Estimation of Baseline Air Quality Concentrations with the GEOS-Chem Global Chemical Transport Model

2016 CPANS Annual Conference and General Meeting
May 3, 2016

Christian Reuten, Ph.D., ACM [1,2]
Zahra Hosseini, Ph.D. [1,2]
Golnoosh Bizhani, Ph.D. [1]
Jeff Lundgren, M.Sc. [1]
[1] RWDI Air Inc.
[2] University of Calgary, Department of Physics and Astronomy

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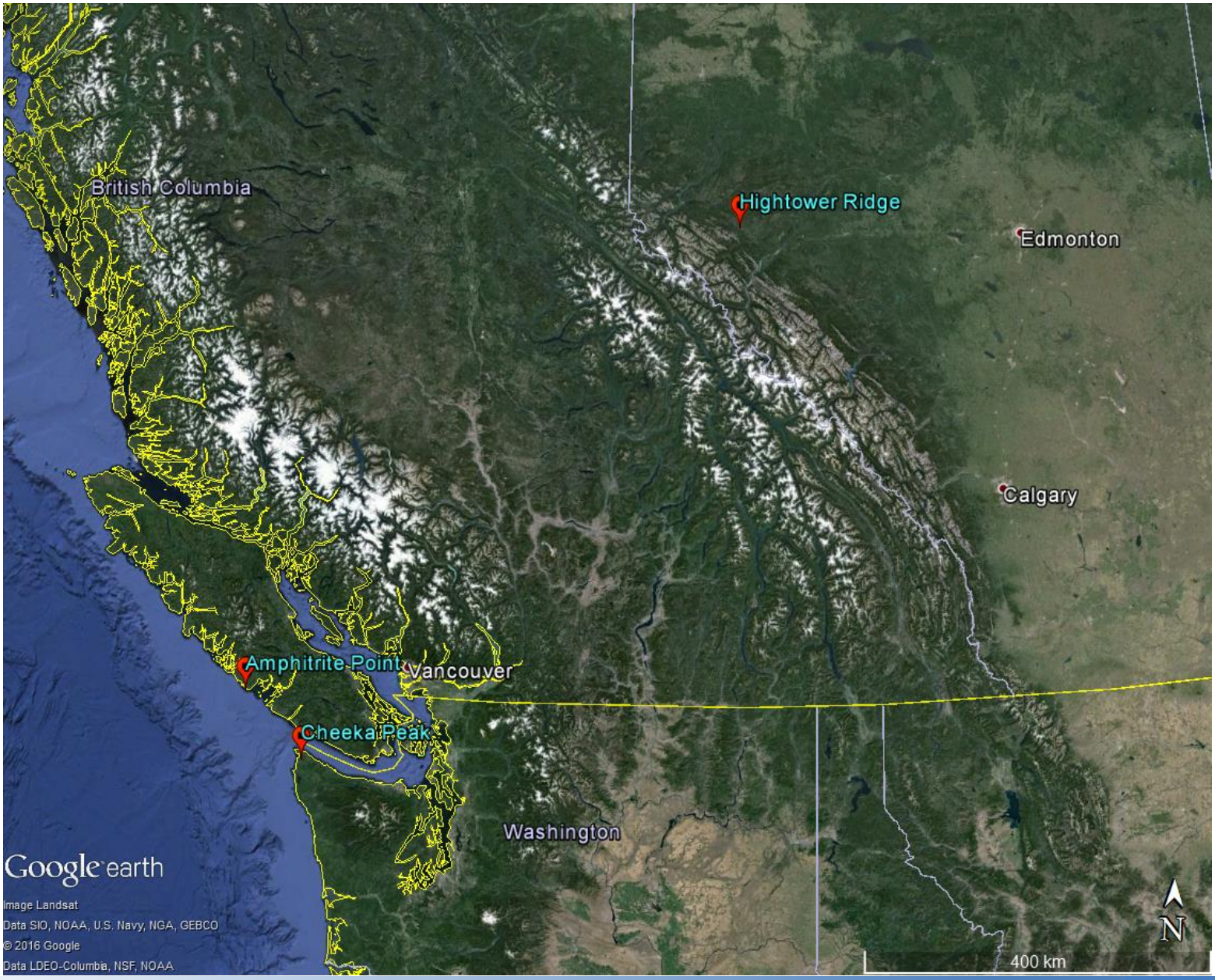
Air Quality Model Guideline (AEP 2013):

1. Dispersion modelling of emissions from proposed facility
2. Dispersion modelling of emissions from other nearby industrial emission sources
3. Addition of baseline concentrations ("chemical concentrations from natural sources, nearby sources, and unidentified, possibly distant sources")

Introduction: Method to Determine Baseline Concentration

- Validated, QA/QC'ed, continuous (preferred), 75% complete
- At least one year (most recent)
- Remove:
  - 0.1% highest concentrations for screening assessment
  - 10% highest concentrations for refined assessment
- Calculate averages greater than one hour if applicable

