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Combining MISR and MODIS data to automatically catalogue smoke plumes in North America

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Introduction: We are in the early stages of work on an EPA task to investigate the effects of fires on air quality in North America, led by Jennifer Logan of Harvard University. JPL's contribution to this study is to find thousands of smoke plumes in satellite images of North America, and derive statistics about their geographic distribution, extent, orientation, and injection height. Because of the data volume, we are using automatic techniques to search for smoke plumes in terabytes worth of data from several years. Making use of both MISR and MODIS data allows us to automatically find plumes with higher precision and accuracy than with either instrument alone.

MISR contribution: MISR has the unique ability to determine the height of a smoke plume, using the stereoscopically-derived height product, automatically computed as part of standard MISR processing at the 1.1-km resolution. In addition, MISR's oblique angles make thin smoke appear more opaque, and looking at the angular signature can help distinguish smoke from clouds and other aerosols.

MODIS contribution: MODIS's thermal infrared sensing capabilities give it the unique ability to detect burning forest fires. The MODIS Thermal Anomalies data product uses the 4μm brightness temperature and the difference between the 4μm and 11μm brightness temperatures, in comparison to nearby pixels for context, to detect fires and other thermal anomalies.

Data Mining approach: We have been developing and testing several techniques to mine through multiple terabytes of MISR and MODIS data and pull out images containing smoke plumes. Our current methods operate at the granularity of one MISR block, which is approximately 400 x 140 km. The goal is to find all of the blocks that contain smoke plumes, and reject all of the rest. Note that we prefer to err on the side of more false positives, because it is easy to throw out blocks that were identified by our method that do not contain any plumes, but it is impractical to manually look through the entire data set to find plumes that were missed.

We use Support Vector Machines, a form of supervised classification, to detect MISR pixels that are smoky, based on color, texture, and angular features. This classifier was trained using dozens of hand-labeled scenes containing smoke, clouds, land, water, and/or ice and snow. Out of blocks that contain smoke, we have been developing algorithms that look for plume-like shapes using techniques from the field of machine vision. This helps reject images that contain smoke but no plumes, and often allows the automatic extraction of the plume orientation.

We use a combination of the number of MISR smoky pixels, number of MISR plume shapes, and number of MODIS thermal anomalies as heuristics to order all of the blocks we're searching through; blocks containing plumes get sorted towards the top.

Current status: We are using the summer of 2004 as a case study. We have analyzed ~22,000 blocks of data from ~460 orbits. Of these, in 635 we both detected smoke in the MISR image and found fire in the MODIS thermal anomalies product. Manually, we determed that 44 of these contain distinct smoke plumes. Our goal is to develop a system that will automatically flag all 44 of these blocks as worth pursuing while flagging as few of the others.

