Impact of Recent Changes to Emissions Factors in BEIS on Estimation of Biogenic VOC Emissions for GEM-MACH

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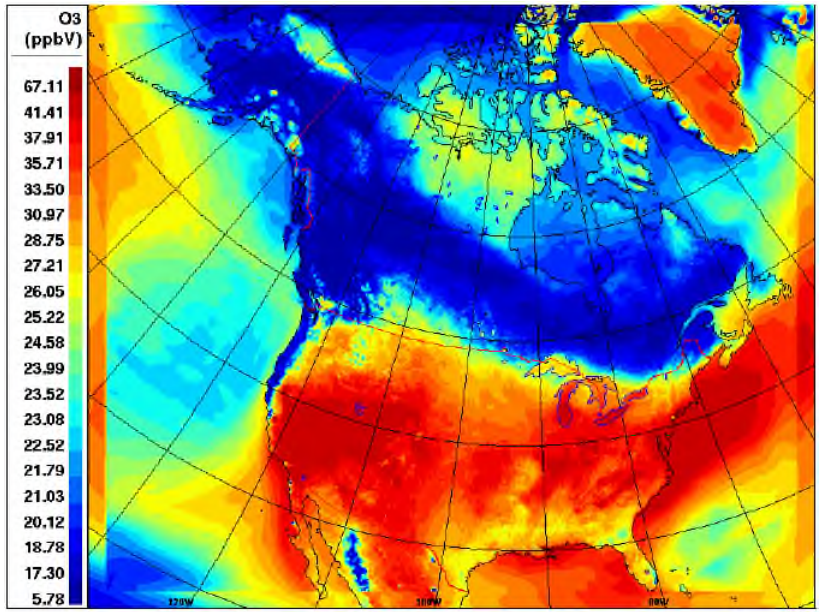
OUTLINE

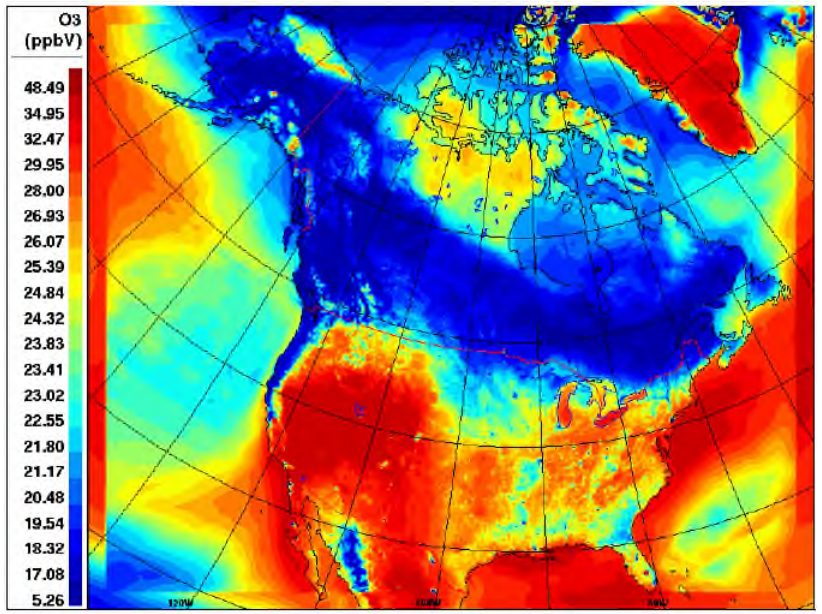
- Motivation for this study
- Biogenic emissions for the Canadian air quality model GEM-MACH
- Comparison of biogenic emissions calculated from combinations of different versions of Biogenic Emissions Landuse Database (BELD) and Biogenic Emission Inventory System (BEIS)
- Impacts of different biogenic emissions on GEM-MACH prediction of gaseous and particulate species
- Summary

MOTIVATION

- Biogenic VOC emissions have been estimated to be much larger than anthropogenic sources, accounting for 80-90% of total global VOC emissions
- Sensitivity study shows biogenic emissions can contribute more than 10 ppb to monthly mean O_3 concentration for summer months



Base Run



Test Run – Without Biogenic VOC

- New versions of BELD database and BEIS model have been released recently. It is important to understand the impacts of the recent changes to the biogenic emissions on GEM-MACH model predictions

BIOGENIC EMISSIONS FOR GEM-MACH

- GEM-MACH (Global Environmental Multiscale – Modelling Air-quality and CHemistry) is Environment and Climate Change Canada's (ECCC) air-quality modelling system
- Summer and winter normalized emission fluxes (30ºC and 1000 umol·m^{-2}·s^{-1} PAR for isoprene and 30ºC for monoterpenes, other VOCs, and NO) are calculated for GEM-MACH using the gridded BELD landuse data and BEIS emission rates
- Biogenic emissions are then calculated on-line within GEM-MACH using the normalized emission fluxes based on model-predicted meteorological conditions
- Biogenic emissions for the current operational GEM-MACH are based on BELD3 and BEIS3.09 with updated emission rates for spruce and pine

UPDATES TO BEIS3.09 EMISSIONS FACTORS

- BEIS3.09 emission factors are available for four species/compounds (ISOP, MONO,OVOC, NO) for 230 land use types of **BELD3** with two updates (**BEIS3.09-ECCC**):

a) Examination of the emission factors concluded the isoprene emission rate was overestimated by 50% for spruce. This **update has been included in BEIS3.13** (Schwede et al., 2005)

b) Model predictions of unrealistically high biogenic SOA levels over the Canadian boreal forest imply that basal emission rates for monoterpene and OVOC were also overestimated for Pine and Spruce by up to a factor of 5 (Stroud et al., 2010). Emission factors were updated accordingly for these two types of trees

EMISSIONS FACTORS FOR BEIS3.60 & BEIS3.70

- BEIS3.60 has 35 species/compounds (including 14 monoterpenes and 1 sesquiterpene) for BELD4 with 286 landuse types
- BEIS3.70 also has 35 species/compounds designed for BELD5 with 286 land use types too. BEIS3.70 rates can also be applied to BELD4
- On average, VOC emission rates were decreased by about 50% from BEIS3.60 to BEIS3.70
- LAI (Leaf Area Index) values for crops were also updated from 0.0 in BEIS3.60 to 3.5 in BEIS3.70
- BELD4 is used for both BEIS3.60 and BEIS3.70 in this study

