ARCTAS

Arctic Research of the Composition of the Troposphere from Aircraft and Satellites

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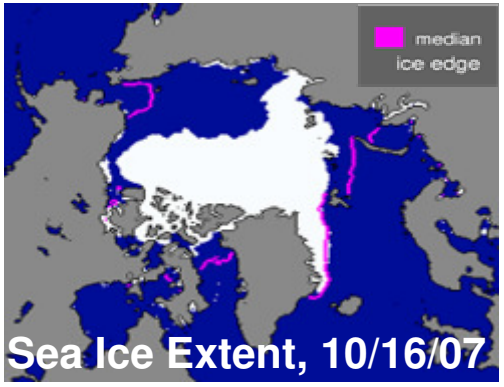
***with thanks to Jim Crawford, Mike Fromm, Amber Soja, & the ARCTAS Science Team**

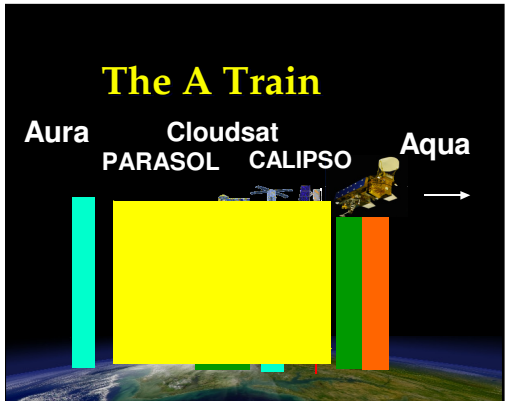
Institute for Catastrophic Loss Reduction
October 16, 2009

ARCTAS
Spring/Summer 2008

$24,000,000 USD
(NASA contribution to IPY and POLARCAT)

Urgent Need to Better Understand ARCTIC Atmospheric Composition & Climate





ARCTIC A BEACON OF GLOBAL CHANGE

- Rapid warming over past decades
- Receptor of mid-latitudes pollution – arctic haze, ozone, persistent pollutants
- Large and increasing influence from boreal forest fires in Siberia and North America

POTENTIALLY LARGE RESPONSE

- Melting of polar ice sheets and permafrost
- Decrease of snow albedo from soot deposition
- Efficient UV/Vis absorption by ozone, soot
- Halogen radical chemistry

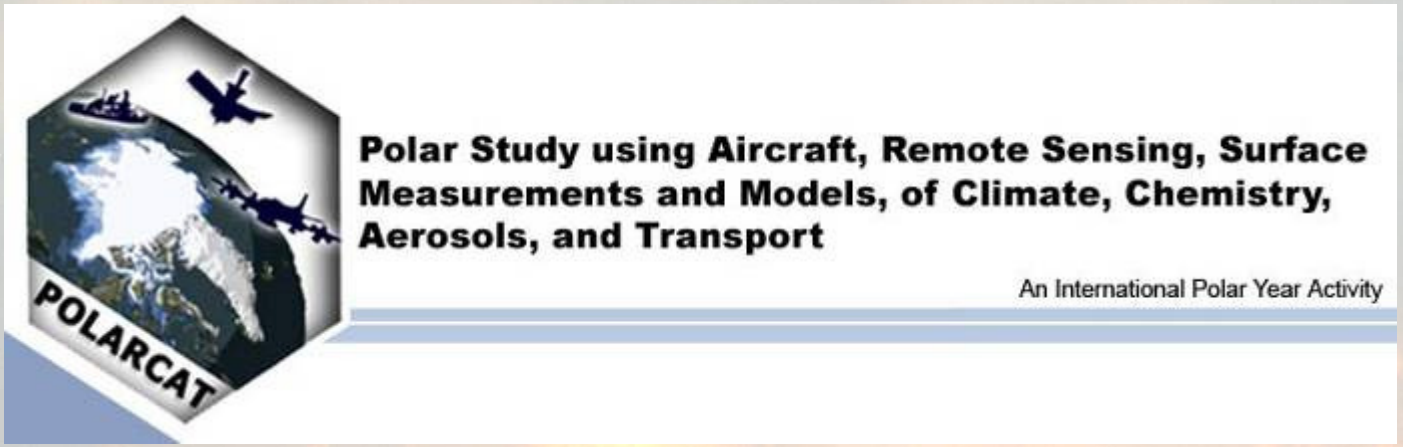
UNIQUE OPPORTUNITY FOR NASA

- Large NASA satellite fleet for atmospheric composition and radiation
- Interagency and international collaboration through POLARCAT international atmospheric chemistry field program during IPY

International Polar Year 2007-2008

IPY Concept:

- The concept of the International Polar Year 2007-2008 is of an international program of coordinated, interdisciplinary scientific research and observations in the Earth's polar regions:
- to explore new scientific frontiers
- to deepen our understanding of polar processes and their global linkages
- to increase our ability to detect changes, to attract and develop the next generation of polar scientists, engineers and logistics experts
- to capture the interest of schoolchildren, the public and decision-makers
- overarching proposals evaluated by IPY international steering committee
- sub-projects within each overarching proposal submitted for scientific evaluation to individual IPY-sponsoring countries



- POLARCAT will execute a series of aircraft experiments at different times of the year in order to follow pollution plumes of different origin as they are transported into the Arctic and observe the chemistry, aerosol processes, and radiation effects of these plumes. It will also observe the atmospheric composition in relatively cleaner regions outside major plumes.
- The experiments will also take advantage of the long residence times of pollutants in the stably stratified Arctic atmosphere to study ageing processes by targeting air masses that have spent considerable time in the Arctic.

Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS)

A NASA contribution to IPY and the international POLARCAT initiative

http://cloud1.arc.nasa.gov/arctas

Conducted in spring and summer 2008 with the following foci:

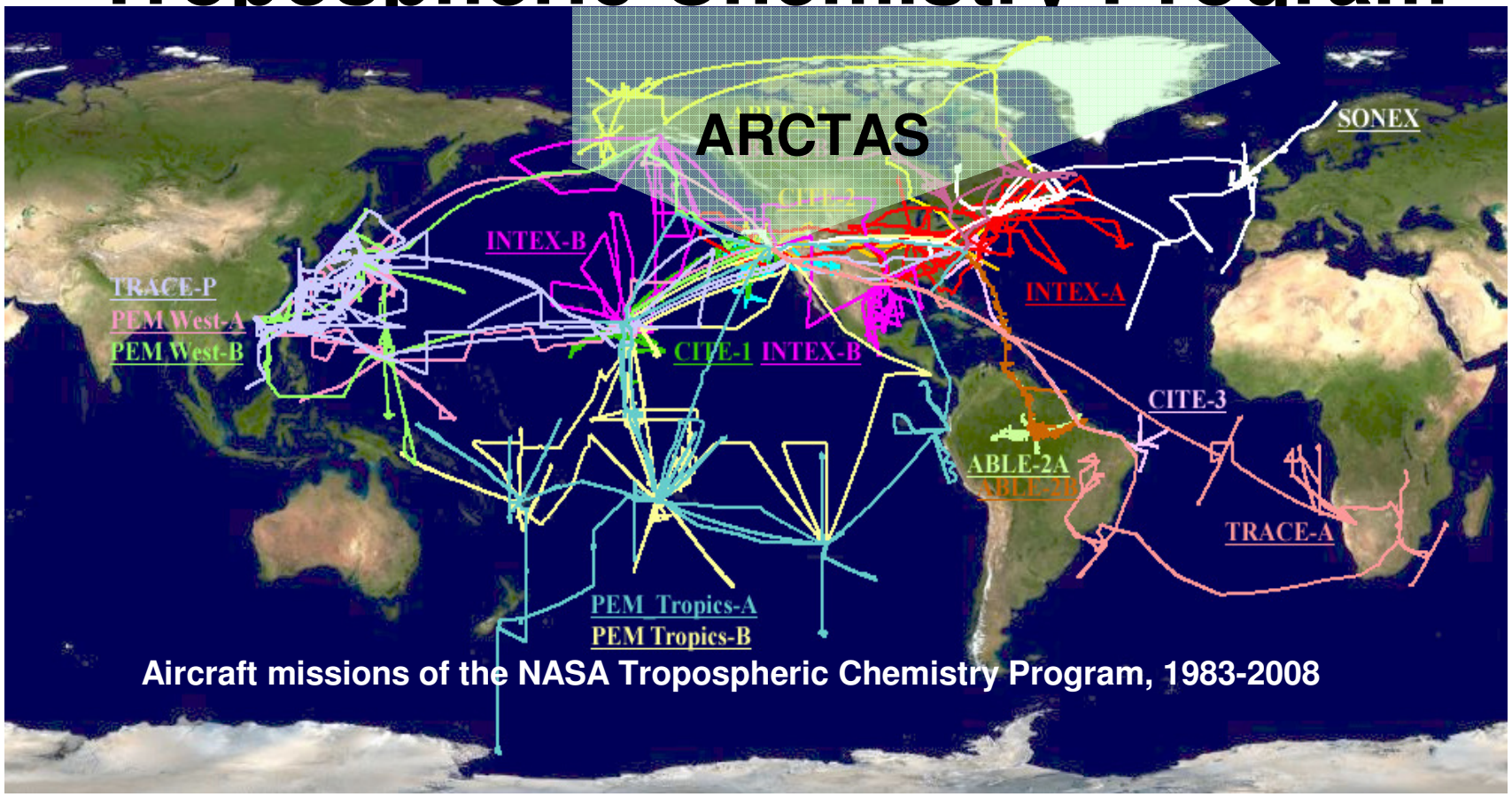
1. **Long-range transport of pollution to the Arctic** (including arctic haze, tropospheric ozone, and persistent pollutants such as mercury)
2. **Boreal forest fires** (implications for atmospheric composition and climate)
3. **Aerosol radiative forcing** (from arctic haze, boreal fires, surface-deposited black carbon, and other perturbations)
4. **Chemical processes** (with focus on ozone, aerosols, mercury, and halogens)

April 2008: *Fairbanks and Barrow, Alaska; Thule, Greenland*

July 2008: *Cold Lake, Alberta; Yellowknife, NW Territories*

Partners: *NASA, NOAA, DOE, NSF, Canada, France, Germany*

ARCTAS Continues Legacy of NASA Tropospheric Chemistry Program



Two 3-week deployments: Apr 1-21 Apr (Fairbanks), Jun 26 – Jul 14 (Cold Lake)

- **Three NASA aircraft: DC-8 (in situ chemistry and aerosols, DIAL), P-3 (radiation, in situ aerosols), B-200 (remote aerosols, CALIPSO validation)**

Aircraft Platforms and Payloads

DC-8: in situ chemistry and aerosols

Ceiling 37 kft, range 4000 nmi, endurance 9 h
Payload: O_3, H_2O, CO, CO_2, CH_4, NO_x and HO_x chemistry, BrO, mercury, NMVOCs, halocarbons, SO_2. HCN/CH_3CN, actinic fluxes, aerosol composition, aerosol mass and number concentrations, aerosol physical and optical properties, remote ozone and aerosol

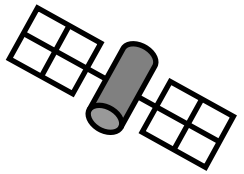
P-3: radiation and in situ aerosols

Ceiling 30 kft, range 3800 nmi, endurance 8 h
Payload: optical depth, radiative flux, radiance spectra, aerosol composition, black carbon

B-200: aerosol remote sensing and CALIPSO validation

Ceiling 32 kft, range 800 nmi, endurance 3.5 h
Payload: High Spectral Resolution Lidar (HSRL)
Research Scanning Polarimeter (RSP)

ARCTAS STRATEGY: use aircraft to increase value of satellite data for models of Arctic atmospheric composition and climate



Satellite instruments: CALIPSO, OMI, TES, HIRDLS, MLS, MODIS, AIRS, MISR, MOPITT

- **Aerosol optical depth, properties**
- **CO, ozone, BrO, NO_2, HCHO**

Aircraft: DC-8, P-3B, B200

- **Detailed in situ chemical and aerosol measurements**
- **Remote sensing of ozone, aerosol, surface properties**

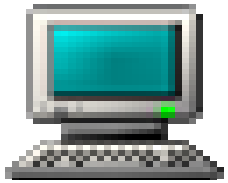
Retrieval development & validation

- **Observational error characterization**
- **Correlative information**
- **Local chemical & aerosol processes**

Models: CTMs, GCMs, ESMs

- **Source-receptor relationships for Arctic pollution**
- **Effects of boreal forest fires**
- **Aerosol radiative forcing**
- **Arctic chemistry**
- **Climate response**

