Poorly-Characterized Sources of Black Carbon

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Despite attention, BC emissions inventories lag those for other pollutants

- Currently, worldwide, there is no regulation of BC *per se*.
  - Some possible BC regulations are under development (Europe, Calif.)
- Lack of regulations and mandated inventories: coarse inventories
  - Much activity underway is currently improving inventories
- Focus here: sectors needing more attention
  - significant point sources
  - open burning affecting the Arctic

Sectors / Sources to consider

- Brick Kilns
- Coke Ovens
- Gas Flaring
- Wood Stoves
- Tar Sands operations

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- Open Fires

  focused on the near-Arctic: if fire emissions reach cryosphere, OC co-emissions become less of a cooling balance to BC warming

Industrial BC Emissions

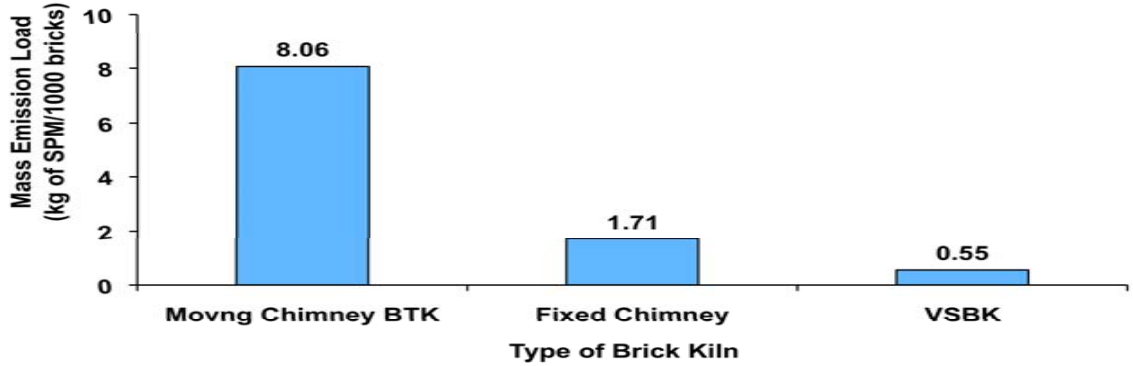
- Industrial sources are estimated to produce a significant fraction, 18 percent, of global black carbon emissions. Major source fractions are uncertain, but in order of contribution:
  - Kilns (mostly brick making)
  - Coke making
  - Boilers, industrial process, steel, lime
- ***Emissions information for most sources are extremely limited.***

Brick Kilns

- ~300,000 worldwide. Production expected to grow: for example, of total constructed area which will exist in India in 2030, about 70% will be built 2010 – 2030.
- Primary fuel is coal, plus any low-cost fuel that can be obtained (tires, battery cases, dung, etc.)
- Most brick kilns in developing countries are primitive and appear to have significant BC and other emissions.
- 75% of global production is in China (54%) and South Asia (1 trillion bricks / yr total)
- Shifting to improved kilns will typically reduce fuel consumption and CO_2 emissions.
- BC emissions reductions will ***likely*** occur by replacing kilns with improved technology.
- Measurement of climate-relevant emissions are needed to quantify the climate mitigation opportunity from improving brick kilns.

Brick kilns: Controls, measurements

Various kiln designs produce widely varying amounts of PM



- Low efficiency, high polluting kilns have been banned in China since at least the mid-1990's because of low efficiency. Upgrading of the brick industry is an important component of China's programs to encourage sustainable building materials production.
- In January 2009, the Environmental Protection Agency of Pakistan ordered brick makers in and around the capital to close or switch to cleaner technology because of the high level of pollution produced by primitive kilns.

  We don't know how effectively these bans are enforced.

Brick kilns: Controls, measurements

Various kiln designs produce widely varying amounts of BC

CATF is working with T. Bond and partners in India and Vietnam to obtain measurements from a variety of kiln types (from highly to least polluting) in those nations in 2011

Results expected in about one year

Coke Ovens

- Relatively small number of coke facilities: ~1500 worldwide
- Recent production (2006) dominated by China:

China	59%	Russia	6%
Ukraine	4	US	3
India	2.5		

- China accounts for 96% of global production growth since 2000.