CHANGES OF EMISSION FACTORS: EXAMPLES

	Monoterpene (gC/km2/hr)		
	BEIS3.13	BEIS3.09 ECCC	ECCC-3.13 Change (%)
Spruce_black	3971	722	-82%
Spruce_blue	3975	722	-82%
Spruce_Englemann	3971	722	-82%
Spruce_Norway	3975	722	-82%
Spruce_red	3967	722	-82%
Spruce_Sitka	3971	722	-82%
Spruce_white	3971	722	-82%

	Alpha-pinene (gC/km2/hr)		
	BEIS3.60	BEIS3.70	3.60-3.70 Change (%)
Spruce_black	554	137	-75%
Spruce_blue	777	204	-74%
Spruce_Englemann	841	432	-49%
Spruce_Norway	1038	266	-74%
Spruce_red	458	150	-67%
Spruce_Sitka	396	288	-27%
Spruce_white	550	126	-77%

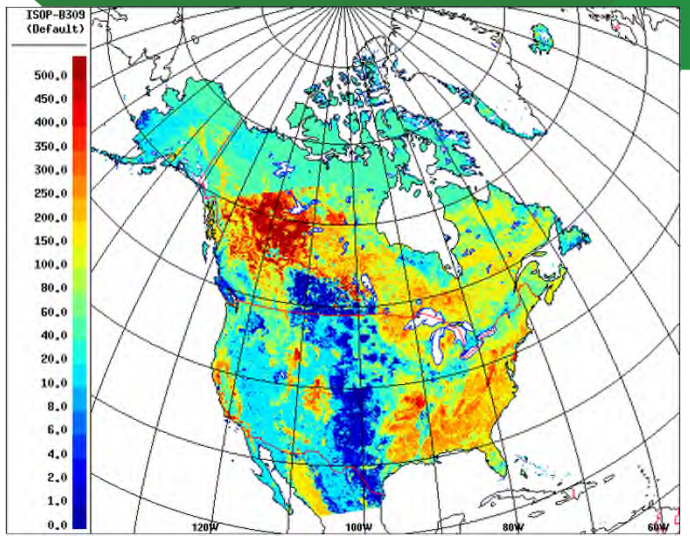
	ISOPRENE (gC/km2/hr)			
	BEIS3.13	BEIS3.60	BEIS3.70	3.60-3.70 Change (%)
Spruce_black	10500	10500	2590	-75%
Spruce_blue	10500	10500	2758	-74%
Spruce_Englemann	10500	10500	5390	-49%
Spruce_Norway	1500	1500	384	-74%
Spruce_red	1500	1500	490	-67%
Spruce_Sitka	1500	1500	1091	-27%
Spruce_white	10500	10500	2408	-77%

	Methanol (gC/km2/hr)		
	BEIS3.60	BEIS3.70	3.60-3.70 Change (%)
Spruce_black	900	222	-75%
Spruce_blue	900	236	-74%
Spruce_Englemann	900	462	-49%
Spruce_Norway	900	230	-74%
Spruce_red	900	294	-67%
Spruce_Sitka	900	655	-27%
Spruce_white	900	206	-77%

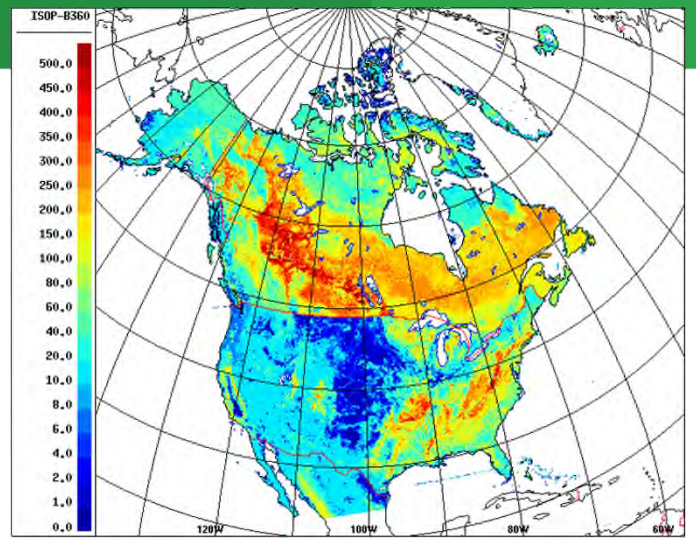
- From BEIS3.60 to 3.70, same % change applied to all VOC species for the same type of vegetation
- Changes made by ECCC for pine and spruce were in the same direction with slight higher reduction

COMPARISON OF GRIDDED EMISSIONS (1)

