WACCM-D:
Modelling mesospheric ion chemistry for particle precipitation studies

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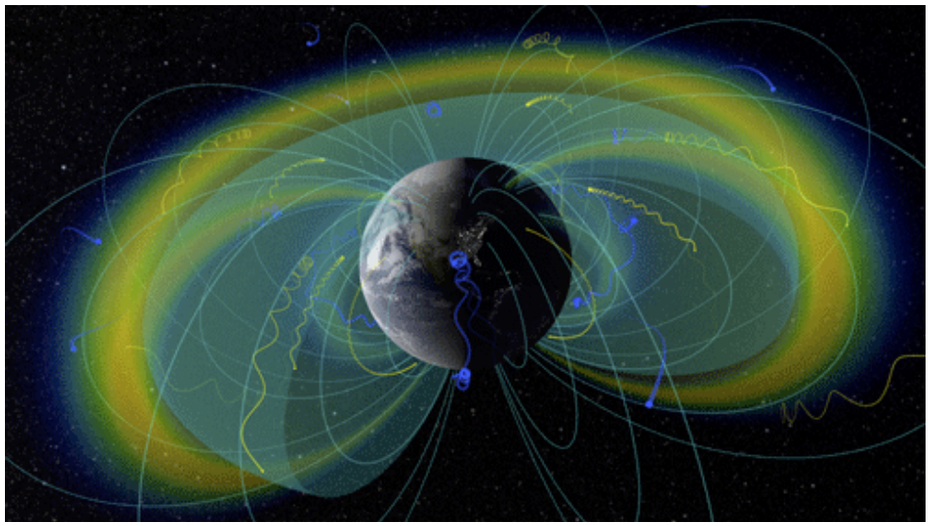
Finnish Meteorological Institute

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

UNIVERSITY OF LEEDS

What we did?

energetic particle precipitation

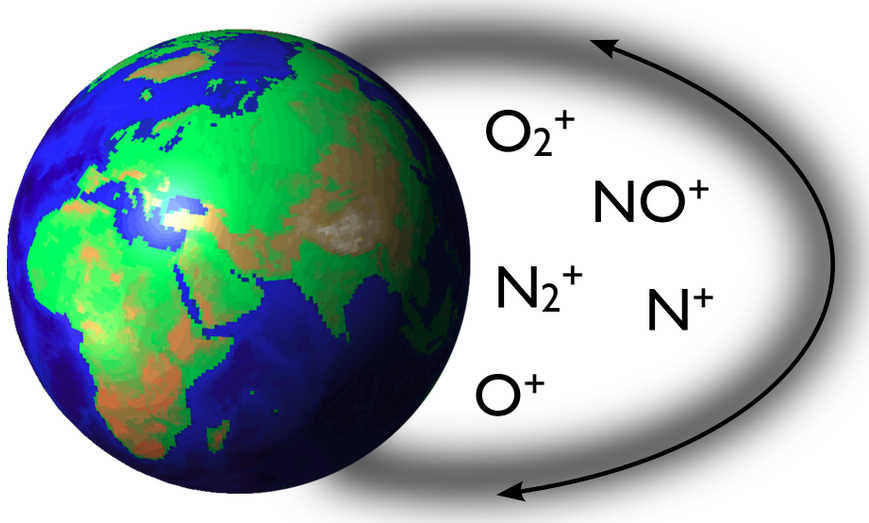


What we did?

energetic particle precipitation

↓

increased ionisation



What we did?

energetic particle precipitation

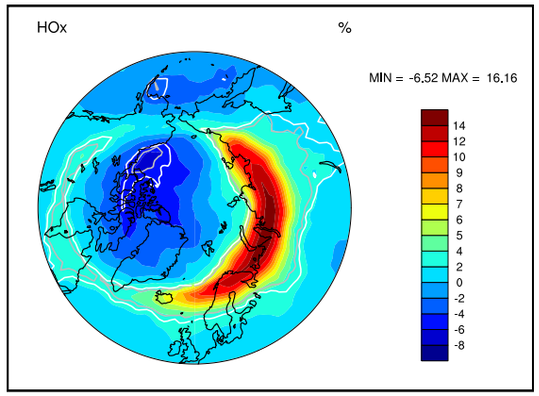
↓

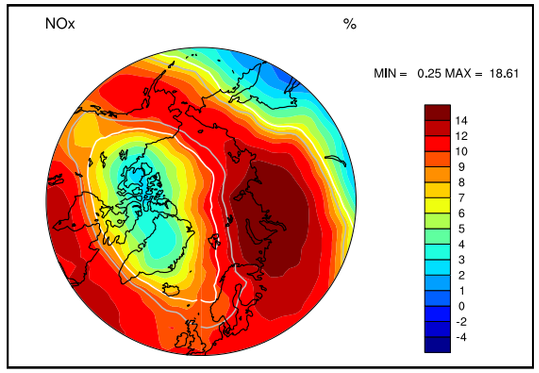
increased ionisation

↙ ↘

HO_x enhancement
direct effect

NO_x enhancement
indirect effect





What we did?

energetic particle precipitation

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increased ionisation

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HO_x enhancement
direct effect

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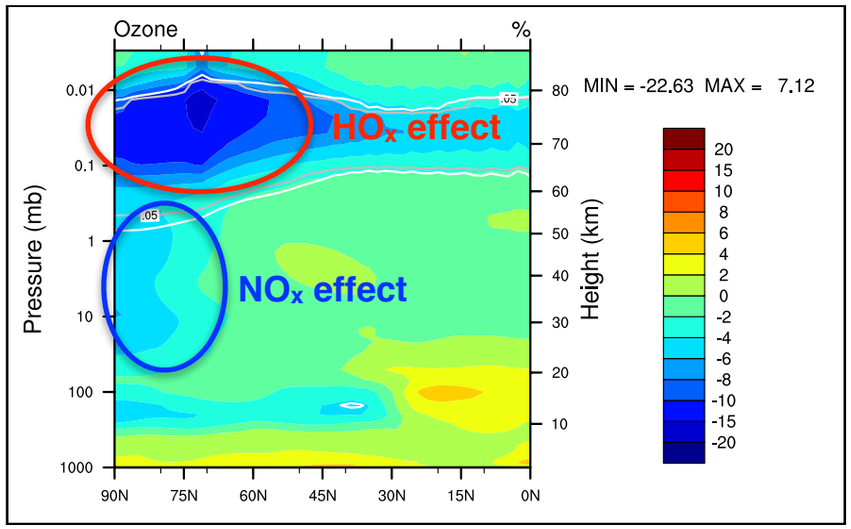
ozone loss: mesosphere