Coke Oven, Al Nasser Coke and Chemical Plant, Cairo
courtesy A Gertler, DRI

- Most traditional coke ovens (prevalent through the late 1990s) are probably gone.
- Most coke ovens today support chemicals “recovery” -- need lots of emissions control measures – or “non-recovery” facilities – a much cleaner process.
- Plausible BC emissions reduction measures will come from a complex range of small particulate emissions control, most of which achieve or go beyond current US EPA control levels.

Coke Making -- Controls

- PM reductions will come from
  - Upgrading from primitive to modern kilns
  - Control measures during stages of processing and operation
  - Regular maintenance
  - Stacks on modern coke ovens allow for installation of pollution control equipment
- China is phasing out primitive ovens
- Need measurements of climate relevant properties

Flaring from oil and gas

- Oil and gas flaring is a source of PM and black carbon.
- Questions/Issues
  - How much PM and black carbon are produced?
  - How does this vary by location, gas composition, conditions/operation?
  - How will this change in the Arctic with increased oil and gas exploration?
- No accepted protocols for quantifying PM from these or other open sources

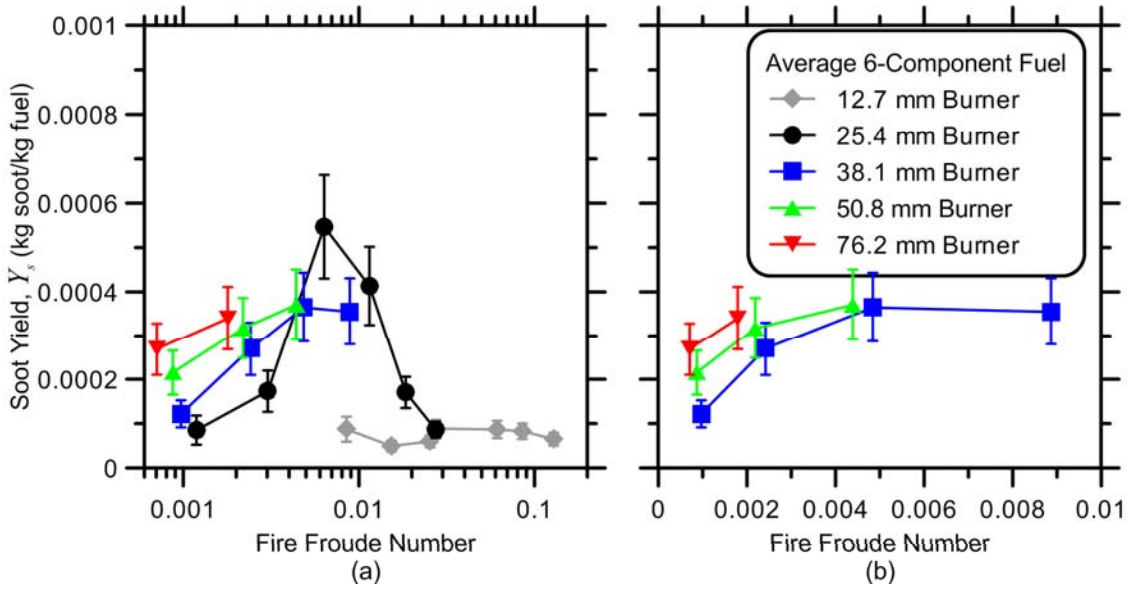
Flaring Soot & PM emissions studies from Matthew Johnson, Carleton University

Two main areas of interest:

1. Direct measurement of soot emissions from flares in controlled lab setting
   - Sampling protocol development
   - Fundamental investigation
   - Emission factors development
2. Novel diagnostic to measure soot from flares in the field
   - Desire simple tool to improve upon qualitative “opacity”
   - Related work on measuring optical properties of soot aggregates

1. Soot Measurements at Lab Scale

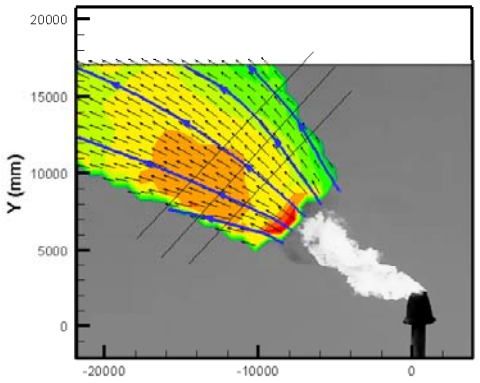
- Critical steps toward predictive models
  - Regime transition effect apparent for larger flares

