Current Status of Operational Air-Quality Forecasting in Canada

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Photo: Anne-Marie MacDonald

Talk Outline

- Why? ("drivers")
- What? (predictands)
- Where? (context, domain)
- When? (chronology)
- How? (CANFIS, CEPS/GEM/CHRONOS)
- Forecast Performance
- Lessons Learned
- Next Steps

Why? ("Drivers")

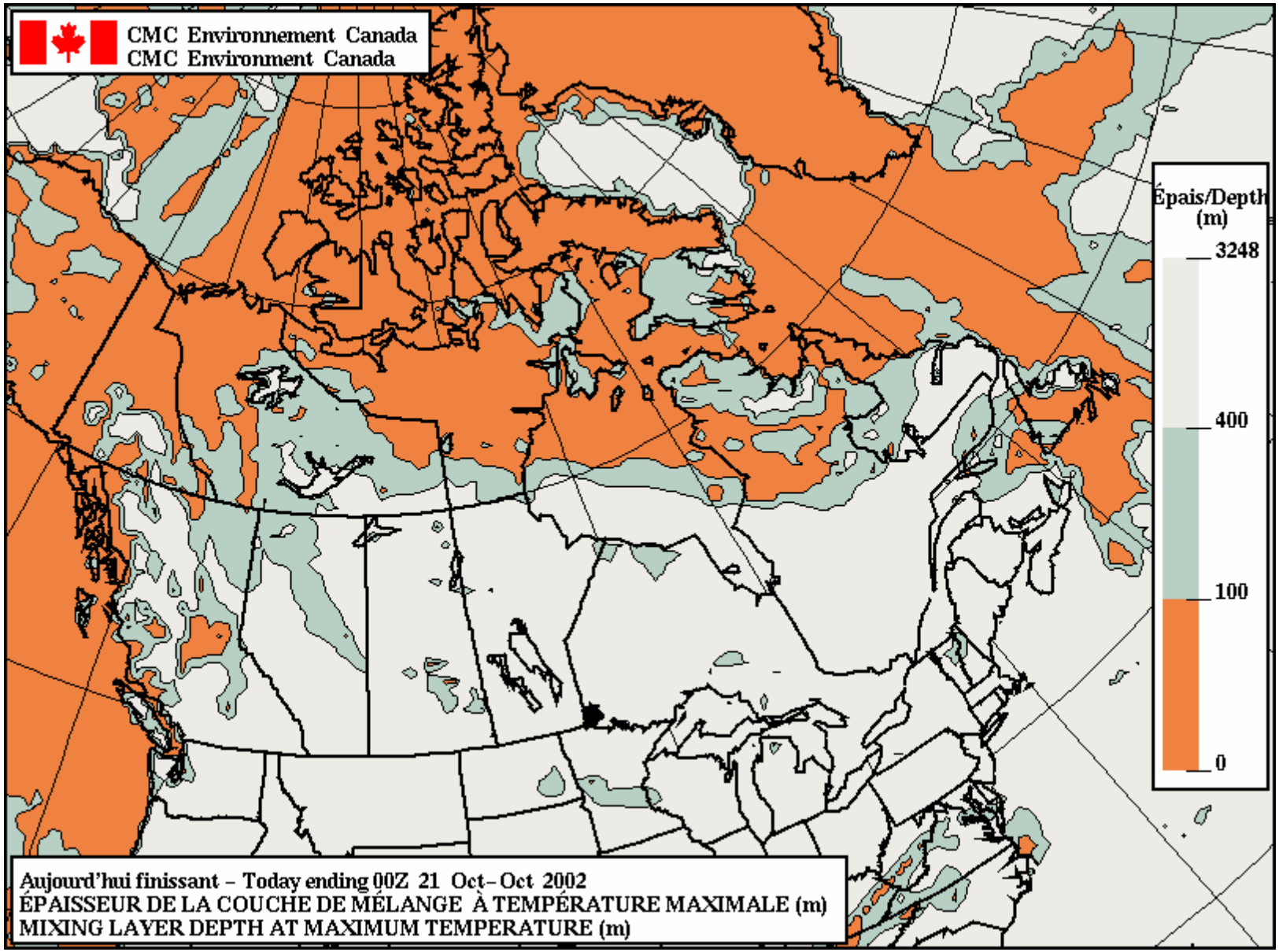
- Concerns over AQ impacts on public health
  - ⇒ new Canadian air-quality legislation in 2000 (Canada Wide Standards for PM and Ozone)
- Government "belt-tightening" in 1990s
  - ⇒ broadened MSC mandate to "add value"
    - ♦ weather prediction ==> environmental prediction
    - ♦ builds on existing MSC infrastructure
    - ♦ builds on existing MSC AQ modelling expertise
- Ministerial announcements in 2000, 2001

Which Air-Quality-Related Predictands?

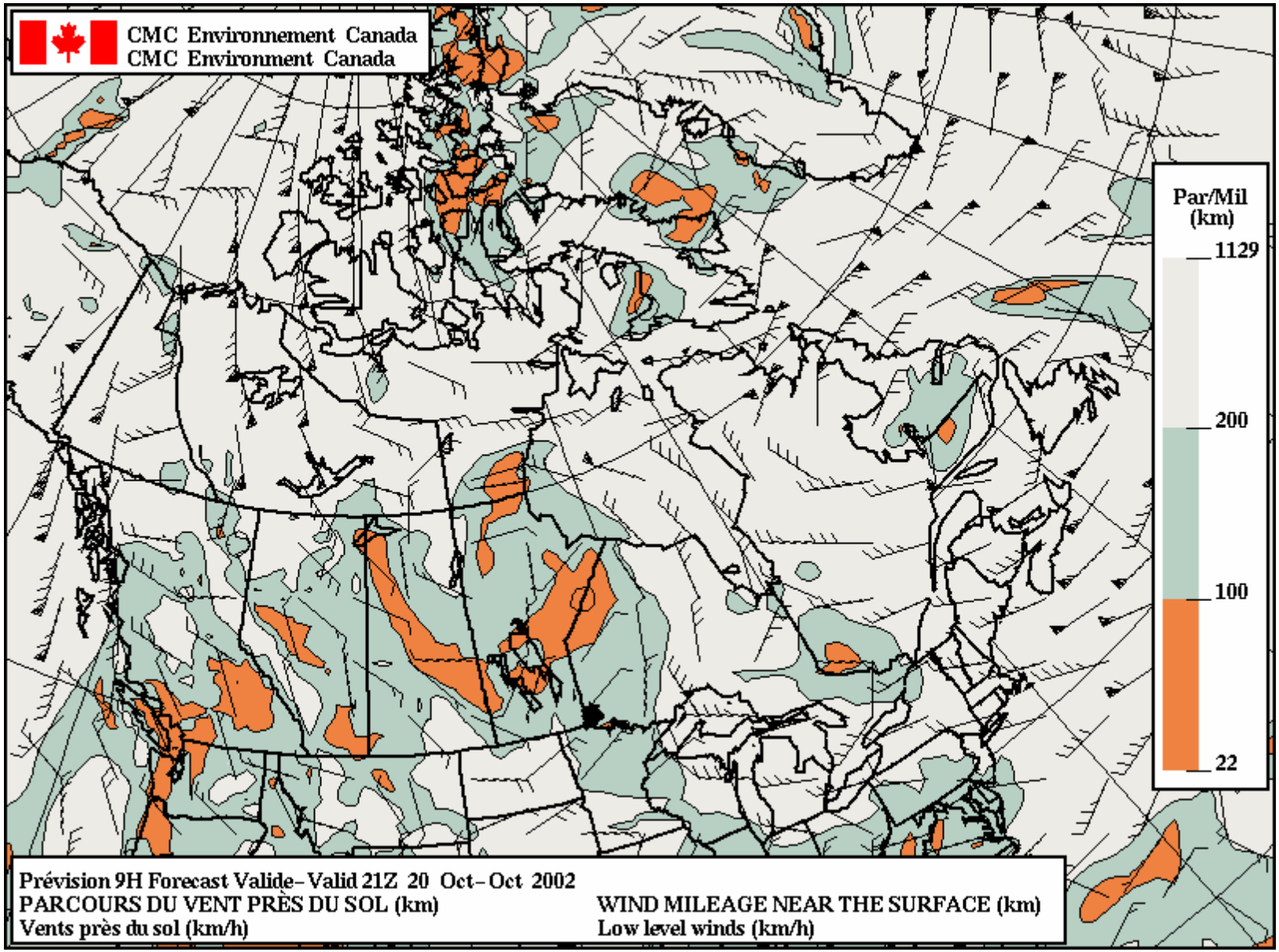
- 3 air-pollution-potential metrics [NWP model]
  - maximum mixing height
  - wind mileage
  - ventilation
- Total Column Ozone & UV Index [NWP model]
- Ground-level ozone [NWP + CTM]
- Bulk $PM_{2.5}/PM_{10}$ [NWP + CTM]

