Influences on Spring and Summer-time Tropospheric Ozone in Western Siberia, and the Russian Arctic.

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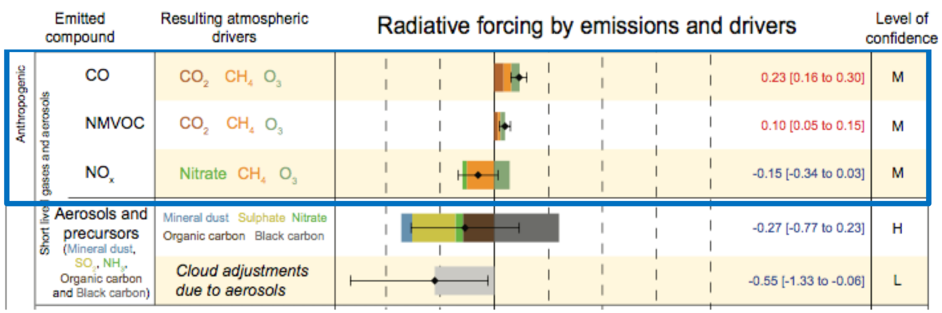
Motivation - Tropospheric Ozone (O_3)

Climate

- Greenhouse gas which has a net positive radiative forcing since pre-industrial. Accounts for 20-25% of total radiative forcing from greenhouse gases (Monks et al., 2009)
- Lifetime 1-2 weeks in remote troposphere.



IPCC, 2013

Air Quality

- 142 000 premature deaths globally in 2010, 358 000 in 2050 (Lelieveld, 2015)
- Agricultural damage (reduction in carbon uptake and photosynthesis) (Wilkinson, 2012)

Tropospheric O_3

- **Sources:**
  - Secondary pollutant predominantly formed from in-situ photochemical production
    - $NO_2 + h\nu \rightarrow NO + O$ (R1)
    - $O + O_2 + M \rightarrow O_3 + M$ (R2)
  - Transport from Stratospheric downwelling
- **Sinks:**
  - OH precursor
    - $O_3 + h\nu \rightarrow O_2 + O(^1D)$ (R3)
    - $O(^1D) + H_2O \rightarrow 2OH$ (R4)
  - Polluted Environment
    - $O_3 + NO \rightarrow NO_2 + O_2$ (R5)
  - Dry deposition

Motivation – The Arctic

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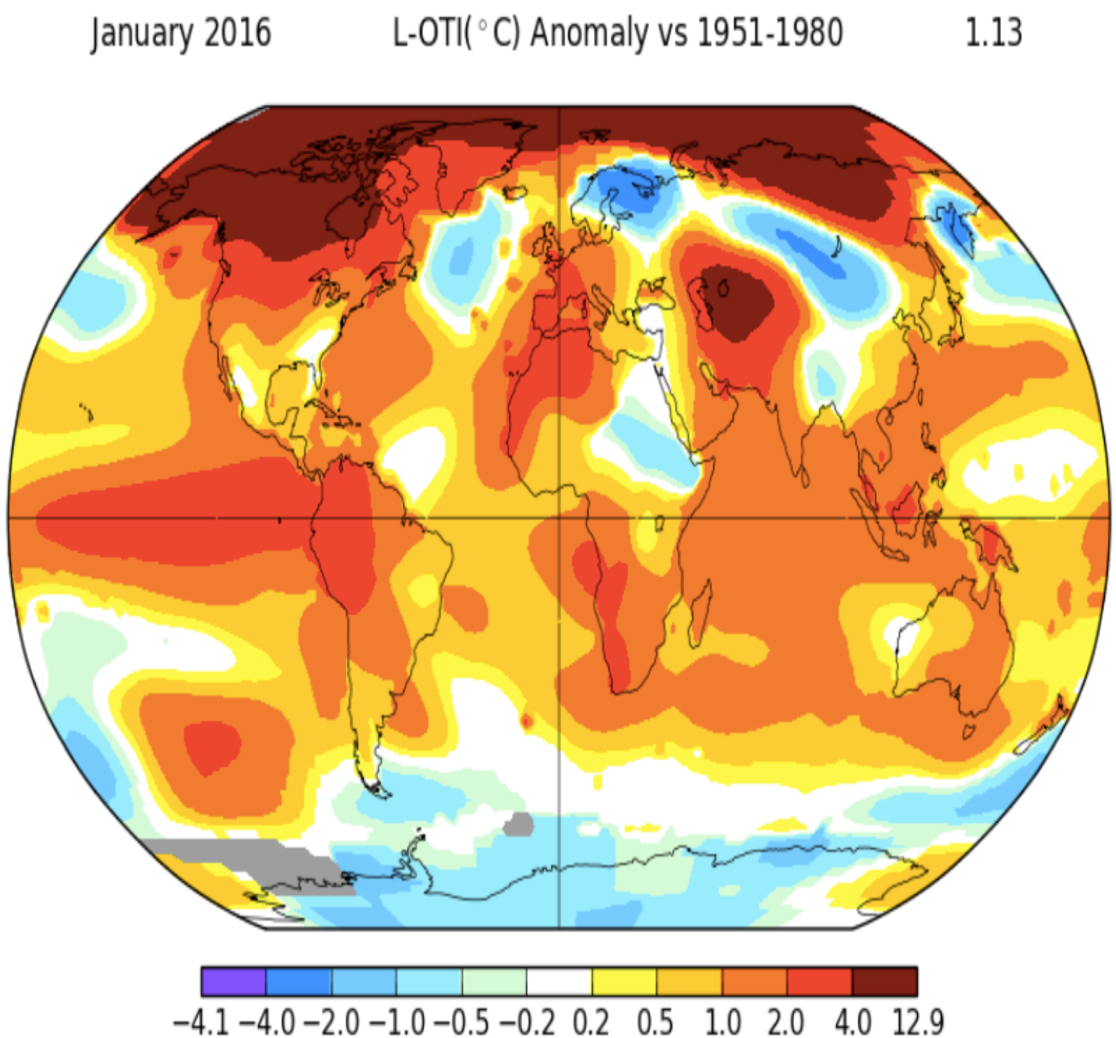
Arctic Amplification (Overland et al., 2016)



