

The Impact of Pine Beetle Kill on Monoterpene Emissions and SOA Formation in Western North America

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J. Hicke, A. Meddens, G. Hallar, K. Huff-Hartz (for data)



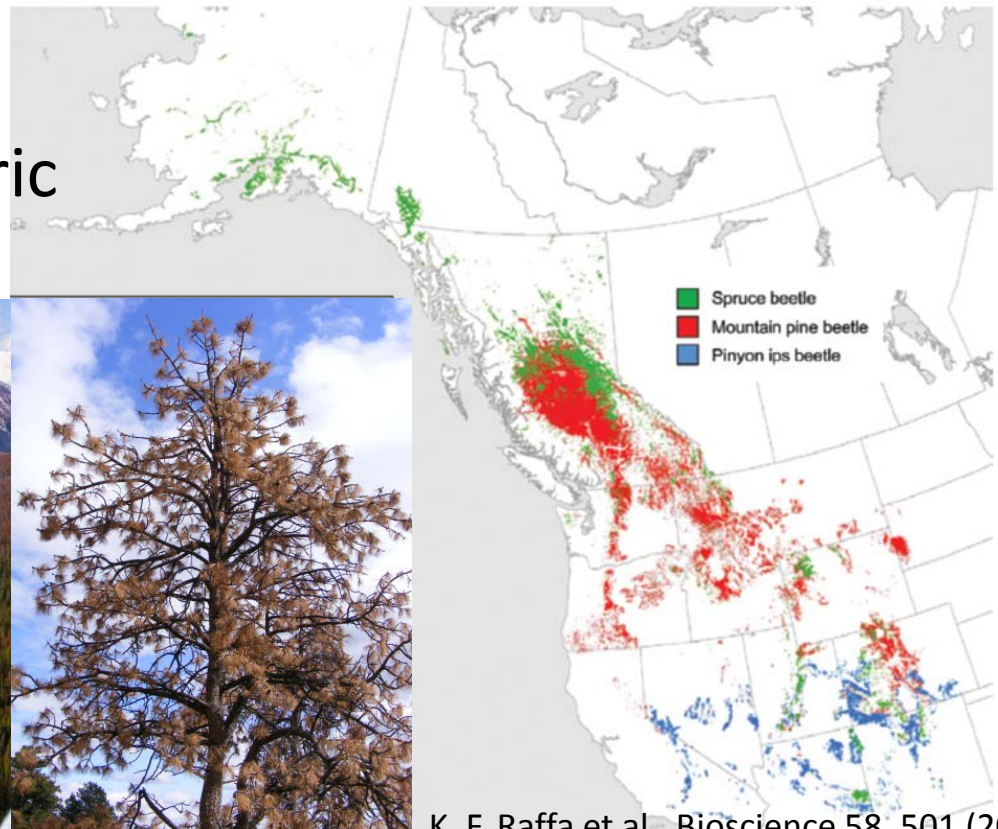
Massachusetts
Institute of
Technology



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Beetle Infestation

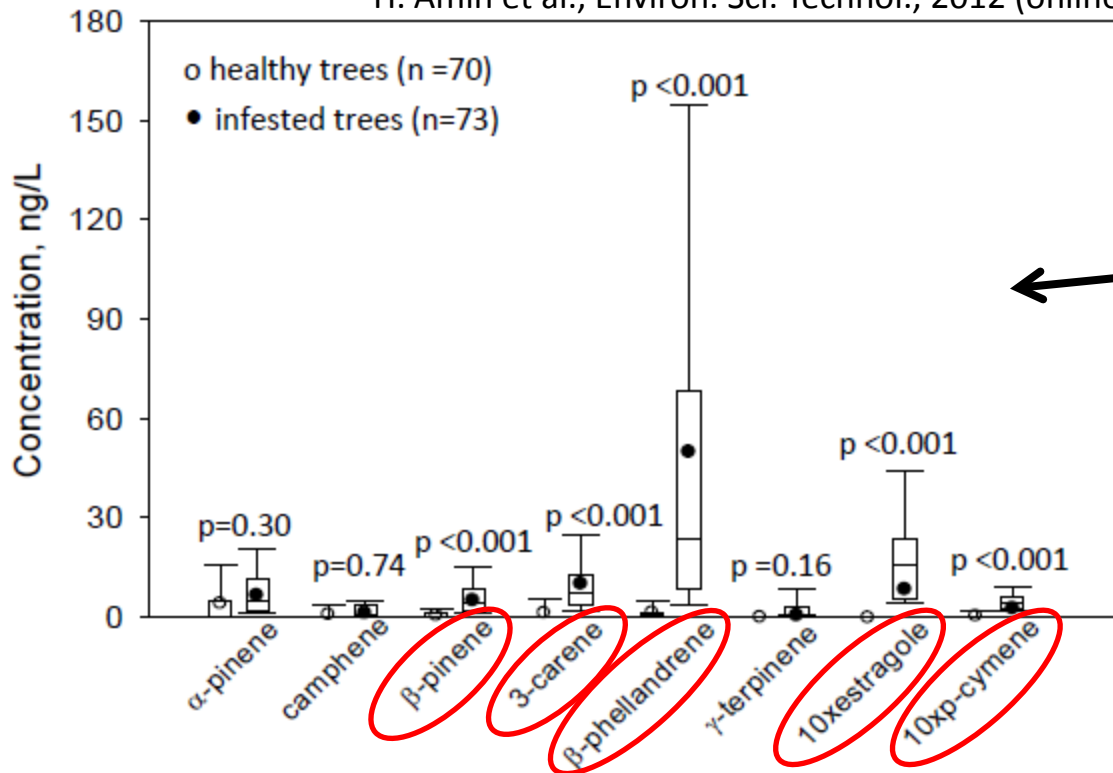
- Beetle infestation in western North America has lasted more than a decade, aided by climate change
- Impacts carbon cycling, fuel distributions, sfc-atm exchanges...
- What about atmospheric composition?