Data assimilation
Diagnostic studies



Chemistry and Aerosols
21 instruments

Radiation and Aerosols
9 Instruments

Aerosol satellite validation
HSRL – CALIPSO
RSP – GLORY

Satellite Teams: CALIPSO, MODIS, TES, OMI, AIRS, MISR, MOPITT
Model Forecasting: GEOS-5, GOCART, STEM, MOZART
ARC-IONS: Ozonesonde network in cooperation with Environment Canada

The ARCTAS science team includes over 150 scientists and support personnel representing 8 NASA installations, 12 Universities, and 3 Government Labs

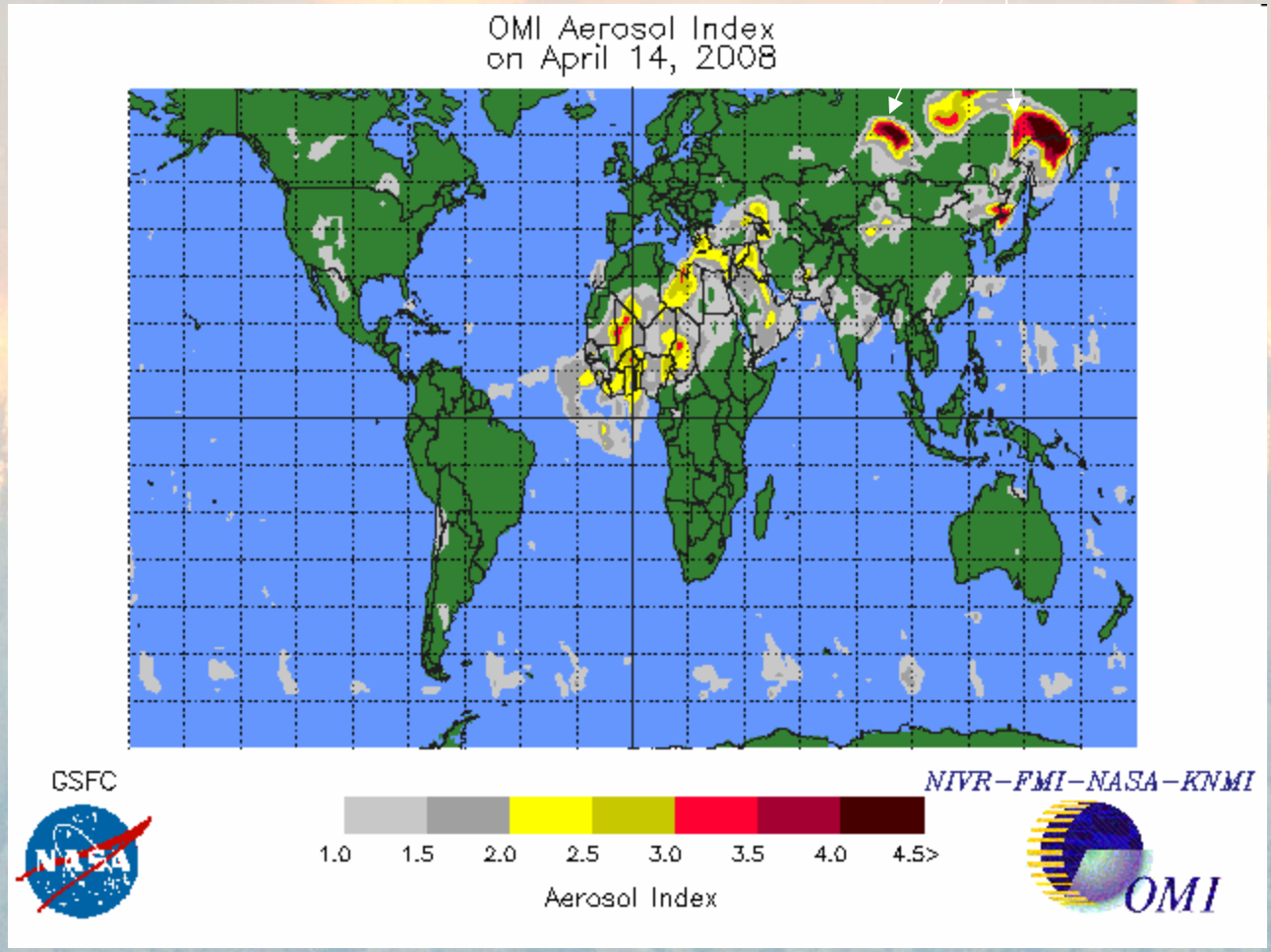
	LaRC	ARC	GSFC	JPL	MSFC	GISS	DFRC	WFF	Univ/OGOV
Measurements	X	X				X			X
Satellite Teams	X		X	X					X
Model Forecasting	X		X						X
Science Leadership and Decision Support	X	X			X				X
Aircraft operations	X						X	X	X
Logistics and Data Archival	X	X							

ARCTAS Spring Phase (April 2008)

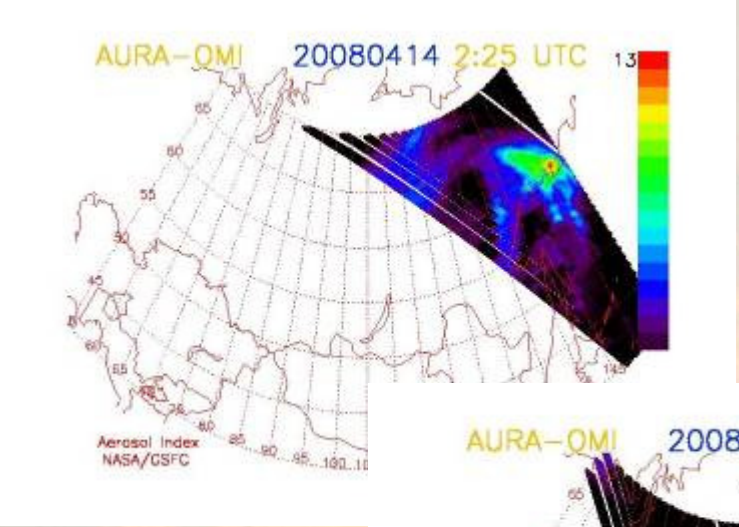
- Focus on long-range transport of pollution to Arctic
  - Arctic Haze
  - Tropospheric ozone
  - Mercury
- Based in Fairbanks & Barrow AK, and Thule, Greenland
- Russian spring fires a surprise

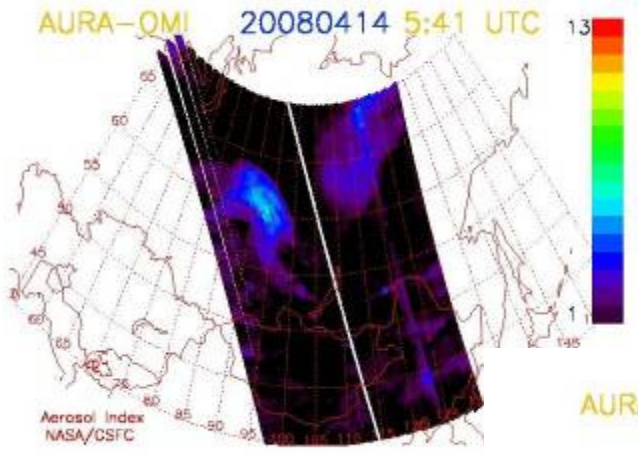
ARCTAS/ARCPAC Spring

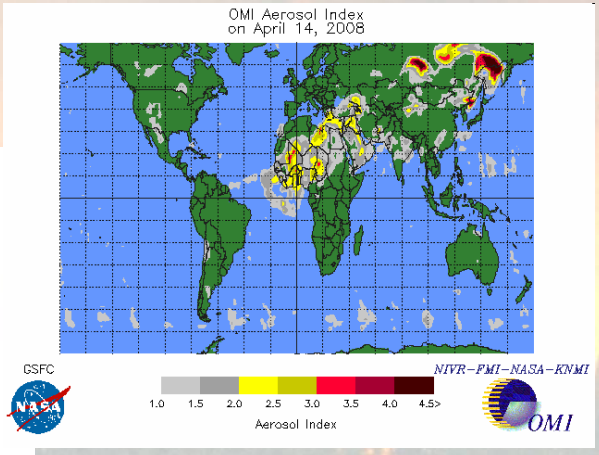
Eurasian biomass burning smoke transport to Northeast

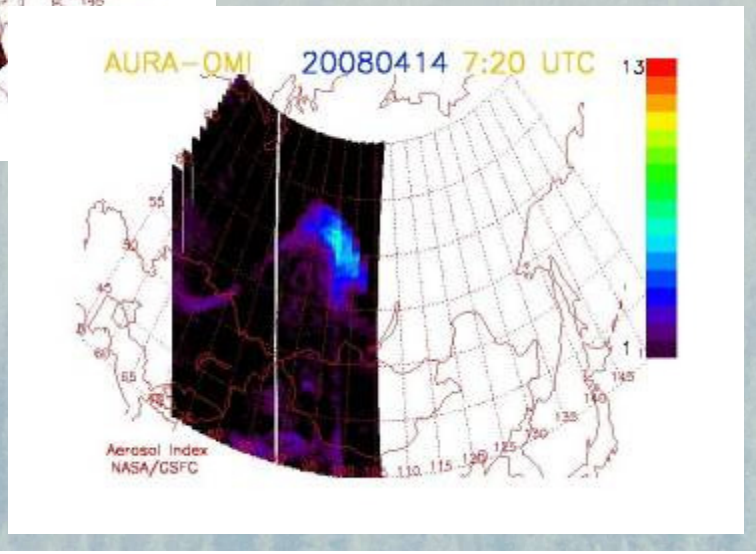


Smoke Transport
April 14, 2008





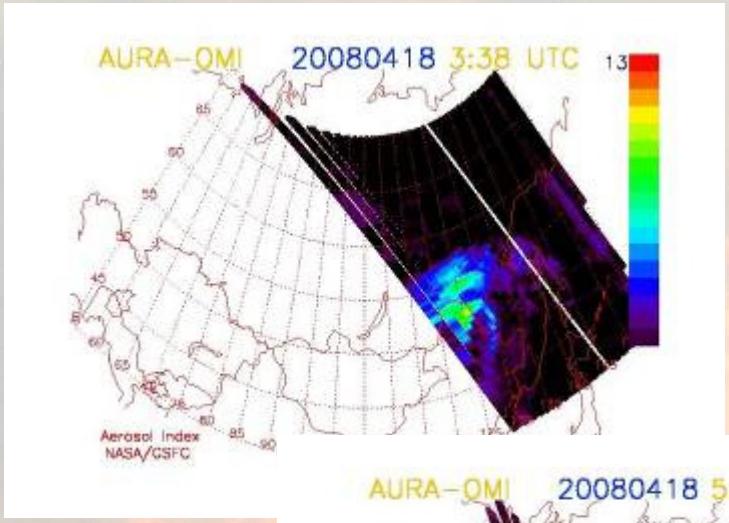


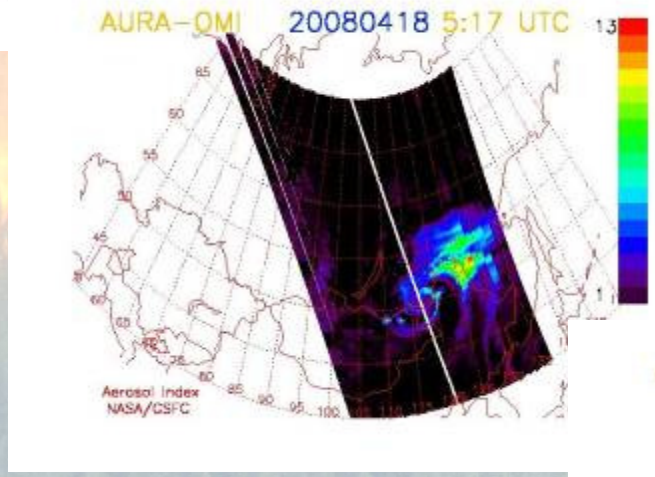


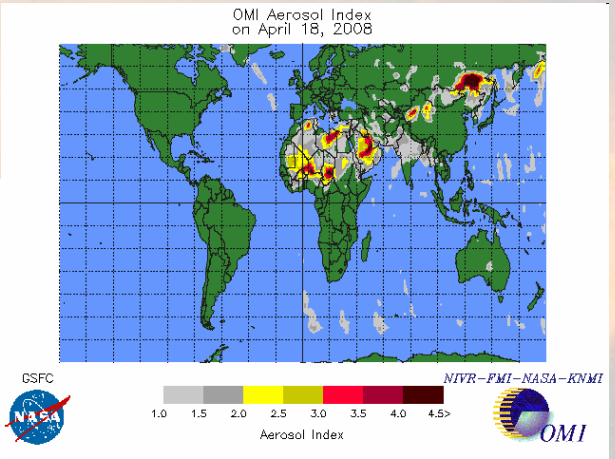
- KAZ and Chita fire smoke separate
- Lower altitude for KAZ fires?
- Less intense (more steppe vs forest)?

