

Attribution of tropospheric ozone production in CAM-chem using an extended tagging technique

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- Existing tagging in CAM-chem
- New extensions
- Implementation
- Initial results
- Next steps

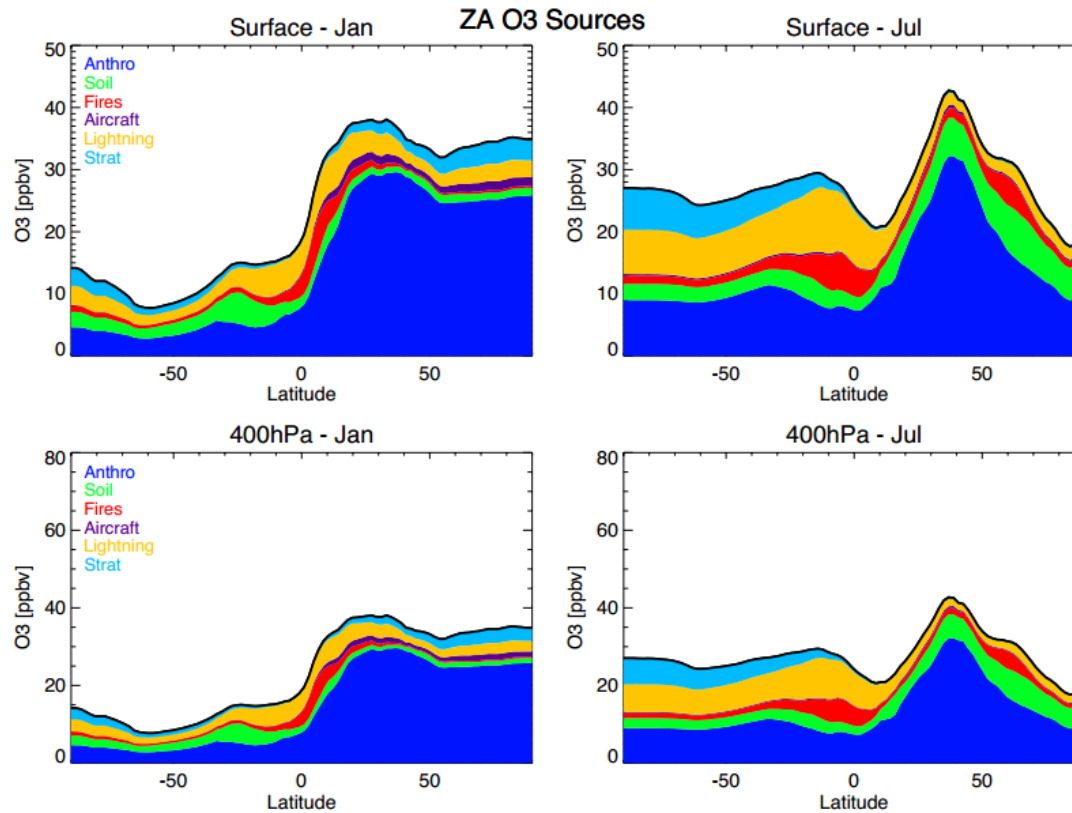


Fig. 6. Zonal average of tagged ozone source contributions at the surface and at 400 hPa, for January and July of 2008. Stratospheric contribution is determined as the difference between total ozone and tagged ozone from all tropospheric sources combined. Emmons et al. (2012)

- Tagged source duplicated as emissions of “XNO”
 - $\text{NO} + \text{RO}_2 \rightarrow \text{NO}_2 + \text{RO}$
 - $\text{XNO} + \text{RO}_2 \rightarrow \text{XNO}_2 (+ \text{RO}_2)$
 - $\text{XNO}_2 + \text{h}\nu \rightarrow \dots \rightarrow \text{O}_3\text{A}$
- Tag is followed through all other reactions involving NO_x and O_3
- One tag allowed per model run
 - Tagging multiple NO_x sources requires multiple runs
- What happens with the “null cycle”
 - $\text{O}_3 + \text{NO} \rightarrow \text{NO}_2$ and then ($\text{NO}_2 + \text{h}\nu \rightarrow \dots \rightarrow \text{O}_3$)
 - Which tag does NO_2 get?
 - It gets the tag from NO
 - The null cycle replaces O_3 tags!

