Development of Long Term Inventory of Fire Burned Areas and Emissions of North America's Boreal and Temperate Forests

Project Report (April 2000 – March 2001)

By

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Abstract

The primary objective of this research is to test and improve an algorithm capable of detecting fires using all historical AVHRR satellite data in the 80s and 90s and to map burnt areas in North America's temperate forests and to estimate their emissions. During the past year, the project team held two face-to-face meetings at Berkeley and in Washington DC. Research coordination has been maintained through frequent email communication and teleconferencing. Data sharing and algorithm sharing have been smoothly done. In December, the program manager and chief scientist for the NASA land cover land use change program visited the Berkeley group and made a number of constructive comments. The project team are aware of the comments and are considering the suggestions as the project progresses. NOAA AVHRR data acquisition has been effectively coordinated by Ivan Csiszar at NOAA/NESDIS and Zhanqing Li's group at UMD and CCRS. Data transfer from NOAA has no problem in meeting the production needs. Algorithm development has been lead by Zhanqing Li and the CCRS group with participation from Berkeley. Algorithm validation has been carried out by all four groups with CCRS responsible for Canada, Wei Min Hao responsible for the US with the participation of Berkeley for algorithm development and testing for California. A fire emission model is being built by Wei Min Hao's group and fire emission factors compilation and data collection has been progressing well.

The algorithm developed at the CCRS (Li et al. 2000a) was selected to fulfil the task of fire detection, pending successful evaluation. The algorithm was initially designed for application in Canada with NOAA-14 AVHRR data. Its ability to correctly identify fires with other AVHRR sensors over the entire North America is tested. Since the project started last summer, we have tested its performance using NOAA-14 and NOAA-11 in Canada, and NOAA-14 in US. Performance was evaluated with regard to the ability to detect active fire pixels accurately and the frequency of false fires and/or missing actual fires.

Georeferencing capability for the entire US and Canada has been established at Berkeley with over one thousand ground control points densely distributed in the US with a plan to add more points to Canada. Provided cloud is not primarily dominating on an entire scene, georeferencing accuracy can be controlled under 1000 m. The fire seasons of 1999 and 1996 have been processed for both US and Canada at Berkeley. Additional processing power will be added at Berkeley early in Year II of this project.

Keywords (could not link to the keyword page currently with the address given by Dr. Gutman)

1) Research Fields: Fire Mapping
2) Geographic area/biome: North America, Temperate forests
3) Remote sensing: NOAA AVHRR, Landsat TM
4) Methods: Temporal analysis, spatial context analysis

Questions, goals, approaches:

This project addresses the first question of the NASA ESE scientific questions: a) what are the changes in land cover and/or land use (monitoring/mapping activities).

The proportion of Social Science used in this study is 0%

Identify the proportion of the themes: 90% GOFC, 10% Carbon

I. EVALUATION AND MODIFICATION OF FIRE DETECTION AND MAPPING ALGORITHMS FOR APPLICATIONS TO NORTH AMERICA

Gaol 1. Fire Monitoring Algorithm Test and Development

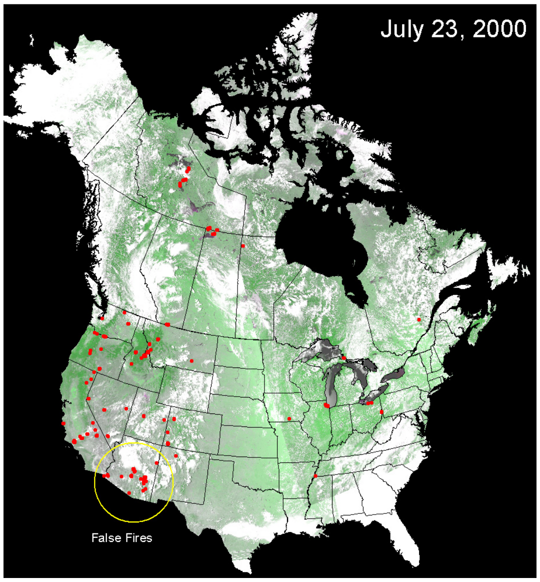
Application in Canada for multiple years

