

Monitoring of the Global Forest Cover using Data Mining



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PLANETARY SKIN

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Project website
Climate and Eco-system: www.cs.umn.edu/~kumar/nasa-umn

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Monitoring Forest Cover Change: Motivation

- Forests are a critical component of planet.
 - Act as sink of carbon from the atmosphere.
 - Provide ecological diversity and protect soil.
 - Livelihood for millions of people.
- Massive degradation in forest cover due to logging, conversions to cropland or plantations and natural disasters like fires.
- Quantifiable knowledge about changes in forest cover is critical for effective management of forest resources
 - Carbon Trading
 - UN REDD: monetary payments for preservation of forests.



Purveyors of water, consumers of carbon, treasure-houses of species, the world's forests are ecological miracles. They must not be allowed to vanish. The Economist, Sep 23rd 2010



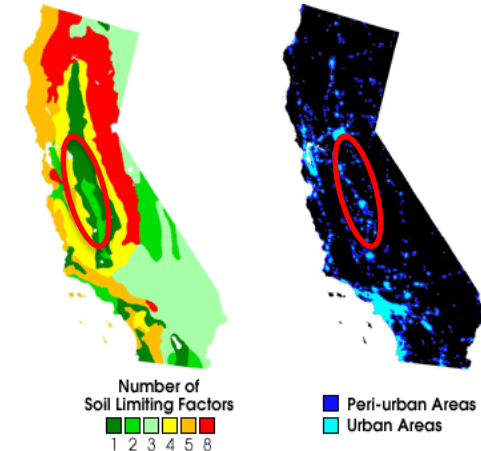
Good to Go Green: SFO Unveils Carbon Offset Kiosks

Land Cover Change Detection

Goal: Determine **where**, **when** and **why** land cover changes occur

- Examples: Deforestation, Urbanization, Agricultural intensification, crop rotation

Motivation: Land cover change can impact local climate, water and food supply, carbon cycle, and diversity/abundance of terrestrial species.



ARAL SEA:

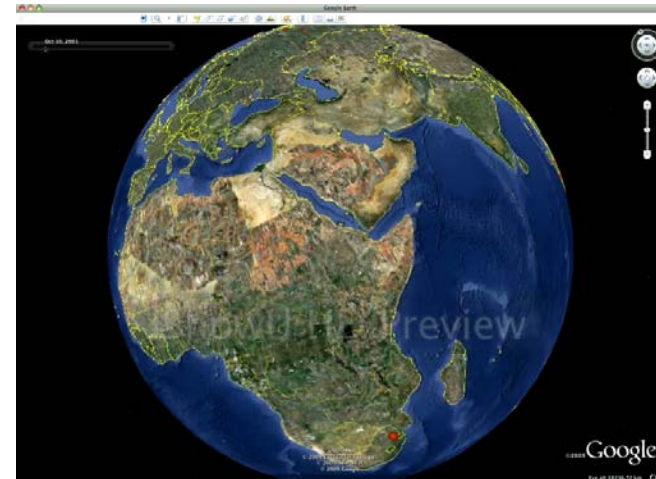
- Water from rivers feeding Aral Sea increasingly used to irrigate Cotton Fields
- Population has increased 3 times since 1960's.
- Size of Aral Sea reduced to $\frac{1}{4}$ since 1960's.
- Surrounding Climate has changed to being more continental with shorter, hotter, rainless summers and longer, colder and snowless winters.

CALIFORNIA:

- Increased urbanization
- Housing development in prime agricultural land.
- Pressure on water resources

Monitoring of Global Forest Cover

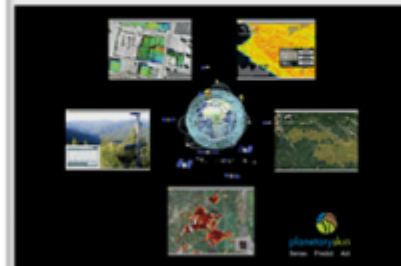
- Planetary Information System for assessment of ecosystem disturbances
 - Forest fires
 - Droughts
 - Floods
 - Logging/deforestation
 - Conversion to agriculture
- This system will help
 - quantify the carbon impact of these changes
 - Understand the relationship to global climate variability and human activity
- Provide **ubiquitous web-based access** to changes occurring across the globe, creating public awareness



TIME

The 50 Best Inventions of 2009

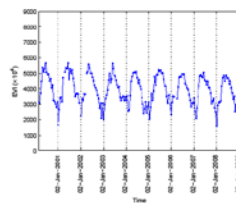
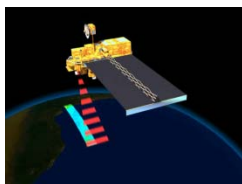
The 50 Best Inventions of 2009 > The Best Inventions
The Planetary Skin



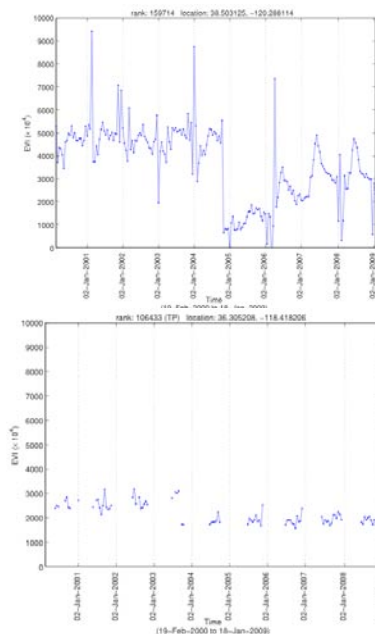
What happens to Earth when a forest is razed or energy use soars? We don't know because environmental data are collected by isolated sources, making it impossible to see the whole picture. With the theory that you can't manage what you can't measure, NASA and Cisco have teamed up to develop Planetary Skin, a global "nervous system" that will integrate land-, sea-, air- and space-based sensors, helping the public and private sectors make decisions to prevent and adapt to climate change. The pilot project — a prototype is due by 2010 — will track how much carbon is held by rain forests and where.

Novel Algorithms for Monitoring Global Eco-system

- State of the art algorithm for land cover change detection do not scale
- Remote Sensing data for global vegetation cover.



- Existing time series change detection algorithms do not address unique characteristics of eco-system data like noise, missing values, outliers, high degree of variability (across regions, vegetation types, and time).
- We have developed new algorithms that build non-parametric models of different segments of the time series and use them to capture the degree of change
- Data sets used in our study :
 - EVI: Enhanced Vegetation Index (250m x 250m)
 - FPAR : Fraction of Photosynthetically Active Radiation (1km x1km and 4 km x 4km)



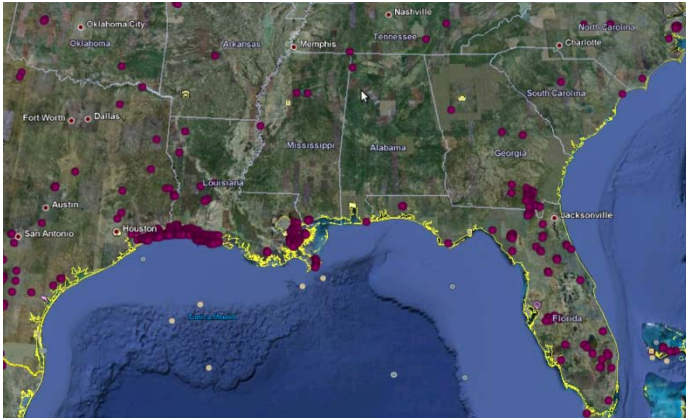
S. Boriah, V. Kumar, M. Steinbach, et al., *Land cover change detection: a case study*, KDD 2008.

V. Mithal, S. Boriah, A. Garg, M. Steinbach, V. Kumar et al., *Monitoring global forest cover using data mining*. Technical Report Department of Computer Science, University of Minnesota 2010.