- Allow for multiple tags in a single model run
- Tagged sources emitted as NO_XXX
 - NO_TAG + RO₂ -> NO₂_TAG
 - NO_FOO + RO₂ -> NO₂_FOO
 - NO_BAR + RO₂ -> NO₂_BAR
- Null cycle
 - O₃ + NO -> NO₂
 - Possibility for NO₂ to inherit from **both** O₃ and NO₂

- Introduce a new set of odd-oxygen tracers “X_TAG” species
- $\text{NO} + \text{RO}_2 \rightarrow \text{NO}_2 + \text{RO}$
- $\text{NO_TAG} + \text{RO}_2 \rightarrow \text{NO}_2_TAG + \text{NO}_2_X_TAG$
 - $\text{NO}_2_TAG + h\nu \rightarrow \text{NO_TAG}$
 - $\text{NO}_2_X_TAG + h\nu \rightarrow \dots \rightarrow \text{O}_3_X_TAG$
- Null cycle
 - $\text{O}_3 + \text{NO} \rightarrow \text{NO}_2$
 - $\text{O}_3 + \text{NO_TAG} \rightarrow \text{NO}_2_TAG$
 - $\text{O}_3_X_TAG + \text{NO} \rightarrow \text{NO}_2_X_TAG$

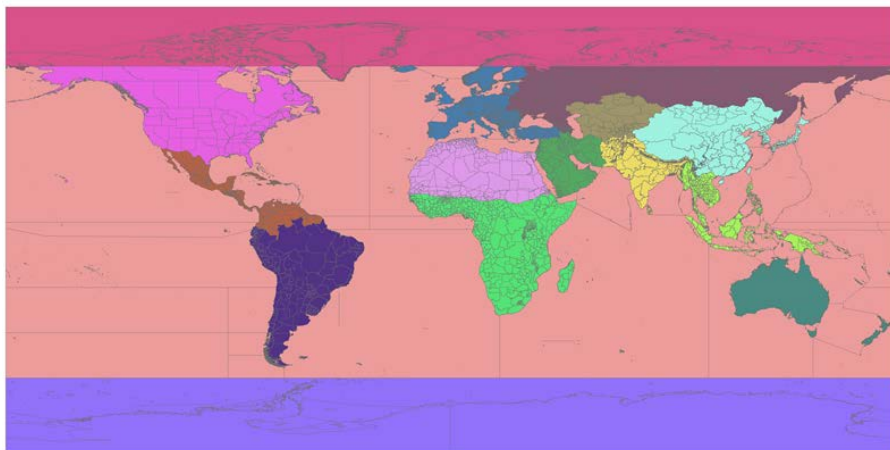
- Perl Scripts
 - Specify a list of tags to apply (eg. "TAG", "FOO", "BAR")
 - Rewrite the mechanism file, adding new reactions and tracers
 - Rewrite model source code (tracers, reaction rates, etc...)

- Each tag adds:
 - 155 reactions
 - 26 tracers

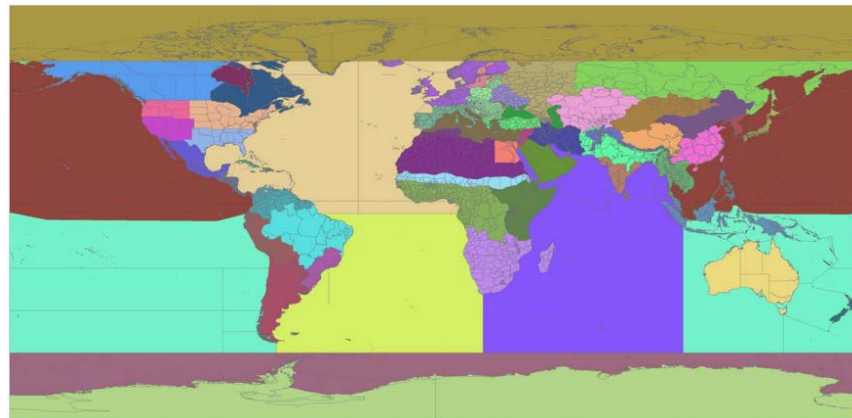
Model setup

- CESM 1.2.2, FSDCHM compset
- Modified mechanism from Emmons et al. (2012)
- Modified chemical preprocessor
- HTAP2 experiment protocol