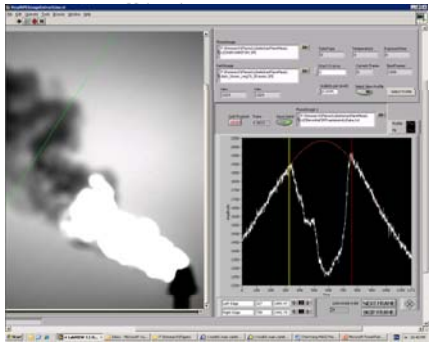


(Journal article to be submitted to JAWMA, Oct. 2010)

  - Testing of larger flares in National Fire Lab proposed

2. Field Diagnostic for Soot Plumes





- Novel camera based technique under development to directly measure strongly sooting flares under field conditions
- Lab-based development:
  - *Thomson et al., Applied Optics, 2008*
  - *Johnson et al. (1), Env. Sci. Technol, accepted pending minor revisions, Sept. 2010.*

- Initial field trial completed to measure emissions from a large sooting flare in Uzbekistan
  - *First ever, quantitative field measurement of soot from a flare*
  - *Johnson et al. (2), currently under review with Env. Sci. Technol. as of Sept. 2010.*

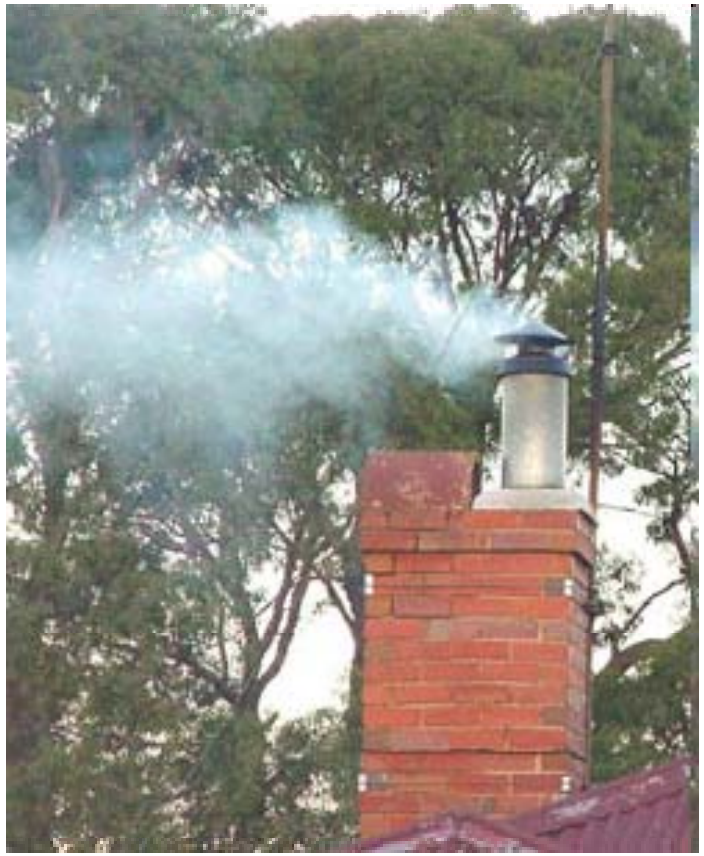
Wood (and Pellet) Stoves

- Wood stoves in far-north locations (esp. Scandinavia) are a very significant source of BC in and near the Arctic.
- Emissions factors uncertain, very widely by stove type, wood, **and operation.** Turnover hard to project.
- Regulation (and much emissions work) has focused on PM. For currently developing NSPS, BC testing is planned, for “information purposes”

Wood (and Pellet) Stoves

- Much work underway to improve emissions estimates:
- National efforts (part of regulatory effort
  - US (NSPS), Finland, Germany, others

Due to variation in operations, technologies, turnover, this will remain a difficult sector to quantify.