(primary pollutants within acceptable limits)

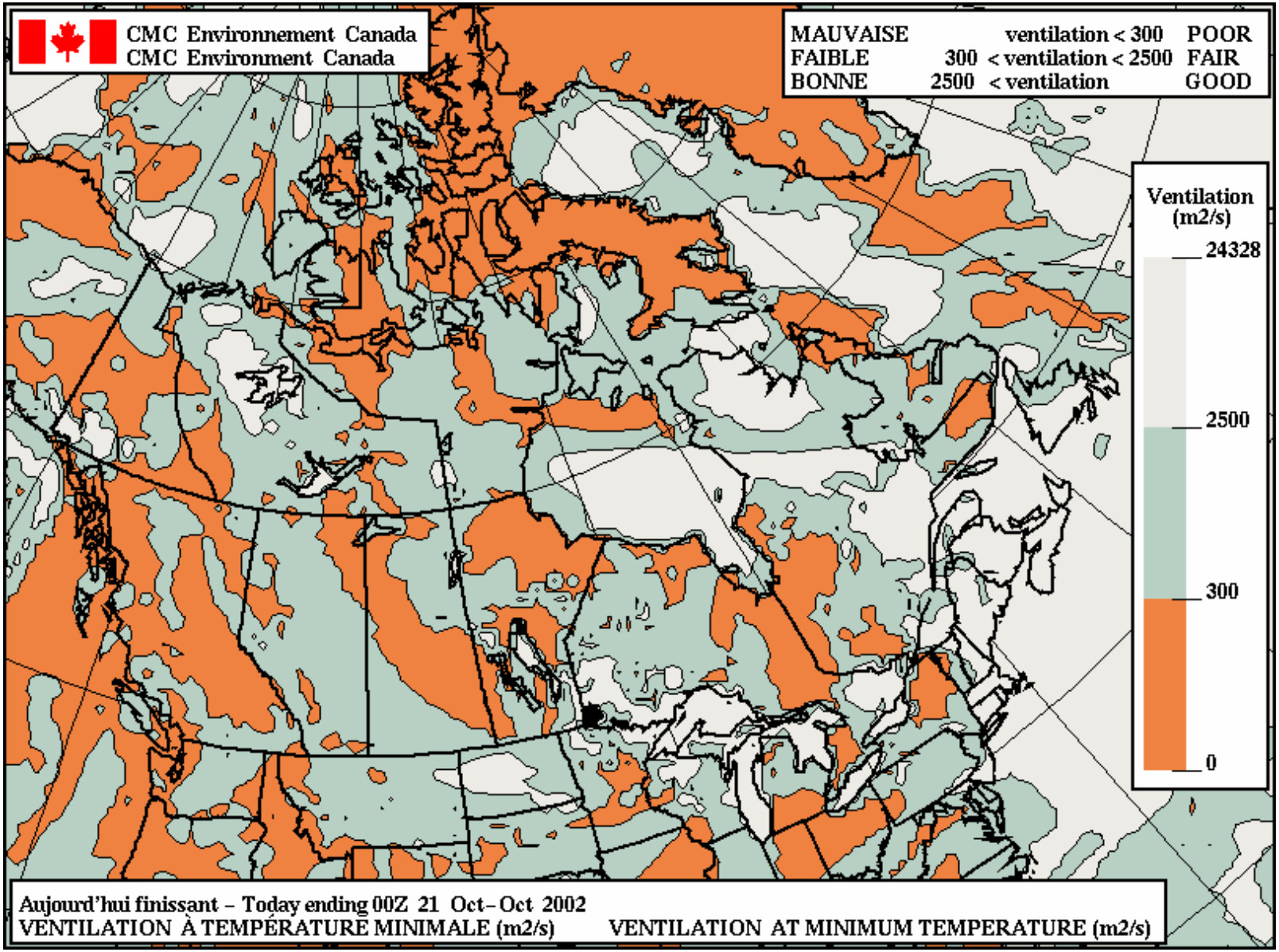
Mixing Height – 20 Oct. 2002



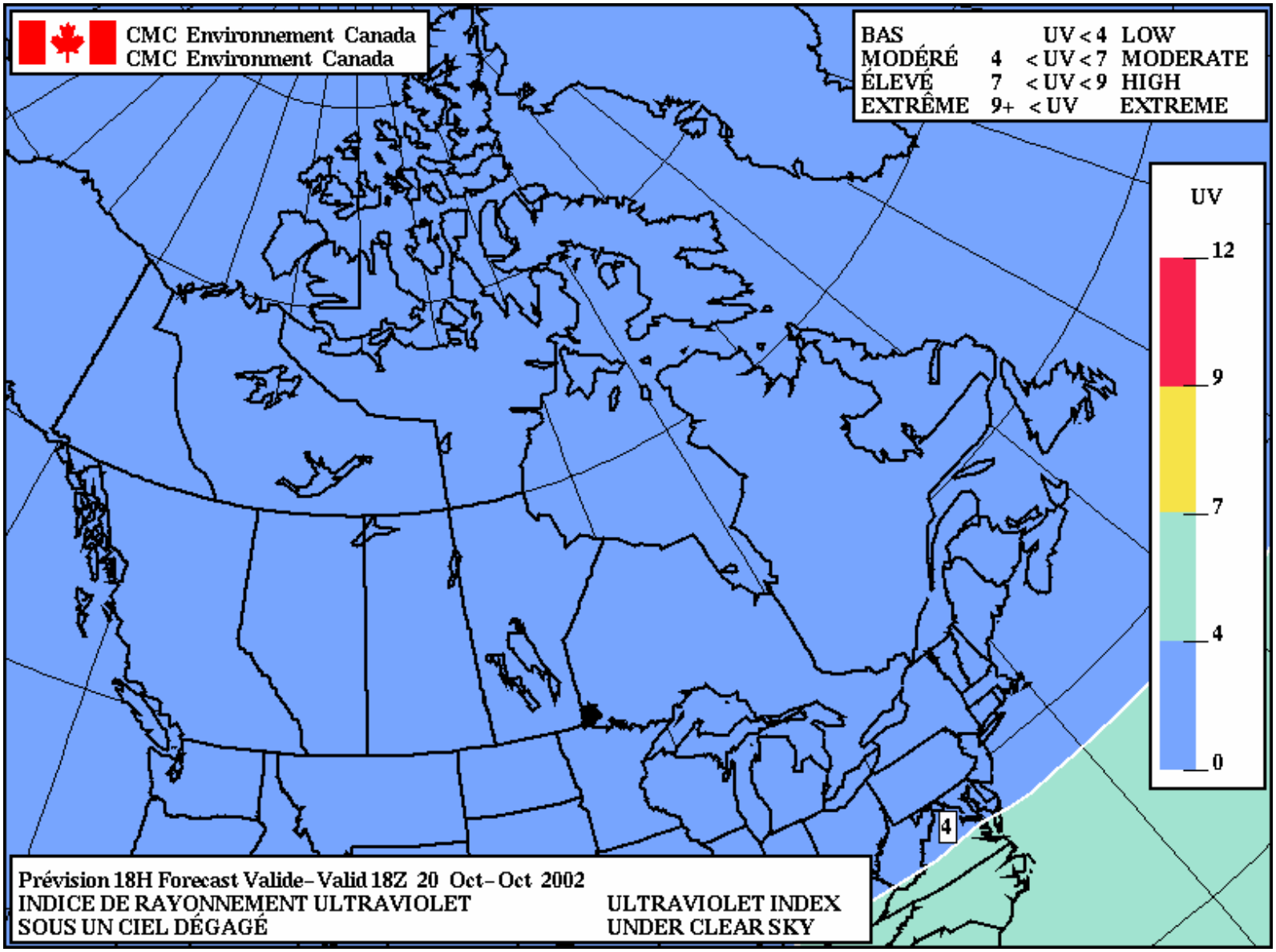
Wind Mileage – 20 Oct. 2002



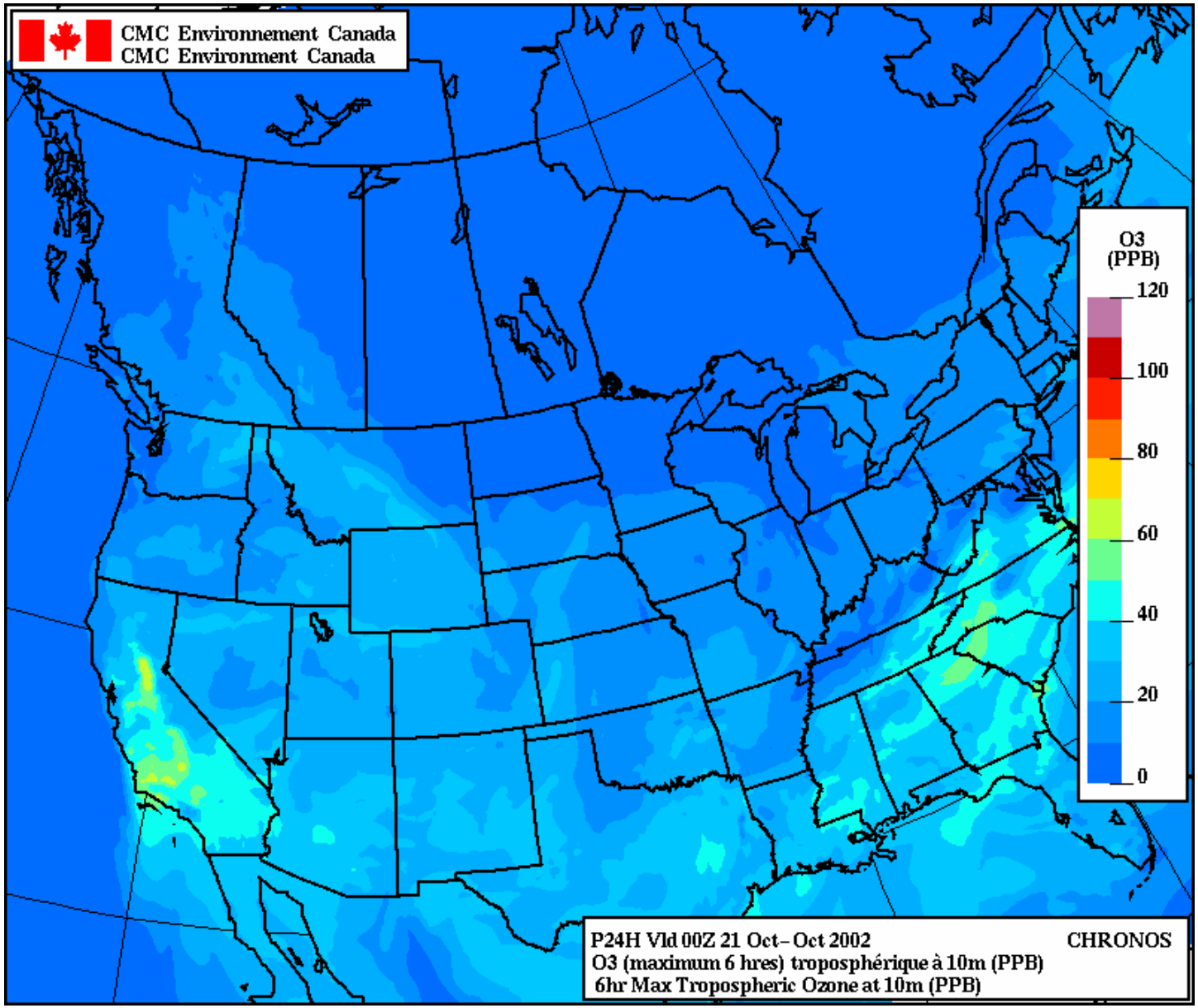
Ventilation – 20 Oct. 2002



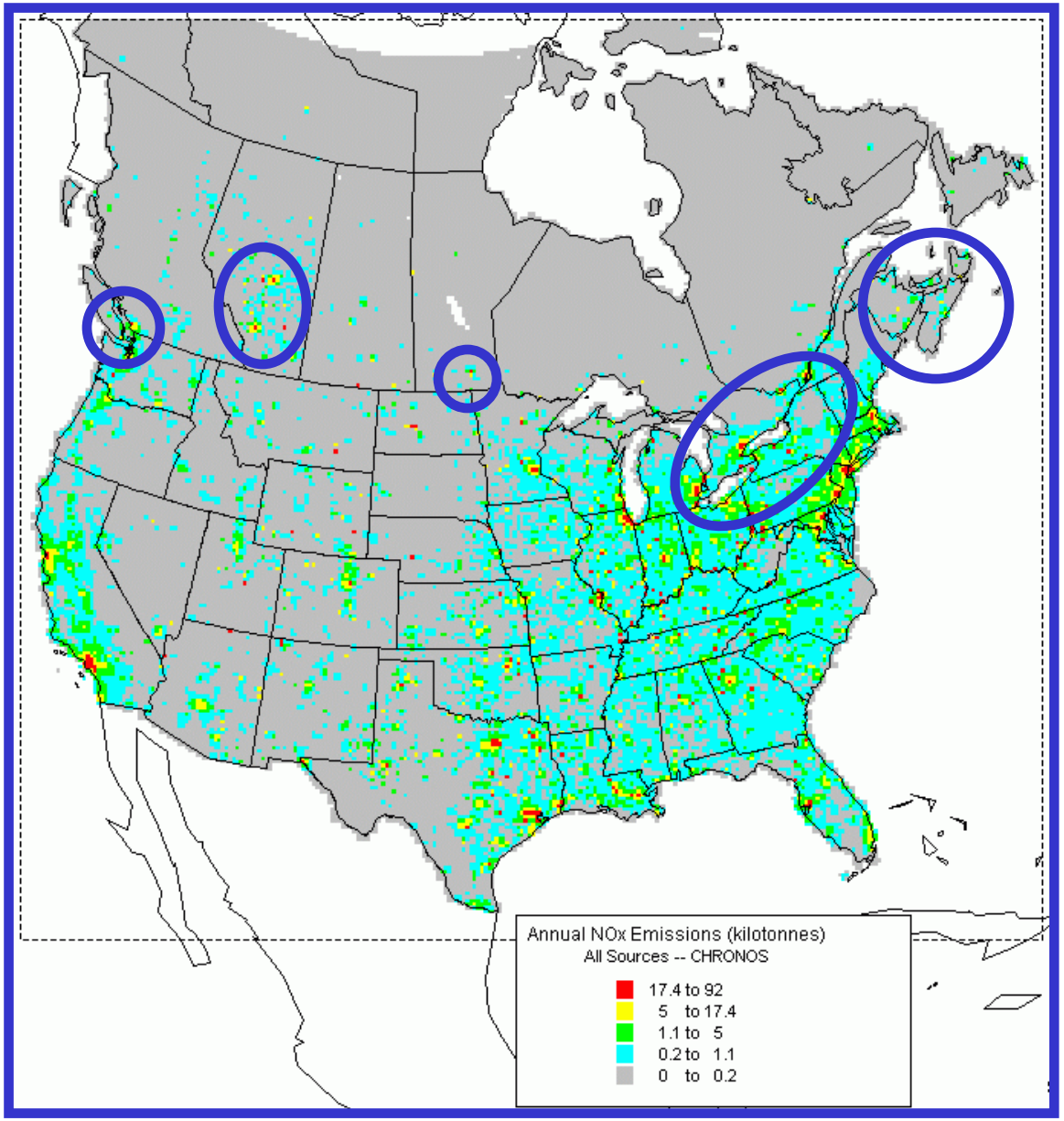
UV Index – 20 Oct. 2002



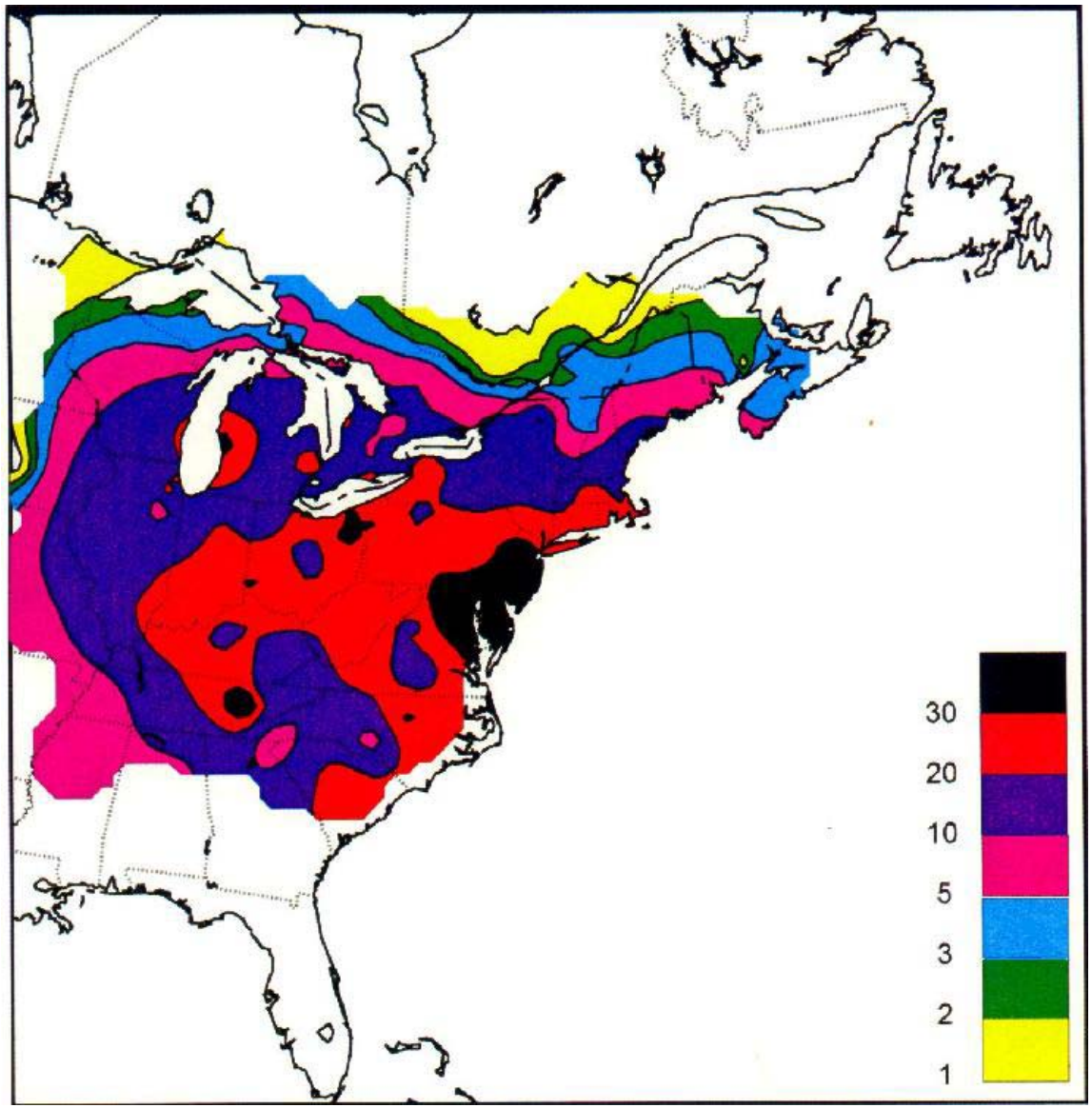
Ground-Level Ozone – 20 Oct. 2002, 18-24Z



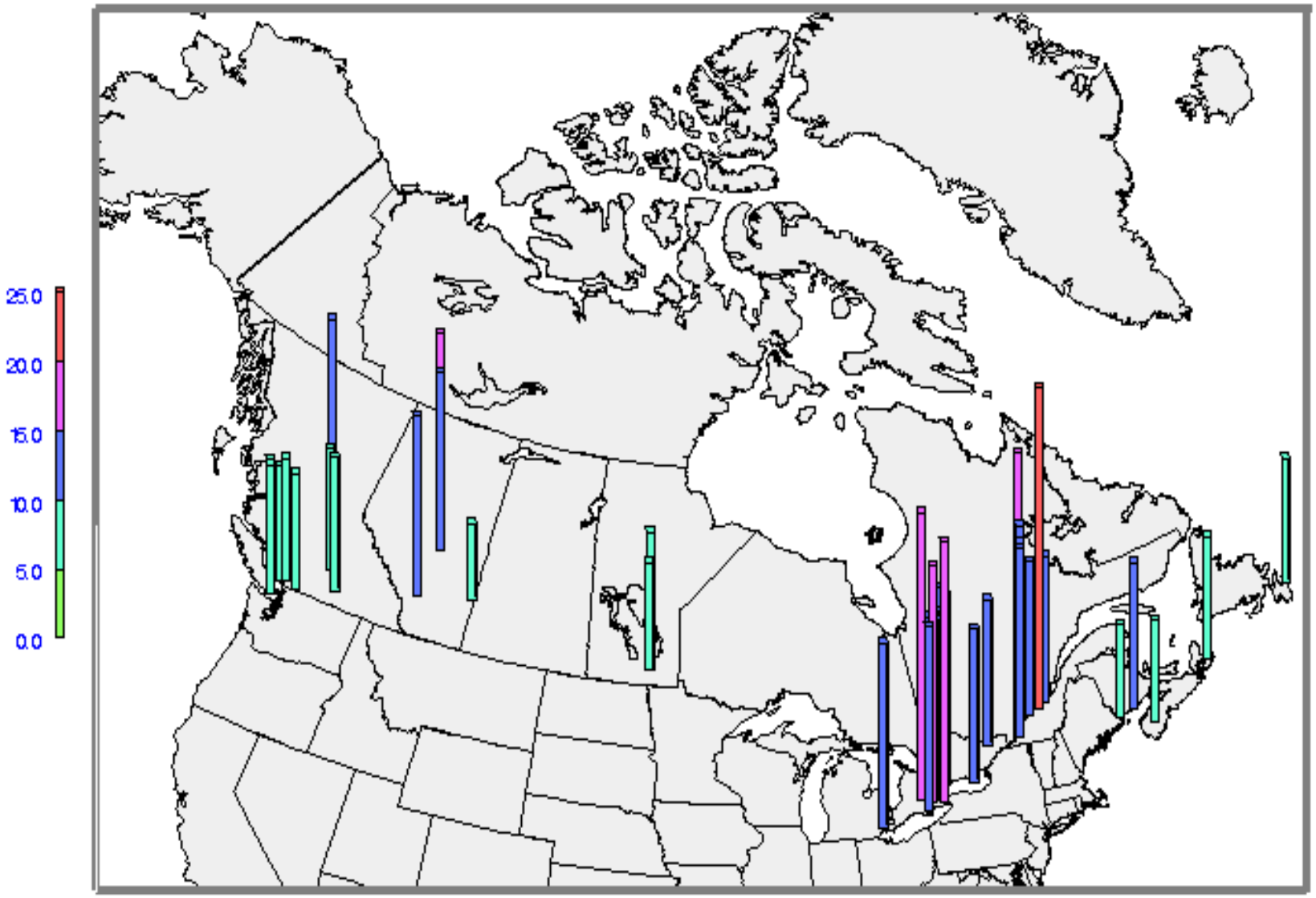
Locations of Major Canadian Cities Relative to 1990 North American Annual Anthropogenic NOx Emissions Field



Average Number of Days per Year in ENA with Ozone > 82 ppb (1986-1993)



1998 Annual Average $PM_{2.5}$ Mass Concentrations Across Canada ($\mu g\ m^{-3}$; MSC, 2001)



Chronology: MSC Air-Quality Prediction Program

- **1992: Experimental UV Index forecasts**
- **1993: Operational nationwide UV Index forecasts; experimental statistical forecasts of ground-level O_3**
- **1997: Operational statistically-based (CANFIS) forecasts of ground-level O_3 for 7 sites in SE New Brunswick**
- **1998: Experimental CTM-based forecasts of ground-level O_3 begin for eastern Canada (CHRONOS, 40-km grid spacing); CANFIS forecasts extended to more sites**
- **1999: National CANFIS forecasts of ground-level O_3**
- **2001: Operational CHRONOS ozone forecasts begin; new national domain, 21 km grid spacing**
- **2002: Experimental bulk $PM_{2.5}/PM_{10}$ forecasts added to CHRONOS output suite (4 chemical components)**