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Motivation – The Arctic

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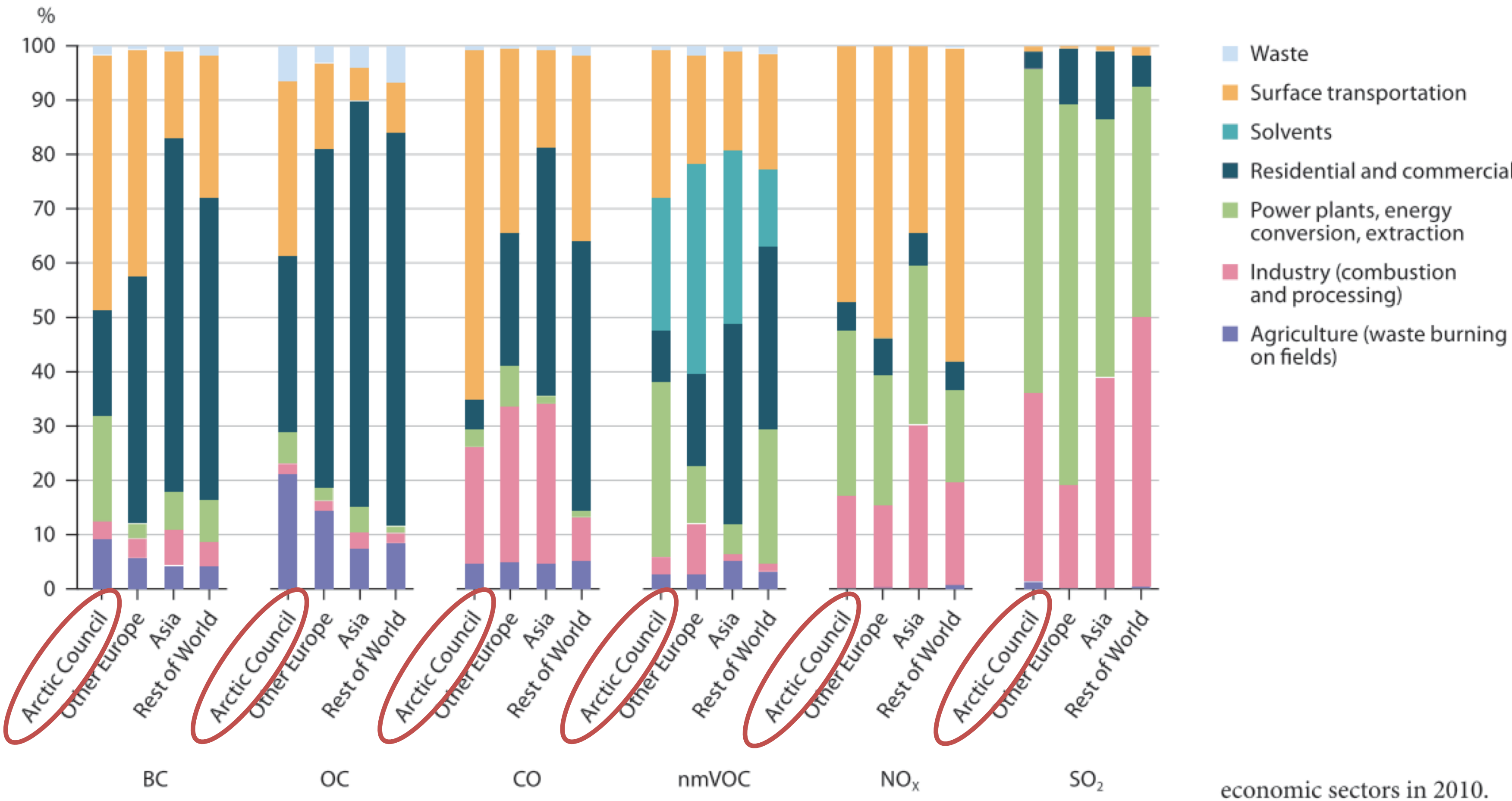
Ozone precursor and aerosol emissions by major economic sector for 2010 (AMAP, 2015)



economic sectors in 2010.

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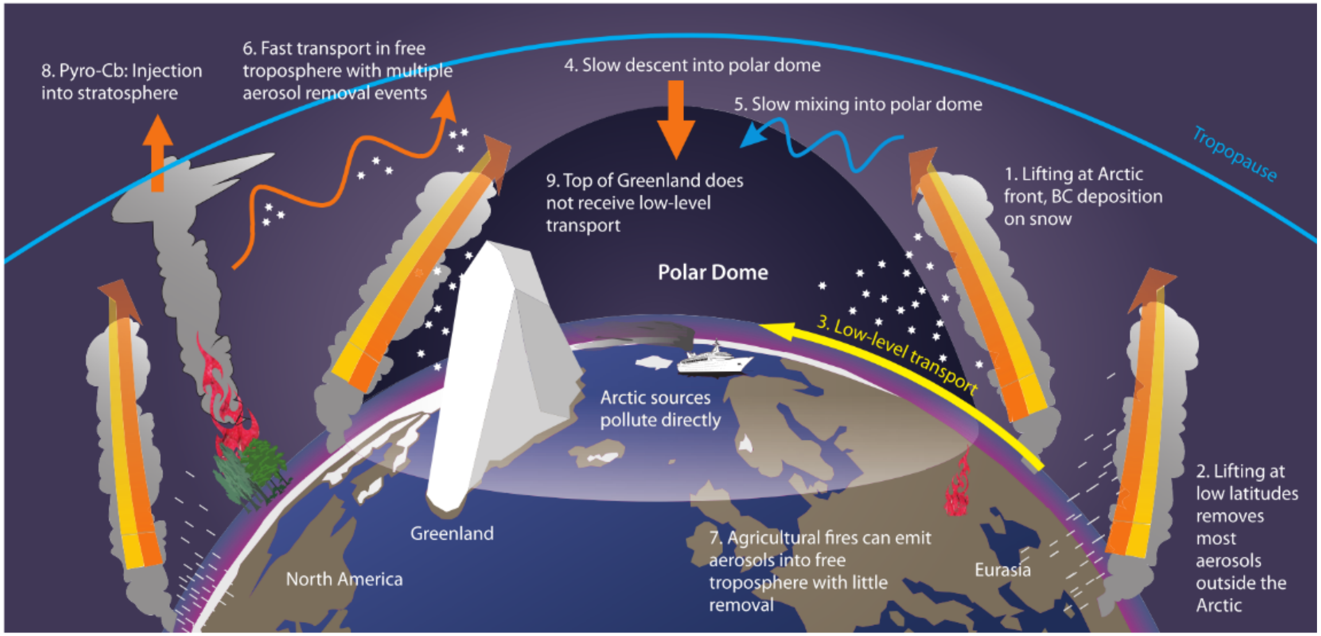
Spring / Summer Transport



AMAP, 2015

- **Spring:**
  - Low level import of Eurasian pollution. Main pathway across Siberia into Russian Arctic.
  - Inefficient removal of pollution leading to Springtime peak (Arctic Haze)
- **Summer:**
  - Removal of pollutants greater during summer (wet + dry deposition)
  - Wind direction change, and greater vertical mixing in Arctic vertical column

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Aims & Objectives

Aim: To evaluate processes controlling regional ozone distribution over Western Siberia during the spring and summer-time.

Objective 1: *Assess the influence of seasonal differences on ozone composition through the use of a regional chemistry-transport model and satellite data.*

Objective 2: *Through model sensitivity studies we aim to quantify the impact of different ozone source/sink processes in the region.*

Model Setup

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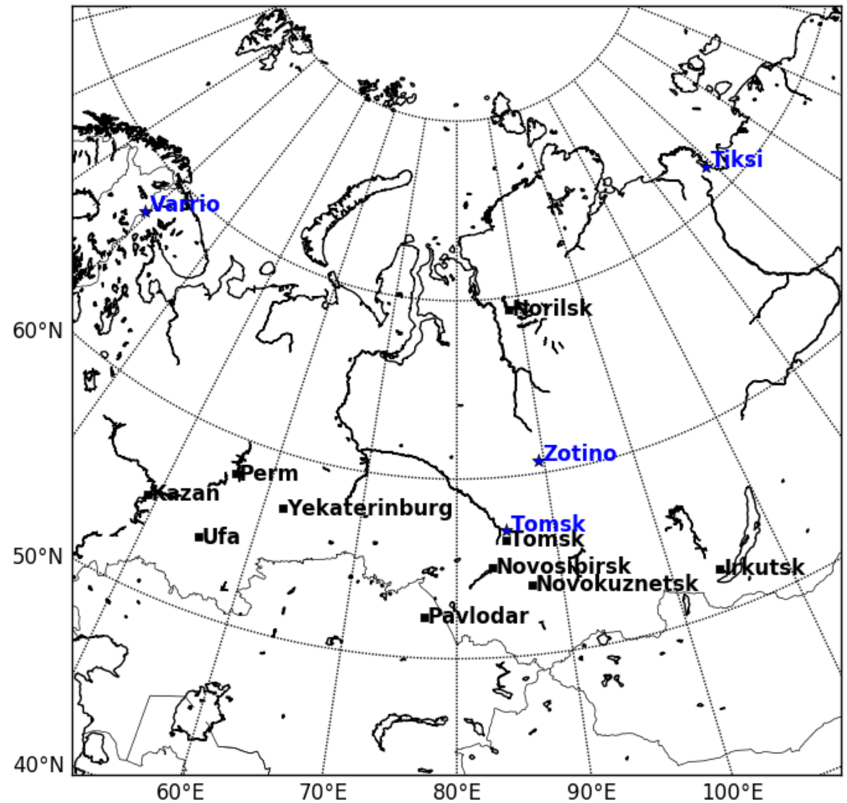
- WRF-Chem 3.7.1

- Horizontal Res: 30km
- Vertical Levels: 33

- Gas-Phase Chem: MOZART 4
- Aerosol Scheme: MOSAIC 4-Bin
- Photolysis Scheme: Madronich FTUV

- Biogenic Emissions: MEGAN
- Fire Emissions: FINN
- Anthropogenic Emissions: EDGAR HTAP v2



Model Domain, major cities marked in black, observation sites marked in blue.