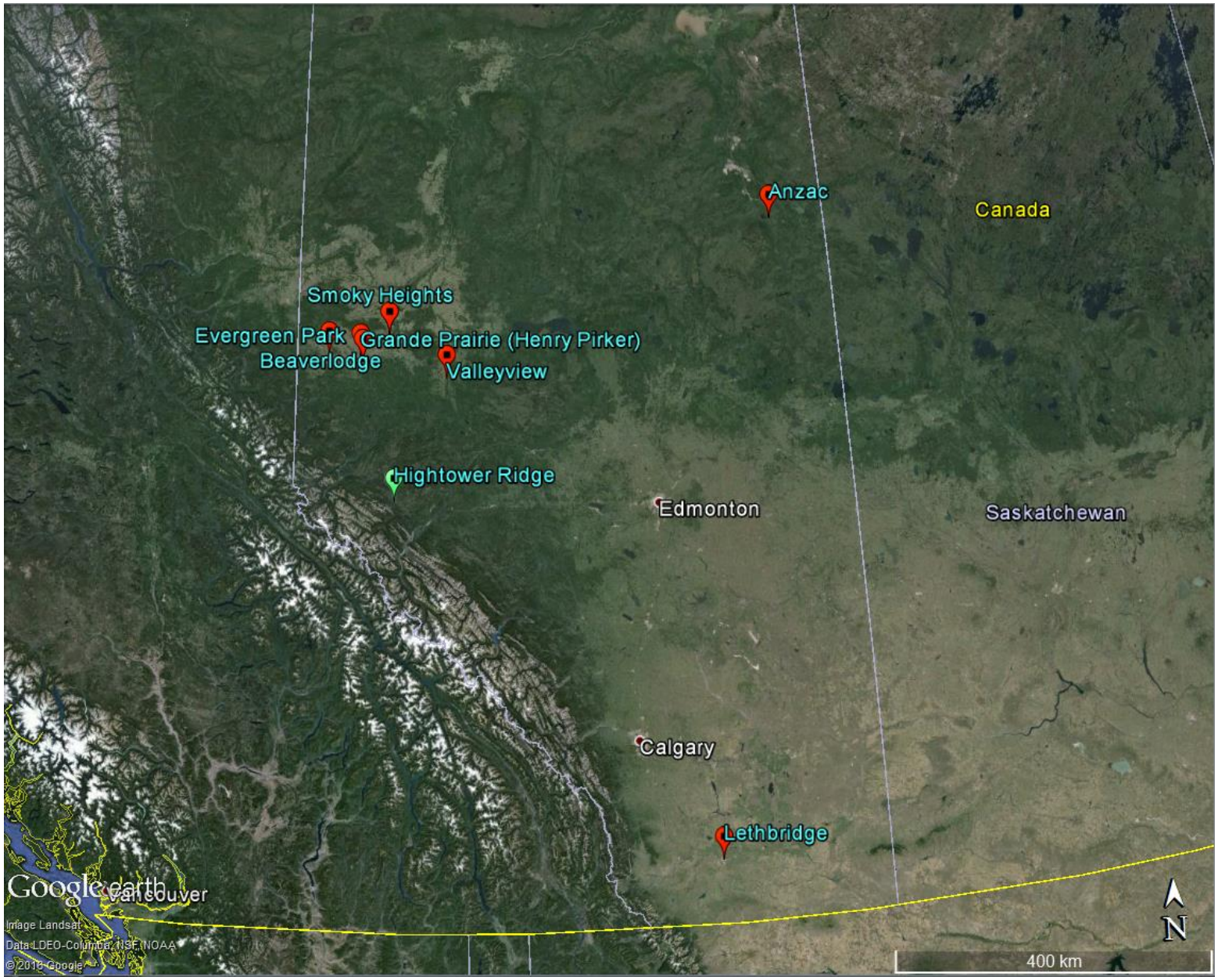
True Background Stations



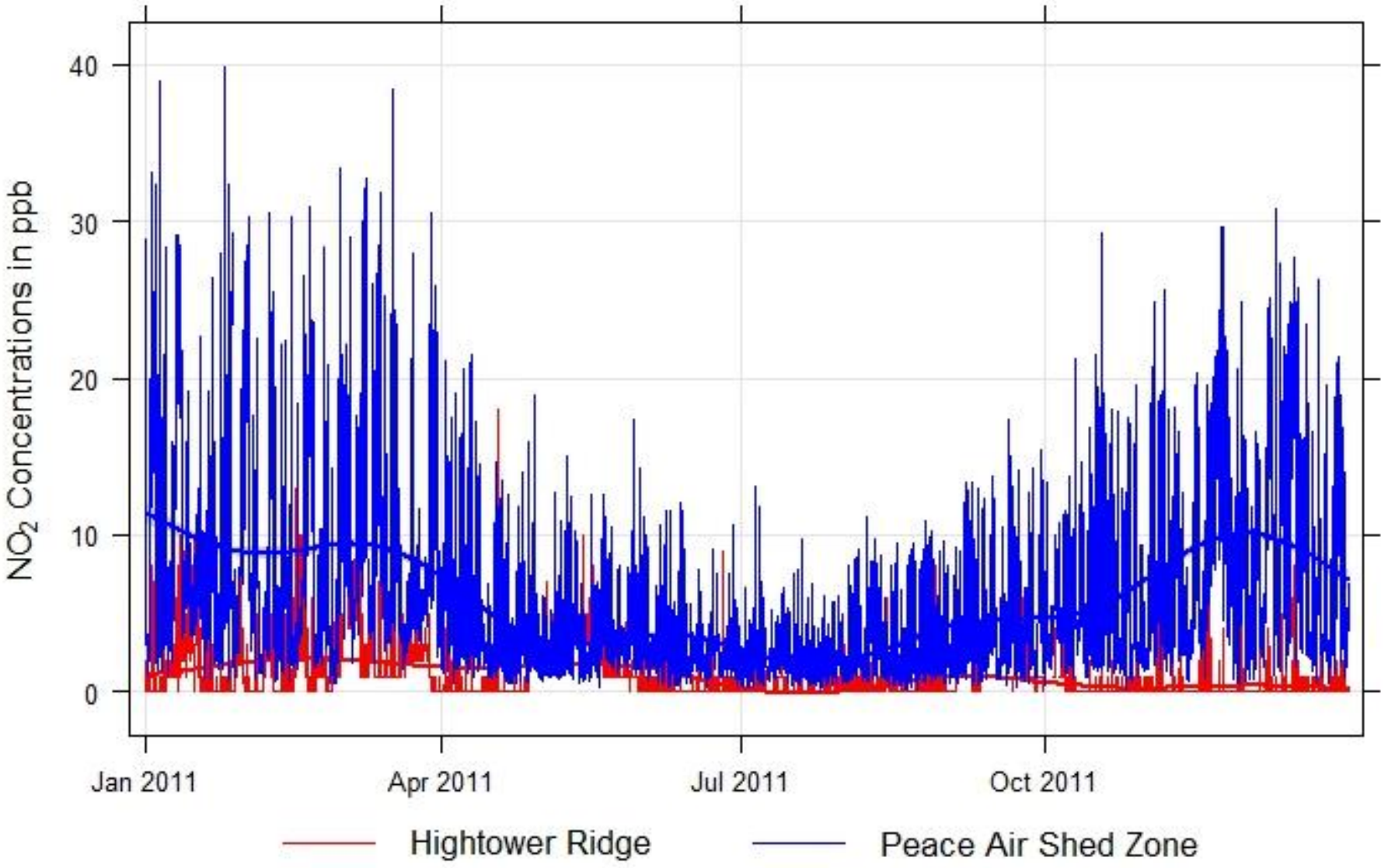
Issues with Background Stations

- Expensive and time consuming to maintain, because they are remote
- They do not protect anybody (presumably), therefore:
  - Sporadic
  - Constantly battling for survival
  - Tend to get shut down
- Unusual or extreme environment:
  - Sea salt, high elevation, etc.