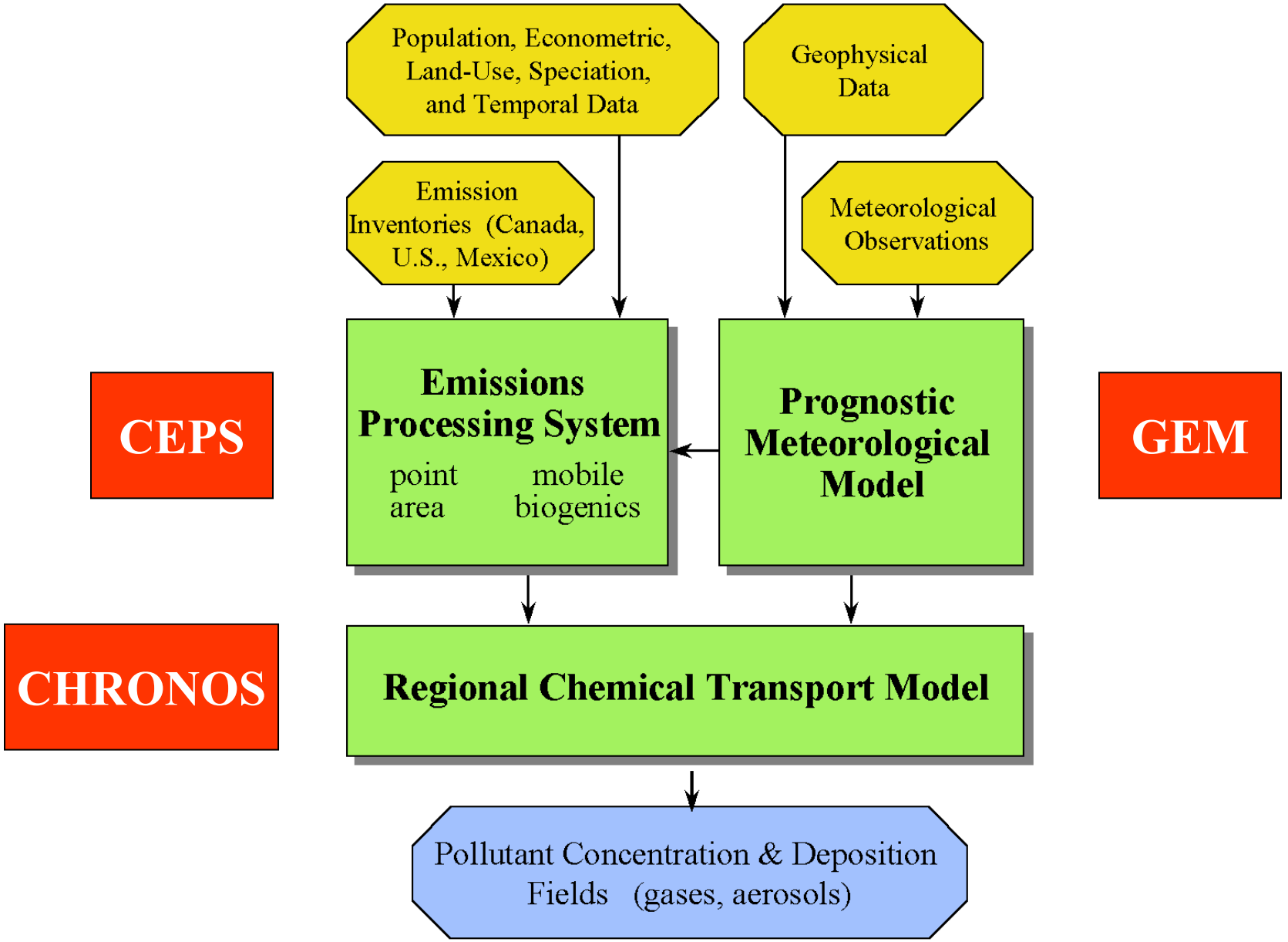
Phase 1: Ground-Level Ozone Dynamic-Statistical Modelling with GEM/CANFIS

- station-specific nonlinear-regression data models built with CANFIS using GEM predictors
- CANFIS is a 2-stage data modelling/mining tool
  - CART (Classification And Regression Trees)
  - NFIS (Neuro-Fuzzy Inference Systems)
- 3 predictands: max 1-h O_3; max 3-h O_3; 24-h av'g O_3
- 643 potential predictors of 5 types (including trajectory-integrated NO_x/VOC emissions)
- data base of hourly O_3 for 1980-1994 at over 100 sites
- two forecasts per day out to 60 hours
- pros: low computer requirements to apply
- cons: coverage limited by ozone (& PM) data availability

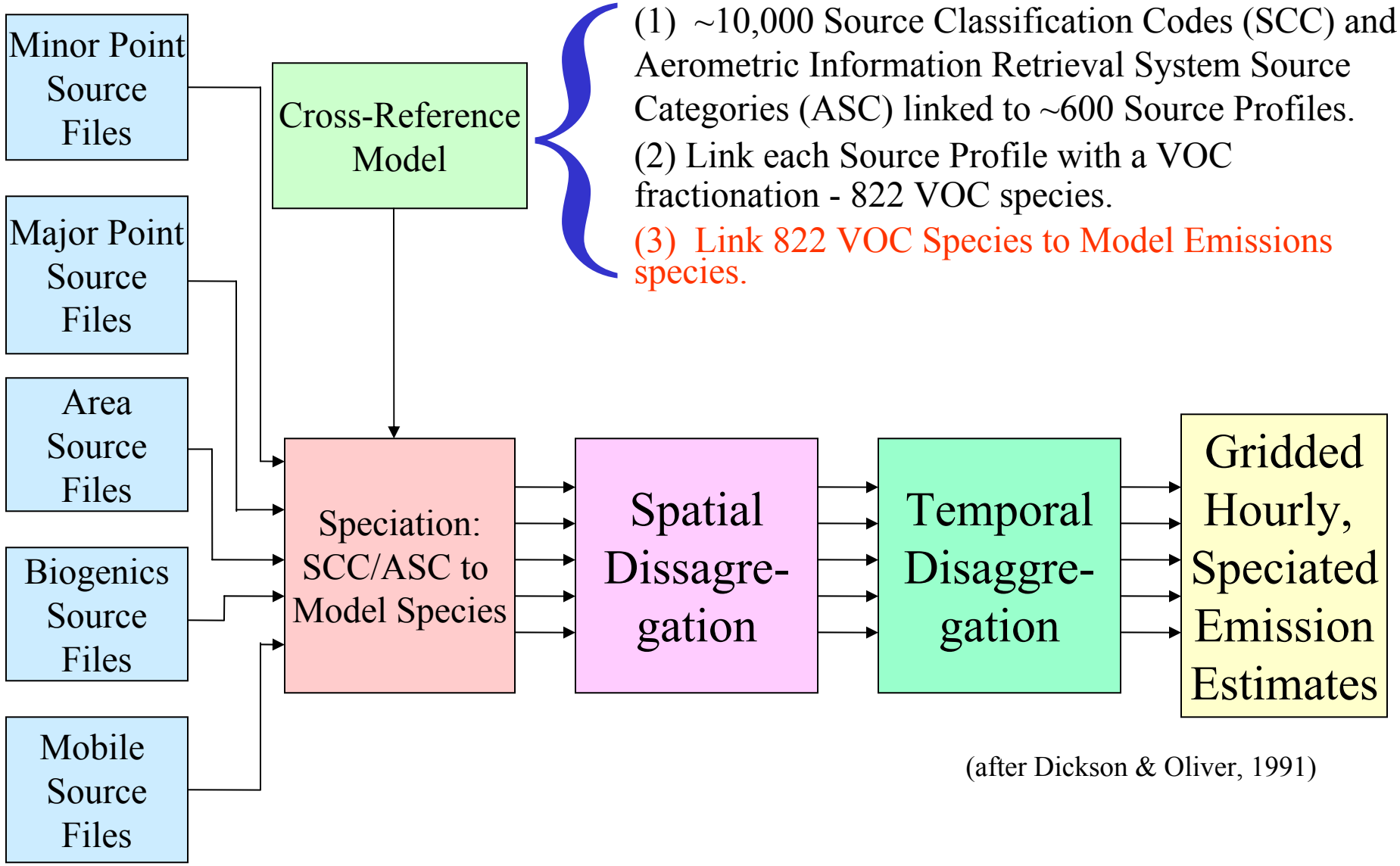
Phase 2: Chemical Transport Modelling with CEPS/GEM/CHRONOS

- CEPS is the Canadian Emissions Processing System
- GEM is the Global Environmental Multiscale model, Canada's current operational weather forecasting model
- CHRONOS (Canadian Hemispheric and Regional Ozone and NOx System) is a source-oriented photochemical oxidant model
- computationally intensive approach: required development of a vectorized solver for the gas-phase chemical mechanism before CHRONOS could be run within operational "window"
- a bulk $PM_{2.5}/PM_{10}$ module was added to CHRONOS in 2002 with four chemical components: bulk primary emissions; secondary gas-phase SO_4; SOA; aerosol H_2O