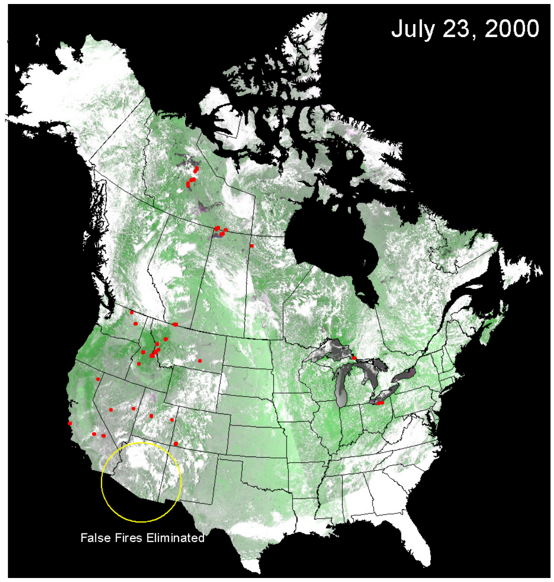
To this end, we have applied the algorithm to many scenes acquired by NOAA-11 and NOAA-14 in Canada of more or less complete duration of the satellites and NOAA-14 in US. The major findings of the investigation in Canada is summarized as follows:

1) The algorithm performs equally well throughout the NOAA-14 operation period so far (1994-2000). No significant degradation is observed.
2) The algorithm performs as good for NOAA-11 as for NOAA-14. There seems to be no need to switch fire detection algorithm for the two different sensors.
3) The results of fire detection in Canada are sufficiently reliable for accurate monitoring of fire occurred in Canada.

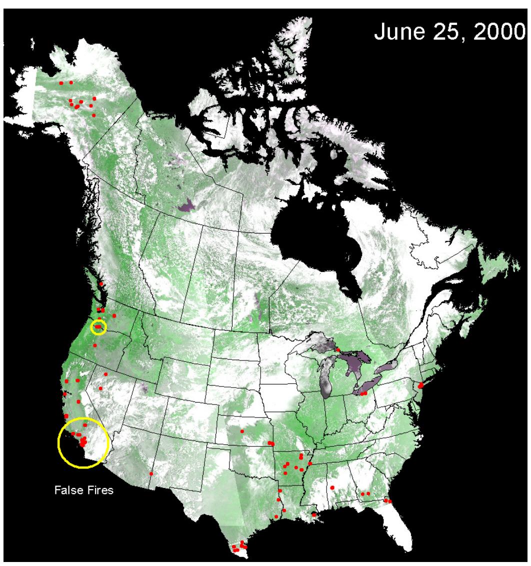
Application in US for year 2000

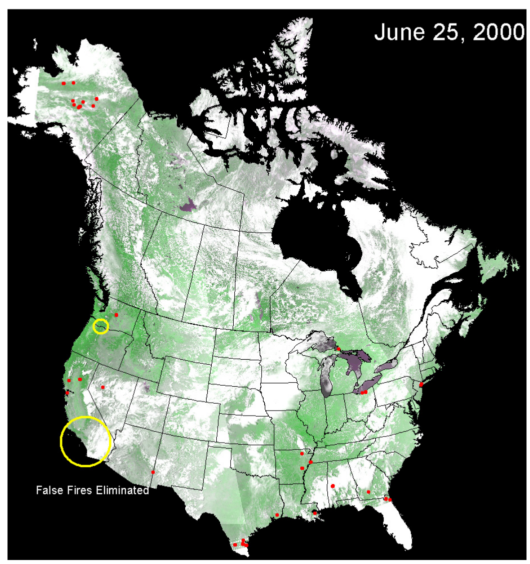
Note that the CCRS fire detection algorithm was originally developed to detect active forest fires across the Canadian boreal forest zone. Preliminary applications of the algorithm in the United States showed an overall satisfactory performance, especially over forest, a biome of main concern to this project. More significant number of falsely detected fires were found in some western and southern regions. The false fires occurred mainly over non-forest warm land cover types such as open shrub land, sparsely vegetated surfaces, pasture and range lands and at the edges of thin clouds. We adjusted some thresholds of the algorithm to adapt it to the special US land cover classes. Two additional tests were introduced to the CCRS algorithm. The first one dealt with eliminating false fires at the edges of thin clouds over warm background. The second one aimed at eliminating false fires due to sun glint. The modified algorithm was used to generate daily active fire maps across North America and the results were compared to a comprehensive database of ground-based survey and reports of actual fires mapped by USDA Forest Service. Good correspondence was found as shown in Fig. 1.