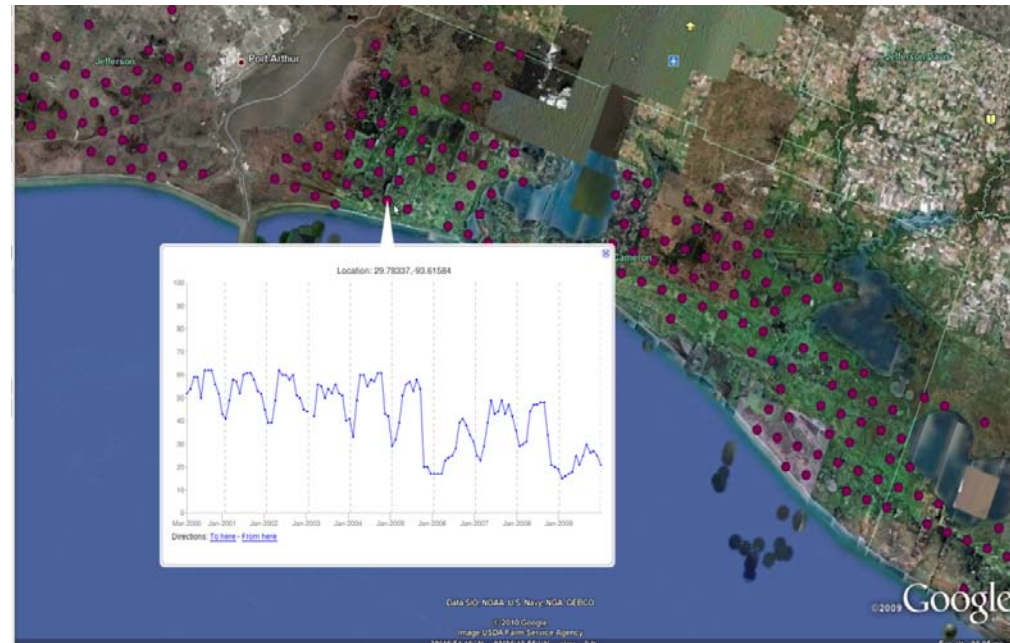
Monitoring Global Forest Cover



Hurricane Katrina



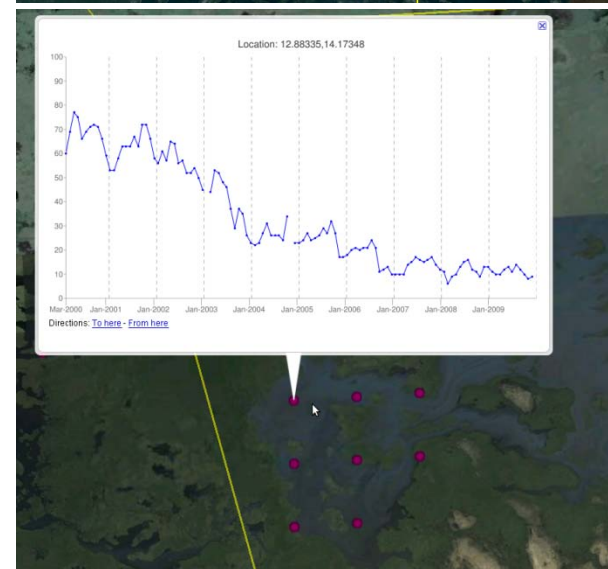
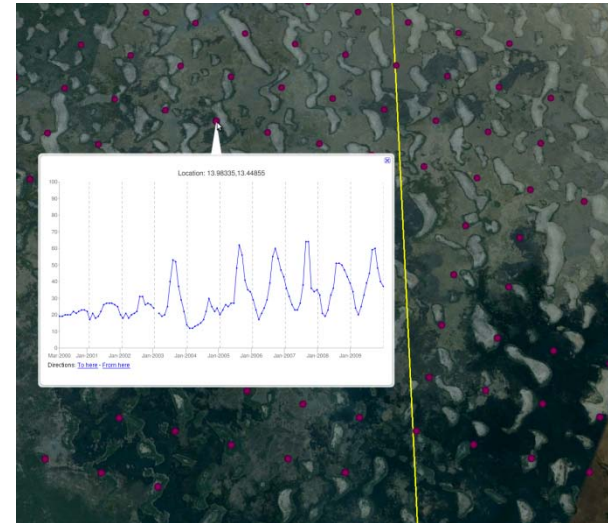
- Hurricanes Katrina and Rita hit the Louisiana coast on August and September 2005.
- The hurricanes transformed 217 square miles of Louisiana's coastal land to water by storm surge.



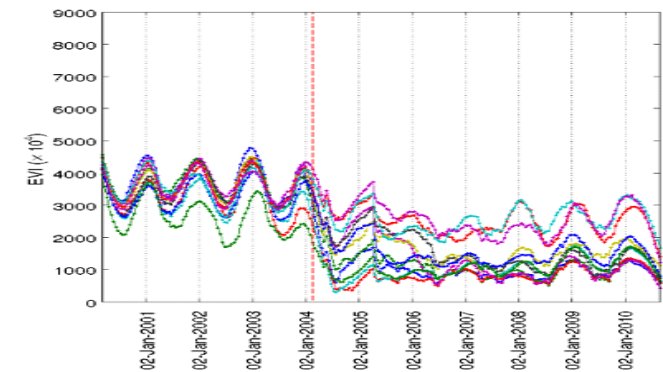
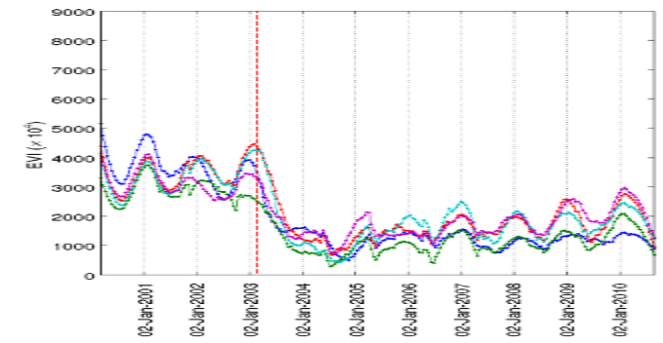
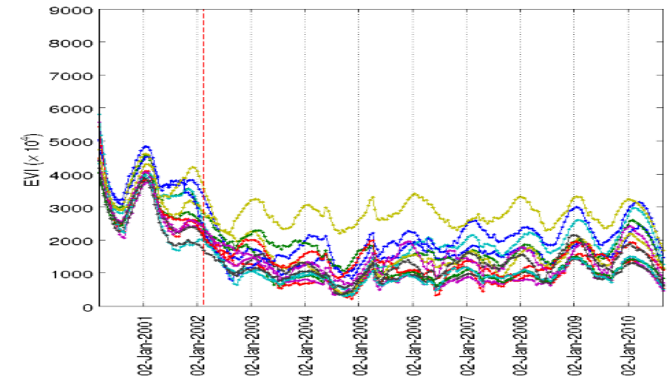
Shrinking of Lake Chad, Nigeria



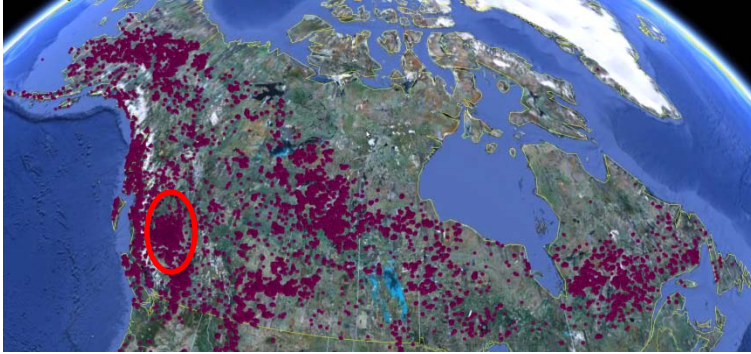
- Lake Chad is economically important, providing water to more than 20 million people living in the four countries that surround it.
- The lake shrank as much as by 95 percent from about 1963 to 1998 and is continuing to shrink further.(Source: UN)
- Efforts are in progress to divert Ubangi River into Lake Chad.



Gold Mine in Protected Forest , Tanzania

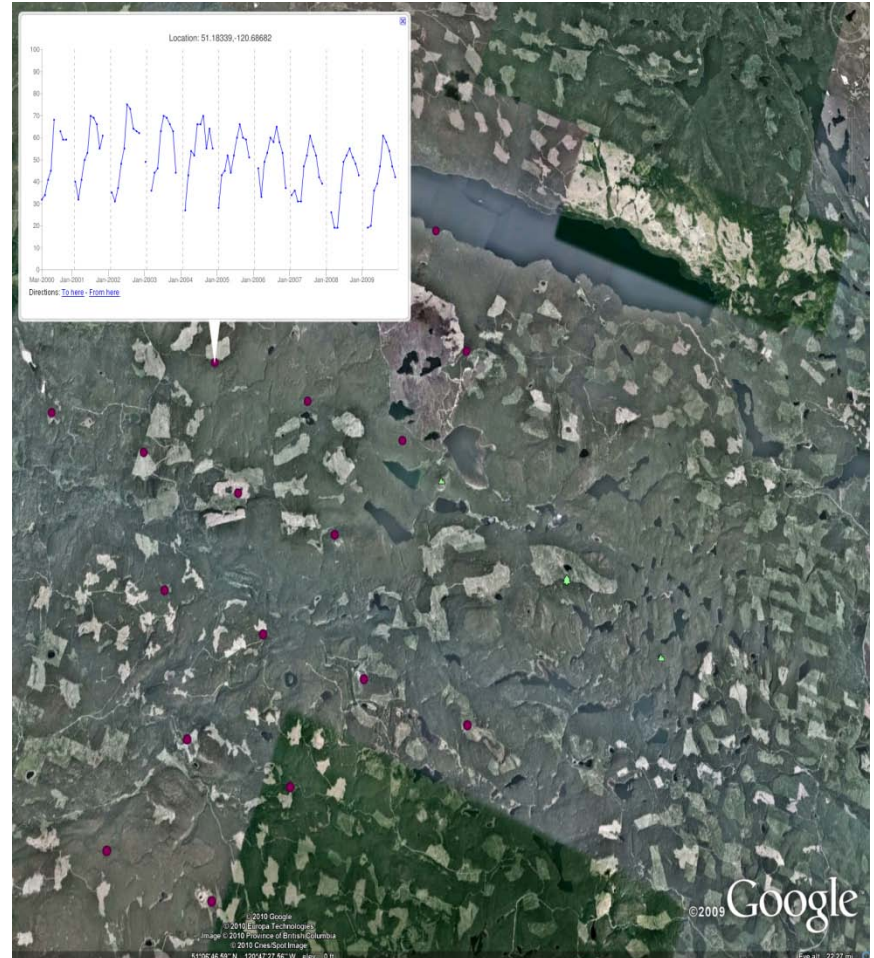


Logging in Canada

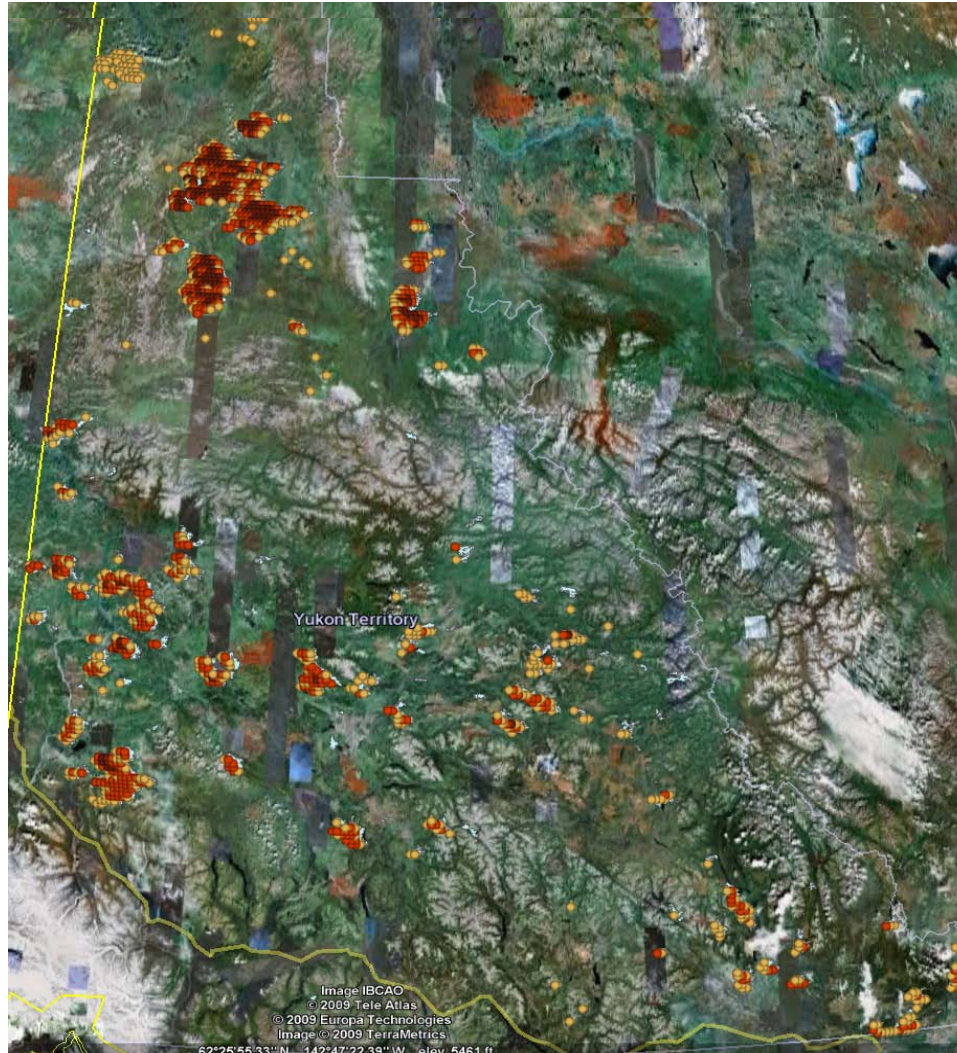


- Logging has produced clear cut areas in British Columbia, which can be identified as regular, generally rectangular shapes.
- The highly reflective clear cut areas stand out in marked contrast to the dark green forested areas.

