GLOBAL ENVIRONMENTAL MULTISCALE MODEL

PLATFORM FOR INTEGRATED ENVIRONMENTAL PREDICTIONS

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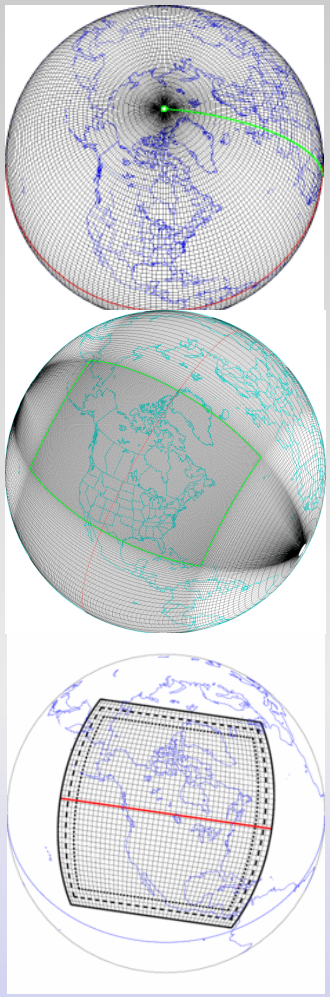
Outline

- Motivation
- Chemical weather model
- Observations and modelling
  - Global
  - Regional
  - Local
- Planetary applications

Modelling – Motivation

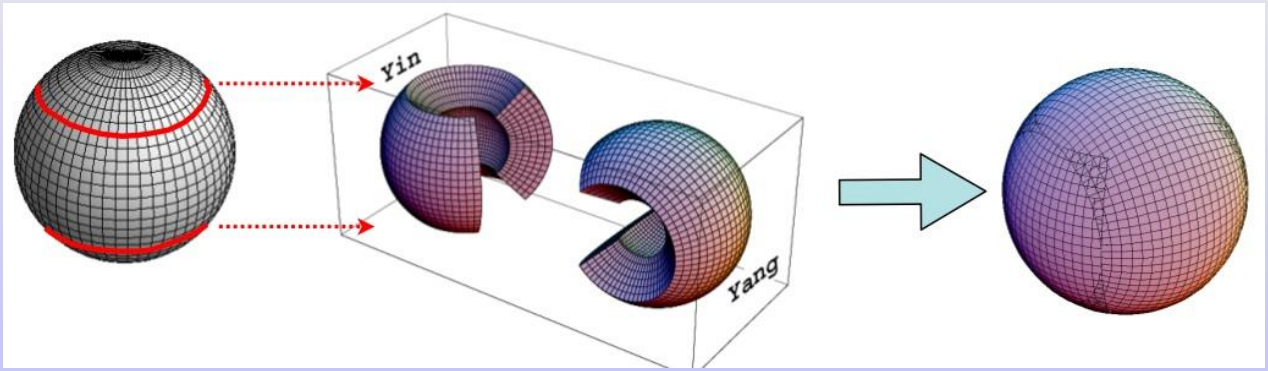
- To develop a state-of-the-art multiscale chemical-dynamical model of the atmosphere that will be used to :
  - Study atmospheric chemistry in the context of air quality and climate change on urban, regional and global scales
  - Facilitate chemical weather forecasting and data assimilation of chemical species
  - Provide simulated atmospheric quantities (model atmosphere) for instrument design and retrieval algorithm testing
- To share the developed modelling system with other researchers, encouraging collaboration and training

The GEM model



Global Environmental Multiscale model

1. Highly flexible domain
   - Global
   - Regional – i.e. NA, EU, Arctic
   - Local – i.e. urban scale dx=250m
2. Weather and climate applications
3. Numerical efficiency and adaptation to new computational platforms



Model components and applications

- Transport processes
- Chemical and aerosol processes specific to
  - Air quality and anthropogenic emissions
  - Troposphere
  - Stratosphere & Mesosphere

- Air quality forecasting – Copernicus Services
- Air quality assessment
- Air quality episode studies
- Environmental impact assessment of new technologies
- Climate simulations
  - Climate change adaptation scenarios
  - Impact of aviation transport on the stratosphere

GEM processes

Operational weather prediction model

Côté J., S. Gravel, A. Méthot, A. Patoine, M. Roch, and A. Staniforth, The operational CMC MRB Global Environmental Multiscale (GEM) model: Part I – Design considerations and formulation, Monthly Weather Review, 126, 1373-1395, 1998