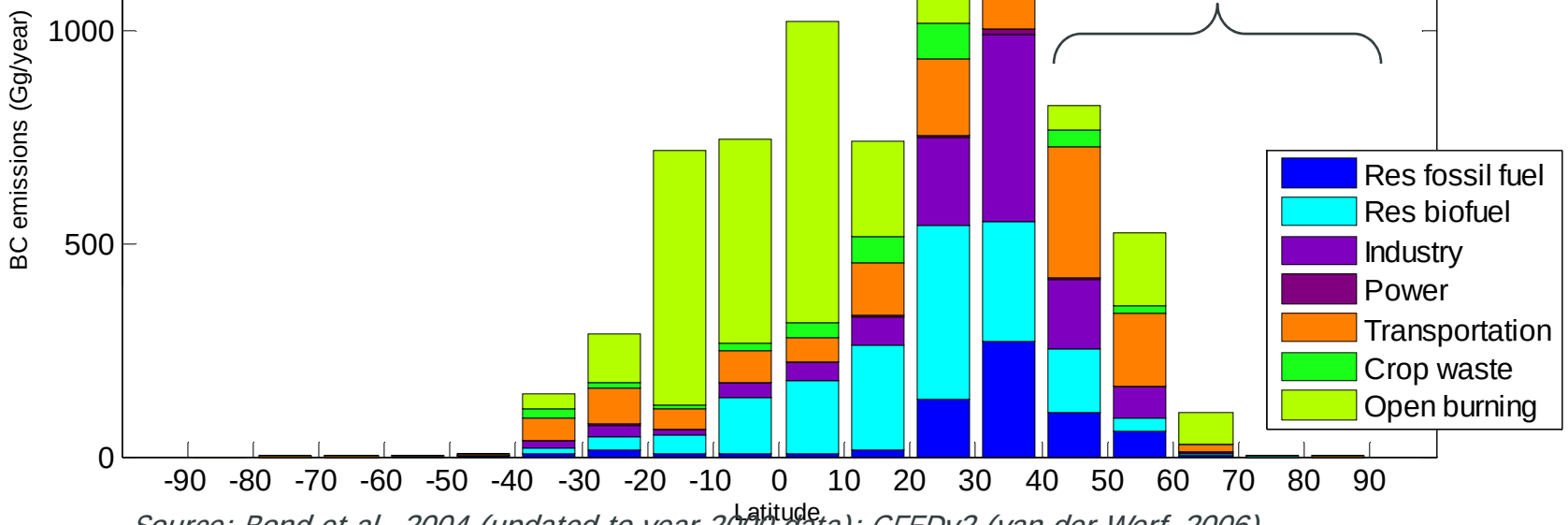


Open Burning: focus on near-Arctic emissions

~6500 Gg
Affects atmospheric warming

~"only" 1500 Gg BUT: affects warming ***and*** Arctic snow melt= greater impact from reductions

Open fires often have high OC/BC so BC warming is ~balanced by OC cooling.



Source: Bond et al., 2004 (updated to year 2000 data); GFEDv2 (van der Werf, 2006)

