Emission of greenhouse gases from wildfires in Eastern Siberia observed from space

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Background

- CH_4 emission from biomass burning including wildfires is estimated as 10% or more of total global emission.
- The estimation uncertainty is mainly due to estimation error of total burned biomass, whereas partly due to variation in datasets of CH_4 emission factors.
- The variation is 20-40%, resulting from limited number of observations by aircraft or on the ground.

emission factor (M: mass of carbon emitted, MW: molecular weight)

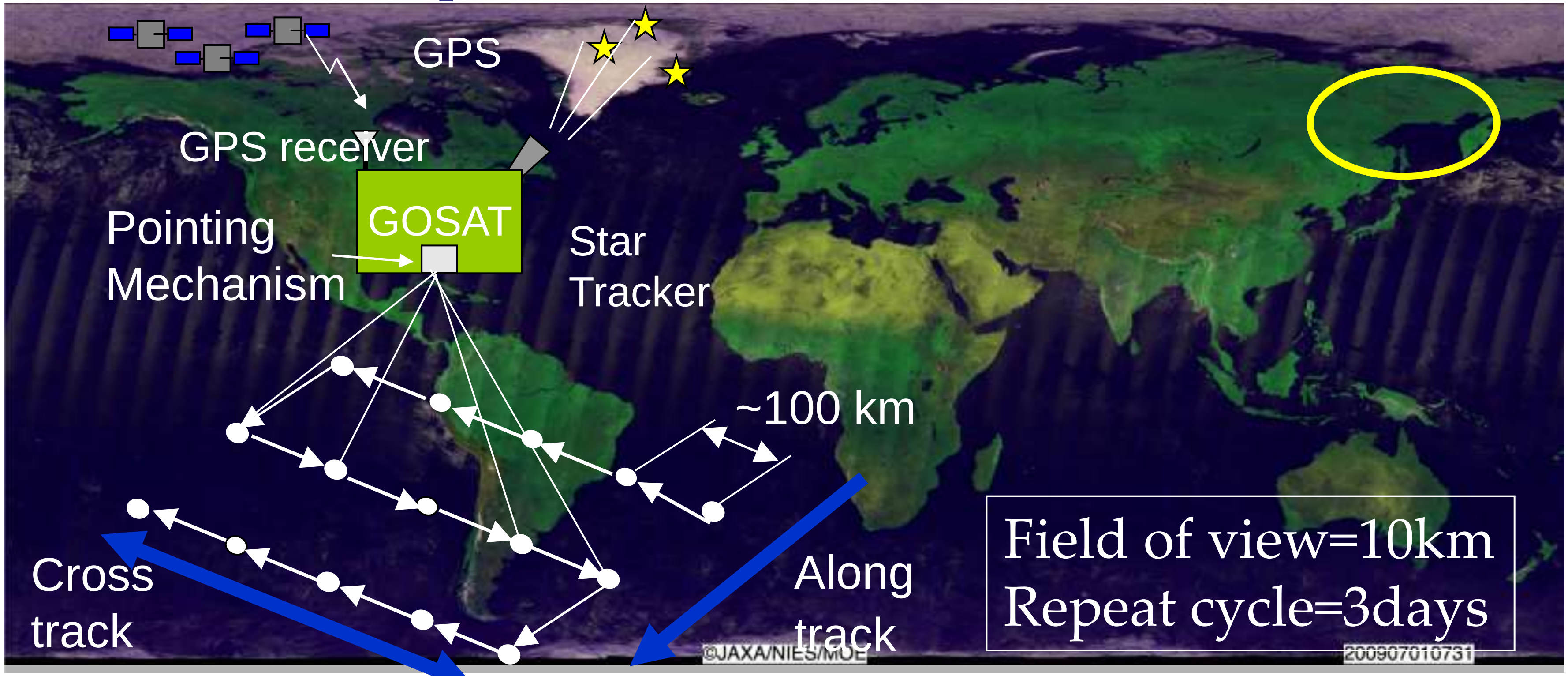
$$EF_{CH_4} = \frac{M_{CH_4}}{M_{bi\ldots}} = ER_{CH_4} \times EF_{CO_2} \times \frac{MW_{CO_2}}{MW_{CH\ldots}}$$

Objective

- To decrease the variation in CH_4 emission factor by increasing observational results of CH_4 emission ratio from satellite data.

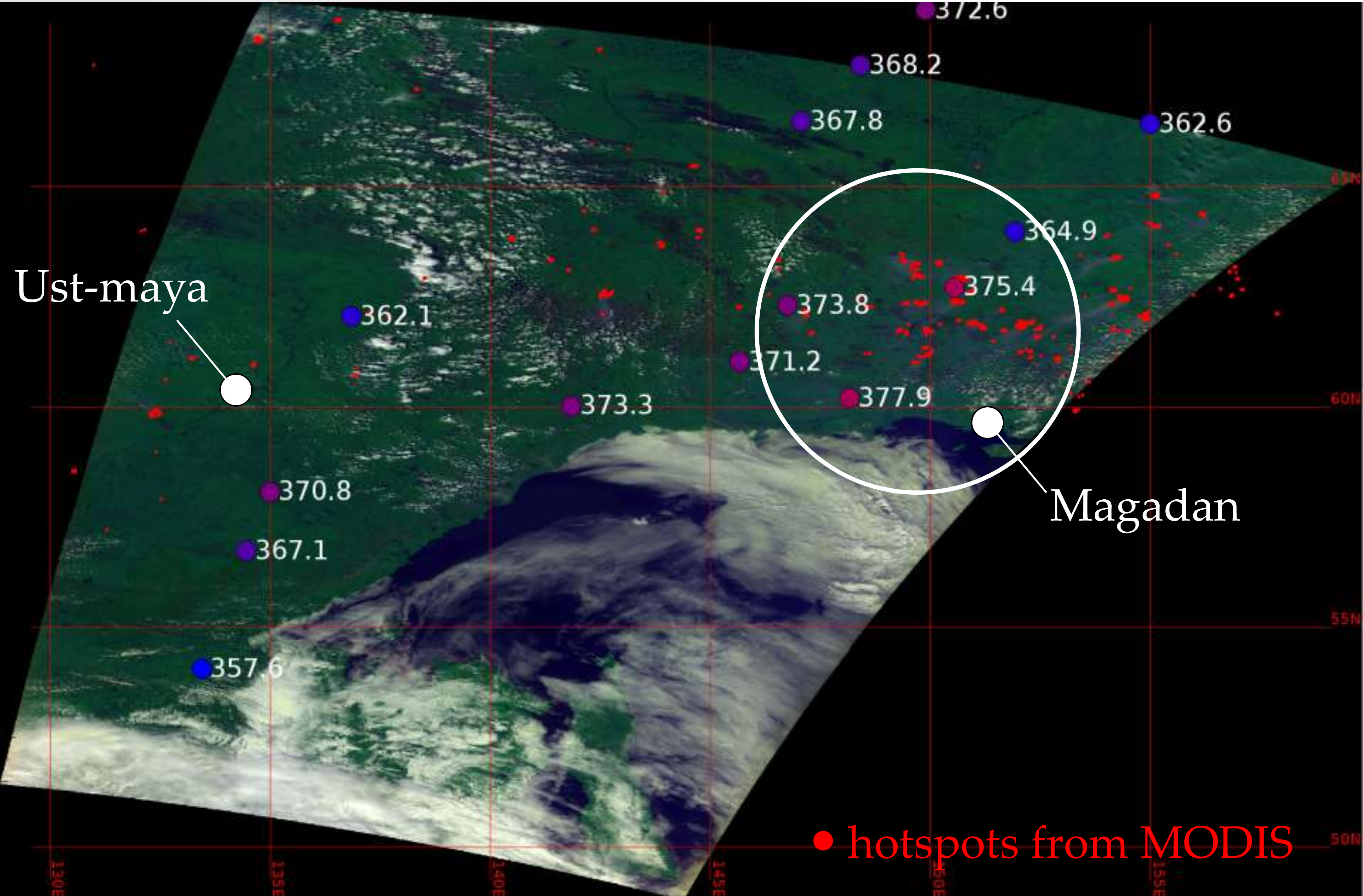
Data

- land image: GOSAT/CAI L1B [V00.03],[V00.50]
- column-averaged volume mixing ratios (XCO_2, XCH_4): GOSAT/FTS L2 [V00.02],[V00.03]
- hotspot data: MODIS Rapid Response System (MOD14/MYD14)
- land surface temperature: MOD11, wind field: NCEP-FNL



Composite image of Cloud and Aerosol Imager (CAI)

CAI image & XCO_2 (29 June 2009)