  - Solar and IR radiation
  - Gravity waves
- Data assimilation

The GEM-AC model

- On-line implementation of stratospheric, tropospheric chemistry and

Fully interactive gas & aerosol heating for climate applications

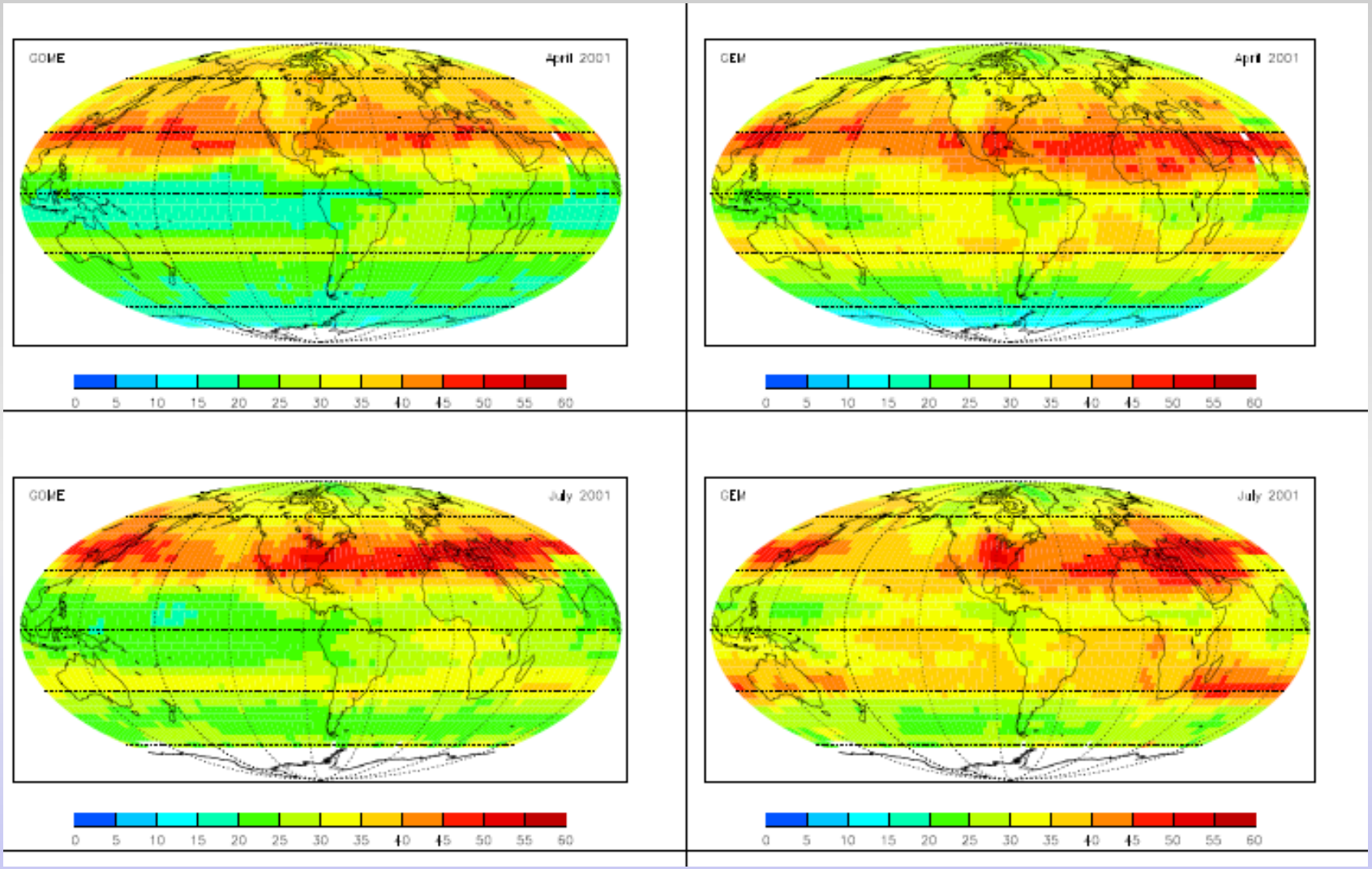
Jennifer Bealy, PhD, York University 2016

Fully interactive GEM-AQ for air quality applications

Maciej Jefimow, PhD Candidate
Warsaw University of Technology

- Aerosol microphysics (sectional and M7) and chemistry
- Ozone and water from chemistry used in radiation calculation
- Wet chemistry
- Dry and wet deposition
- Anthropogenic, Biogenic and Fire emissions
- Lightning NOx emissions
- Climate physics

