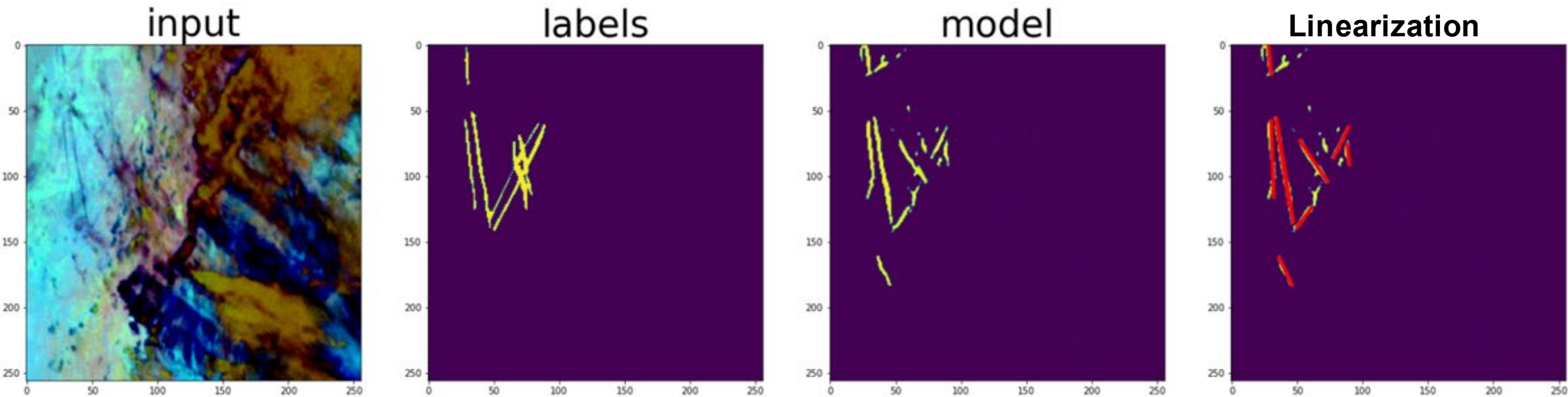


Training/eval label

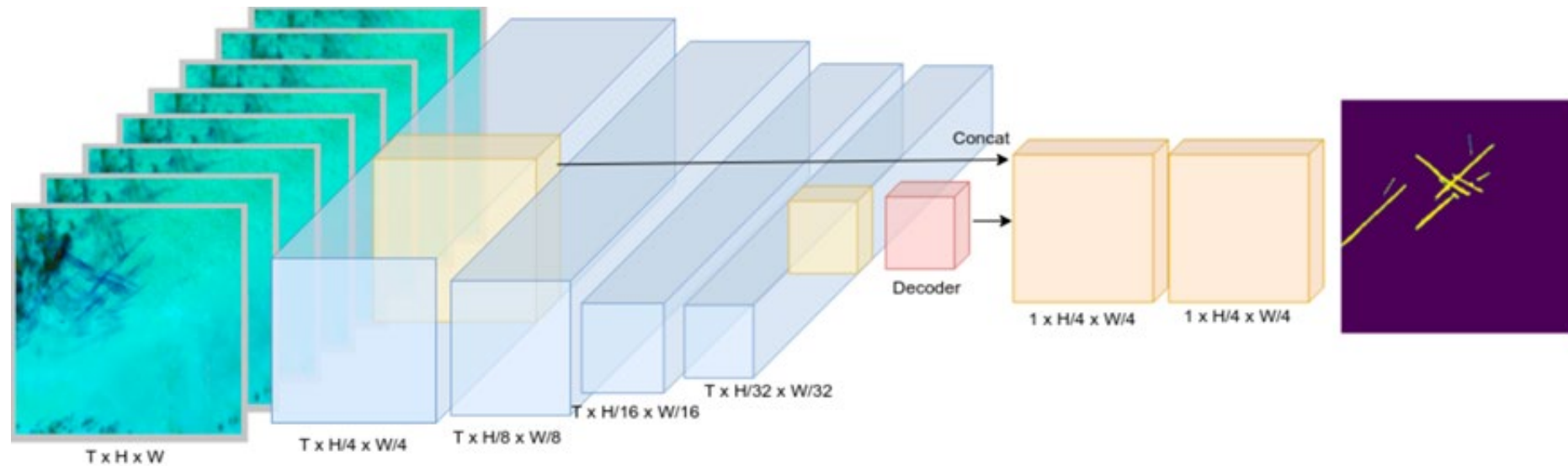


## Open source dataset

- 24000 labeled images, about half contain at least one contrail
- Resnet3D-101 model