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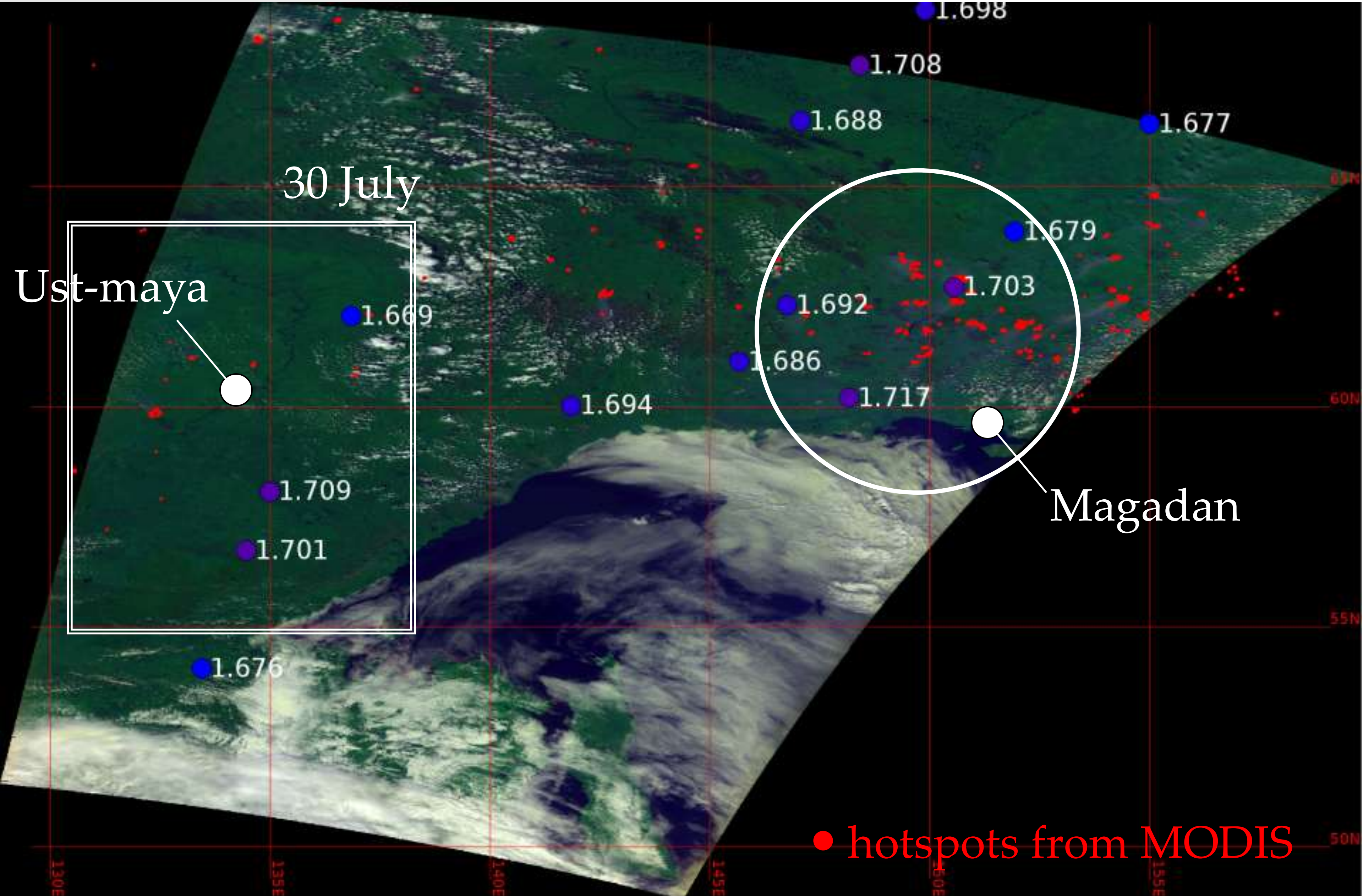
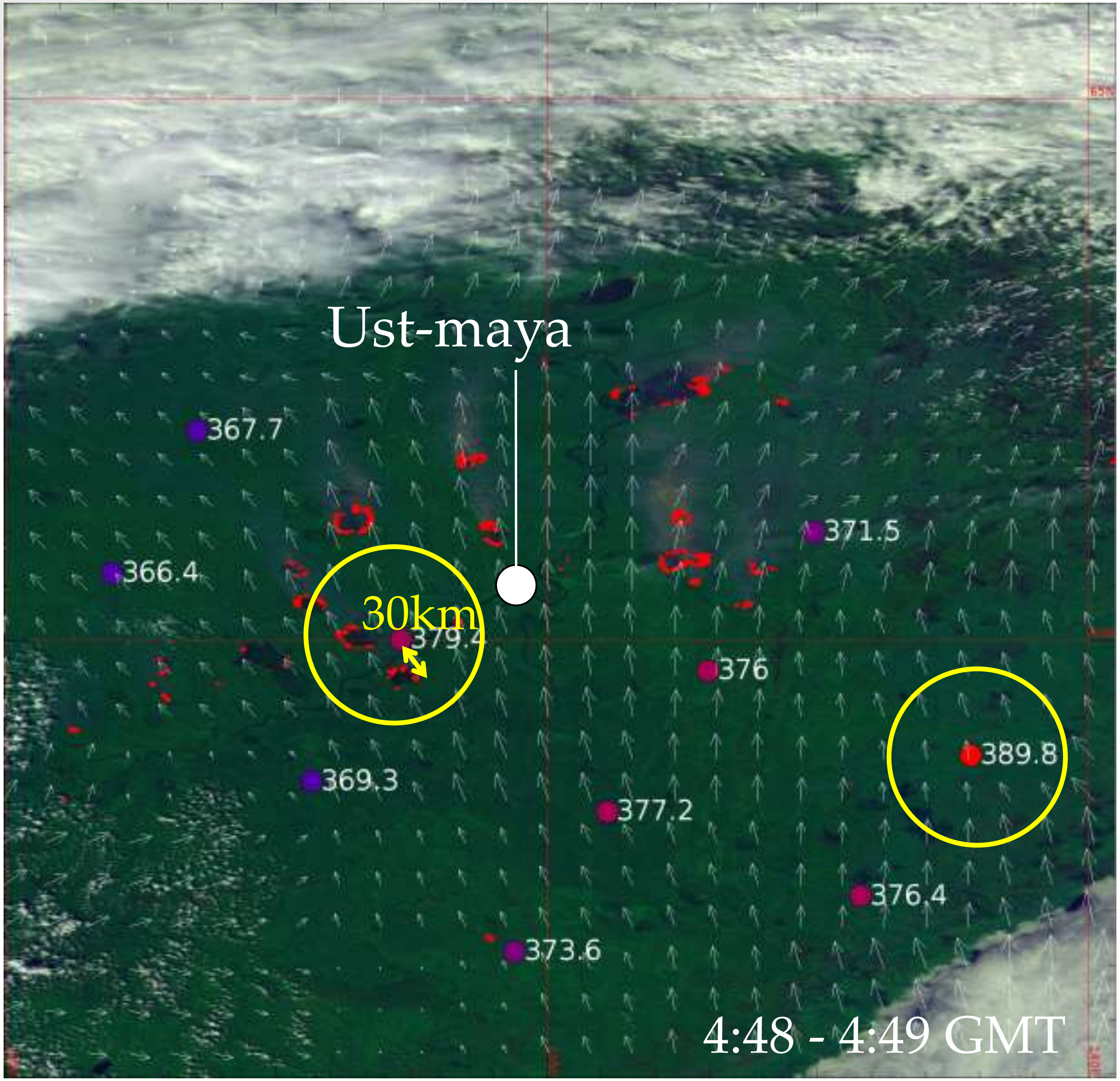
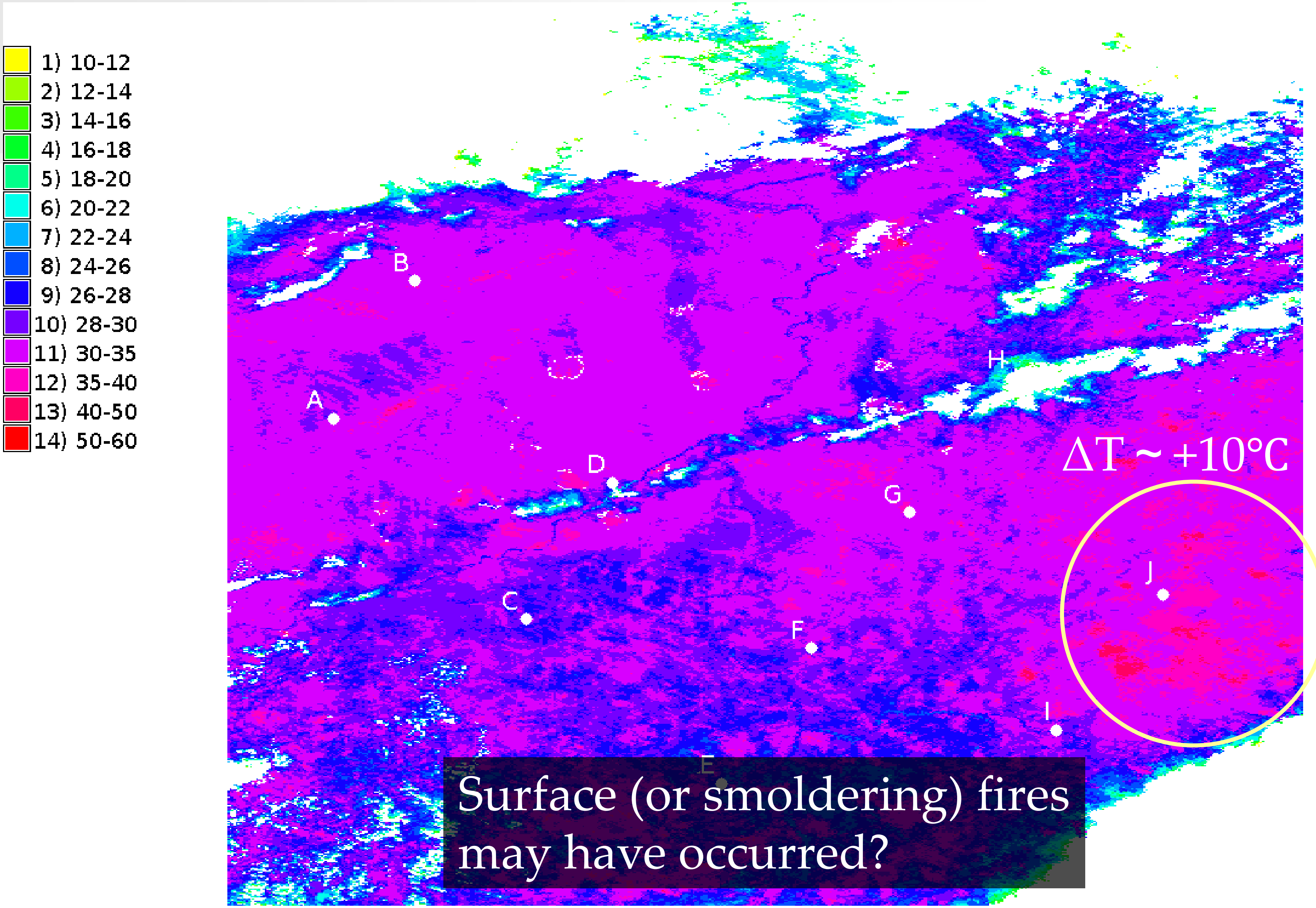