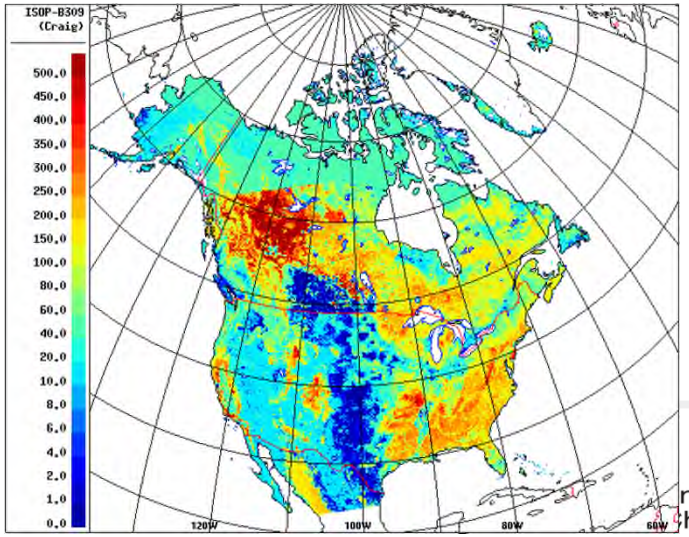
ISOPRENE



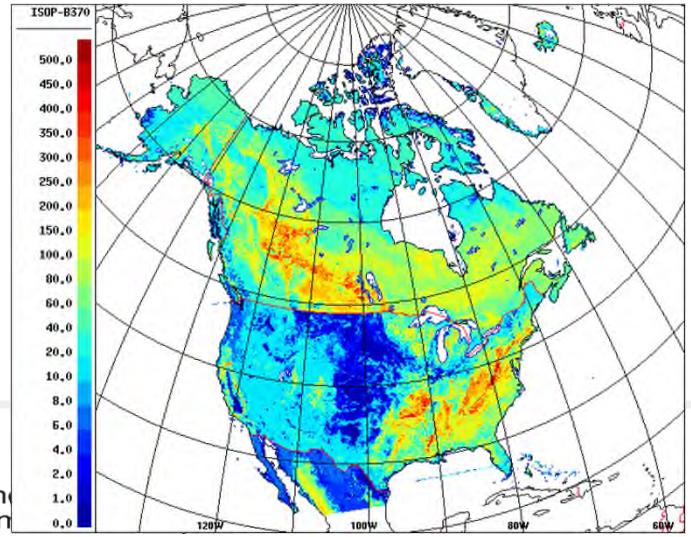
B3.13_ISOP



B3.60_ISOP



B3.09_ECCC_ISOP

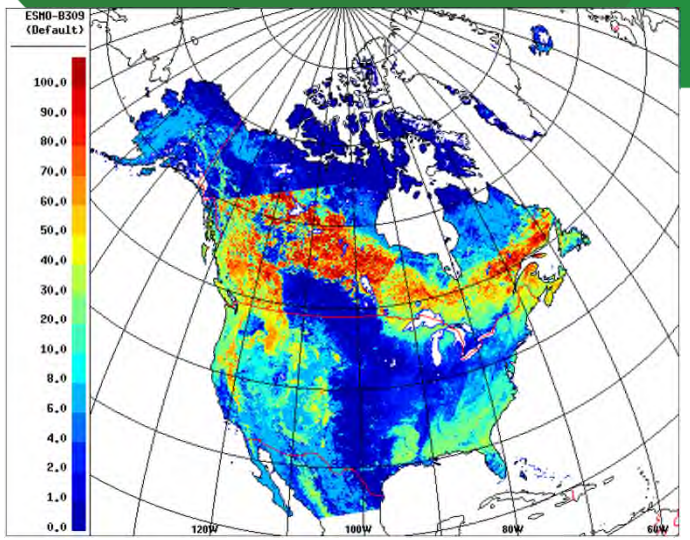


B3.70_ISOP

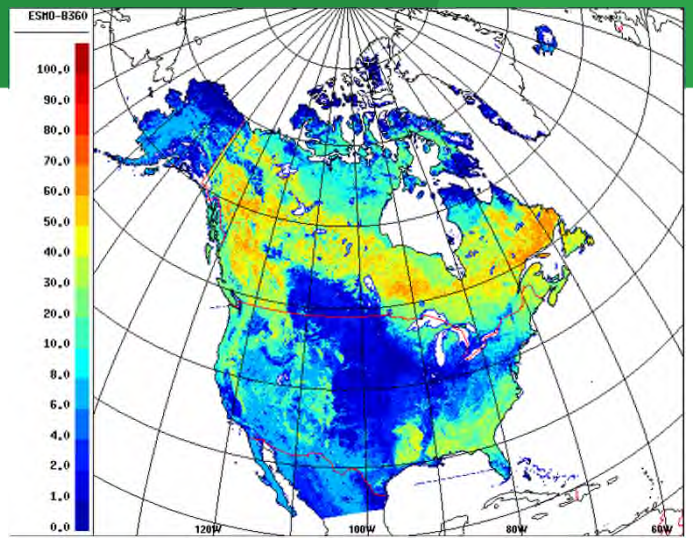
- BELD4 dataset has better coverage than BELD3 for northern part of Canada
- Emissions are the same for BEIS3.13 and BEIS3.09_ECCC
- Overall isoprene emissions from BEIS3.09_ECCC are comparable with those from BEIS3.60
- Isoprene emissions from BEIS3.70 are the lowest, consistent with the changes to the emission rates

COMPARISON OF GRIDDED EMISSIONS (2)

