Fire in the Earth System

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Priorities for a fire module in JULES

- **Basic processes:** **Ignitions (human-caused/lightning), fire spread, area burnt, fire intensity, fire-induced mortality of vegetation, emissions from biomass burning. Draw on current work e.g. LPJ-SPITFIRE, LPJ-GUESS-SPITFIRE, SEVER-FIRE.**

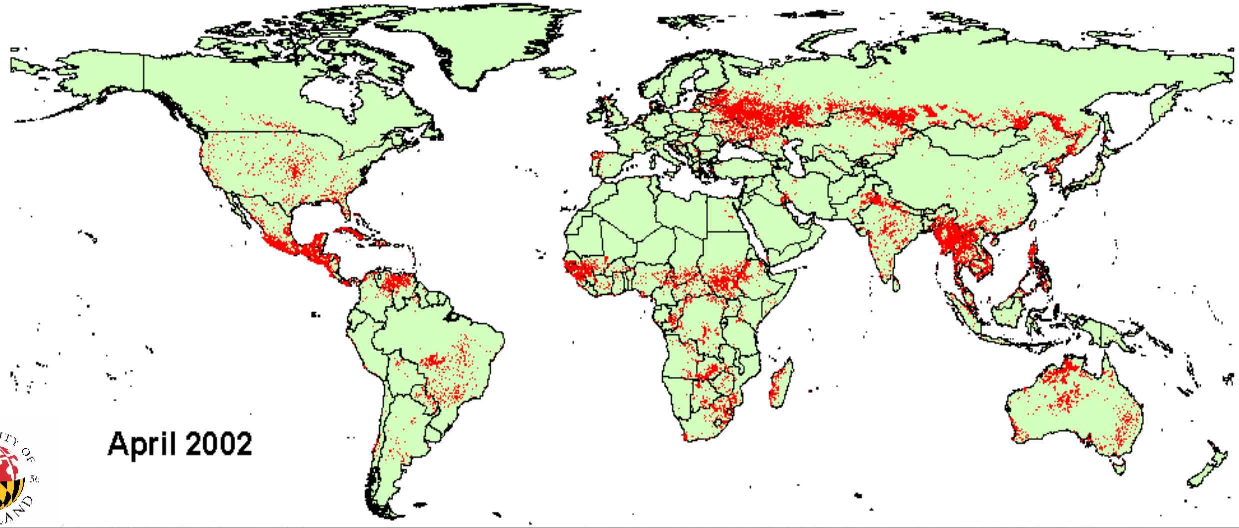
- **Vegetation pattern impacts:** **Interactions between fire and vegetation structure e.g. PFT distribution, LAI patterns, biomass/carbon stocks. Changes to grass: tree ratios. Possible changes to surface albedo.**

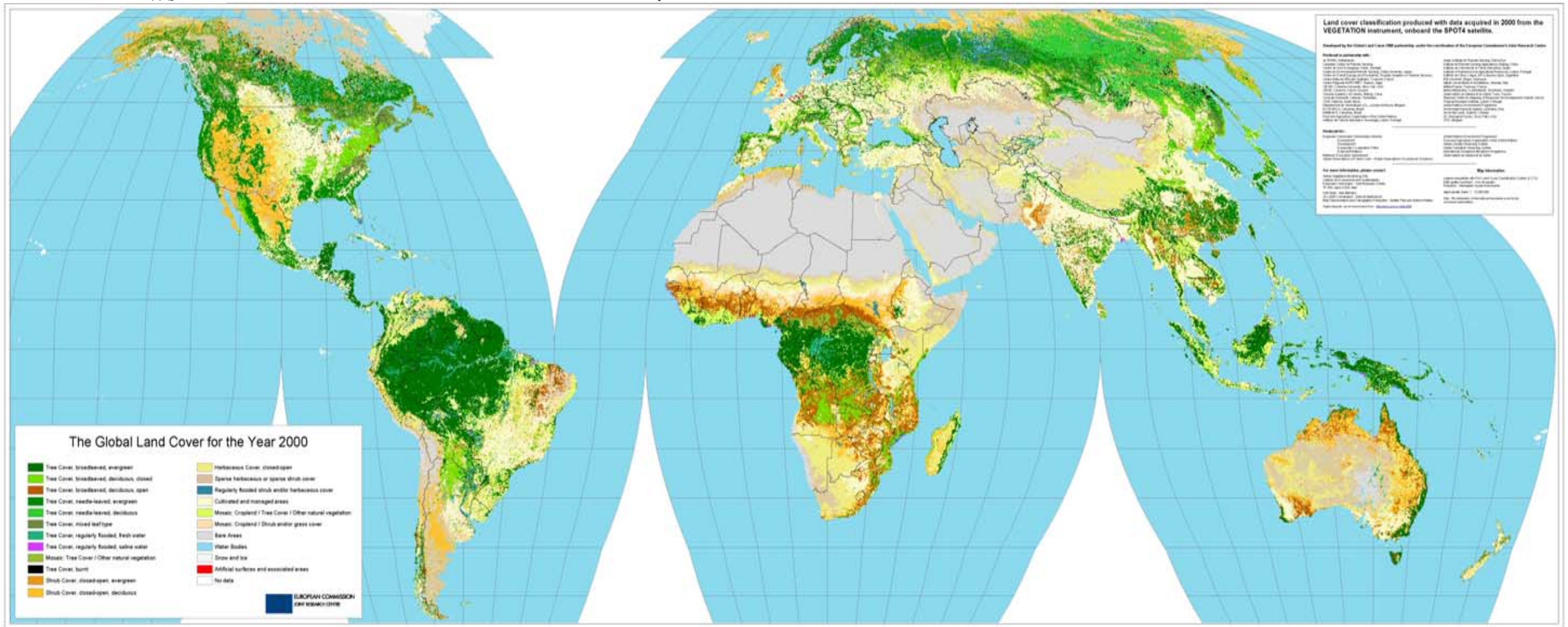
- **Emissions:** **Release of trace gases and aerosols from above-ground vegetation and below-ground peat fires → UKCA.**