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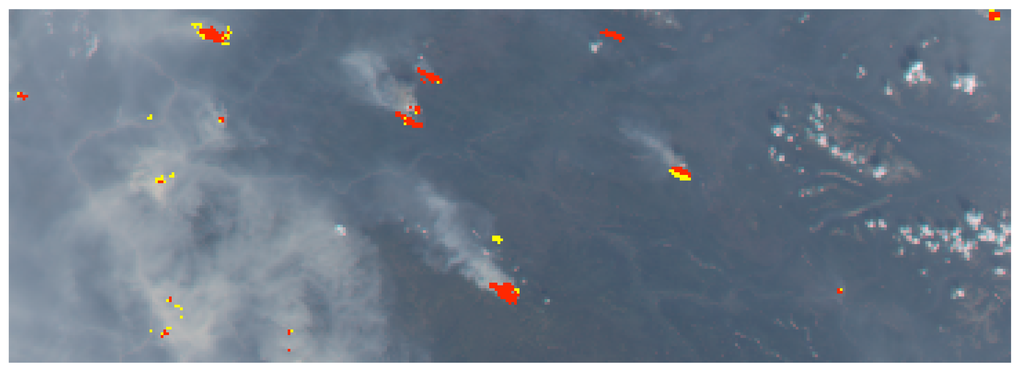
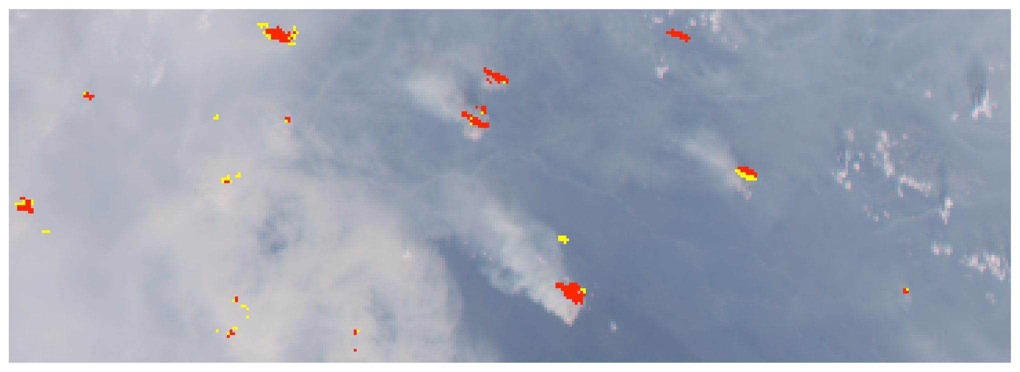
MISR's nadir (AN) camera shows three distinct smoke plumes, plus scattered smoke and clouds, over Alaska and Canada in the summer of 2004.

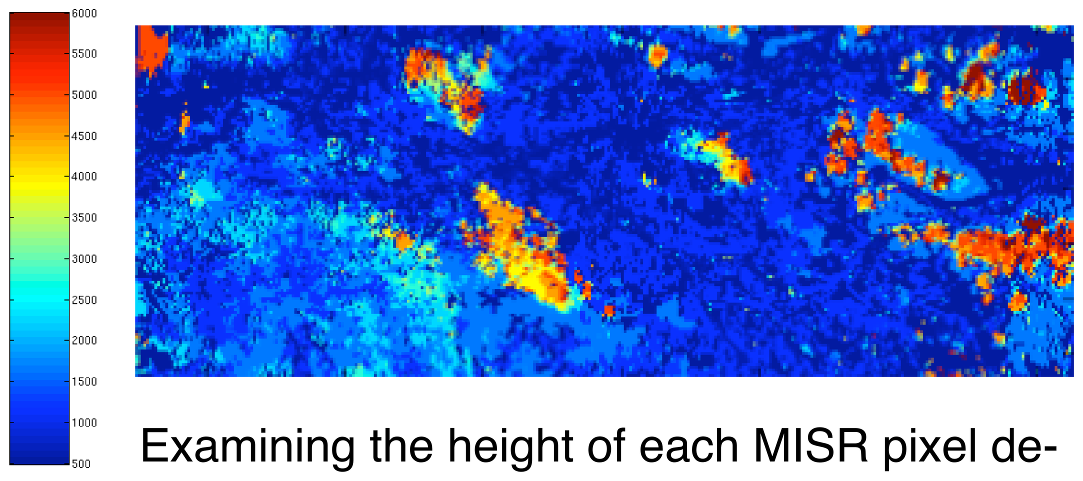
In white, smoke pixels detected by the Support Vector Machine classifier, which uses five of MISR's nine cameras to detect smoke using color, texture, and angular features.