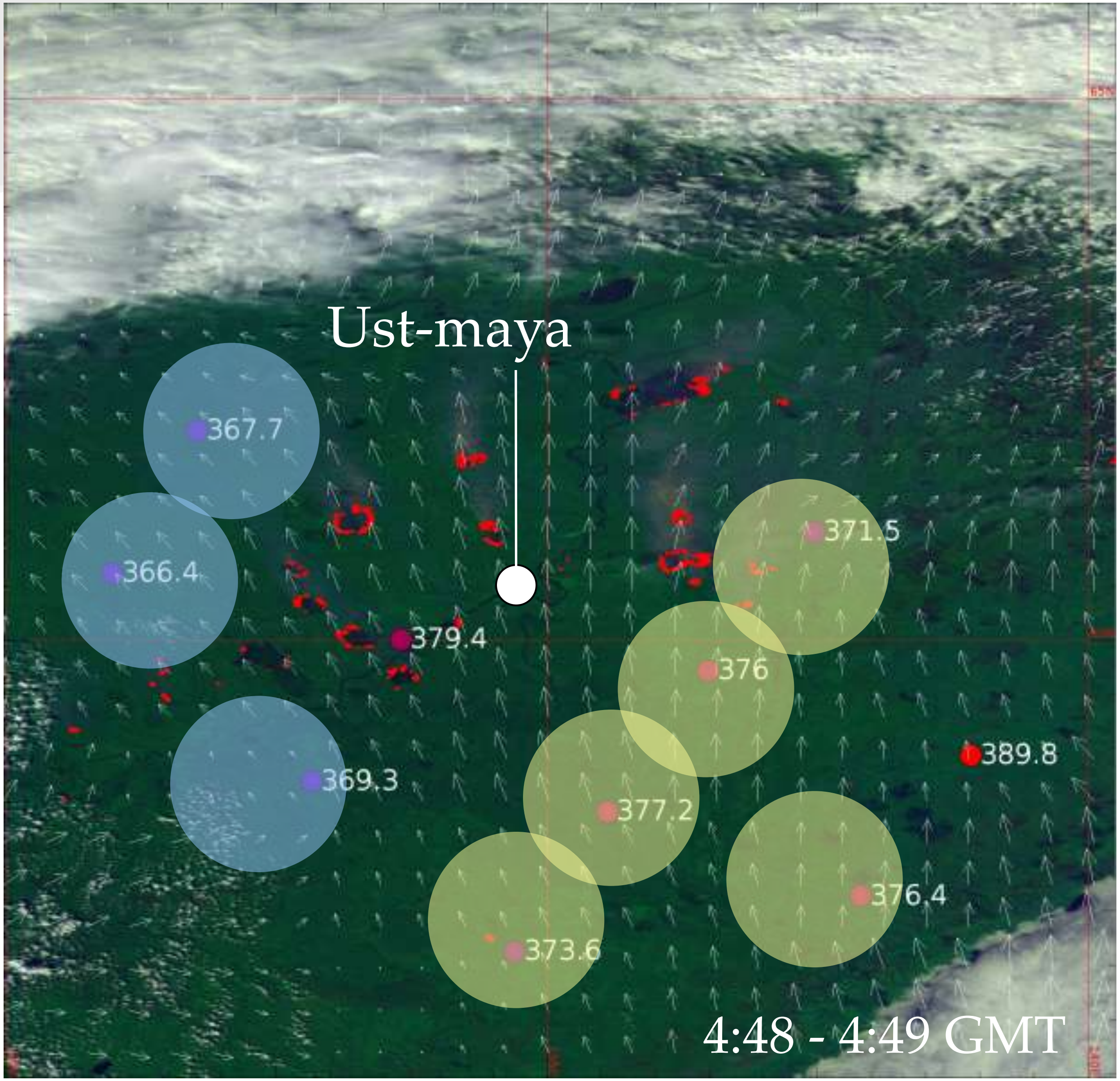
CAI image & XCO_2 (30 July 2009)

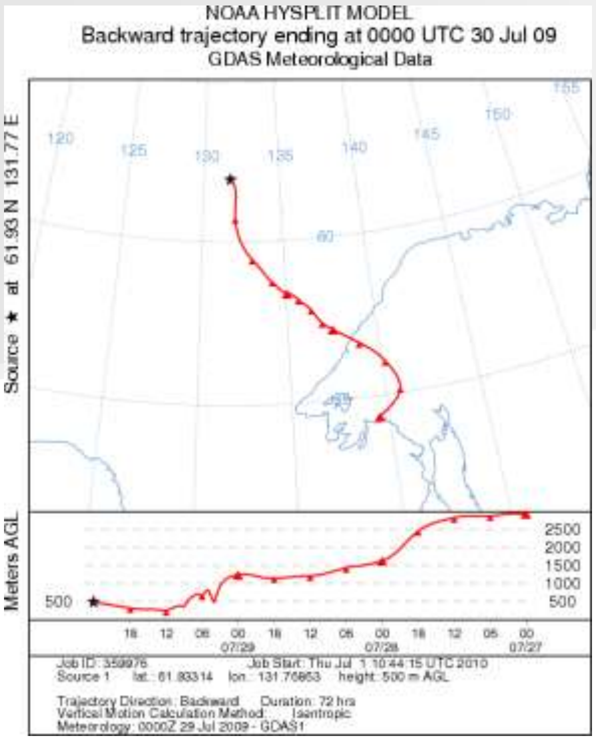


Land surface temperature (30 July 2009)