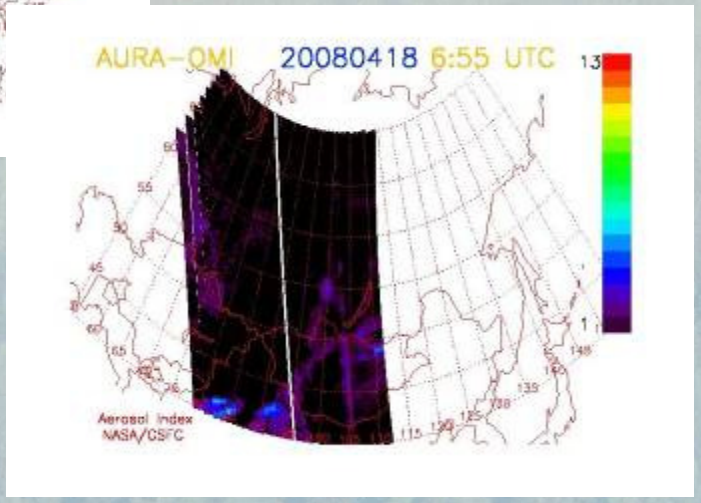
Mike Fromm

Smoke Transport
April 18, 2008





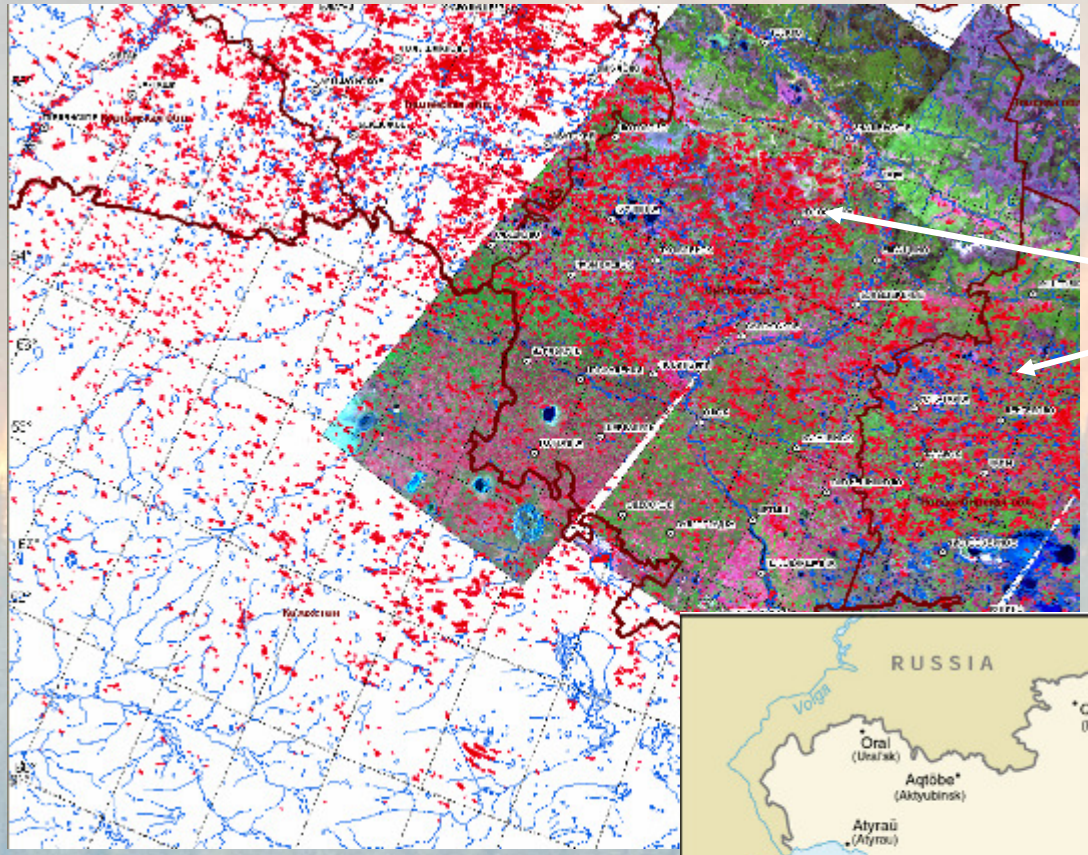




- Chita smoke dominates
- KAZ fires quiet

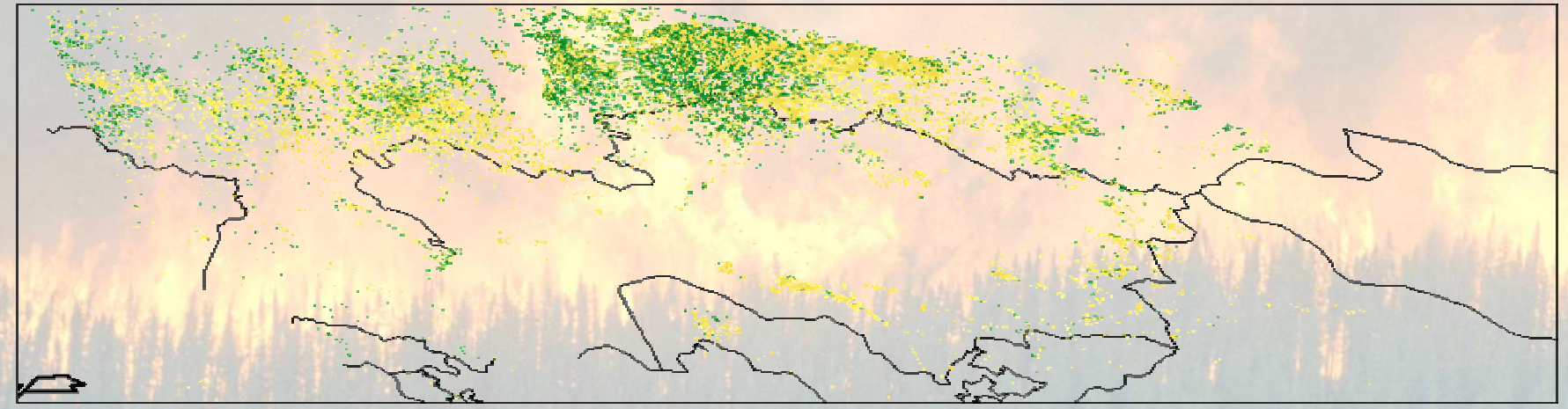
Mike Fromm

Russian Fire Detections April 2008



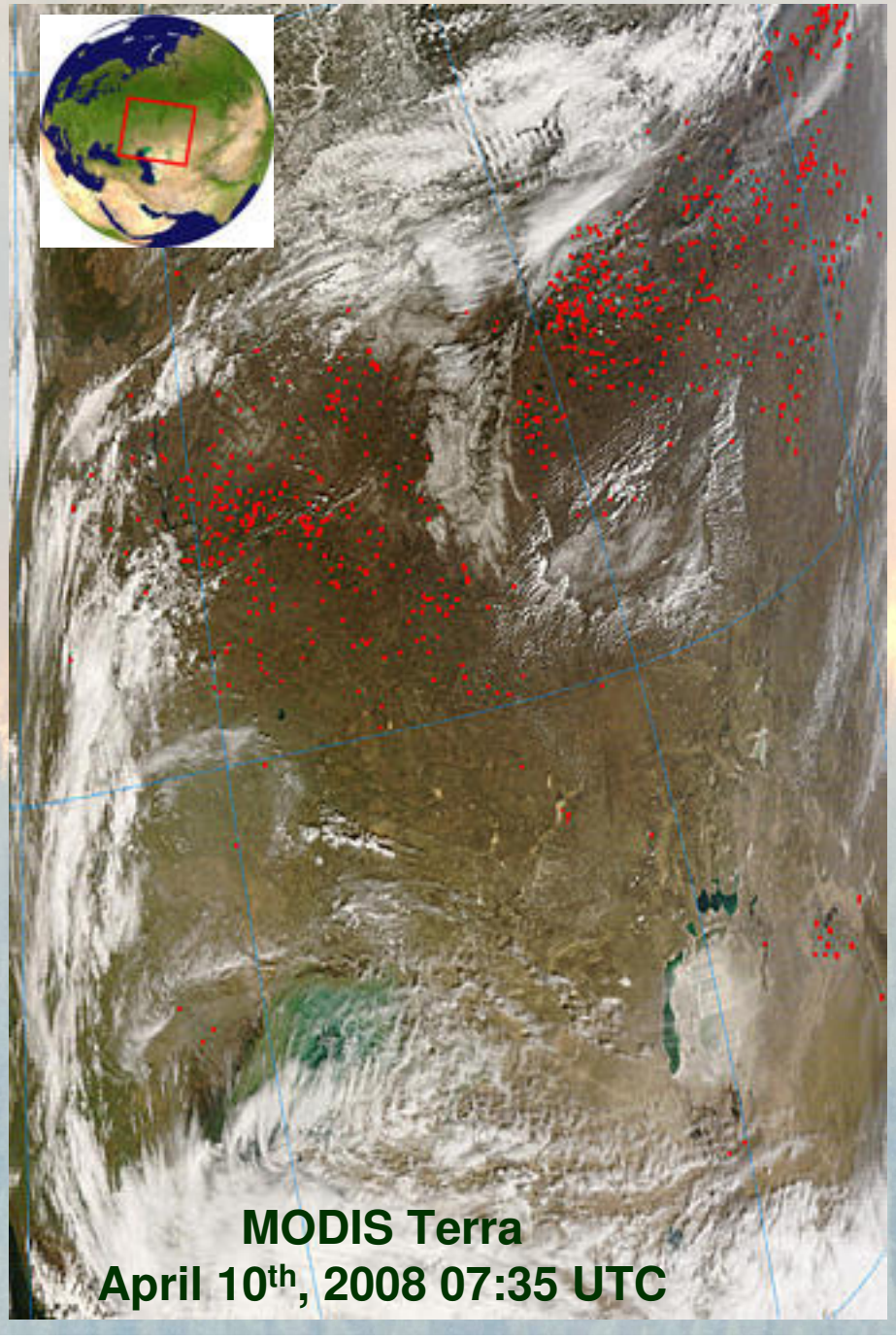
Forest & steppe

KAZ – What is Burning?