# Incorporating temporal context



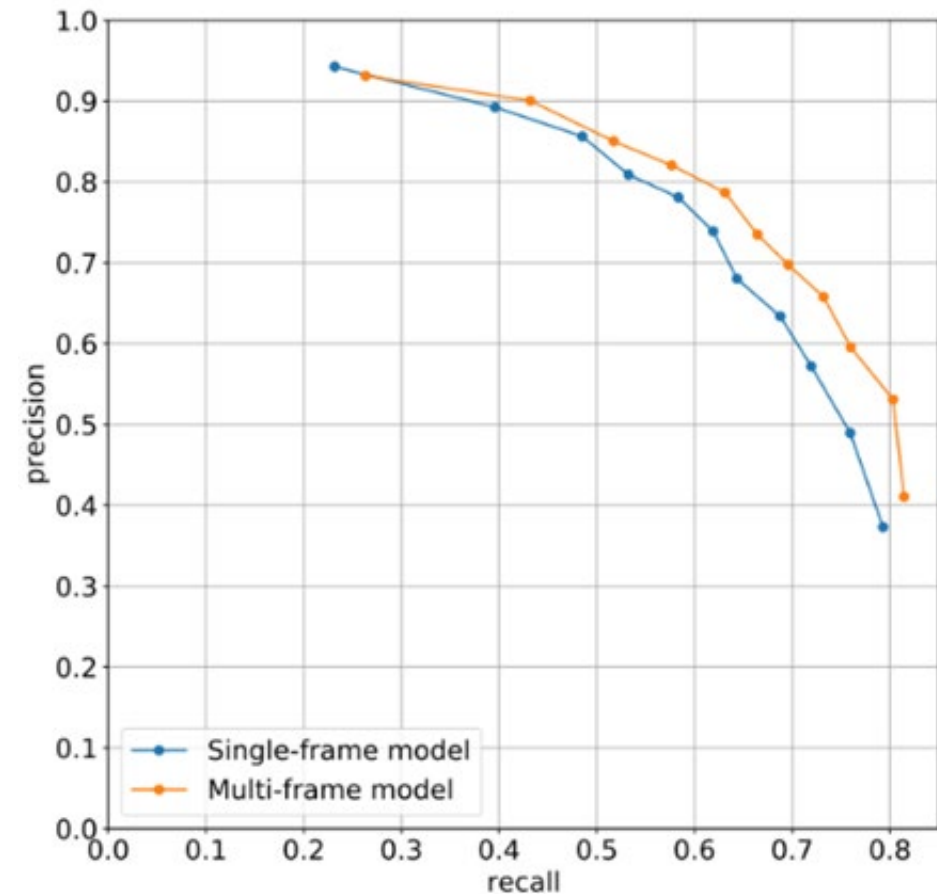
# Evaluation

## Per-pixel

TABLE III  
DETECTION PERFORMANCE WITH DIFFERENT NUMBERS OF INPUT  
FRAMES.

Size of temporal context	Pixel AUC-PR
$T_{\text{before}} = 0, T_{\text{after}} = 0$	71.4
$T_{\text{before}} = 0, T_{\text{after}} = 1$	71.3
$T_{\text{before}} = 1, T_{\text{after}} = 0$	71.7
$T_{\text{before}} = 0, T_{\text{after}} = 3$	70.4
$T_{\text{before}} = 2, T_{\text{after}} = 1$	71.7
$T_{\text{before}} = 3, T_{\text{after}} = 0$	<b>72.7</b>
$T_{\text{before}} = 4, T_{\text{after}} = 3$	72.0