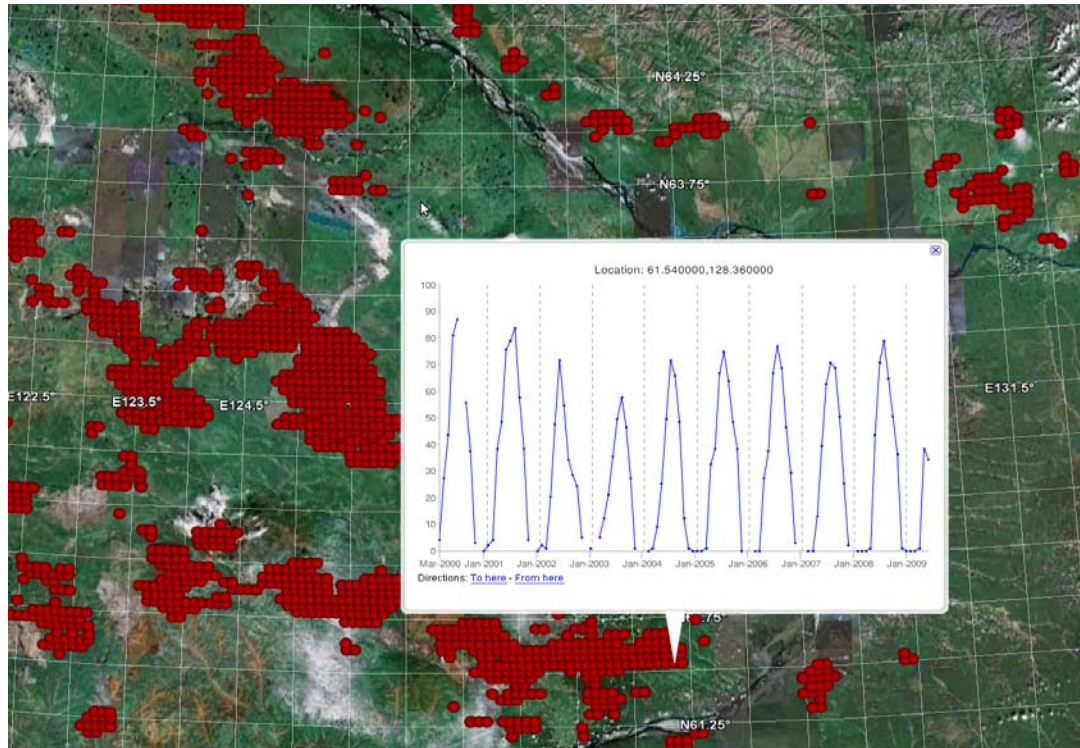
(Source: NASA)



Canada: Fires in Yukon Province



Large Outbreak of Fires near Yakutsk, Russia

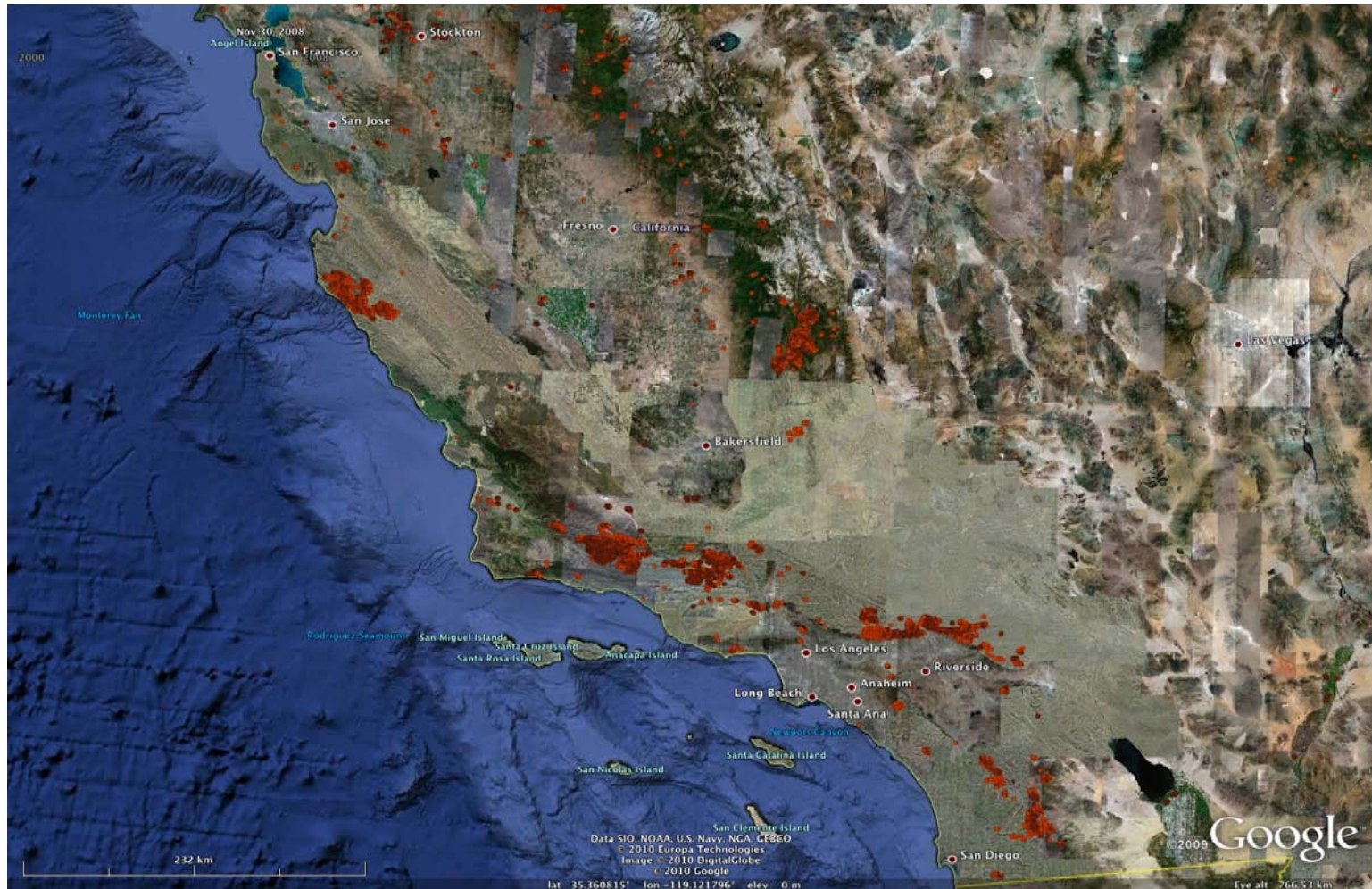


During the summer months in the Northern Hemisphere, many fires are ignited in the boreal forests of Canada and Russia by lightning striking the surface

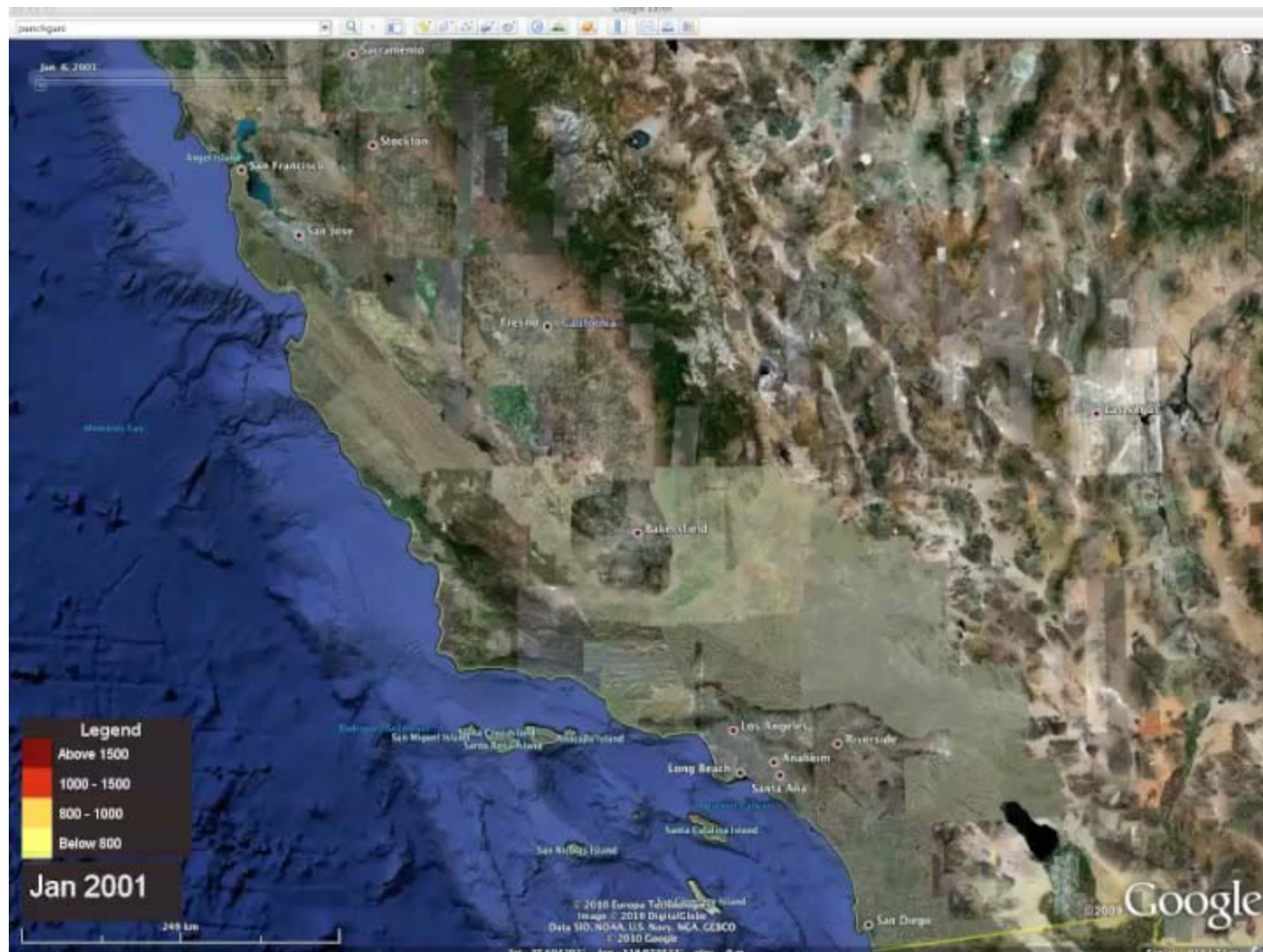
Image courtesy Jacques Desclotres, MODIS Land Rapid Response Team