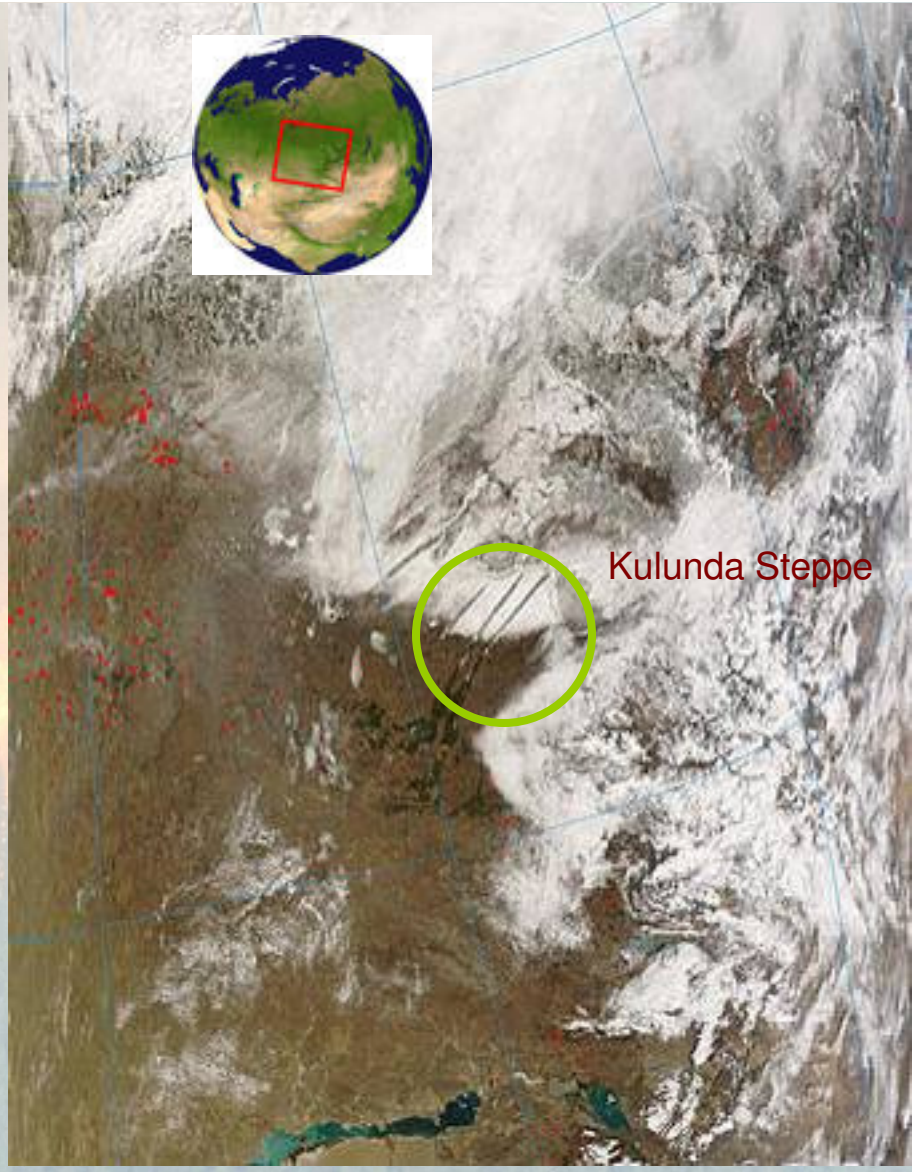


Green = forest (GLCC)
Yellow = everything else (agriculture/steppe)
Note: most fire not actually in Kazakhstan

Ed Hyer (NRL Monterey)



MODIS Terra
April 10th, 2008 07:35 UTC



MODIS Terra
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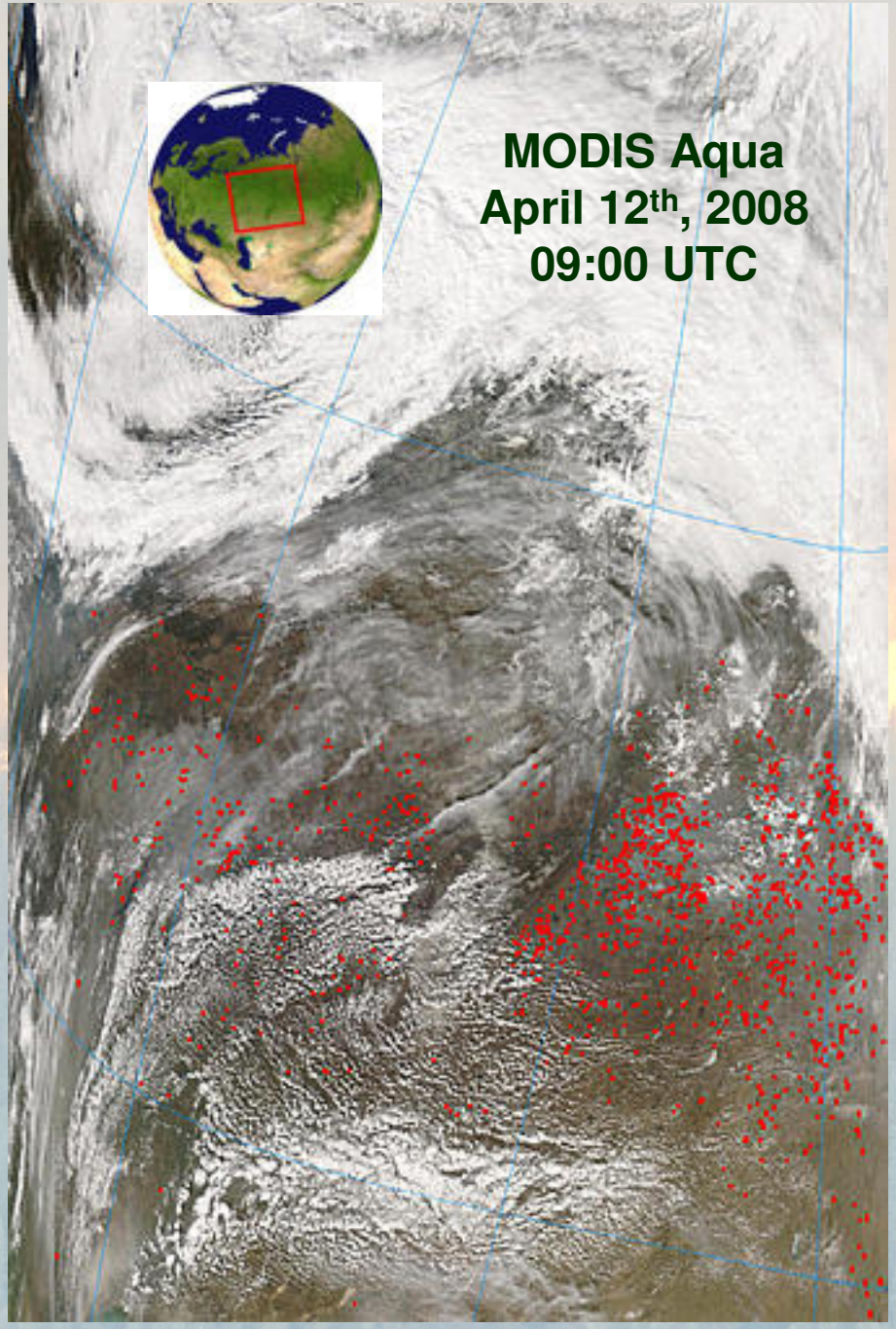
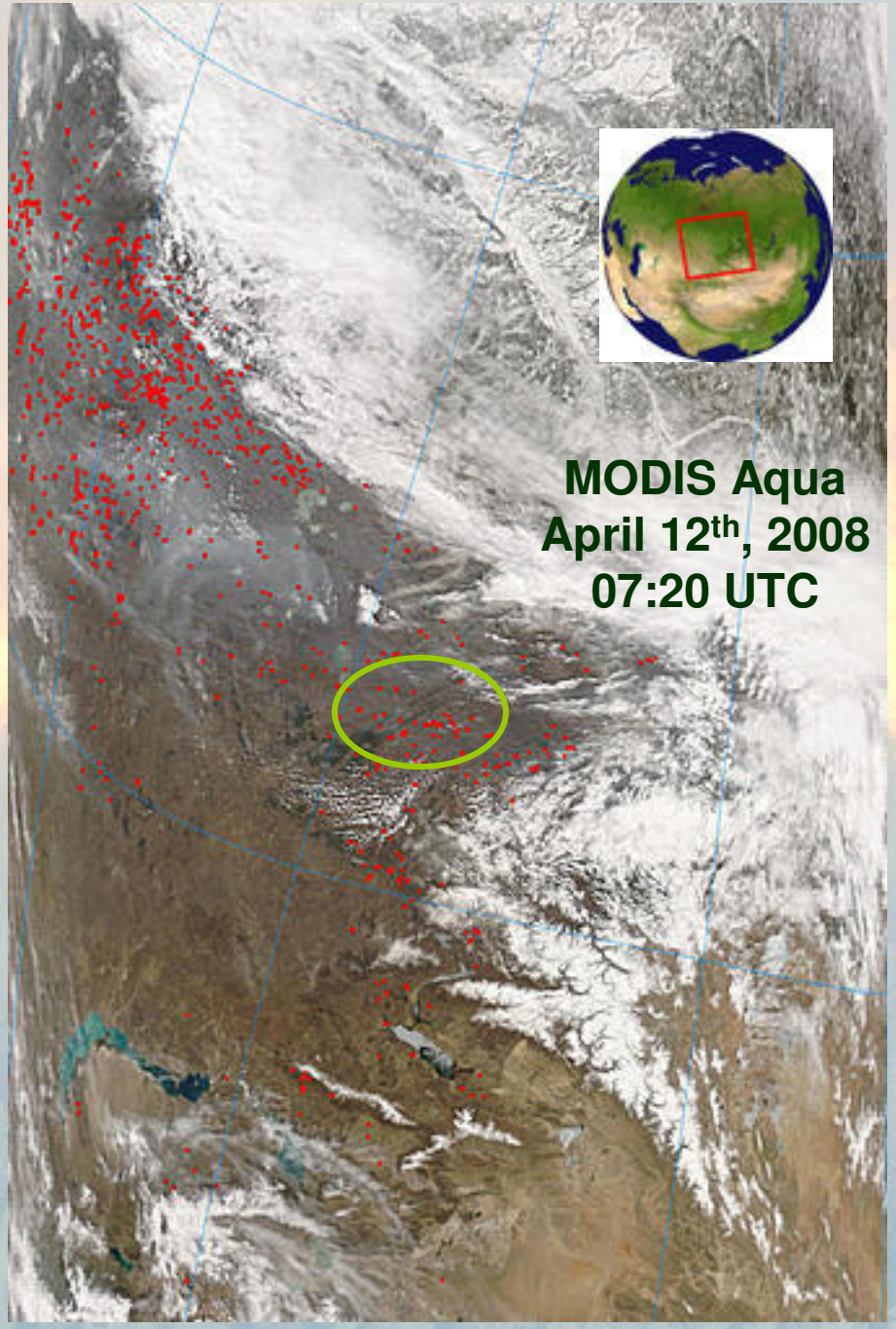
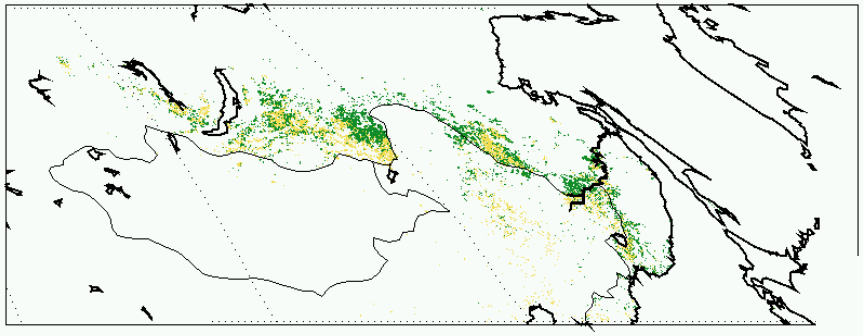
05:25 UTC


