Wildfire semi real time monitoring and modeling using MODIS data

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Needs for better understanding

- Wildfire is a natural and fundamental disturbance regime essential in controlling many ecosystem processes, helping to shape landscape structure, improve the availability of soil nutrients, and initiate natural cycles of plant succession [UNEP, 2001].
- Fire behaviors (ignition, expansion, and extinction) are indispensable to simulate carbon budget of a fire-prone forests on the basis of an ecophysiological carbon cycle model (Sim-CYCLE) [Itoh, 2005].
- Since a lot of forest fires take place in hardly accessible areas, remote sensing seems to be the most appropriate tool to monitor fire behaviors in forests.
- Monitoring active fire mapping would require wide coverage and frequency, such as from NOAA AVHRR or Aqua/Terra MODIS.

Objectives of this study

- To set up the near-real time network based active fire mapping and carbon-cycle modeling system over Asia using MODIS.
  - MODIS data providing scheme for active fire monitoring is presented.
  - A coupling of hot spot information with a carbon-cycle model is introduced.
  - Our current status of fire product production and algorithm is presented and the way to obtain them through FTP or WWW is described.
  - Some caveats to bear in mind when using our fire product and our future works are described for the refinement of our algorithm.

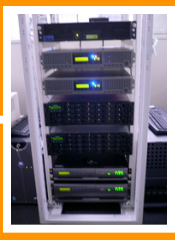
Integration of remote sensing and modeling

Direct broadcast

MODIS/AVHRR (IIS)

MODIS/AVHRR (AIT)

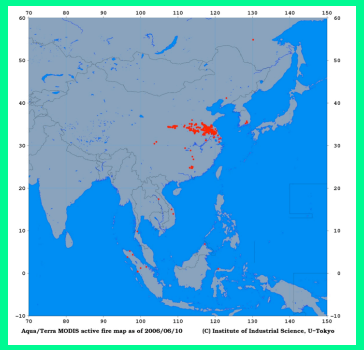
Receiving



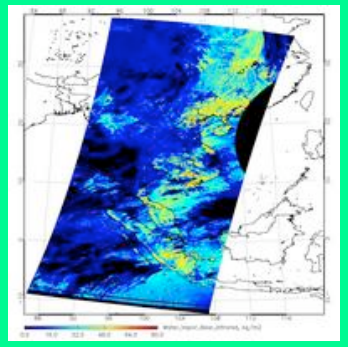
Archiving

Processing

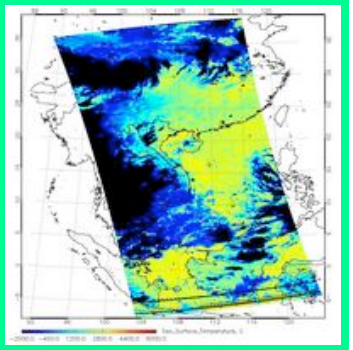
Thematic map



Forest fire

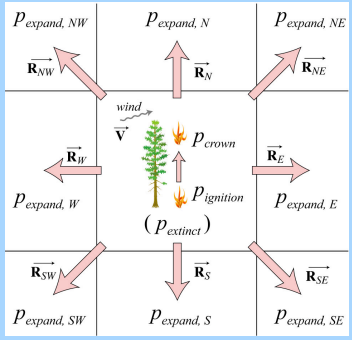


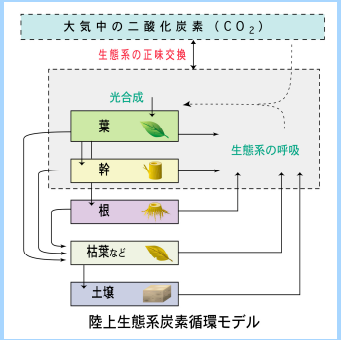
Water vapor



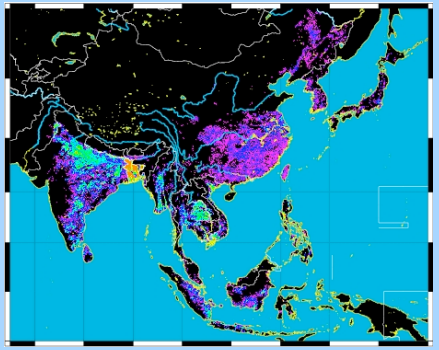
Cloud

Prediction of disaster or environmental change



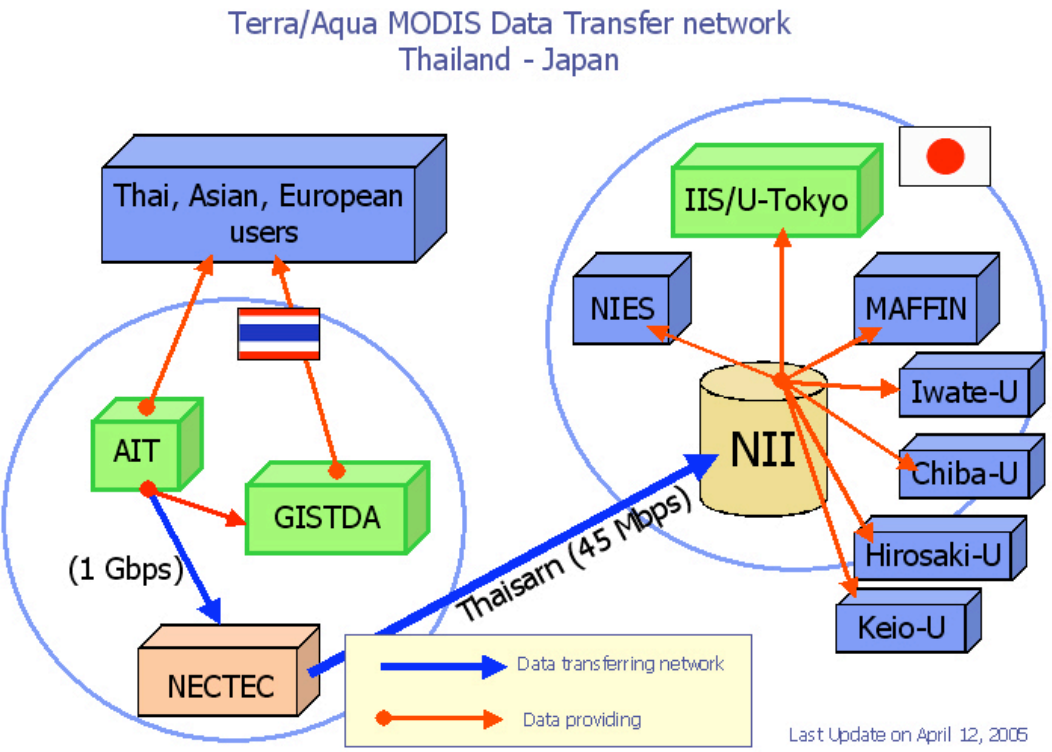


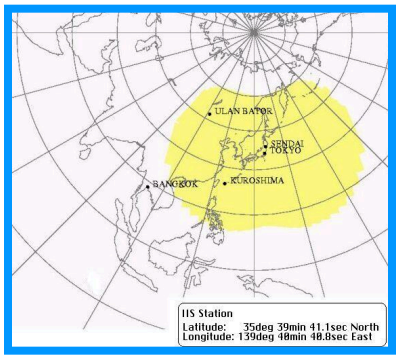
CO2 and forest fire spread prediction with sym-cycle

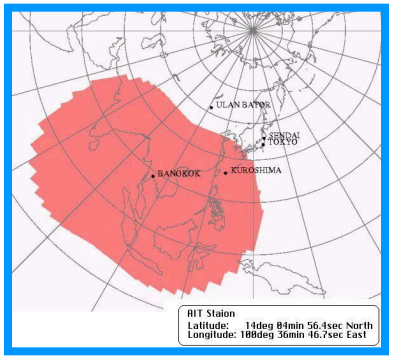


Rice paddy (CH4)