- Simulations for 01.02.2011 – 30.09.2011

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Initial Results

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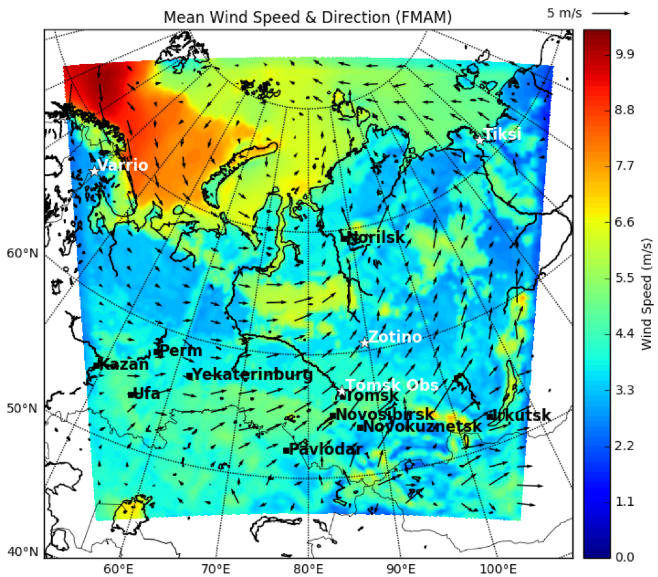
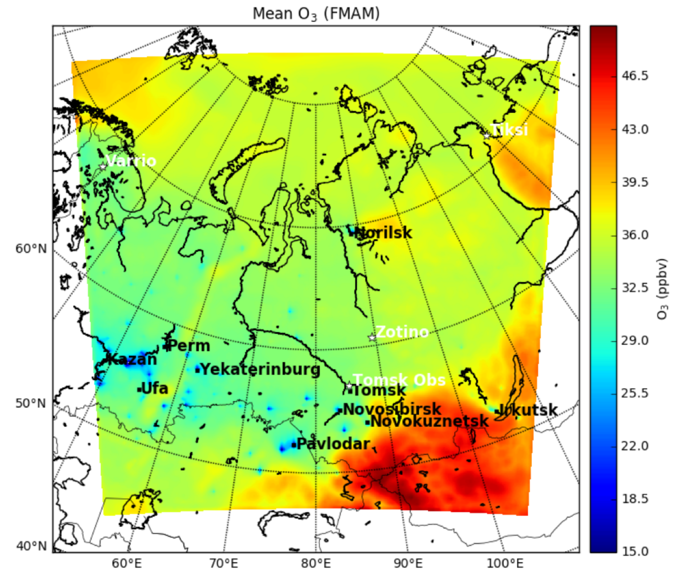
Mean Wind Speed and Direction

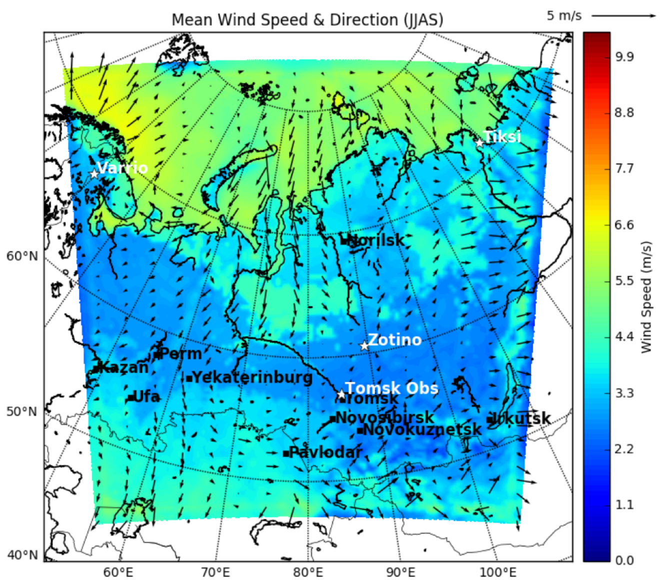
Mean Surface O_3

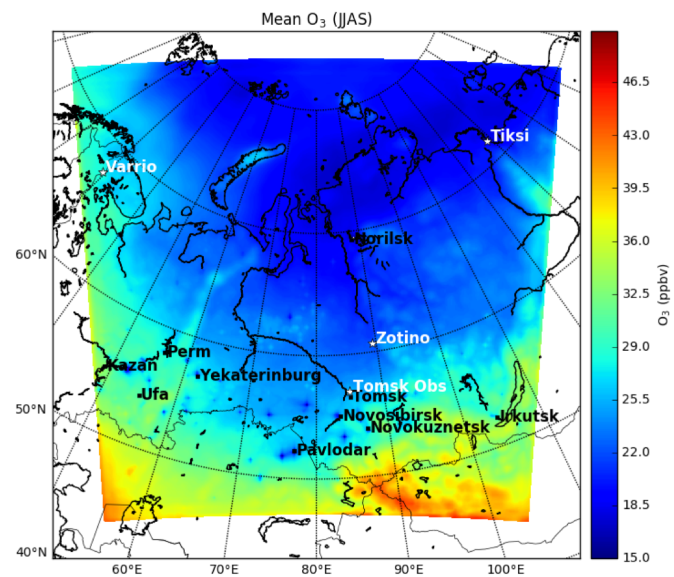
Feb, Mar, Apr May Mean





Jun, Jul, Aug, Sep Mean





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Model Evaluation

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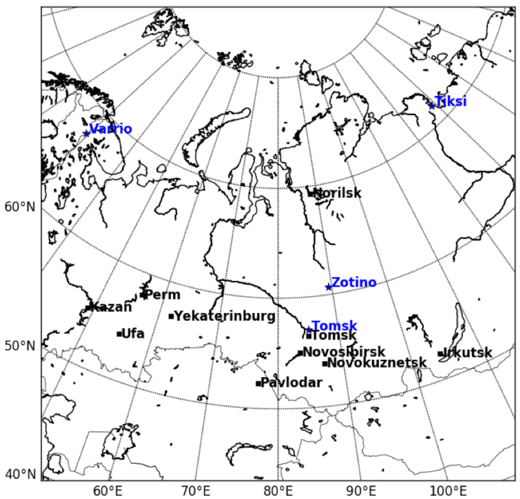