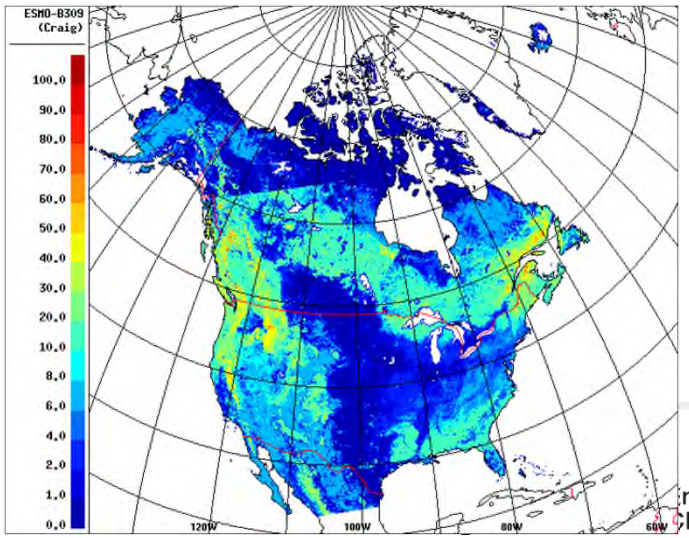
MONOTERPENE



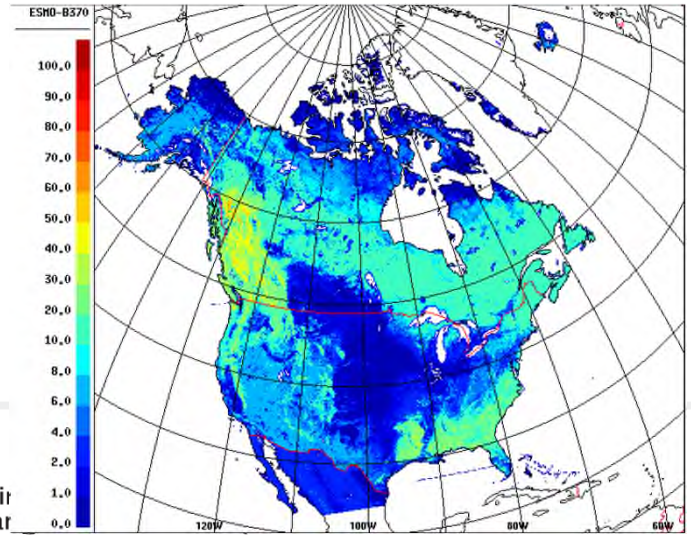
B3.13_MONO



B3.60_MONO



B3.09_ECCC_MONO

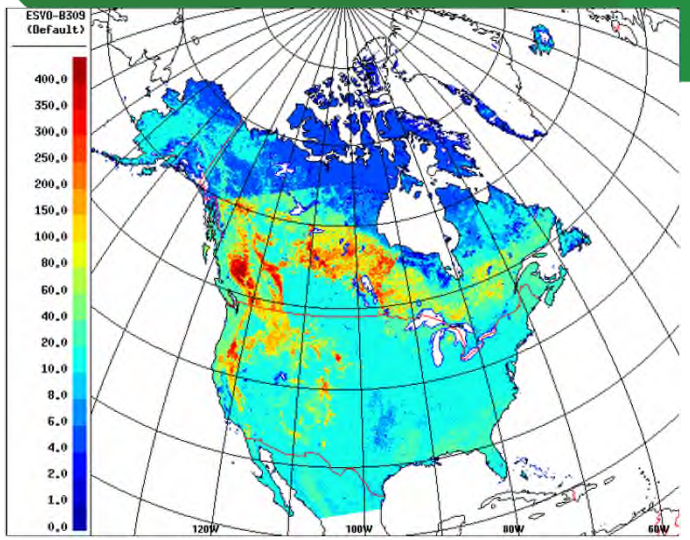


B3.70_MONO

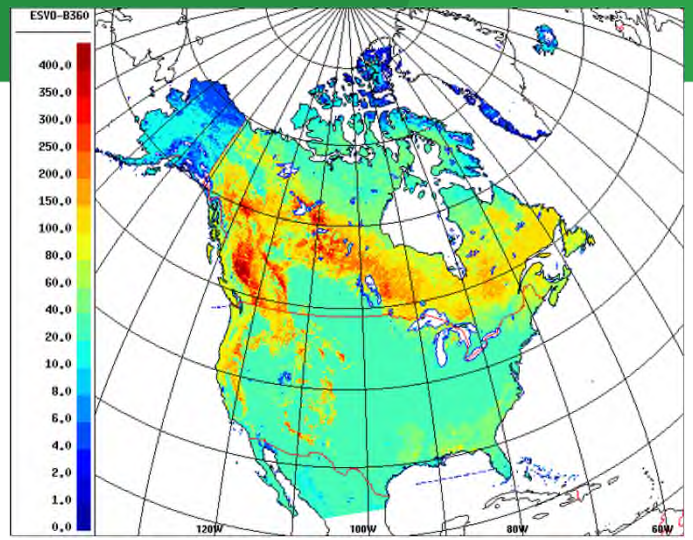
- Monoterpene emissions from BEIS3.60 and 3.70 are aggregated to total monoterpene emission to compare with the ones from BEIS3.09_ECCC and BEIS3.13
- BEIS3.13 has the highest emissions, particularly for the Canadian boreal forest
- Emissions from BEIS3.60 are much higher than those from BEIS3.70
- BEIS3.09_ECCC and BEIS3.70 are comparable

COMPARISON OF GRIDDED EMISSIONS (3)

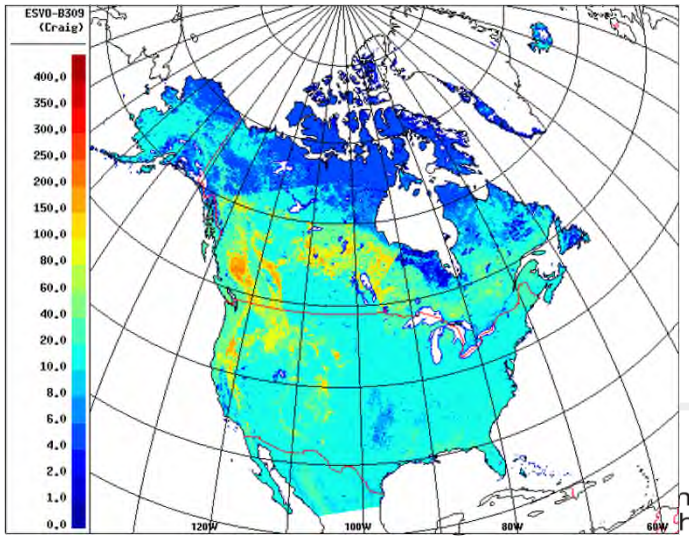
OTHER VOC (OVOC)