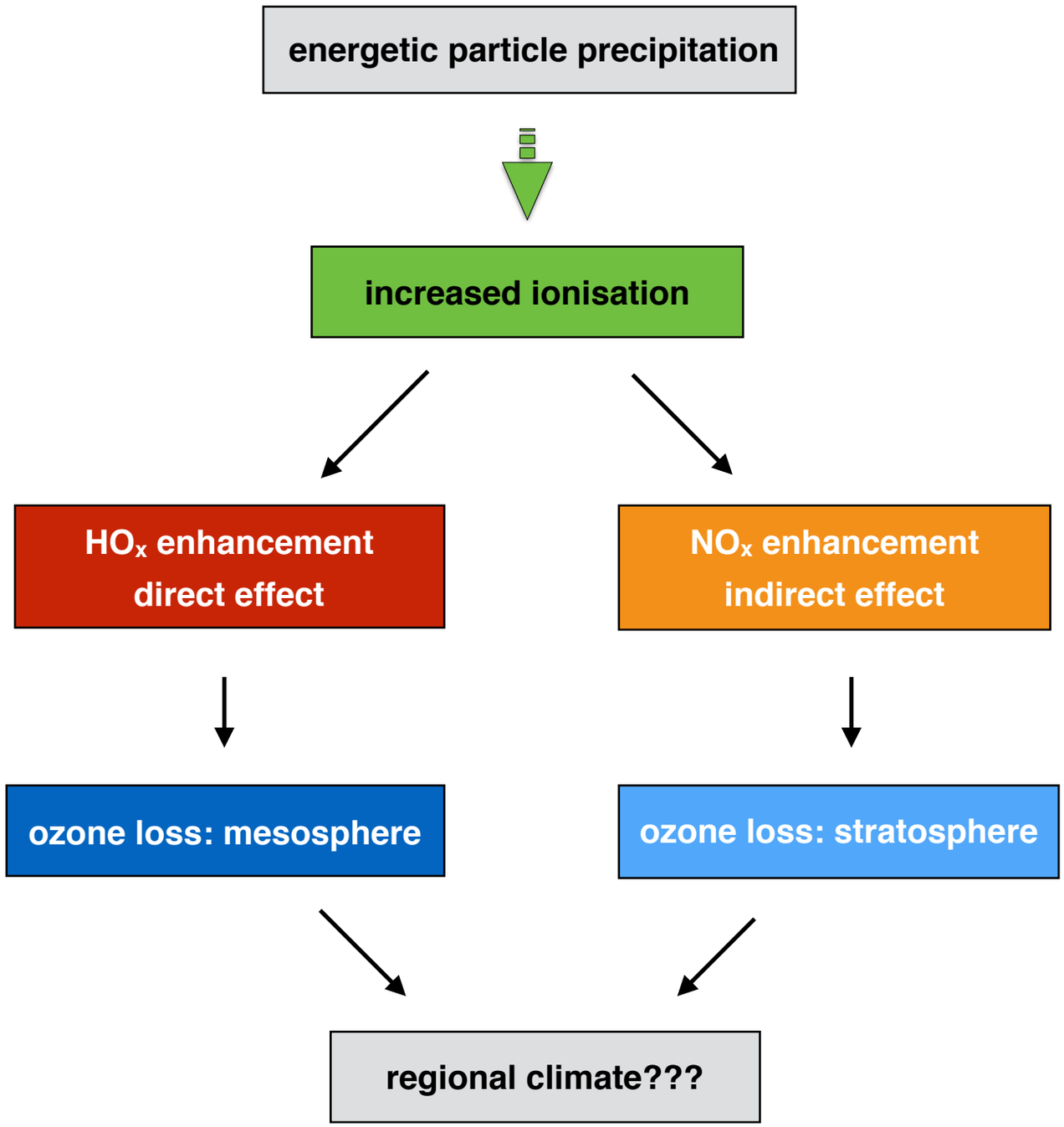
NO_x enhancement
indirect effect

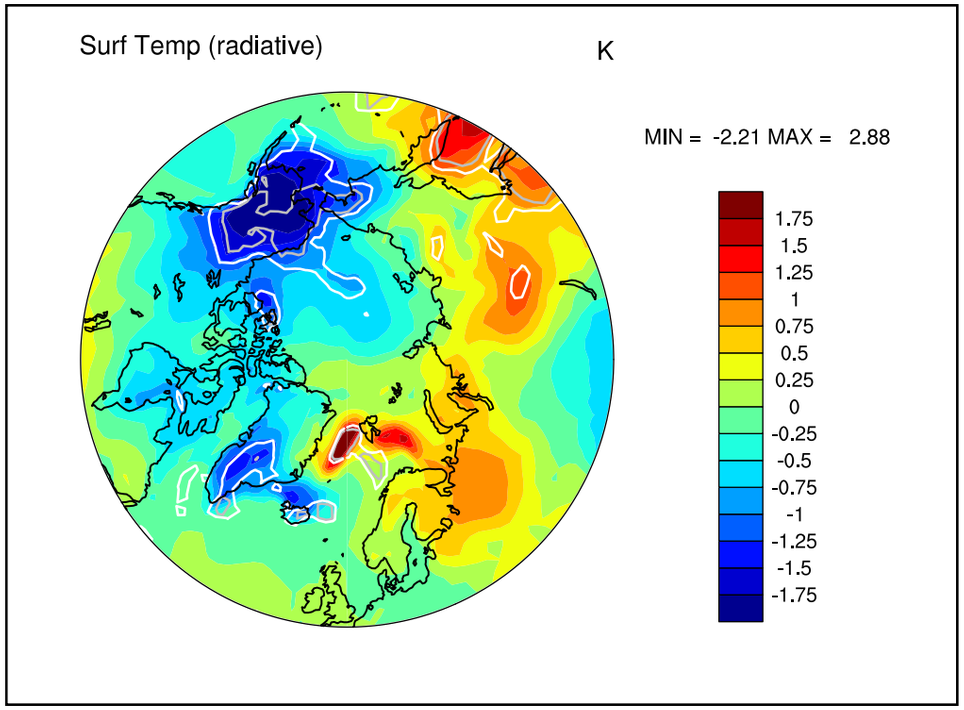
↓

ozone loss: stratosphere

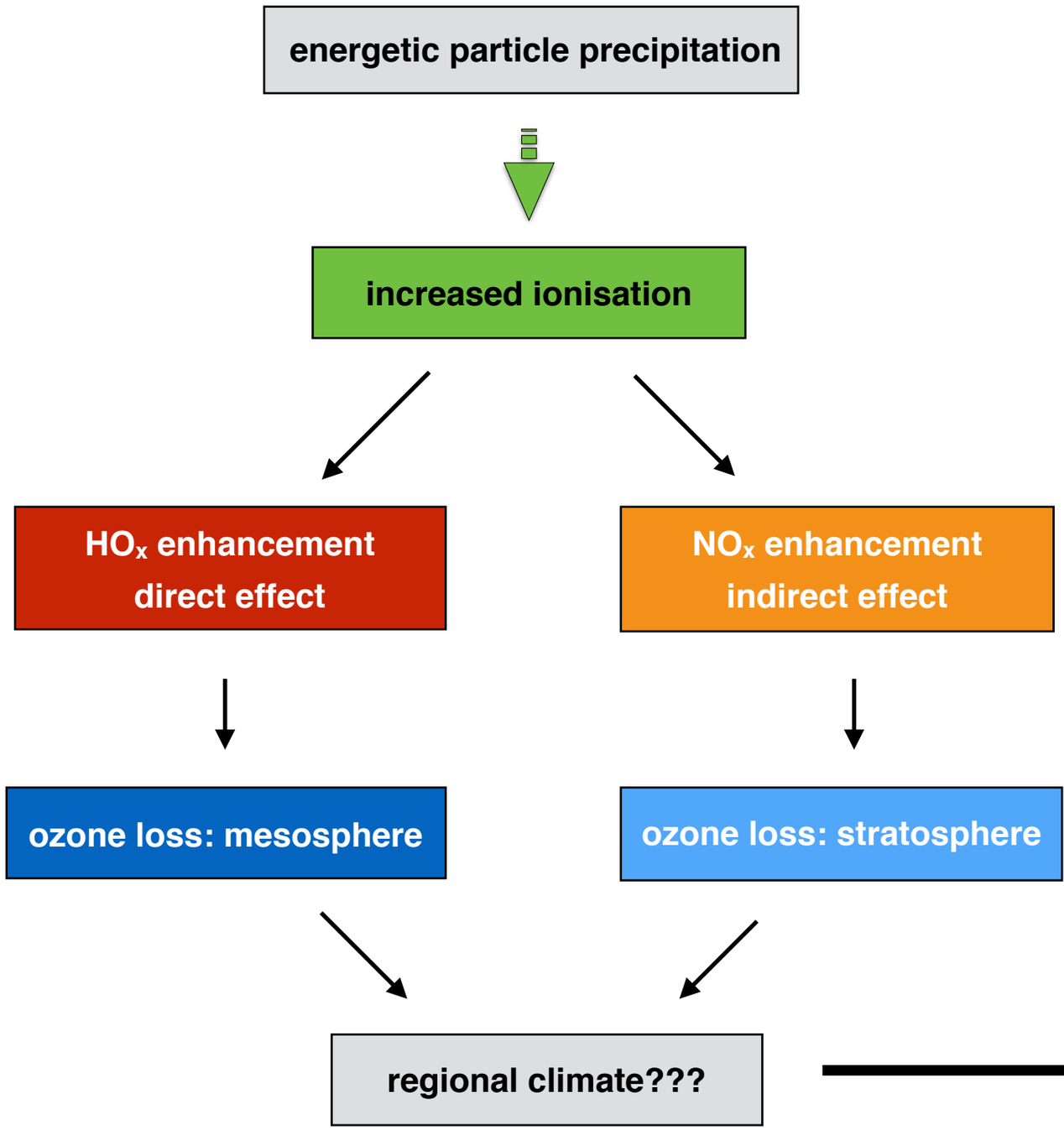


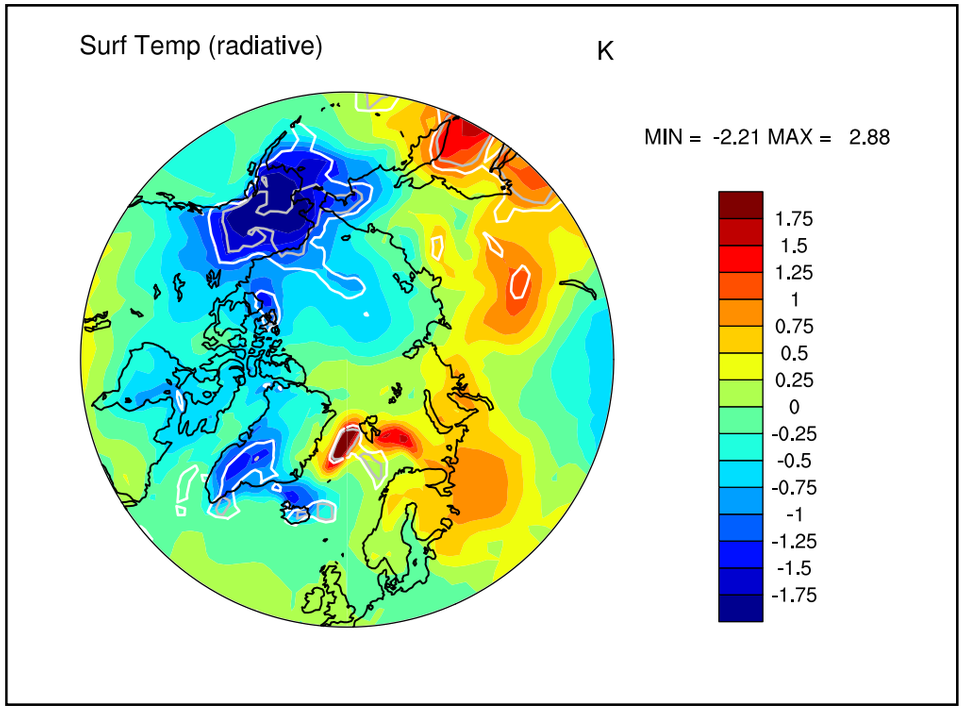
What we did?


energetic particle precipitation
increased ionisation
HO_x enhancement
direct effect
NO_x enhancement
indirect effect
ozone loss: mesosphere
ozone loss: stratosphere
regional climate???