MSC Regional Air Quality Modelling System

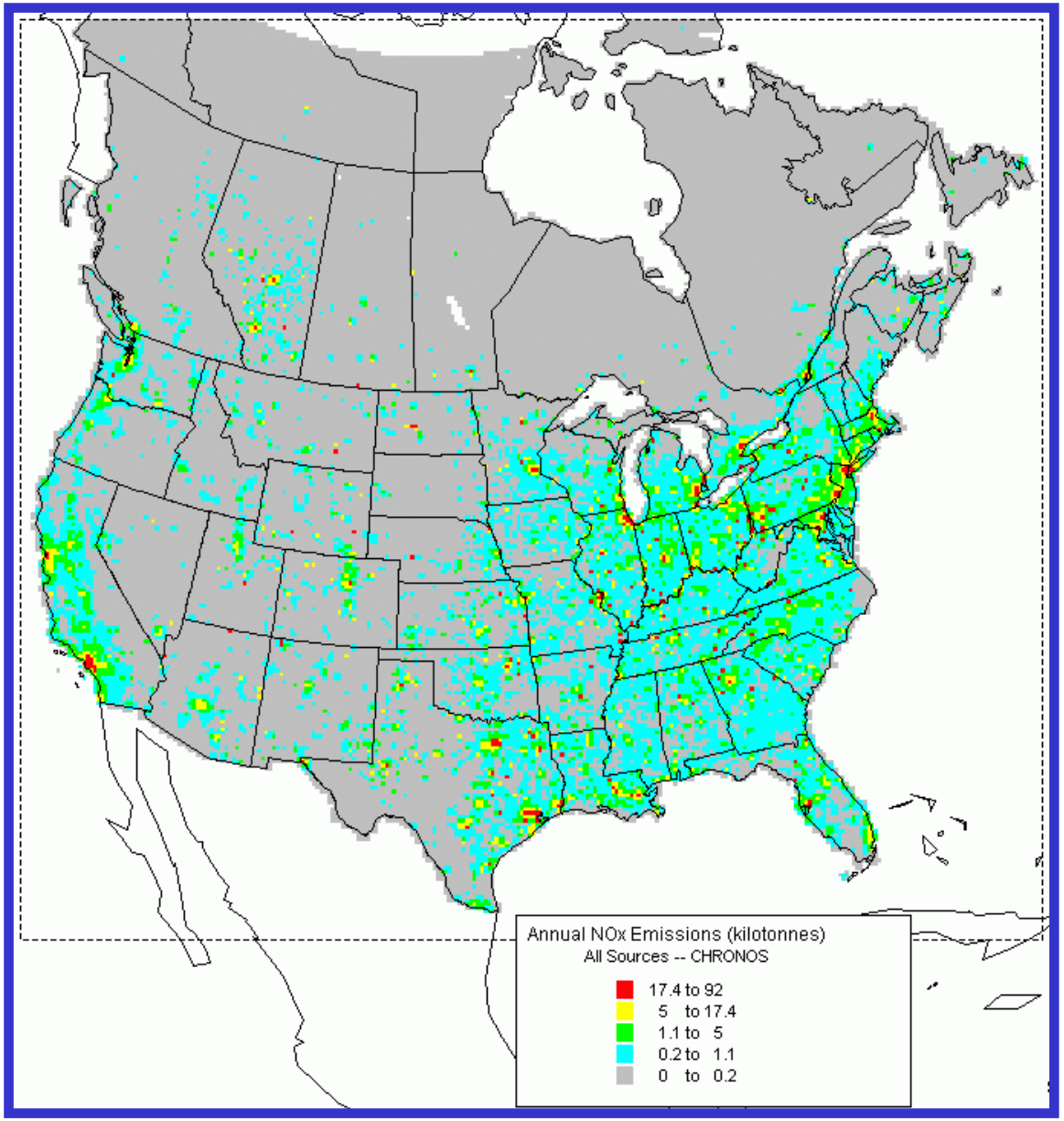


What Is an "Emissions Processing System" and What Does It Do?