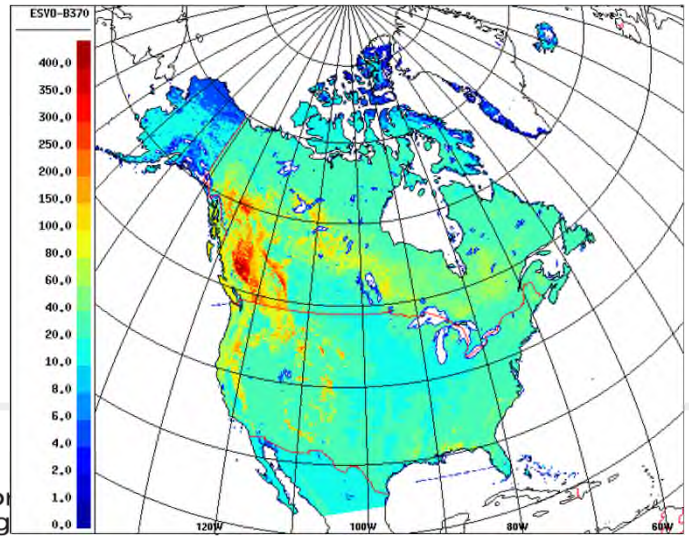
B3.13_OVOC



B3.60_OVOC



B3.09_ECCC_OVOC

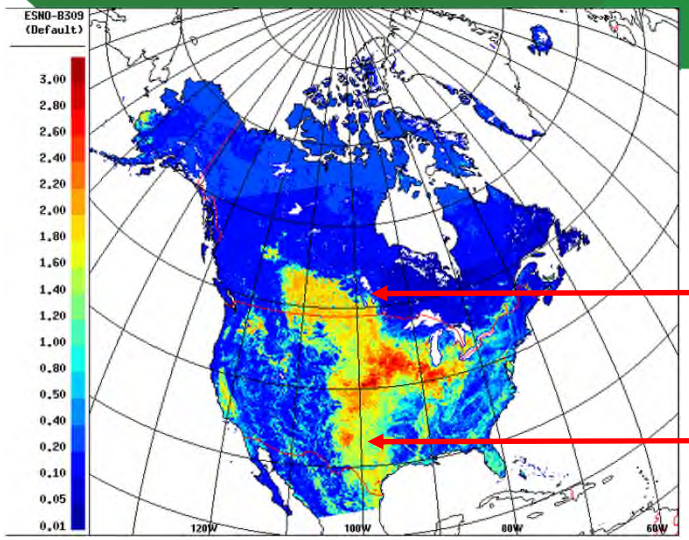


B3.70_OVOC

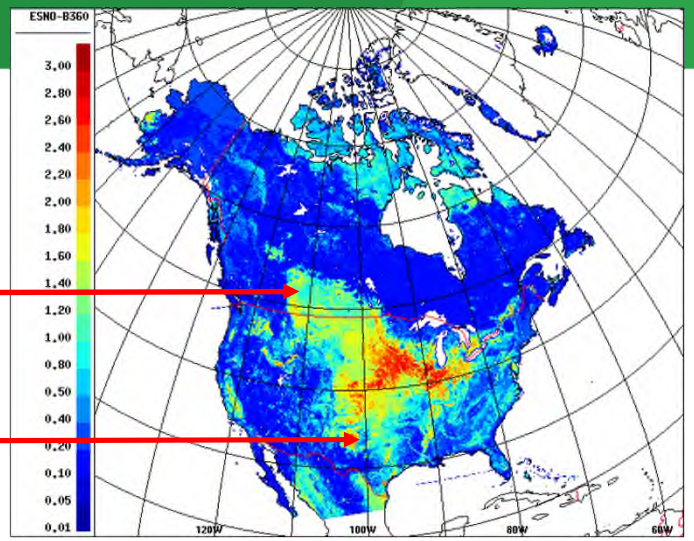
- OVOC emissions from BEIS3.60 and BEIS3.70 are aggregated to compare with the one from BEIS3.09_ECCC and BEIS3.13
- BEIS3.60 has the highest OVOC emissions, particularly for the Canadian boreal forest
- BEIS3.09_ECCC, which is currently being used by GEM-MACH, has the lowest OVOC emissions

COMPARISON OF GRIDDED EMISSIONS (4)

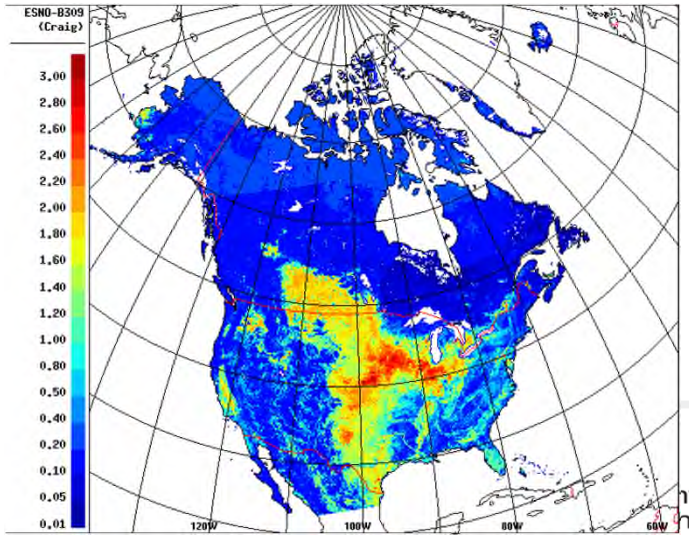
NO



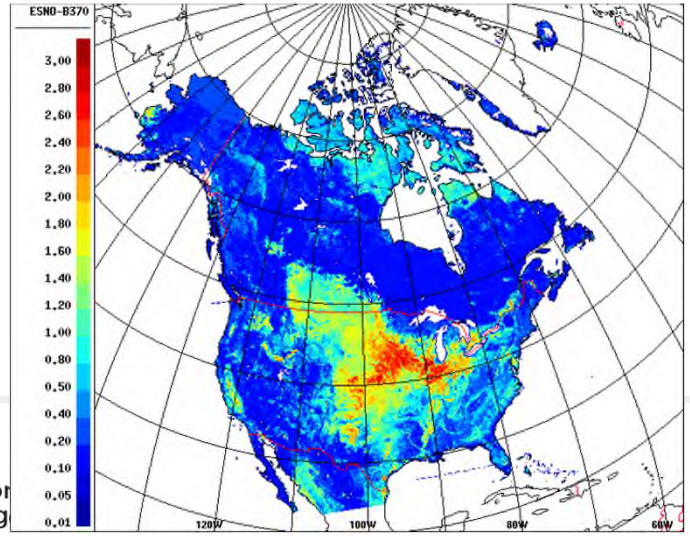
B3.13_NO



B3.60_NO



B3.09_ECCC_NO



B3.70_NO

- NO emissions are mainly from cropland
- A constant emission rate of 2 $gN/km^2/hr$ is assigned to all types of trees
- No changes made to emission rates
- Significant differences are seen for areas in both Canada and the U.S. due to landuse changes from BELD3 to BELD4

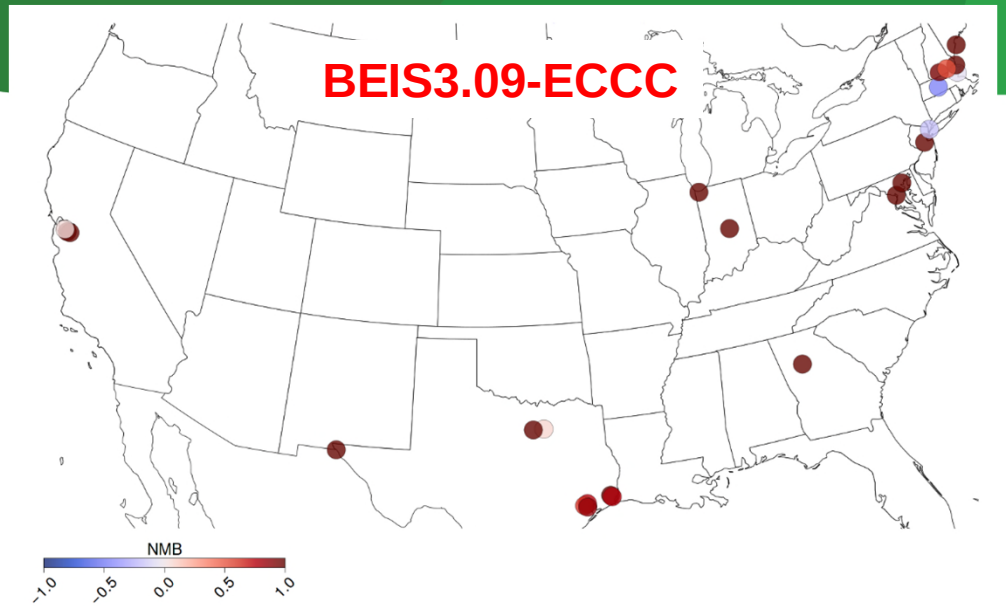
IMPACTS ON GEM-MACH PREDICTIONS (1)
ISOPRENE (2016 MONTHLY MEAN CONCENTRATION)