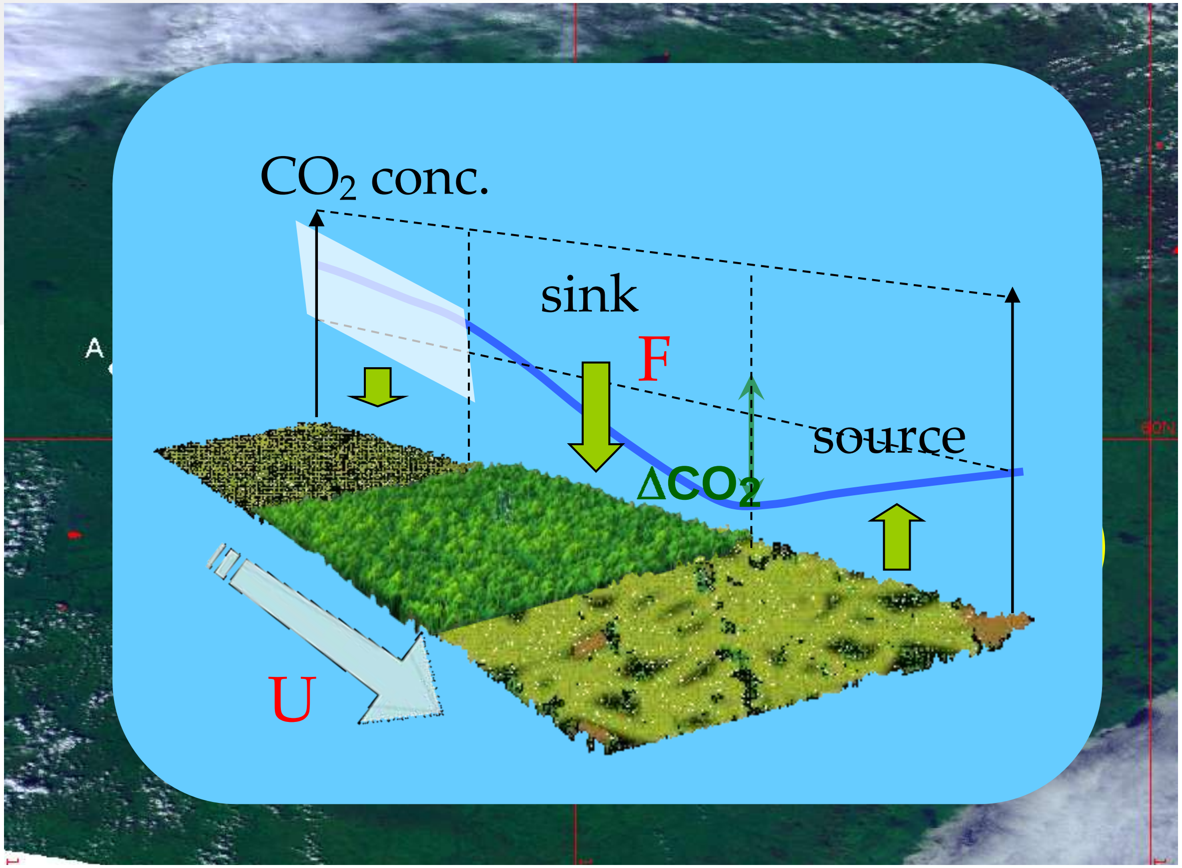


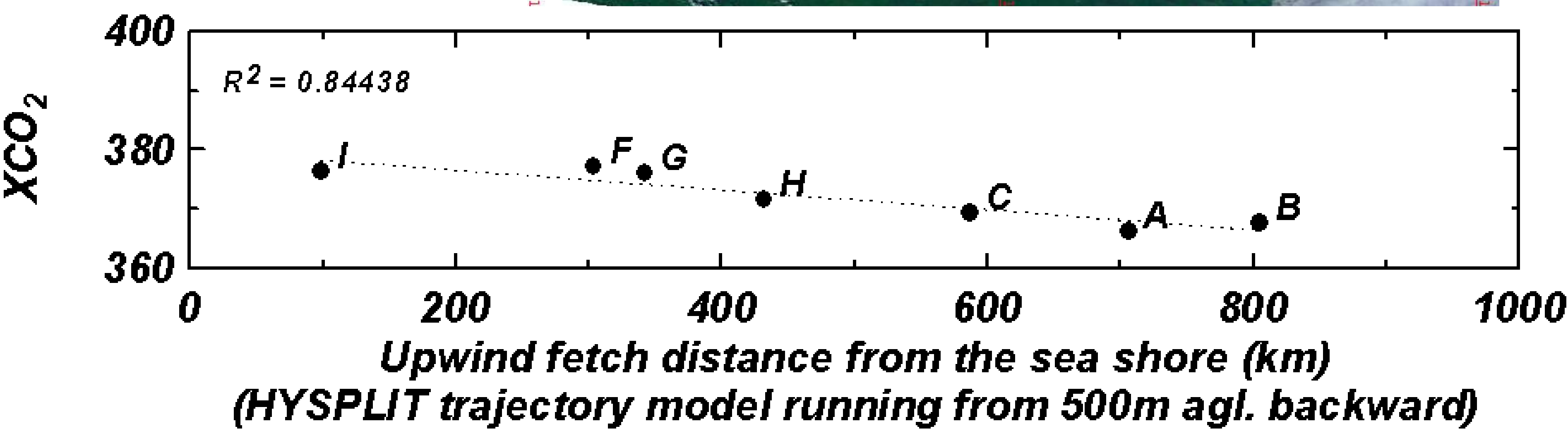
Background XCO_2 (30 July 2009)