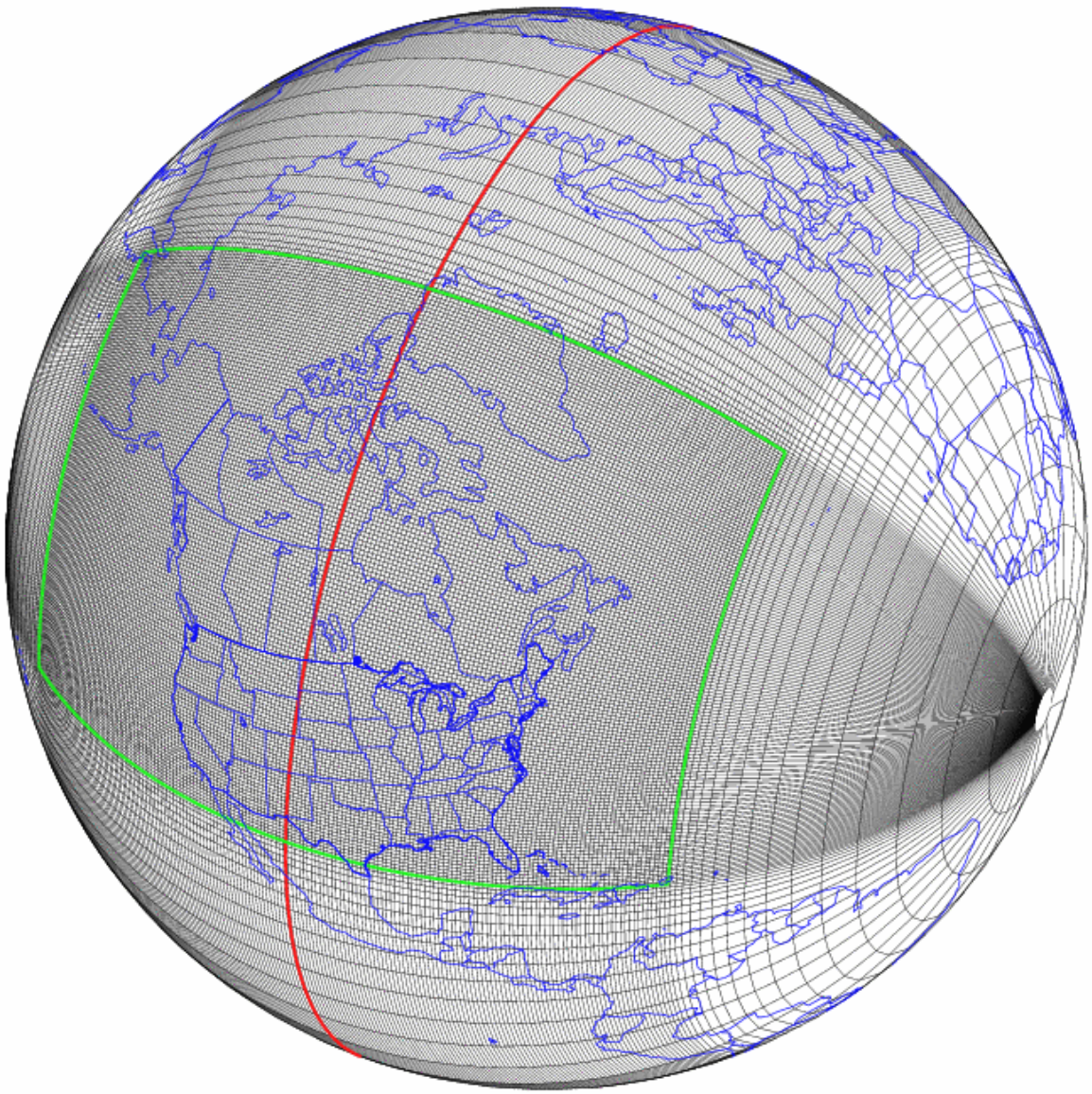


Air Quality Modelling and Integration Division
Meteorological Service of Canada

1990 North American Annual Anthropogenic NOx Emissions Field Produced By CEPS On 21-km X 21-km Grid



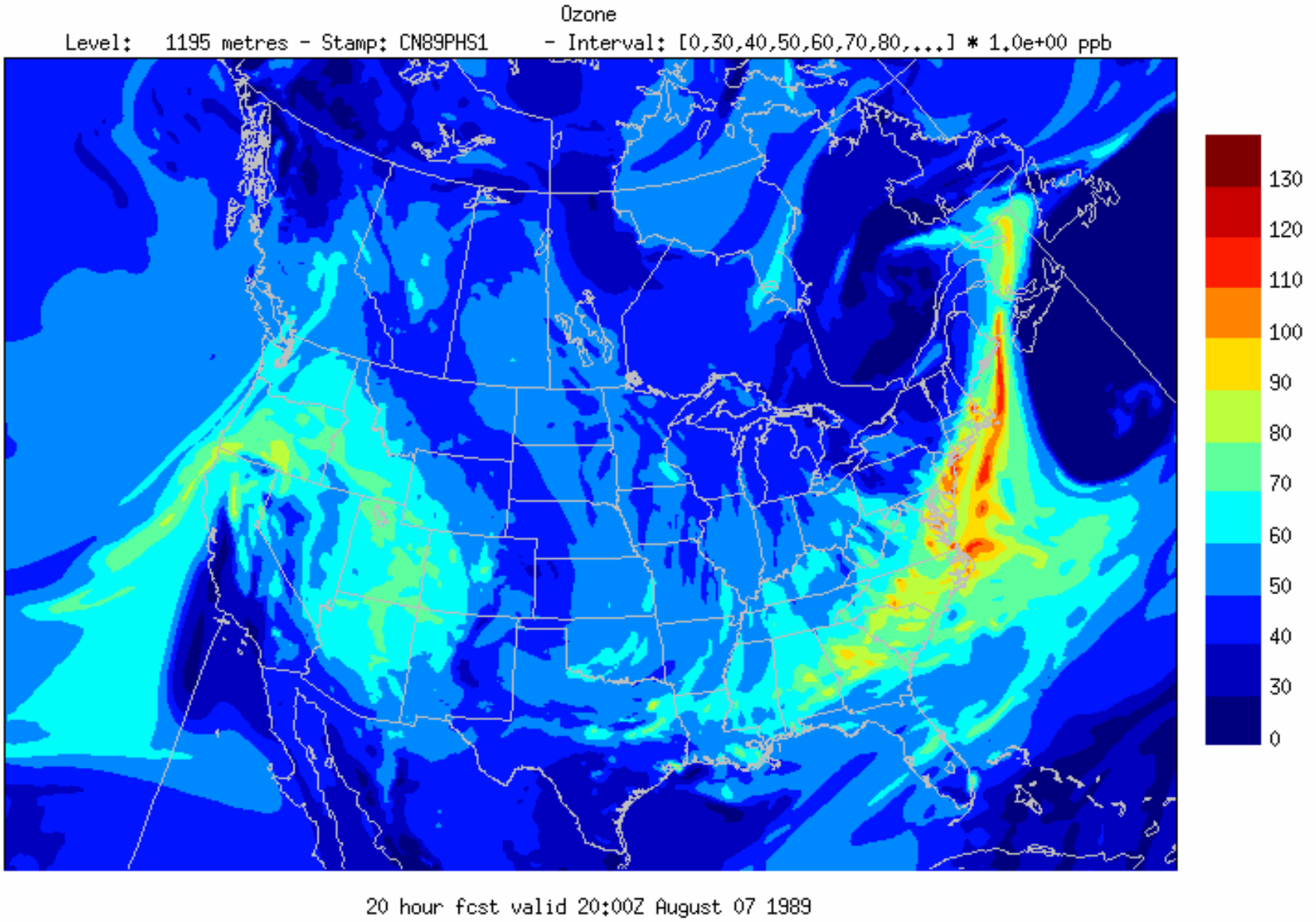
Grid of Operational Regional Version of MSC's Global Environmental Multiscale (GEM) Model (grid spacing of 24 km in uniform area)



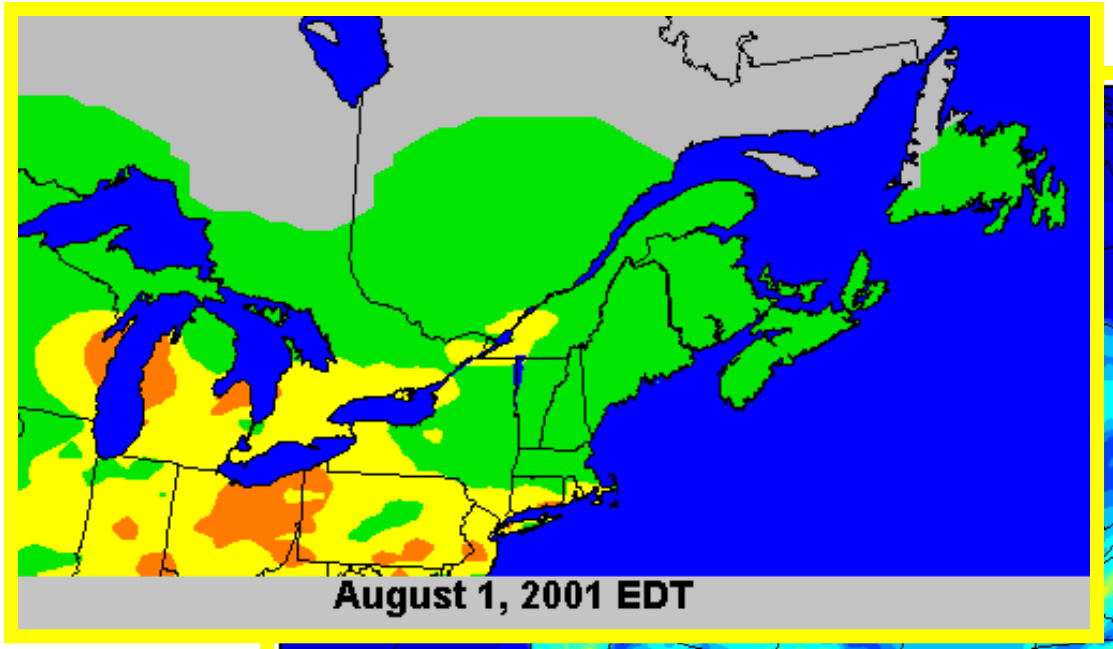
AQPP CHRONOS Characteristics

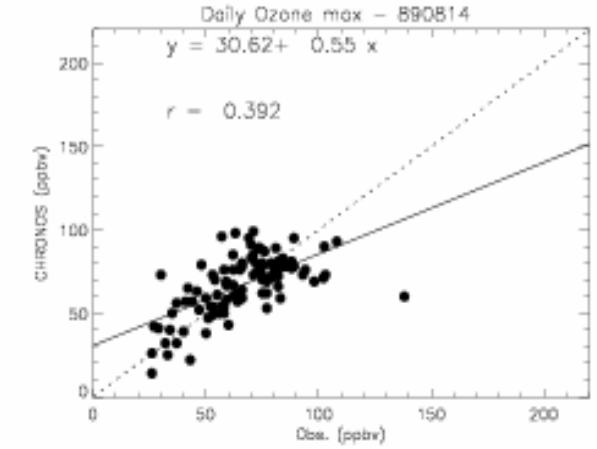
- 350 X 250 grid points horizontal domain
- 21-km horizontal grid interval, polar stereographic projection
- Terrain-following vertical coordinate (modified Gal-chen): 20 levels with ceiling at 5000 meters
- Semi-Lagrangian, positive-definite, nonoscillatory advection scheme
- Gas-phase chemistry mechanism based on Lurmann et al. (ADOM-II mechanism): 47 species, 114 reactions
- 18 emitted species, emissions based on 1990 inventories
- Biogenic emissions modelled on-line (BEIS2 algorithms)
- Execution time: ~ 50 minutes per 24-h simulation on one processor of NEC SX-5 supercomputer

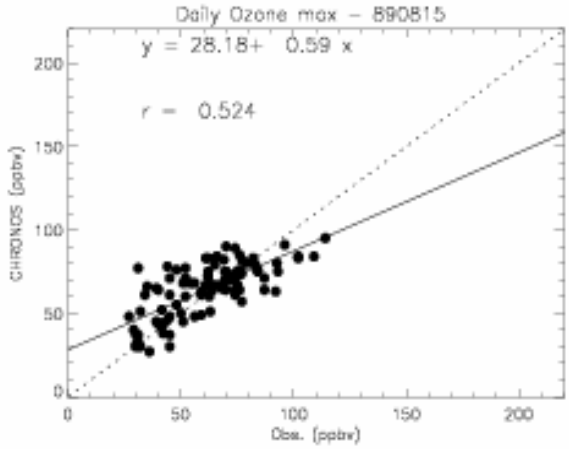
Example of a LRTAP Episode to Atlantic Canada

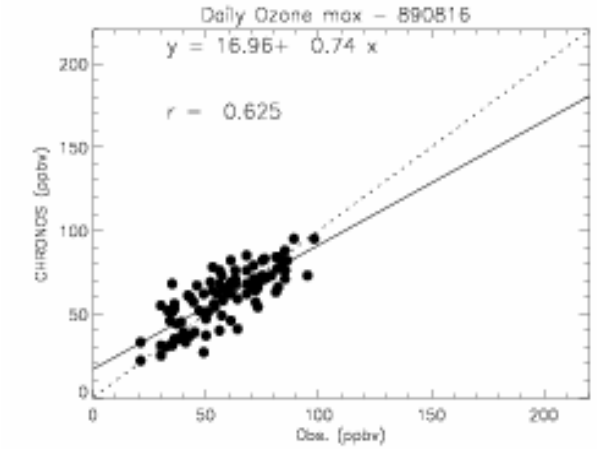


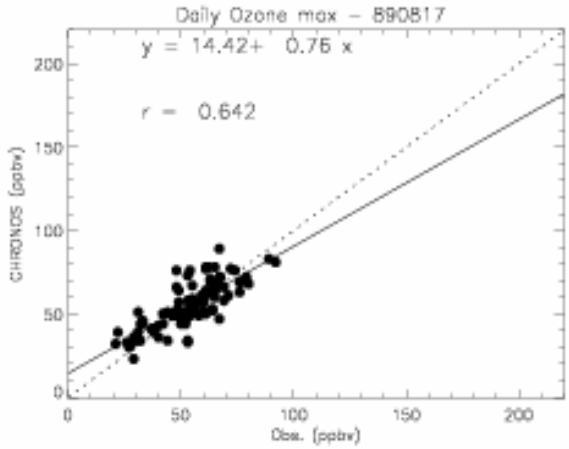
CHRONOS 24-h ozone forecast, valid 18 Z, Aug. 1, 2001 and U.S. EPA AIR*Now* 8-hour average peak ozone map for Aug. 1, 2001