Source regions

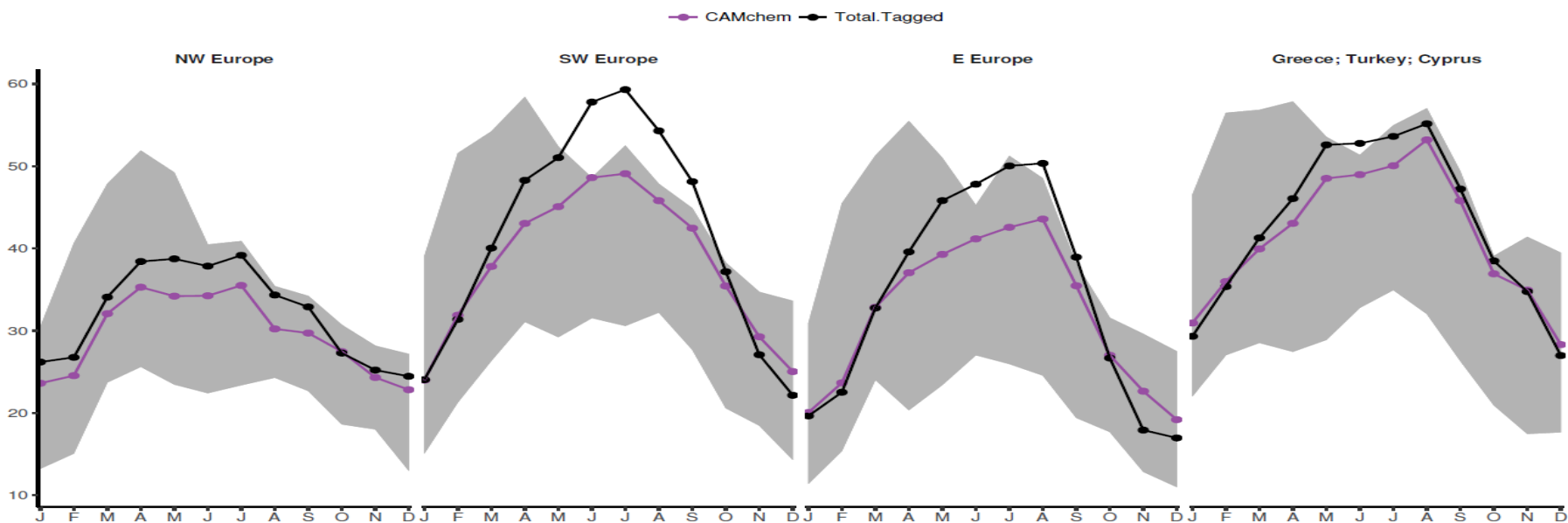
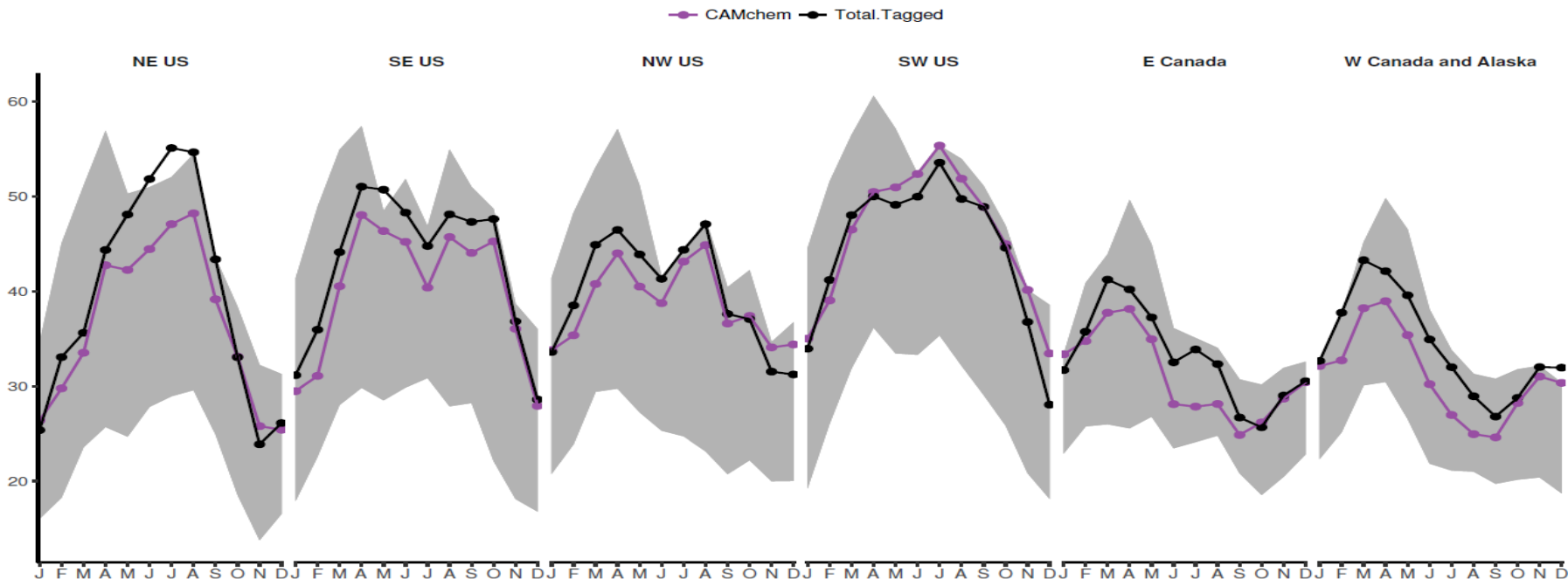