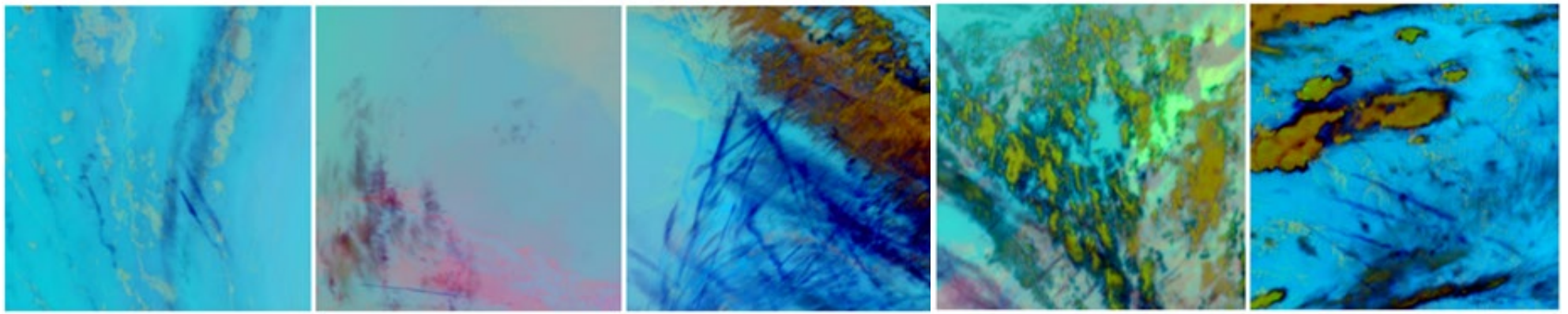
## Per-contrail



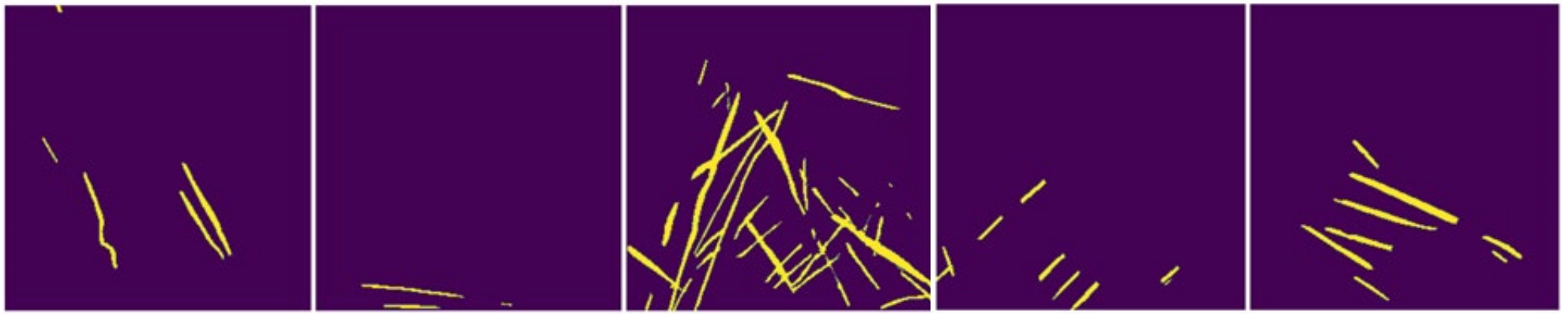


# Performs well in a broad range of imagery

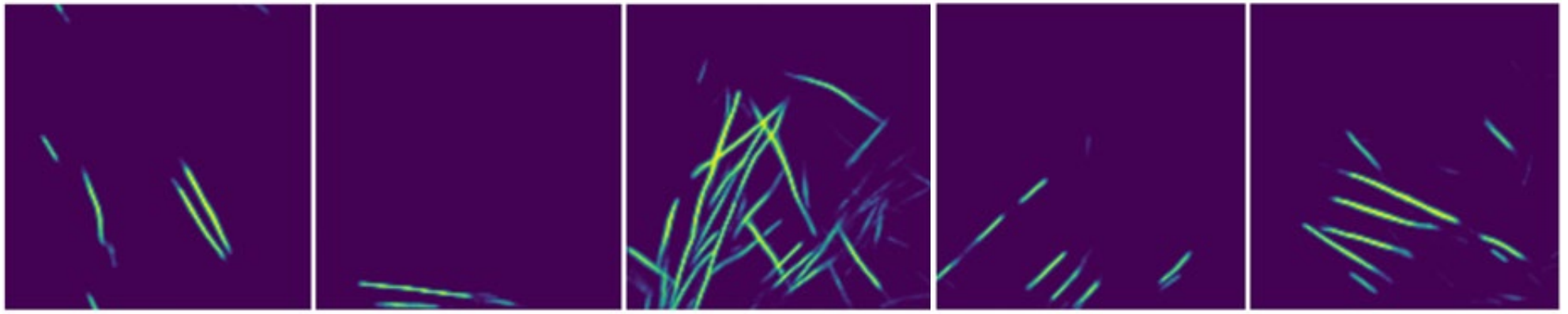
Ash color scheme



Majority label



Model prediction



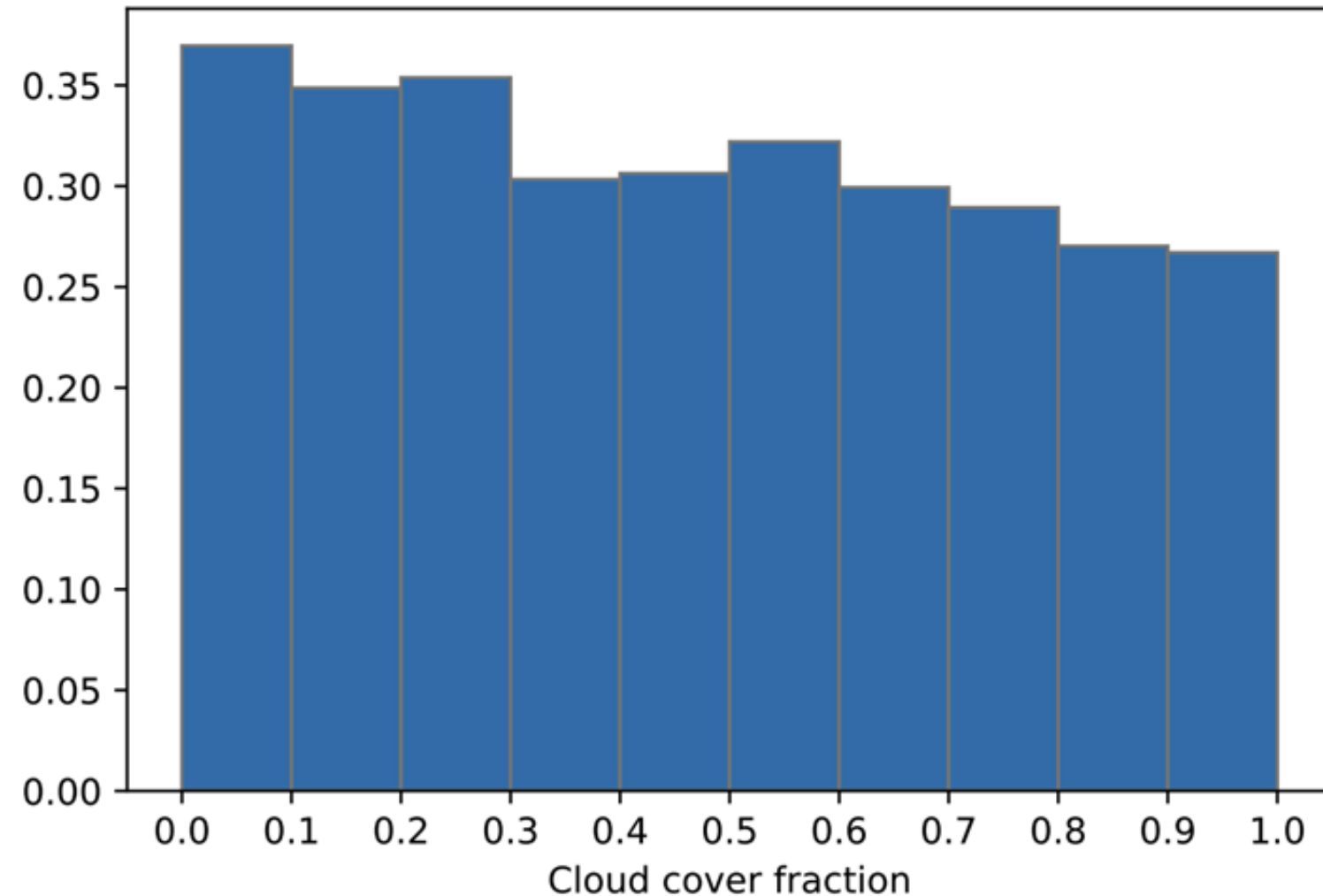
## similarities and differences with Mannstein's 1999 algorithm

	Mannstein et al 1999	Ng et al 2023
Convolutional operation	Difference-of-Gaussian line kernels at 16 angles	Learned inflated-3D kernels
Multiscale technique	Applied to original resolution and one downsampled resolution	Atrous convolutions; multiple conv layers; dataset augmentation
False-positive mitigation	Large-scale regional gradient mask;	Training dataset variety;
Evaluation	Excluded areas with overly heterogeneous earth surface	Temporal context; Majority vote labels