Surf Temp (radiative)
K
MIN = -2.21 MAX = 2.88
1.75
1.5
1.25
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
-1.25
-1.5
-1.75

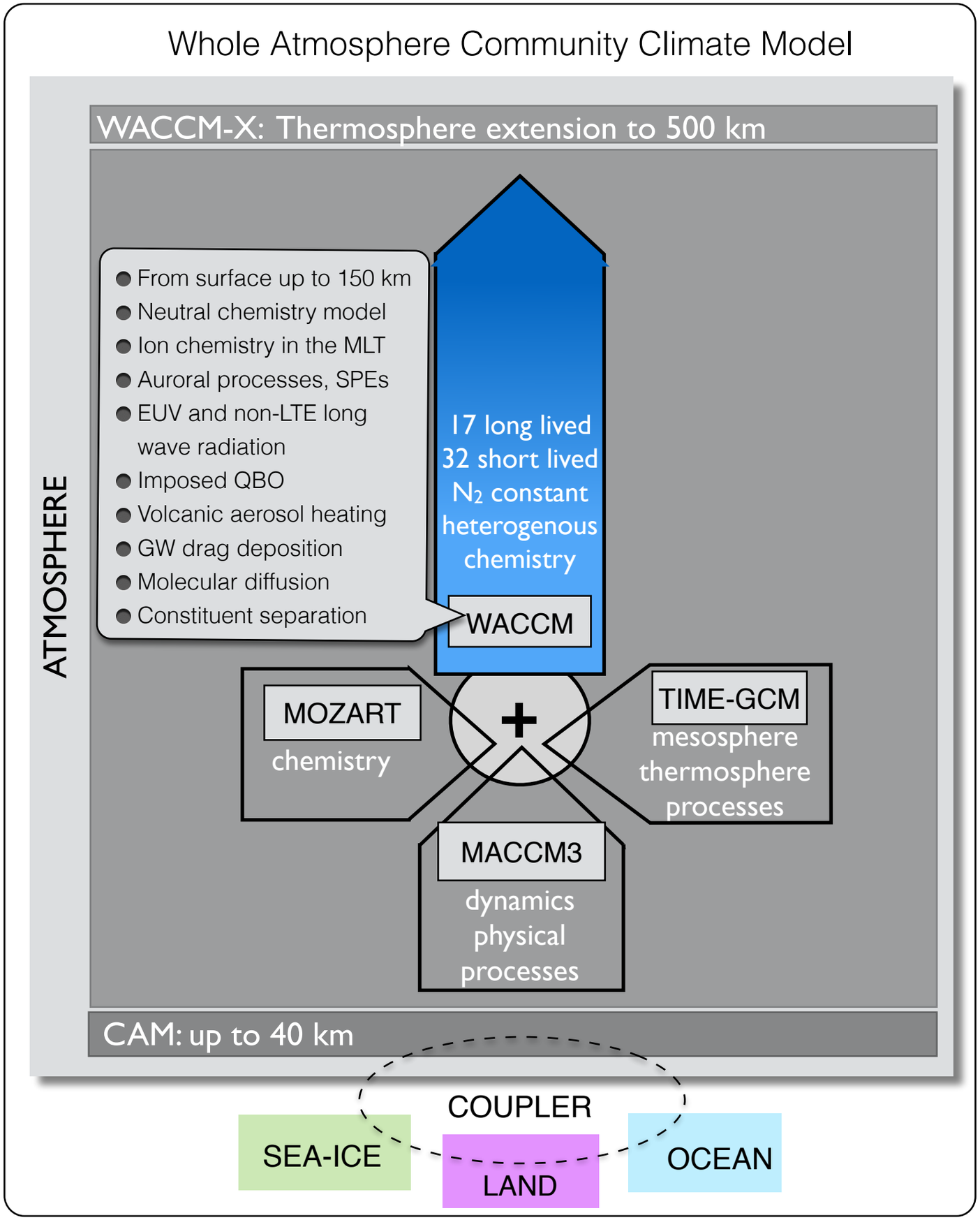
What we did?



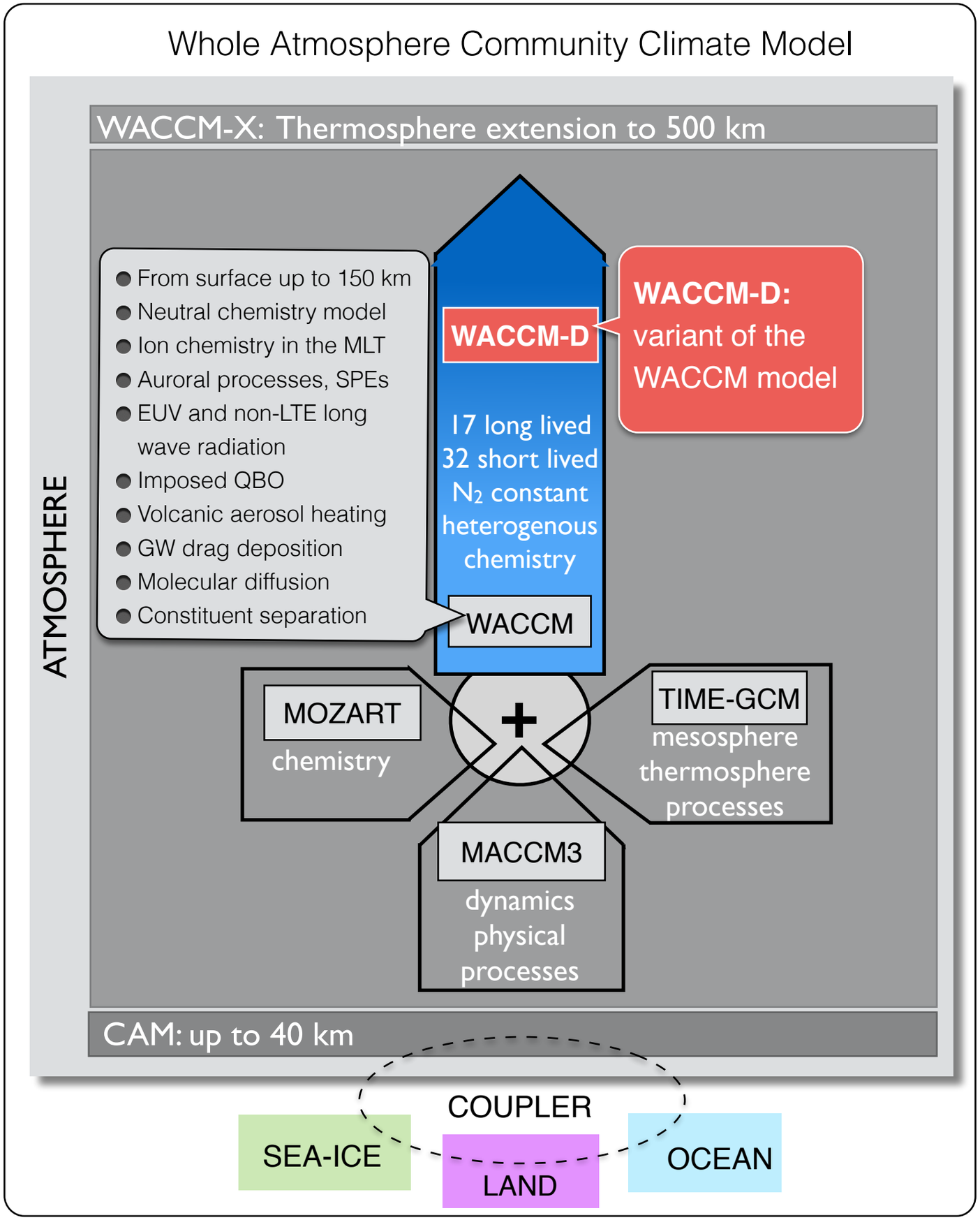


- The ion-neutral connection in the middle atmosphere is missing from the climate models today
- Medium Energy Electrons are not included in the models

WACCM-D


Whole Atmosphere Community Climate Model
WACCM-X: Thermosphere extension to 500 km
ATMOSPHERE
From surface up to 150 km
Neutral chemistry model
Ion chemistry in the MLT
Auroral processes, SPEs
EUV and non-LTE long wave radiation
Imposed QBO
Volcanic aerosol heating
GW drag deposition
Molecular diffusion
Constituent separation
17 long lived
32 short lived
N_2 constant
heterogenous chemistry
WACCM
MOZART
chemistry
+
TIME-GCM
mesosphere
thermosphere
processes
MACCM3
dynamics
physical
processes
CAM: up to 40 km
COUPLER
SEA-ICE
LAND
OCEAN