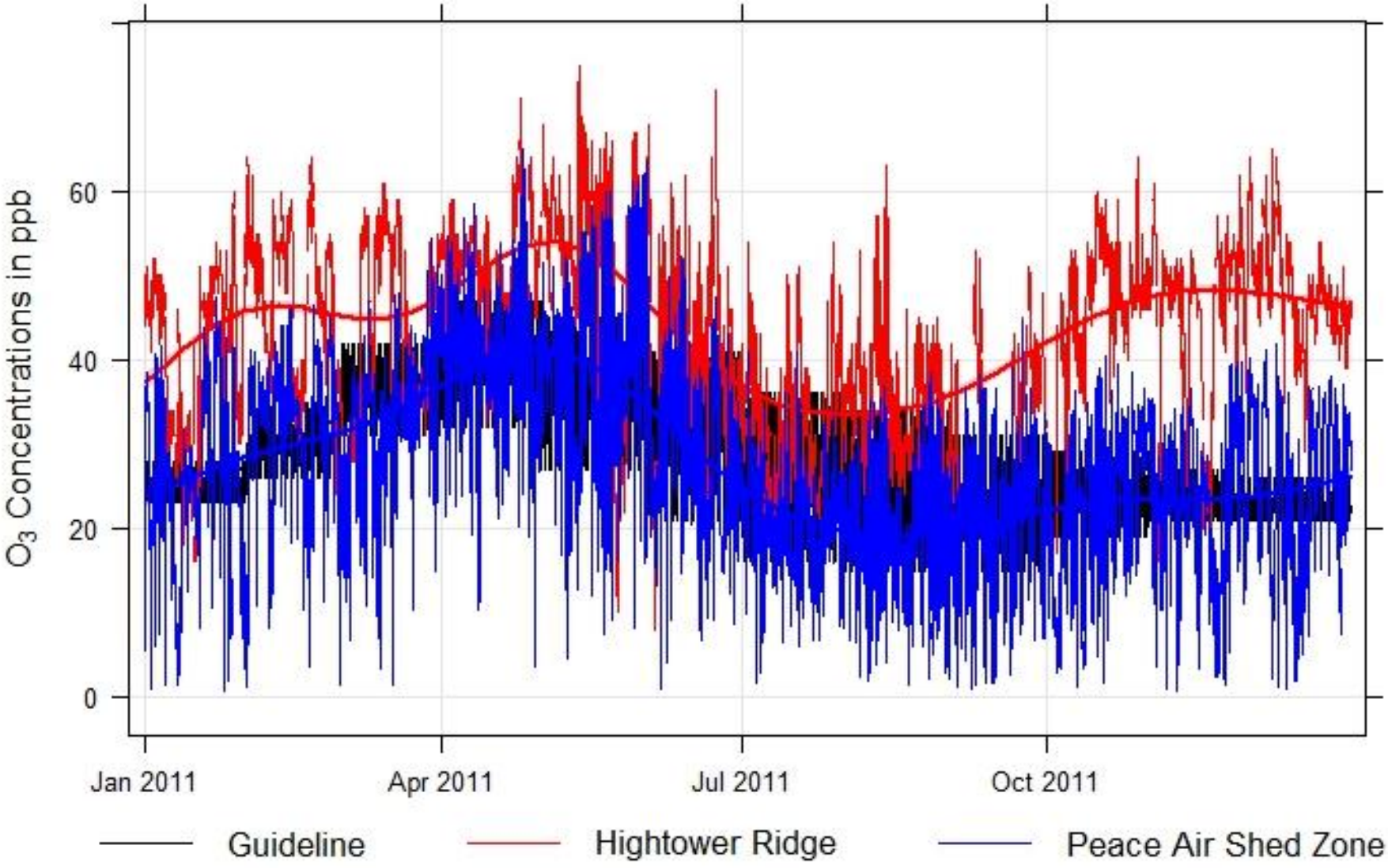
Workaround Background Stations



Comparison: NO_2 at Hightower Ridge and Peace Air Shed Zone



Comparison: O_3 at Hightower Ridge and Peace Air Shed Zone



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Recommended Rural Ozone Levels based on:

- Anzac
- Beaverlodge
- Caroline
- Elk Island
- Fort Chipewyan
- Genesee
- Tomahawk
- Violet Grove

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GEOS-Chem v10-01:

- Global 3-D chemical transport model for atmospheric composition.
- Driven by meteorological input from the Goddard Earth Observing System (GEOS) of the NASA Global Modeling and Assimilation Office.
- “Grass-roots community model owned by its users”.
- Support teams at Harvard and Dalhousie Universities.

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Aerosols:

- Volcanic SO_2 (1979 to 2009),
- Black and organic carbon (2001 & 2000)
- Non-volatile organic carbon (1990)
- Anthropogenic/biofuel emissions of OC and BC (1998)

Anthropogenic and biofuel:

- NO_x, CO, SO_2, and NH_3 (1970-2008)
- Volatile organic compound (2000)
- Biofuel (1985)
- Agricultural

Anthropogenic aircraft and ship:

- Aircraft emissions of fuel burned, NO, CO, and hydrocarbons (2005)
- Ship emissions of SO_2, CO_2, CO, NO (2008)

Biomass burning:

- Monthly-mean data from 1998-2014
- Daily and 3-hourly scale factors

Bromine:

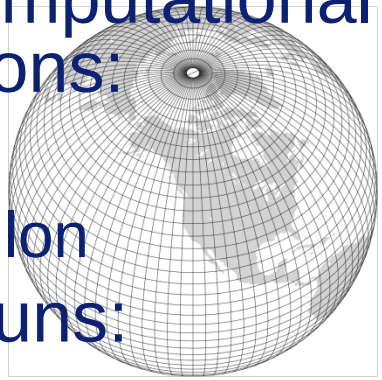
- Very short lived bromine species $CHBr_3$ and CH_2Br_2 (2000)

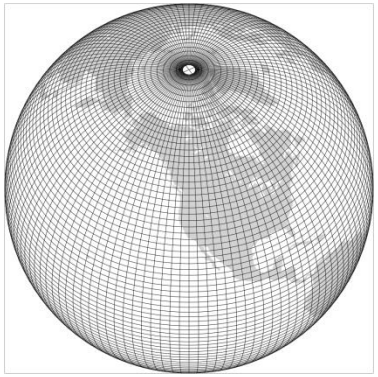
GEOS-Chem driven by GMAO assimilated meteorological data:

- 1-hour averaged quantities
- 0.5° lat x 0.667° lon, 72 vertical levels
- 3-hour averaged and instantaneous quantities
  - 10-m winds, roughness height, friction velocity
  - PBL height, column cloud fraction, surface temperature
  - Convective & total precipitation at ground