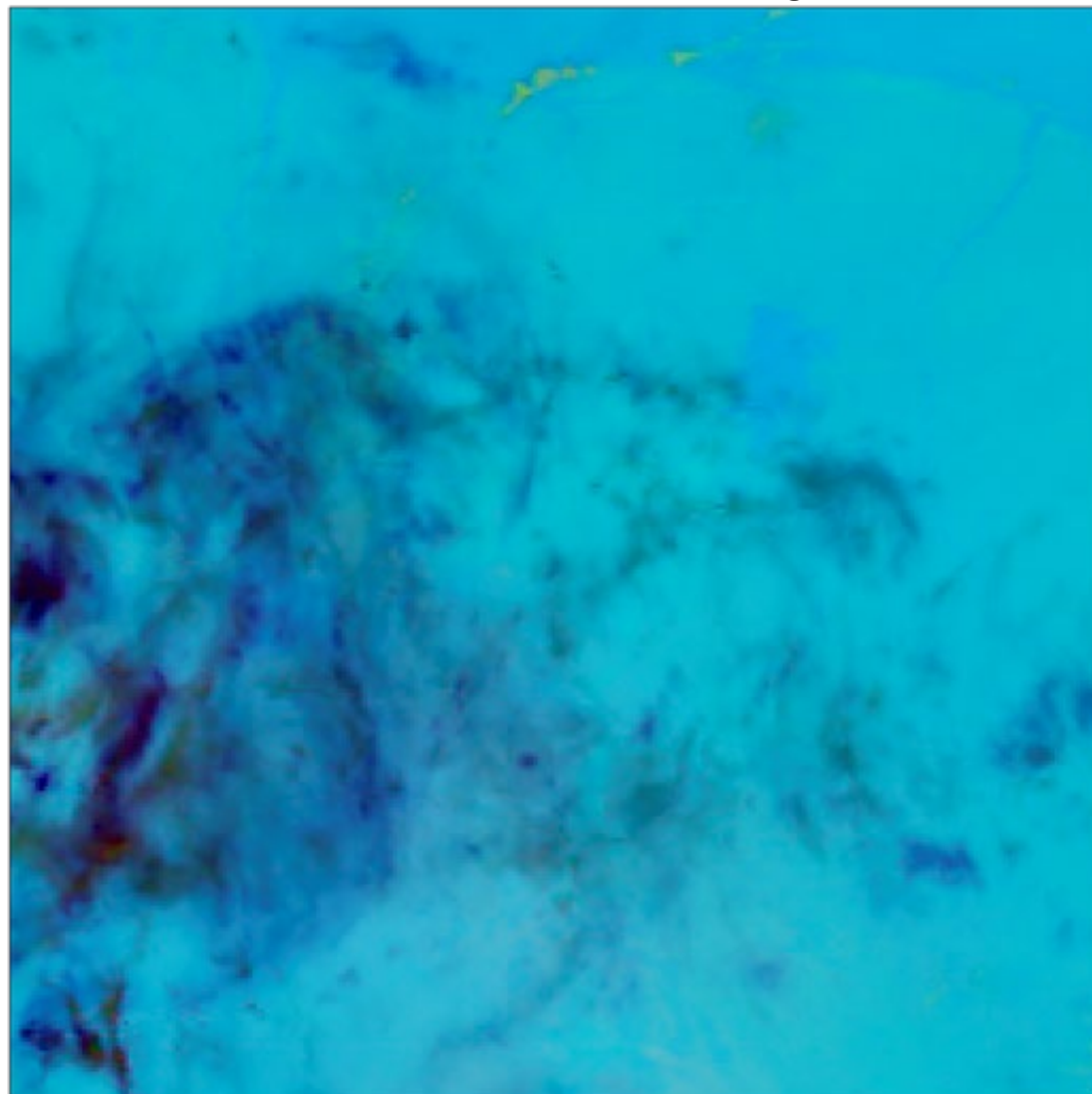
## Detection amongst natural clouds

Ratio of contrail pixels from majority label : any labeler

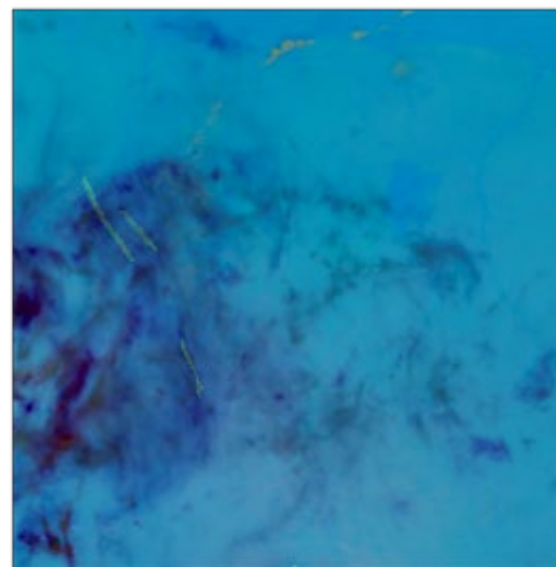


# Detection amongst natural clouds - random samples

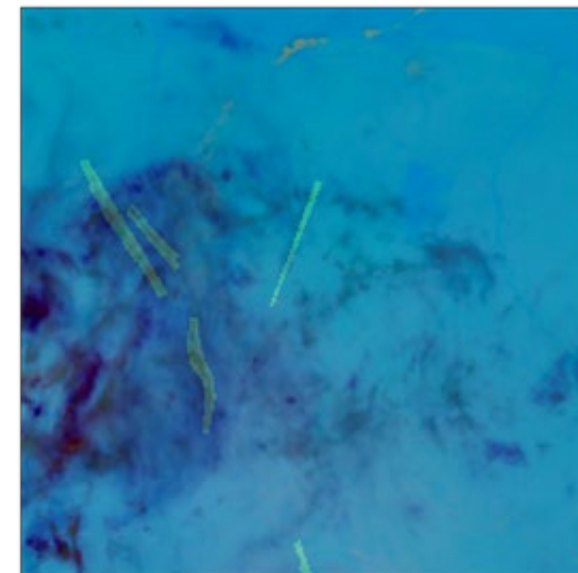