Beetle Infestation

Trees respond to beetle attack with enhanced VOC emissions

H. Amin et al., Environ. Sci. Technol., 2012 (online)



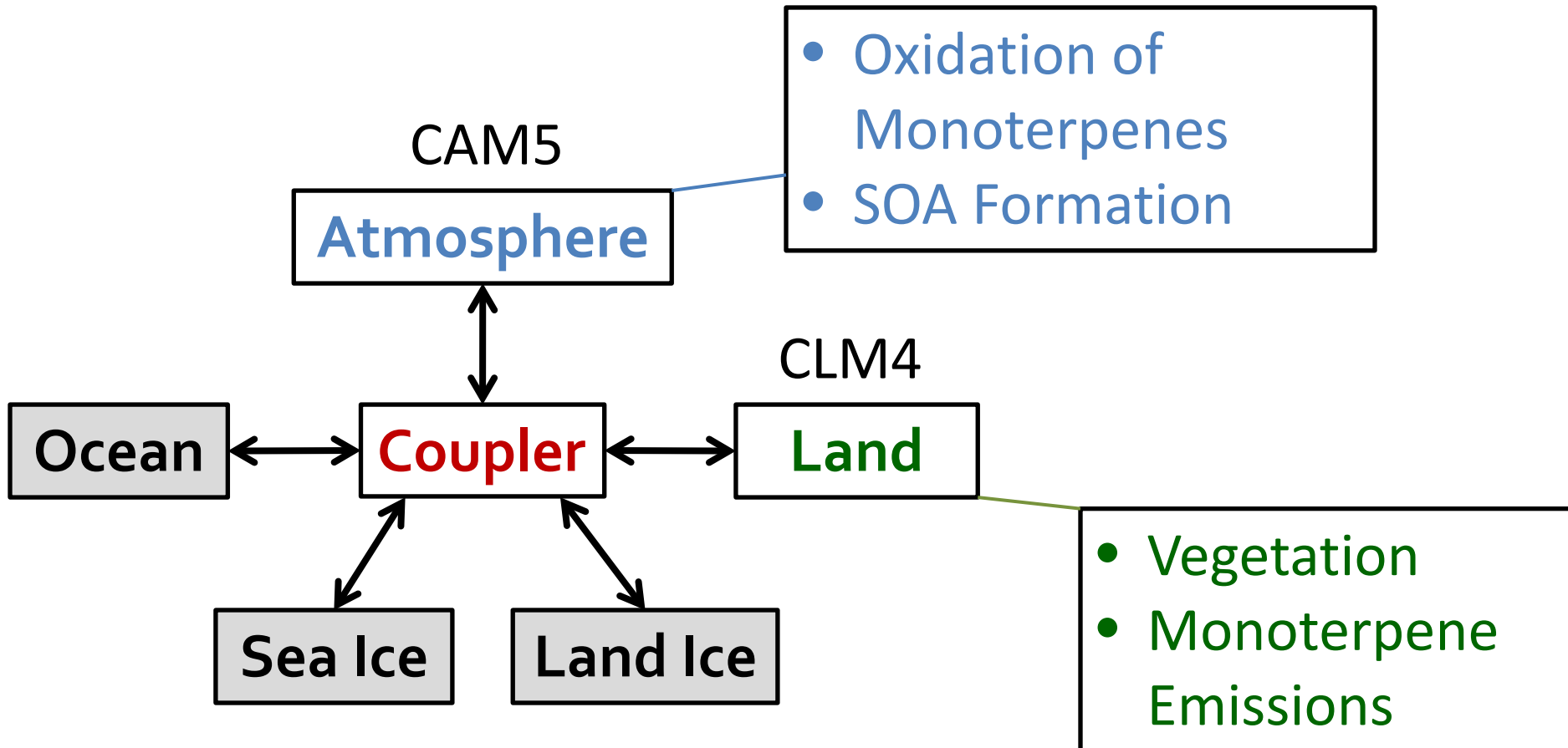
Very few quantitative studies have been done