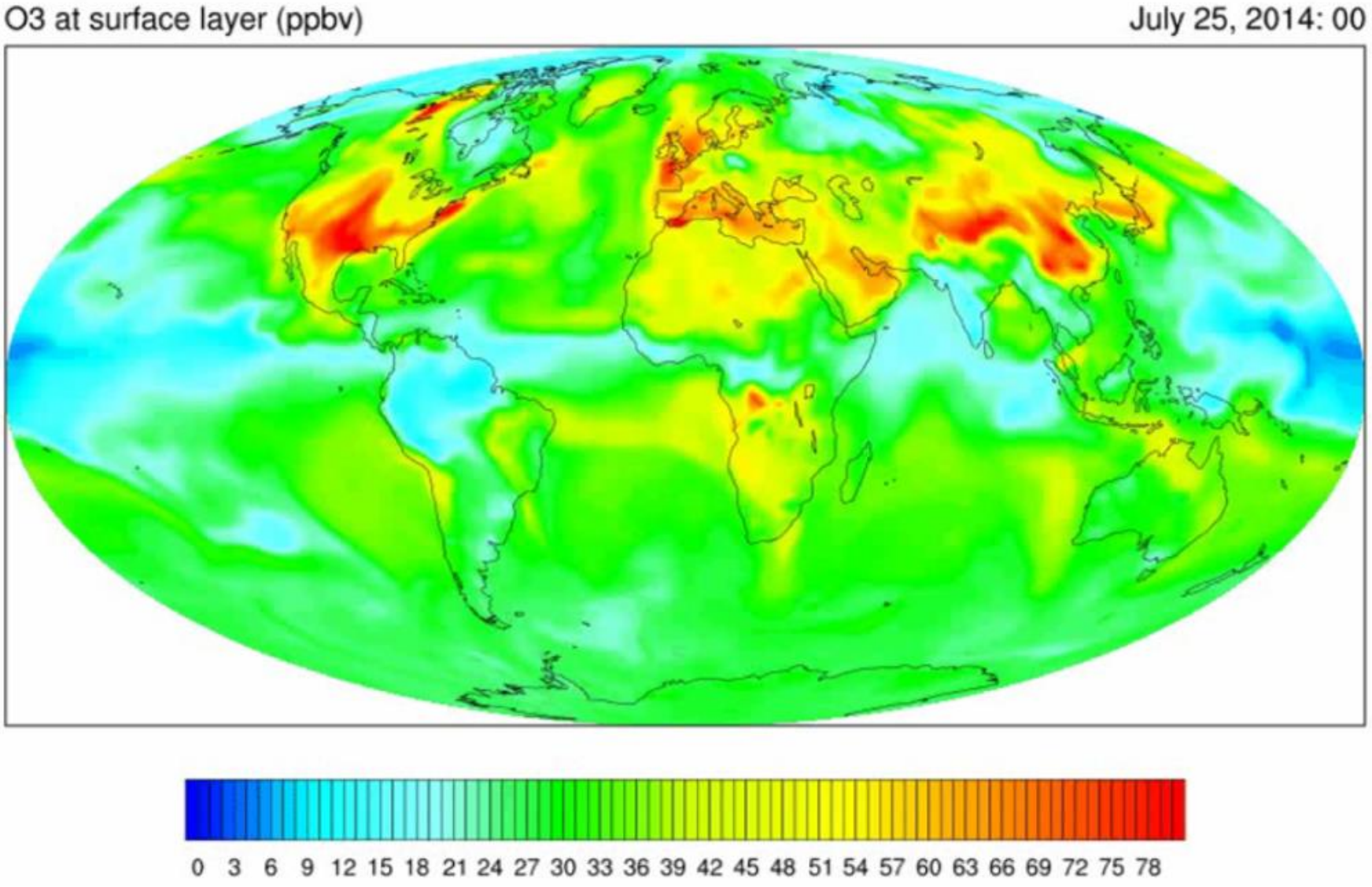
Met data regridded to reduce computational requirements for longer simulations:

- Global scale runs:
  - 4° lat x 5° lon and 2° lat x 2.5° lon
- Regional scale (nested grid) runs:
  - 0.5° lat x 0.667° lon