Scheme of network based monitoring



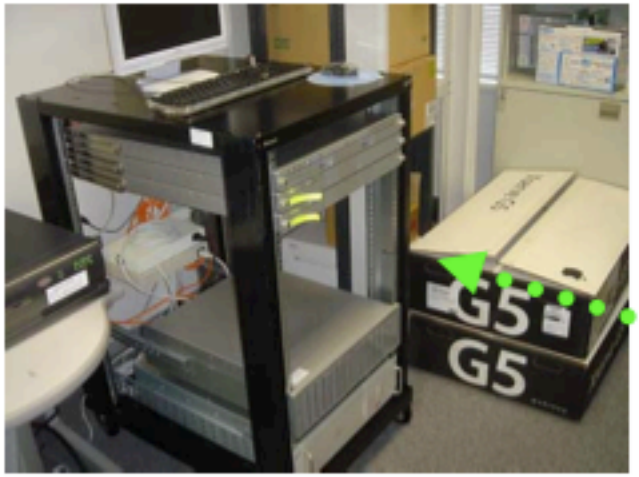


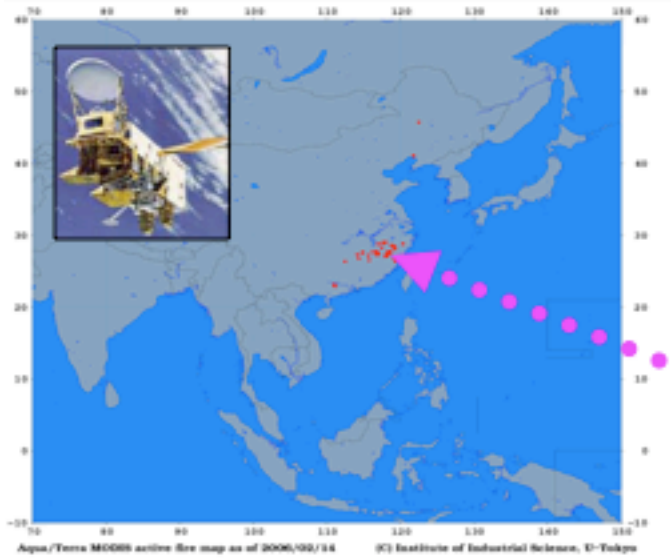


IIS/U-Tokyo **ACRoRS/AIT**

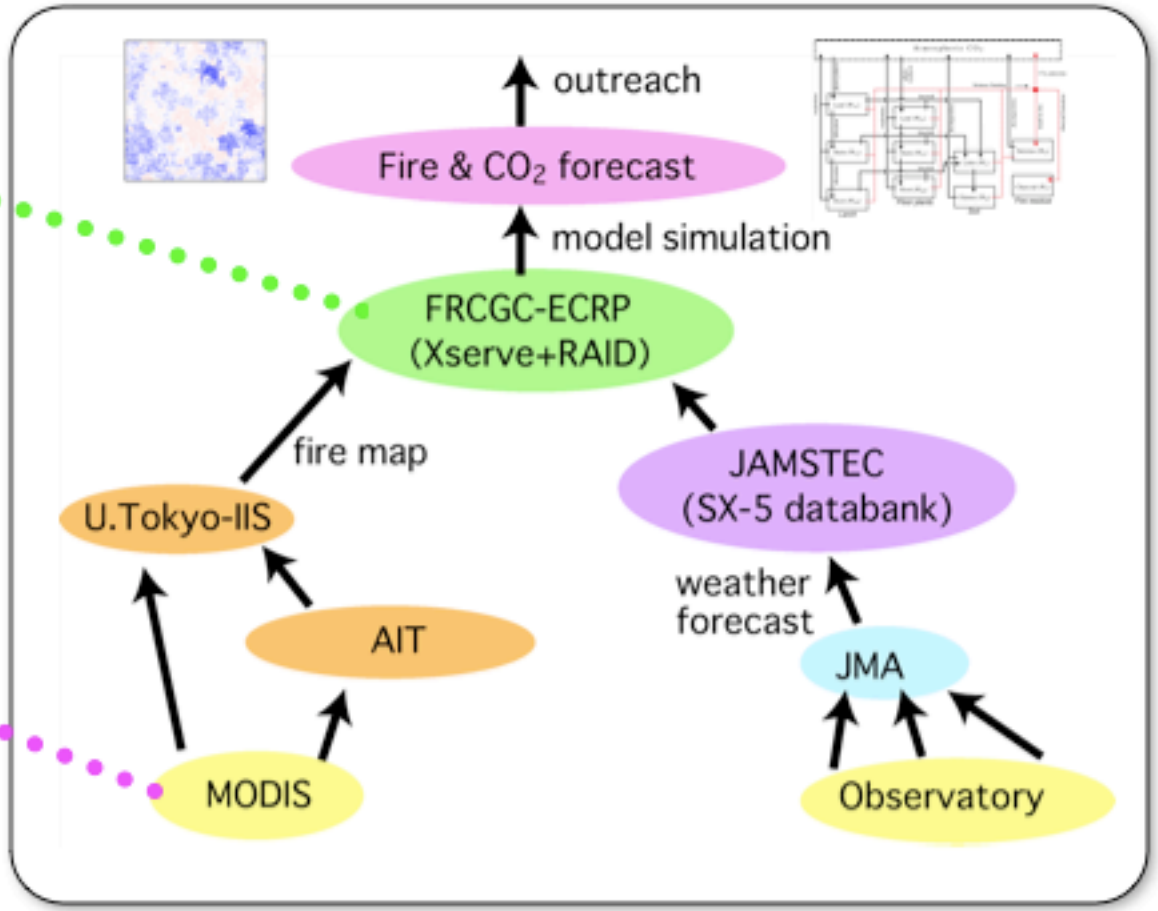
- Two MODIS antennas are installed at IIS/U-Tokyo in Japan and ACRoRS/AIT in Thailand and work to monitor earth environmental monitoring.
- All MODIS data are transferred to IIS/U-Tokyo via FTP and is kept in online tape archiving database with 600TB of volume.
- The scheme has started in 2001 May and has been working fully automatic aided by grid computers through network.

From satellite monitoring to modeling



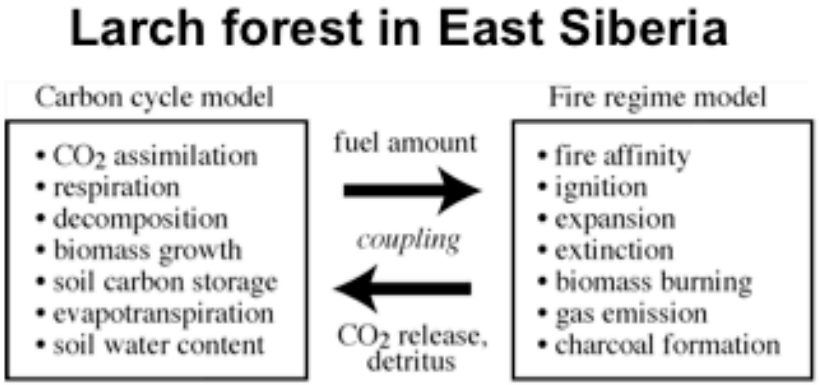


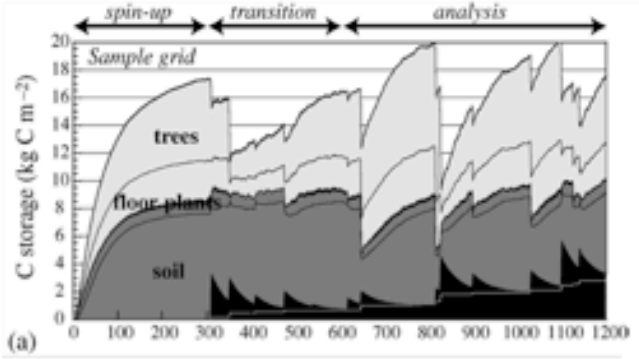
JST-SORST Project (PI. Y.Yasuoka)