History of fires in CA/AZ 2000-2009

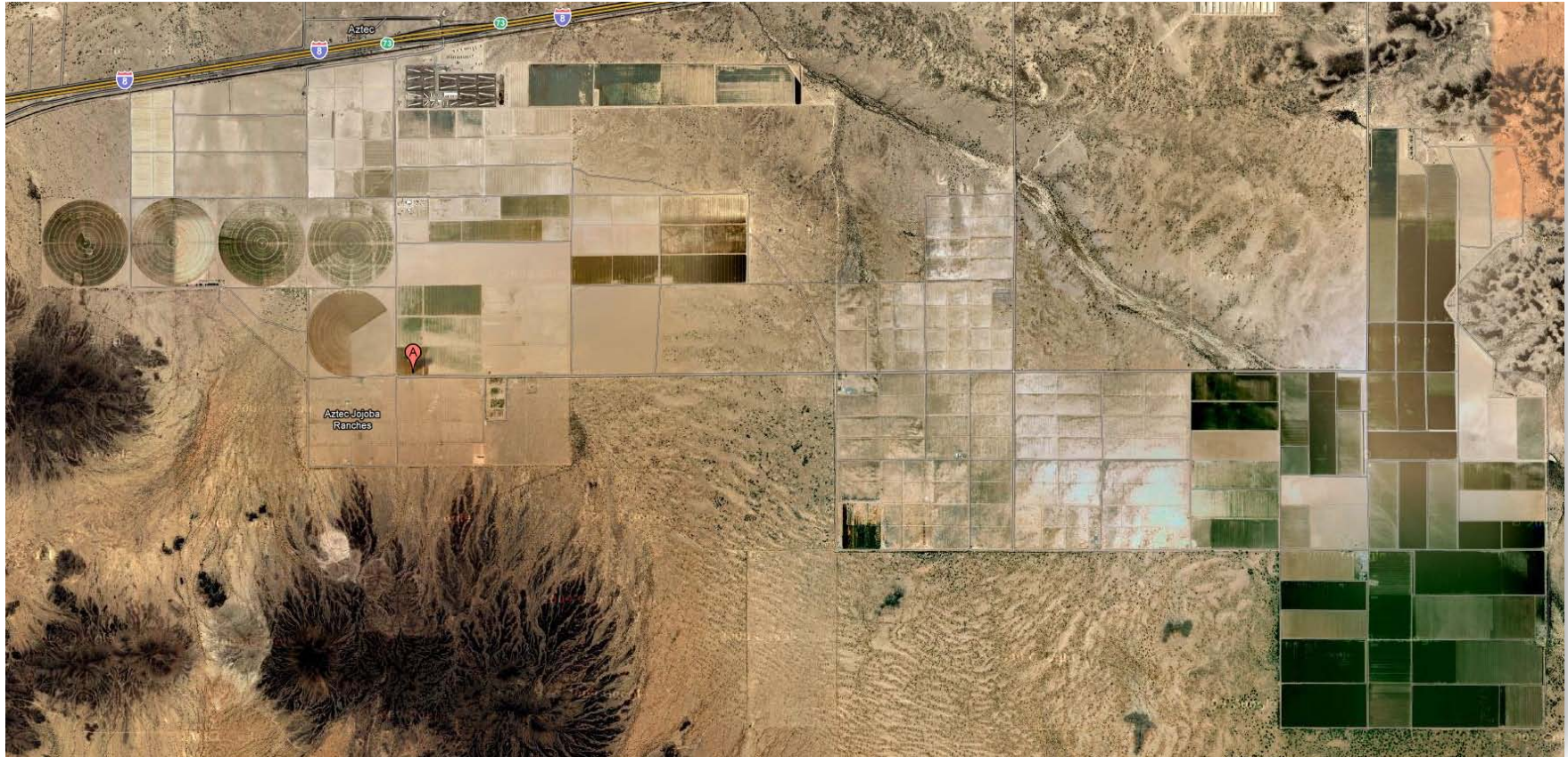


California Forest Fire Animation



Other Land Cover Changes In California

Conversion to farmland



Time (02/2000 to 05/2006)

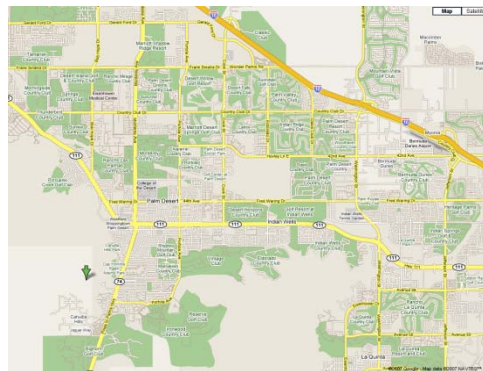
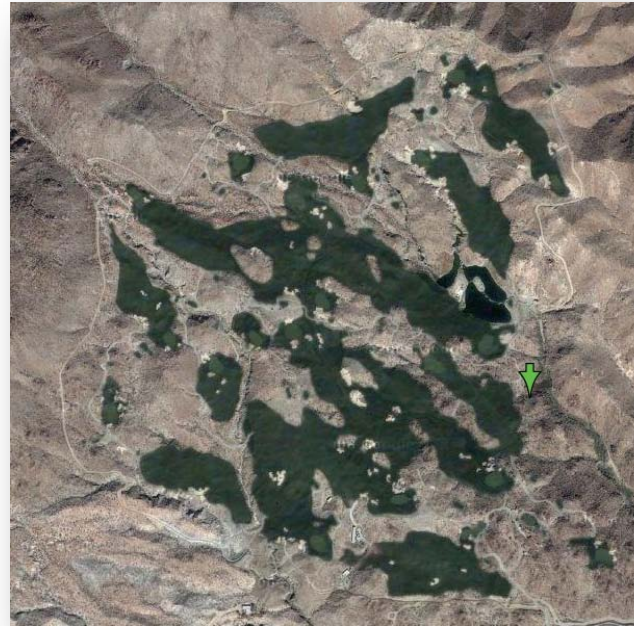
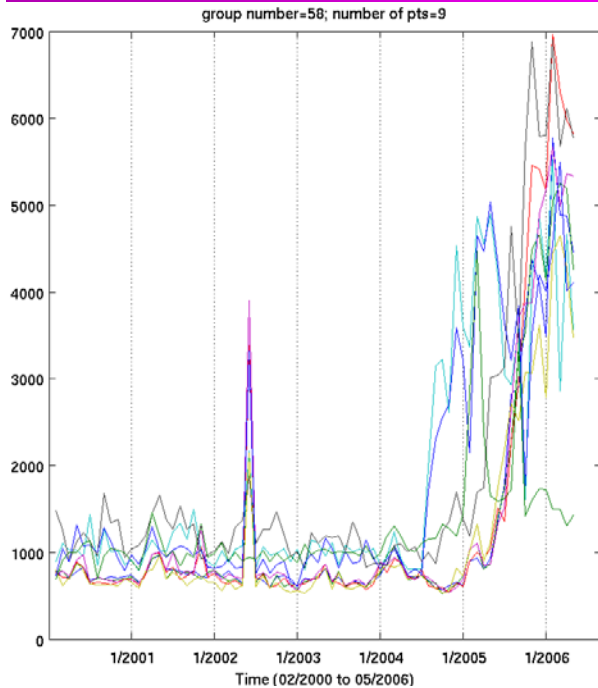
Group of pixels that were all detected by our algorithm, spatially located close to each other

Example: Farmland to subdivision



Location in Sacramento where farm land has been cleared and a subdivision is being built.

Bunch of Golf Courses in SE California Desert



**In the California desert,
they use water like
there's no tomorrow**

THE ASSOCIATED PRESS

PALM DESERT, Calif. — In the middle of the Southern California desert, resort guests can travel by gondola to waterfront bistros, homeowners can water-ski on a manmade lake, and golfers can tee off at more than 100 courses made lush and green from constant watering.

How much longer can this go on?

arrive this fall for the popular Skins Game. The club is one of several spending more than \$200,000 each to drill into the aquifer far beneath the course.

"You don't have a whole lot of choices," Twedt said. "It's not like we'll be put out of business because, thank goodness, we can drill an irrigation well."