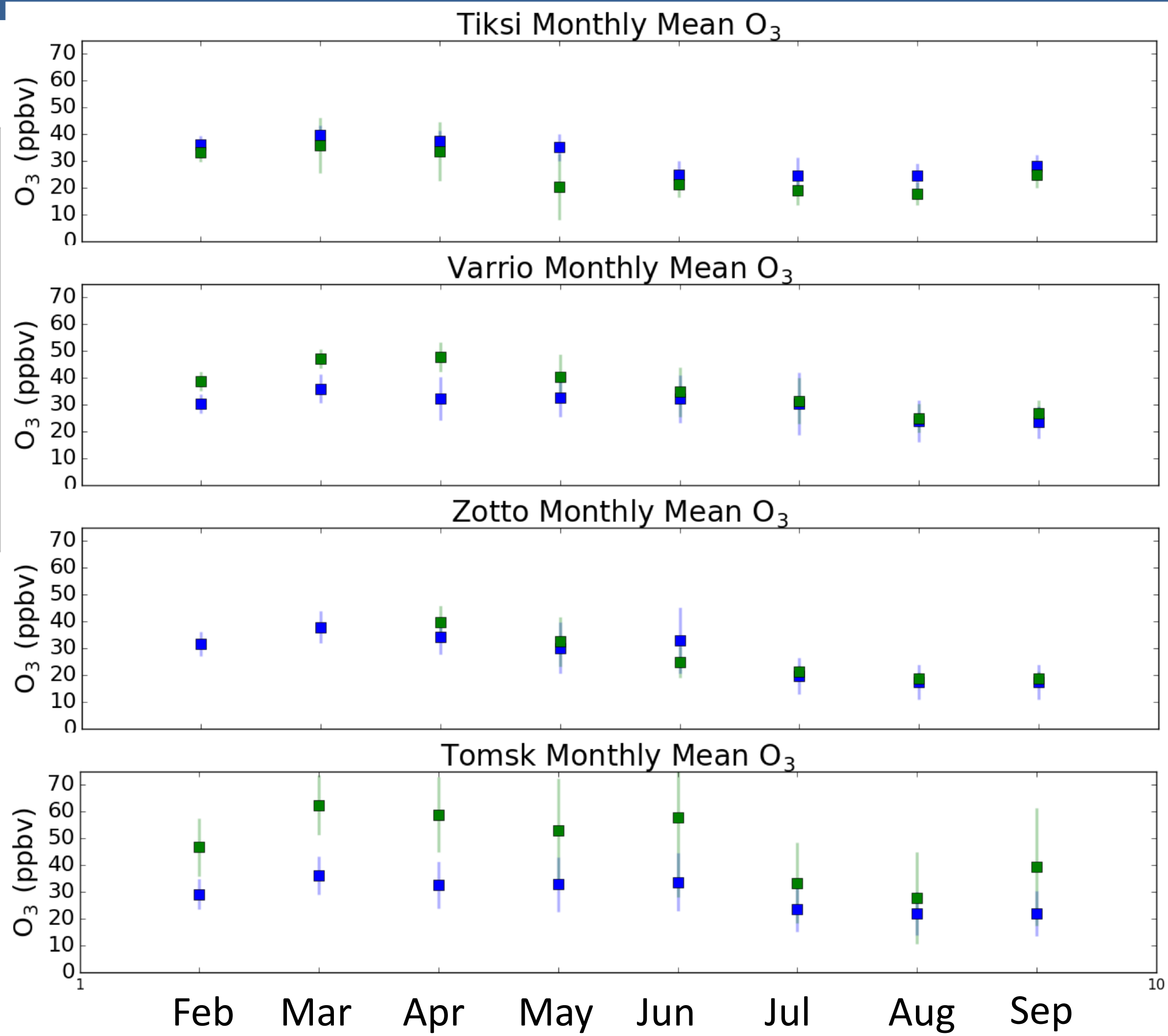

Observations

Model

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Model Evaluation

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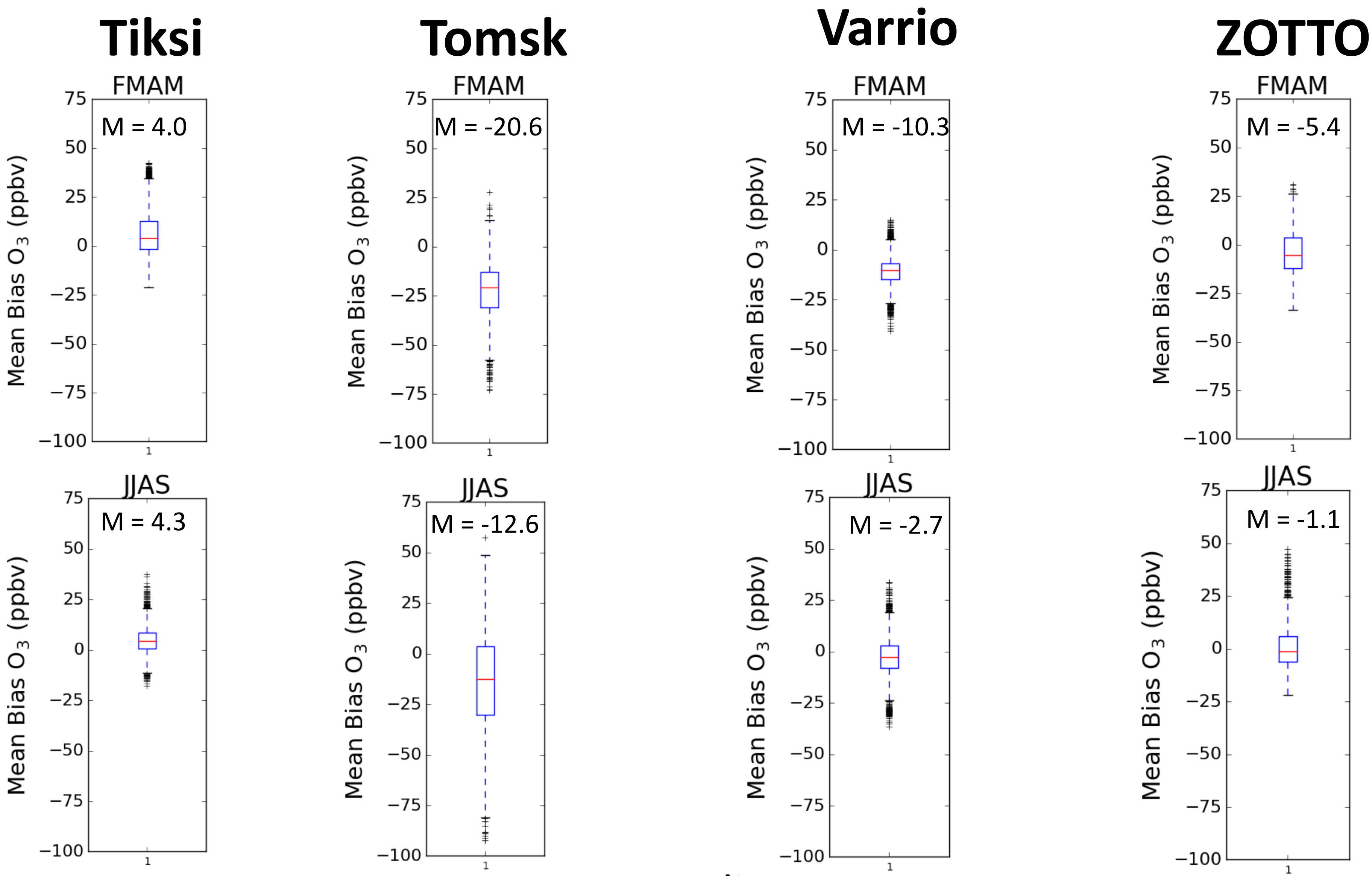
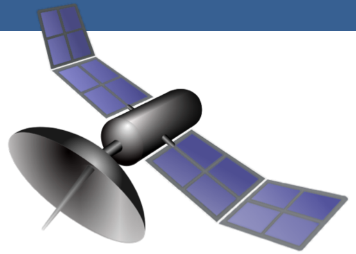


M = Median

OMI NO_2 Comparisons



- Dutch Ozone Monitoring Instrument for NO_2 (DOMINO), on board NASA's Aura satellite (13:30 local time passing).
- Uses Differential Optical Absorption Spectroscopy (DOAS) to make UV-visible measurements.
- Provided with quality checked Tropospheric Column NO_2 at high resolution
- For direct WRF-Chem comparison averaging kernels applied to model, as OMI sensitivity differs through the tropospheric column.