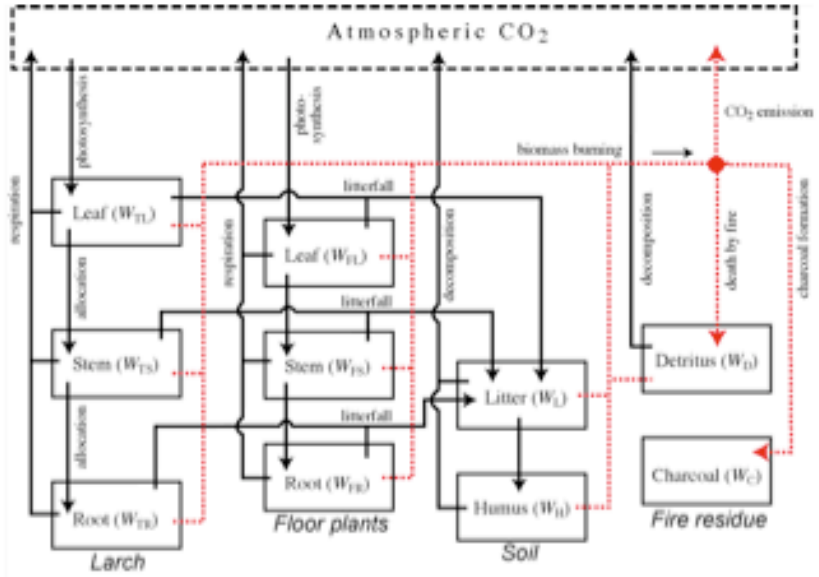


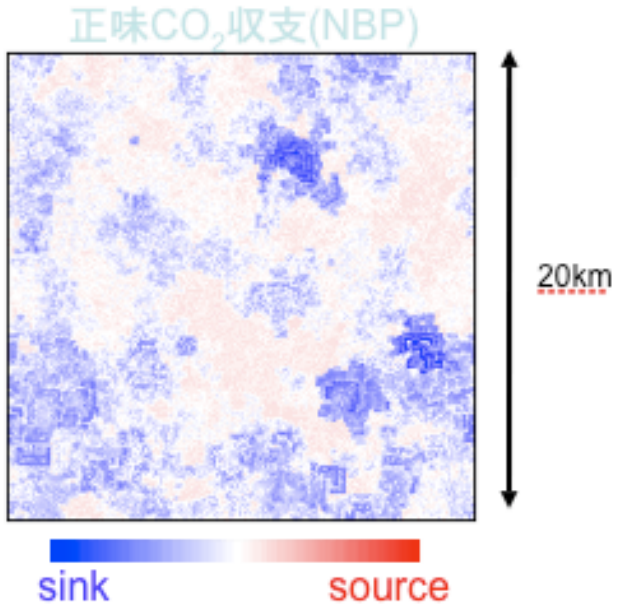
by Dr. A. Ito, D. Dye and H. Kobayashi

CO2 estimation with MOD-FIRE-SIMCYCLE



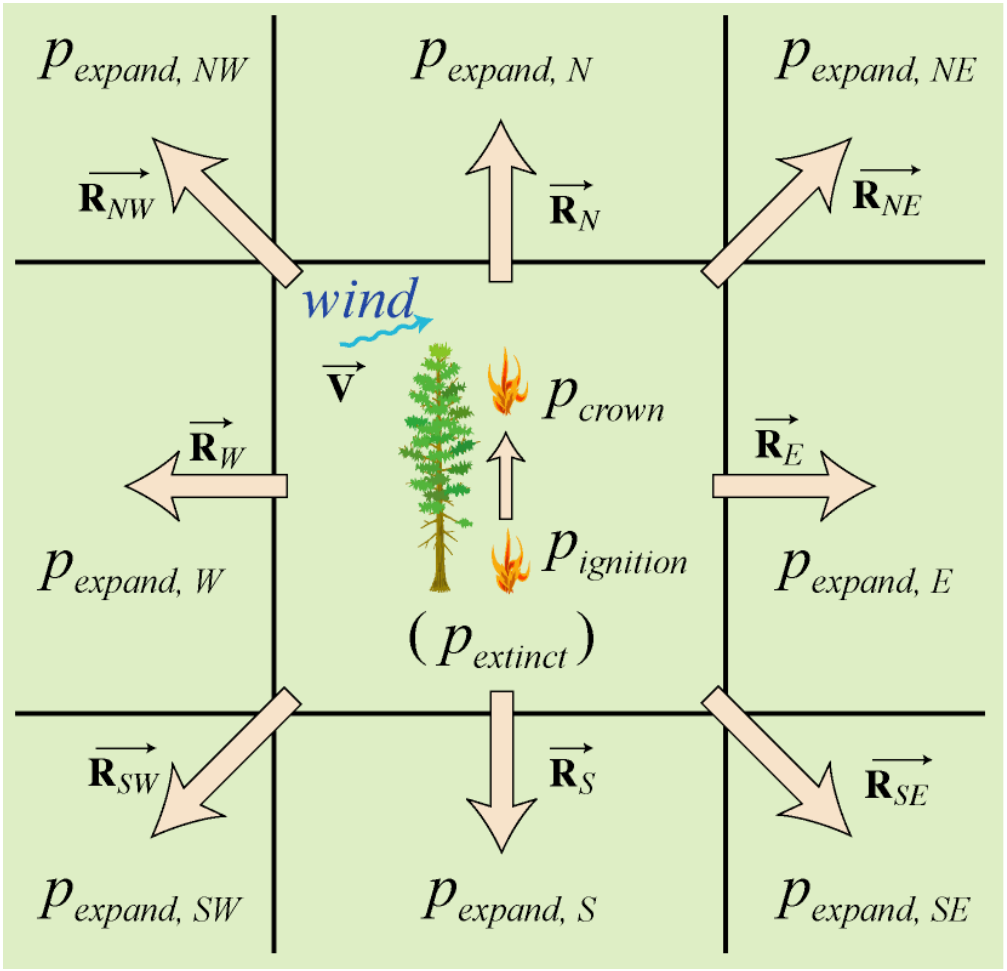






Ito, A. 2005. Modelling of carbon cycle and fire regime in an east Siberian larch forest. *Ecological Modelling* **187**:121-139.

Fire forecasting with modeling



- Stochastic processes
  (time-homogeneous Markov chain)
  (pseudo-random numbers by the MT method)
- Environmental effect
  FA (Fire Affinity)
  FA = f(Air Temp)•f(Air Hmd)
  •f(Tree C)•f(Shrub C)
  •f(Soil C)•f(Soil Water)