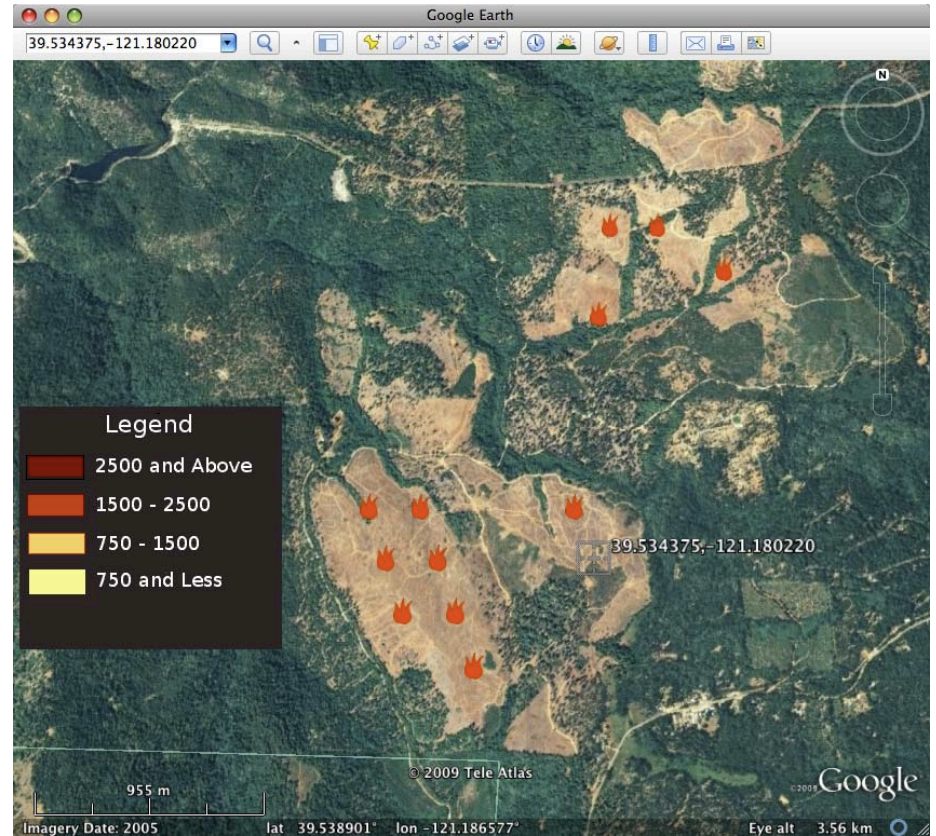
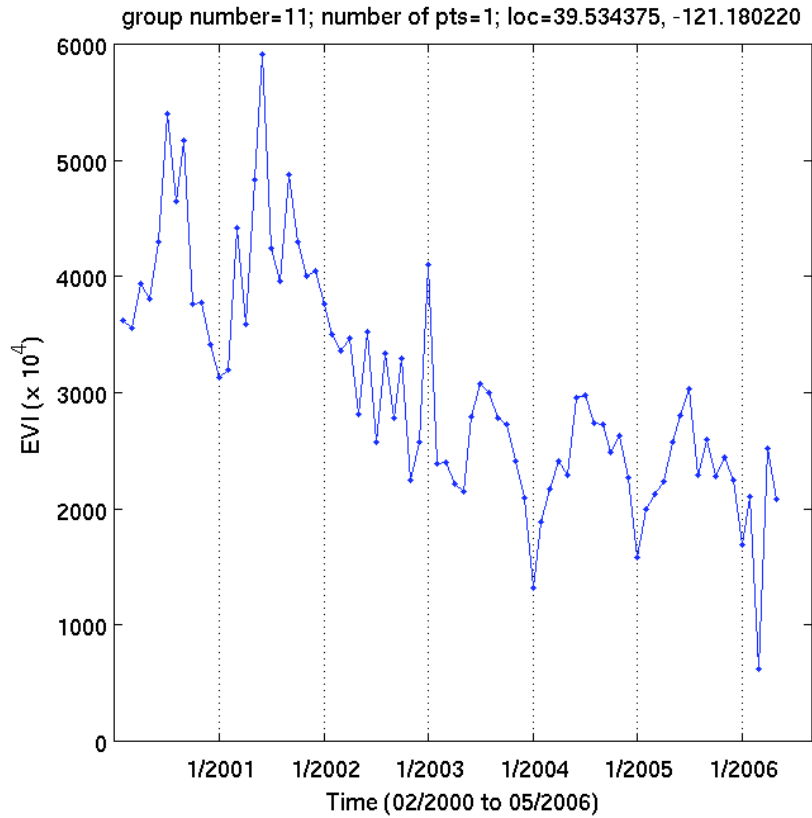
Drilling wells, though, may not be the long-range answer either.

New golf course being built in Palm Desert, CA

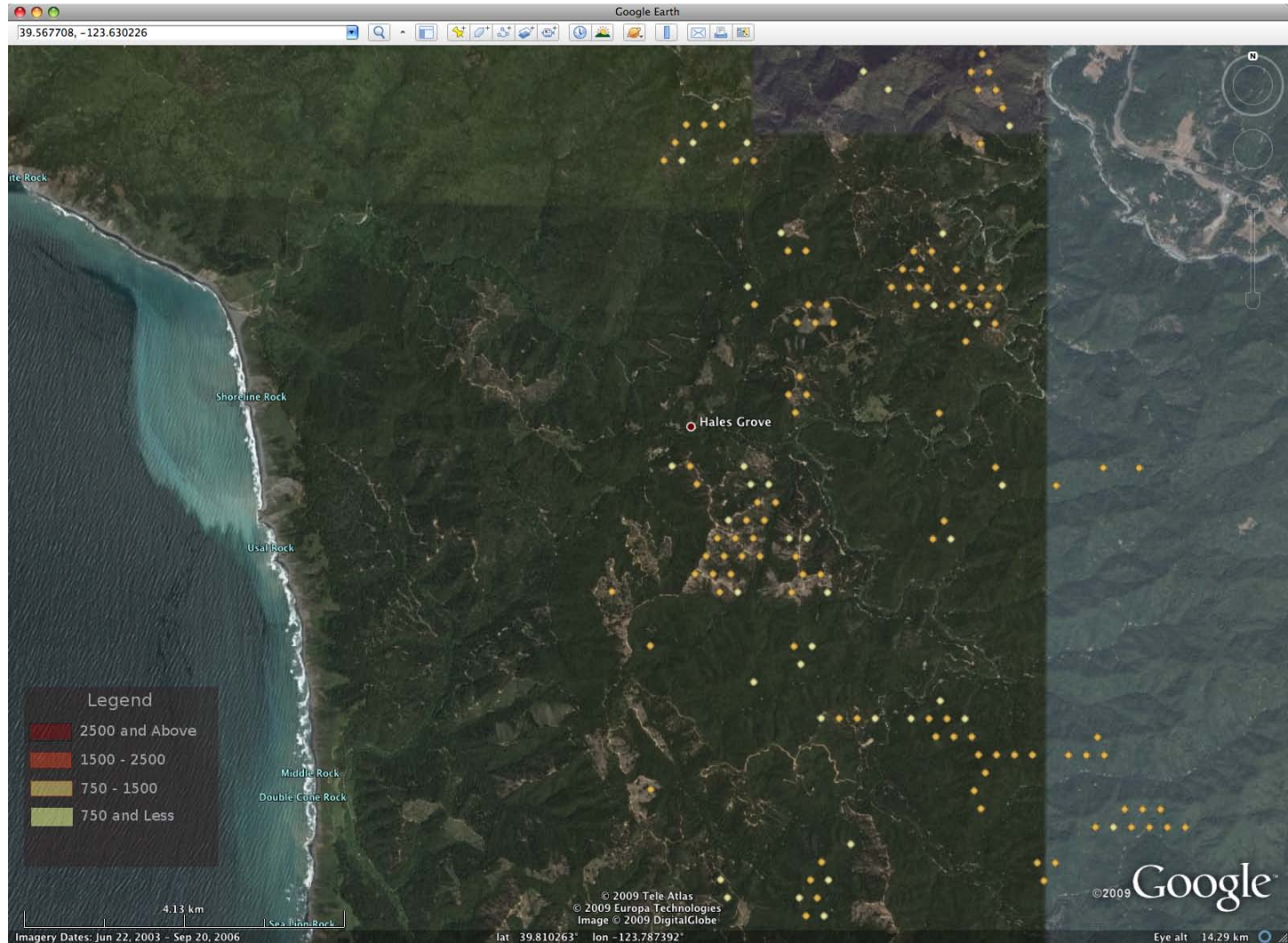
This town has over 100 golf courses, putting intense pressure on the water supply