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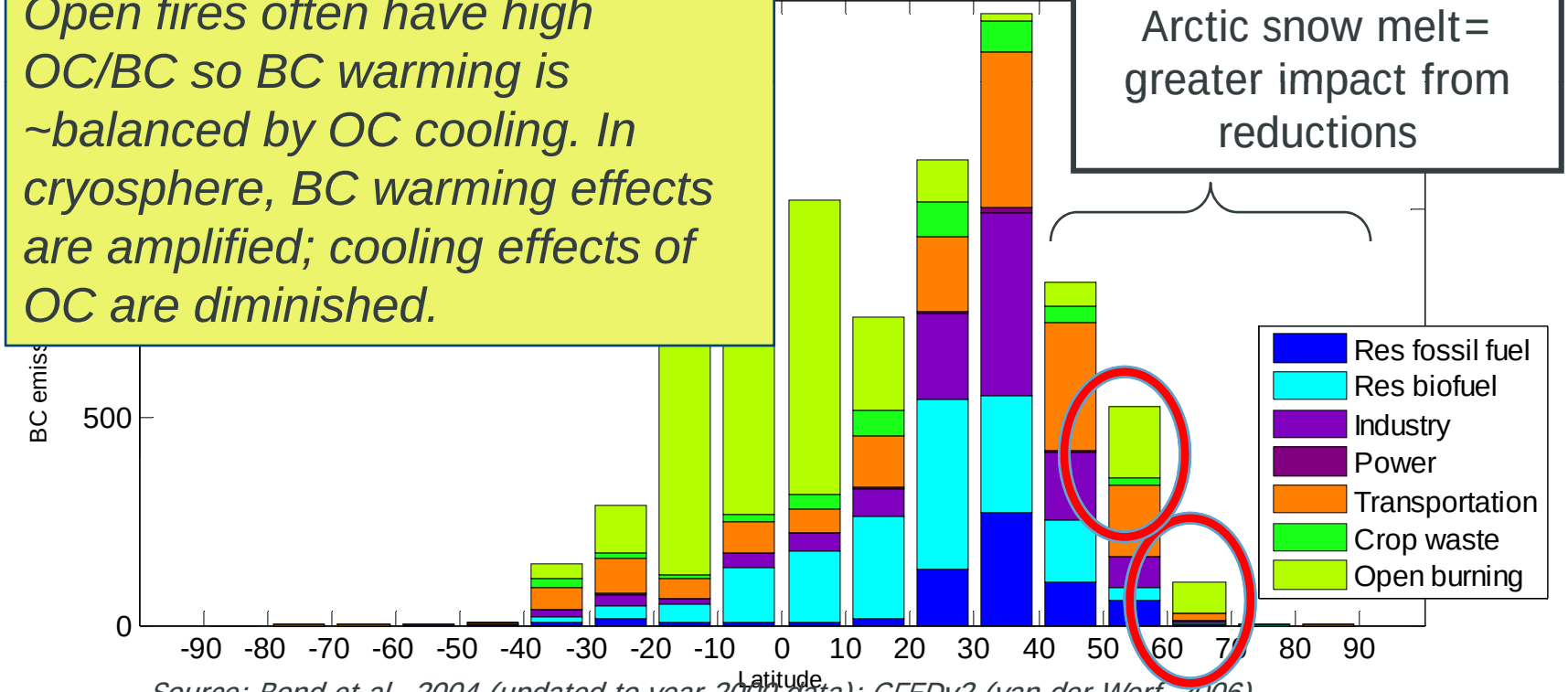
Open fires often have high OC/BC so BC warming is ~balanced by OC cooling. In cryosphere, BC warming effects are amplified; cooling effects of OC are diminished.



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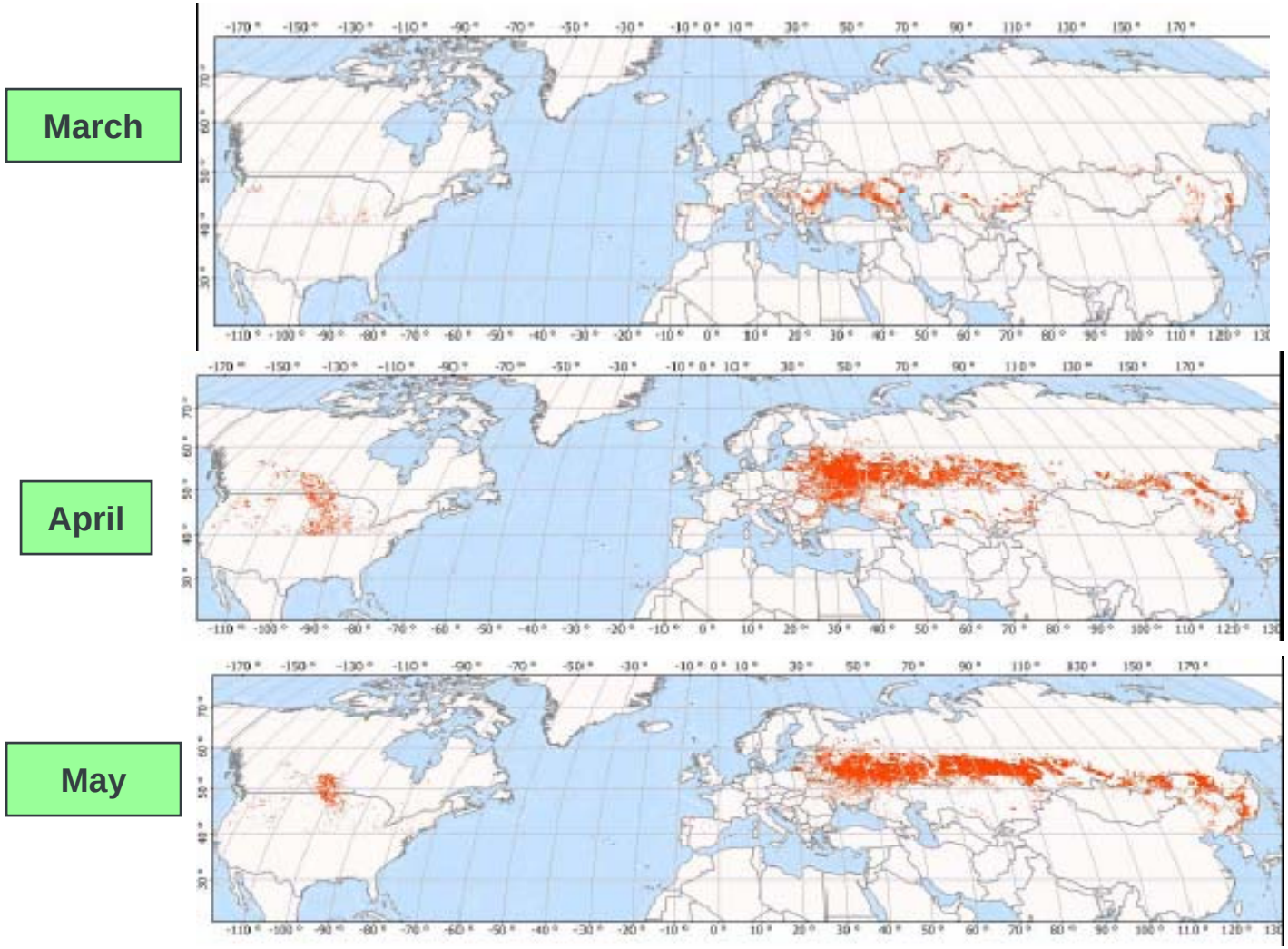
Focus on springtime set fires capable of affecting the Arctic