MODIS Aqua
April 12th, 2008
09:00 UTC

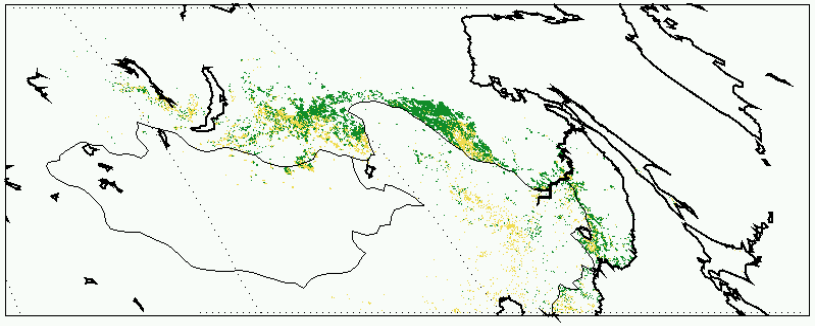

MODIS Aqua
April 12th, 2008
07:20 UTC

Chita/Amur Maps

2003 April



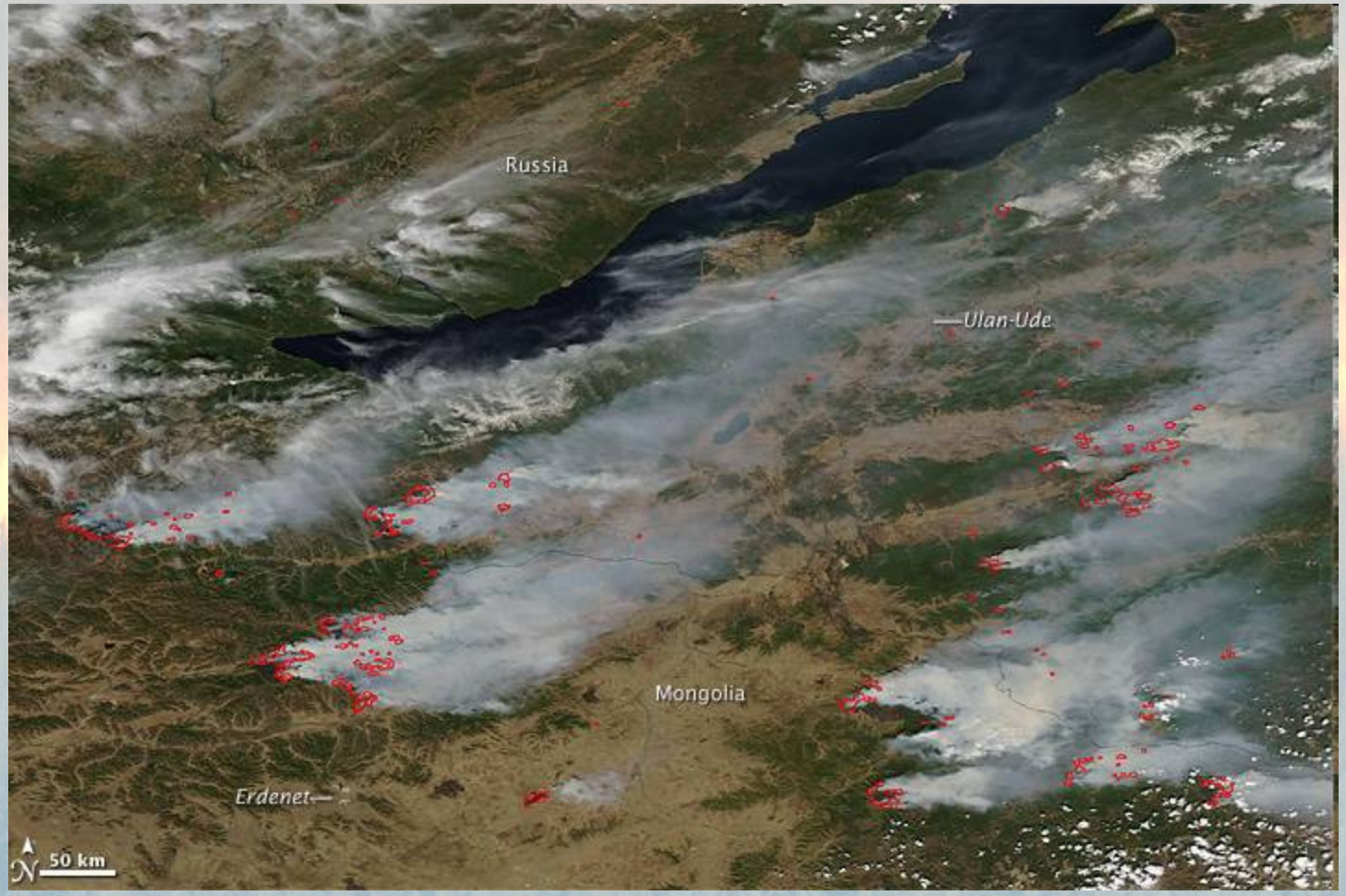
2008 April

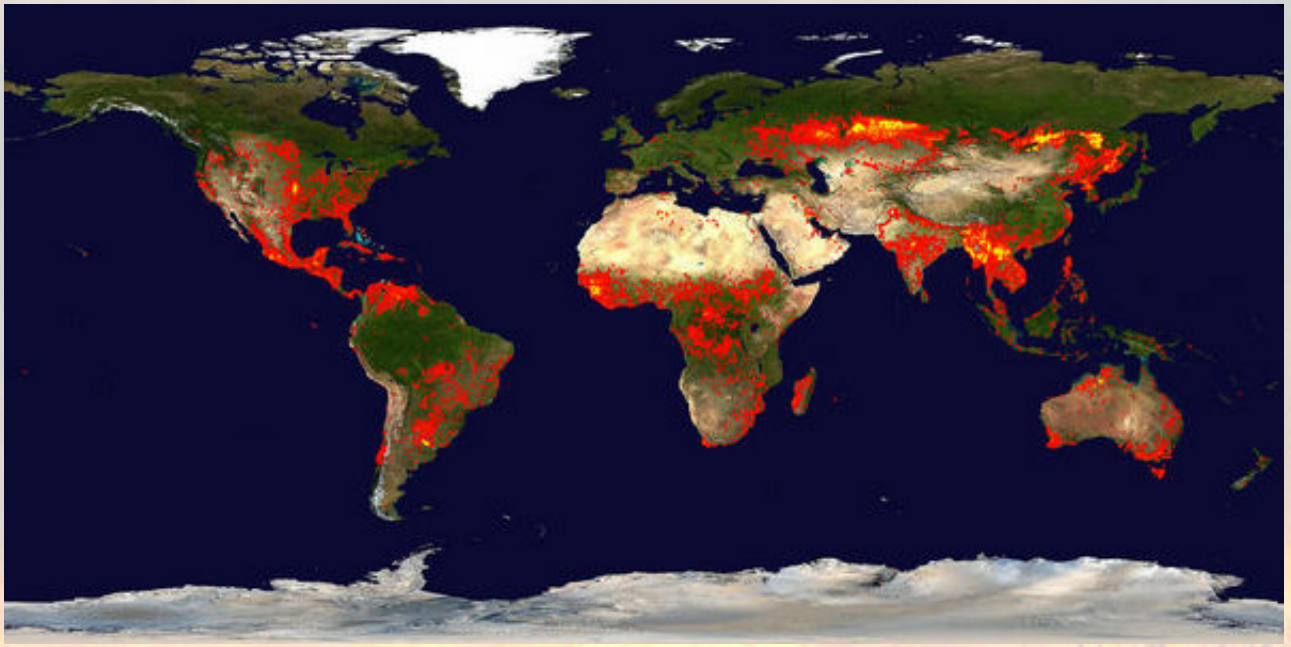


- Very similar burning patterns
- Annual event in this region
- Poorly controlled agricultural fires
- Illegal logging

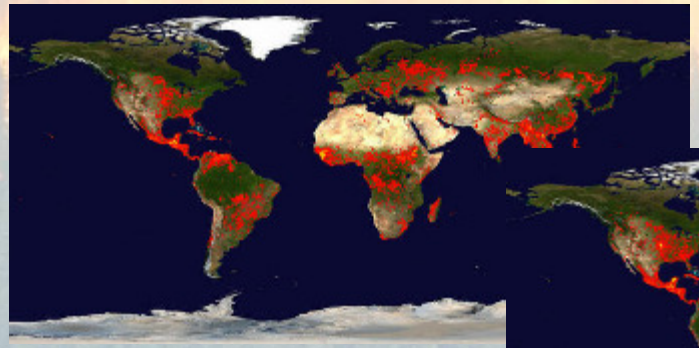
Ed Hyer

May 22, 2009



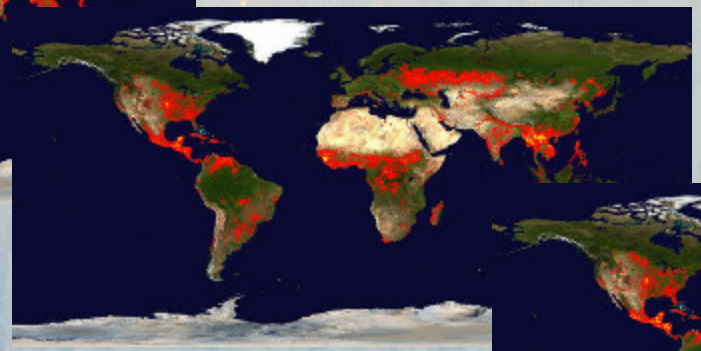


2008



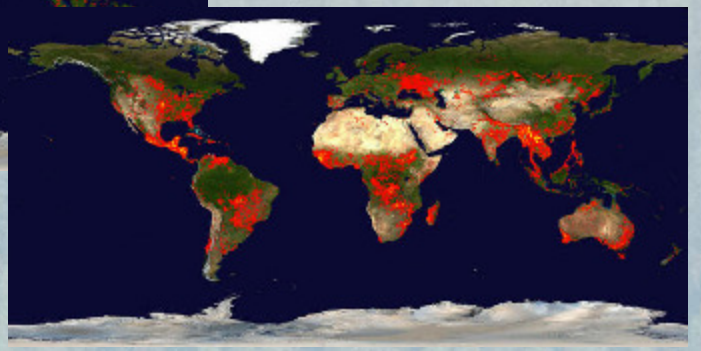
2007

April 11-20

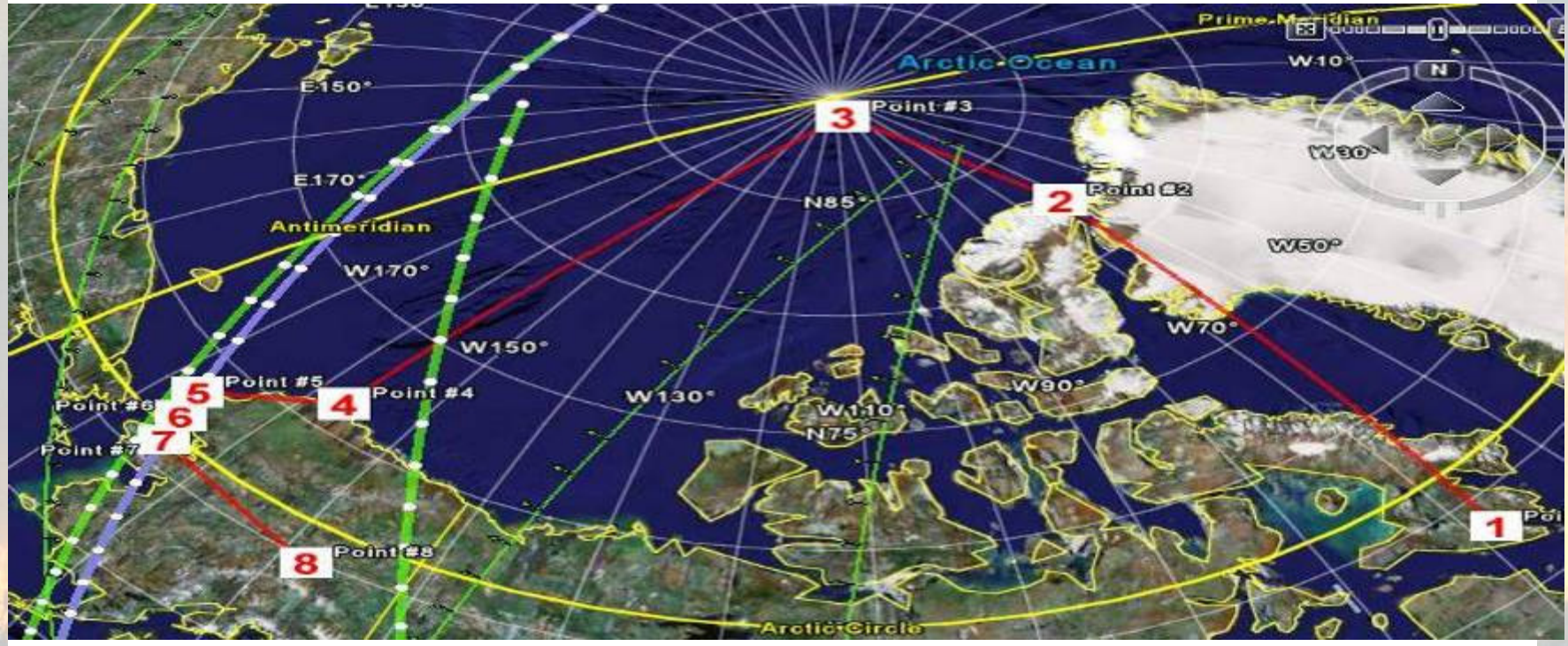


2006

2005



Draft Plan: Flight 07 – 04/09/2008 (version 3)