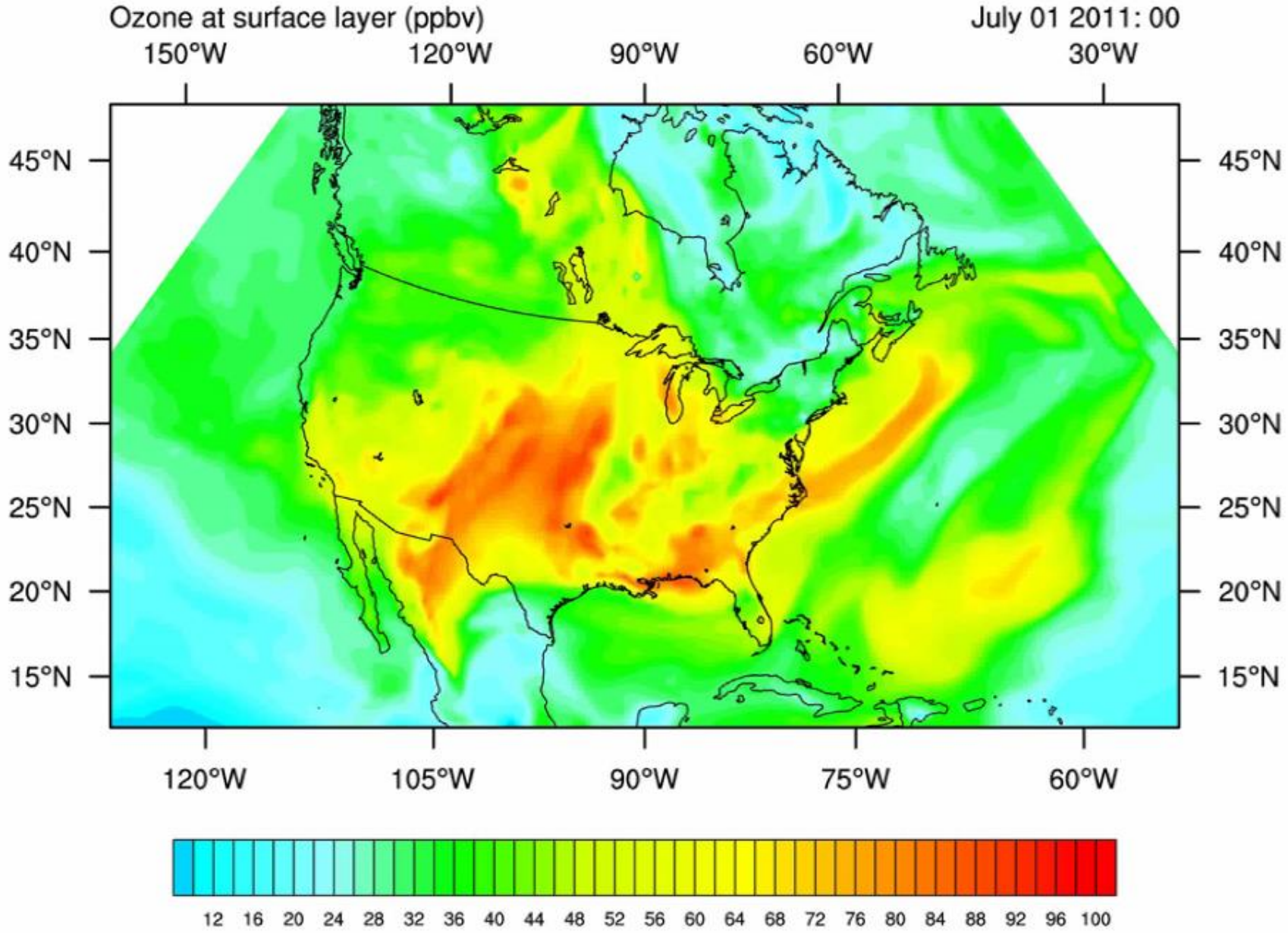




Example of Coarse Resolution Output - Ozone



Example of Fine Resolution Output: Movie



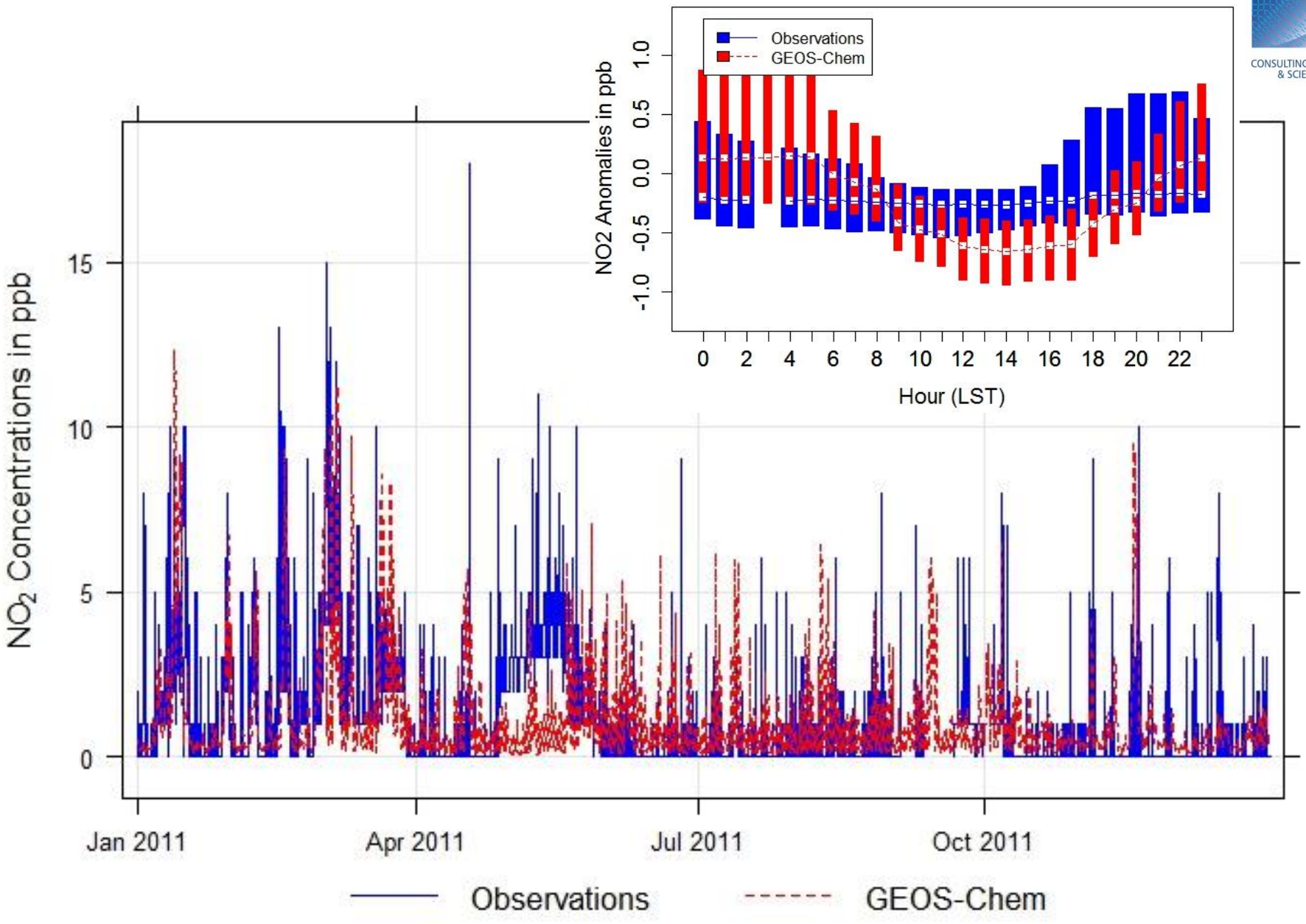
Focus for this Presentation

- 2011 1-hour averages for observations and GEOS-Chem
- GEOS-Chem output at fine resolution
- NO_2 and O_3
- Averages across Peace Air Shed Zone stations