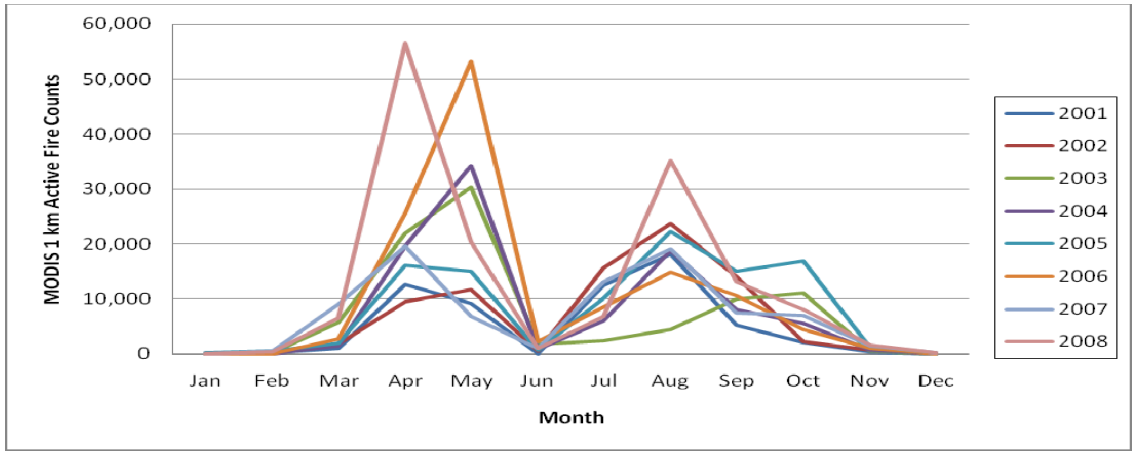
Spring 2006 burn locations, on croplands north of 40°N.

2006 was a typical fire year.

From, MODIS Terra Global Land Cover and Burned Area, 1 km

BC emissions from cropland burning in Russia

- Assign 1-km MODIS Active Fire (MOD14/MYD14) with land cover from 1-km MODIS Land Cover Dataset (MOD12)
- For European Russia, focus on burned area analysis from MODIS 8-day surface reflectance and MODIS Burned Area Product
- Estimate BC from both the active fire product and the burned area products using bottom-up approach (Seiler and Crutzen, 1980)
- BC emission factors from the literature; Russian collaborators determining more appropriate fuel load values



Monthly Russian cropland fires detected by 1-km MODIS active fire, defined as IGBP classes 12 and 14, 2001- 2008.