Boca Raton News

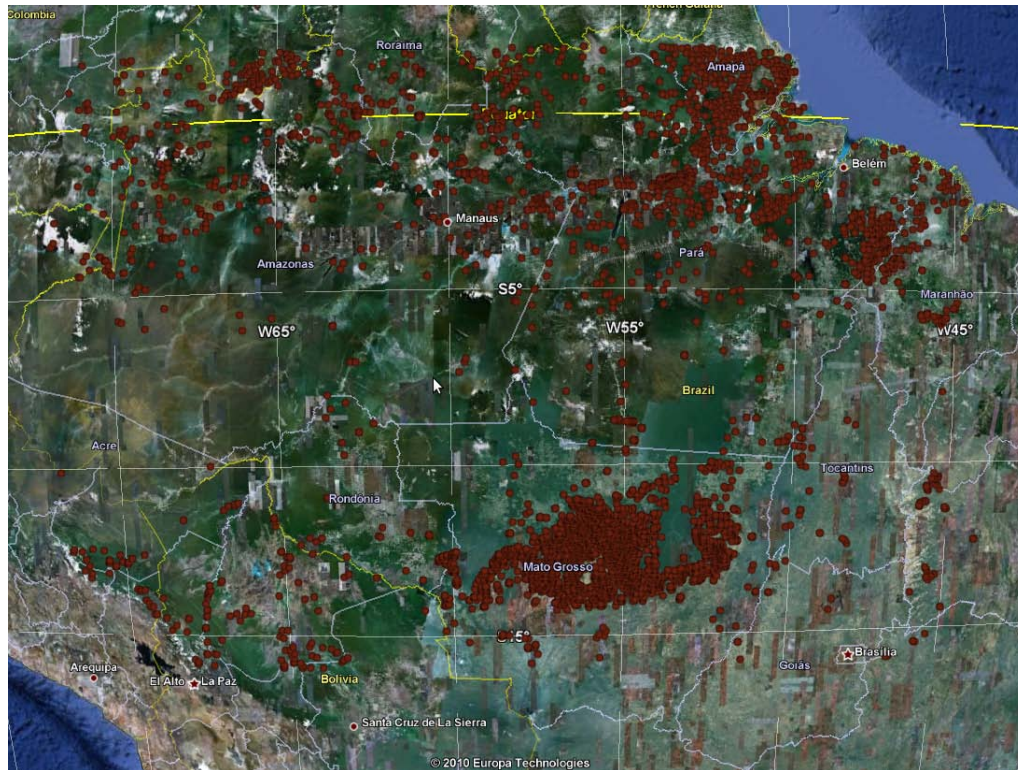
Logging in Northern CA



Logging in Mendocino County, CA



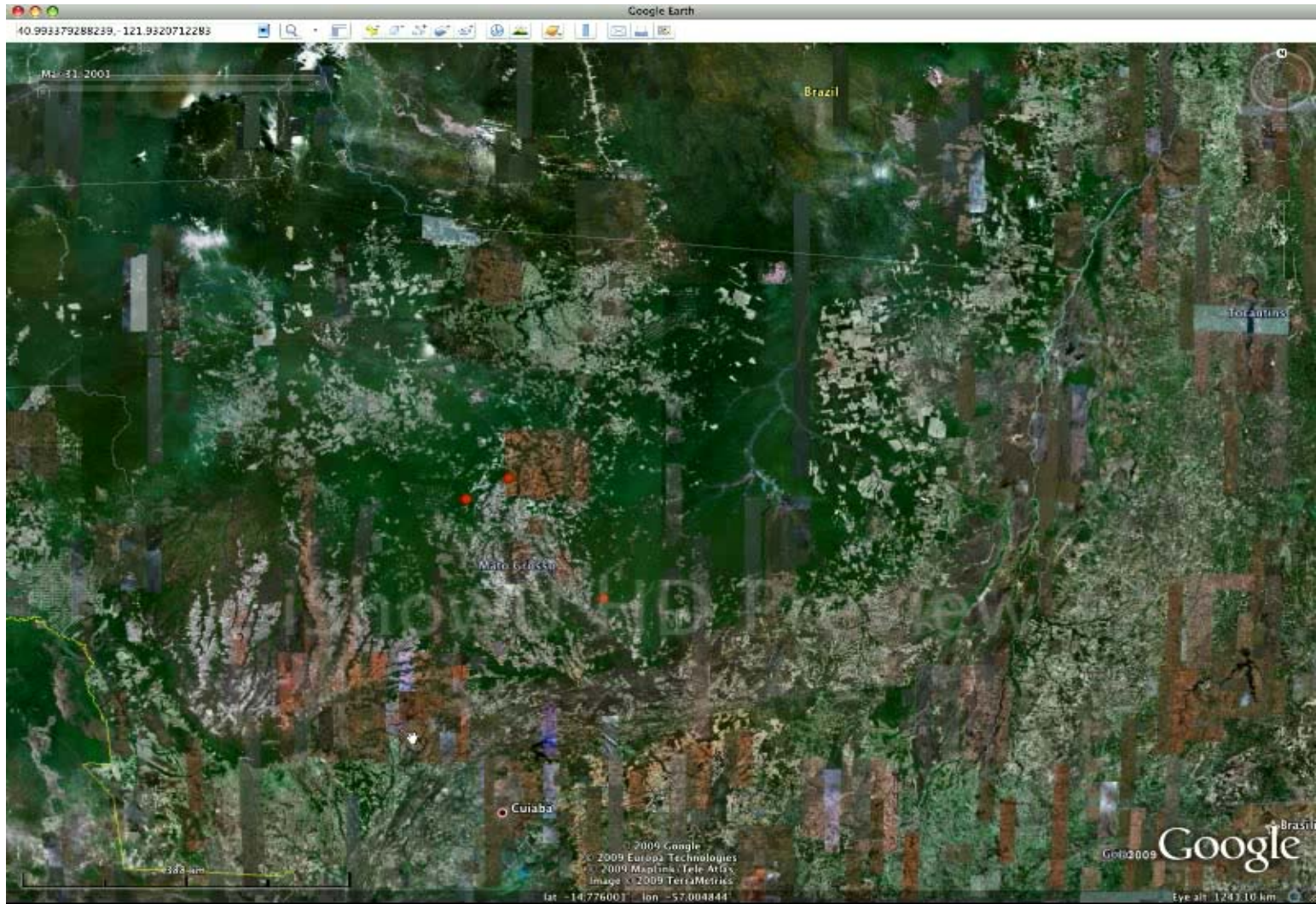
Amazon Rainforest



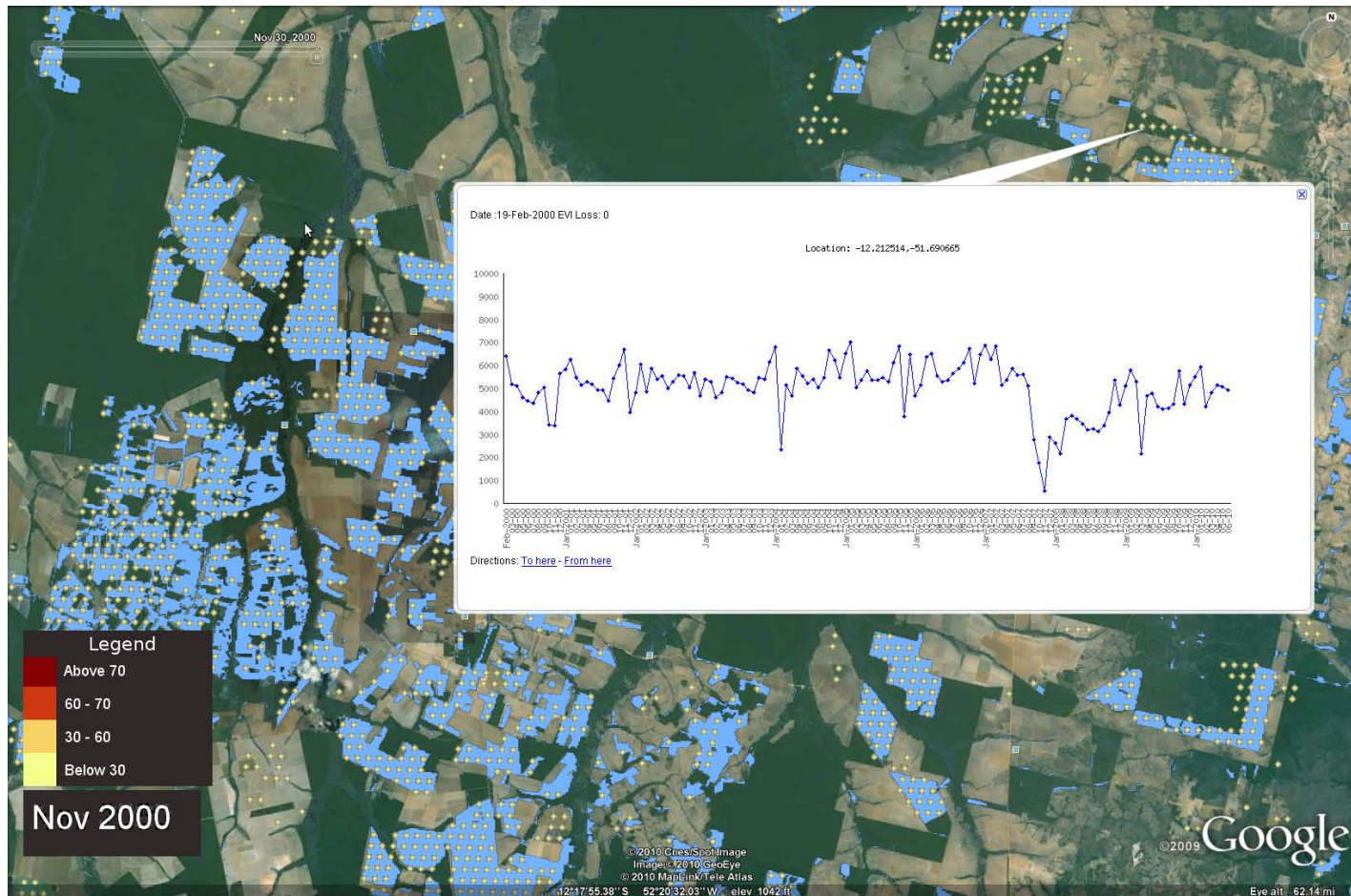
Brazil Accounts for almost 50% of all humid tropical forest clearing, nearly 4 times that of the next highest country, which accounts for 12.8% of the total.



Amazon Animation

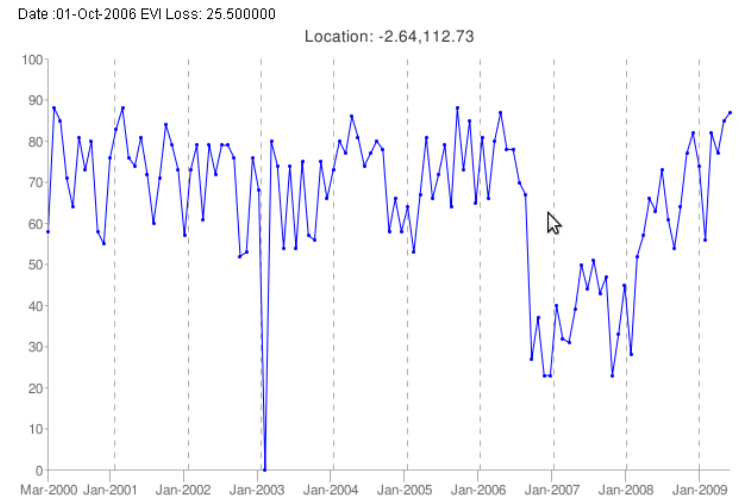


Deforestation in Amazon



The blue polygons are deforestation changes marked by PRODES.
Yellow dots are events detected by our algorithm.