Model Evaluation

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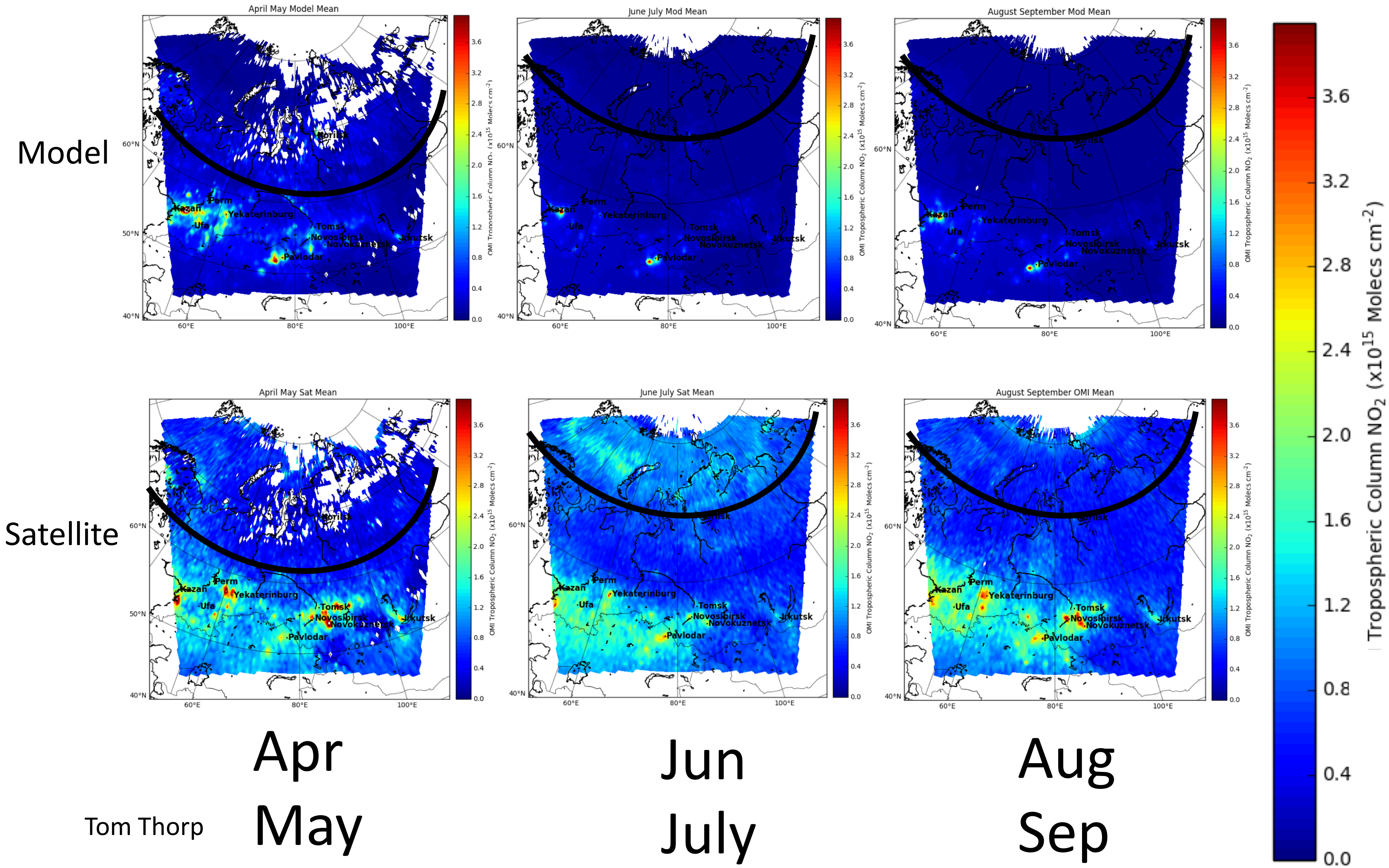

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Model Evaluation

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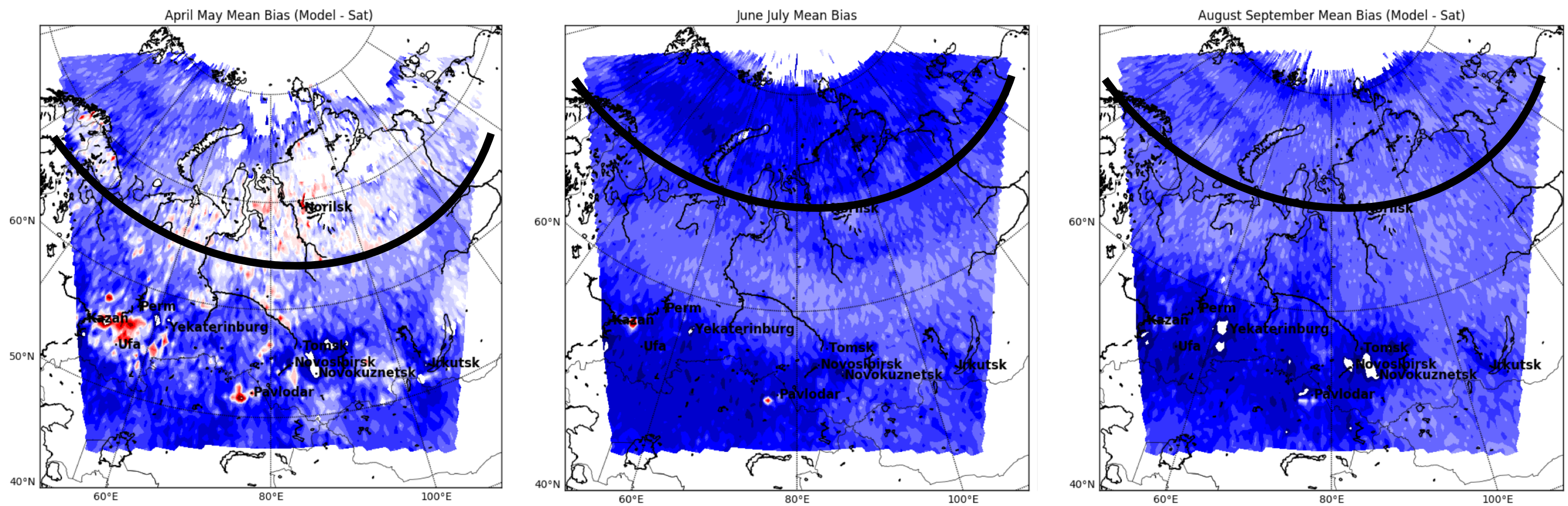
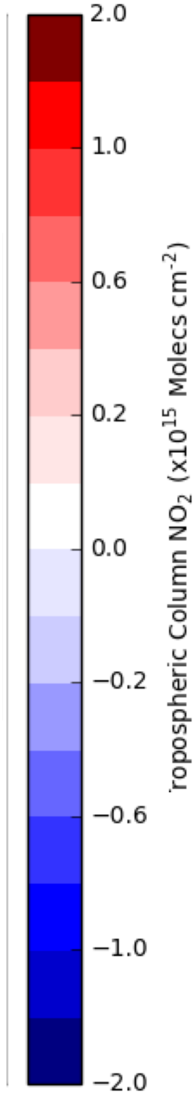
Mean Bias (Model - Sat)