- **Respond to climate drivers:** **temperature, rainfall, relative humidity, wind.**

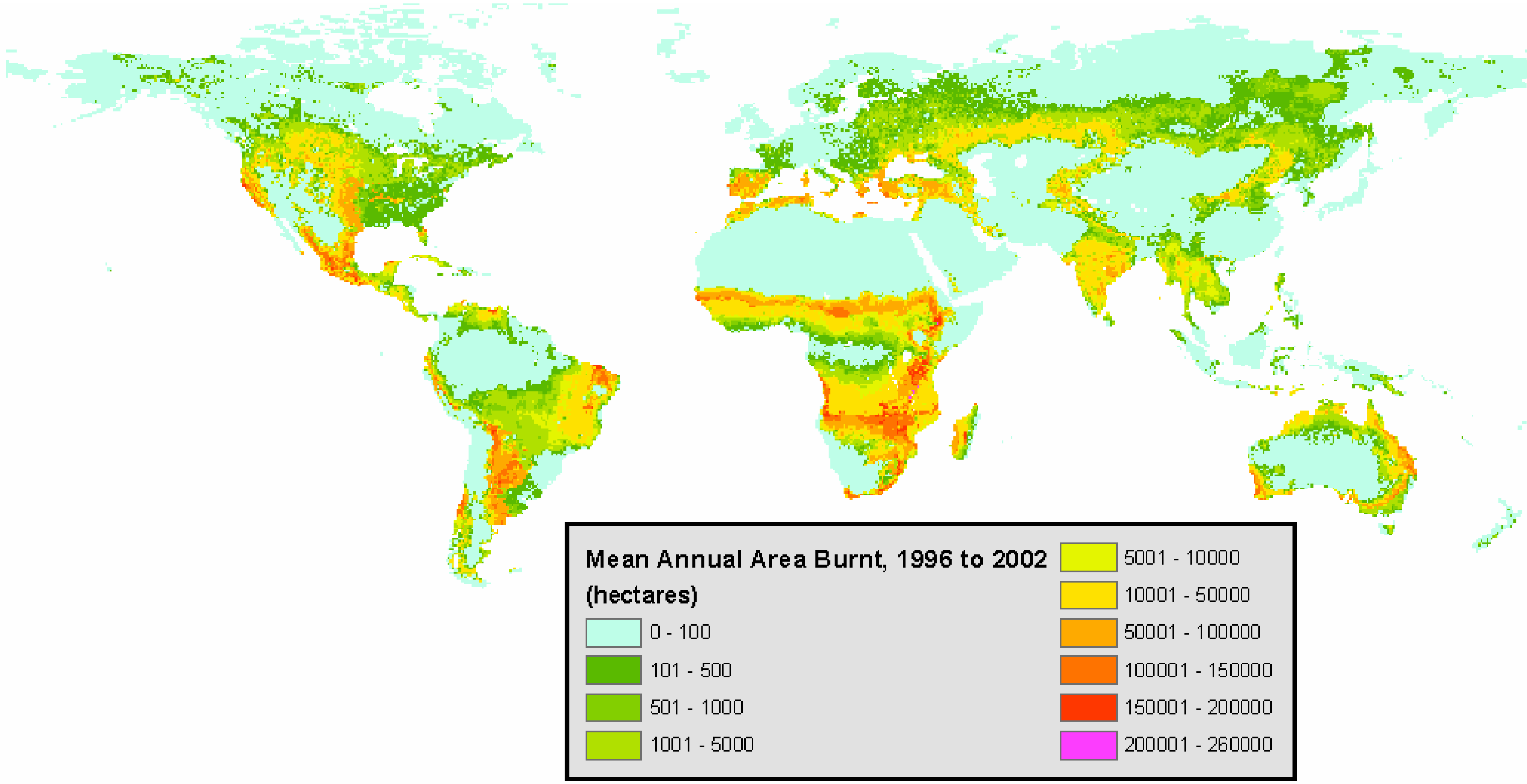
- **Land cover/use change impacts on ignitions and emissions:** **forest fragmentation, road density, land abandonment. Empirical data exist for capturing first-order effects.**