← Amin et al. (2012) measure emissions from Lodgepole pine under attack by mountain pine beetle

Significant increase in emissions of certain compounds

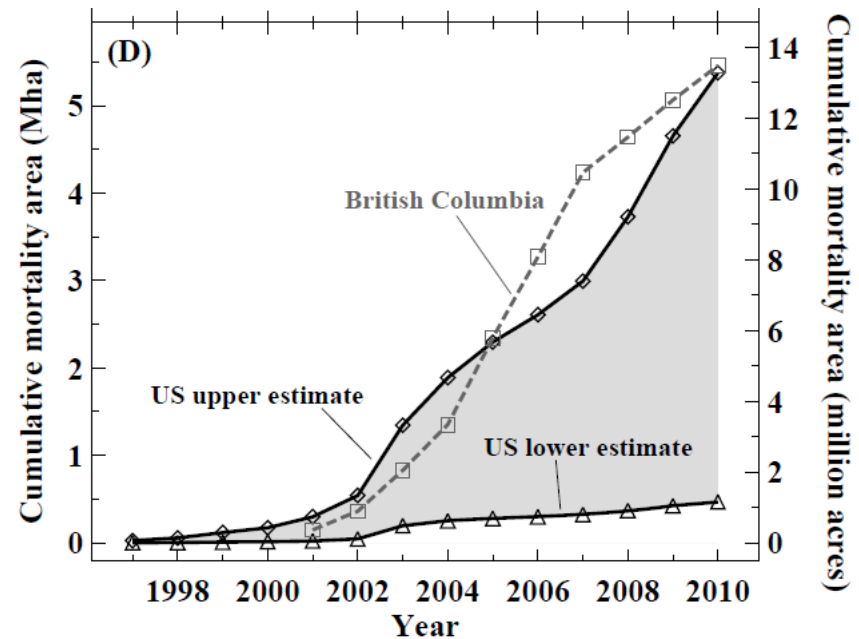
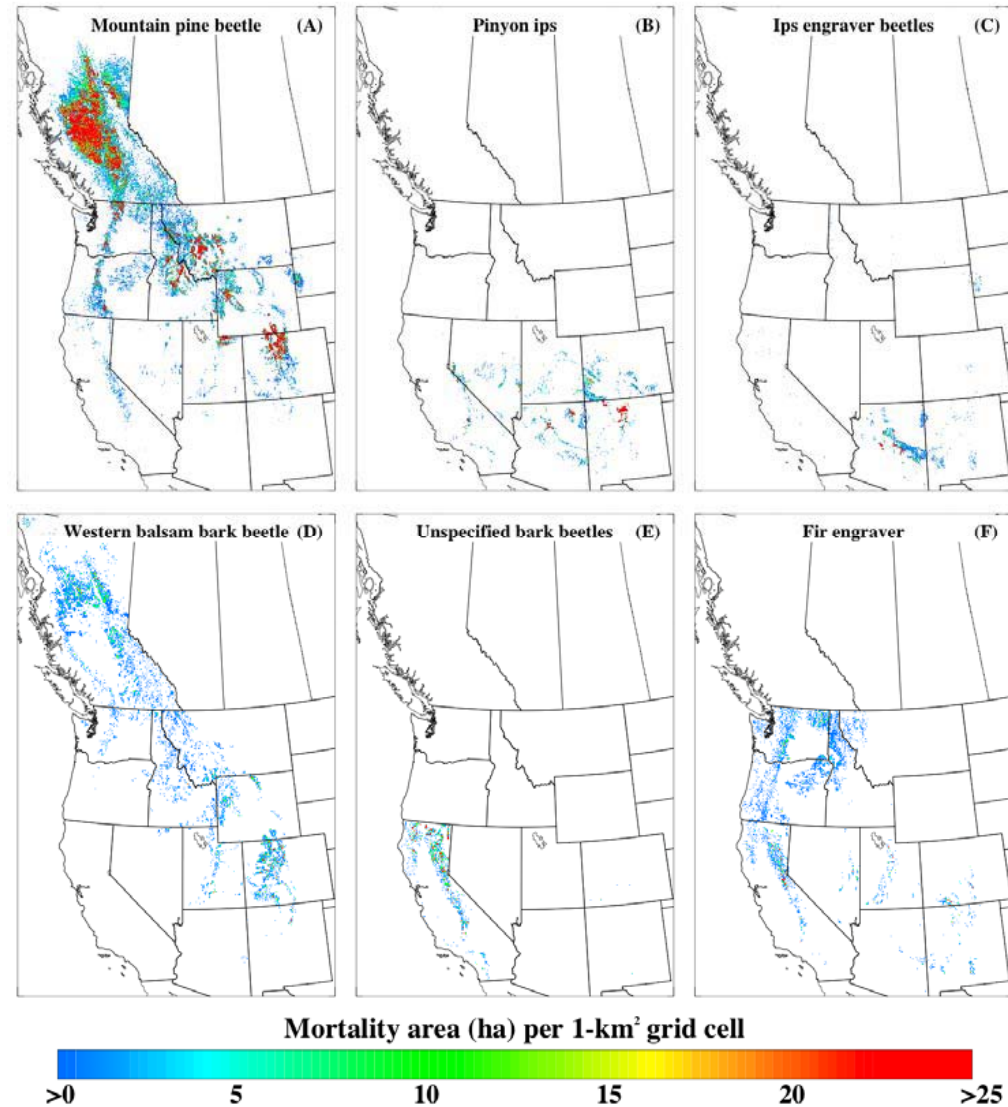
Objective