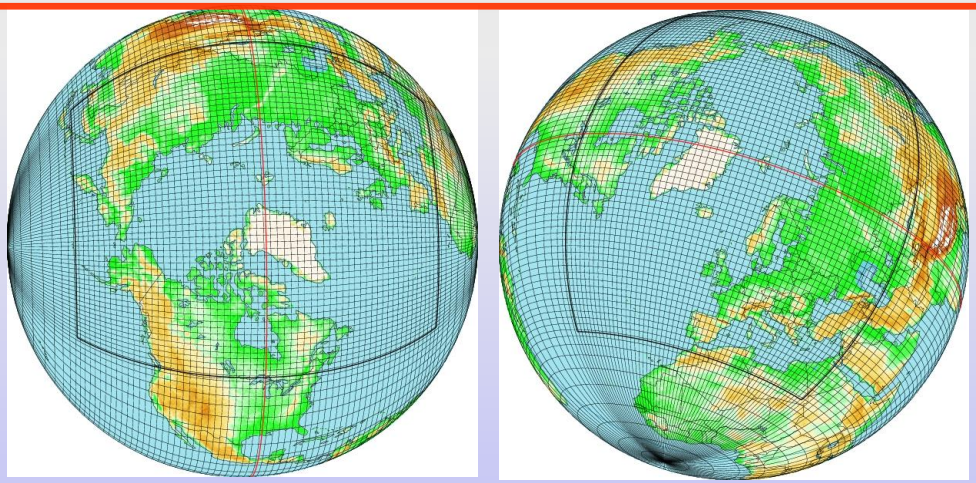
GOME and GEM-AQ tropospheric O3 columns



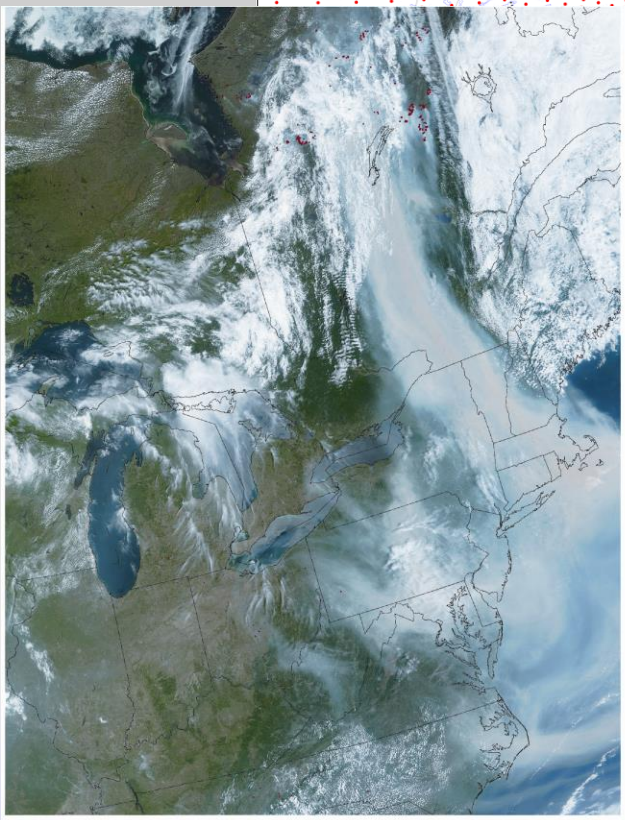
Kaminski et al., Atmos. Chem. Phys., 8, 3255-3281, 2008.

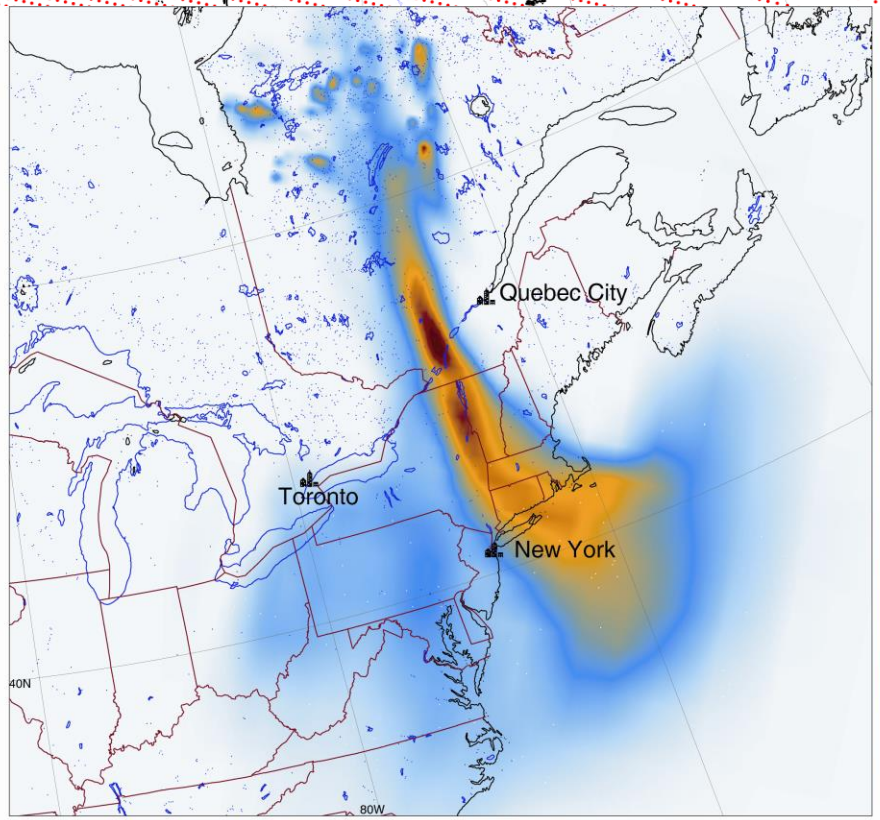
Modelling – Impact of aviation emissions