MODIS Land Rapid Response Fire Detections





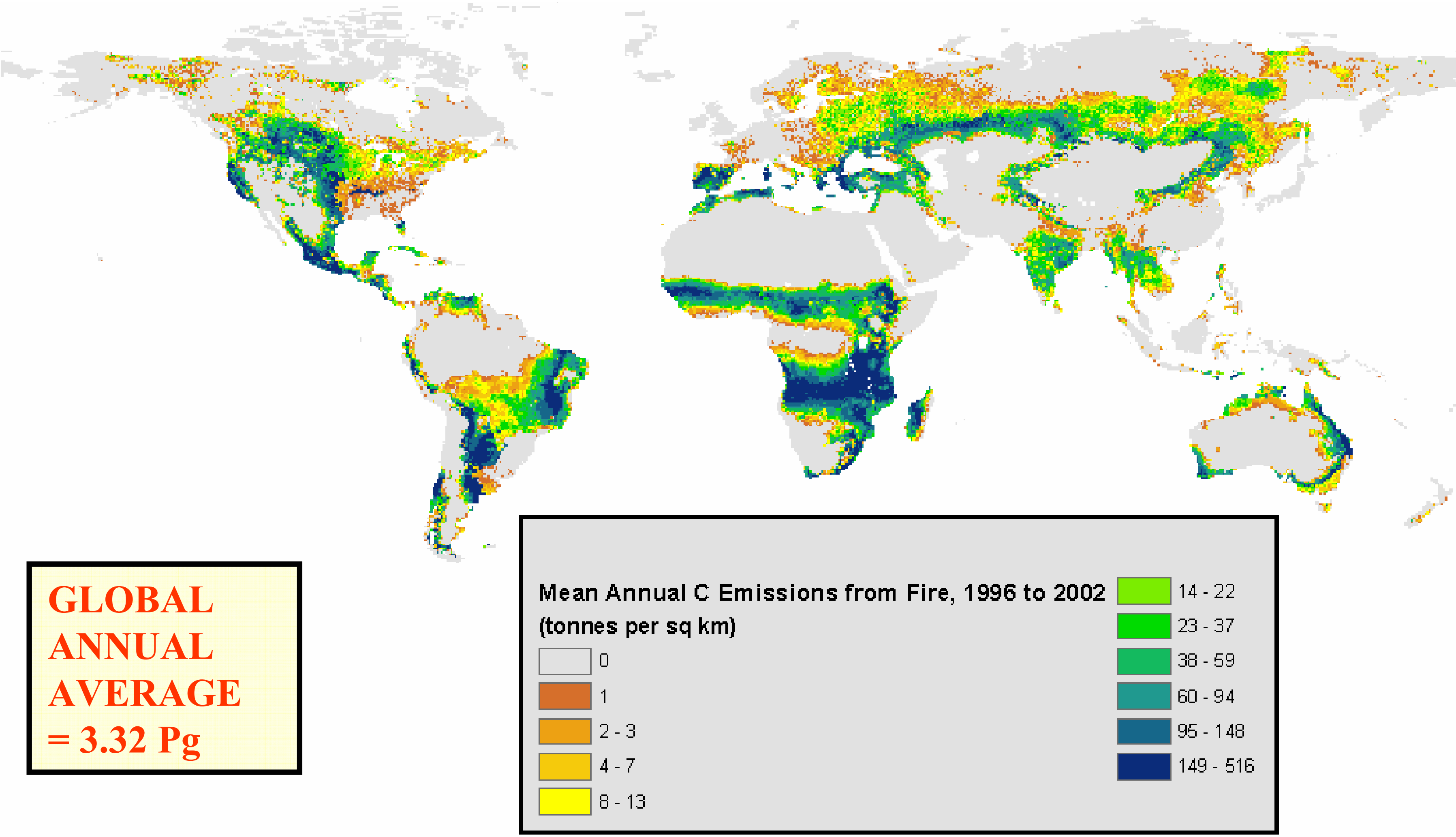
Global burnt area:
LPJ-SPITFIRE simulated mean annual annual area burnt, 1996 to 2002.



(after Thonicke, Spessa, Prentice, Harrison, & Carmona-Moreno *Global Change Biology*).

Global carbon emissions:

LPJ-SPITFIRE simulated mean annual carbon emissions from fire, 1996 to 2002.



GLOBAL ANNUAL AVERAGE = 3.32 Pg

(after Thonicke, Spessa, Prentice, Harrison, & Carmona-Moreno *Global Change Biology*).