Use beetle mortality data from 1997-2010 and beetle-induced monoterpene data in the Community Earth System Model



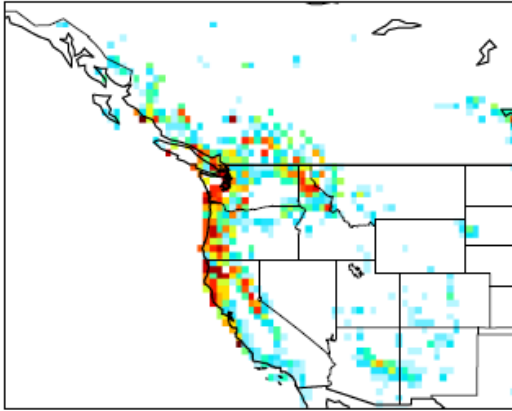
Beetle Mortality Data

- ▶ 1-km grid of % mortality from aerial overview surveys, 1997 – 2010
- ▶ 13 Beetles, 17 Host types



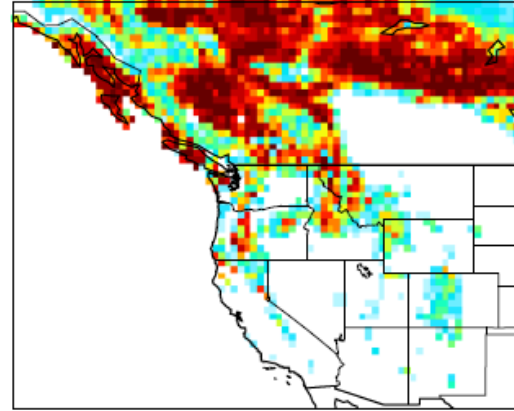
Figures: Meddens et al., 2012 (submitted)