Active and False Fires in North America Active Fires in North America (False fires eliminated)
(Note False Fires in Western USA)





Active and False Fires in North America Active Fires in North America (False fires eliminated)
(Note False Fires in Western and Southern USA)

Fig. 1 Results of application of the original and modified CCRS Algorithm Over North America

Goal 2. Burnt Area Mapping

The burnt area algorithm developed at CCRS named HANDS was tested over a 500 km by 375 km region within the Northern Rockies of Montana and Idaho (Fig. 2). The HANDS method maps burnt areas by using the location of satellite active fires to derive a statistical differencing threshold for a pair of pre-fire (Fig. 2) and post-fire satellite images. A composite of satellite active fires alone underestimates burnt areas by comparison to fire perimeters mapped by the USDA Forest Service. However, the HANDS burnt area product identifies most of the burnt areas not detected as active fires, yet eliminates many falsely detected fires (note that burns lying outside the USDA Northern Region are not included in the fire survey). A comparison of the satellite-mapped burnt areas to conventional fire maps and Landsat TM imagery demonstrates a good correspondence for most burns larger than 10 km^2, which represent 98% of the total burnt area of 398,377 ha

II. VALIDATION OF ACTIVE FIRES AND BURNED AREAS DETECTED BY AVHRR AND DEVELOPMENT OF AN EMISSIONS INVENTORY MODEL

Goal 1. Validation of Active Fires and Burned Areas

Year 2000: The 2000 fire season was the worst fire season in the United States in the past 90 years. Approximately 3.3 million ha were burned in the continental U.S. and Alaska. Because of the severe fire season, ground surveys of fire locations and burned areas were conducted daily in Montana and Idaho by the Forest Service in August and September 2000. In addition, more than 60 airborne measurements were taken by infrared cameras in order to map fire perimeters in the Northern Rockies. We have collected these data from a variety of sources in the Forest Service to create the most comprehensive fire database ever assembled. The data were archived in the GIS ARC/Info format. The complete data set has been provided to the CCRS to validate and improve its HANDS algorithm for mapping burned areas in temperate ecosystems in the U.S. The AVHRR-derived burned areas using the HANDS algorithm were compared with the fire polygons mapped by the Forest Service (Fig. 2). The preliminary results have shown that the (STILL ORIGINAL ONE) HANDS algorithm is quite suitable for mapping burned areas larger than 1000 ha or 10 pixels in temperate forests. However, the algorithm has to be improved substantially for mapping fires smaller than 1000 ha. Some of these small fires were detected by the AVHRR satellite using the HANDS algorithm, but about 15 burn scars were not detected by the satellite.

In Year II, we will compare burned areas from 2000 derived by the HANDS algorithm with burned areas compiled by ground surveys throughout the US. Although it is not the objective of the current project, we will attempt to improve the HANDS algorithm for mapping burned areas in non-forest regions. One focus will be on mapping fires less than 1000 ha. The overall goal is to determine the percentage of burn scars detected in sizes of < 10 ha, 10 to 100 ha, 100 to 1000 ha, and > 1000 ha.