- FAA Emissions 2006 - reference year.
- High resolution (0.5 deg) model simulations over Arctic
- Climate runs using RCP 8.5 emissions
- For 2006 base run:
  - NOx increases by 40% in the Arctic UTLS
  - Ozone increases by typically 2% in response to NOx in the Arctic UTLS



PhD research – Magdelena Porębska, WUT, NCN-Preludium, 2014-2016



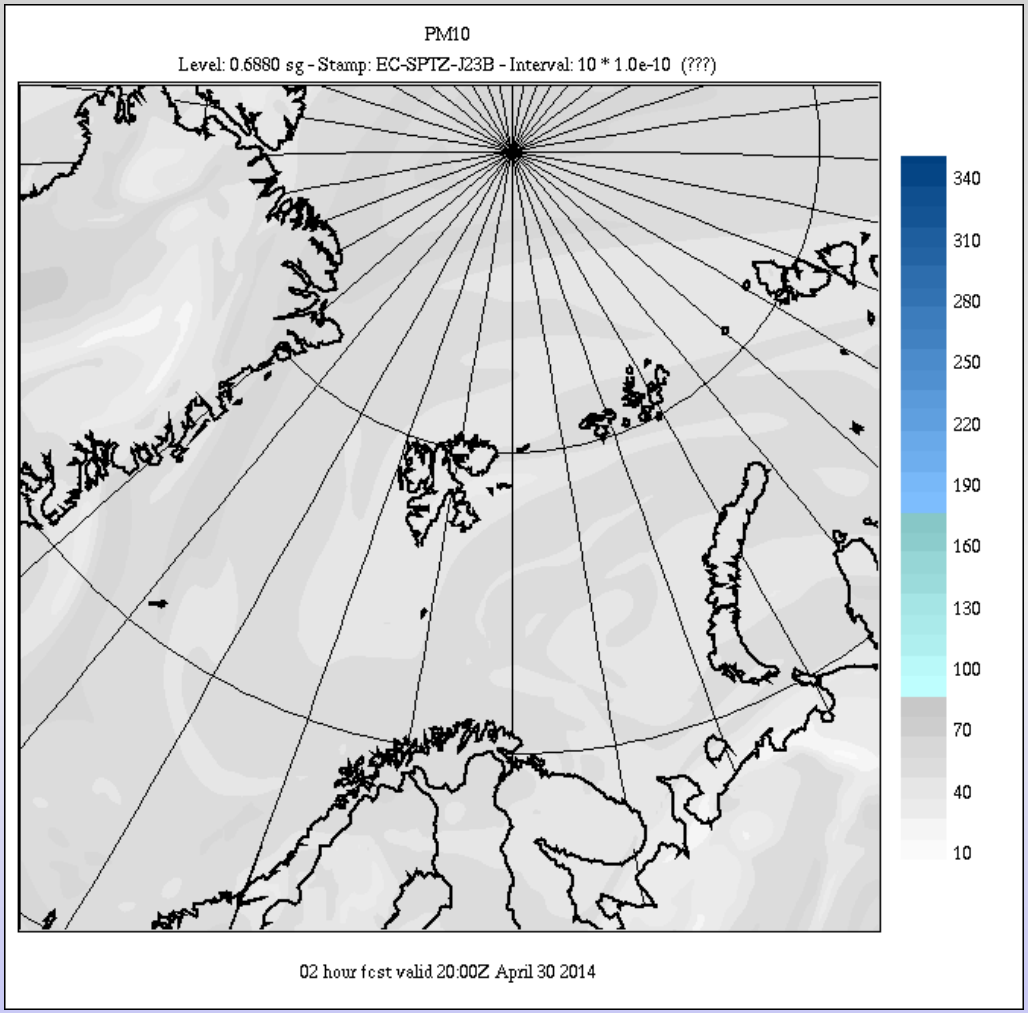


MODIS visible image of eastern Canada and north-eastern United States for July 7, 2002 (left) and modelled aerosol optical depth (right). Active wildfires are shown as red squares on the satellite photograph. The smoke plume blankets southern Québec and extends southwards over the Great Lakes and eastern United States into the Atlantic Ocean.

O'Neill et al., Atmos. Environ., 40, 3737-3749, 2006.