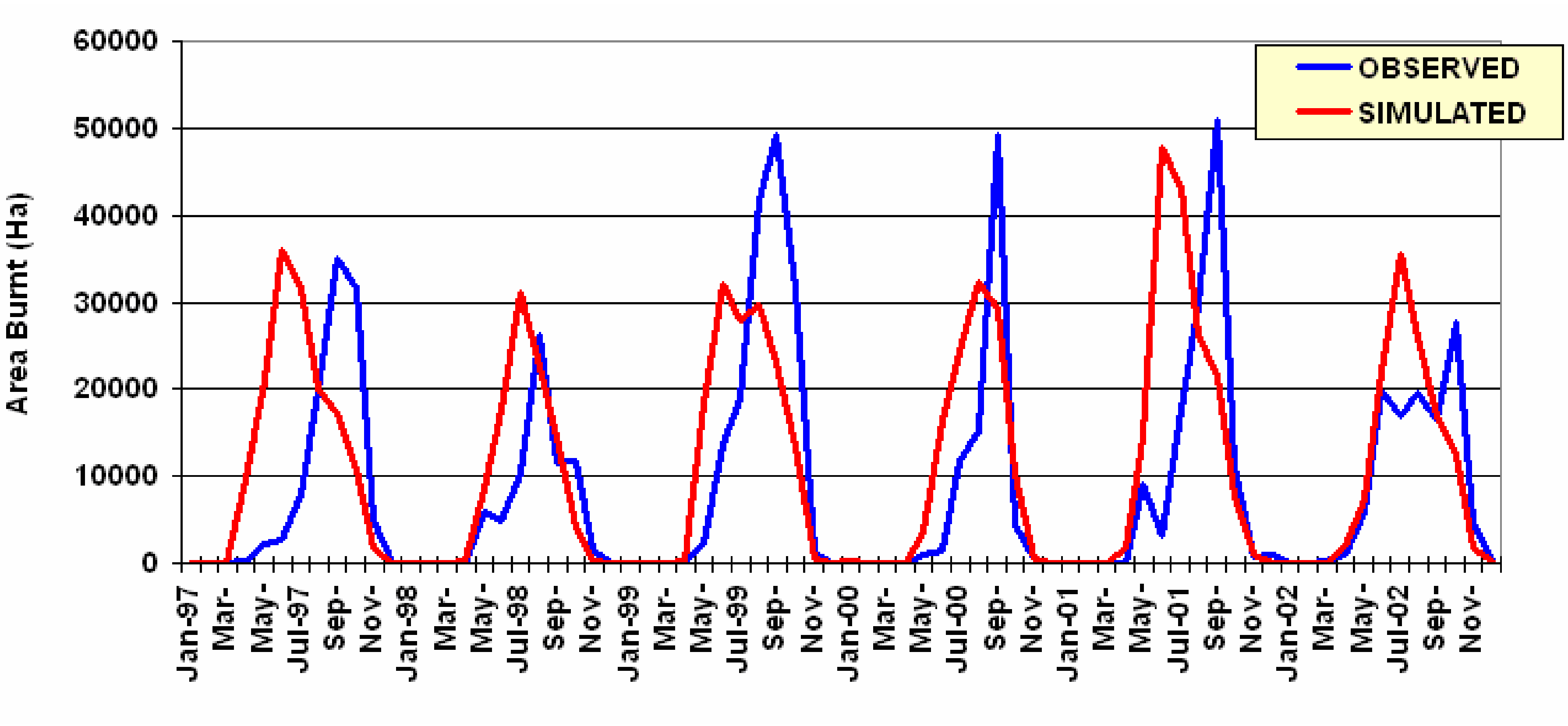
1903

1997

Dramatic woody vegetation thickening over 90 years caused by over-grazing and an absence of fire.

Confluence of the Victoria and Angallarri Rivers at Bradshaw Homestead, Northern Territory, Australia. (Sharp & Whittaker (2003). *J. Biogeography* **783-802).**

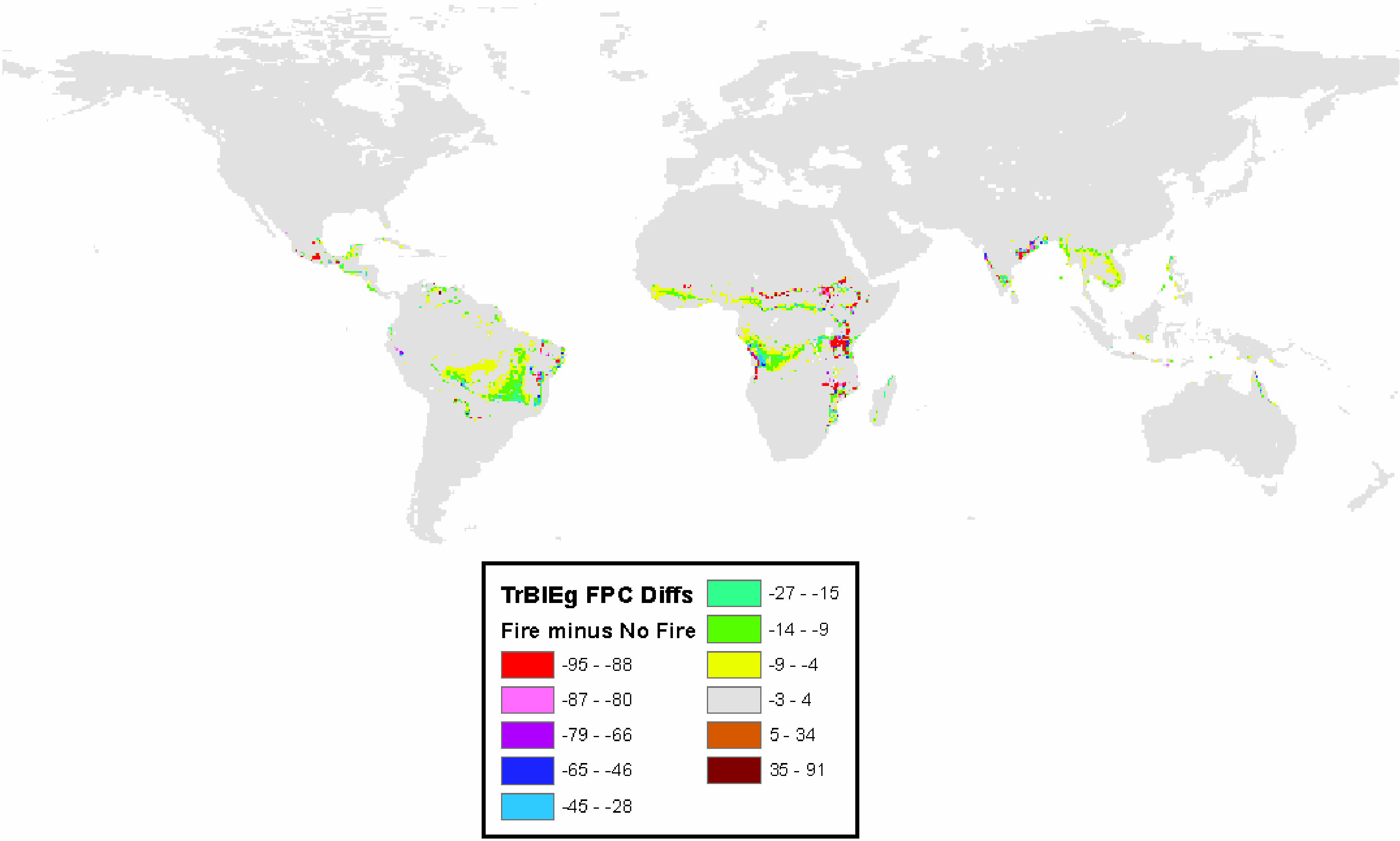
Central Arnhem, Northern Territory, Australia:
Spatially-averaged LPJ-SPITFIRE simulated burnt area vs observed burnt area, 1997 to 2002. Observed data: AVHRR-derived FAA product, Western Australia DILA).