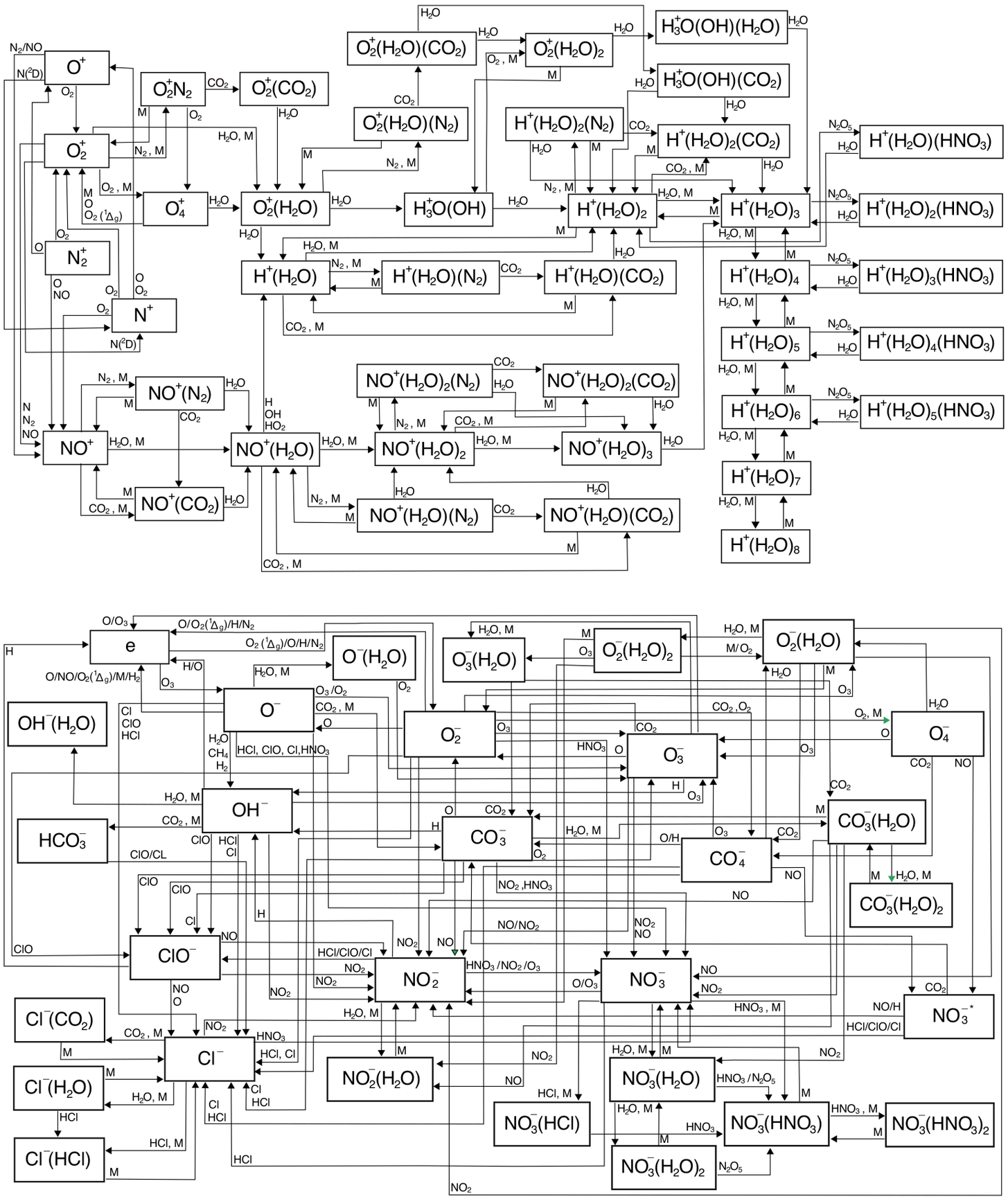
WACCM-D



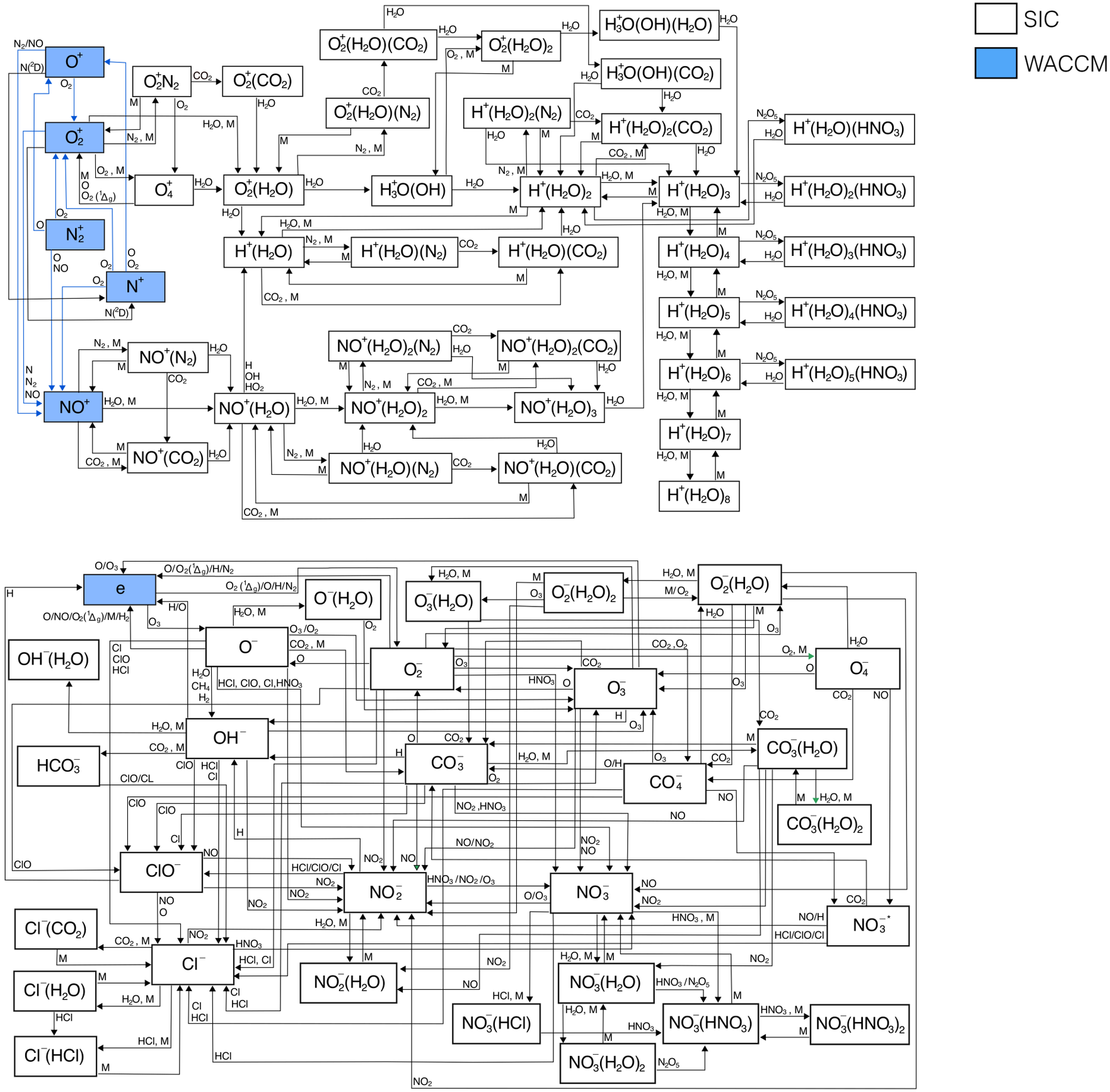
WACCM-D

- incorporates D-region ion chemistry to produce the observed EPP effects
- ion reaction schemes based on 1D ion chemistry model (SIC)
- parameterised HO_X and NO_X production replaced by initial production rates of ions and neutrals due to particle impact