PFT 1



Needleleaf Evergreen
Temperate Trees

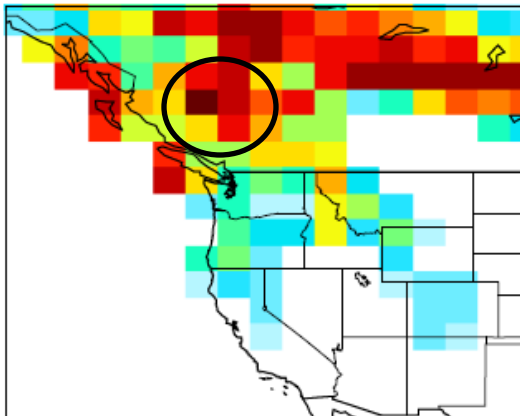
PFT 2



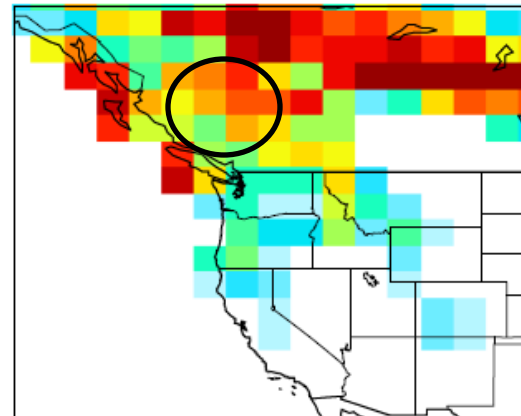
Needleleaf Evergreen
Boreal Trees

**Apply mortality to Needleleaf PFTs
And convert to 1.9x2.5 degrees:**

PFT 2 Baseline

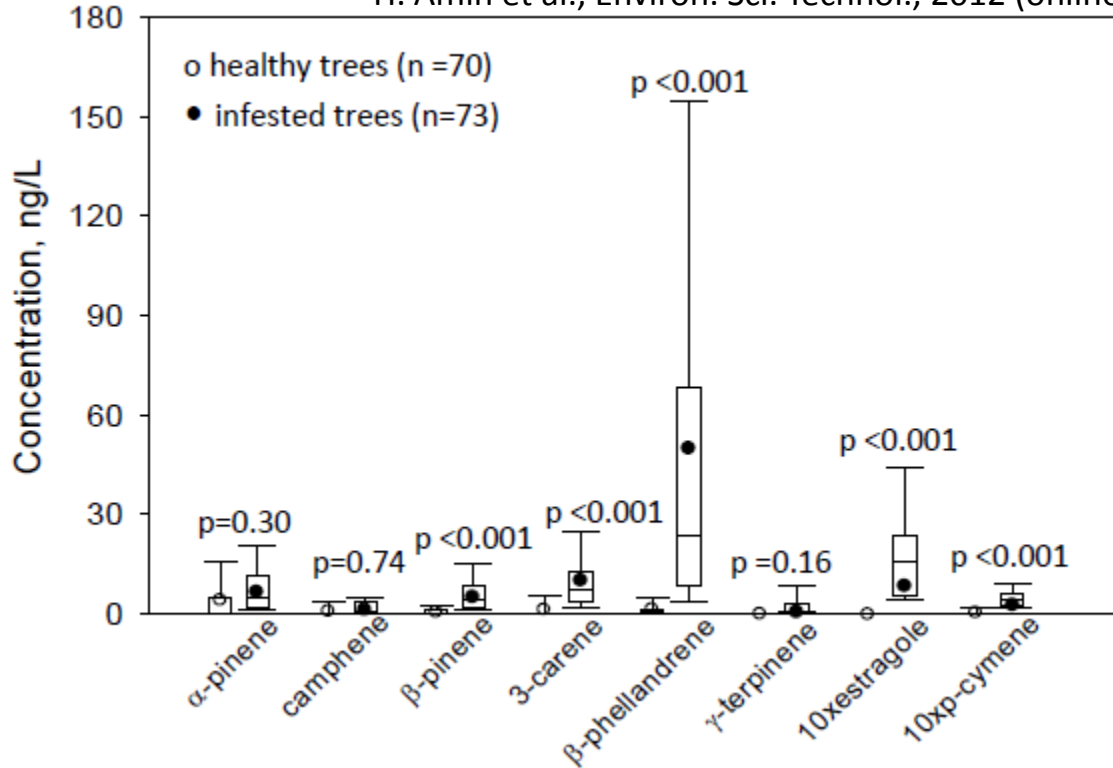


PFT 2 2010



Enhanced Monoterpene Emissions Data

H. Amin et al., Environ. Sci. Technol., 2012 (online)



Monoterpene	Scale-Up Factor
β -pinene	7.7
3-carene	7.3
β -phellandrene	33
P-cymene	5.4

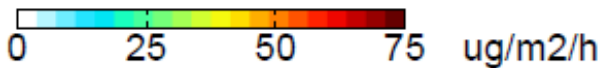
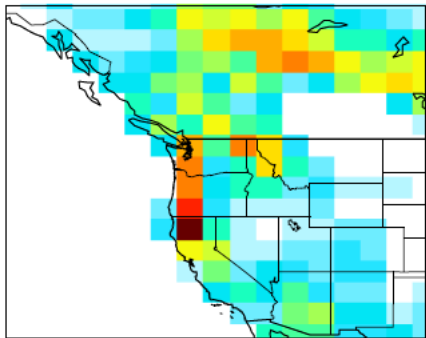
Scale-up factors calculated from data are applied to monoterpene emissions from fraction of Needleleaf trees under attack.

SOA data

- In the chemical mechanism: add photochemical (OH) and ozonolysis reactions for SOA formation from single monoterpenes as irreversible yields
 - SOA yields from Lee et al. (2006)
 - Reaction rates at 298K from Atkinson (1997)

Monoterpene	SOA Yield (OH)	Lifetime assuming [OH] = 1×10^6 molecules cm^{-3}	SOA Yield (O_3)	Lifetime assuming [O_3] = 40 ppb
B-pinene	29%	3.5 hours	16%	17 hours
3-carene	36%	3.2 hours	51%	7 hours
B-phellandrene	55%	1.7 hours	-	-
P-cymene	6%	19 hours	-	-