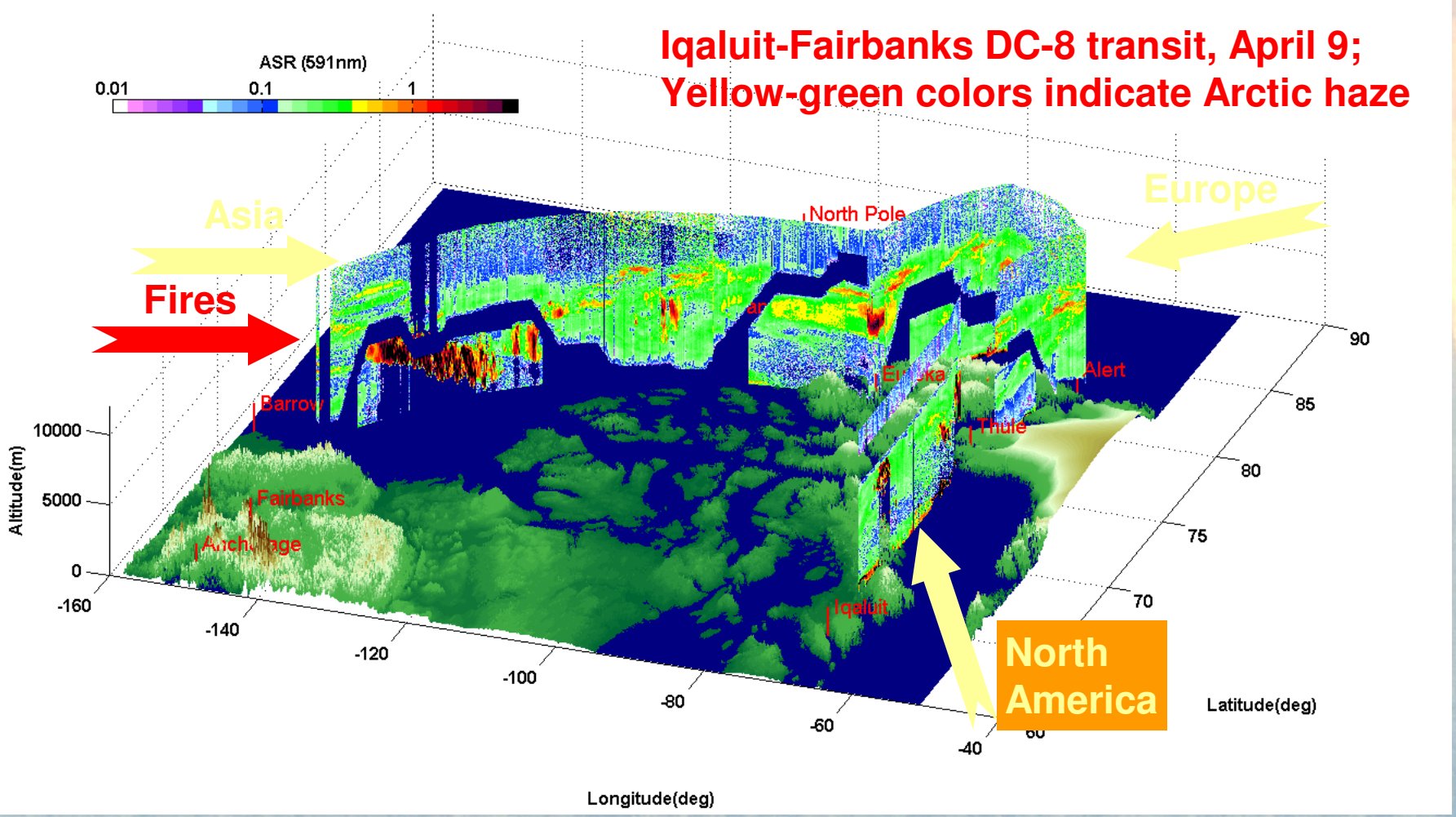


Objectives:

- aged pollution air masses – vertical profiling (points 1-2)
- 20-min MBL run north of Alert (point 2)
- OMI ozone validation track (using DIAL) - vertical profiling (points 3-4)
- aged pollution air masses – vertical profiling (points 2-4)
- missed approach at Barrow and rendez-vous with B-200 (point 4)
- MBL run (points 4-5)
- partial spiral at point 5 – serves as delay while B-200 catches up with us at point 6
- CALIPSO underpass, coordinated with B-200 (points 5-7)
- Vertical profiling, aged European pollution (points 7-8)

LIDAR INSTRUMENTS ON THE AIRCRAFT OBSERVE ARCTIC HAZE FROM THE SURFACE TO 30,000 FEET

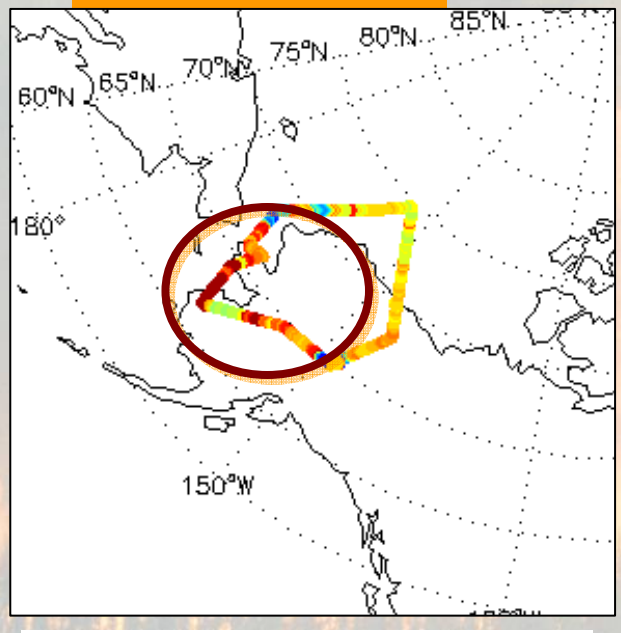
Other instruments on the aircraft provides clues to the origin of this haze



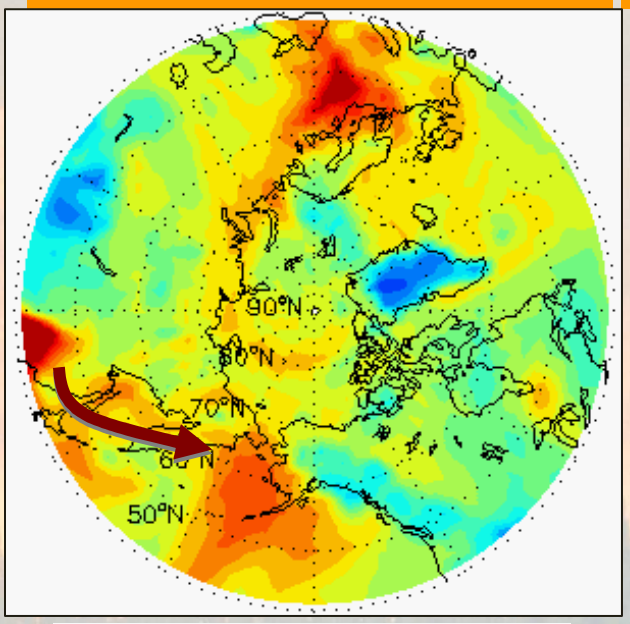
Johnathan Hair, NASA/LaRC

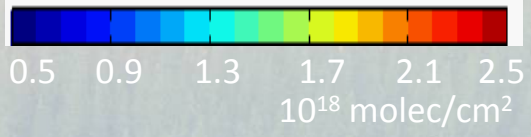
Examining pollution transport with aircraft, models, and satellites…

DC-8 in situ CO

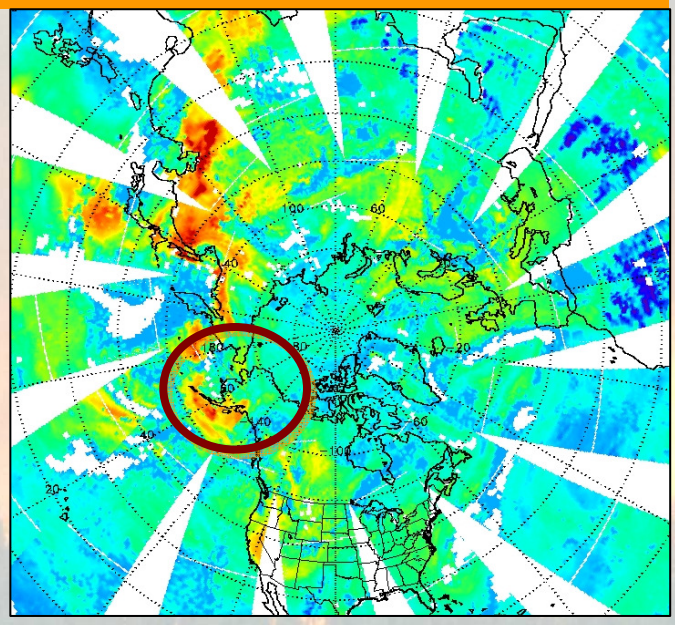


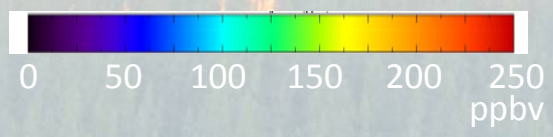
GEOS-Chem Column CO





AIRS 500 mb CO (ascending)





Characteristics of the pollution plume:

- Observed at ~4-6 km
- Elevated CO, SO_4, and HCN
- Source could be:
  - anthropogenic emissions from eastern Asia
  - biomass burning from southern Siberia
  - mixture of both

Jenny A. Fisher [Harvard], Glenn Diskin [LaRC], Juying Warner [UMBC]

ARCTAS
Summer Phase 2008
Cold Lake AB/Yellowknife NT

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- IPY and the Arctic Region
- Boreal Fire Impacts
- Planning/Conducting ARCTAS
- Preliminary Results

Presentation to CIFFC Fire S&T Working Group
October 1, 2008
Haines Junction YK

• ***With thanks to Mike Fromm, Amber Soja, and Jim Crawford***

POLARCAT Goals Relative to Boreal Fire

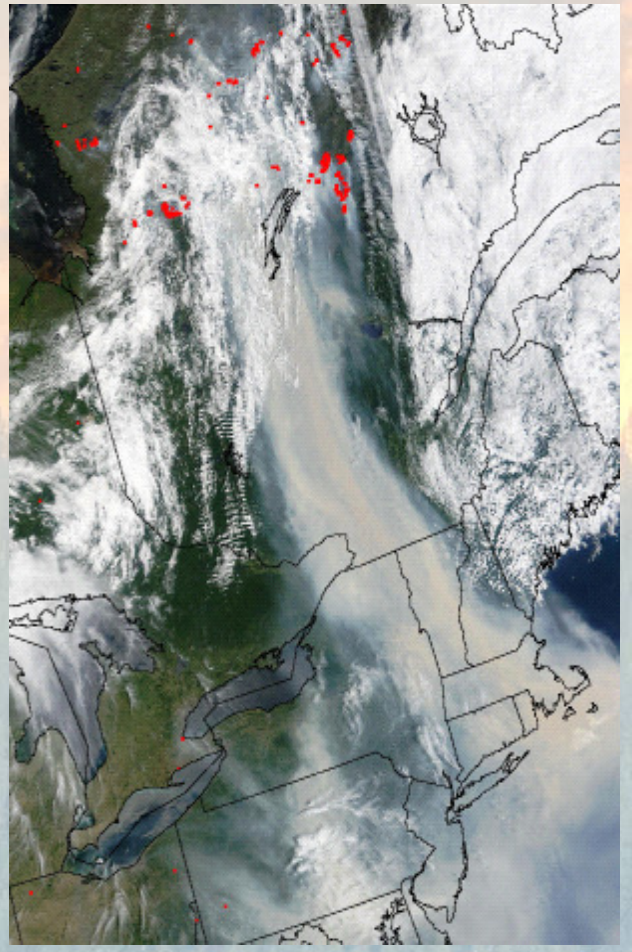
- Overall goals of POLARCAT include the following related to boreal forest fires:
  - Study the impact of boreal forest fire emissions on the chemical composition of the Arctic troposphere.
  - Study the pathways of boreal forest fire plumes into the Arctic, with particular emphasis on plume altitudes.
  - Quantification of the impact of the deposition of soot from forest fires on the surface albedo of snow and ice surfaces, and investigation of the linkage with the retreat of Arctic sea ice and glaciers.
  - Determination of the residence times of pyroCb aerosols in the Arctic stratosphere and their contribution to stratospheric background aerosol concentrations.
  - Investigation of the fate and effects of aerosols and chemical compounds injected into the stratosphere by pyro-convection, including their role for ozone formation and ozone depletion in the polar stratosphere.