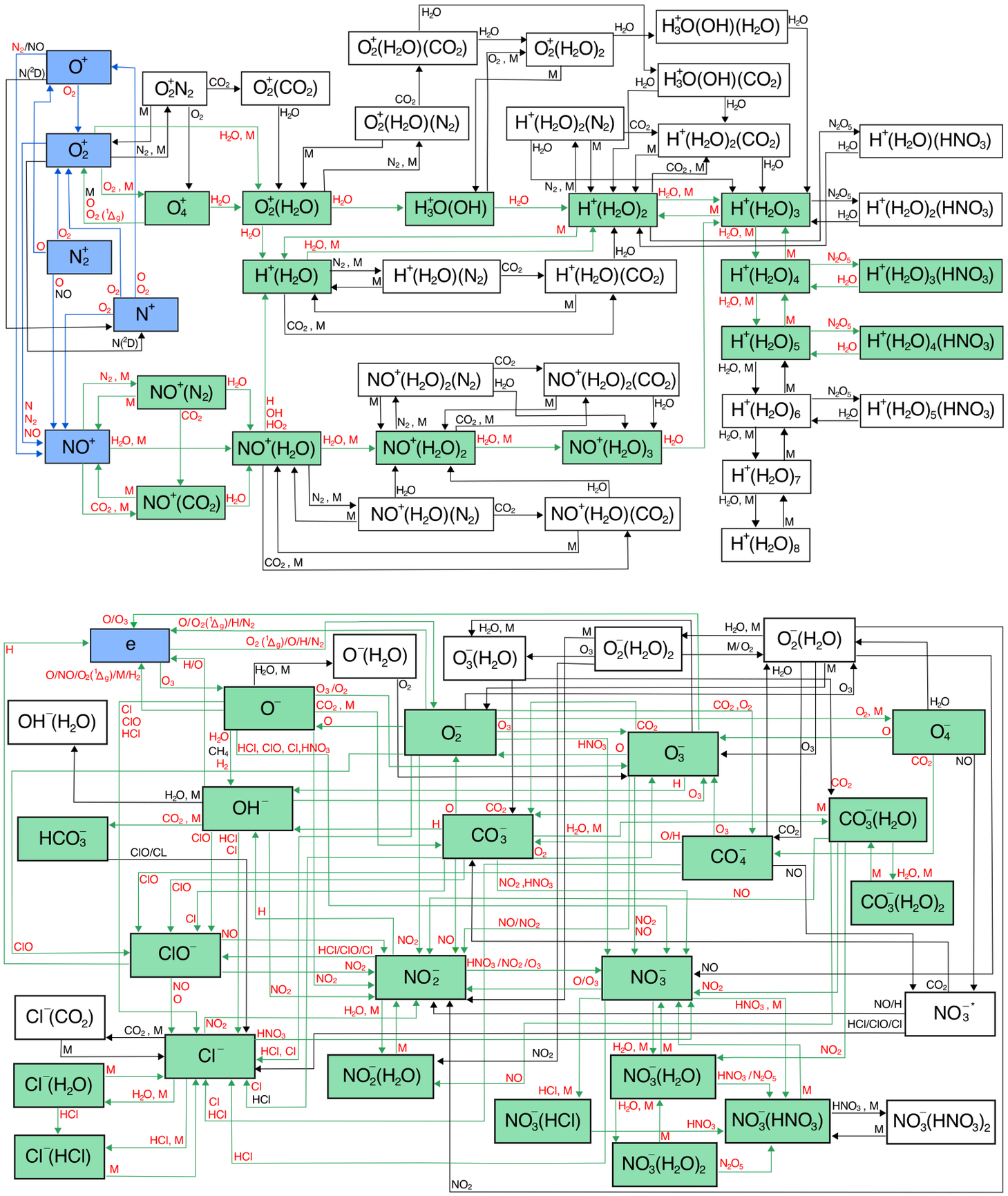
Positive and negative ions



Positive and negative ions



Positive and negative ions



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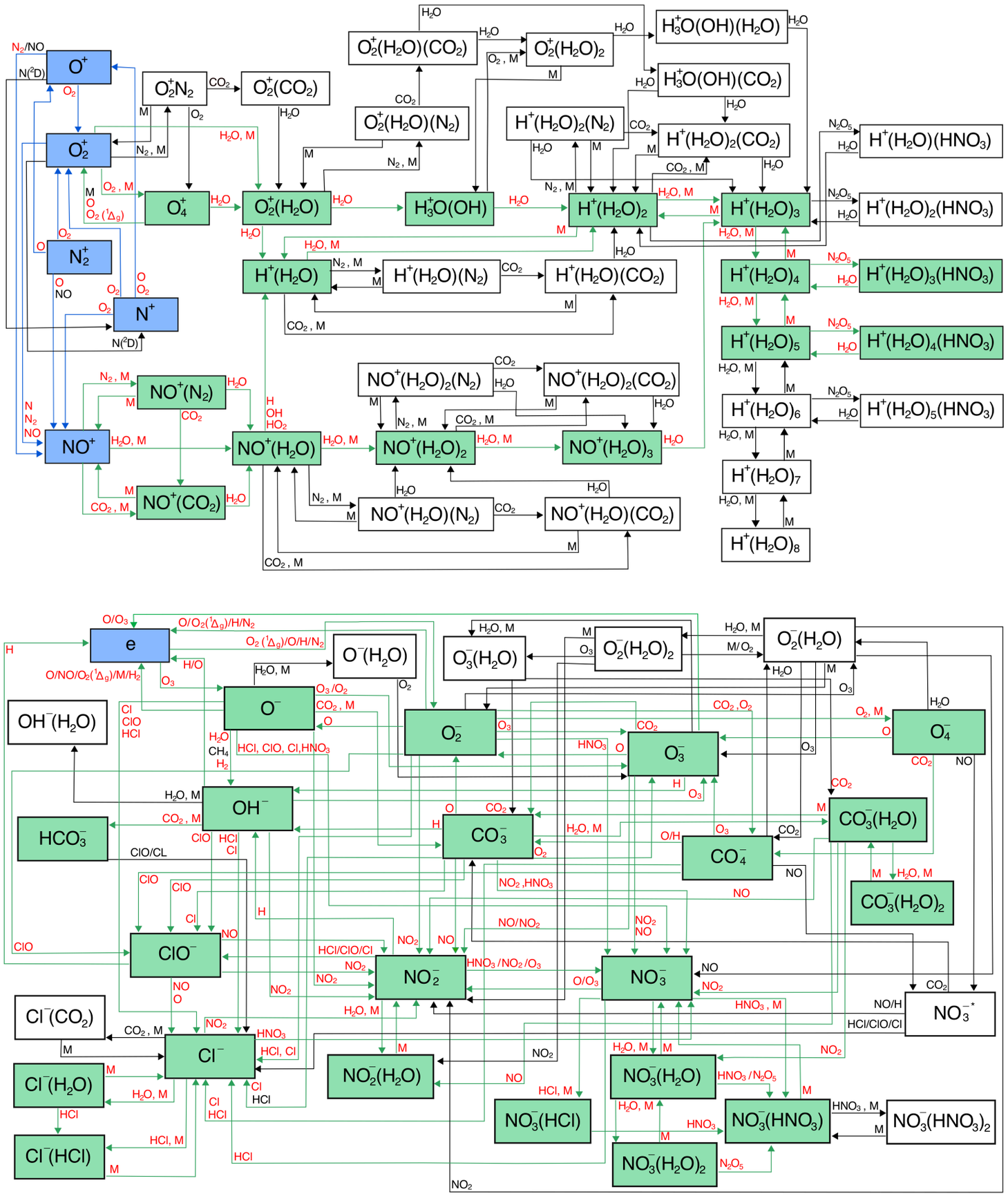