J McCarty, Univ. Louisville & V. Romanekov, All-Russian Inst. for Agrochemistry

BC emissions from cropland burning in Russia

Focus on accuracy assessment of BC emission estimates:

- AGU Fall 2010 Meeting presentation (McCarty & Romanekov)
- Accuracy assessment of active fire detections
- Accuracy of land cover dataset
  - Russia has not produced moderate to high resolution land cover map
  - Limited ground-level crop data

J McCarty, Univ. Louisville & V. Romanekov, All-Russian Inst. for Agrochemistry

Emissions, transport, & deposition of BC from northern Eurasian fires to Arctic Ice

- Validation of algorithms of different satellite sensors to map burn areas of agricultural, grassland, and forest fires in N Eurasia.
- Scientific exchanges with Russian scientists in methodology development and acquisition of land cover maps and fuel loading dataset.
- Cooperation with Russian and USDA scientists on areas, yields, production, and practices for different crops in different regions.
- Development of daily fire emissions of BC at a 1 km x 1 km resolution from 2002 to 2010.
- Analysis of sources, transport, and deposition of fire-emitted BC to Arctic ice using GEOS-Chem.
- Effectiveness of various mitigation scenarios of BC emissions based on different changes of agricultural and forest management and practices.

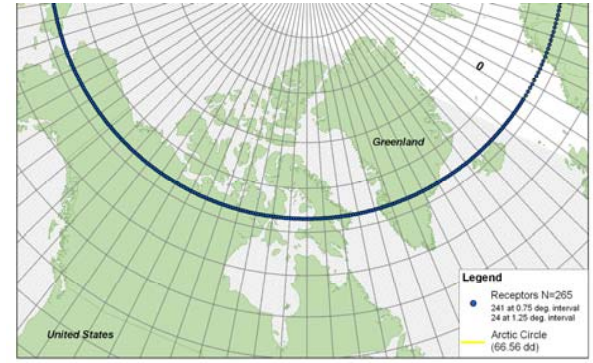
W.-M. Hao, US Forest Service Missoula Lab

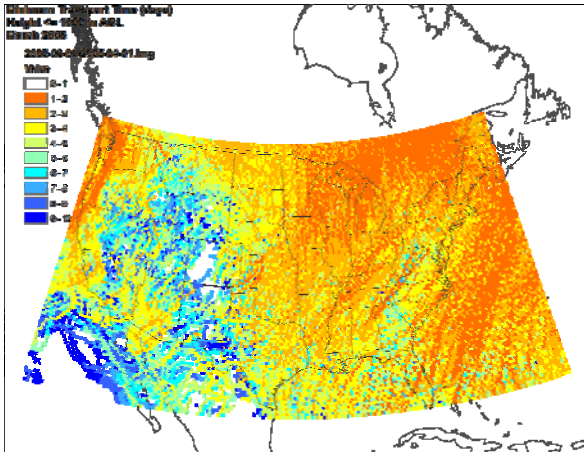
Transport to the Arctic

What are the necessary seasonal timing, meteorological patterns and plume injection height conditions that allow for transport to the Arctic?

- 30 yr back trajectory study
- Global, source-type agnostic
- All points on the Arctic circle, Greenland
- North American Regional Reanalysis nested in Global (NCEP) Reanalysis

- Current analysis: sources in CONUS
- Prescribed *vs.* wildfire contributions
- Other regions, source types possible





S. Larkin, US Forest Service PNW Lab

Emissions from tar-sands operations?

The Salt Lake Tribune

Utah agency approves oil-sands project

By Steven Oberbeck
The Salt Lake Tribune

Published Sep 15, 2010 11:39AM
Updated Sep 14, 2010 10:21PM

A small Canadian company has received approval from the director of the Utah Division of Oil, Gas & Mining to proceed with its plans to develop a commercial tar-sands mine in eastern Utah.

Any measurements of BC available for this sector?

Extra Slide

Options to reduce agricultural burning

- Ban spring time burning
- Expand uses for crop waste, including biochar production *via* pyrolysis.
- Timing and permit fires, based on meteorological conditions and forecasts to avoid transport of black carbon to the Arctic and other vulnerable snow covered areas.