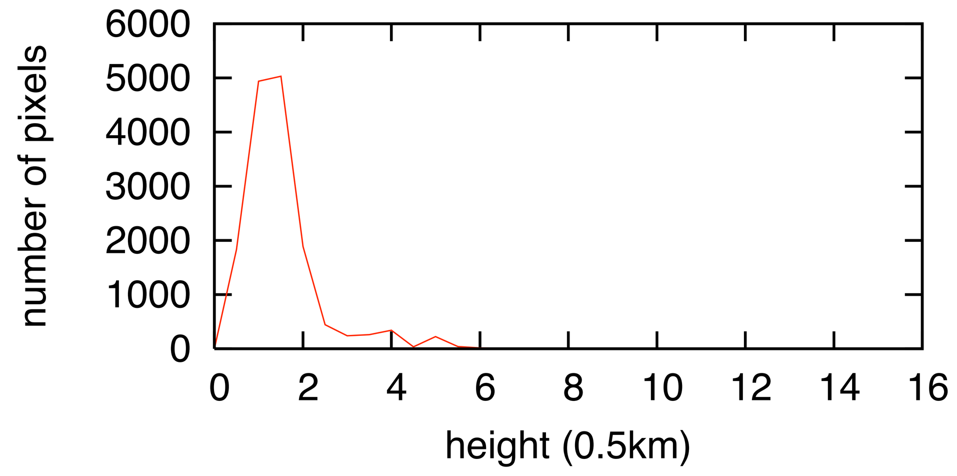
MODIS fire detections overlaid on the MISR image in red (high confidence) and yellow (low confidence).



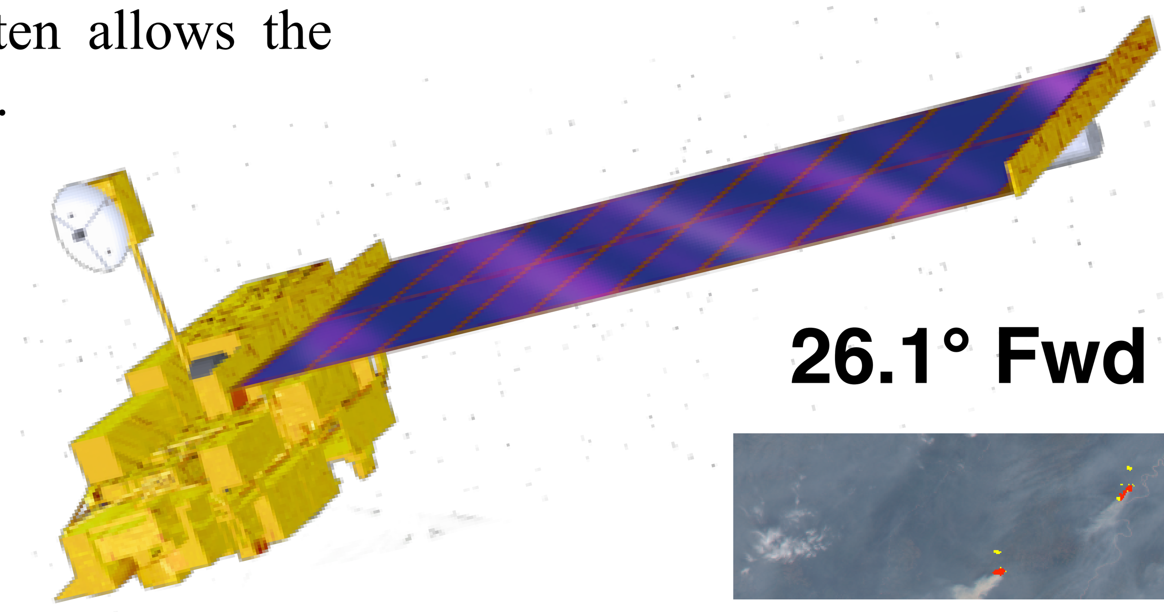
MODIS fire detections overlaid on MISR's 70.5 degree forward view. Objects above the surface shift due to parallax, but smoke is more opaque.