$p_{ignition} = f_1\,(FA) + p_{human}$

$p_{expand} = f_2\,(FA, |\vec{V}\bullet\vec{R}|)$

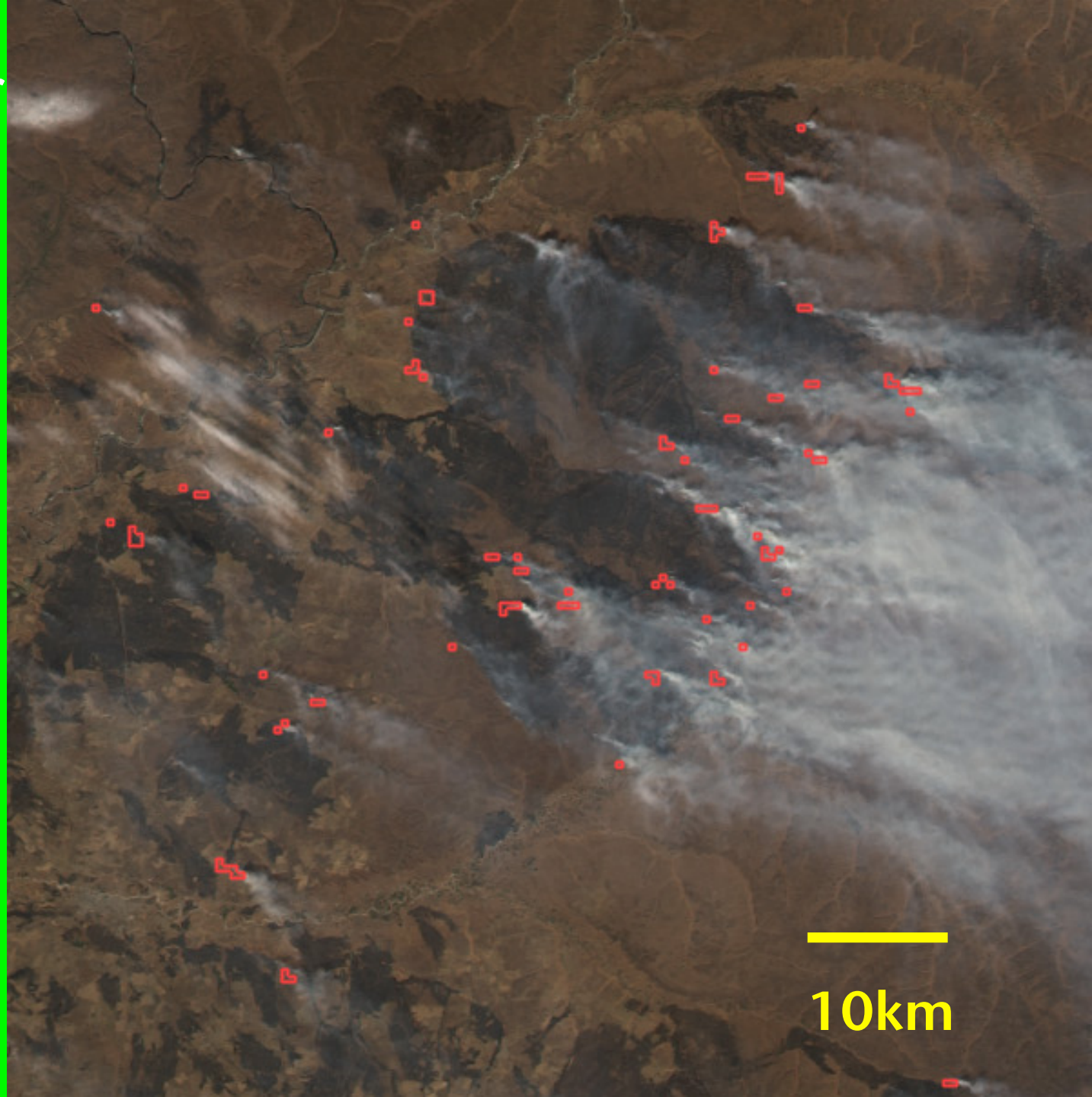
$p_{extinction} = f_3\,(FA)$

- Floor fire to crown fire

$p_{crown} = f_4\,(FA)$

by Dr. A. Ito, D. Dye and H. Kobayashi

Wild fires in Far East Russia



Active burning spot is shown by red rectangles.

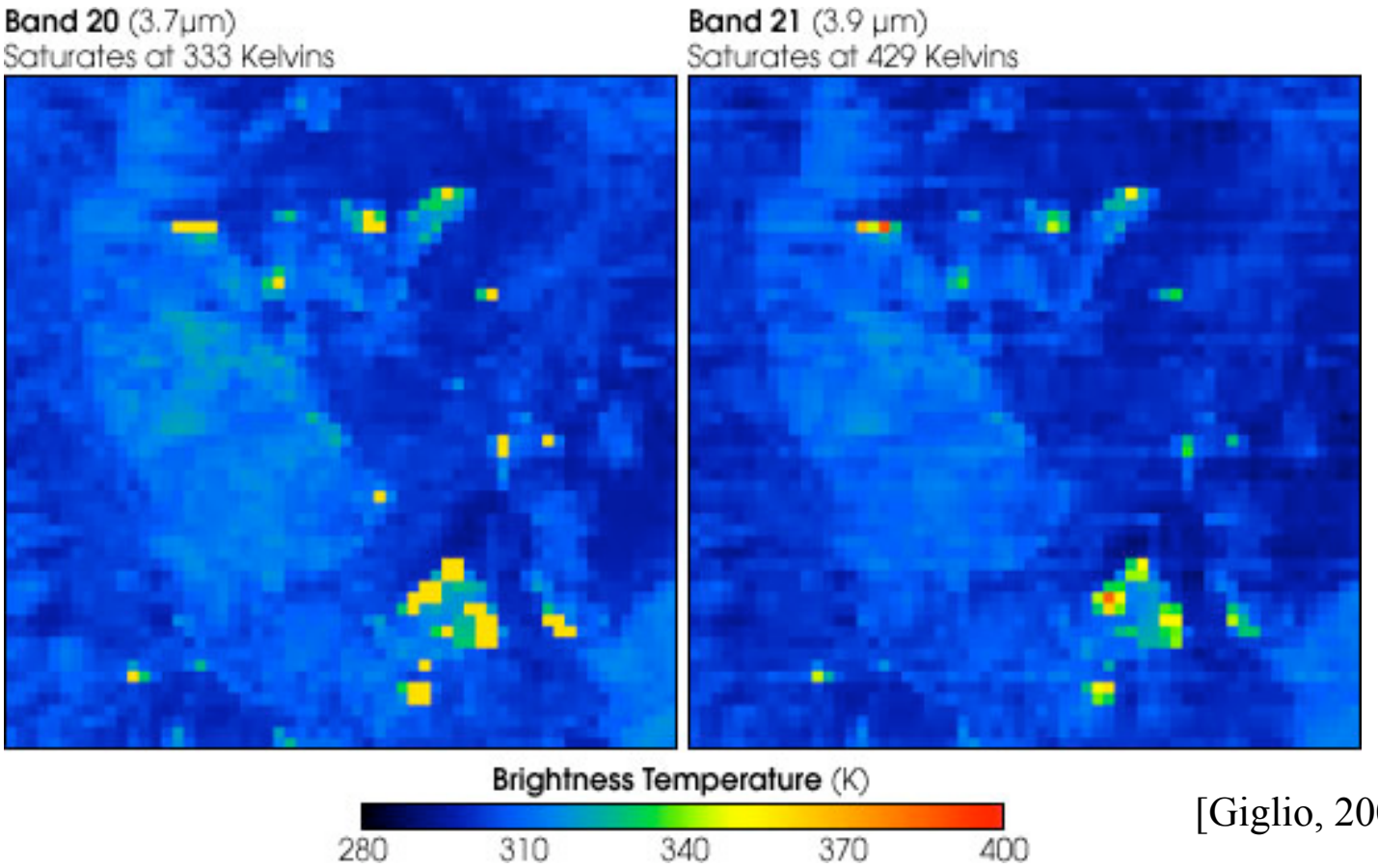
Terra MODIS

2005 Oct. 2005 2:35 (UTC)

Why on MODIS?

- High spatial resolution data such as Landsat TM, SPOT HRV and Terra ASTER may not cover an target area frequently because of their narrow swath width and not suitable for continental-scale and rapid monitoring.
- Another objection to monitoring the fire with higher spatial resolution data is cost and logistics of handling the data volume.
- The MODIS instrument has two 4μm channels, numbered 21 and 22, both of which are specially designed and useful for fire monitoring.

Saturation problem in 4μm channels



[Giglio, 2003]

Description: This pair of images was acquired by MODIS on Aug. 23 over Montana and Idaho; each image is 60 by 60 pixels and a single pixel is 1 square kilometer. The image on the left was made using MODIS' channel 20 (centered at 3.7 micrometers); this image approximates the capability of the NOAA Advanced Very High Resolution Radiometer (AVHRR) to detect fires and measure their intensities. The image on the right uses MODIS' channel 21 (centered at 3.90 micrometers). Notice how MODIS channel 21 shows greater sensitivity to the temperatures of the fires, which can help fire scientists pin point where there are active flaming fires and where fires are less intense or smoldering. This is important because large smoldering fires can contribute heavy amounts of pollutants into the atmosphere, while active flaming fires are often where fire firefighters concentrate their efforts for containment and suppression.

Physics of active fire detection

- Active fire detection basically uses brightness temperatures derived from the MODIS 4-and 11-μm channels, denoted by T22 and T31, respectively.
  - channel 21 saturates at nearly 500 K
  - channel 22 saturates at 331 K
  - since the low-saturation channel (22) is less noisy and has a smaller quantization error, T22 is derived from this channel whenever possible.
  - when channel 22 saturates or has missing data, it is replaced with the high saturation channel to derive T22.

Fire detection algorithm

- Active fire detection follows the rules;
  - Basically after (Giglio et al., 2003) and improvement is applied to several thresholds on the following conditions.
  - All pixels for which $T_4 < 315$ K (305 K at night) or $\Delta T_{41} <$ 5 K (3 K) are not considered as fires.
  - If the standard deviations dT_{4b} and $d\Delta T_{41b}$ are less than 2 K, then 2 K is used instead.
  - A pixel is defined as a fire pixel (from the remaining fire pixels) if one of the following five combinations of logical conditions.