Indonesia



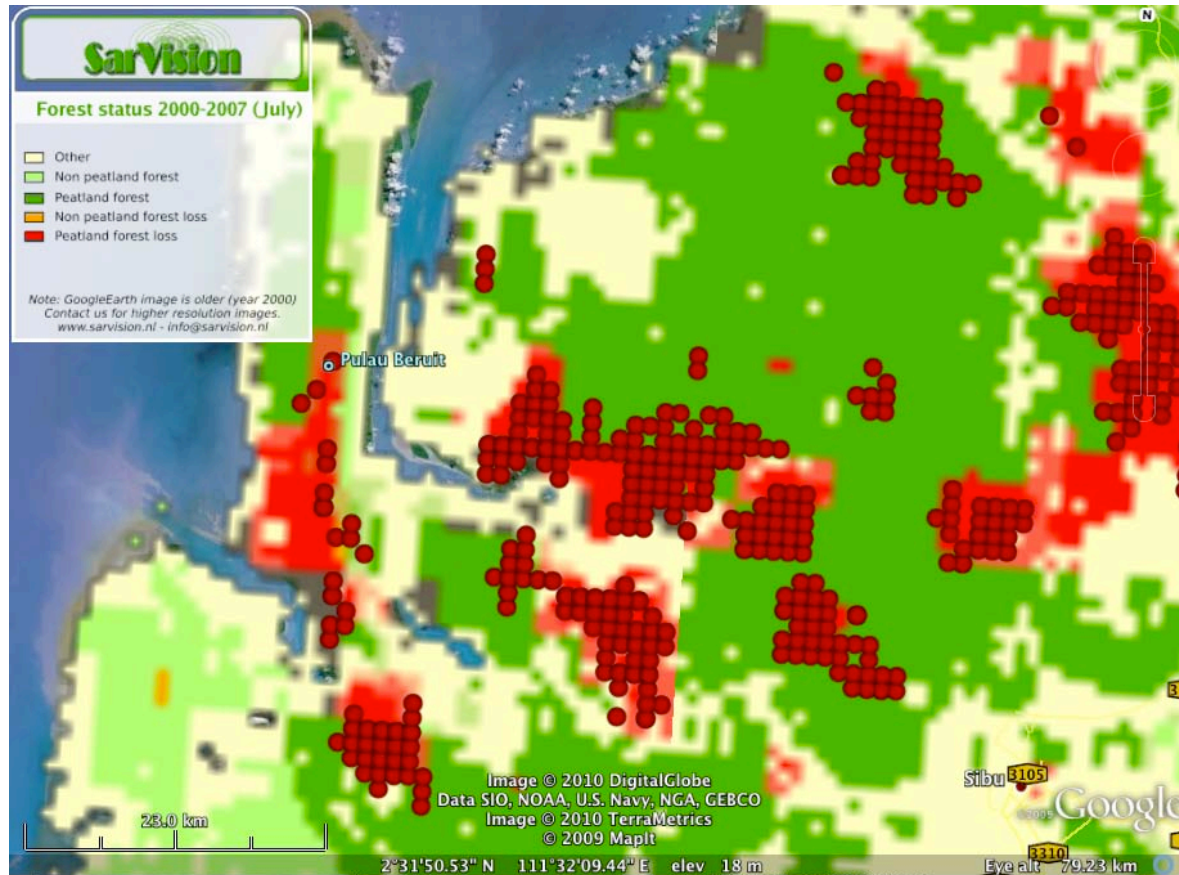
newsV.com

Forest Fires Sweep Indonesia Borneo and Sumatra.

Officials in Indonesia say illegal burning to clear land has caused rampant wildfires across Borneo and Sumatra ... eight million hectares have gone up in smoke over the last month, and fires are still burning out of control on the island of Borneo.

11 September 2006

Evaluation: Forest loss in SE Asia



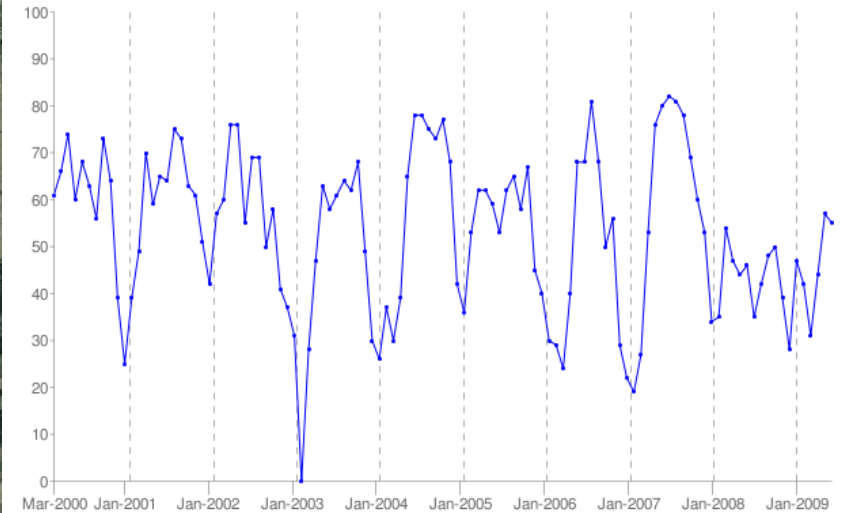
Events detected by our time series change detection algorithms overlaid with a change map generated by SAR Vision group.

Victoria (Australia)



Date :01-Mar-2008 EVI Loss: 21.333333

Location: -37.98,147.4



Drought in southern Australia declared 'worst on record'

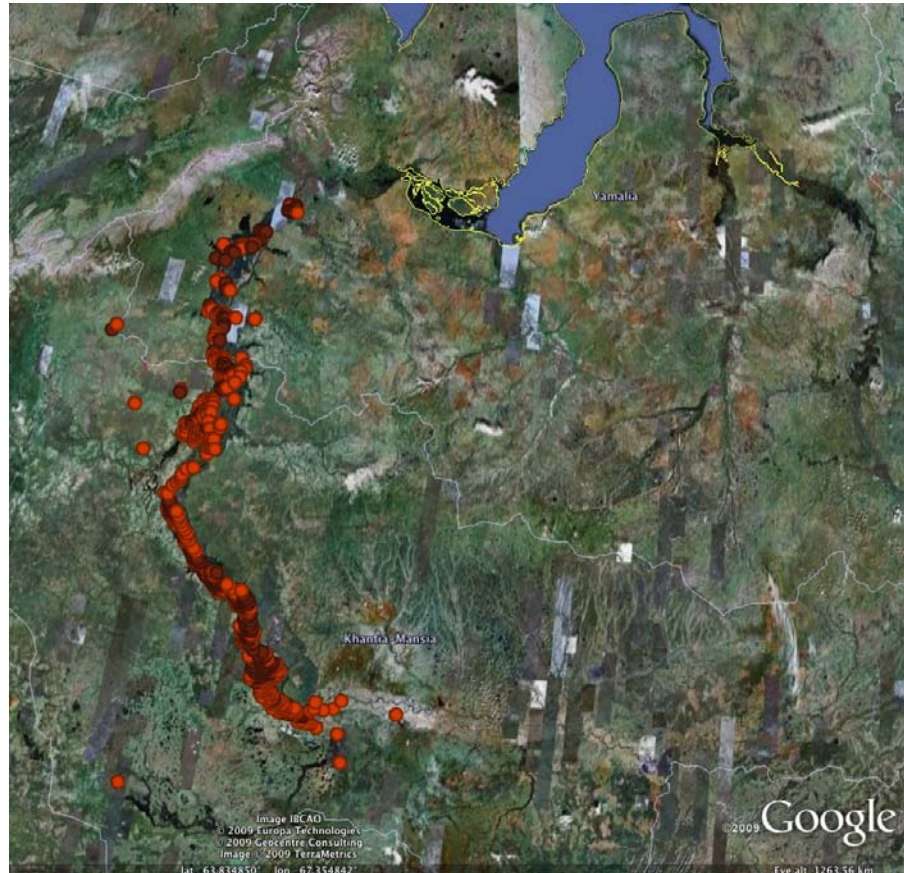
October 10, 2008

David Jones, the head of climate analysis at the Bureau of Meteorology, said the drought affecting south-west Western Australia, south-east South Australia, Victoria and northern Tasmania "is now very severe and without historical precedent".