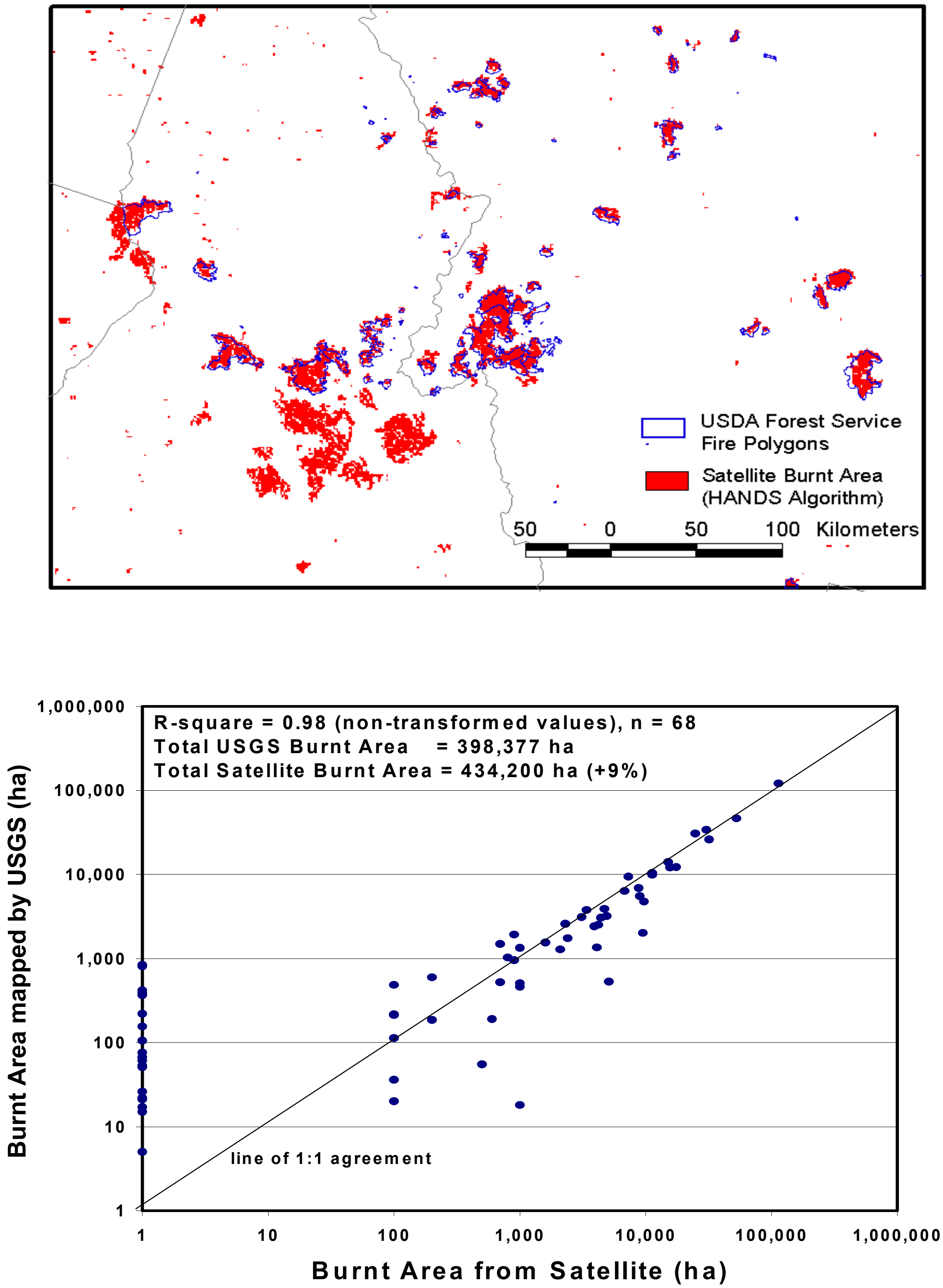


Fig. 2. Mapping burned area in Northern Rockies of Montana and Idaho using AVHRR data with the HANDS algorithm, in comparison with fire polygons from USDA Forest Service.

1986-1996: We have obtained the historical database of the time and locations of active fires and burned areas in continental U.S. **In the second year, we will** work closely with the CCRS and University of Maryland to improve the HANDS algorithm by comparing AVHRR-derived burned areas with the burned areas collected from ground surveys from 1986 to 1996. The methodology will be the same as the one used for 2000. The goal is also to determine the percentage of burned areas detected in different size ranges.