Baseline Monoterpene Emissions



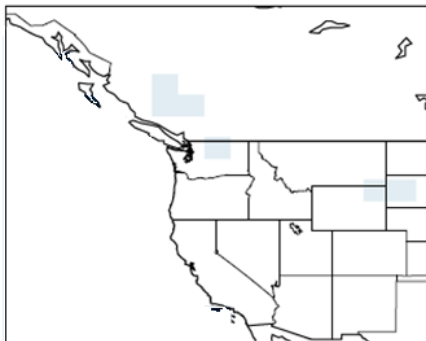
Impact on Monoterpene Emissions

B-pinene, B-phellandrene, 3-carene, P-cymene

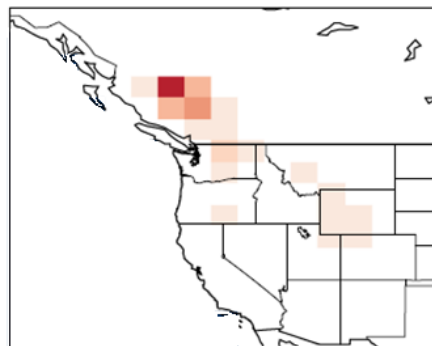
Mortality Effect – decrease due to beetle kill

Attack Effect – increase due to beetle attack

Mortality Effect

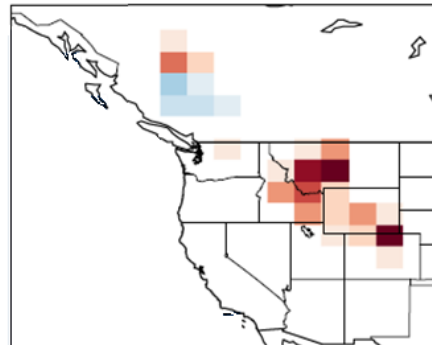
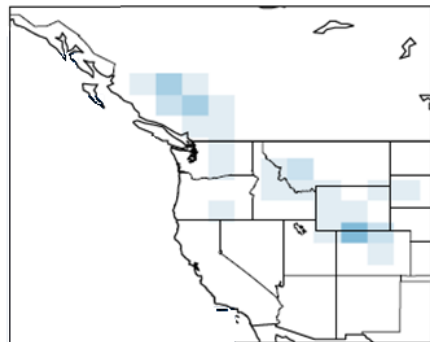


Mortality Effect + Attack Effect



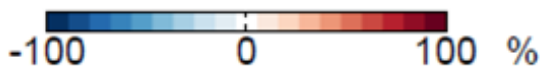
2004 Mountain Pine Beetle Attack

Largest impact of MPB in British Columbia
Maximum increase above baseline **70%**

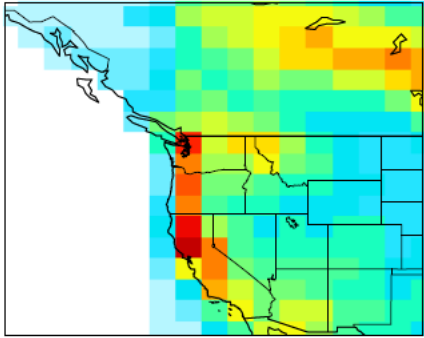


2008 Mountain Pine Beetle Attack

Largest impact of MPB in United States
Maximum increase above baseline **104%**



Baseline Summertime SOA Concentration



0.00 0.50 1.00 ug/m³

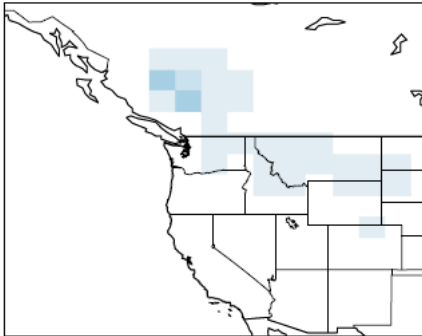
Impact on SOA Concentrations

from B-pinene, B-phellandrene, 3-carene, P-cymene

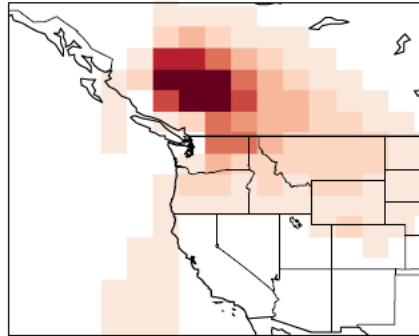
Mortality Effect – decrease due to beetle kill

Attack Effect – increase due to beetle attack

Mortality Effect

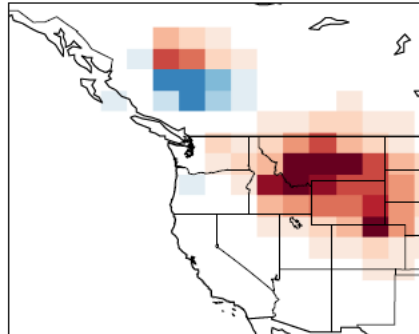
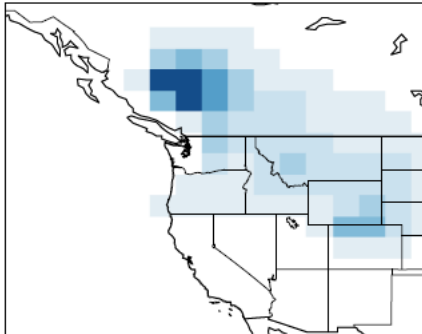