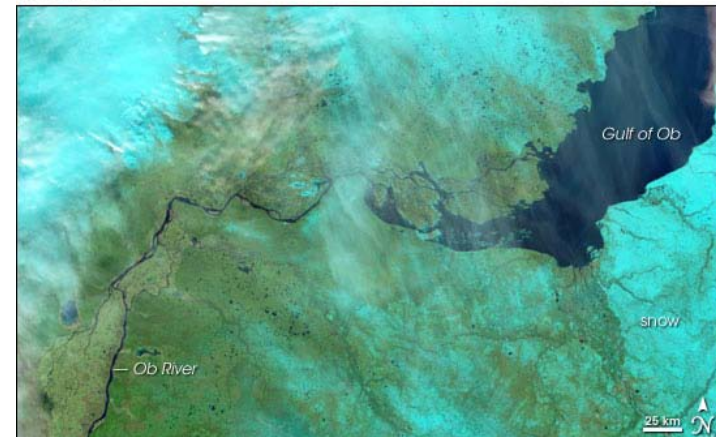


Source: climateprogress.org

Flooding along Ob River, Russia



June 20, 2007

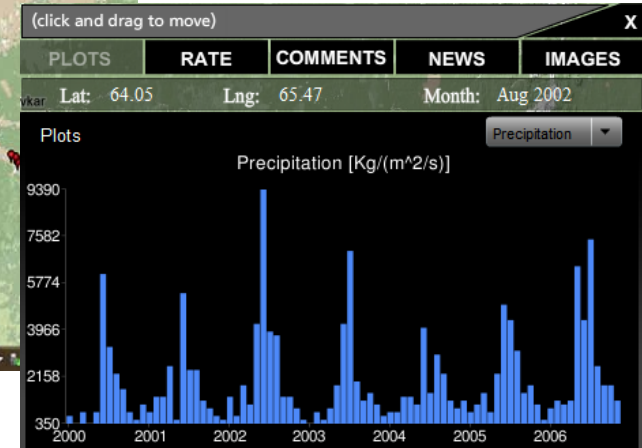
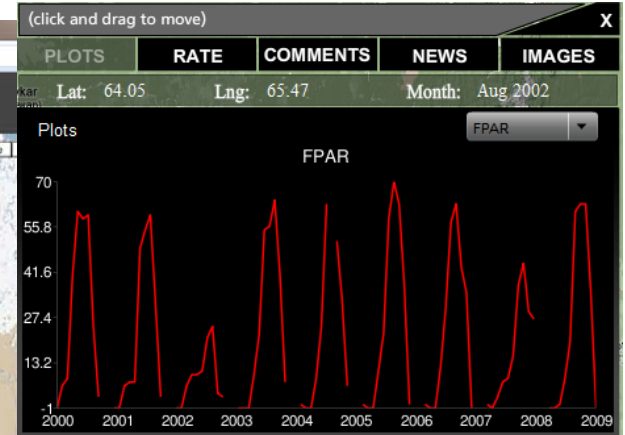
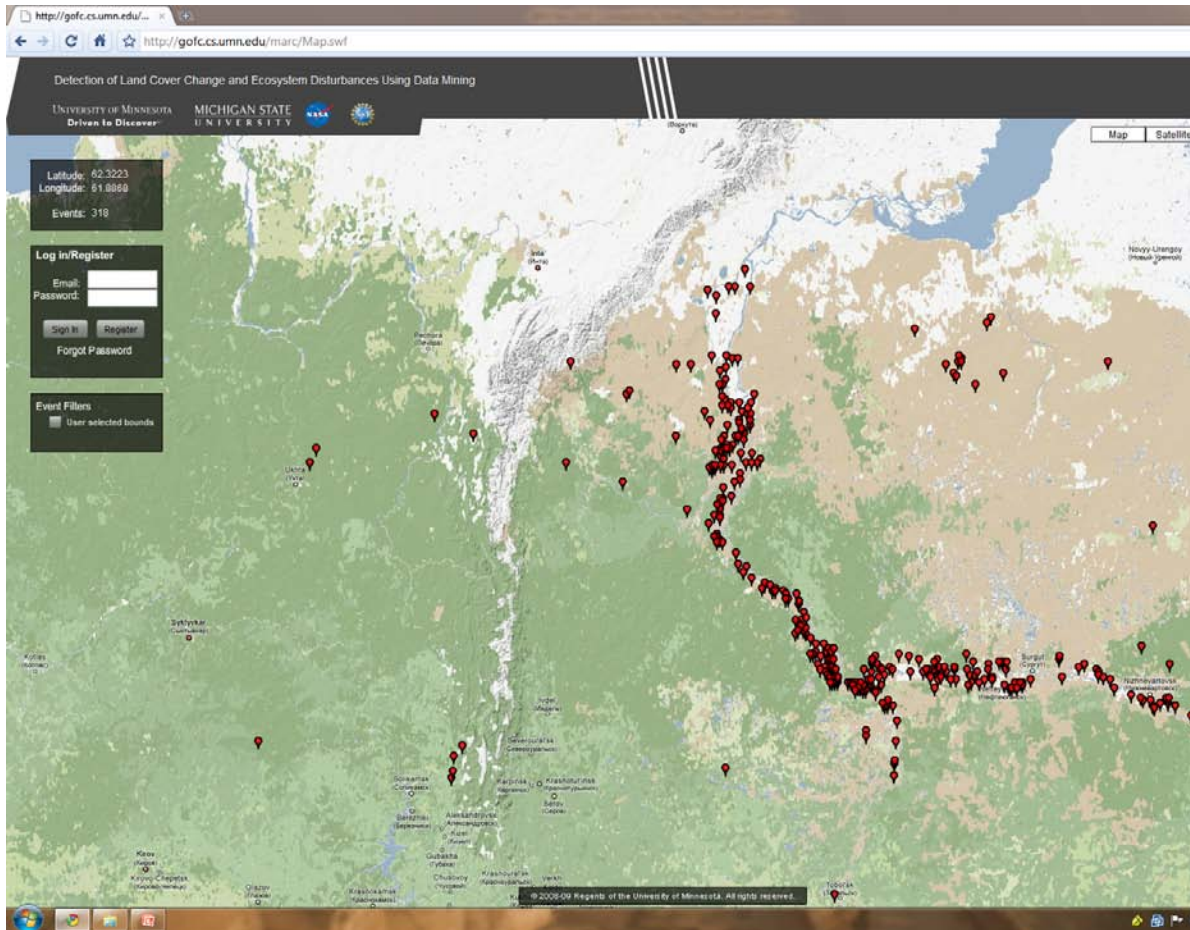


October 5, 2006

The river flows north and is blocked by ice (top right), which causes flooding. Under normal circumstances the river flows into the Gulf of Ob.

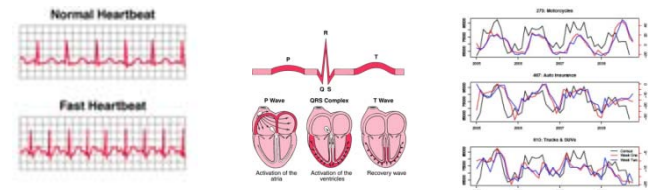
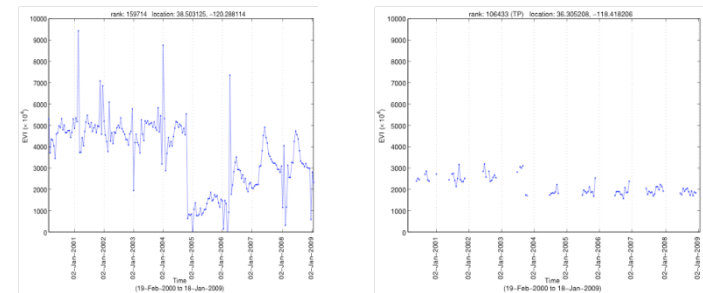
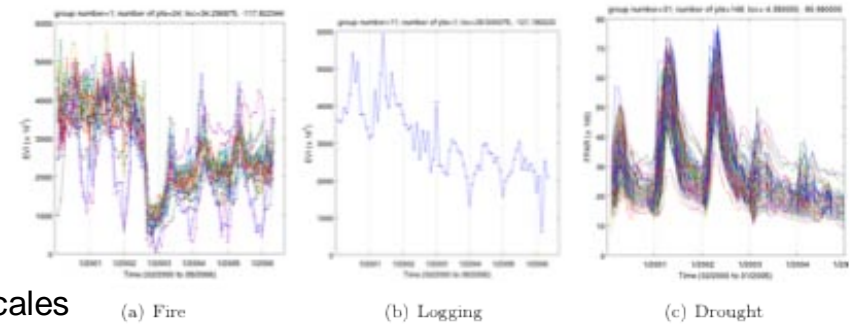
Source: NASA Earth Observatory

Web 2.0 interface for planetary information system



Monitoring Forest Cover Change: Challenges Ahead

- Designing robust change detection algorithms
- Characterization of land cover changes
- Multi-resolution analysis (250m vs 1km vs 4km)
 - Different kinds of changes are visible at different scales
- Multivariate analysis
 - Detecting some types of changes (e.g. crop rotations) will require additional variables.
- Data quality improvement
 - Preprocessing of data using spatio-temporal noise removal and smoothing techniques can increase performance of change detection.
- Incremental update and Real-time detection
- Spatial event identification
- Applications in variety of domains:
 - Climate, agriculture, energy
 - Economics, health care, network traffic



Source: Merck, Google.

Application of a Global Land Cover Monitoring System

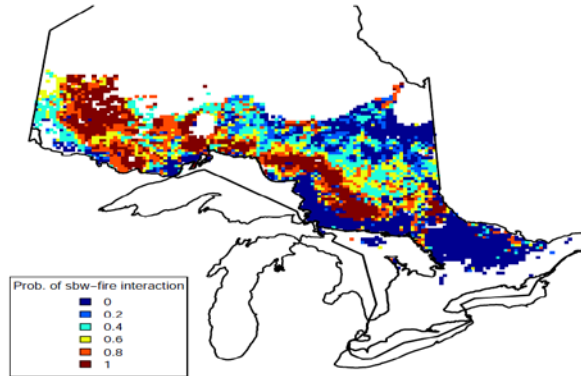
- Risk Analysis
 - Input to carbon trading
 - United Nations REDD(Reducing Emissions from Deforestation and Forest Degradation) program for protecting forests.
- Inform Policy Makers and Public at large
- Climate Change Research
 - What is the impact of climate change on ecosystems?
 - What is the relationship of bio-fuel subsidy to deforestation dynamics and greenhouse gas emissions ?

What is the impact of climate change on ecosystems ?

Warmer Winters in Canada makes it a net emitter of Carbon



Winters have not been cold enough to kill off mountain beetles



Insect Damage and Fires Are Causally Related

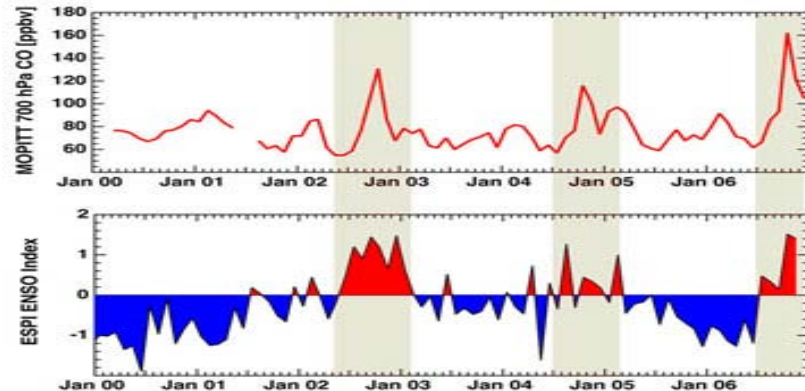


Fire in Yukon Province, Canada

2006 Fires in Indonesia were worsened by el Nino says NASA



Source: CCIAP Project, NASA



Peaks of CO coincide with warm phases of El Niño

What is the relationship between bio-fuel subsidy and deforestation dynamics ?

Biofuel



Increased corn production



A tiny sliver of transitional rainforest is surrounded by hectares of soybean fields in Mato Grosso, Brazil

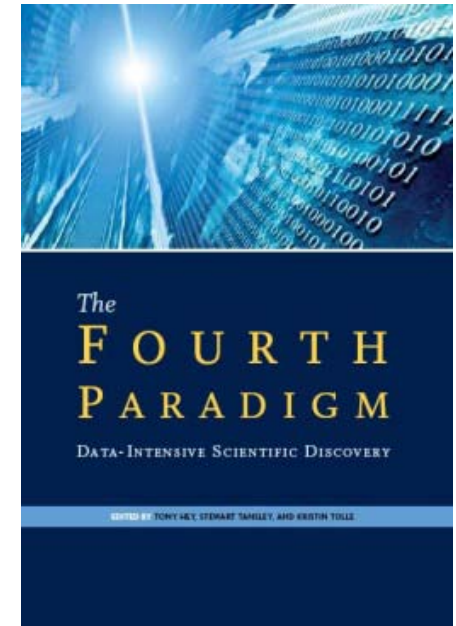
SCIENTIFIC AMERICAN

Biofuel Showdown: Should Domestic Ethanol Producers Pay for Deforestation Abroad?

Source: Time, Climate Central

Summary

- Data driven discovery methods hold great promise for advancement in the mining of climate and eco-system data.
- Scale and nature of the data offer numerous challenges and opportunities for research in mining large datasets.



"The world of science has changed ... data-intensive science [is] so different that it is worth distinguishing [it] ... as a new, fourth paradigm for scientific exploration." - Jim Gray

Project website

Climate and Eco-system: www.cs.umn.edu/~kumar/nasa-umn