Receptor regions

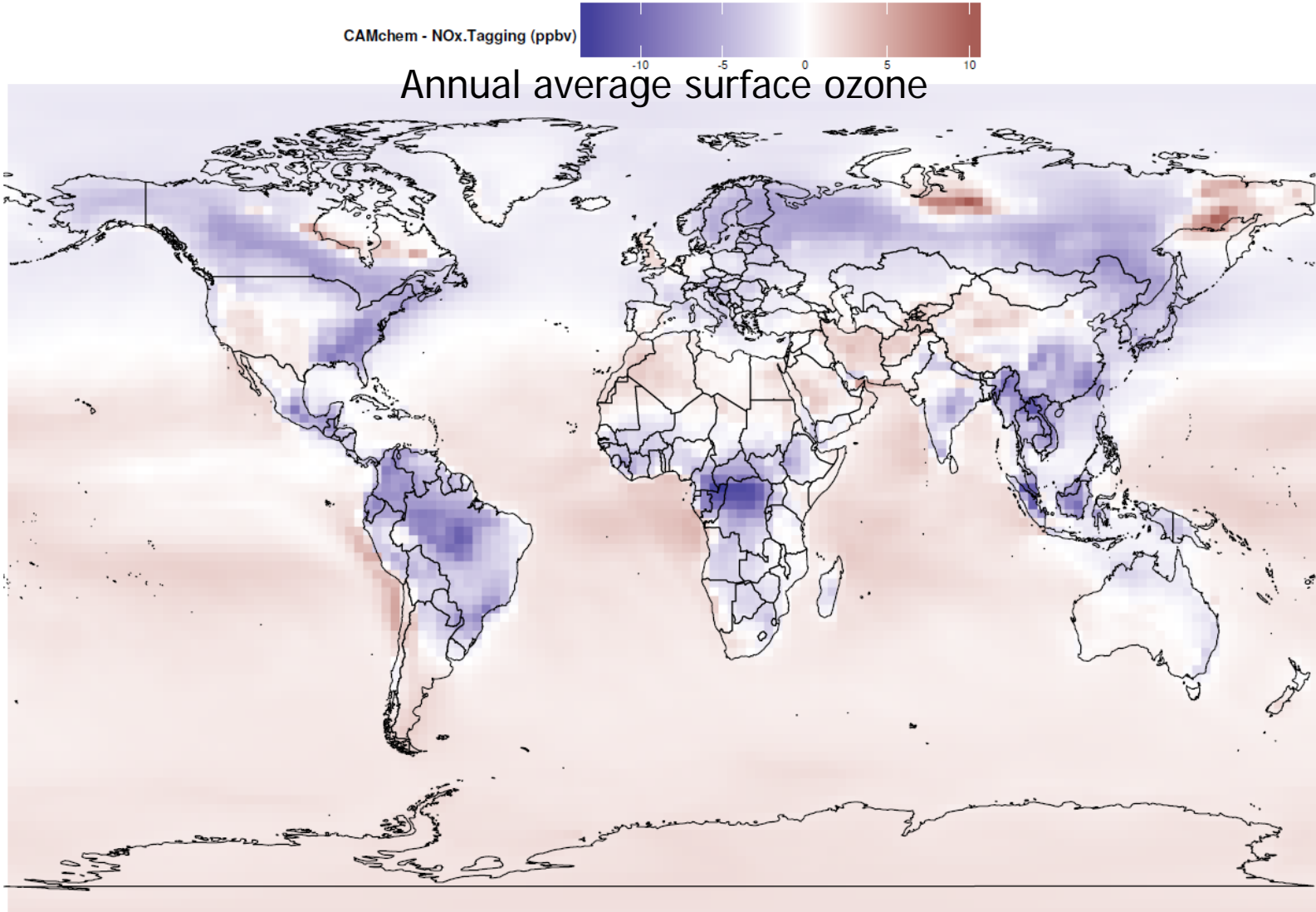


Evaluation: comparison with the HTAP2 ensemble and CAM-chem

Mean Ozone (ppbv) in Tier 2 Receptor Regions from NO_x sources.
Comparison with Min and Max of HTAP ensemble and NCAR CAMchem run