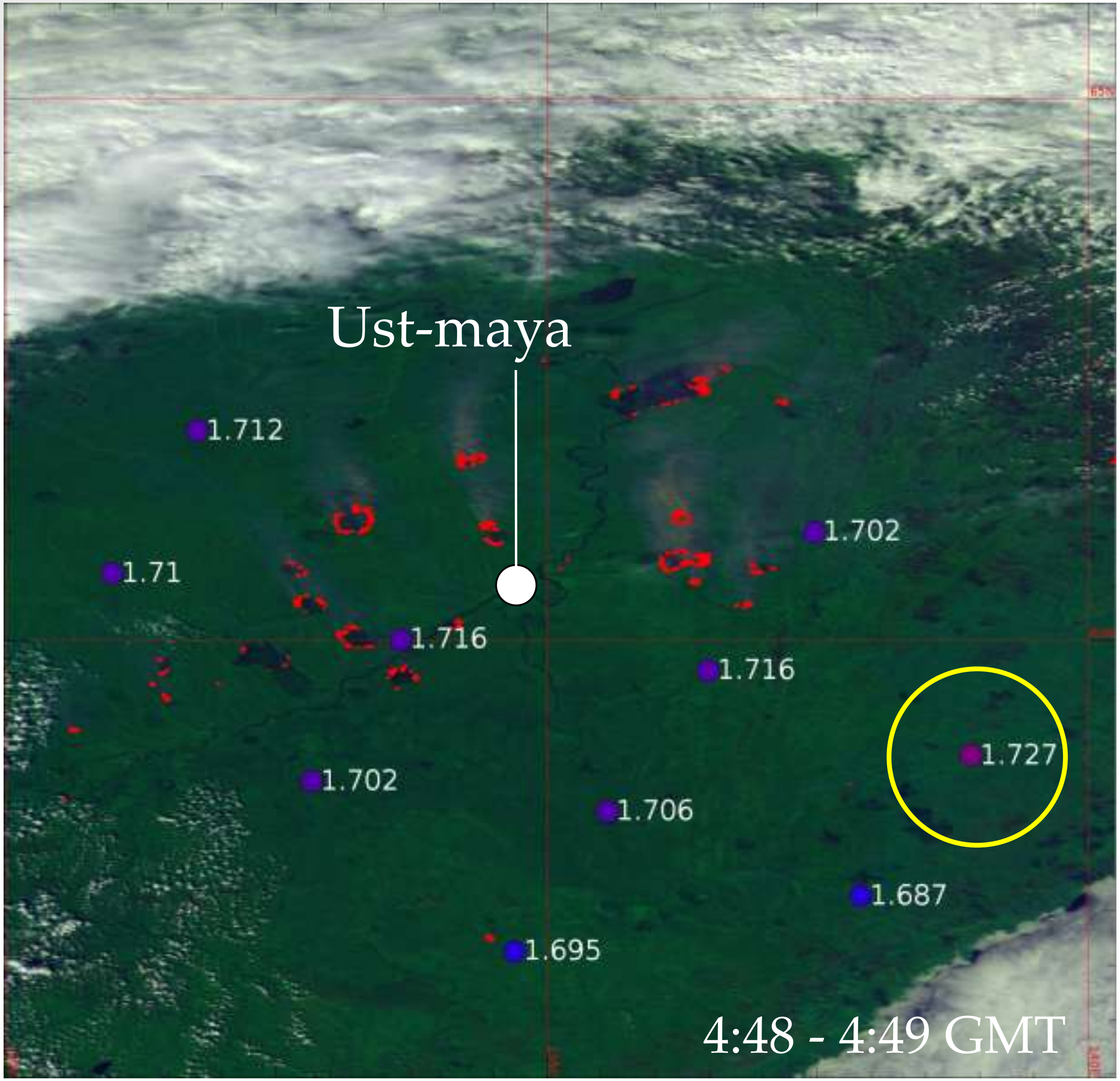


HYSPLIT trajectory model



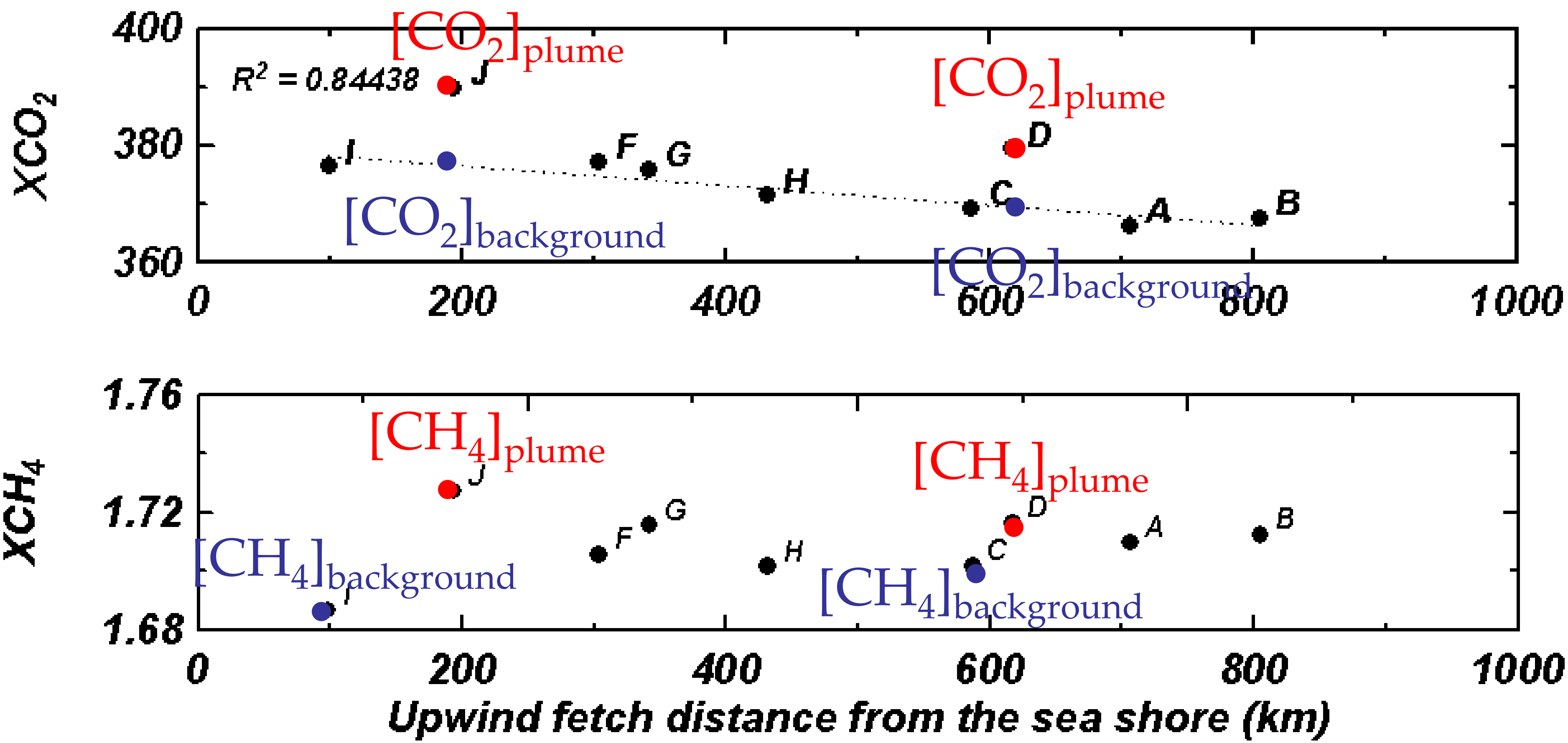


CAI image & XCH_4 (30 July 2009)



Trial calculation of CH_4 emission ratio at D and J

$$ER_{CH_4} = \frac{[CH_4]_{plume} - [CH_4]_{background}}{[CO_2]_{plume} - [CO_2]_{background}}$$



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	Point D	Point J	Boreal flaming	Boreal smoldering
$\Delta[CO_2]$	9.8	13.2		
$\Delta[CH_4]$	0.015	0.04		
ER_{CH4}(%)	0.148	0.307	0.16±0.21	1.22±0.29

(Cofer III et al. 1996)

Current issues:
"How to determine the background values?"
"How to compare the results based on column-averaged VMRs to existing knowledge based on VMRs near the surface?"

Summary

✓ Emission gas from intense and long-lived fires in Siberian region were clearly detected by GOSAT CAI & FTS.

XCO_2 was enhanced in the 30km downwind of actively burning area.

Background XCO_2 showed systematic decrease with upwind fetch distance from the sea shore; it suggests CO_2 assimilation by vegetation photosynthetic activity.

✓ Estimated CH_4 emission ratio was smaller than or comparable to the value for flaming fire of boreal forest.

This value would become larger if we assumed concentration in plume raised only near the surface.

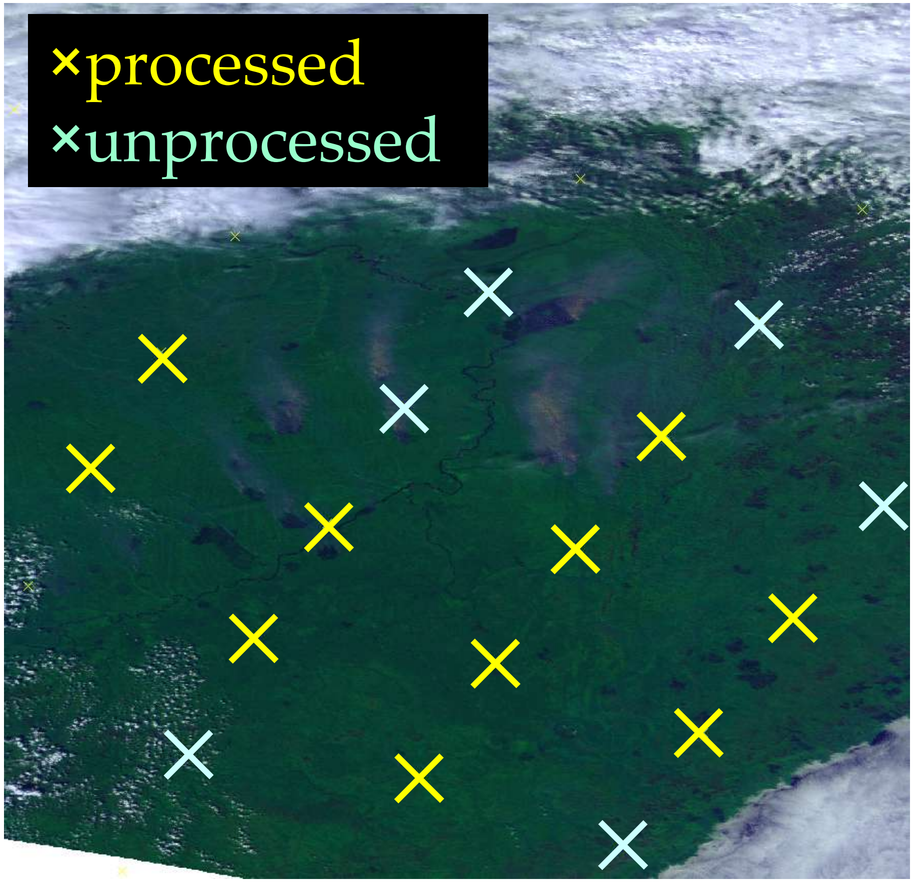
It is crucial to correctly estimate background concentrations because of relatively large spacing of GOSAT data.

Thank you for your attention !