SIC

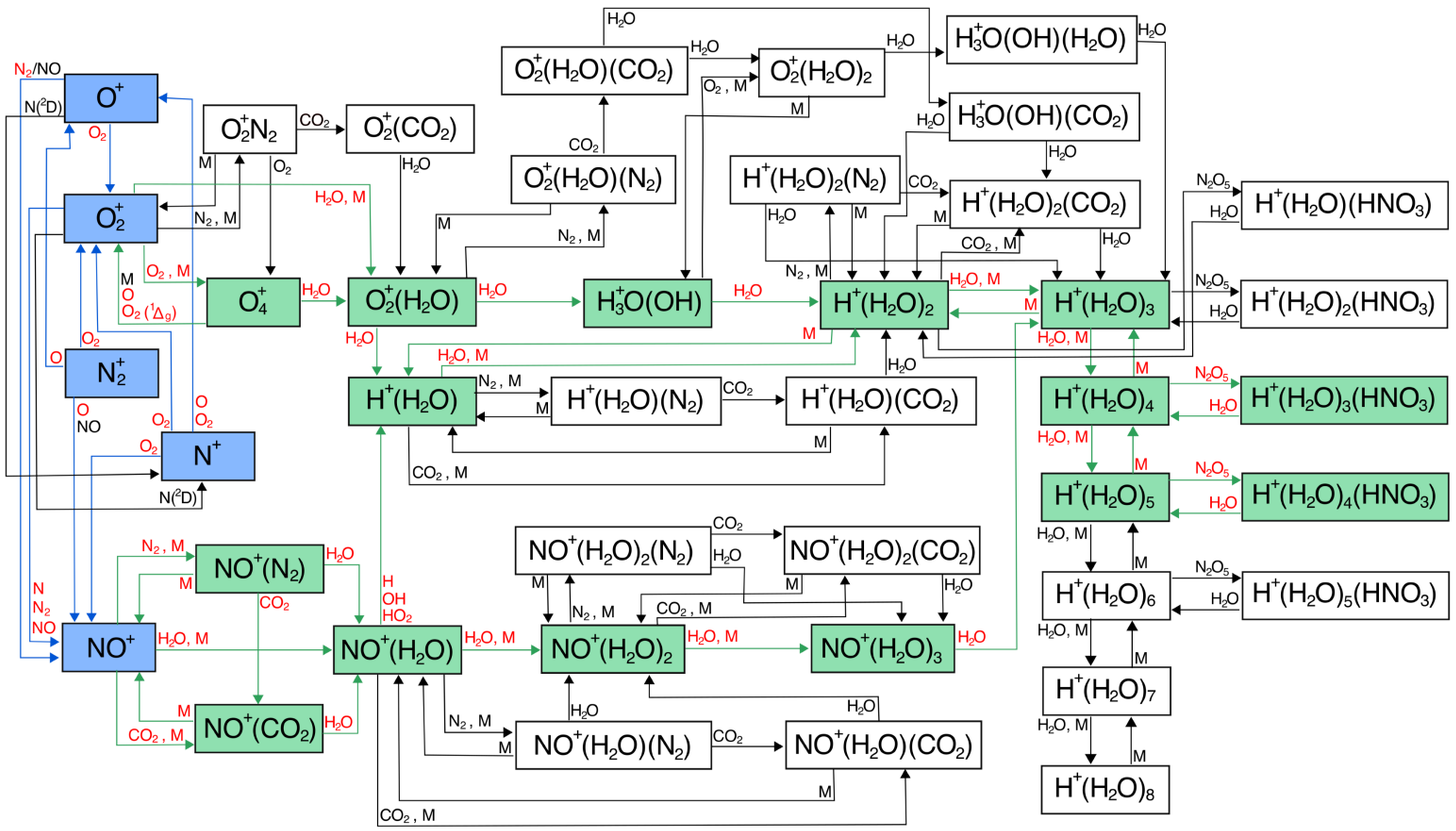
WACCM

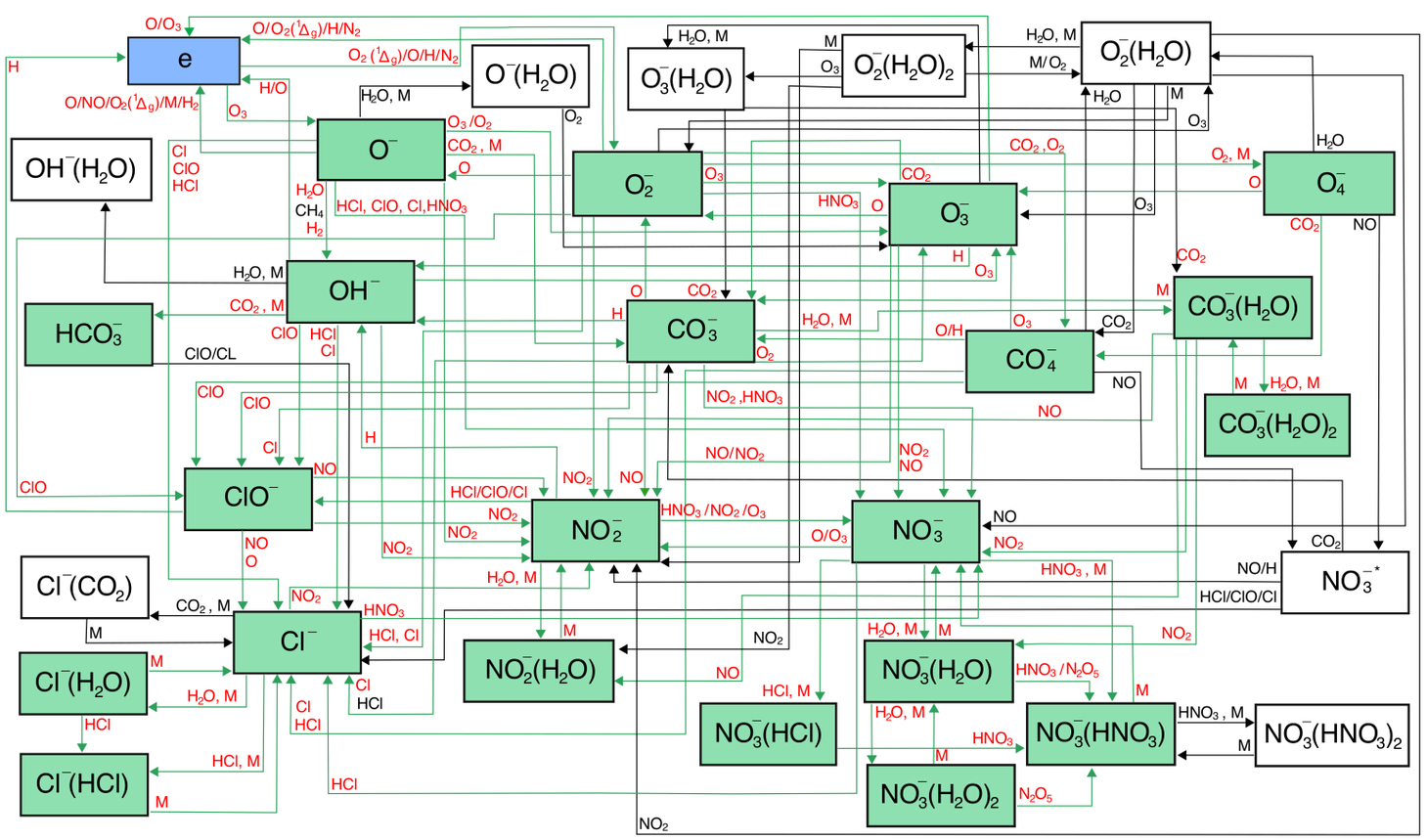
WACCM-D

SIC

42 positive ions
30 negative ions
400 ion-neutral reactions
~1000 IIR reactions

Positive and negative ions





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WACCM-D

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42 positive ions
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400 ion-neutral reactions
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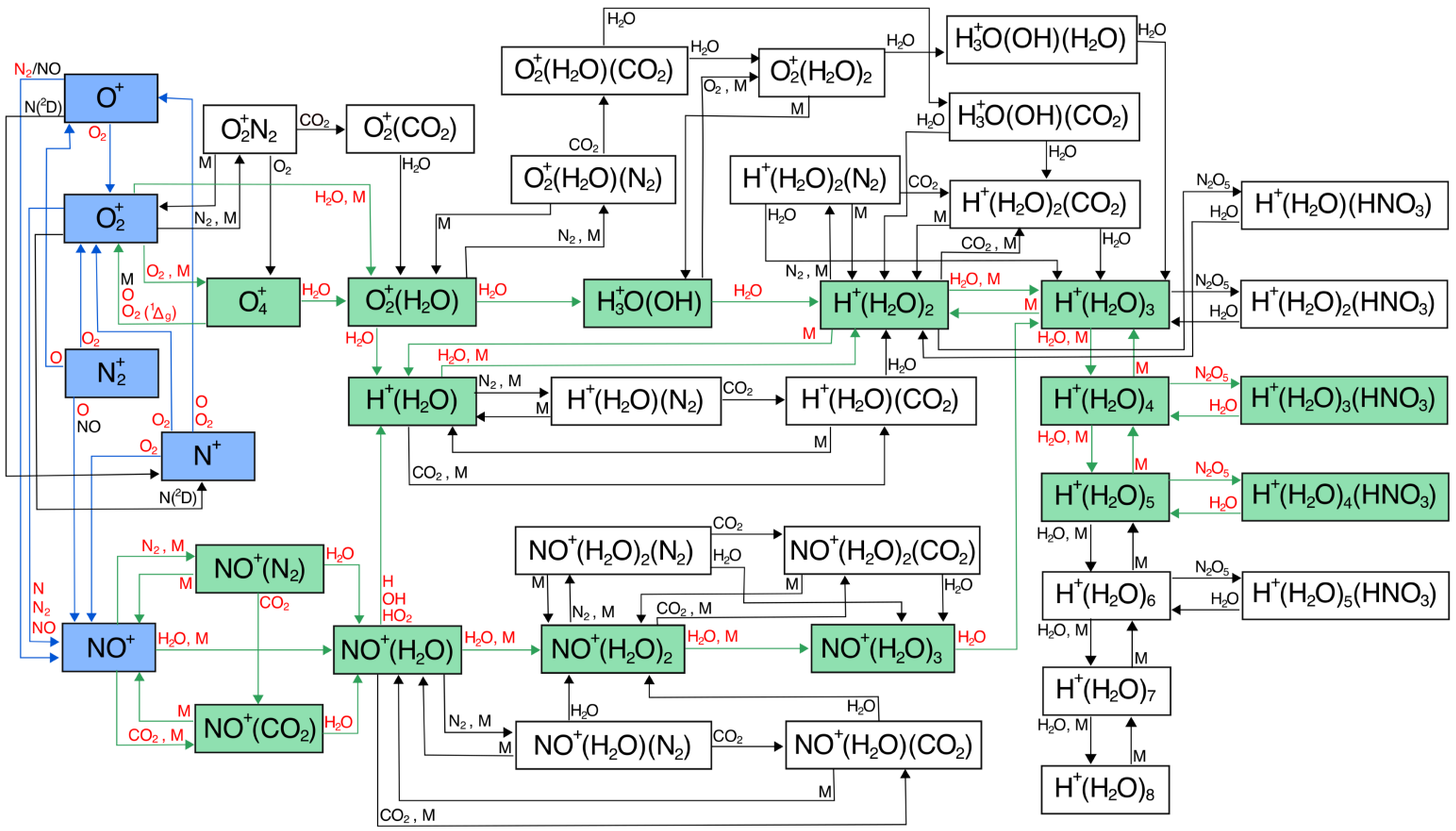
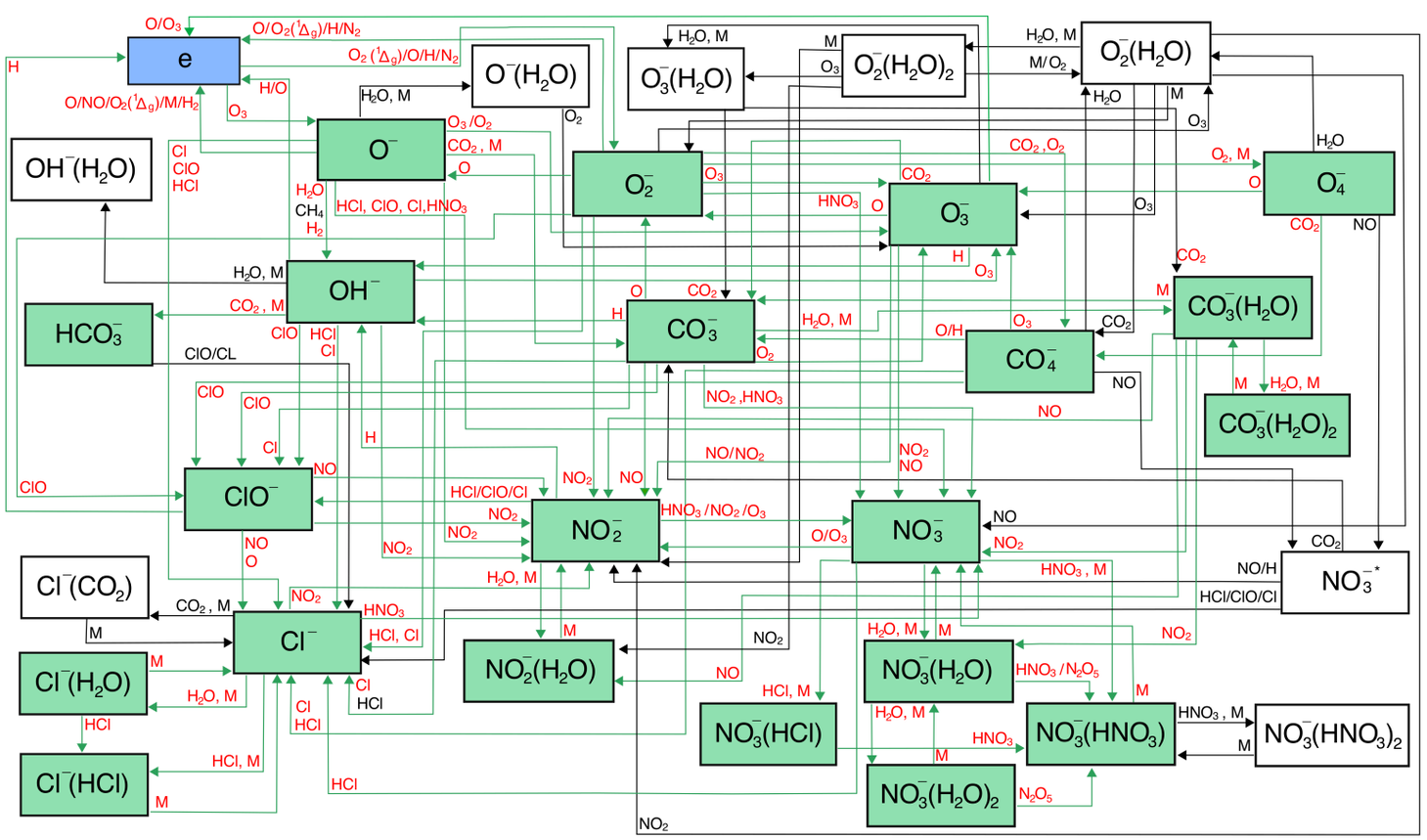
Reduction:
ions: 50%
reactions: 80%