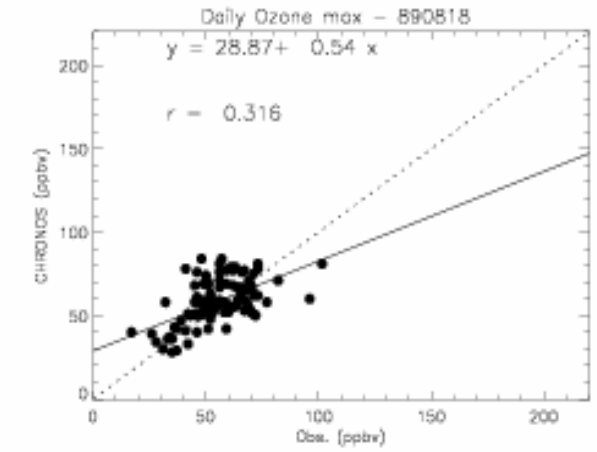






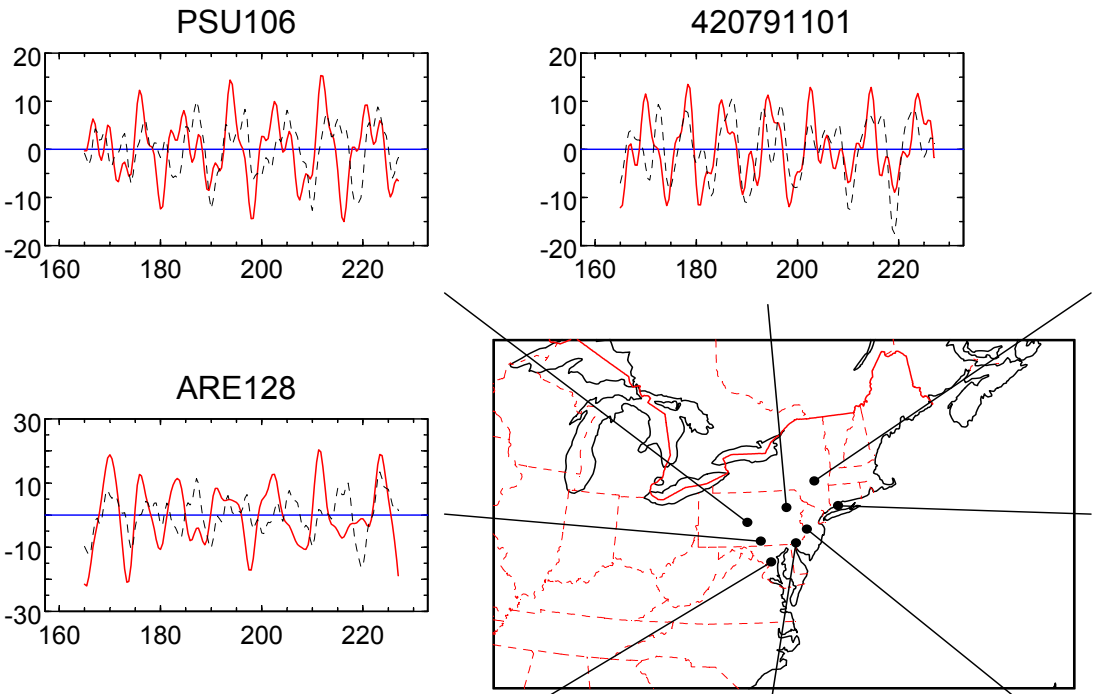






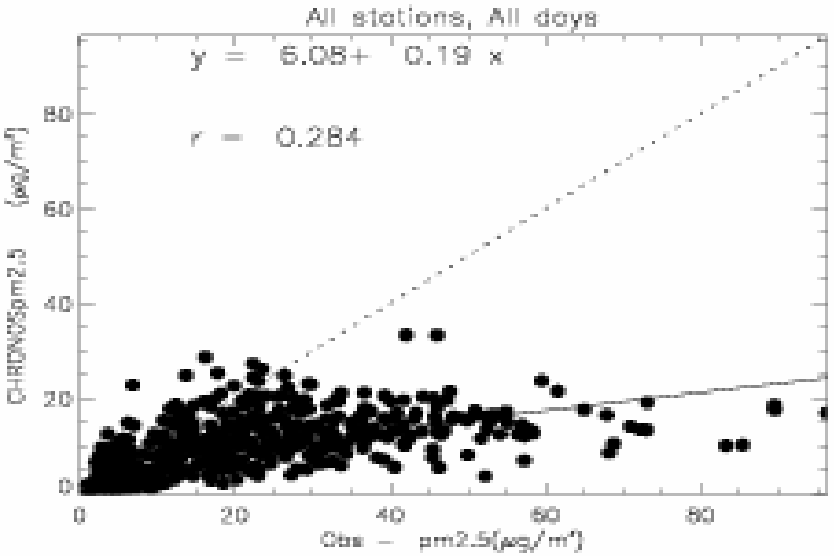
Observed vs. CHRONOS daily maximum ozone, Aug. 14-18, 1989, eastern North America (EMEFS data set)

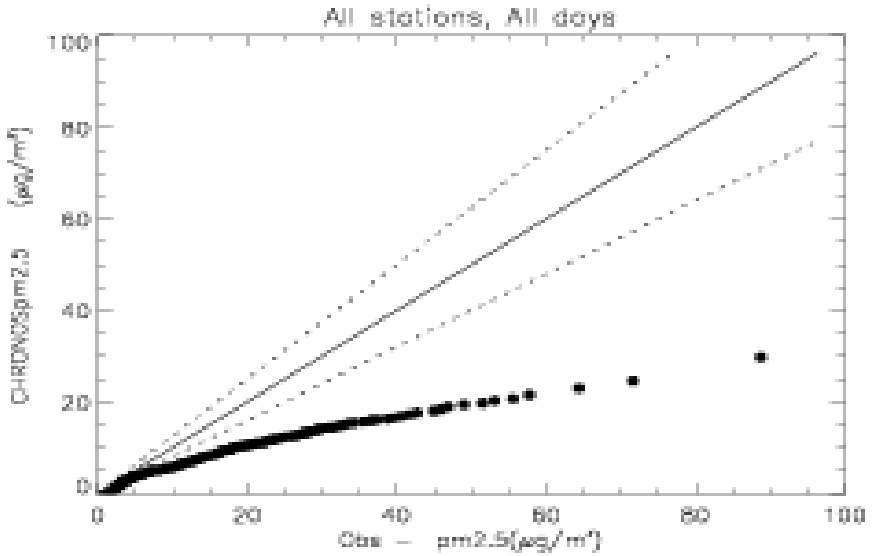
Evaluation of O_3 Episodic Component for NARSTO-NE Field Experiment, July 1995 (Sirois et al., 1999)



Contingency table, AQPP CHRONOS 6-h max predicted O_3, summer 2001

Obs\Fct	Good	Fair	Poor	V. Poor
Good	7249	1096	44	0
Fair	955	1160	138	1
Poor	68	329	198	1
V. Poor	7	33	45	7





CHRONOS_2002 PM2.5 mass predictions vs. TEOM observations, eastern Canada, summer 2001

Some Lessons Learned

- Both statistical and CTM approaches can be useful
- Role of long-range transport must be considered in choosing and implementing AQ forecast tools
- Operational forecasts may be the most demanding application of an air-quality modelling system
- Gradual implementation provides opportunity for experience to be gained and tools and infrastructure to be improved before official release
- Availability of real-time AQ observations (e.g., AIR*Now)* provides valuable immediate feedback on performance
- AQ forecasting is a learning experience for both AQ modellers (e.g., robustness, time constraints) and for NWP operational community (e.g, input emissions)

Next Steps

- Switch to newer emissions inventories
- Improved (operational) emissions modelling
- Additional PM mass components
- Other CTM parameterization improvements
- O_3 data assimilation
- Continued performance evaluation for forecasts and for new case studies (esp. speciated PM)
- Coarse parallelization of CTM