Ash color-scheme image



Majority label



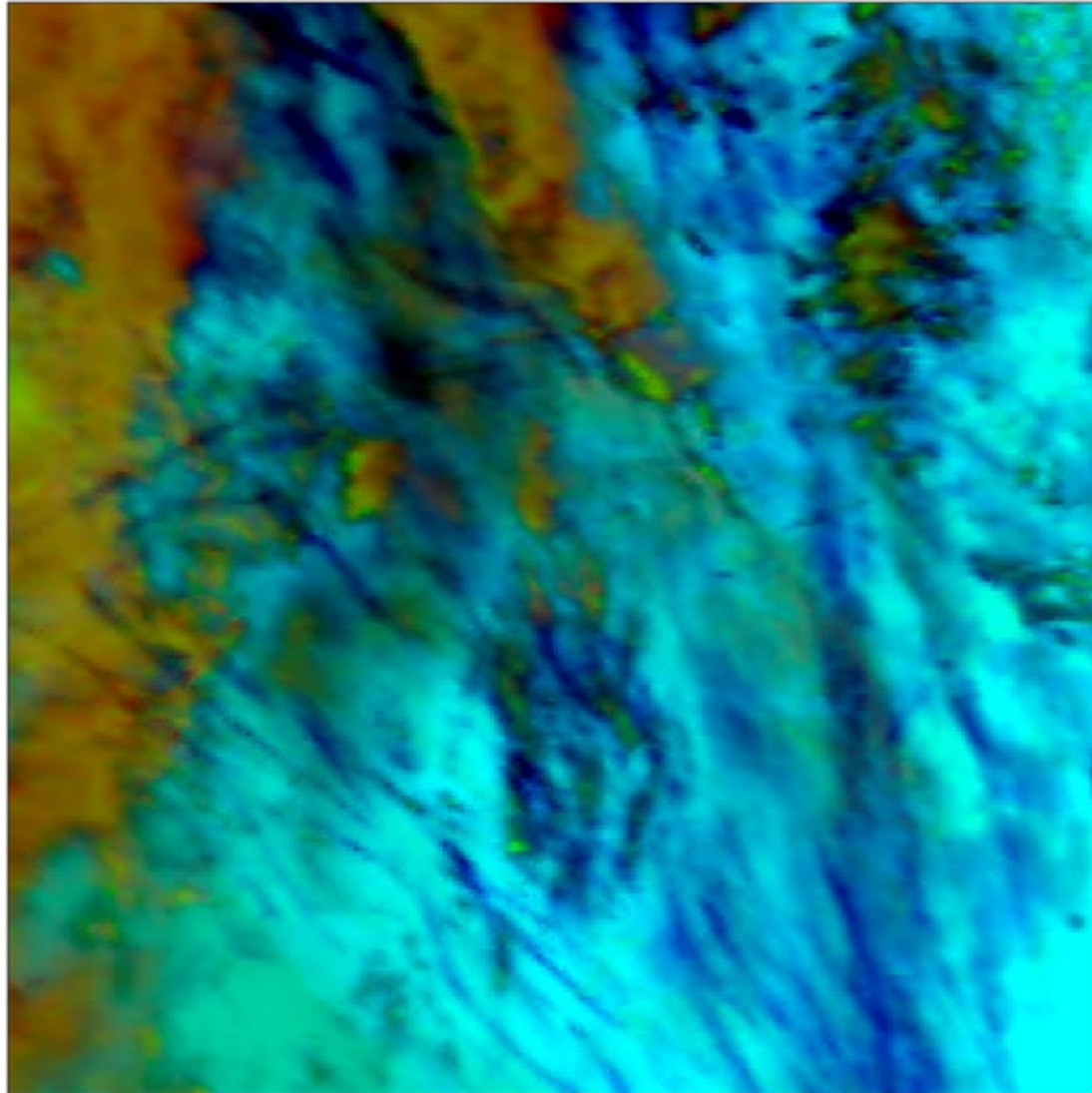
Union of labeler masks



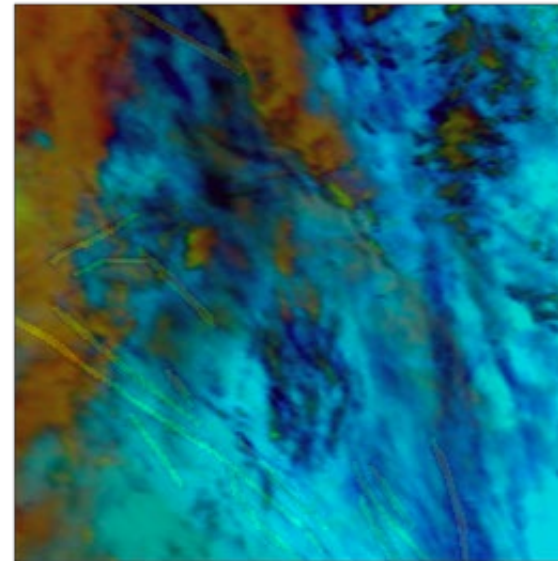
Ratio of contrail pixels from  
majority label : any labeler  
= 0.21