Synoptic context of aerosol transport episodes in the Arctic

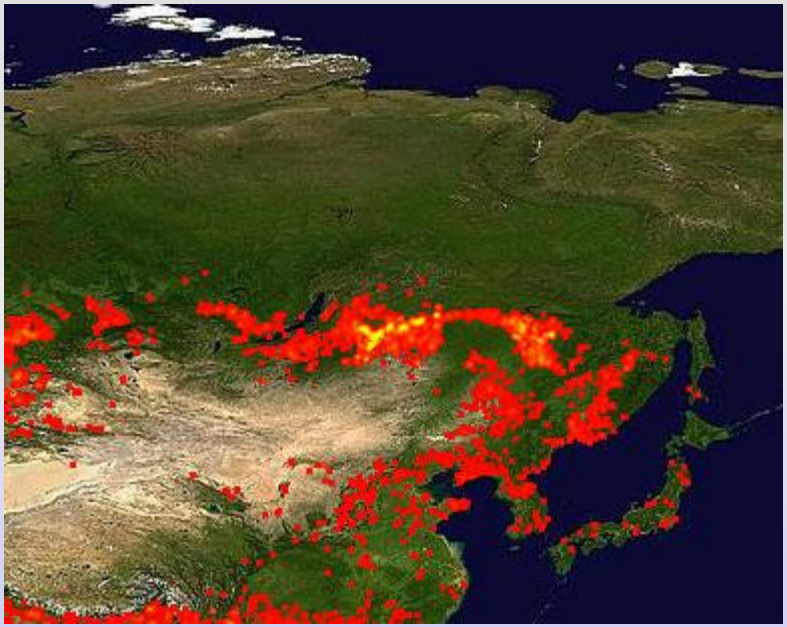
30.04-5.05 2014 – transport event at 700 hPa

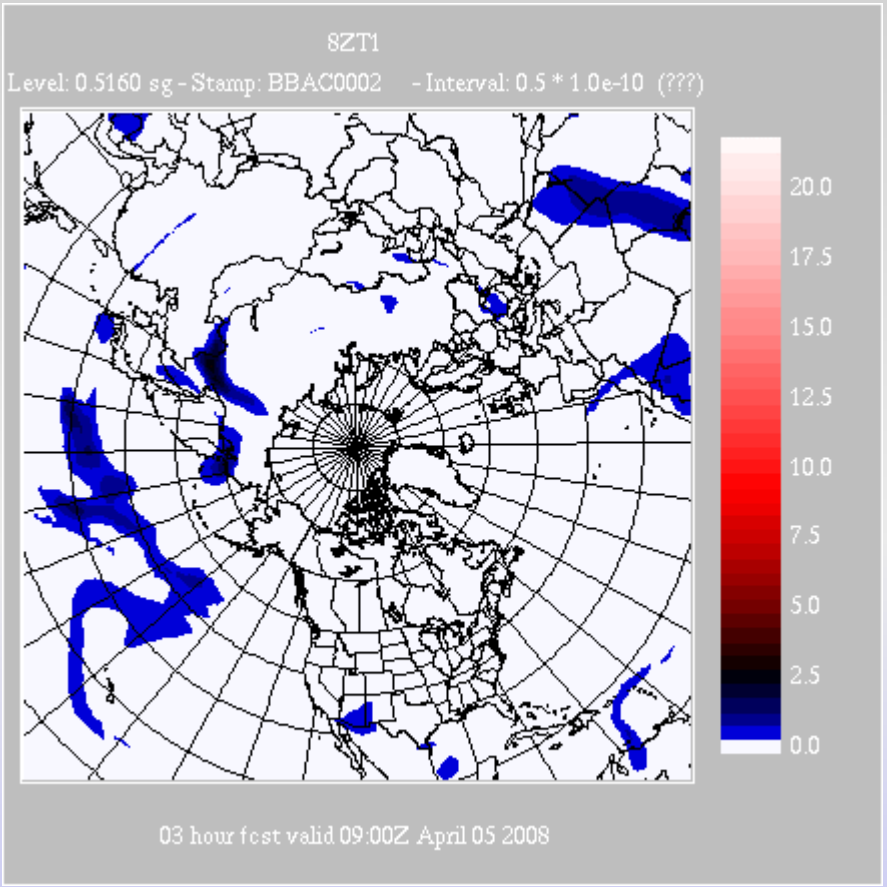


Lisok et al., Atmos. Environ., 2016.