Future work

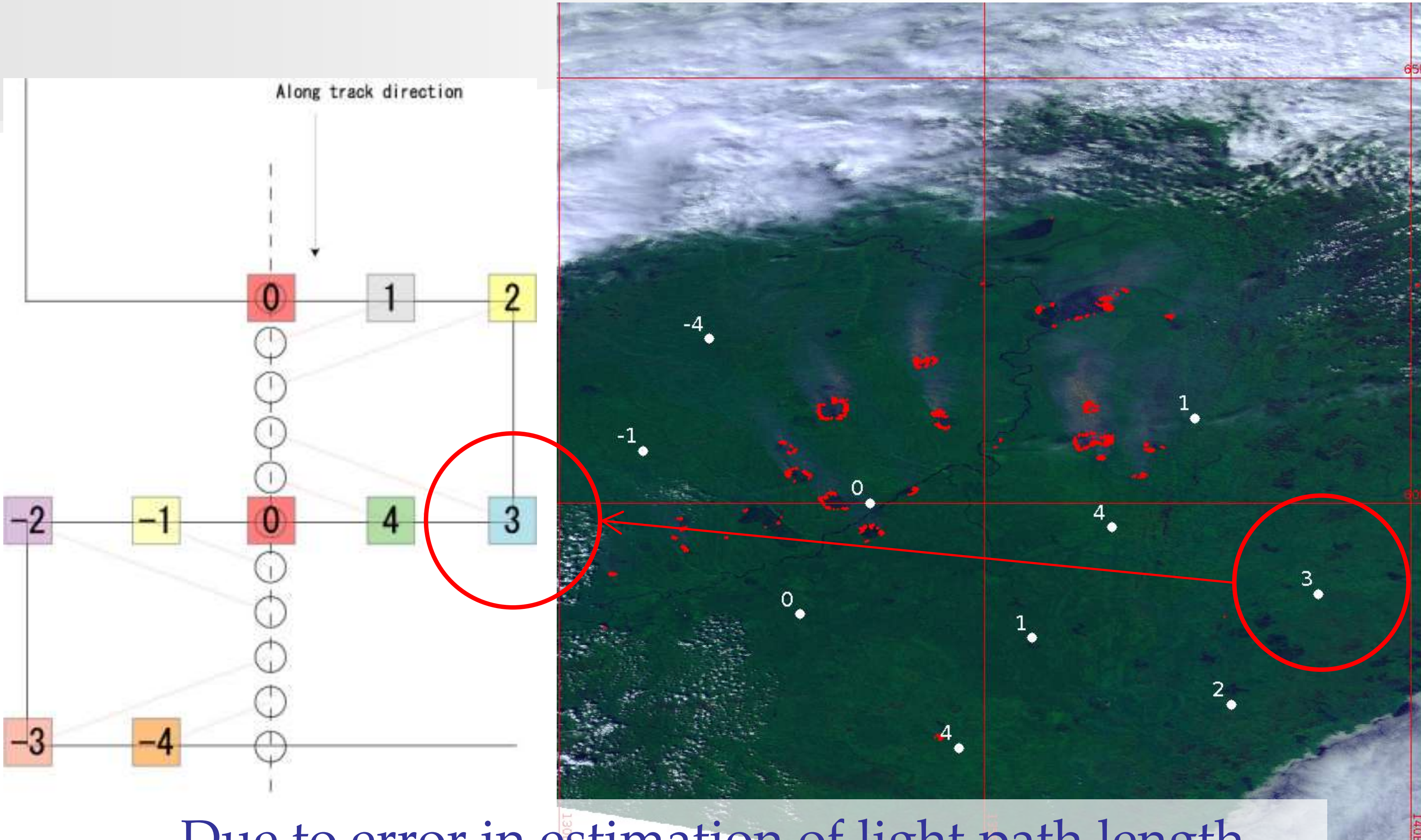
✓ Data processing algorithm of GOSAT is still developing and it needs to confirm the data accuracy by model simulation (forward dispersion model or inverse model).

✓ So far, data affected by thick aerosol are not provided. For this case, request for data processing and examination of data accuracy are needed.



✓ Comparison with data of other satellites (e.g., MOPITT, SCIMACHY, TES) is needed.

Possibility of problem in the observation



Due to error in estimation of light path length resulting from misalignment of pointing mirror?

Regions affected by wildfires (including land-use fire)

1.	Africa, sub-Saharan	230	(2000)
2.	Australasia	54.5	(1997-2003)
3.	Southeast Asia	6.9	
4.	South Asia	4.1	(2000)
5.	North America	4.1	(2000-2004)
6.	South America	2.9	(1986-2004)
7.	Central Asia	2.0	
8.	Northeast Asia	1.0	(1990-2004)
9.	Mediterranean	0.7-1.0	
10.	Caribbean and Mesoamerica	0.446	(2000-2004)
11.	Balkans	0.156	(1988-2004)
12.	Baltic countries	0.032	

[million ha / yr]

(Fire management – global assessment 2006, FAO)

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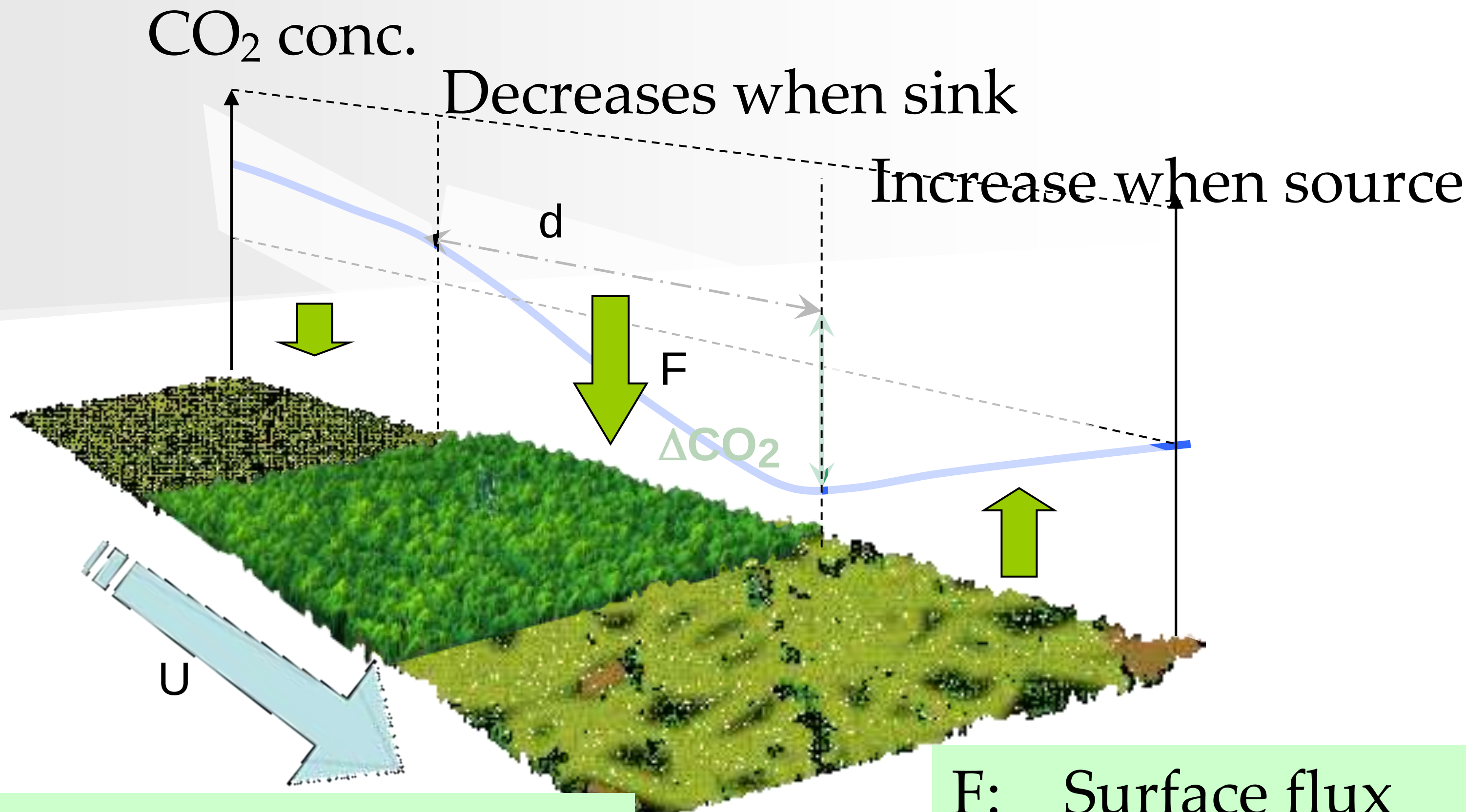
Satellite (launch)	Organization (Country)	FOV (vertical profile)	Repeat Cycle	Expected accuracy	Species
GOSAT (Jan 2009)	JAXA, NIES (Japan)	10kmϕ (no)	3days	1%(CO_2) 2%(CH_4)	CO_2 CH_4
SCIAMACHY (March 2002)	ESA (Europe)	25km (yes)	3days	1-5%	esp. O_3, NO_2, SO_2, H_2O, CO_2, CO, CH_4
MOPITT (Dec. 1999)	NASA (USA)	22km (yes)	16days	10%(CO) 1%(CH_4)	CO CH_4
TES (July 2004)	NASA (multi-national)	5.3 x 8.5km (yes)	16days	N/A	esp. CO, H_2O, CH_4, HDO, O_3
IASI (Oct. 2006)	ESA /EUMETSAT (Europe)	25-100km (yes)	16days	10%	esp. O_3, CO, H_2O, CH_4,N_2O



Δn_c [mol/m^2] = F t = F d /U
$\Delta XCO_2 = \Delta n_c / n_a$

F: Surface flux
d: Distance
U: Wind speed
nc, na: mol number of CO_2 and dry air

obs: ΔXCO_2 (ppm/km) = -0.0167
assumption: U=3 (m/s)
F=18μmolCO_2/m^2/s (in Yakutsk by Dolman et al., 2004)
result: ΔXCO_2 (ppm/km) = -0.0178

Why the wildfire in Siberian region should be studied?

General reason

✓ CH_4 Emission factor is relatively high (dominated by smoldering fire).

✓ There is extremely large carbon storage in soil.