Goal 2. Prototype of Operational Fire Monitoring System

The development of a prototype fire monitoring system was one of the original objectives of this project, but descoped in the final approved project due to funding limitation. Nevertheless, a limited effort was made towards achieving this uncommitted goal as a by-product. By working closely with the CCRS, we were able to provide daily maps of AVHRR-derived active fires, burned areas, and smoke dispersion to the Northern Rockies Geographic Area Coordination Center (GAC) in Missoula, Mont., during the 2000 fire season. The information was provided to the GAC overnight after the satellite overpass. The GAC used the information to formulate daily firefighting strategies and allocate resources to control fires. Although this objective is no longer a major priority of the revised project, we have demonstrated that it was feasible to use AVHRR satellite images for operational use after improving fire and smoke detection algorithms and automating the prototype system.

Goal 3. Emissions Inventory Model

We are currently developing a GIS-based emissions inventory model. The vegetation and fuel maps of 1-km resolution have been integrated into the ARC/Info. We have completed compiling and categorizing all the data on emission factors of various trace gases and particulate from understory burning in Ponderosa pine forests. This is the most common type of fire in forested areas in the western U.S. We have also categorized most of the emission factor data in the southeastern U.S. In the second year, we will finish compiling and categorizing all the emission factor data for the continental U.S. We will also develop a prototype of an emissions inventory model and use the burned area data from 2000 to test the model.

III. DATA ACQUISITION AND PREPARATION

Goal 1. Coordinate acquisition of historical AVHRR data from NOAA archives. Extract North American scenes from the separate HRPT and LAC data sets.

Special arrangements have been made with NOAA Satellite Active Archive (SAA) for the delivery of level-1B data files created from AVHRR data the High Resolution Picture Transmission (HRPT) data stream as received by NOAA's operational receiving stations. The arrangement includes the exclusive usage of a "test disk", which allows a fast and efficient extraction of the desired data files from the Robotic Tape Archival System ("Big Bird") of NOAA Office of Satellite Data Processing and Distribution (OSDPD). With this arrangement the delivery of HRPT data for the project became independent from the one available to the general user community, the efficiency of the latter being subject to fluctuations due to varying system load.

Because of gaps in the spatial coverage of HRPT data over North America (especially California), the collection of Local Area Coverage (LHRR) data is also necessary. These data are recorded by the satellite over selected areas of the globe and transmitted to the NOAA receiving stations. The data are then transformed into level-1B format, which is identical to the one created from HRPT data.

Issues: Initially, LHRR data were delivered by SAA in a similar way to those of HRPT. However, it was realized that while the vast majority of HRPT data indeed cover the North American land mass and thus are useful for the project, LHRR data cover various parts of the globe, and only a portion of them is necessary to collect. As the direct data extraction system described above is not able to sub-set the data by area, it's use for the project's purposes is very inefficient. Thus it was decided to collect the data through SAA's web-based data query and order system, where selection of the coverage by area is possible. Although this way the orders for the LHRR has no priority over orders by other users, our experience has shown that in the case of the fewer LHRR this does not cause any delays in the data acquisition and archival activity. In addition, as part of the special arrangements, SAA allowed us to obtain larger amounts of data within specific orders as compared to regular users.

After both HRPT and LHRR data are transferred to NOAA/NESDIS/ORA, and after a final sub-setting step (eliminating nighttime data and data over the ocean along the North American coastline), the merged HRPT-LHRR data sets are saved on DLT tapes, organized by day. The total volume of 1 month of data is about 15 Gigabytes. Thus 2 months of data are stored on each 35 Gigabyte capacity DLT tape.

By the end of 2000, data from 1995-1999 and 1990-1993 have been archived at NOAA/NESDIS/ORA.

Goal 2. Transfer 1993-1999 data to UC/Berkeley

A special account and a data directory have been set up for the project on the HP Polar Processor at NOAA/NESDIS/ORA, which allow the direct access of data to co-investigators at UC/Berkeley. Data from the years 1996 and 1999 have been transferred to UC/Berkeley. Further data are ready to be transferred.