Apr May | Jun July | Aug Sep

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Model Evaluation

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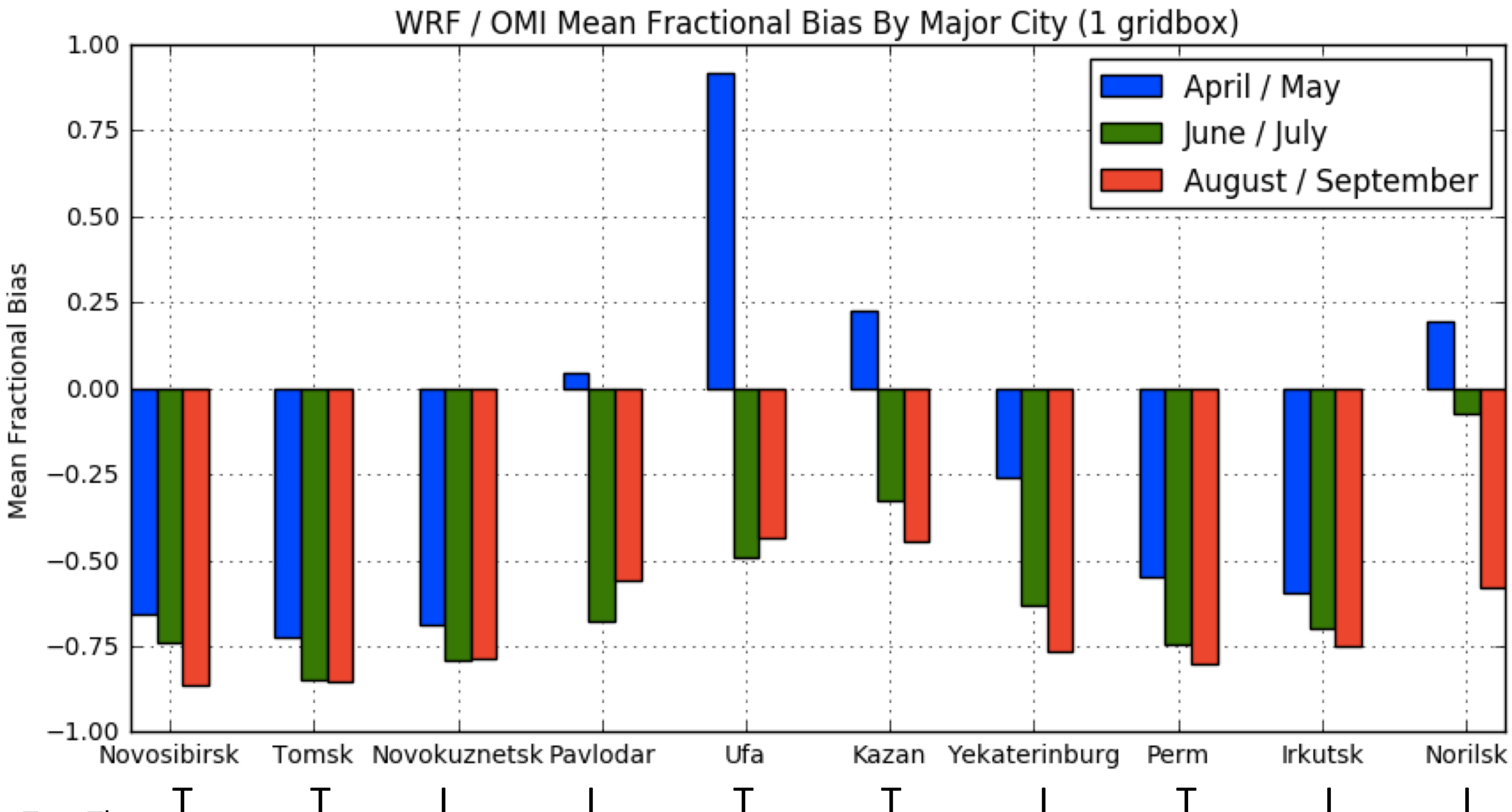
City Mean Bias : (Model – Sat)/Sat



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Future Work – Anthropogenic Emissions

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- Current setup using **EDGAR HTAP 2**
- Not well represented at high latitudes, potential missing sources.

- Setting up WRF-Chem to use **ECLIPSE V5a**, which is most frequently inventory used for high-latitude regional studies

- Better representation of high-latitude emissions

Future Work – NO / NO_2 Cycling Rates

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- Upper troposphere reactions impacted by uncertainties in NO/NO_2 reaction rates
- Figures 1 + 2 show GEOS-Chem output with J_{NO2} – 20%, 1.4k_1
- NO_2 photolysis rate decreased by 20%
- Temperature dependence of the NO + O_3 rate constant k_1 increased by factor of 1.4
- Problem with modelling NO/NO_2 in Antarctica.

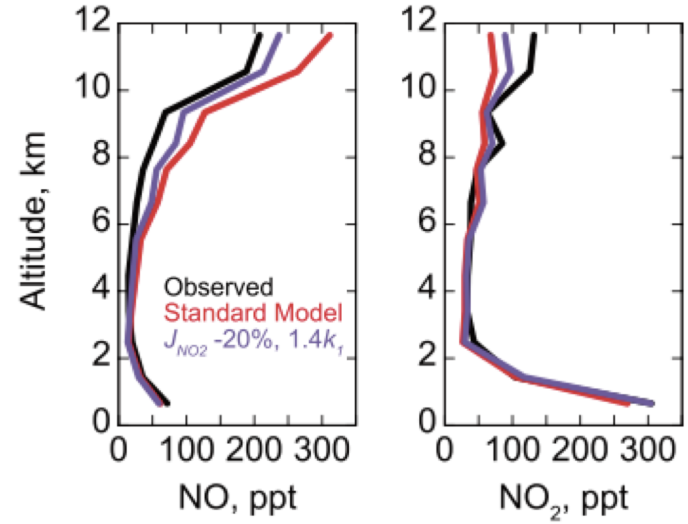

Fig 1

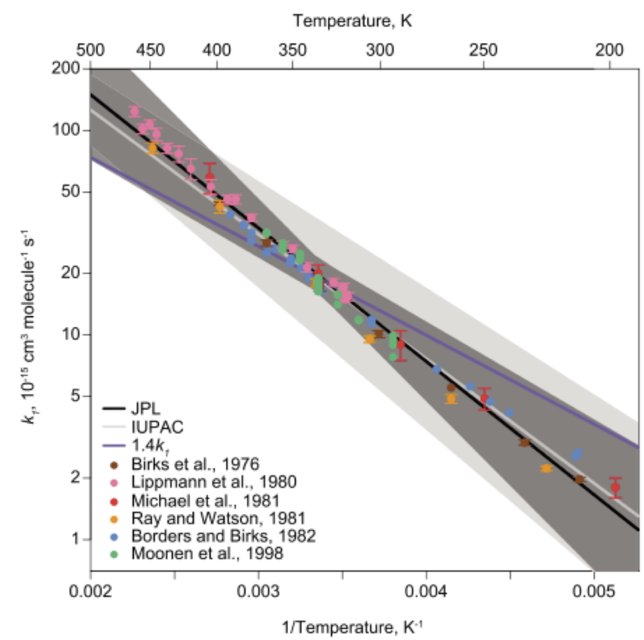

Fig 2

Silvern et al., 2018

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Future Work – Dry Deposition

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- Large parts of Siberia dominated by boreal forests – potentially significant surface O_3 sink.