Smoke event at Eureka (12 April 2008)

Fires burning
East of Lake Baikal, Russia
at the beginning of April

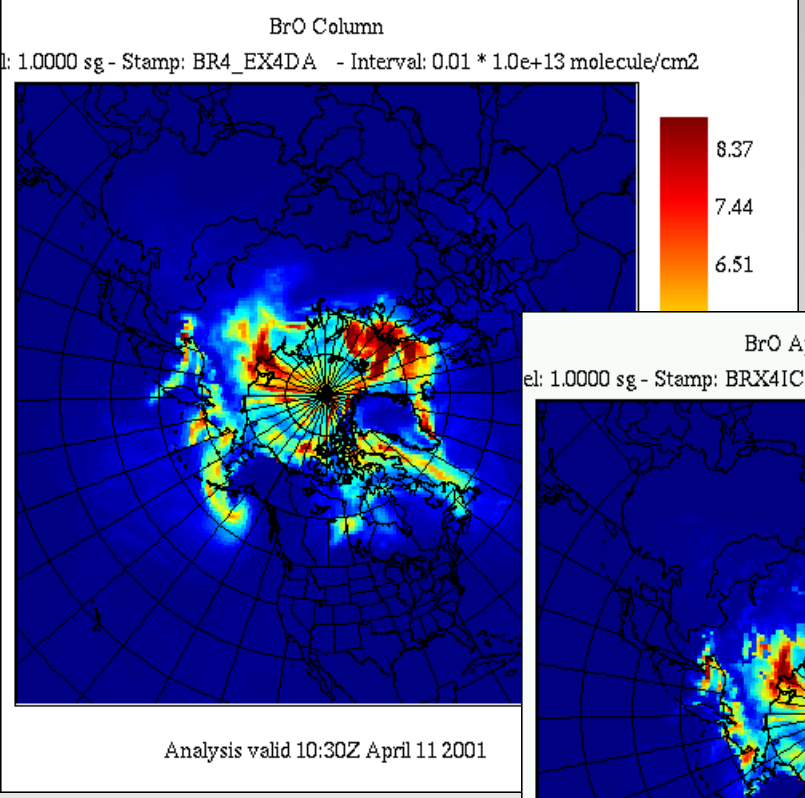


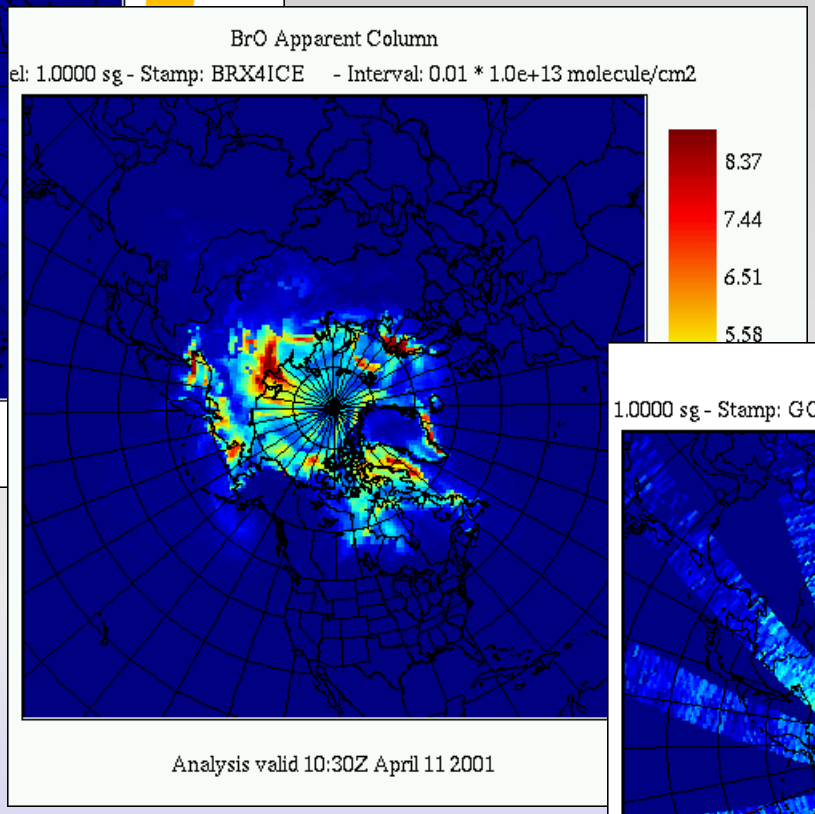


Lupu et al., Atmos. Chem. Phys., 9, 54301-4313, 2009

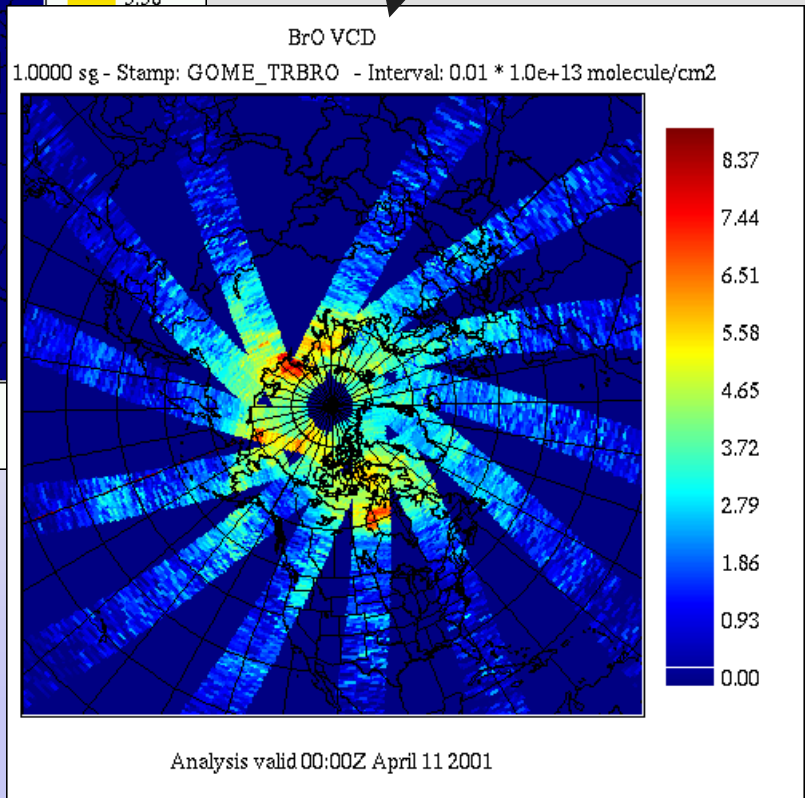
HCN at ~500 hPa for April 4–14

April 11, 2001
BrO column





GOME observations

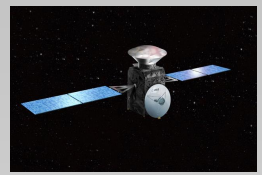


GEM-AQ model simulations

Unit: 10^{13} molecule/cm^2

Toyota et al., ACP, 2011.

Satellite concept studies



1. PCW – Polar communication and weather
   Concept study
   Focus on the Arctic

2. ODIN
3. MOPITT
4. Sentinel 4 & TEMPO
5. Other …

Polar Communications & Weather (PCW) Mission

2 satellites

12 hour orbits

Meteorological Imager, operational, quasi-geostationary around apogee +/- 4 hours

Focus on Arctic

Air quality – summer Hi-Pressure

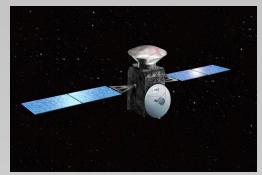
Boreal Forest burning/Volcanoes

East coast Low Pressure Bomb

Apogee – 4 hours

Apogee

Apogee + 4 hours



Monsoon, meteorology + Air Quality

Siberian Fires

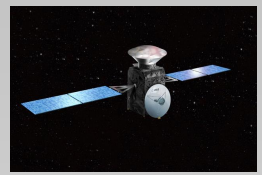
Dust Storms over China

Apogee – 4 hours

Apogee

Apogee + 4 hours

Planetary applications



GEM-Mars

- Modelling – radiation, dynamics and chemistry
- Data assimilation
- Observations
  - NOMAD – Nadir and Occultation for MArs Discovery
  - The only CH_4- sensitive nadir mapper onboard ExoMars TGO

GEM – Mars …dynamics