Goal 3.Cooperate with CCRS and Forest Service in algorithm development and validation for non- forest wildfires from NOAA-14, -12 and -11 satellites

Special sub-sets have been created for Canadian and US target areas for periods of known major fire activity from NOAA-14 and NOAA-11 data. The data have been transferred to CCRS and the algorithm has been tested. An intercomparison of the CCRS single-pixel and contextual algorithms, as well as CCRS algorithm performance in different years has been done. This component of the work is under way and results are expected by the end of April 2001.

Goal 4. Work on obtaining 1985-1988 and 1994 data from NCDC that is unavailable at SAA

Issue: Officials of SAA, NOAA/NCDC and NESDIS have been contacted regarding the recovery of the data that are currently missing from the SAA data record and are available only (especially the 1985-88 data) from the NCDC low-capacity tape archive. Officials of the United States Geological Survey (USGS) EROS Data Center (Sioux Falls, SD) have also been contacted regarding the historical data. They, however, informed us that 1. Their continuous data record goes back to1989, and before that only sporadic data area available, and 2. According to arrangements between USGS and NCDC, the latter is the premier provider of historical AVHRR data and every effort needs to be made first to obtain the data from NCDC.

NCDC has offered an 80% discount on the data sets, yielding a $6/dataset price. It was also indicated that the data are being transferred from the low-capacity cartridges to the NCDC robotic system. The total number of scenes for the periods in question is ~10000. By excluding time periods and areas without fire activity, this number can be significantly reduced. Currently considerations are being made about obtaining 1994 data from the CCRS archives.

IV. FIRE PRODUCT PRODUCTION OF THE NORTH AMERICA

Goal 1. AVHRR Data Geocoding and Composting

Since installation of the GeoComp-n that is used for NOAA/AVHRR data geocoding and composting in December, 2000, we have expanded the chip database (ground control areas) and processed more than one-year of daily AVHRR data (geocoding and composite) of the North America (NA). Now we have a total of 1042 chips (288 coming with Geocomp, 754 added to it) in the chip database. The additional chips (754) all cover US, made by orthoTM images (TM4, 1000 m resolution). We will add more chips for Canada after getting orthoTM images later on in Year II. The preliminary tested result by running Geocomp with the expanded chip database indicates that some missing orbits now can be geocoded because the Geocomp collected more chips and the accuracy of geocoding AVHRR data is less one pixel (< 1000 m).

Using the Geocomp-n with the expanded chip database, we have processed daily AVHRR data June through October of 1999 and January through July of 1996 by now. Those Geocomp products have been backed up on DLT tapes for daily hotspot detection and burned scar mapping later on. Based on the current processing rate on one machine, we can process approximately 8 months daily data per month. We need one additional machine to run the Geocomp to speed up the production of geocoding and composite products.

Goal 2. Running Hotspot Detection and Burned Scar Mapping Algorithms

To produce the final fire products, we need to generate daily fire mask first. We have gotten a new version of hotspot detection algorithm from CCRS for daily hotspot detection for NA and we are testing the effectiveness of the algorithm applicable to NA. In June this year, we will test HANDS that has been modified to fit NA situation. We are familiar with both algorithms. After testing both algorithms and obtaining the Geocomp product, the production of the final fire products should be very quick because the time of running both algorithms is not a big issue. Additional tests and specific adjustments of thresholds have been made to the HANDS algorithm and fire scar mapping have been applied and tested over California for 1999. Results were confirmed with historical data provided by California Department of Forestry and Fire Protection (CDF) and Landsat TM fire interpretation. Good agreements were achieved.

Problems

During the processing of daily AVHRR data of NA with Geocomp, we found that most of the winter and spring AVHRR data could not be geocoded because of the weather (too cloudy). We found during the winter of 1996, geocoding and composite image covering the entire North America was impossible for almost every day. For the entire US only a few of the daily scenes were geocoded because of cloud, but almost no winter data were geocoded for Canada (almost every day is cloudy). This may be a problem for us to use winter and early spring data to do hotspot detection and burn scar mapping, even for southern US like Florida. There is no forest fire in Canada in the winter and spring, and the level of severity of lacking properly geocoded data for southern America will be further assessed in Year II. We will consider alternative ways to address this problem such as limiting the processing to southern US during the winter and spring seasons and not processing images in the winter seasons.

IV. PUBLICATIONS

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