WACCM-D

20 positive ions
22 negative ions
166 ion-neutral reactions
126 IIR reactions

Positive and negative ions





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WACCM

WACCM-D

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400 ion-neutral reactions
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Reduction:
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WACCM-D

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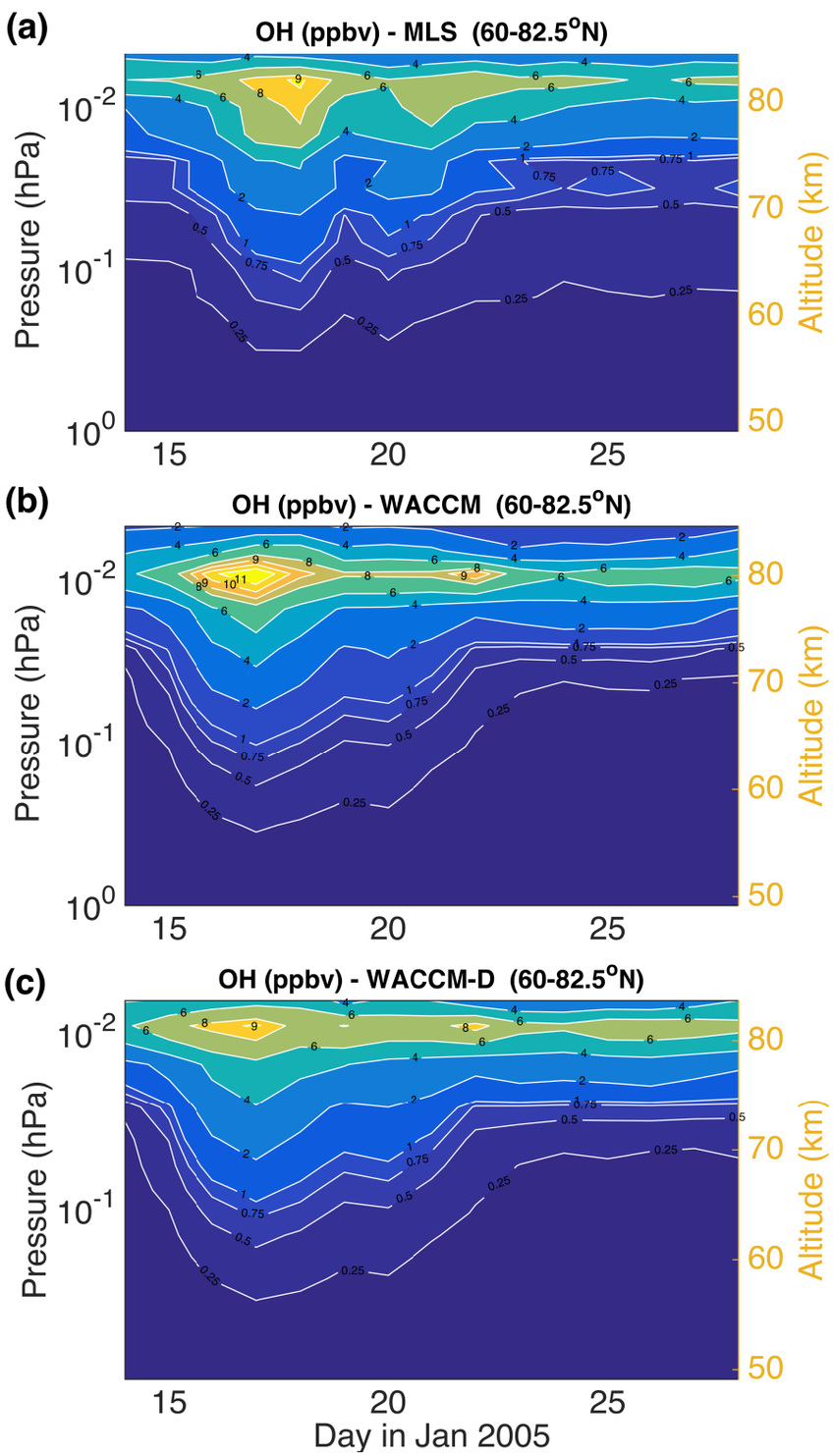
Performance

WACCM:
2.1 simulated years/day
WACCM-D:
1.1 simulated years/day

WACCM-D vs MLS

1. **REF run:**
   compset F_SD_WACCM (FSDW)
   prescribed sea ice, data ocean
   WACCM driven by GEOS meteorological fields
   resolution: 1.9x2.5 with 88 levels
   solar proton events, auroral electrons
2. **WACCM-D run:**
   same as REF run
   D-region ion chemistry

OH, 60-90°N



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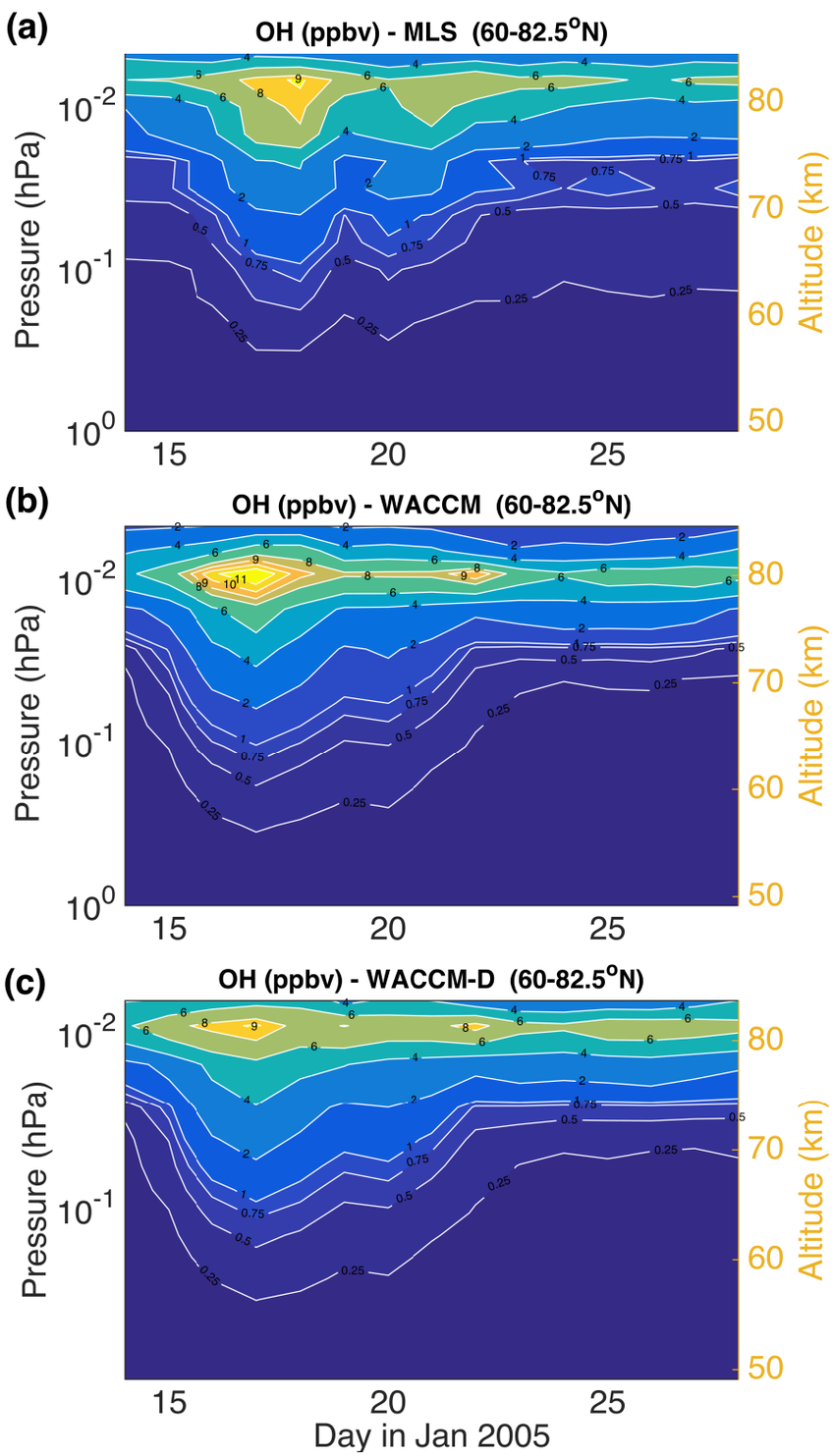
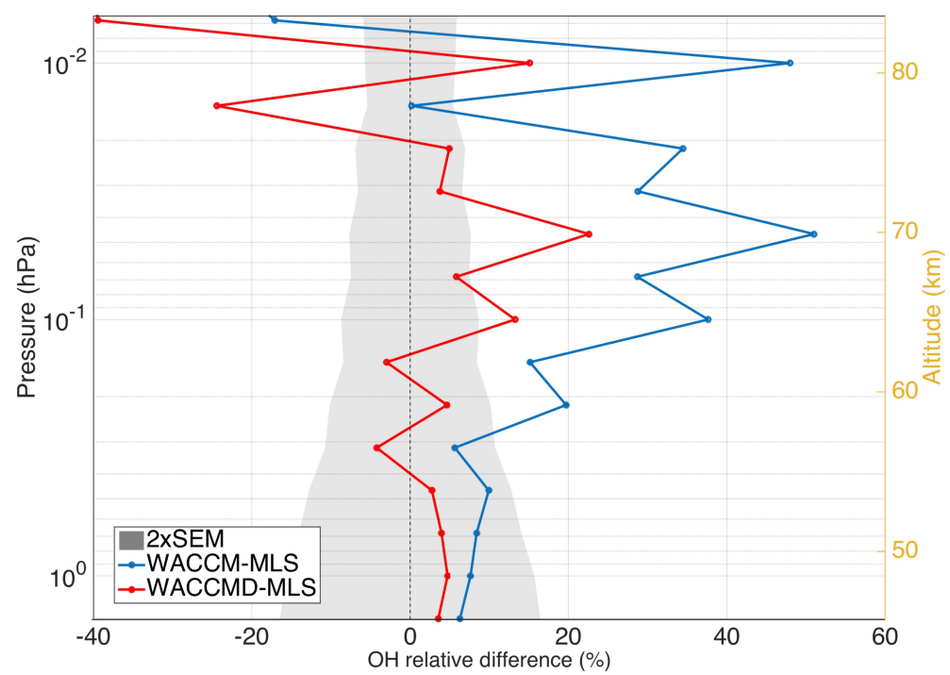