(after Thonicke, Spessa, Prentice, Harrison, & Carmona-Moreno *Global Change Biology*).

A world with fire versus no fire:

LPJ-SPITFIRE vs LPJ w/o SPITFIRE simulated difference in TrBlEg foliage projective cover.



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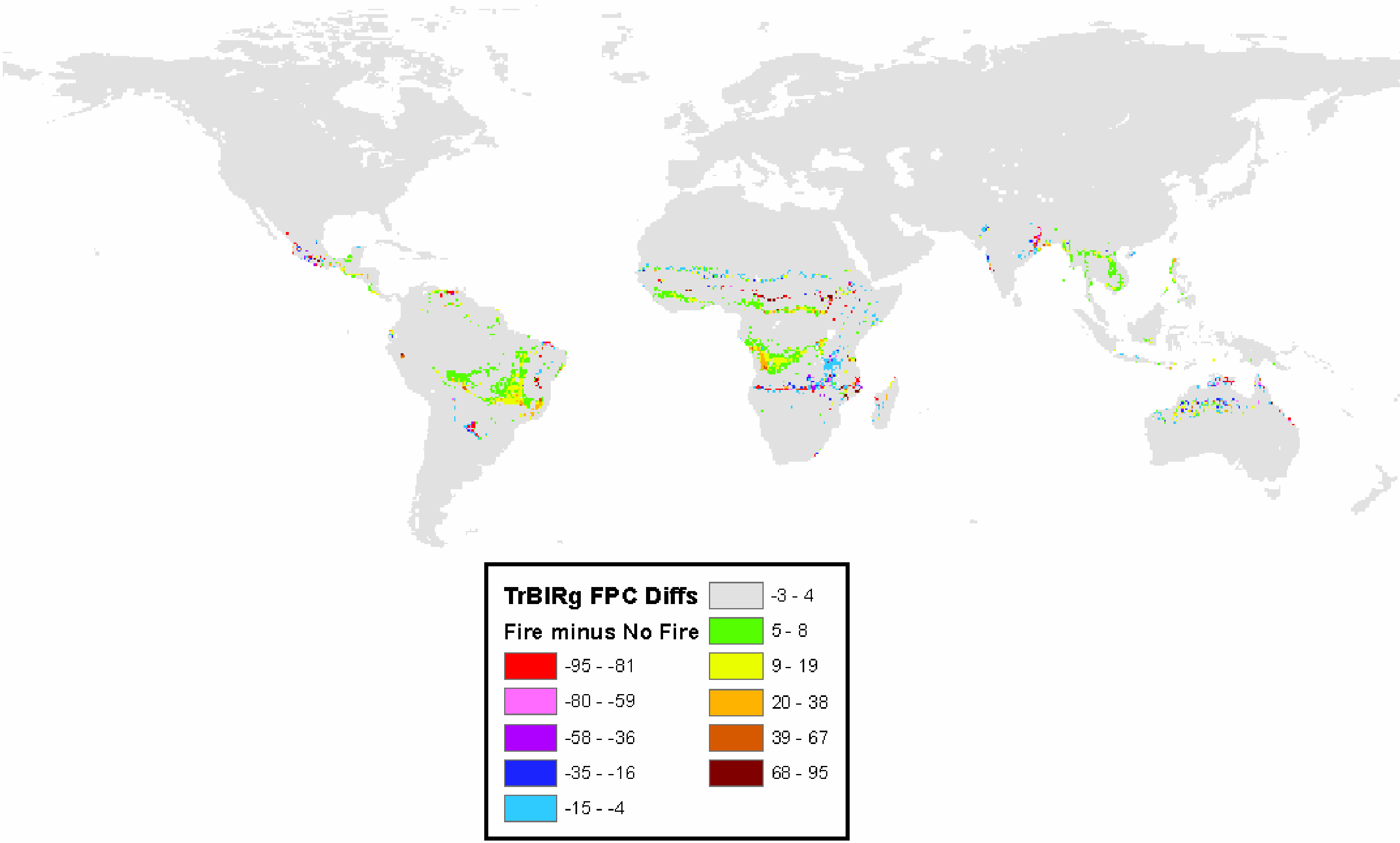