Mortality Effect + Attack Effect



2004 Mountain Pine Beetle Attack

Largest impact of MPB in British Columbia
Maximum increase above baseline **43%**



2008 Mountain Pine Beetle Attack

Largest impact of MPB in United States
Maximum increase above baseline **36%**

-20 0 20 %

Impact due to Other Beetles

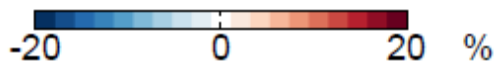
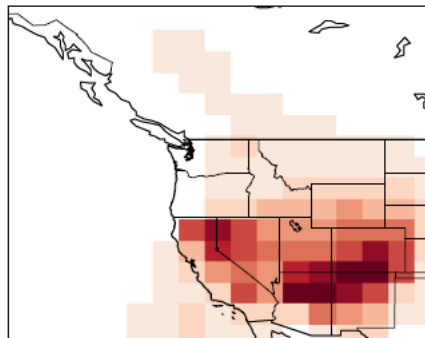
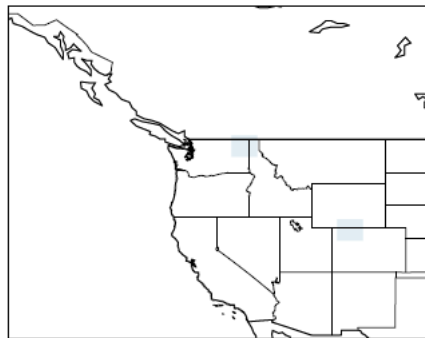
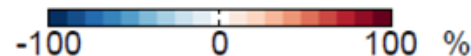
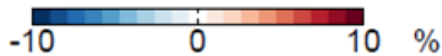
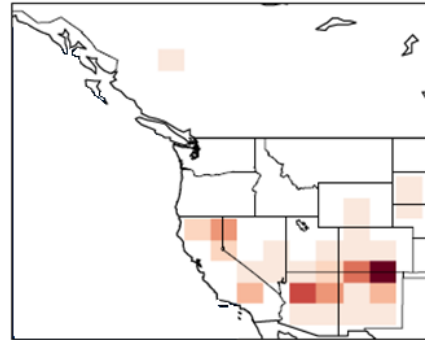
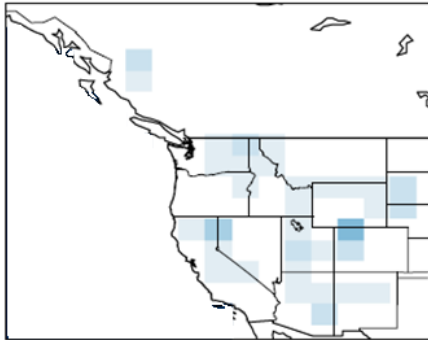
on monoterpenes and SOA

Mortality Effect – decrease due to beetle kill

Attack Effect – increase due to beetle attack

Mortality Effect

Mortality Effect + Attack Effect



Monoterpenes

2002 Other Beetle Attack

Largest impact of OB in British Columbia and the United States

Maximum increase above baseline **111%**

SOA

2002 Other Beetle Attack

Largest impact of OB in British Columbia and the United States

Maximum increase above baseline **37%**

A second beetle attack scenario:

Spruce under attack by mountain pine beetle

Scale-up Factors

Monoterpene	Pine	Spruce
β -pinene	7.7	16
3-carene	7.3	65
β -phellandrene	33	5.3
P-cymene	5.4	42

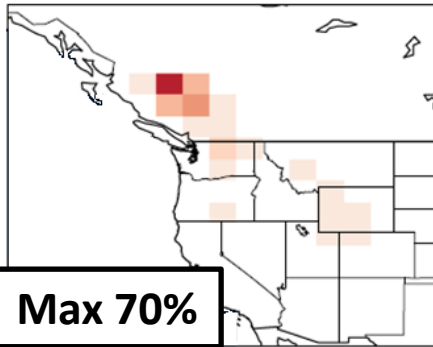
Pine calculated from Amin et al., 2012,
Spruce from same group

2004 Mountain Pine Beetle Mortality Effect + Attack Effect

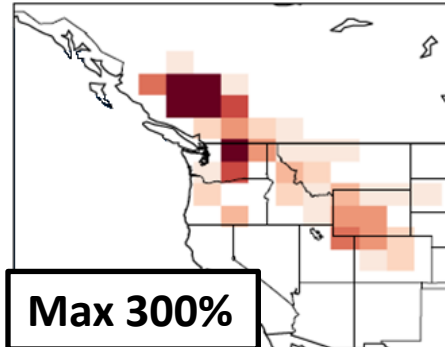
- Large species-variability in response to beetle attack
- Highlights uncertainties surrounding impact of beetles on atmospheric composition