- Modification to the NWP core to account for:
  - Different atmospheric composition – CO_2 - 95 %
  - Surface pressure ~10hPa
  - Orbit 1.52 AU from Sun
  - ½ the power from Sun than Earth
  - Variation of solar energy along elliptical orbit is about 40% vs. Earth 7%
  - Orbital year is about 2 Earth years
  - Day is very similar to Earth Day
  - Inclination of rotational axes is 25° - similar to Earth (for the next millennium!)

ExoMars Trace Gas Orbiter - 2016

- **Timeline**

7-27 Jan 2016	Launch window
16 Oct 2016	EDM Release
19 Oct 2016	Mars Orbit Insertion, EDL Relay Coverage and EDM Landing
27 Oct 2016	End of EDM surface operations and Relay Coverage
29 Oct 2016	Inclination change to Science Orbit
31 Oct 2016	Apocenter reduction
8 Nov 2016	Start of Aerobraking Phase
Spring 2017	End of Aerobraking Phase, Start of the Science!
11 Jul-11 Aug 2017	Superior Conjunction
14 Jan 2019	Start of Data Relay Phase for the rovers

Composition

Current Mars atmospheric

Table 1. Chemical composition of the Martian atmosphere. Spacecraft data are in black, ground-based spectroscopy is in red, spectroscopy from Earth-orbiting observatories in blue.

Species	Mixing ratio	Instrument
CO_2	0.955	GS
H_2S	< 100 ppb	Mariner/IRIS
HCl	< 2 ppb	KPNO/FTS
H_2CO	< 3 ppb	KPNO/FTS
SO_2	< 1 ppb	IRTF/TEXES
NO	< 1.7 ppb	IRTF/TEXES

GS is grating spectrometer, MS mass spectrometer, FPI Fabry-Perot interferometer, FTS Fourier transform spectrometer.