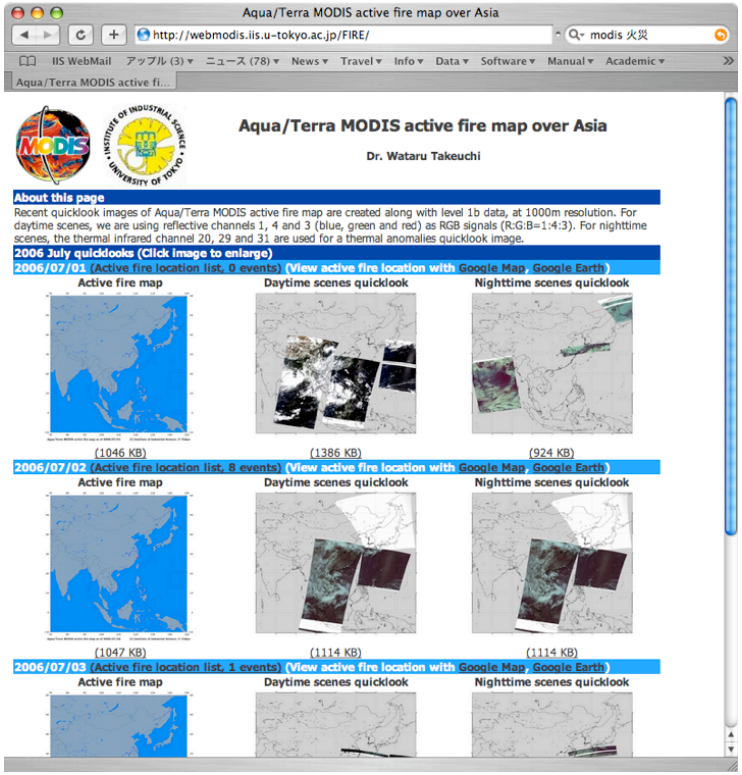
$$\{ [(T_4 > T_{4b} + 4\delta T_{4b}) \text{ or } T_4 > 320 \text{ K (315 K at night)}] \underline{\text{and}}$$
$$[(\Delta T_{41} > \Delta T_{41b} + 4\delta \Delta T_{41b}) \text{ or } T_{41} > 20 \text{ K(10 K)}] \} \text{ or } \{T_4 > 360 \text{ K (330 K)}\} \quad (1)$$

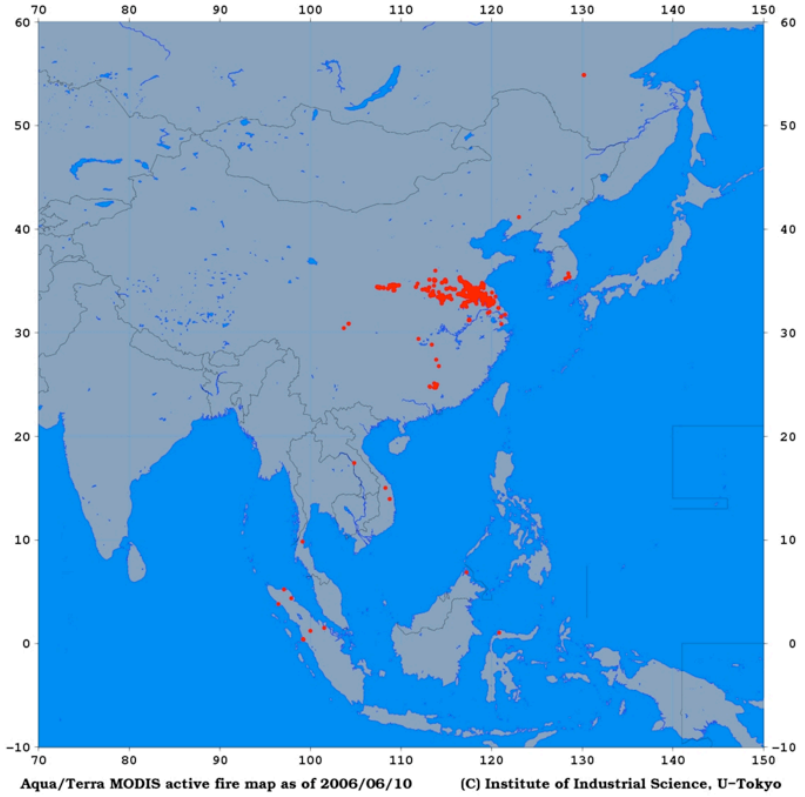
Fire detection algorithm (cont'd)

- Cloud detection and scan angle check;
  - the presence of clouds is determined using the MODIS cloud mask scheme.
  - scan angle cut-off is enforced to limit problems at extreme view angles.
- Atmospheric correction;
  - apparent temperatures T4 and T11 are corrected for gaseous and water vapor absorption 11 μm.
- Background characterization;
  - relationship between the apparent temperatures of the examined pixel and its surrounding pixels is established.
- Glint exclusion;
  - exclude a fire pixel during the day if it corresponds to glint measurements

Obtaining fire product

- The are are mainly two ways to obtain our MODIS fire products;
  - Anonymous FTP at WebMODIS or SORST/IIS WWW.
  - Currently fire product in hdf and ascii text format is available online during 2002 Jan - present over IIS and AIT coverage (22,514 scenes).





Fire product description

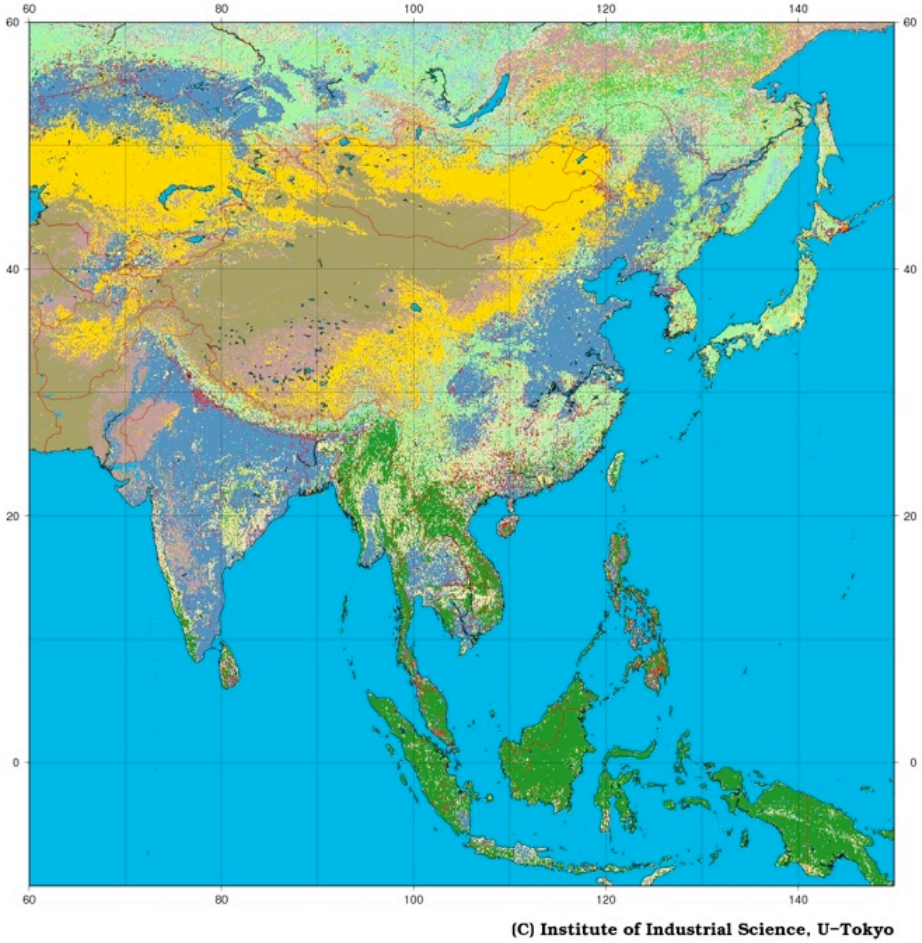
- Many of the product-specific metadata fields of each fire pixel in simple ascii text file to reduce file size;
  - Latitude, Longitude, R2 reflectance, T22 (K), T31 (K) and confidence value.
- A detection confidence intended to help users gauge the quality of individual fire pixels.
  - The confidence estimate, which ranges between 0% and 100%, is used to assign one of the three fire classes (low-confidence fire, nominal-confidence fire, or high confidence fire) to all fire pixels within the fire mask.