Canada and the IPY

- Canada contributed 150 million $
- Many more proposals than $
- Resulted in a small % of proposals being funded in smaller amounts
- We proposed a smaller version of ARCTAS – not funded although supported strongly internationally (a key component of POLARCAT)
- No atmospheric proposals funded
- Primary criteria: CC and beneficial to northern communities
- Vetted by NWT groups (science licence) – still rejected
- Became integral component of ARCTAS

Some Boreal Fire Smoke Issues

- UTLS injection and circumpolar transport becoming common
- Impacts on human health (urban smog and evacuations)
- More fire = more smoke
- Feedback to climate change?
- Impacts on Arctic environment – IPY and acceleration of sea ice/snow cover melting

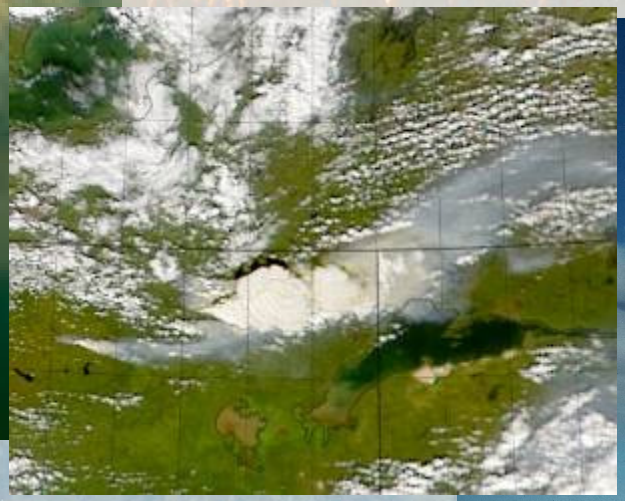


Terra MODIS 1629-1641 UTC (NA)

Smoking Pyrocumulonimbus: Analysis of Two Major Canadian Boreal Fire Blowups from Satellite and Ground Measurements

Brian Stocks[1], Mike Fromm[2], René Servranckx[3], Steve Miller[4], Joe Turk[4], and David Diner[5]

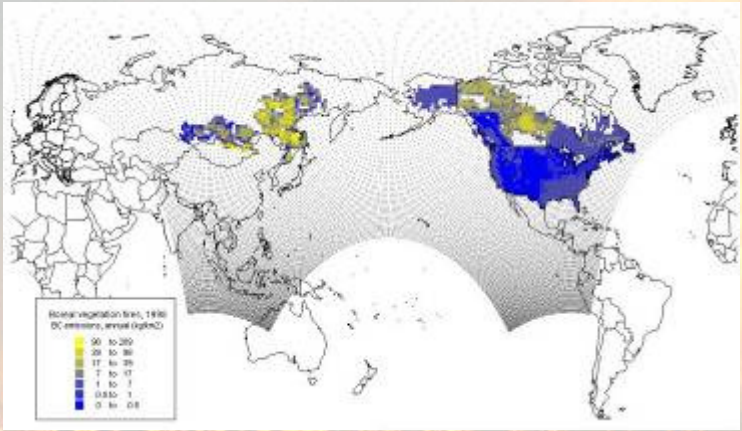
[1] Canadian Forest Service, Sault Ste. Marie, ON
[2] Naval Research Laboratory, Washington, DC
[3] Canadian Meteorological Centre, Dorval, QC
[4] Naval Research Laboratory, Monterey, CA
[5] Jet Propulsion Laboratory, Pasadena, CA

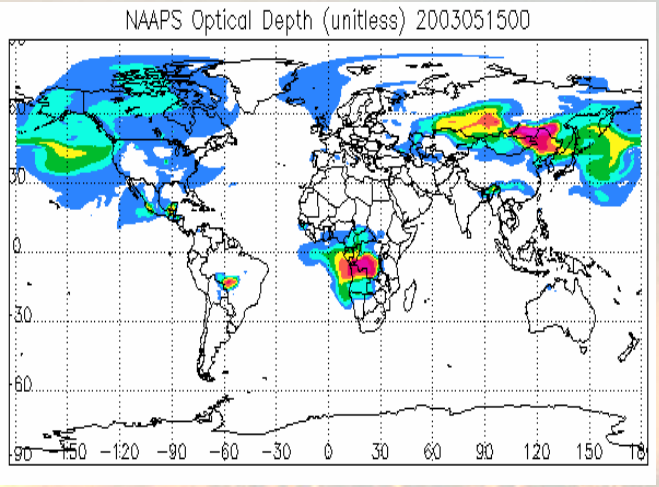


AGU 2005 Fall Meeting – San Francisco, CA

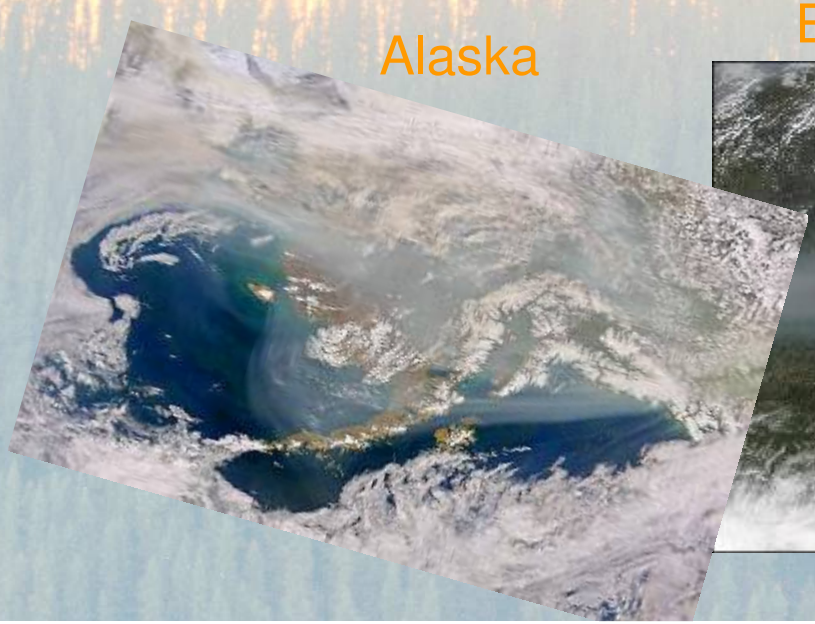
Smoke Transport From Russian 2003 Wildfires

Focus of numerous smoke transport presentations at AGU in 2003 and 200
– strong interdisciplinary interest



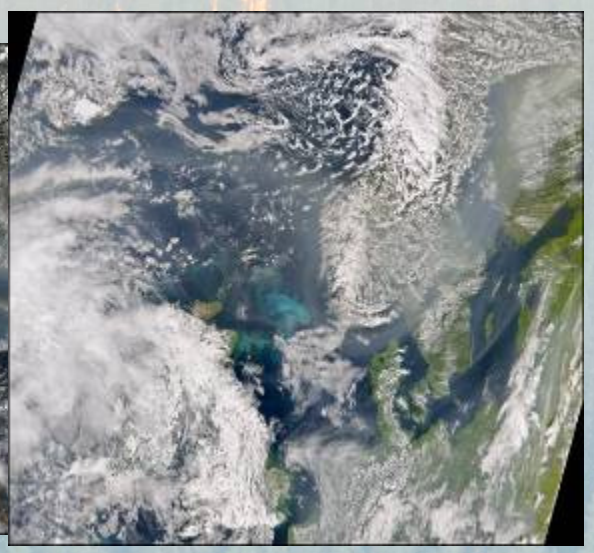


Alaska

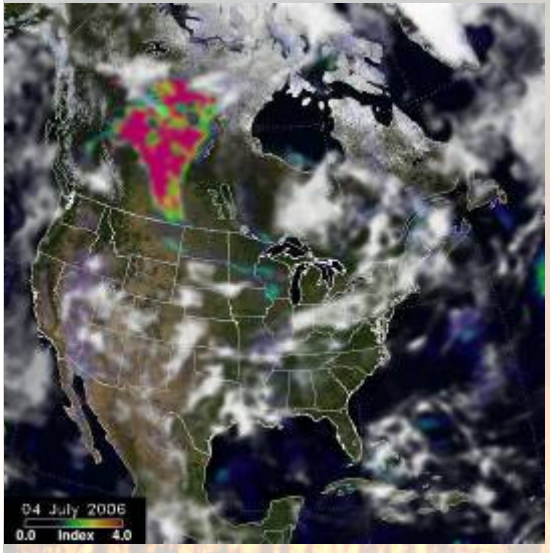


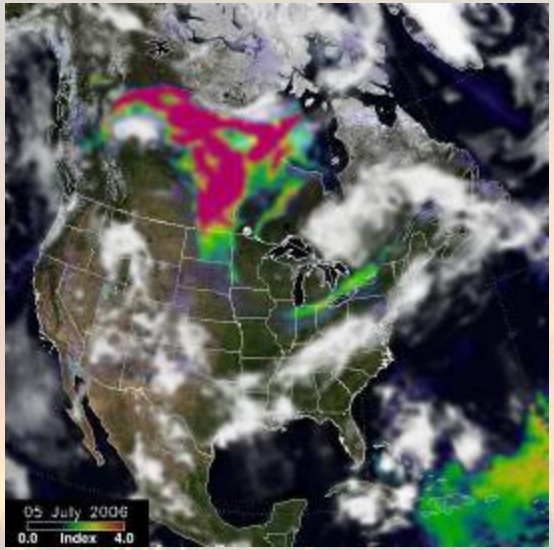
Eastern Canada

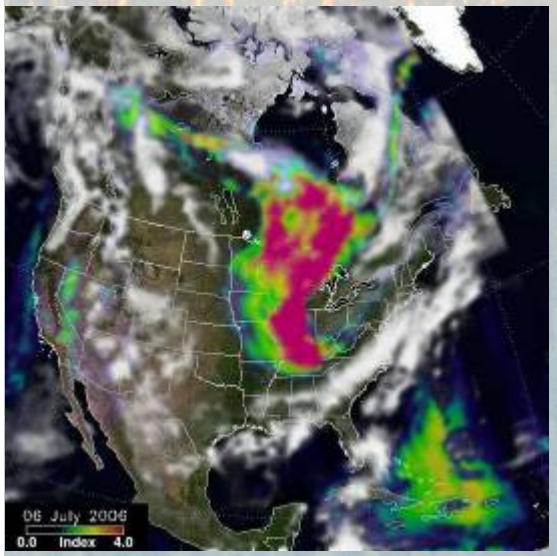
Finland

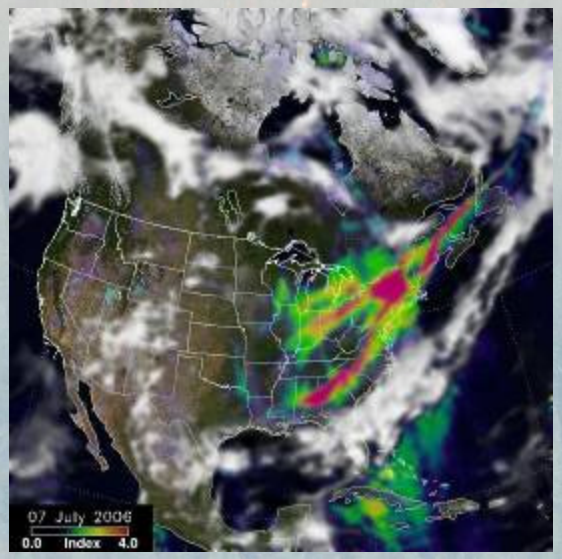


Smoke Transport from West-Central Canada Fires: July 4-7, 2006









Smoke moves to southeast, affecting air quality in populated regions of eastern Canada and USA