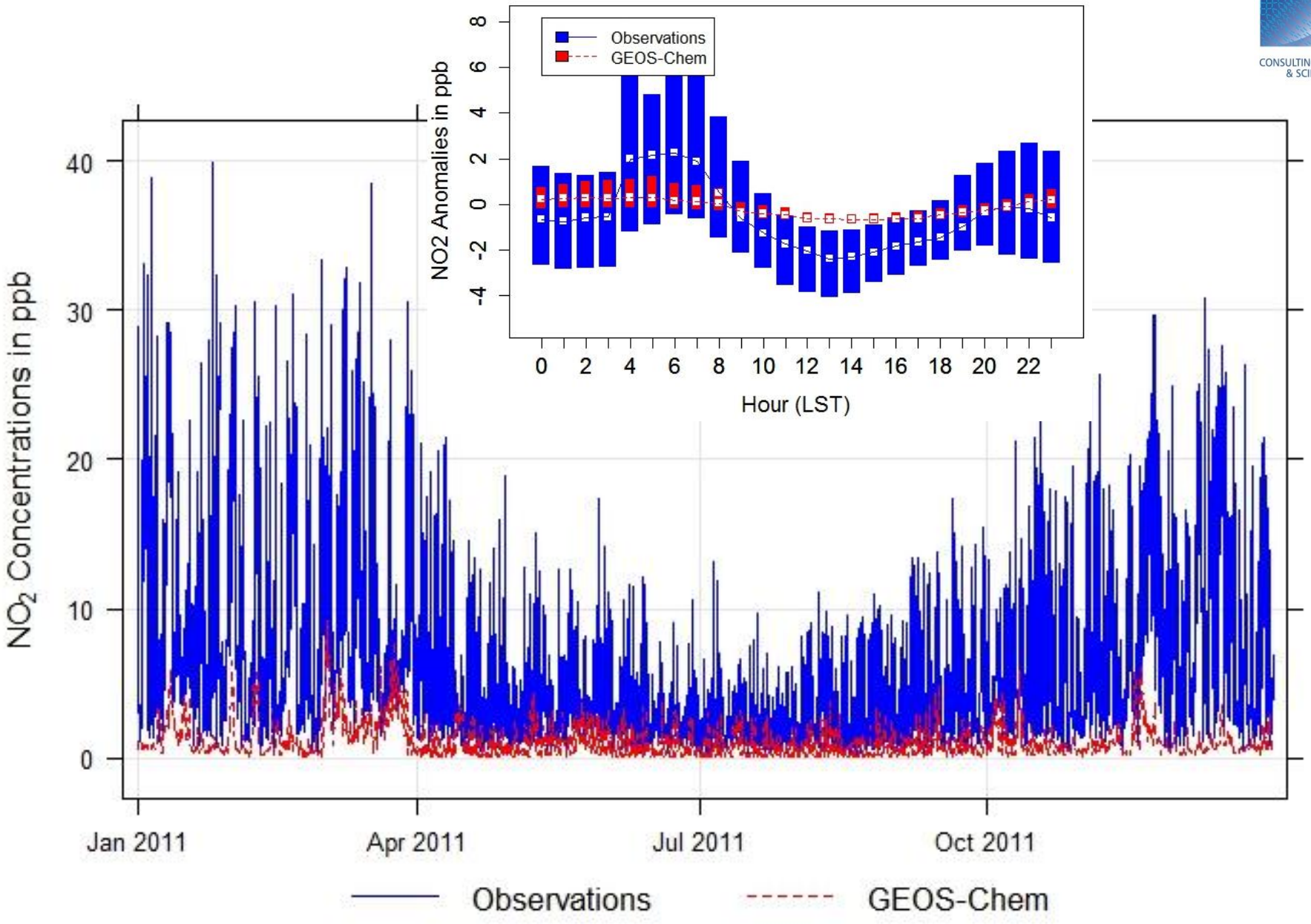
Why Does GEOS-Chem Output Represent Background?

- Emissions are homogenized within each Eulerian grid box.
- No small scale, local spikes in ambient concentrations.
- Chemistry has time to act (NO_x-to-NO_2 conversion, photochemistry, etc.).
- Representative of the average ambient concentrations in a typical regional study area.

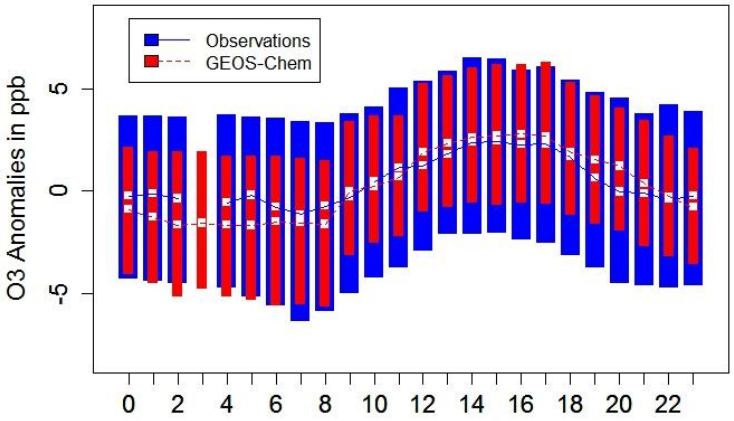
Observed and Modelled NO_2 at Hightower Ridge