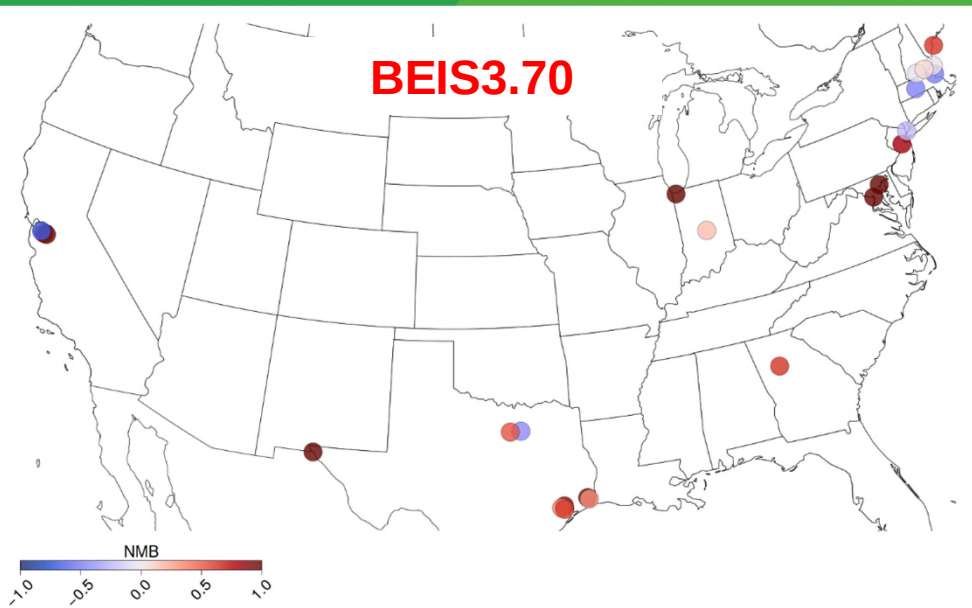
	ISOP	ISOP_Bias		
	OBS (ppb)	B3.09 ECCC	B3.60	B3.70
Jan	0.01	0.10	0.08	0.08
Feb	0.02	0.10	0.08	0.08
Mar	0.02	0.17	0.13	0.12
Apr	0.06	0.23	0.17	0.14
May	0.13	0.37	0.21	0.16
Jun	0.39	0.55	0.30	0.22
Jul	0.62	0.54	0.24	0.13
Aug	0.55	0.67	0.34	0.23
Sep	0.25	0.56	0.30	0.22
Oct	0.10	0.38	0.24	0.19
Nov	0.06	0.33	0.21	0.17
Dec	0.02	0.13	0.09	0.09

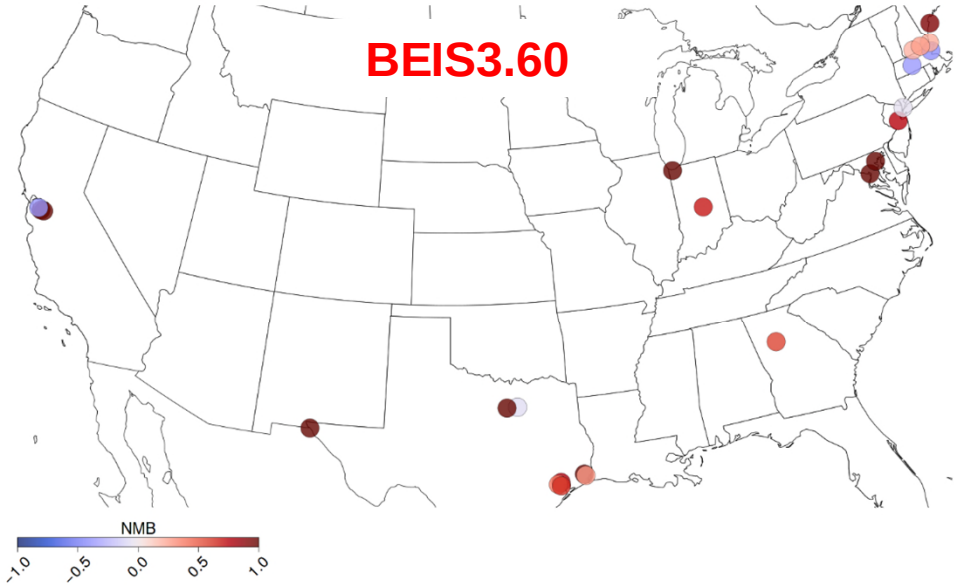
- GEM-MACH was run for 2016 and results were compared with observations
- Significant improvements to predictions of isoprene concentrations for all months using the newer versions of BEIS3.60 and 3.70
- BEIS3.70 has the lowest biases for all months but is still biased high

IMPACTS ON GEM-MACH PREDICTIONS (2)

ISOPRENE (JULY NMB BY STATION)







- Improvement was seen for most of the stations using the newer versions of BEIS

IMPACTS ON GEM-MACH PREDICTIONS (3)
O_3 (2016 MONTHLY MEAN CONCENTRATION)

	US	O3_AQS_Bias		
	OBS (ppb)	B3.09 ECCC	B3.60	B3.70
Jan	25.2	-2.2	-2.2	-2.3
Feb	29.8	-0.4	-0.6	-0.8
Mar	33.0	0.2	-0.1	-0.2
Apr	36.8	-2.3	-2.7	-2.8
May	35.6	-3.3	-3.8	-4.1
Jun	36.0	1.1	0.3	-0.5
Jul	32.4	4.8	4.0	3.1
Aug	29.8	5.4	4.6	3.6
Sep	27.9	7.4	6.8	6.1
Oct	26.7	2.9	2.5	2.0
Nov	25.1	-1.4	-1.6	-2.0
Dec	22.4	-1.5	-1.6	-1.7