Practical reason

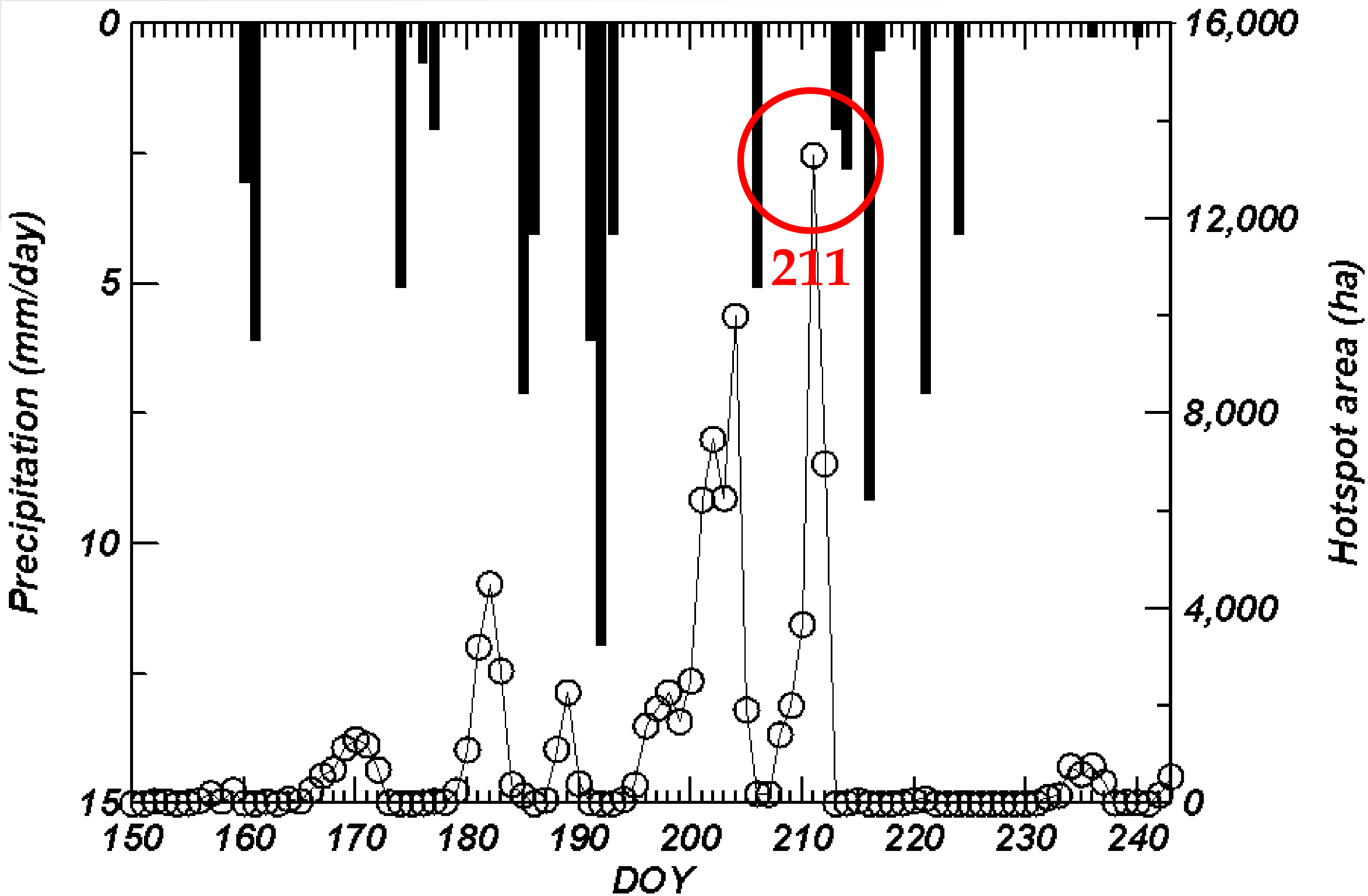
✓ If fuel becomes completely dry, giant fires tend to occur.

✓ The fire has long duration of life.

→ detectable from satellite!

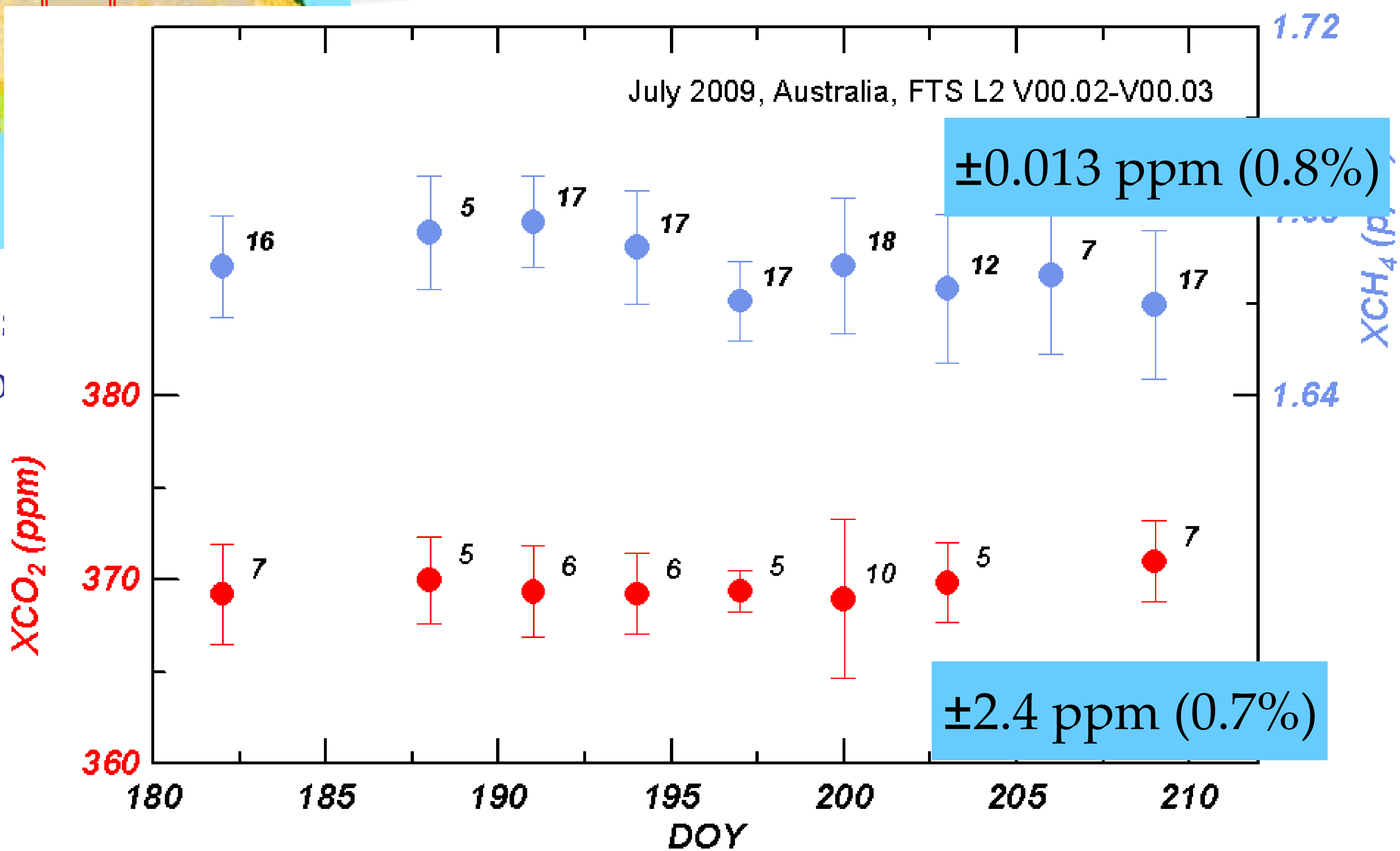
Figure 4. Typical surface fire of medium frontal fire intensity levels ranging between 1500 and 5000 kW/m. Location: Bor Forest Island Experiment, Central Siberia, July 1993 (8).

(GFMC, 2003)



Time series of precipitation mount in Ust-judoma and hotspot area detected by MODIS in 2009.