(after Thonicke, Spessa, Prentice, Harrison, & Carmona-Moreno *Global Change Biology*).

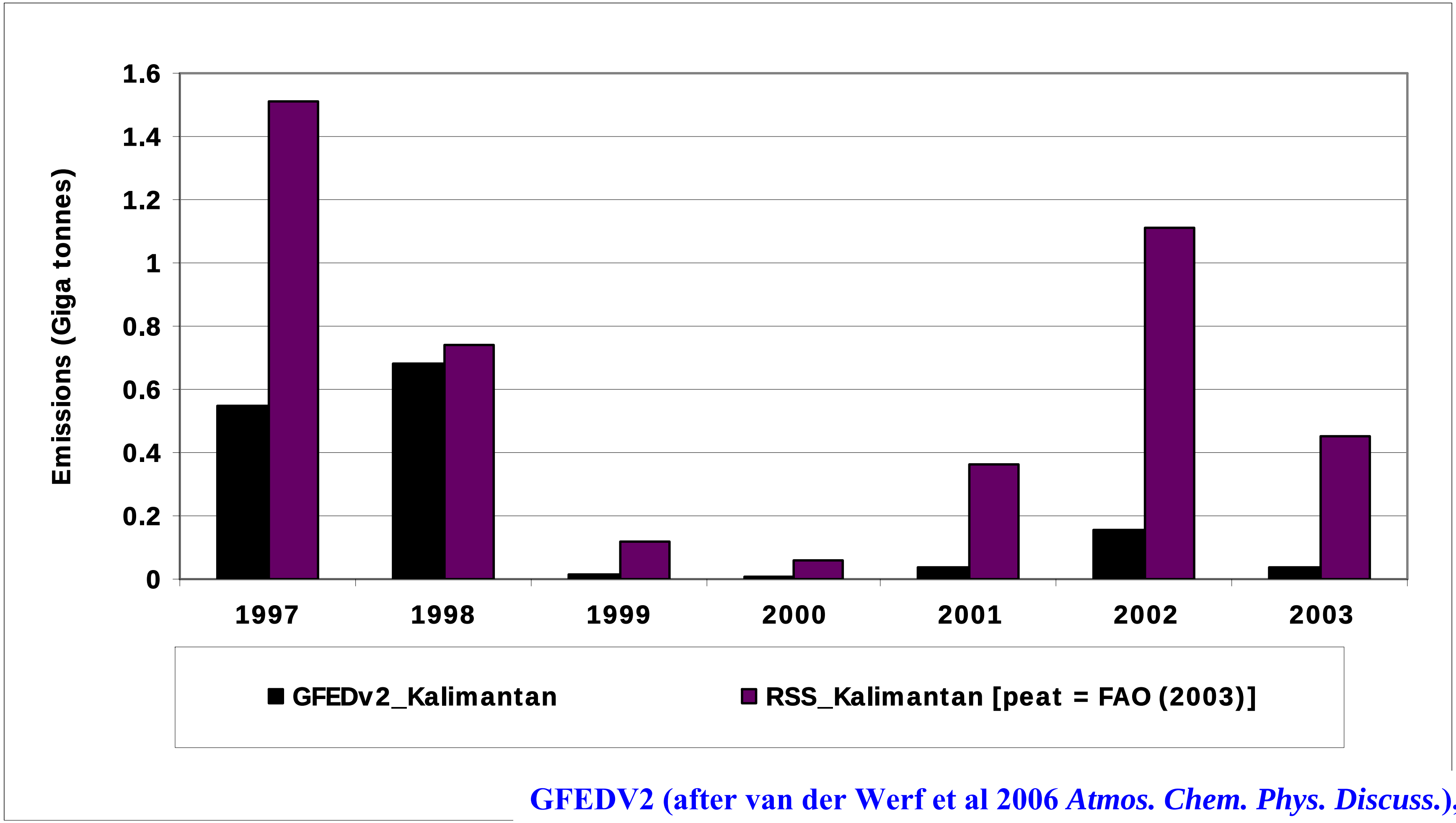
Total devastation after the forest fires of 1997 and 1998 in Kalimantan, Indonesia. Over two years, approx. 180,000 sq kms were burnt, and 2.26 Gt carbon released to the atmosphere [1].