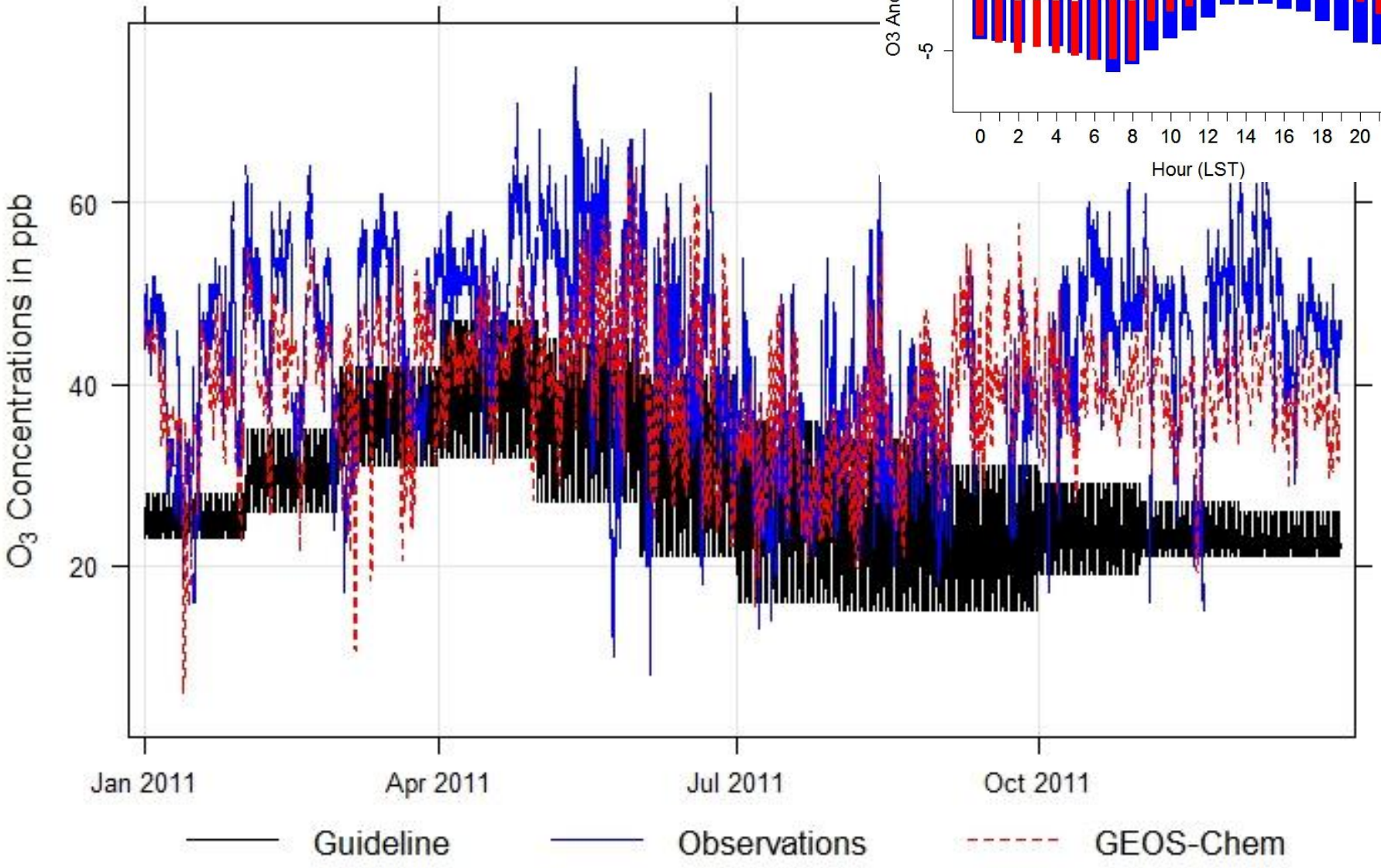


Observed and Modelled NO_2 at Peace Air Shed Zone



Observed and Modelled O_3 at Hightower Ridge





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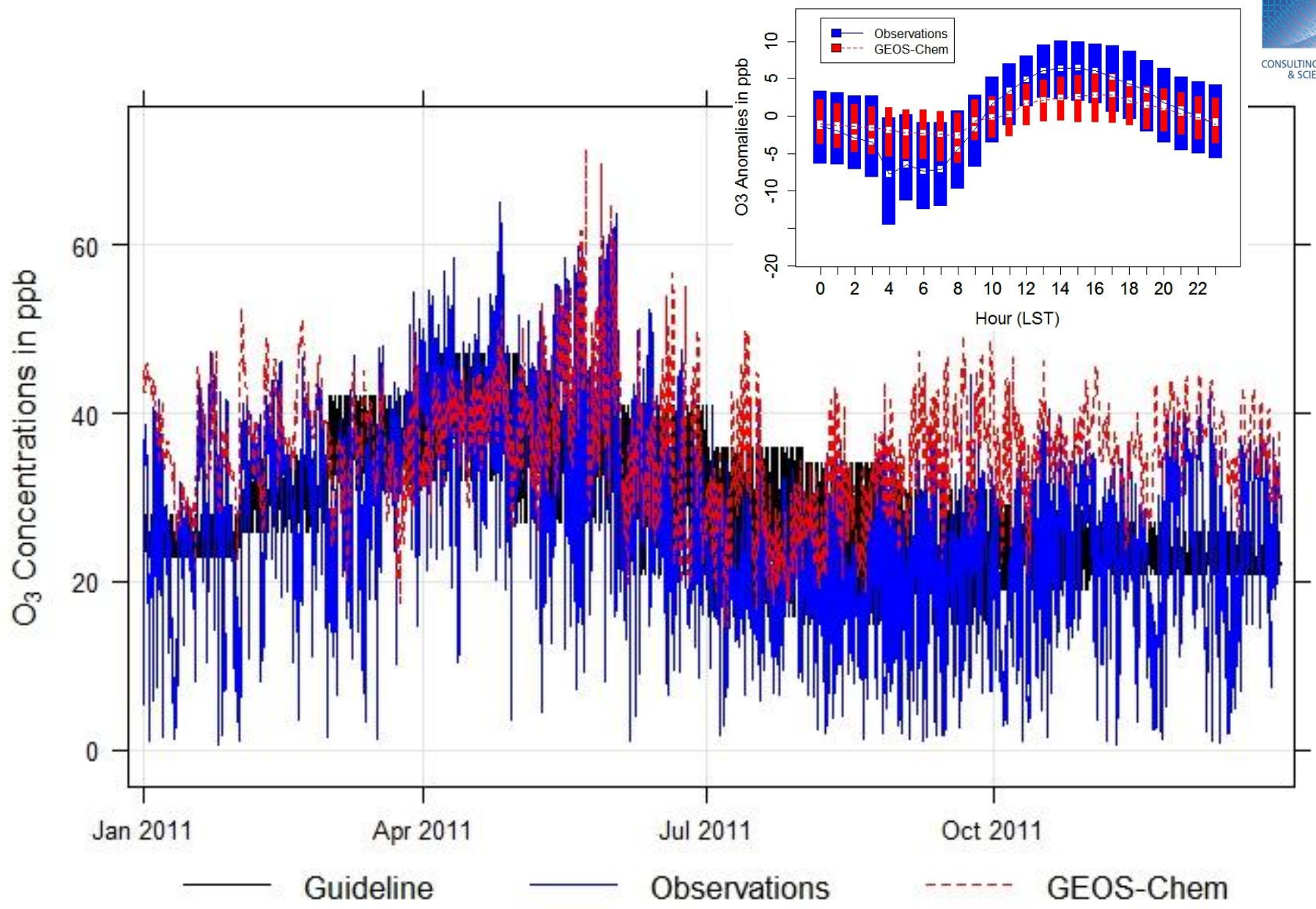
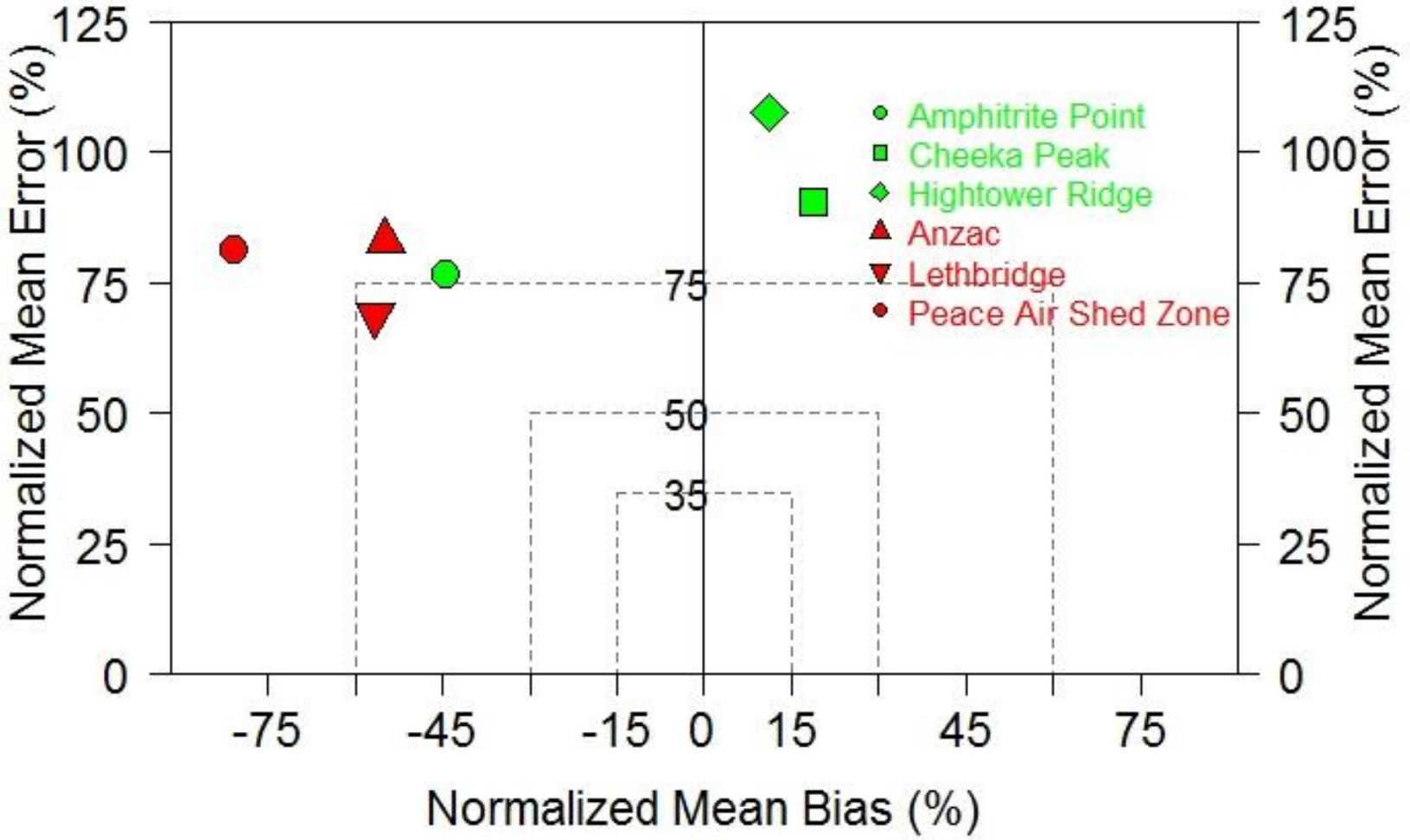
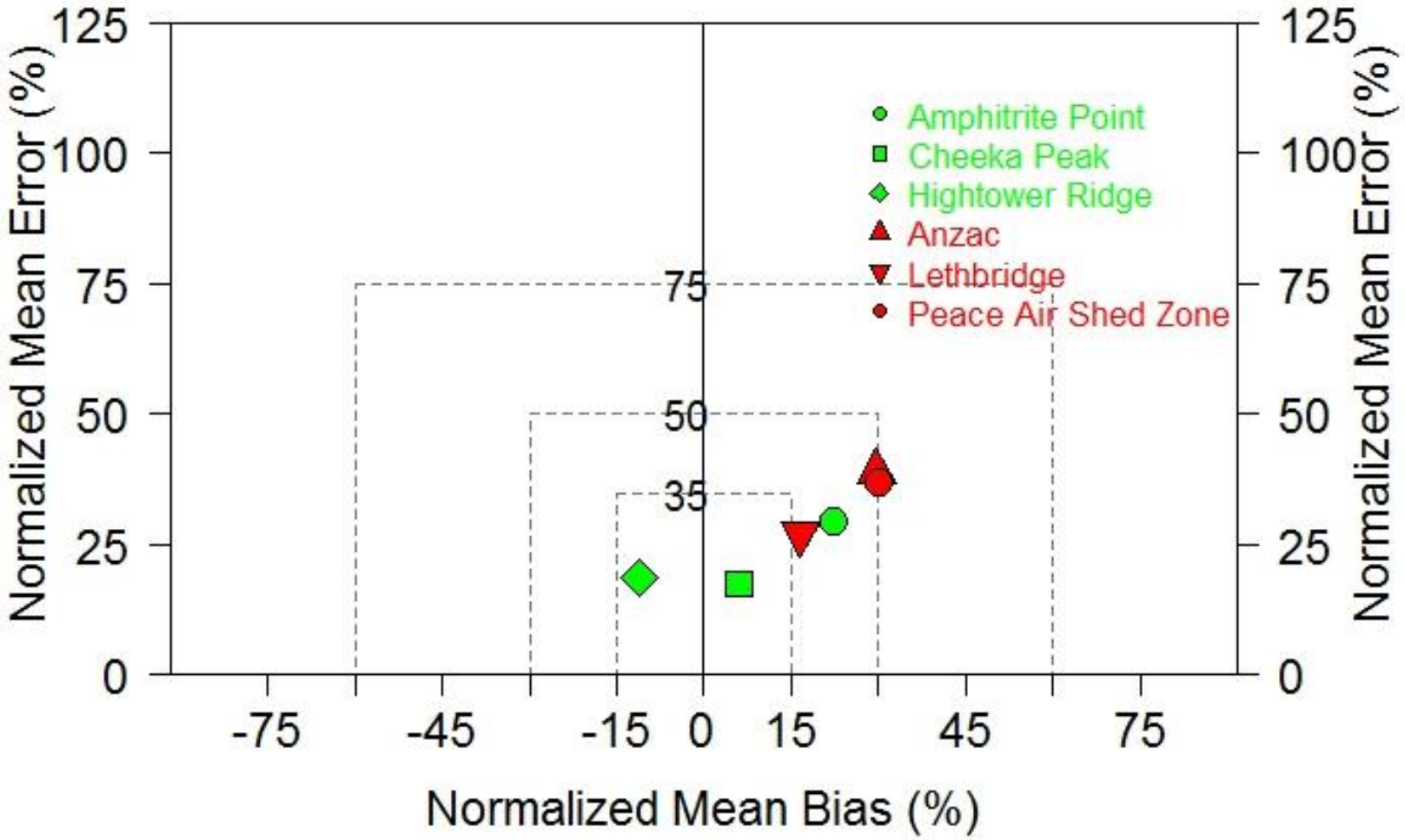


Normalized Mean Errors and Biases for NO_2



Normalized Mean Errors and Biases for O_3



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GEOS-Chem averages emissions and chemistry over scales of order 10-100 km:

Limitation: Does not capture local effects	Virtue: Not biased by local effects
Ozone depletion events at Amphitrite Point (McKendry et al. 2014)	Background for cumulative effects assessments
Photochemistry in Lower Fraser Valley	More realistic NO_x-to-NO_2 conversion
	Improved boundary conditions for photochemical modelling

Acknowledgements

We thank Mitacs for the postdoctoral funding provided to Zahra Hosseini and Dr. Ann-Lise Norman from the University of Calgary for collaborating with RWDI on this Mitacs internship

References

AEP 2013: Air Quality Model Guideline. Alberta Environment and Sustainable Resource Development, Oct. 2013 (http://aep.alberta.ca/air/modelling/documents/AirQualityModelGuideline-Oct1-2013.pdf)

McKendry et al. 2014: Low ozone episodes at Amphitrite Point Marine Boundary Layer Observatory, British Columbia, Canada. Atmosphere-Ocean, 52(3), 271-280.