Accuracy of GOSAT single scan data



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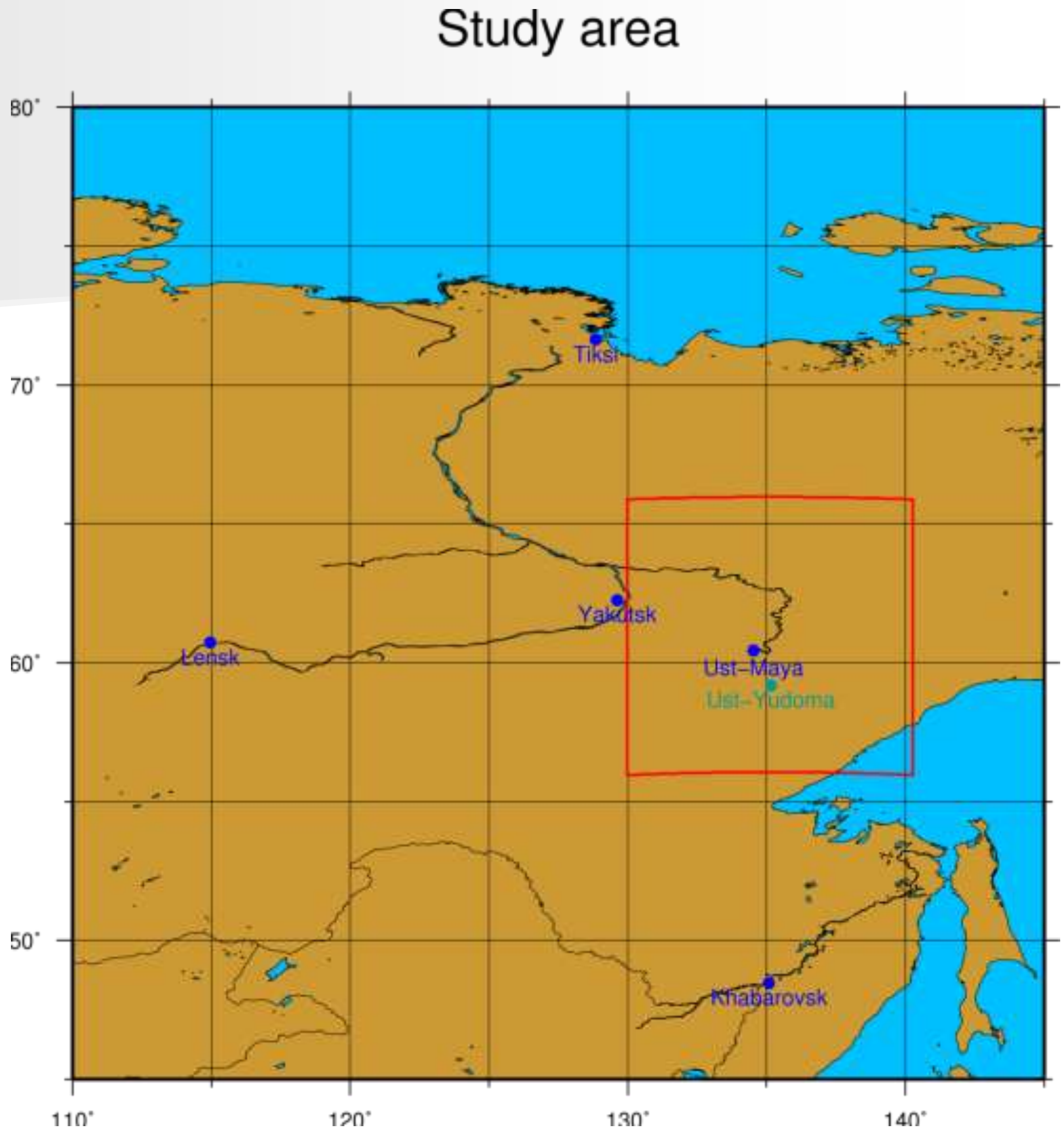

Study area of the present study
(Ust-maya: 60°25'38.81"N, 134°32'10.66"E).

Trial calculation of CH_4 emission ratio at D and J

$$ER_{CH_4} = \frac{[CH_4]_{plume} - [CH_4]_{background}}{[CO_2]_{plume} - [CO_2]_{background}}$$

case 1.

$[CO_2]_{plume}$ or $[CH_4]_{plume}$ = $[CO_2]_{obs}$ or $[CH_4]_{obs}$

$[CO_2]_{background} = a\,D + b$

$[CH_4]_{background} = [CH_4]_{obs}$ at the nearest points

case 2.

$[CO_2]_{plume}$ and $[CH4]_{plume}$ = $[CO_2]_{obs}$ or $[CH_4]_{obs}$

$[CO_2]_{background} = a\,D + b$

$[CO_2]/[CH_4] = a'\,D + b'$

$[CH_4]_{background} = [CO_2]_{background} / (a'\,D + b')$

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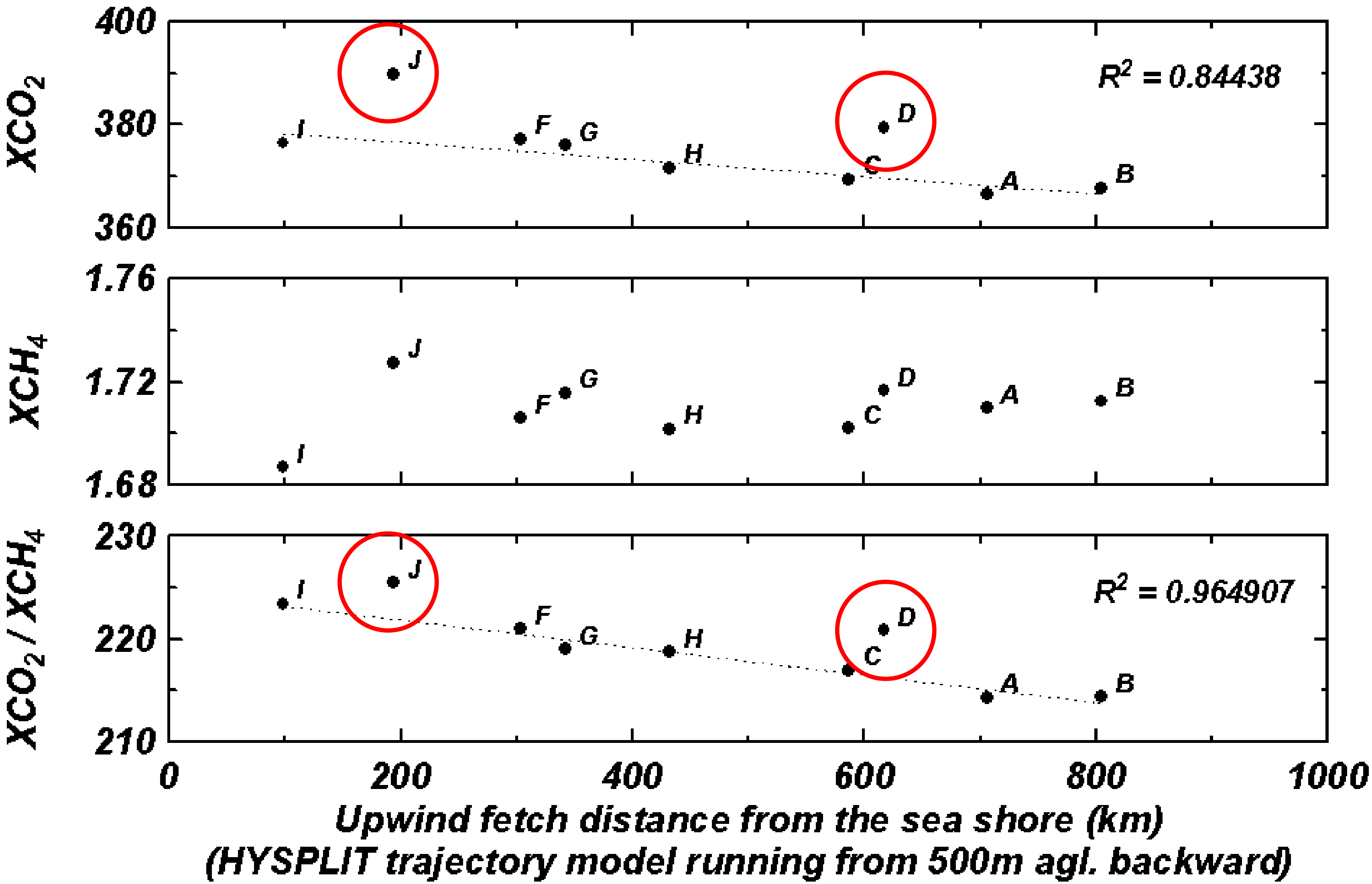
Point D	Case1	Case2	Boreal flaming	Boreal smoldering
$\Delta[CO_2]$	9.8	9.8		
$\Delta[CH_4]$	0.015	0.007		
ER_{CH4}(%)	0.148	0.076	0.16±0.21	1.22±0.29

Point J	Case1	Case2
$\Delta[CO_2]$	13.2	13.2
$\Delta[CH_4]$	0.04	0.03
ER_{CH4}(%)	0.307	0.228

(Cofer III et al. 1996)

Distance & volume mixing ratios



Dotted line represents linear regression line without values at J and D

What are the CH_4 emission factor and CH_4 emission ratio?

emission factor (M: mass of carbon emitted, MW: molecular weight)

$$EF_{CH_4} = \frac{M_{CH_4}}{M_{biomass}} = ER_{CH_4} \times EF_{CO_2} \times \frac{MW_{CO_2}}{MW_{CH_4}}$$

emission ratio ($[CO_2]$, $[CH_4]$: CO_2, CH_4 concentrations in the air)

$$ER_{CH_4} = \frac{[CH_4]_{plume} - [CH_4]_{background}}{[CO_2]_{plume} - [CO_2]_{background}}$$

Table. Emission Factors for pyrogenic species (Andreae and Merlet, 2001)

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(			
CH_4	2.3±0.9	6.8±2.0	4.7±1.9

%

20-40%

Objective

・ To estimate CH_4 emission ratio from satellite data.