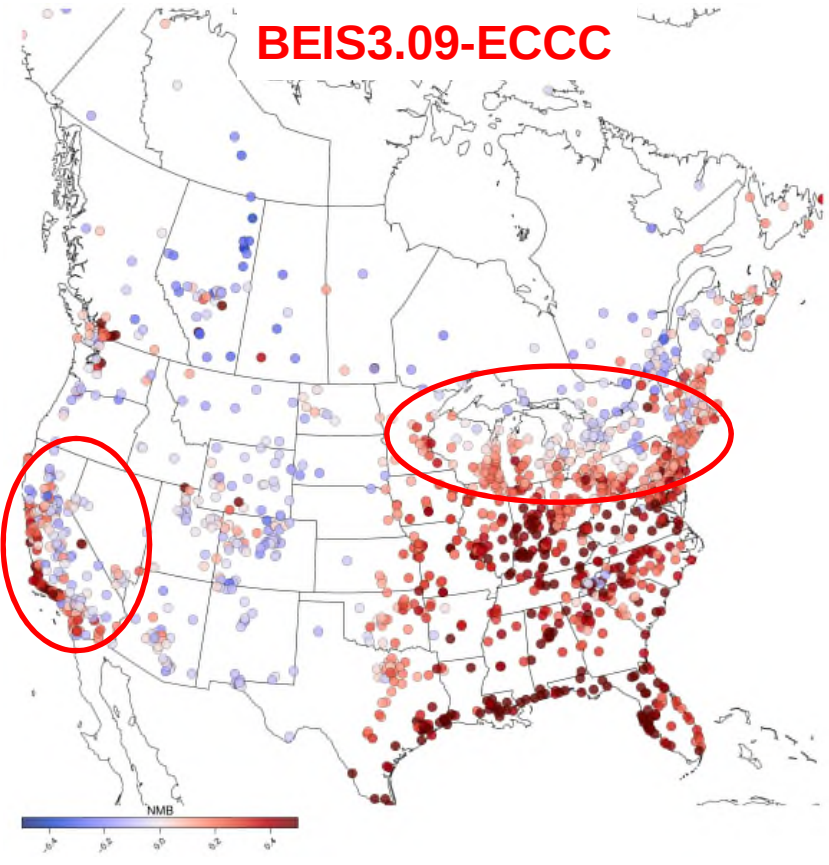
	CANADA	O3_NAPS_Bias		
	OBS (ppb)	B3.09 ECCC	B3.60	B3.70
Jan	23.0	-5.5	-5.6	-5.5
Feb	26.9	-5.4	-5.5	-5.4
Mar	29.9	-2.5	-2.7	-2.6
Apr	32.6	-3.3	-3.6	-3.4
May	30.5	-4.2	-4.6	-4.4
Jun	27.6	-4.8	-4.6	-4.6
Jul	23.3	-1.2	-1.0	-1.1
Aug	22.0	0.5	0.9	0.7
Sep	19.1	3.1	3.0	2.9
Oct	18.4	-0.2	-0.3	-0.3
Nov	18.9	-3.0	-3.2	-3.2
Dec	24.0	-7.4	-7.5	-7.4

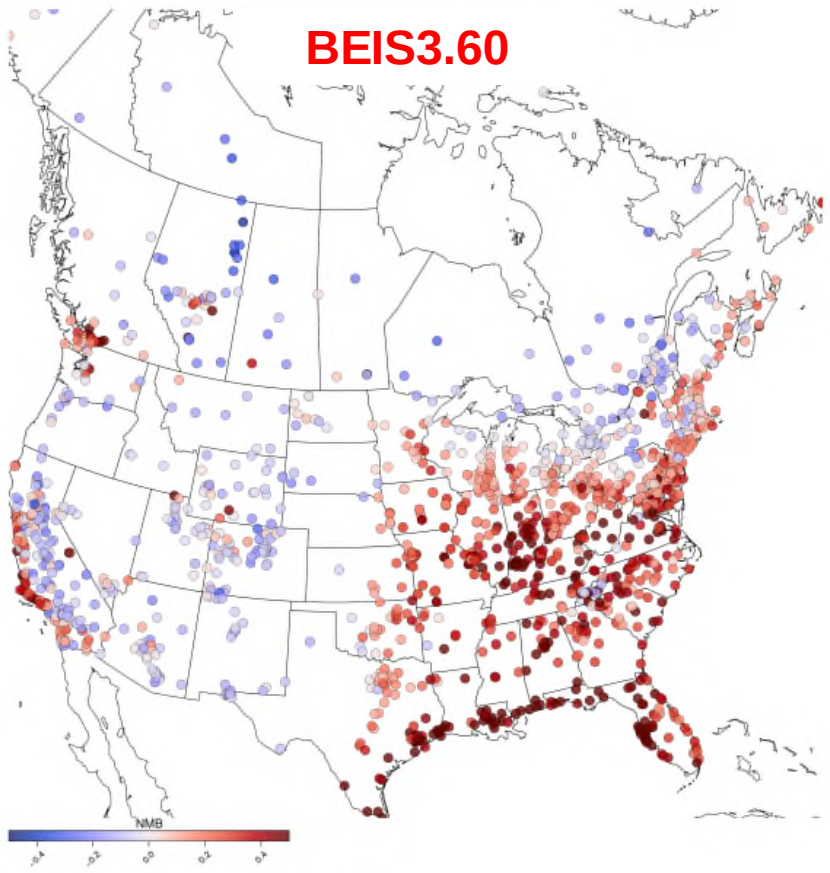
(numbers shown above in red are the best scores for each month)