Krasnopolsky, 2006

NOMAD – Nadir and Occultation for MArs Discovery

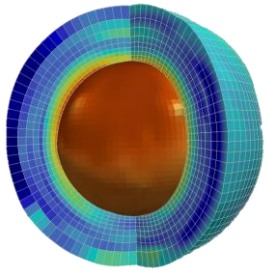
The only CH_4-sensitive nadir mapper onboard ExoMars TGO

NOMAD advances current orbital spectral resolution for CH_4 by an order of magnitude, allowing detection of individual absorption lines

Except: H_2O_2, CH_4

Zonal mean column H_2O

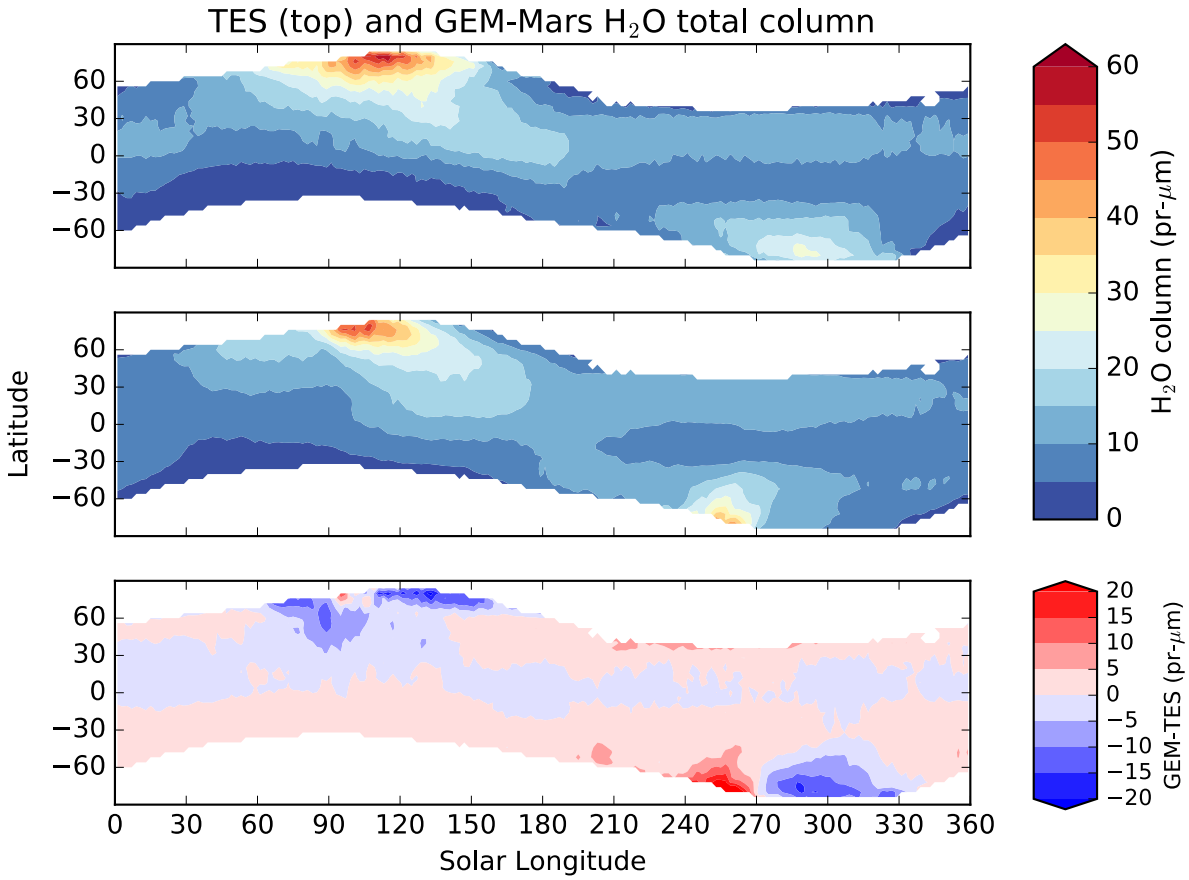
Comparison with MGS-TES



provided by Lori Neary and Frank Dearden

Obs

GEM-Mars



Future of the GEM modelling platform

- Yin-Yang 2km global on the order 100K cores is already feasible … end game at 1km
- Ready to address computer architecture changes:
  - GPUs
  - Larger vectors
  - Larger # of cores per node
- Keep investigating new numerics:
  - that will enhance data locality and limit communications
  - that will be better suited for upcoming architectures
- Keep developing scale-dependent physics and chemistry
- Anticipate new observations leading to new science
  - From new instruments

Thank you