20050705.FIRE.txt

LAT(deg.)	LON(deg.)	REF2(%)	T22(K)	T31(K)	CONFIDENCE(%)
31.979397	117.255943	0.265969	320.278168	295.943878	57
31.939053	117.259239	0.270117	322.583588	293.936523	73
31.936943	117.271469	0.271943	328.083862	296.270966	90
31.835857	117.318924	0.251624	321.923523	294.569916	27
31.476776	118.412544	0.270130	313.733917	294.438507	55
29.819904	112.897804	0.246956	315.107361	293.052795	26
...					

Land cover map as a comparison

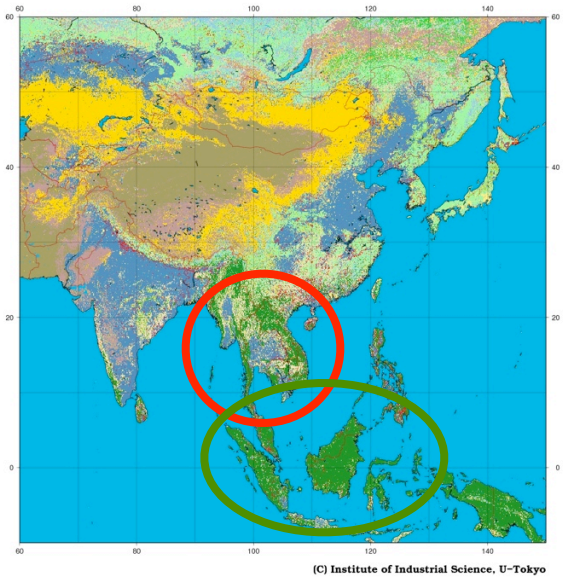
MODIS based 1km global land cover map (MOD43A1) [Friedl et al. (2002)]

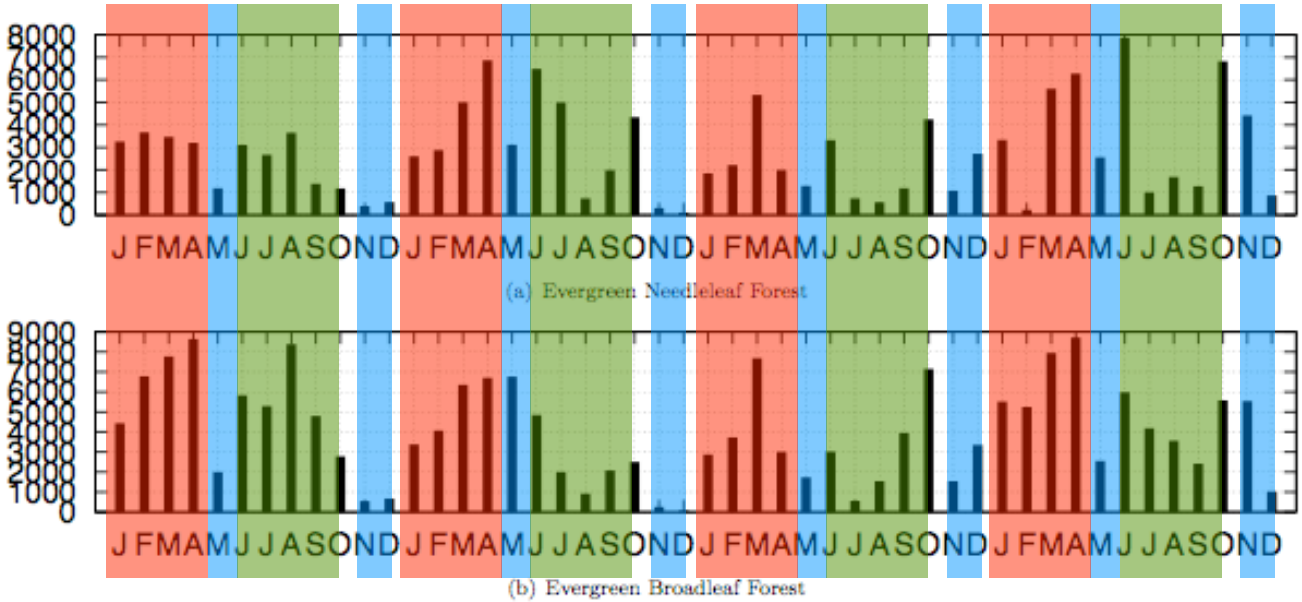


0 Water
1 Evergreen Needleleaf Forest
2 Evergreen Broadleaf Forest
3 Deciduous Needleleaf Forest
4 Deciduous Broadleaf Forest
5 Mixed Forests
6 Closed Shrublands
7 Open Shrublands
8 Woody Savannas
9 Savannas
10 Grasslands
11 Permanent Wetlands
12 Croplands
13 Urban and Built-Up
14 Cropland/Natural Vegetation Mosaic
15 Snow and Ice
16 Barren or Sparsely Vegetated

Fire event statistics

Evergreen needle and broad leaf forests

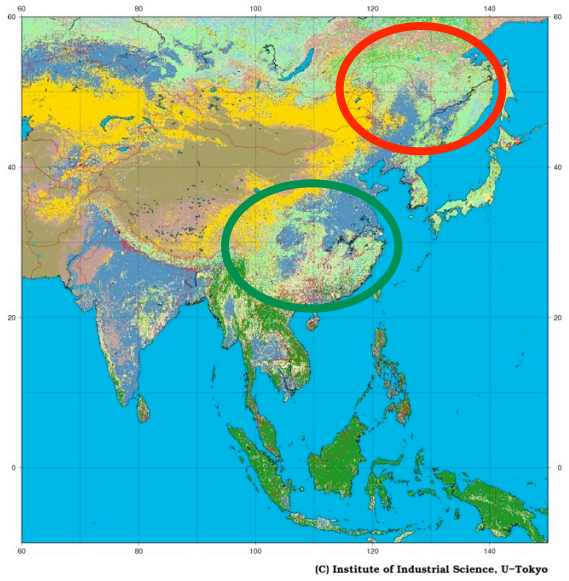


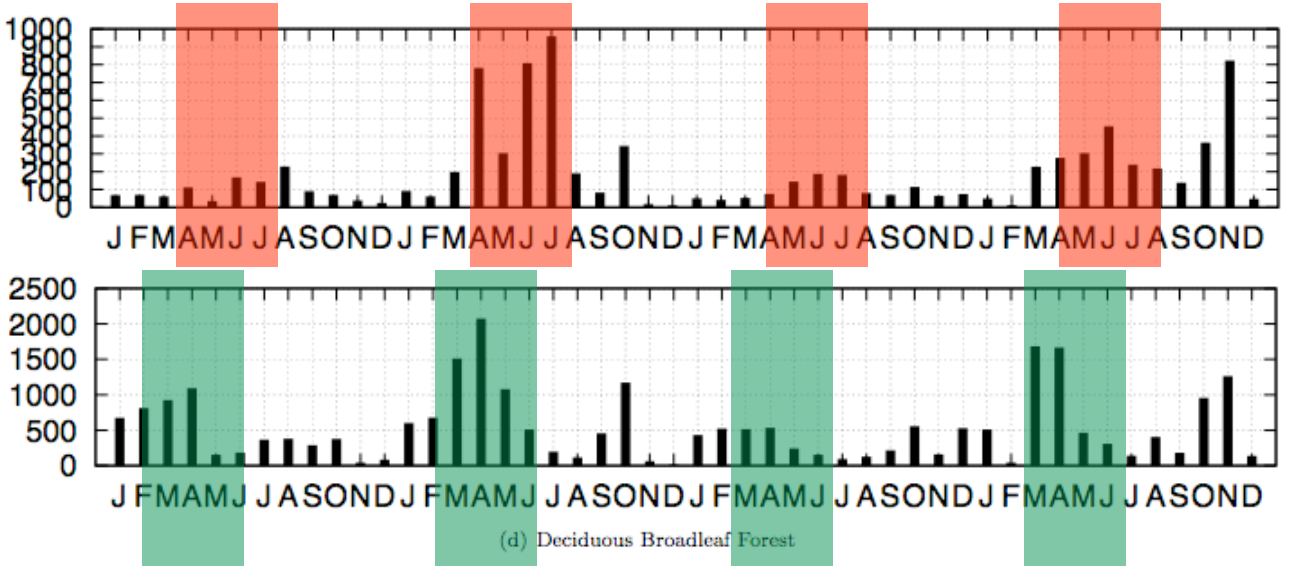


- Many fire events occurred in dry season in Thailand and Vietnam from Jan to Apr whereas in Malaysia and Indonesia from Jul to Oct.
- The number of fires drops off in May and Dec when dry and wet season switches.