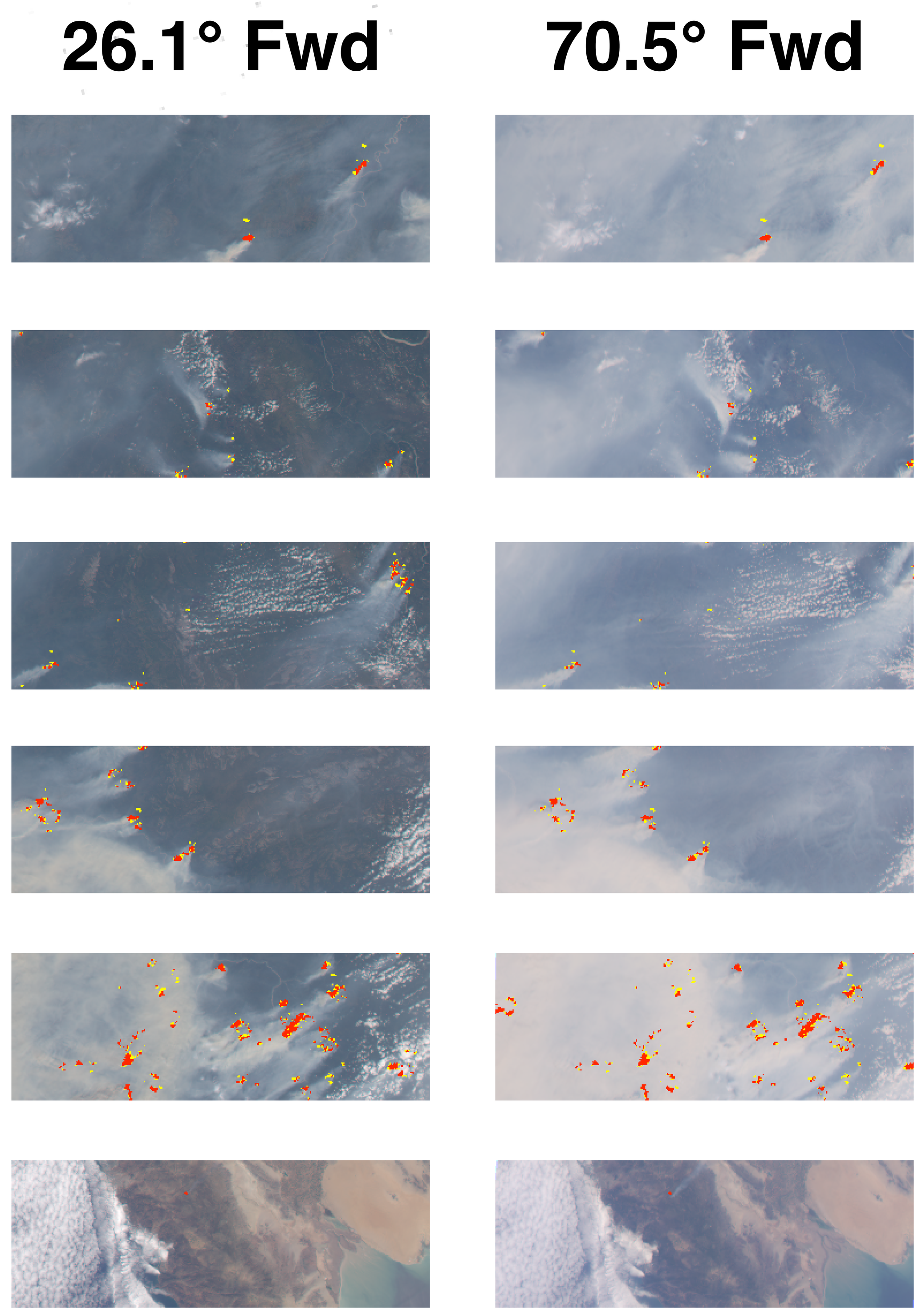
Examining the height of each MISR pixel determined by automatic stereo pattern matching allows us to estimate the injection height of the smoke plumes.



We intend to automatically process a histogram of the heights of smoky pixels, like this one, to infer the injection height.



Map showing the location of the block shown on the left: Terra orbit 24050, MISR block 39.



Additional images of smoke plumes found during the summer of 2004 show that fire detected by MODIS often corresponds quite well to smoke seen in the MISR image.

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