MT

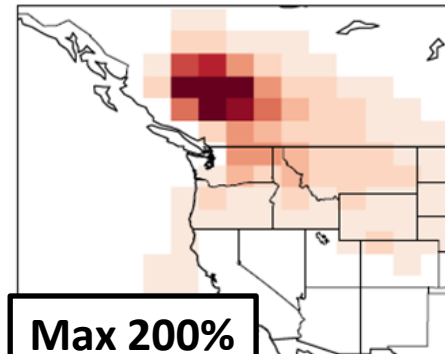
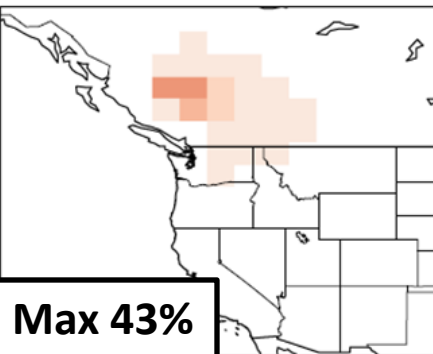
Pine



Spruce



SOA

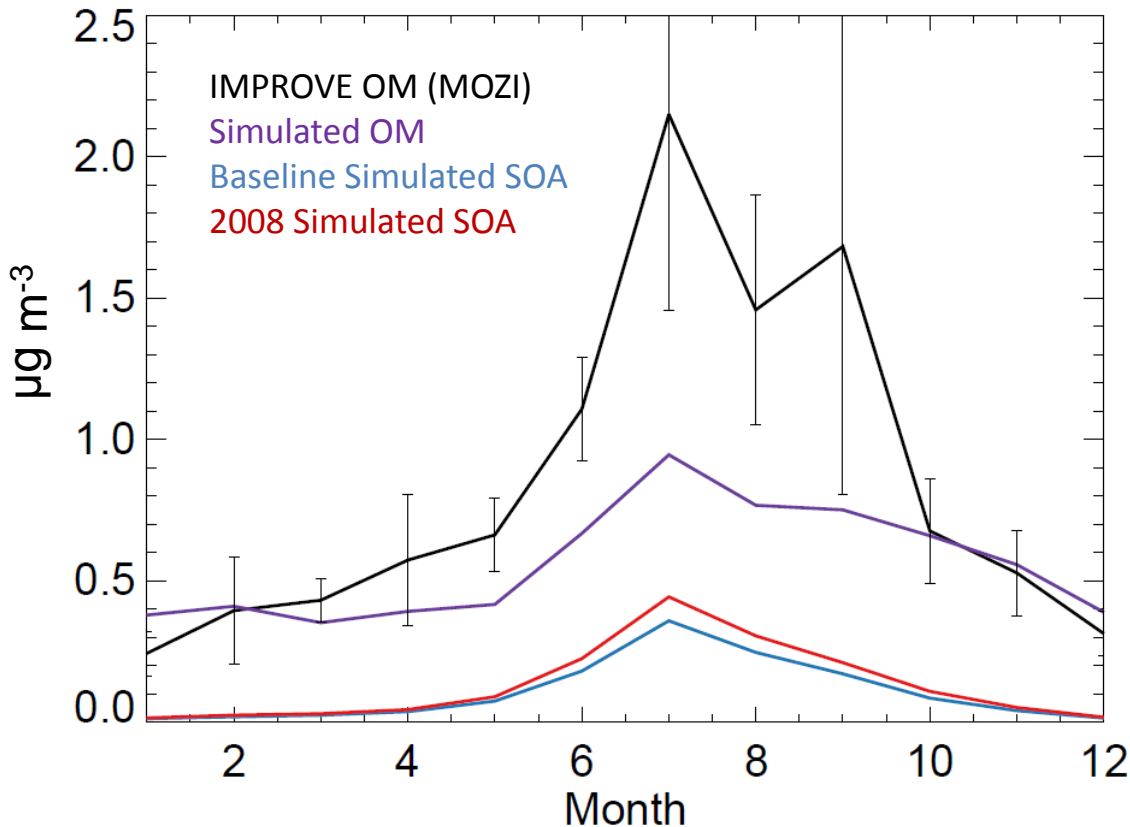


-100 0 100 %

-100 0 100 %

Now let's provide some context: IMPROVE OM observations

Comparing simulated SOA to monthly average OM (2005-2010)
observed at MOZI - a Colorado site



- Annual/interannual variability in OM observations is much larger than beetle-induced SOA changes – not observable
- While changes are not large compared to OM observations in Colorado, some other regions may be experiencing higher localized impacts

Summary and future work

- Limited to broad PFT categories
- SOA may be overestimated
- Need more quantitative studies of MT emission changes
- Beetle infestation may have a significant impact on atmospheric composition in western North America. Future studies may help constrain these impacts.