# Detection amongst natural clouds - random samples

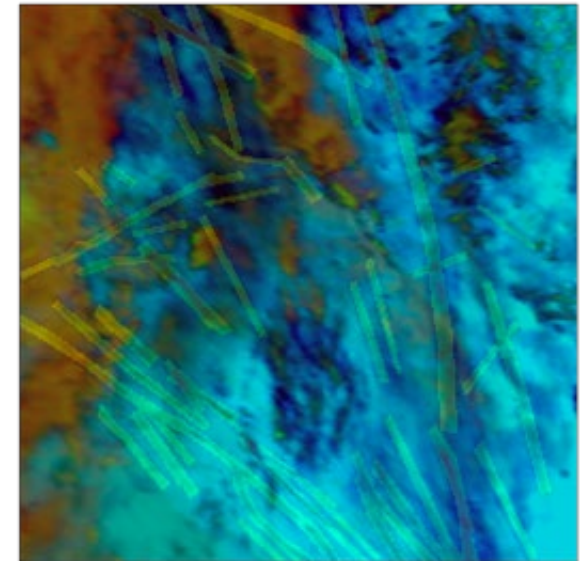
Ash color-scheme image



Majority label



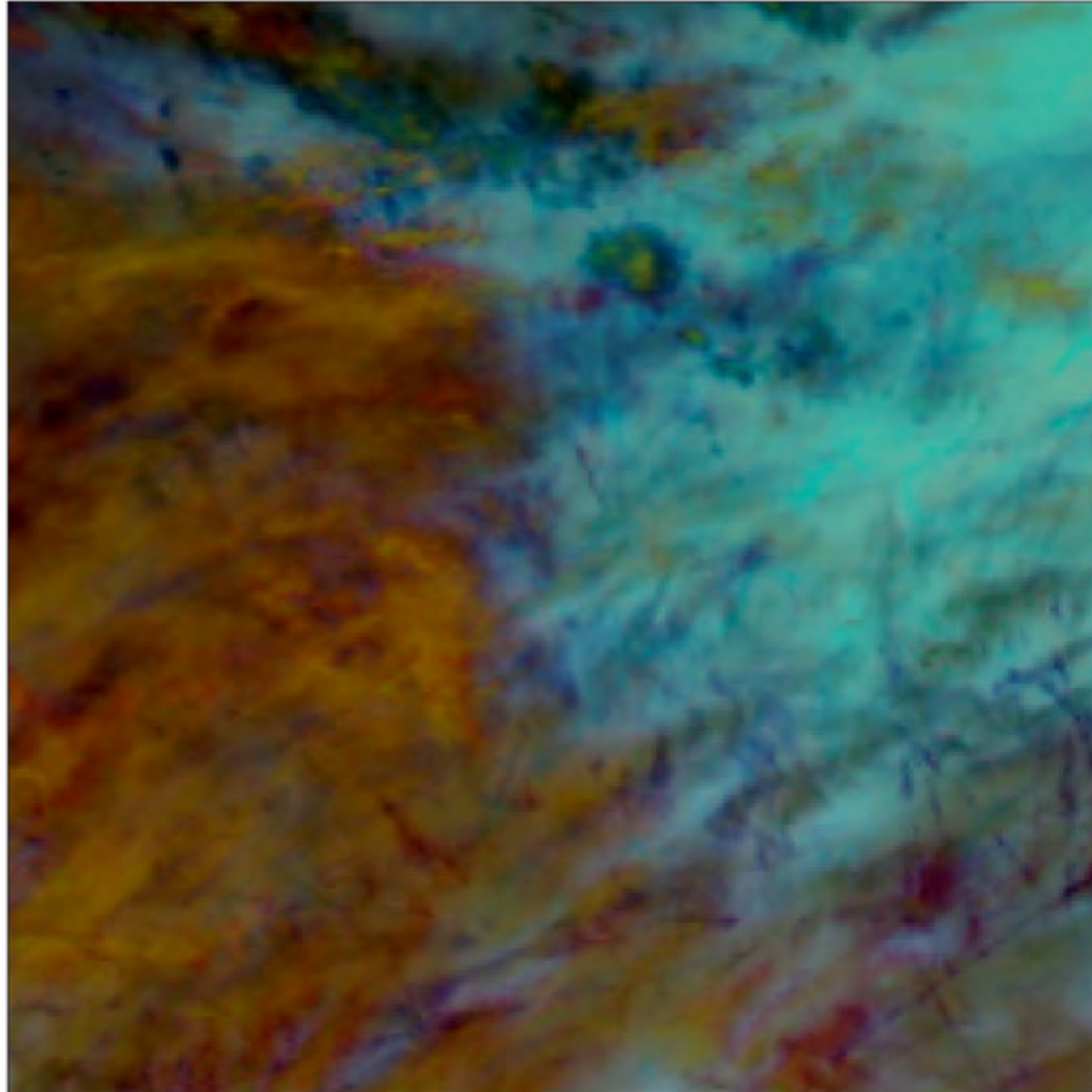
Union of labeler masks



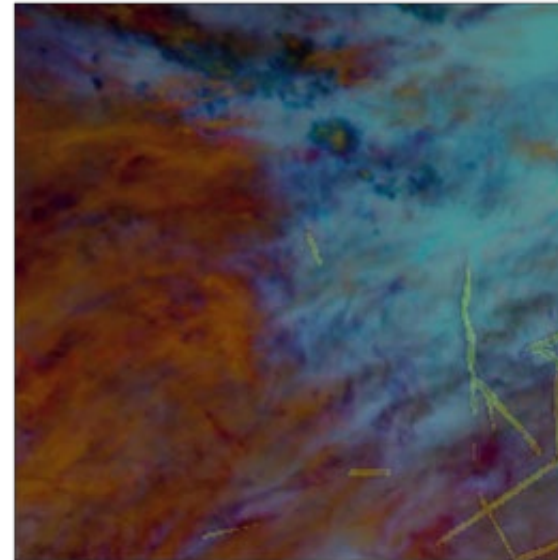
Ratio of contrail pixels from  
majority label : any labeler  
= 0.23

# Detection amongst natural clouds - random samples

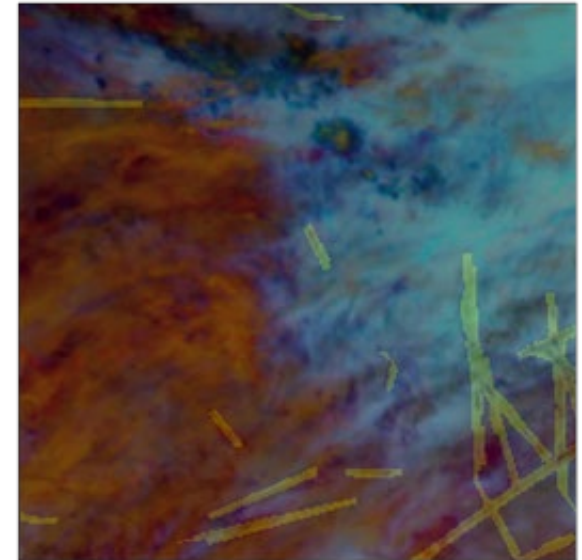
Ash color-scheme image



Majority label



Union of labeler masks



Ratio of contrail pixels from  
majority label : any labeler  
= 0.32

## Areas yet to be explored in published works

Deep Hough-space / Segmentation models

Super-resolution models / collocations with higher-resolution imagery

Active learning - techniques for acquiring highest value labels

Additional input features:

- Shorter wavelength imagery
- Topographic - surface type, elevation, or learned embeddings
- Advected flight tracks

Detection as a joint optimization alongside inferring the atmospheric state

**Thank you, any final questions?**

[g.co/research/contrails](https://g.co/research/contrails)

for further information and contact info