Burnt versus unburnt tropical peat swamp forest- a sharp contrast.

Photos: Florian Siegart, Remote Sensing Solutions GmbH.

1. Spessa, Heil, Langner, Weber, Siegert *Ecosystems*

<u>Kalimantan, Indonesia</u>:
Carbon emissions from peat, forest and non-forest fires, 1997-2003, based on EO data on fires and vegetation change, and peat maps. Contribution from peat fires is on average ≈ 70%.



GFEDV2 (after van der Werf et al 2006 *Atmos. Chem. Phys. Discuss.*), RSS_Kalimantan (Spessa, Heil, Langner, Weber, Siegert *Ecosystems*).

Presentations

1. ***'Modelling Fire on the African Continent: SPITFIRE and LPJ-GUESS'.***
   Dr Veiko Lehsten, Lund University.

2. ***'Experiments with SEVER-FIRE model: lessons for future JULES fire modelling activities'.***
   Dr Sergey Venevsky, Leeds University.

3. ***'Development of a prototype fire module for Hadley GCMs'.***
   Dr Sergey Venevsky, Leeds University.

4. ***'Fires in Russian forests'.***
   Prof. Heiko Balzter. Leicester University.

5. ***'Fires in Indonesian tropical peatland forests'.***
   Dr Susan Page. Leicester University.

6. ***'Fires, Atmospheric composition, and Earth system feedbacks'.***
   Dr Oliver Wild. Cambridge University.

Absent: Dr Kirsten Thonicke. Currently at IPSL (Paris) working on implementation of SPITFIRE into ORCHIDEE.

END OF INTRODUCTION

EXTRAS

Why is Fire Important in the Earth System?

1. Atmospheric forcing

❖ Globally, fires in forest, grasslands and peatlands → 2 to 5 Pg of carbon into the atmosphere per annum. (More than annual USA or EU greenhouse gas budgets.)

❖ Global warming: Fire → greenhouse gases CO_2, CO, CH_4 etc → trap incoming solar radiation.

❖ Global cooling: Fires → aerosols → reflect incoming solar radiation.

❖ Clouds: Smoke and haze can reduce rain droplet formation. Also, burnt areas are darker (lower albedo) → increase in radiation absorbed → increase convective activity.

2. Plant reproduction & survival

❖ Hot fires kill grasses and trees. But, many plant species need fire to help germinate seedlings e.g. eucalypts in Australia, Gamba grass in Africa, birch in Siberia.

❖ Generally, grasses reproduce faster than trees after fire.

3. Carbon sinks and sources, biogeochemical cycling

❖ Increase fire frequency → more grass and fewer trees (more carbon); and VICE-VERSA.

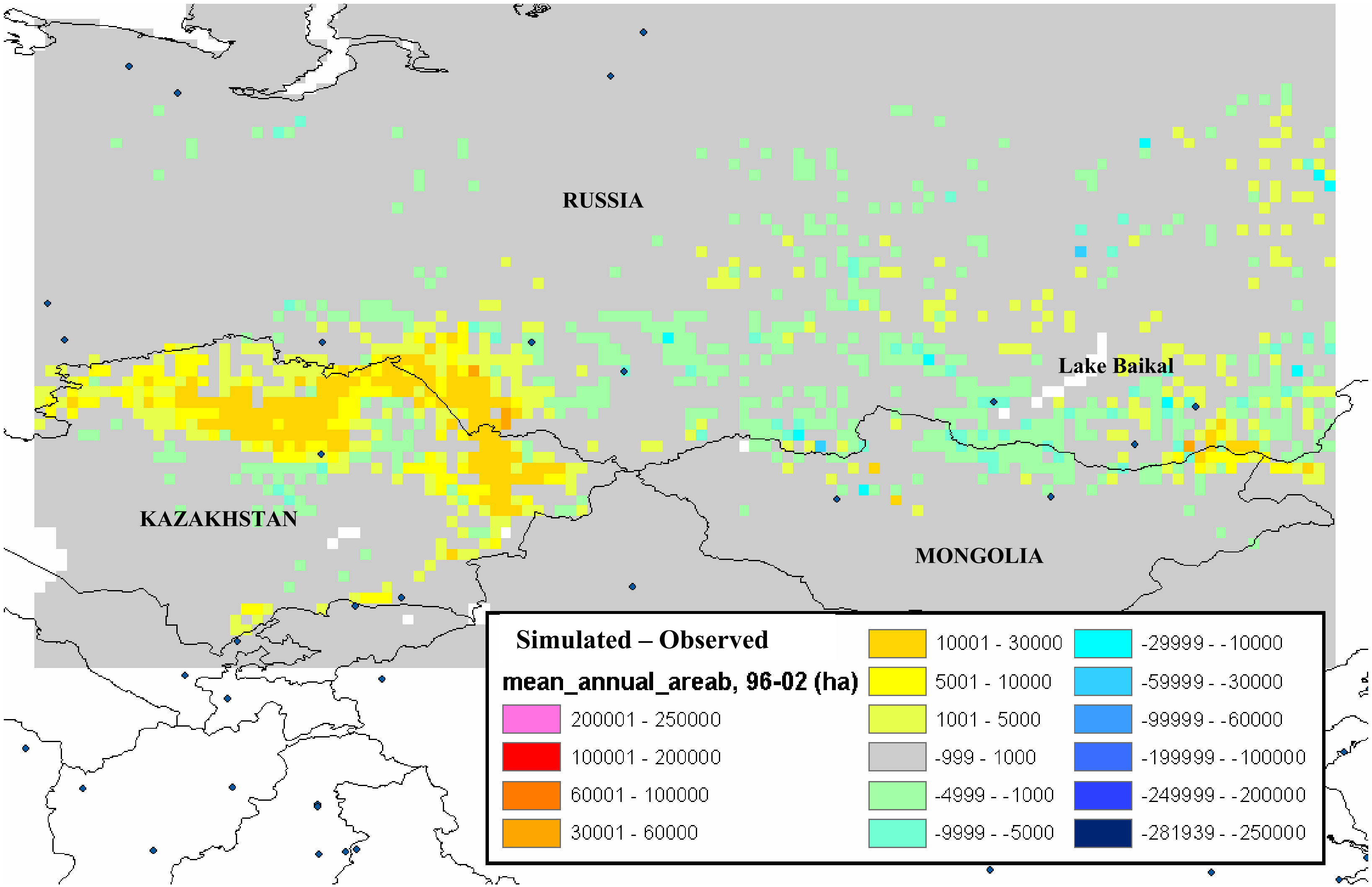
❖ Peat is a below ground carbon sink. Vulnerable to ENSO droughts & fires → carbon source.