Fire event statistics (cont'd)

Deciduous needle and broad leaf forests

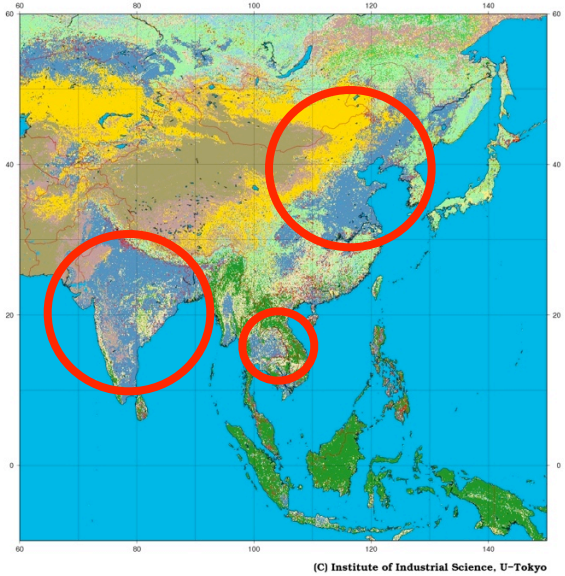


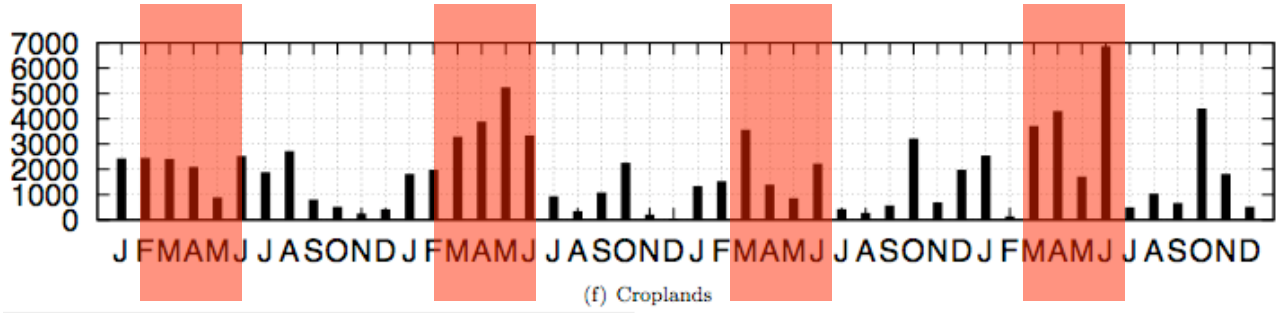


- Many fire events occurred from Apr to Jul in Far east Russia.
- Deciduous forests in mid-latitude area such as Japan and China have fire event peaks from Mar to May.

Fire event statistics (cont'd)

Croplands

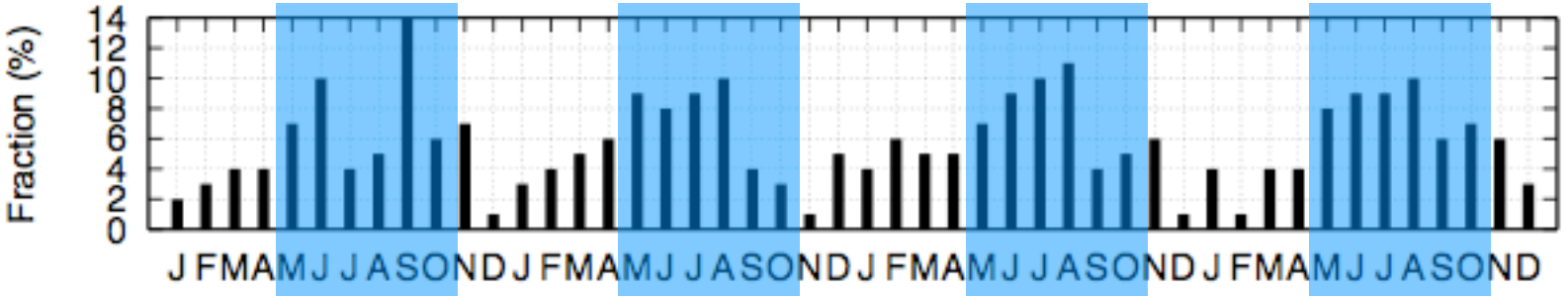




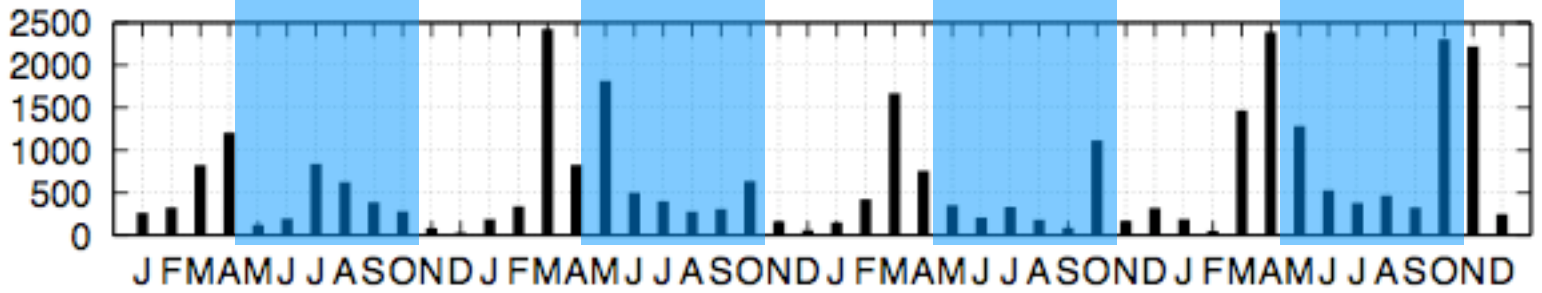
(f) Croplands

- The number of fire events on cropland go near those of forests and it center on a field burning season from Feb to Jul.

Fire event statistics (cont'd)