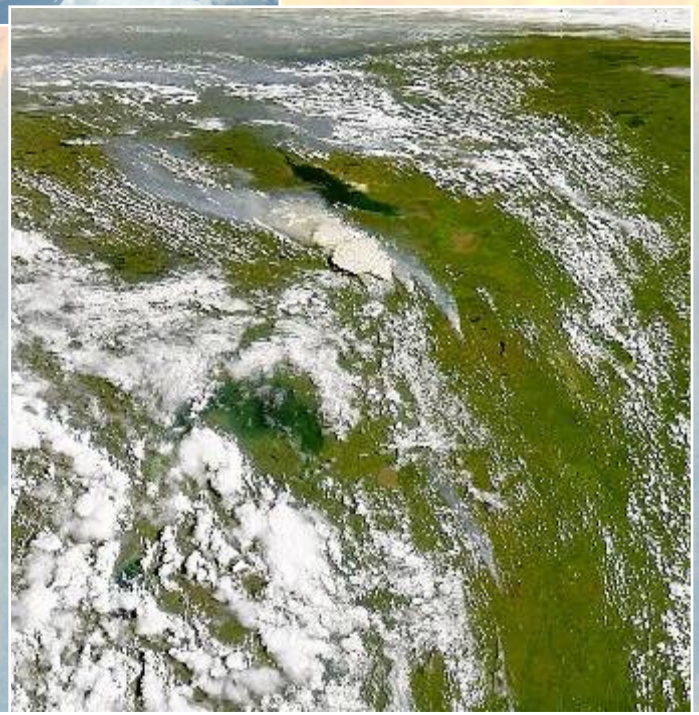
Omar Torres, NASA-GSFC/UMBC-JCET

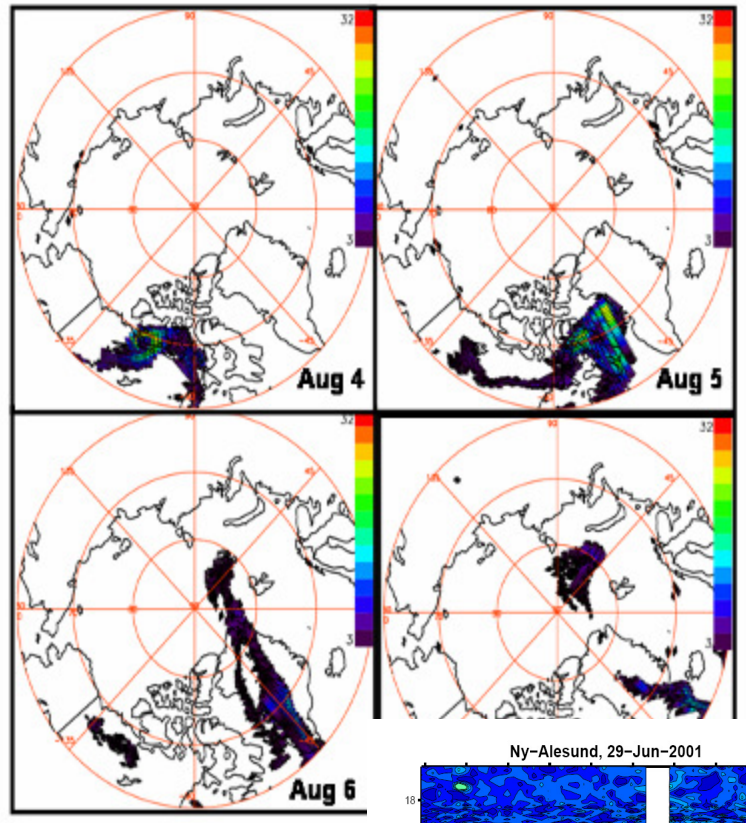
Smoke Above the Tropopause – Transport to the High Arctic

2005 BC Fire - aircraft

1998 NWT Fire
TOMS

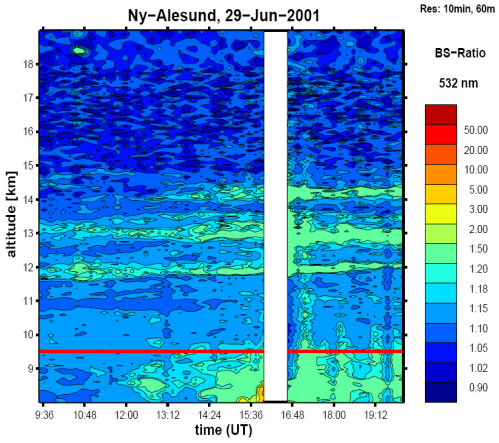
2003 WBNP Fire
- SeaWfiffs





2001 AB Fire
Spitzbergen Lidar

1 month

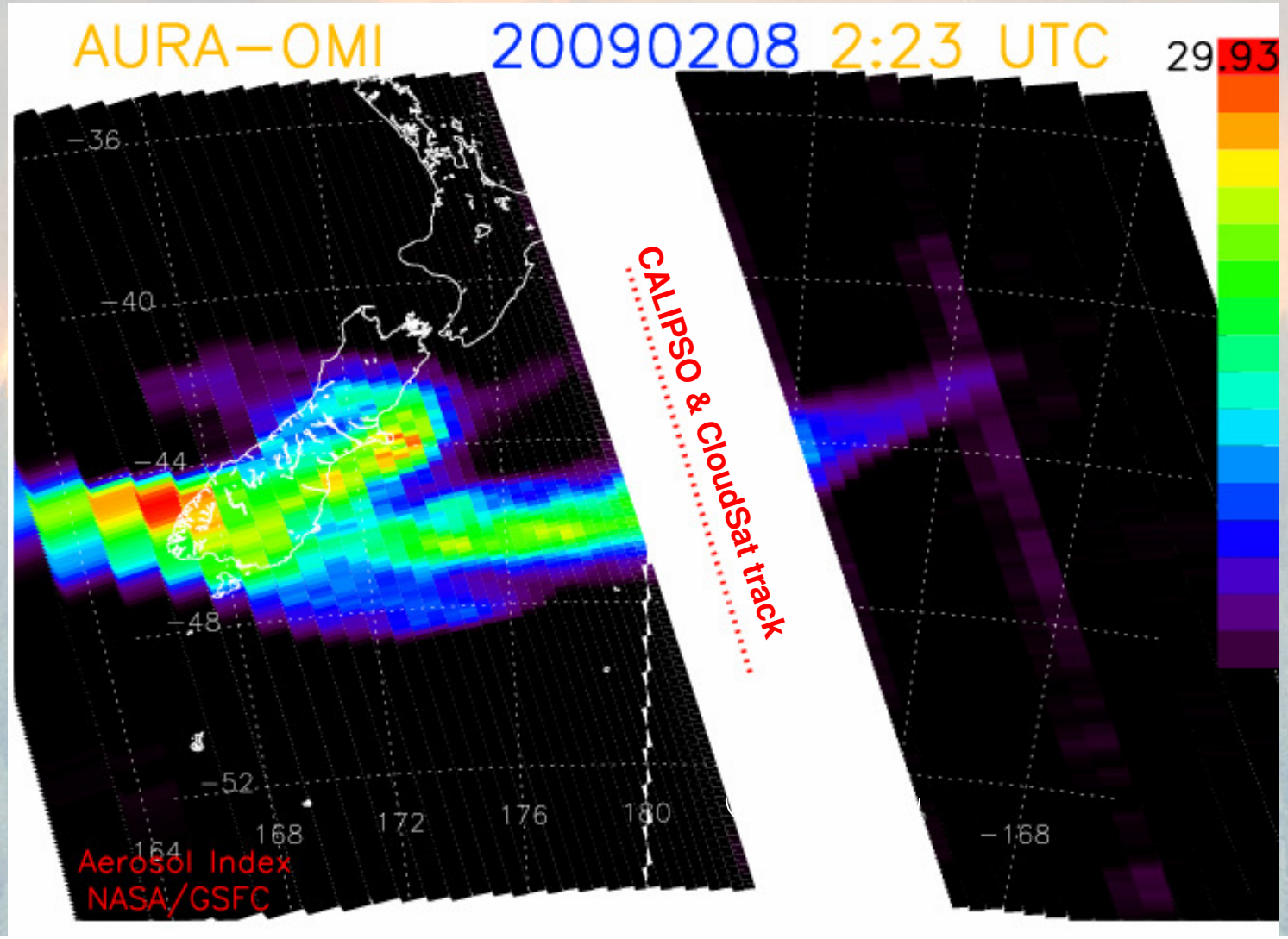


“Black Saturday” PyroCB Development

Victoria, Australia February 7, 2009

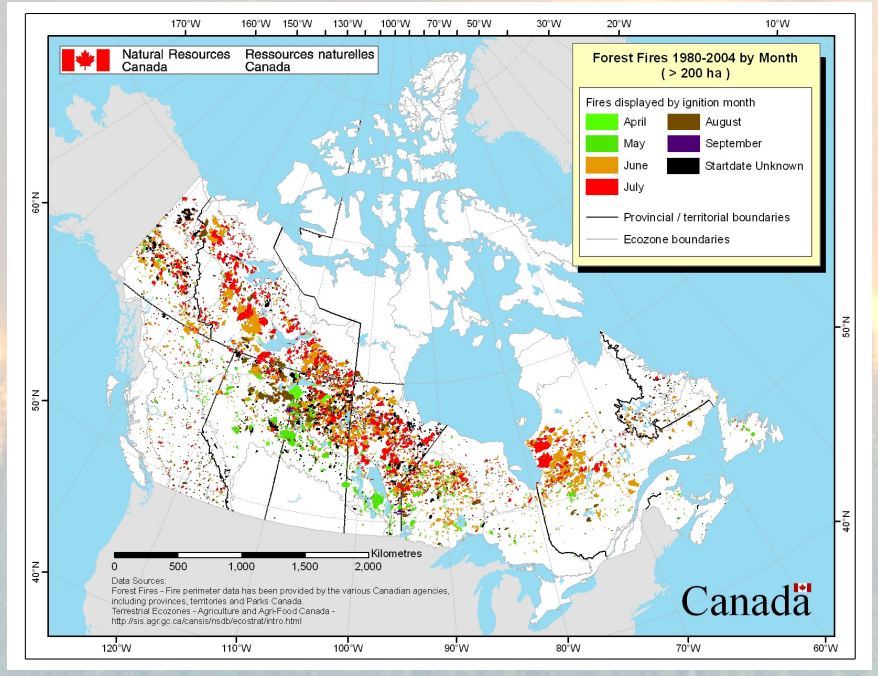
The “Day-After” plume, Sunday 8 Feb 2009

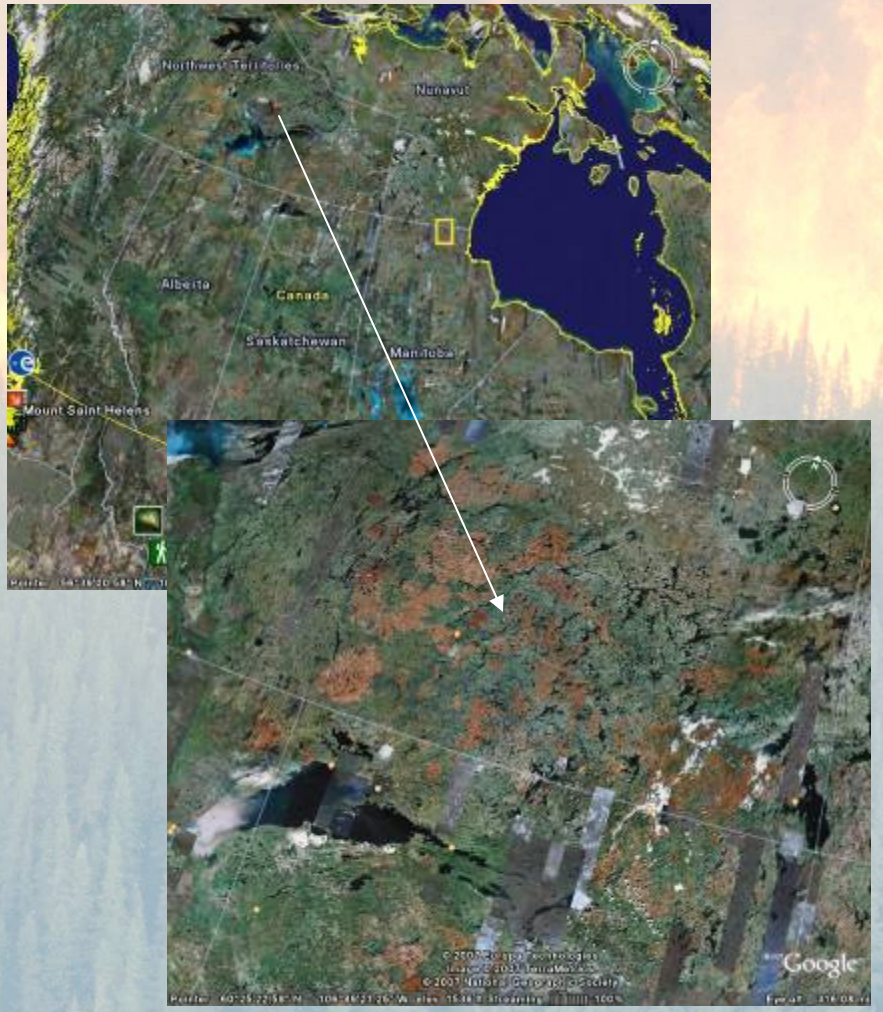
OMI Aerosol Index (AI)



ARCTAS Summer Campaign

CDN Large Fires – Seasonal Pattern – Why Cold Lake?





- Lightning fires
- June/July in high boreal
- Generally freeburning
- Natural/essential