❖ Fires → decrease soil Nitrogen (volitisation and consumption of litter), and also increase soil Nitrogen (stimulation of legumes, nitrifying bacteria).

Siberia & Central Asia:

LPJ-SPITFIRE simulated vs observed mean annual area burnt, 1996 to 2002.

Observed data: AVHRR product (Suhkinin et al 2004 *Remote Sens. Environ.*)



(after Thonicke, Spessa, Prentice, Harrison, & Carmona-Moreno *Global Change Biology*).

Study	Coverage & Focus period	Total Carbon Burnt (Gt)	Comments
Andreae & Merlet (2001) *Global Biogeochemical Cycles*	Global late 1990s	Mean = 4.3 per year	Burnt area, biomass load, moisture & consumption from literature. Emission factors experimentally determined. Peat not included.
Schultz, Holzmann, Heil, Spessa, Thonicke *et al.* RETRO. (submitted to *Global Biogeochemical Cycles).*	Global 1960 to 2000	Mean = 1.7 per year Y1997-98 = 2.5 (El Nino) Y2000 = 1.62	Burnt area from literature, ATSR, and old version of LPJ fire model. Biomass load, moisture & consumption from literature and LPJ. Peat fires from literature.
Van der Werf et al. (2006) *Atmos. Chem. Phys. Discuss.*	Global 1997 to 2004	Mean = 2.46 per year Y1997/98 = 3.18 (El Nino) Y2000 = 2.040	MODIS burnt area, CASA biogeochemical model, no crown fires, peat fires included but depth of burn shallow *cf* literature. Peat distribution out-dated. Burnt area underestimated in Indonesia.
Thonicke, Spessa, Prentice, Harrison, Carmona-Moreno (submitted to *Global Change Biology*)	Global 1996 to 2002	Mean = 3.320 per year Y1997-98 = 3.450 (El Nino) Y2000 = 3.100	LPJ+SPITFIRE- Mechanistic approach to burnt area, biomass load, moisture & consumption. Above-ground fires only. No peats.
Page et al. (2002) *Nature* 420: 61-65.	Indonesia 1997	Y1997 = 0.4 to 2.6	Peat fires: Burnt area from EO data, burn depth fixed. Peat drainage not included. Low vs high emissions based on different assumptions of area burnt.
Spessa, Heil, Langner, Weber, Siegart (*Ecosystems*)	Borneo 1997 to 2003	Y1997 = 0.645 to 1.148 (El Nino) Y1998 = 0.290 to 0.475 (El Nino) Y2002 = 0.489 to 0.836 (El Nino)	Peat fires: Burnt area from fine-resolution EO data. Low vs high emissions. Low: burn depth = simple linear function of water table depth (≈ soil moisture) with account of peat drainage. High: fixed burn depth.

Uncertainties in emission estimates

- Area burnt.
- How much biomass is available for burning through space and time
  (Litter production, crown biomass).
- Relative amount of fine fuels and coarse fuels
  (Flaming vs smouldering combustion).
- Fuel moisture (Flaming vs smouldering combustion).
- What proportion of biomass is combusted (Fire intensity).

Future Challenges…

1. Better simulation of burnt area, biomass load, fuel moisture and combustion completeness by vegetation type (e.g. PFTs).

2. Improved observational data for testing models performance.

3. Inverse modelling of burnt area and emissions. Compare forward estimates with satellite estimates of burnt area, and atmosphere measurements of CO, CO2 etc.

4. Fire radiative power measurements from middle infrared sensors aboard geostationary satellites & MODIS → direct estimate of fuel combustion.

5. Land cover change (eg. deforestation, land abandonment) and fire activity.