Height	Source	O_3 mixing ratio (ppbv)
3000-6500m	Aircraft	67
3000m-surface	Aircraft	32
surface	Surface Obs	18
Surface	Train	27

Stjerngberg et al., 2012

- Uncertainty regarding impact of earlier growing season – will increase annual cumulated ozone uptake

Conclusions

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- WRF-Chem output for 8 month period in 2011, and evaluated results against ground observations and satellite data.
- Found that over polluted areas model is potentially underestimating
- Next steps involve changing anthropogenic emissions, and investigating reaction rates and dry deposition

Extra Slides – FMAM Diurnal

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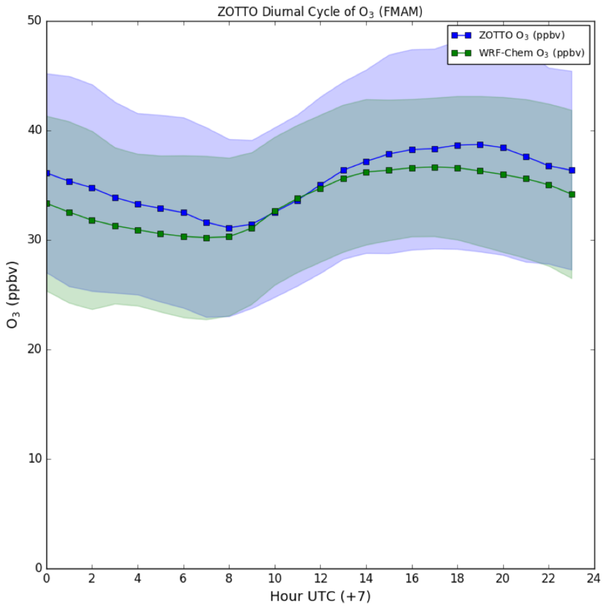
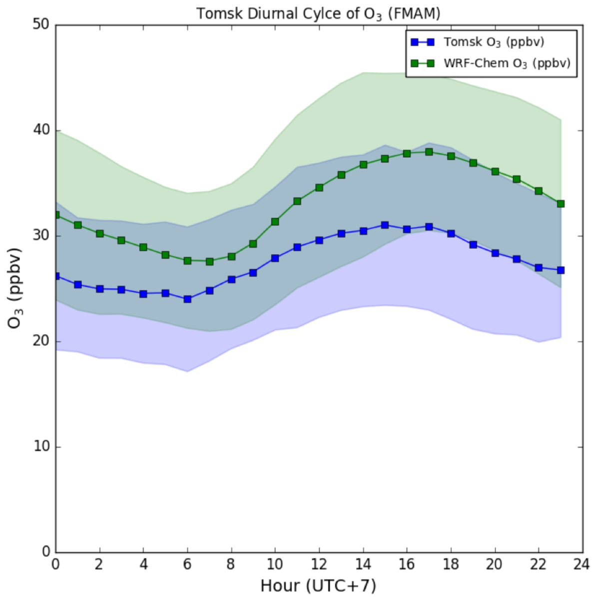
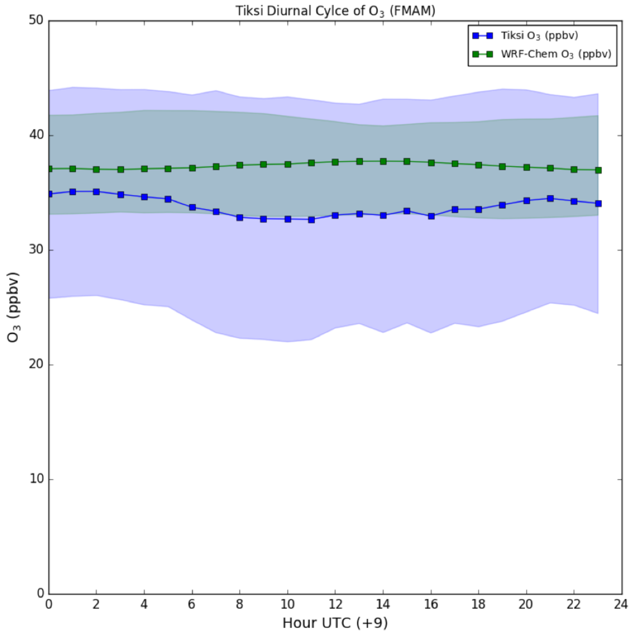
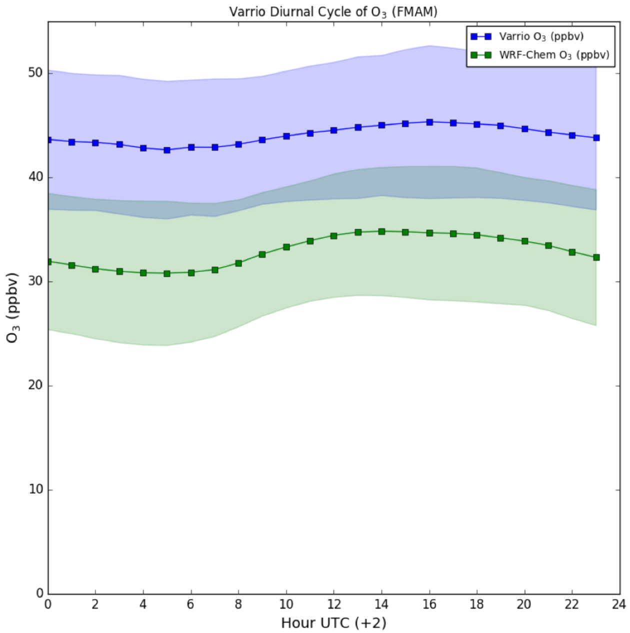
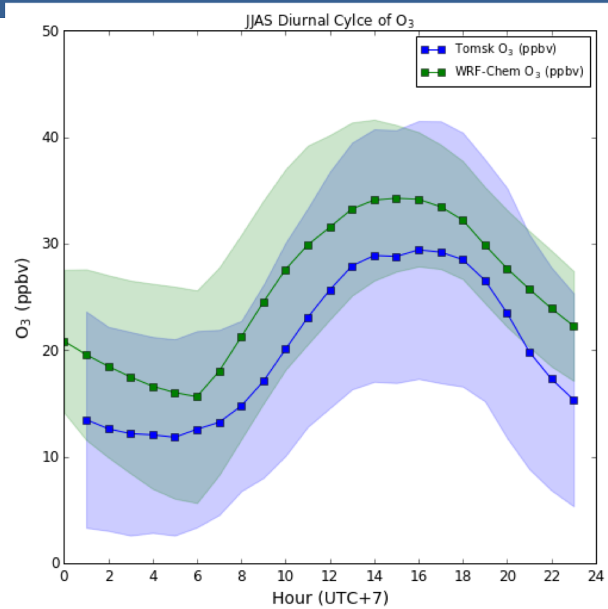