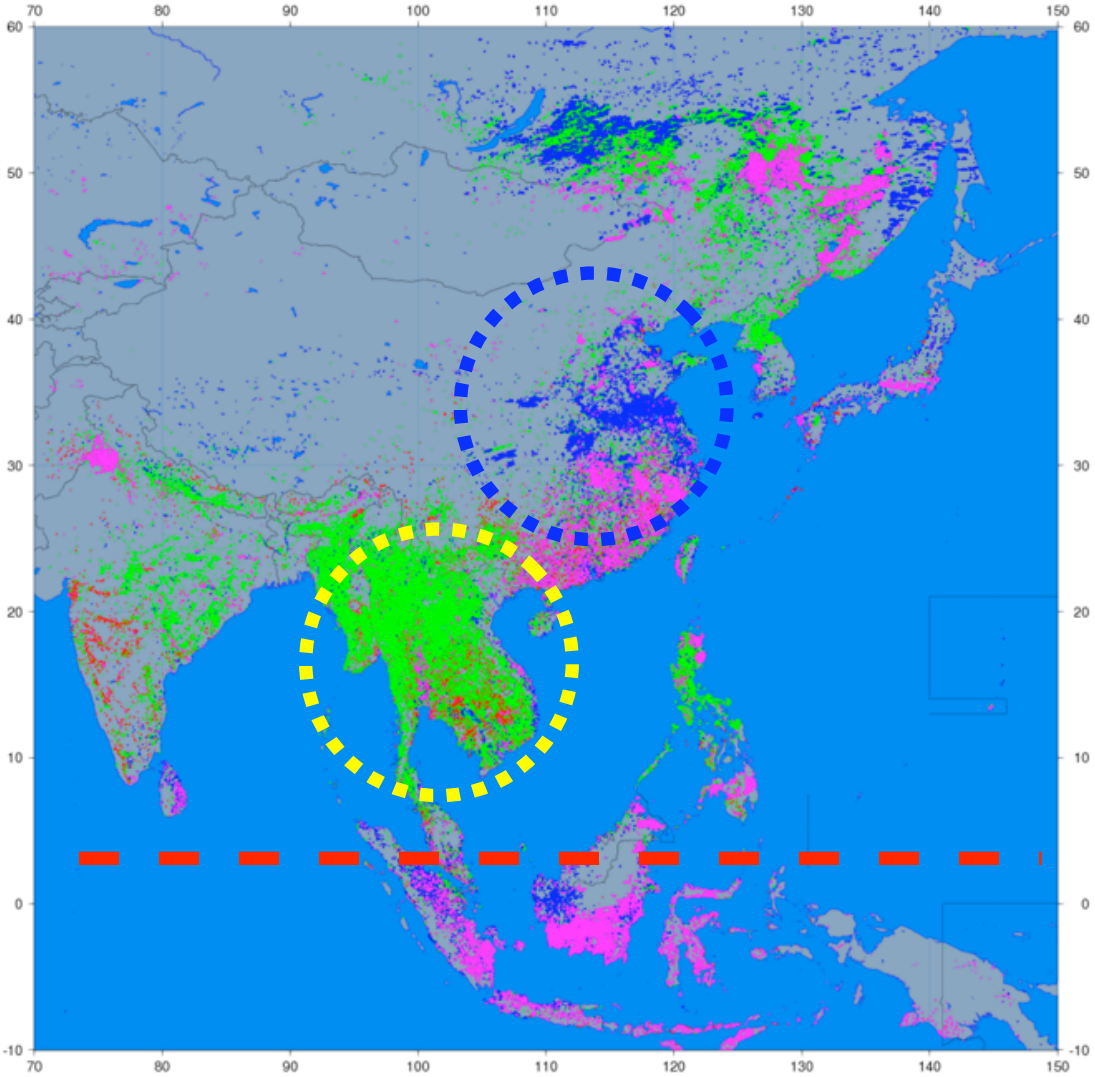
(a) the number of low confidence pixels



(b) the number of fires

- Low confidence pixels are approximately 10% of all fire events
- Low confidence pixels are often extracted from May to Oct, when the number of fire events decrease.
- This is because that air in wet season from May to Oct in northern hemisphere have much water vapor and it resulted in a smaller size of fire events and false alarms in spatial content.

Active fires in 1 year

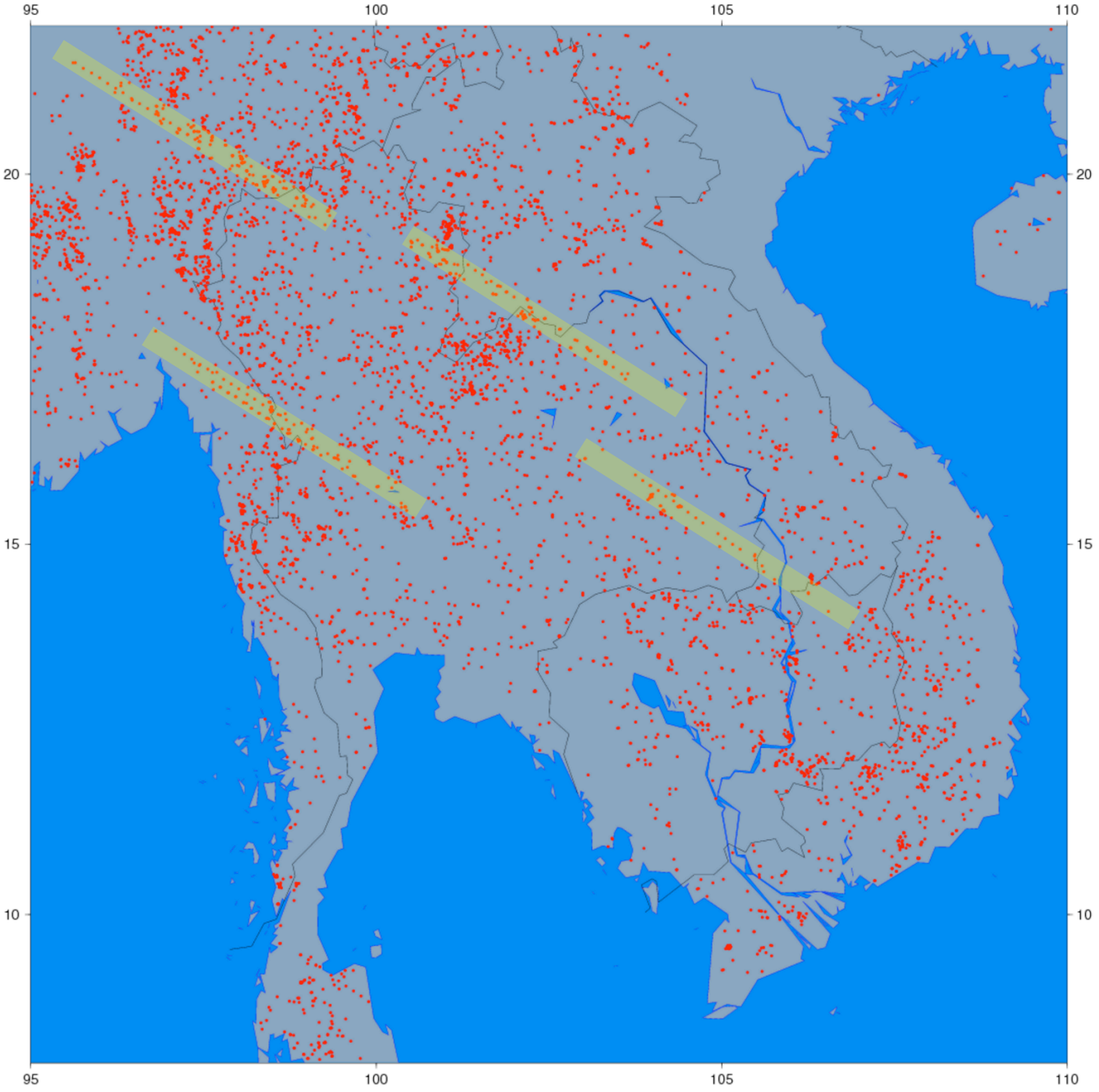


Aqua/Terra MODIS active fire map as of 2001-2005 (C) Institute of Industrial Science, U-Tokyo

DJF MAM JJA SON

- Clear difference in north-south direction in the equator
- Many fire events in east China plane originate from open burning in a grass field
- Thailand and Vietnam have burning season in MAM with field burning

False alarm originated from data receiving noise in a strip



Aqua/Terra MODIS active fire map as of 2002/03

Caveats of fire product

- The active fires observed with the MODIS instrument are generally much smaller than 1 km MODIS pixels
  - It is usually incorrect to assume that the instantaneous fire area is that of the entire pixel.
  - Ground floor fires with active above ground trees are difficult to identify or validate only with MODIS.
- Only fires actively burning at the time of the satellite overpass can be detected.
- Algorithm performance depends on many variables has a long way to validate the fire detection scheme.
  - Fire size and temperature, viewing geometry, biome, season, time of day, and properties of accompanying smoke.
- False alarms routinely occur at gas glares and active volcanoes as thermal anomalies in addition to vegetation fires.

Discussions

- The assessment of thematic accuracy of fire map products and data sets derived from processing of remote sensing data has a long way to go because of its few scientific consensus.
- In order to overcome that problem, the validation efforts should represents a difficult logistics challenge.
- Since the derived fire map created in this study distributes over large area, a considerable number of scientist or their information on the local land use will be indispensable to get the better scientific consensus.

Discussions (cont'd)

- Only through discussion between the intimately familiar with operational organizational needs and those with considerable background in wild fire monitoring strategies and capabilities, can acceptable levels of accuracy of results be achieved. All of this leads to the conclusion that we still have much to do in this study.
- We must continue to study hard toward and the routine or operational development of wildfire mapping over Asia and there are still many lessons to be learned and problems to be solved.

Concluding remarks

- An improved active fire detection with MODIS and CO2 emission estimation by coupling SIM-CYCLE is presented and is working fully operational as part of IIS/AIT MODIS direct broadcasting system.
- How to access our fire product through network and its caveats are presented.
- Validation with ASTER is actively being pursued and globally representative validation is underway.
- Improvements are also being made to the MODIS de-stripe for active fire algorithm refinements.

Thank you for your attention!