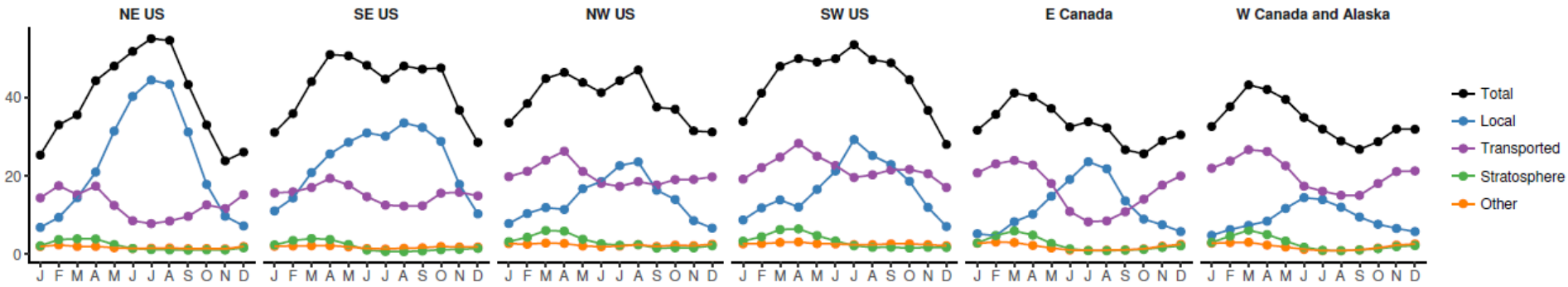


Comparison with CAM-chem HTAP2 run

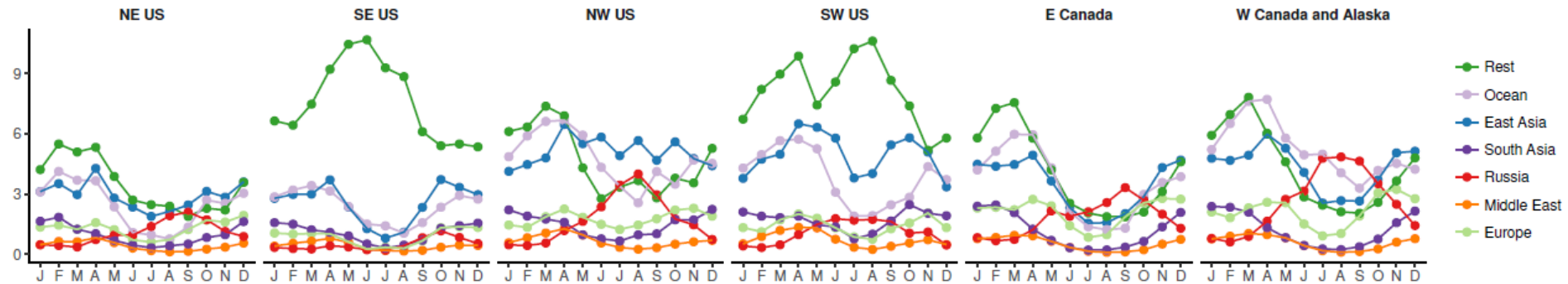


North America: Monthly Average O3 for Emissions and Meteorology for Year 2010

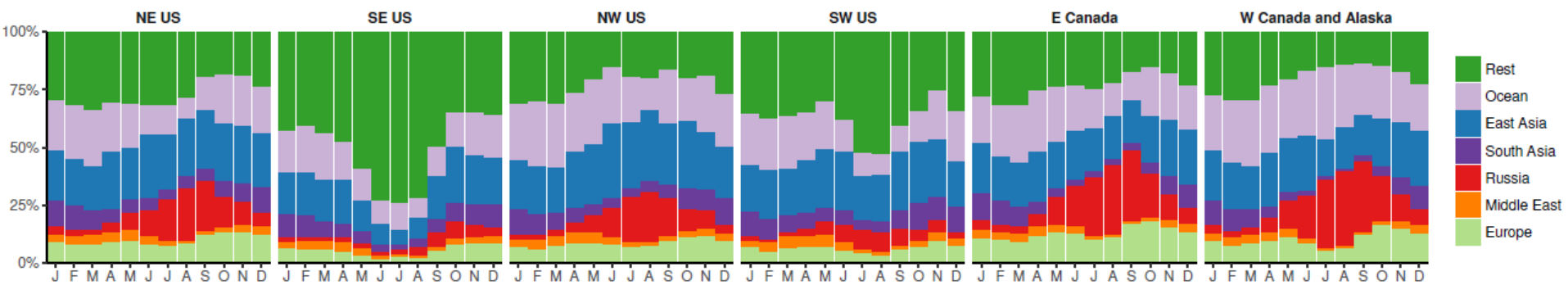