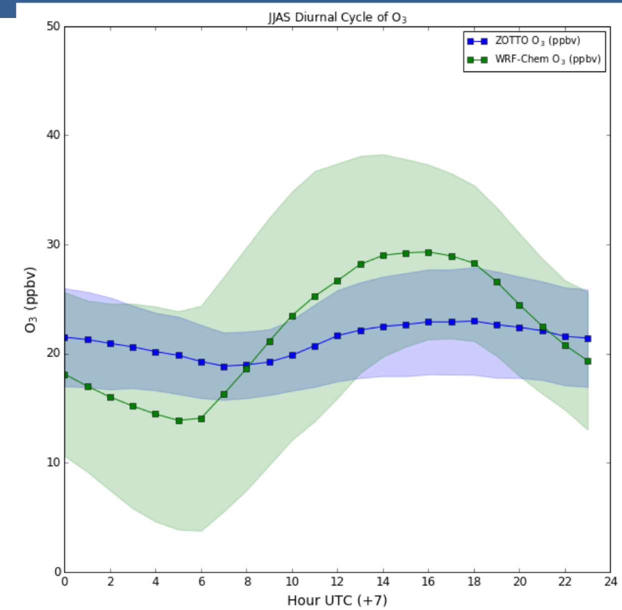


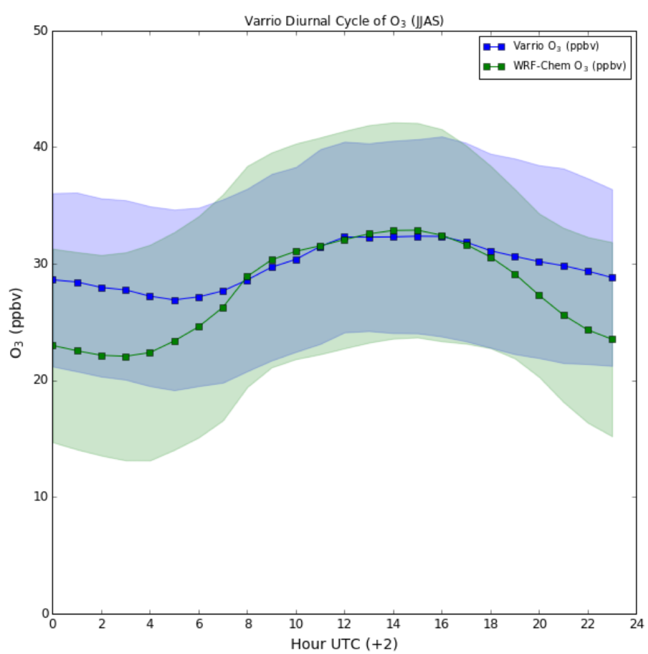


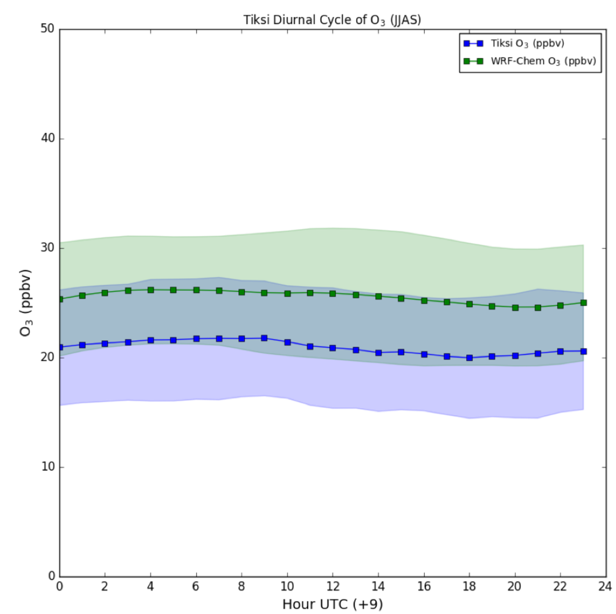


Extra Slides – JJAS Diurnal









Surface Temperature

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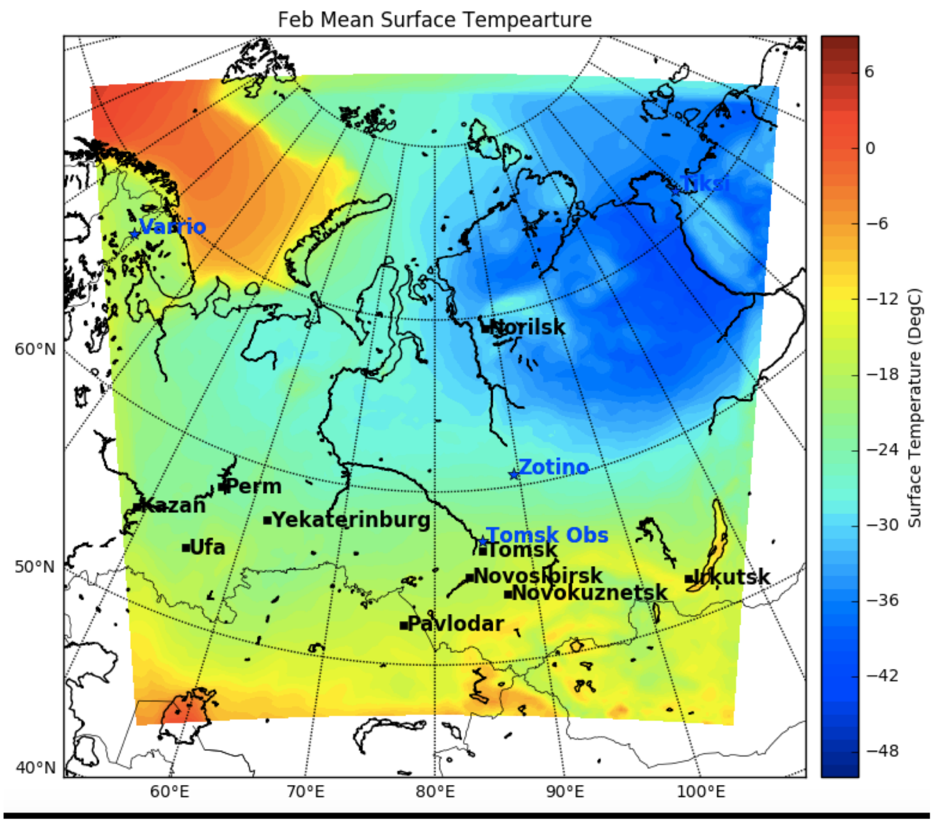

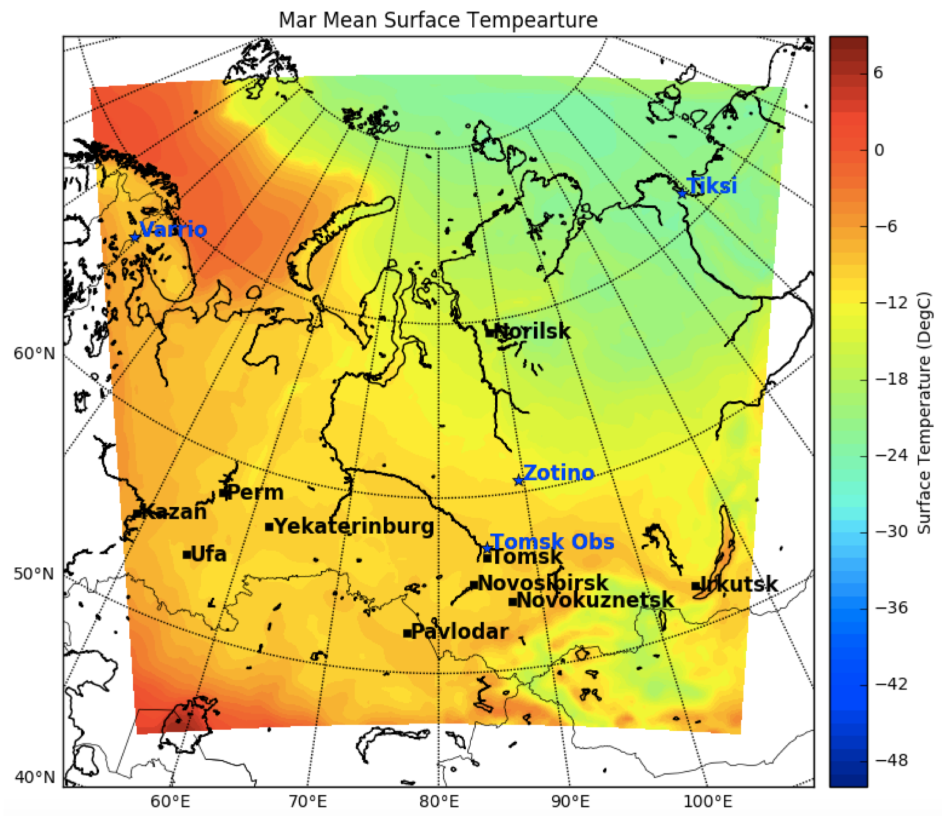

- Mean = -22.6 (250.6K)

Mean = -12.6(260.6K)

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