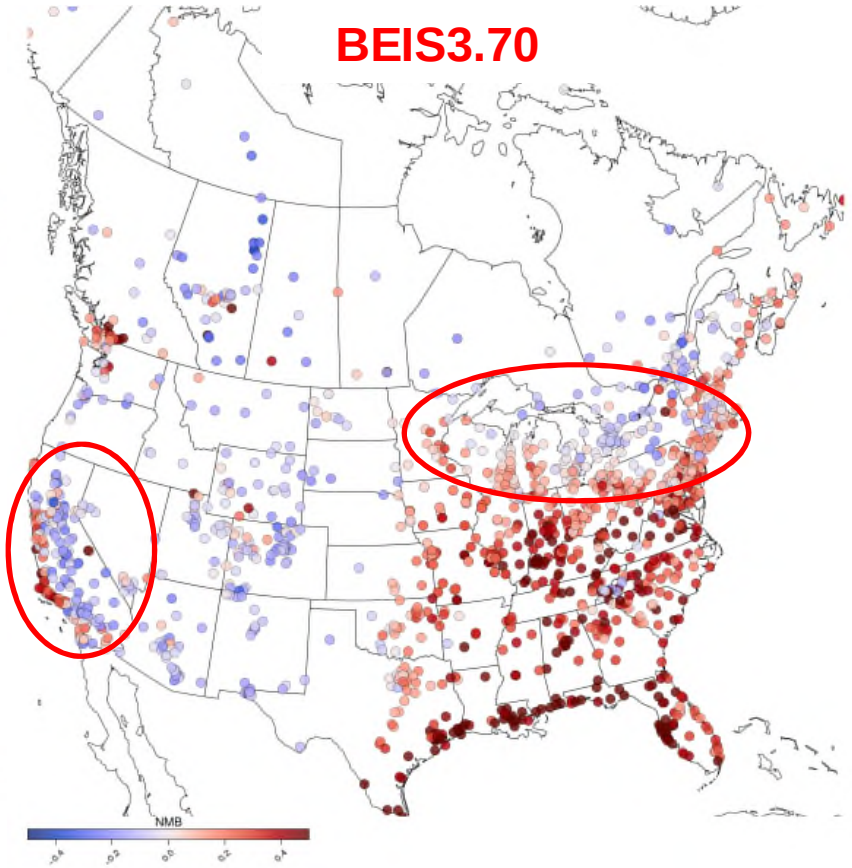
- Up to 1.8 ppb impact is seen for monthly mean O_3 bias
- Significant improvement for the summer months for the US stations using BEIS3.70
- For Canada, results are comparable for the three versions. BEIS3.09-ECCC seems to be the best overall, probably because the updates are made mainly for the tree species dominant in Canada

IMPACTS ON GEM-MACH PREDICTIONS (4)

O_3 (JULY NMB BY STATION)







- Impacts are seen for stations shown in the red ovals

IMPACTS ON GEM-MACH PREDICTIONS (5)
NO_2 (2016 MONTHLY MEAN CONCENTRATION)

	US	NO2_AQS_Bias		
	OBS (ppb)	B3.09 ECCC	B3.60	B3.70
Jan	11.3	0.60	0.56	0.54
Feb	10.5	0.60	0.55	0.53
Mar	8.2	0.57	0.55	0.53
Apr	7.3	0.16	0.13	0.12
May	6.5	0.60	0.57	0.56
Jun	6.6	0.77	0.73	0.71
Jul	6.0	1.52	1.48	1.45
Aug	6.5	2.16	2.11	2.08
Sep	7.5	2.30	2.27	2.22
Oct	8.7	1.89	1.84	1.79
Nov	10.8	0.94	0.90	0.82
Dec	10.6	1.21	1.16	1.13

	CANADA	NO2_NAPS_Bias		
	OBS (ppb)	B3.09 ECCC	B3.60	B3.70
Jan	10.1	0.01	0.01	0.00
Feb	8.3	0.55	0.54	0.53
Mar	7.2	0.99	0.97	0.98
Apr	5.7	0.56	0.55	0.56
May	5.4	0.42	0.39	0.42
Jun	4.6	0.87	0.86	0.88
Jul	4.2	1.42	1.41	1.44
Aug	4.7	2.14	2.14	2.17
Sep	5.4	2.00	2.01	2.01
Oct	5.8	1.45	1.47	1.45
Nov	7.9	0.81	0.81	0.79
Dec	9.1	-0.93	-0.94	-0.94

- For the U.S. stations, an improvement was seen for all months with the newer versions of BEIS; BEIS3.70 has the best performance
- For Canada, results are comparable for the three versions

IMPACTS ON GEM-MACH PREDICTIONS (6)
$PM_{2.5}$ (2016 MONTHLY MEAN CONCENTRATION)

	US	PM2.5_AQS_Bias		
	OBS (ug/m3)	B3.09 ECCC	B3.60	B3.70
Jan	9.0	0.98	1.03	0.97
Feb	7.6	1.37	1.45	1.29
Mar	6.6	-0.18	-0.09	-0.18
Apr	6.2	-1.27	-1.17	-1.27
May	6.7	-2.15	-1.93	-2.12
Jun	7.2	-2.40	-2.04	-2.44
Jul	7.4	-1.41	-0.88	-1.48
Aug	7.2	-1.26	-0.71	-1.30
Sep	6.7	-0.65	-0.20	-0.65
Oct	6.5	-0.12	0.18	-0.10
Nov	8.5	0.02	0.38	0.03
Dec	8.7	0.30	0.37	0.28

	CANADA	PM2.5_NAPS_Bias		
	OBS (ug/m3)	B3.09 ECCC	B3.60	B3.70
Jan	7.5	2.33	2.44	2.37
Feb	5.9	1.42	1.55	1.47
Mar	5.7	0.84	0.93	0.87
Apr	5.4	-0.46	-0.24	-0.36
May	8.8	-4.14	-3.91	-4.10
Jun	5.0	-1.67	-1.36	-1.57
Jul	5.4	-1.50	-0.93	-1.39
Aug	5.3	-0.71	0.03	-0.45
Sep	4.7	0.92	1.32	1.02
Oct	5.1	0.41	0.67	0.46
Nov	6.3	1.07	1.29	1.10
Dec	6.6	0.66	0.69	0.67

- Up to 0.7 ug/m^3 impact is seen to $PM_{2.5}$ concentration
- BEIS3.60 has the lowest bias overall for the summer months
- BEIS3.70 performs the worst overall
- Further investigation by comparing model results with speciated PM measurements, particularly organic PM, needs to be done

SUMMARY

- Vegetation is a very important source of VOC emissions
- Significant changes have been made to biogenic VOC emission factors in the most recent versions of the BEIS model (BEIS3.60 and BEIS3.70)
- Biogenic VOC emissions are reduced by about 50% from BEIS3.60 to BEIS3.70
- Significant impacts were seen on GEM-MACH predictions of O_3 (up to 1.7 ppb) and $PM_{2.5}$ (up to 0.7 ug/m^3) due to the changes to biogenic emissions
- Improvements on model predictions of isoprene, NO_2, and summertime O_3 were also noticed for the U.S. side of the domain using BEIS3.70
- Investigation of speciated PM (organic aerosol) predictions needs to be done to further evaluate and understand model predictions of PM concentration

Thank You for Your Attention!

Schwede, D., G. Pouliot+, and T. Pierce: Changes to the Biogenic Emissions Inventory System Version 3 (BEIS3), *4th Annual CMAS Models-3 Users' Conference*, September 26-28, 2005, Chapel Hill, NC, ttps://www.cmascenter.org/conference/2005/abstracts/2_7.pdf

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