Total Ozone Mean (ppbv) and Mean from NOx Sources in Tier 2 Receptor Regions



Monthly Mean O3 of Transported NOx Sources from Source Regions to Tier 2 Receptor Regions

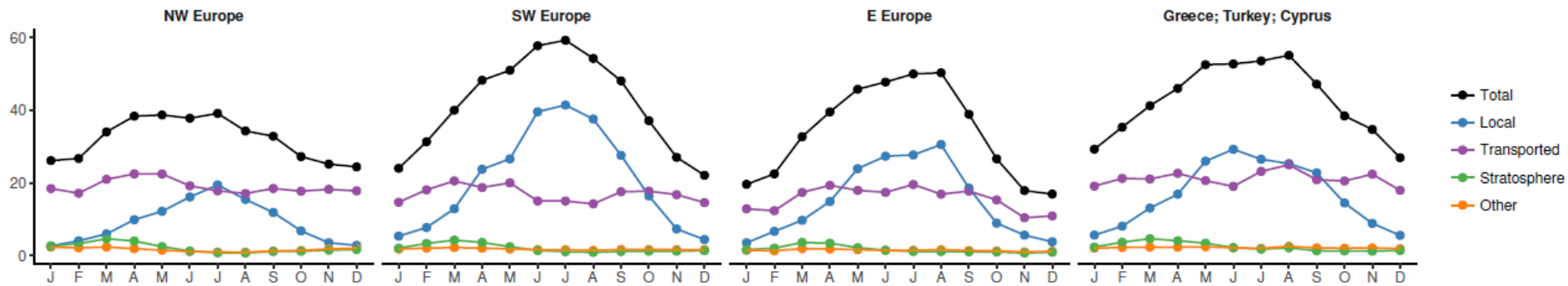


Percent Contributions of Transported NOx Sources from Source Regions to Tier 2 Receptor Regions

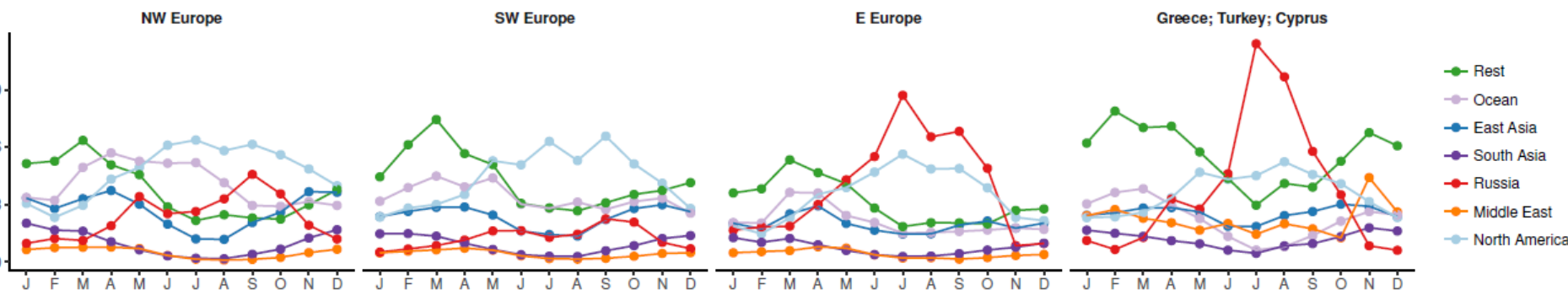


Europe: Monthly Average O3 for Emissions and Meteorology for Year 2010

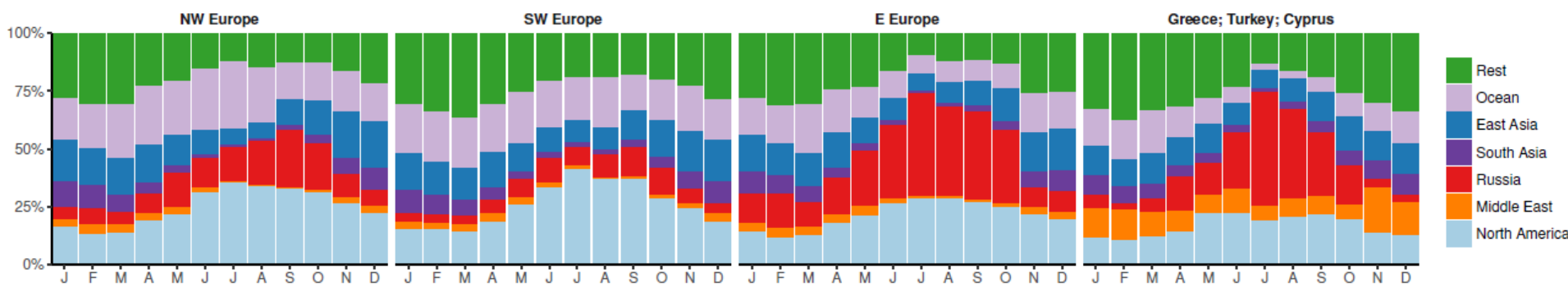
Total Ozone Mean (ppbv) and Mean from NOx Sources in Tier 2 Receptor Regions



Monthly Mean O3 of Transported NOx Sources from Source Regions to Tier 2 Receptor Regions



Percent Contributions of Transported NOx Sources from Source Regions to Tier 2 Receptor Regions



- Extended version of existing tagging in CAM-chem
- Support for multiple tags
- O_x cycling preserves tags
- Application to HTAP2 source/receptor modelling

- Next steps:
 - Obtain a tagged simulation consistent with a scientifically supported CESM compset
 - Most appropriate configuration of CESM2?

 - Add VOC tagging (already in testing)

- Original code:

```
if( jno2a_ndx > 0 .and. jno2_ndx > 0 ) then
    photos(:,:,jno2a_ndx) = photos(:,:,jno2_ndx)
end if
```

- Manually modified “template” code:

```
! BEGIN TAGGING CODE
```

```
if( jno2_tag_ndx > 0 .and. jno2_ndx > 0 ) then
    photos(:,:,jno2_tag_ndx) = photos(:,:,jno2_ndx)
end if
```

```
! END TAGGING CODE
```

- Template code is then automatically processed to produce compiler-ready code...