OH: differences between model and MLS



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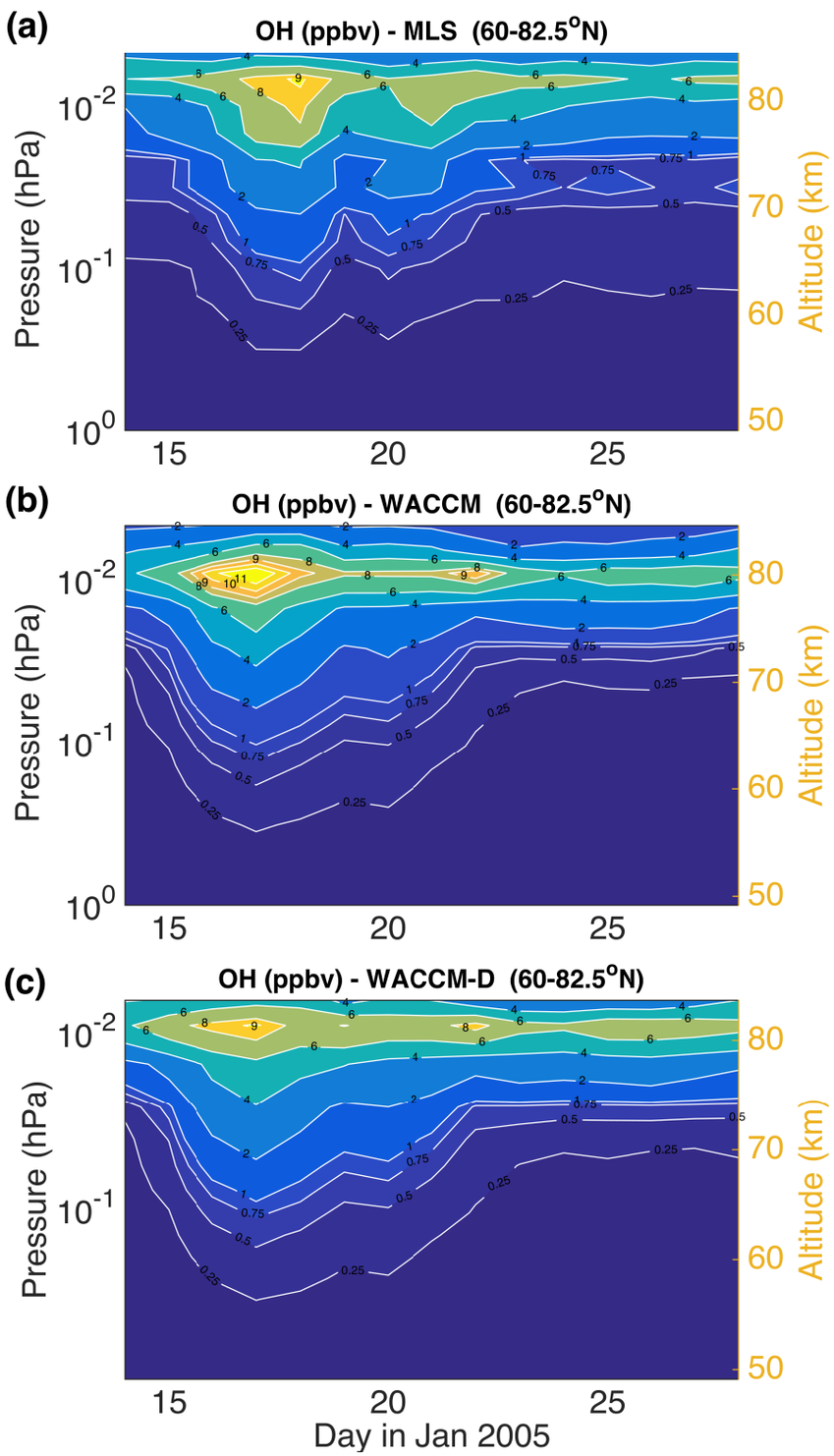
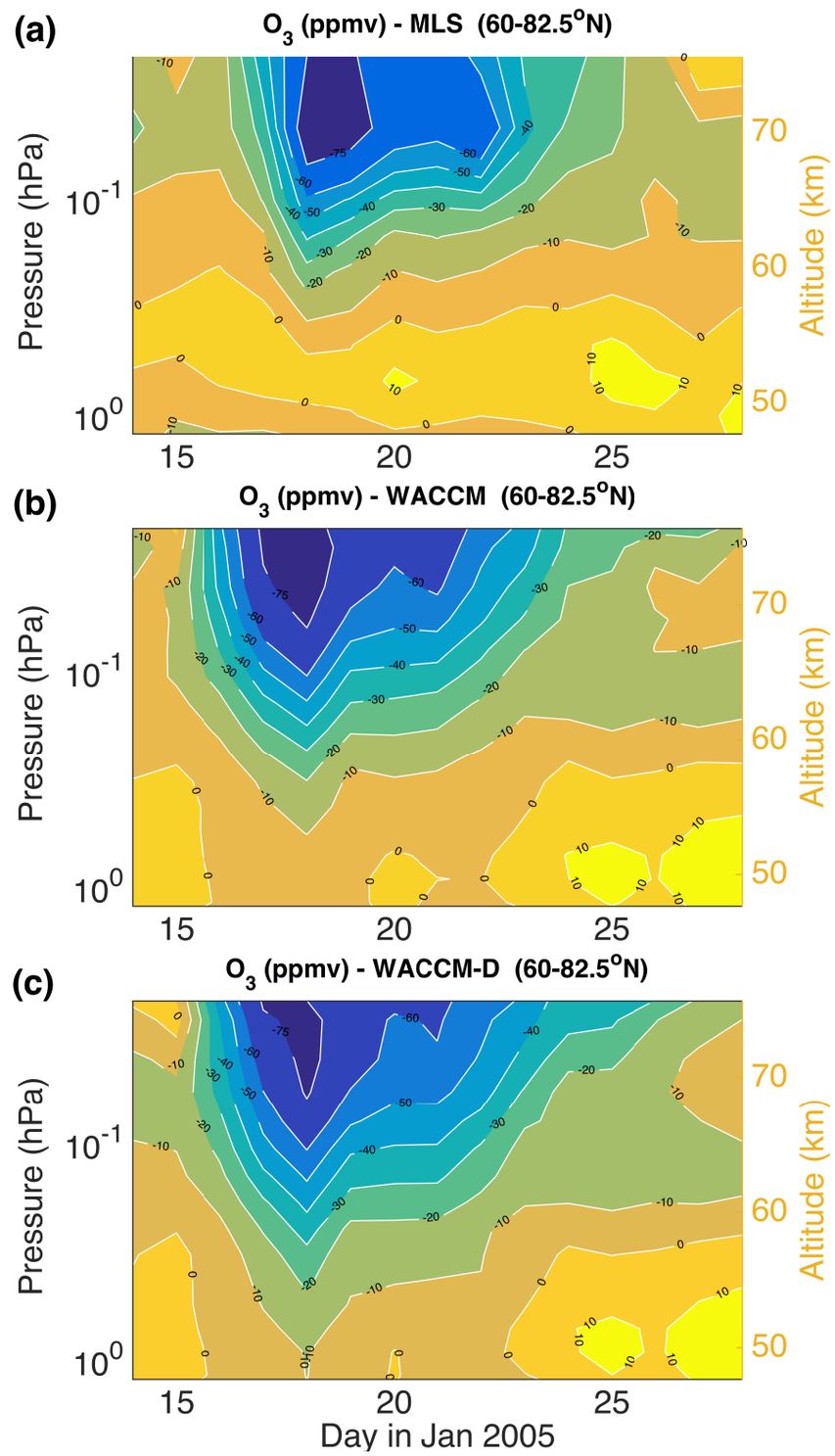
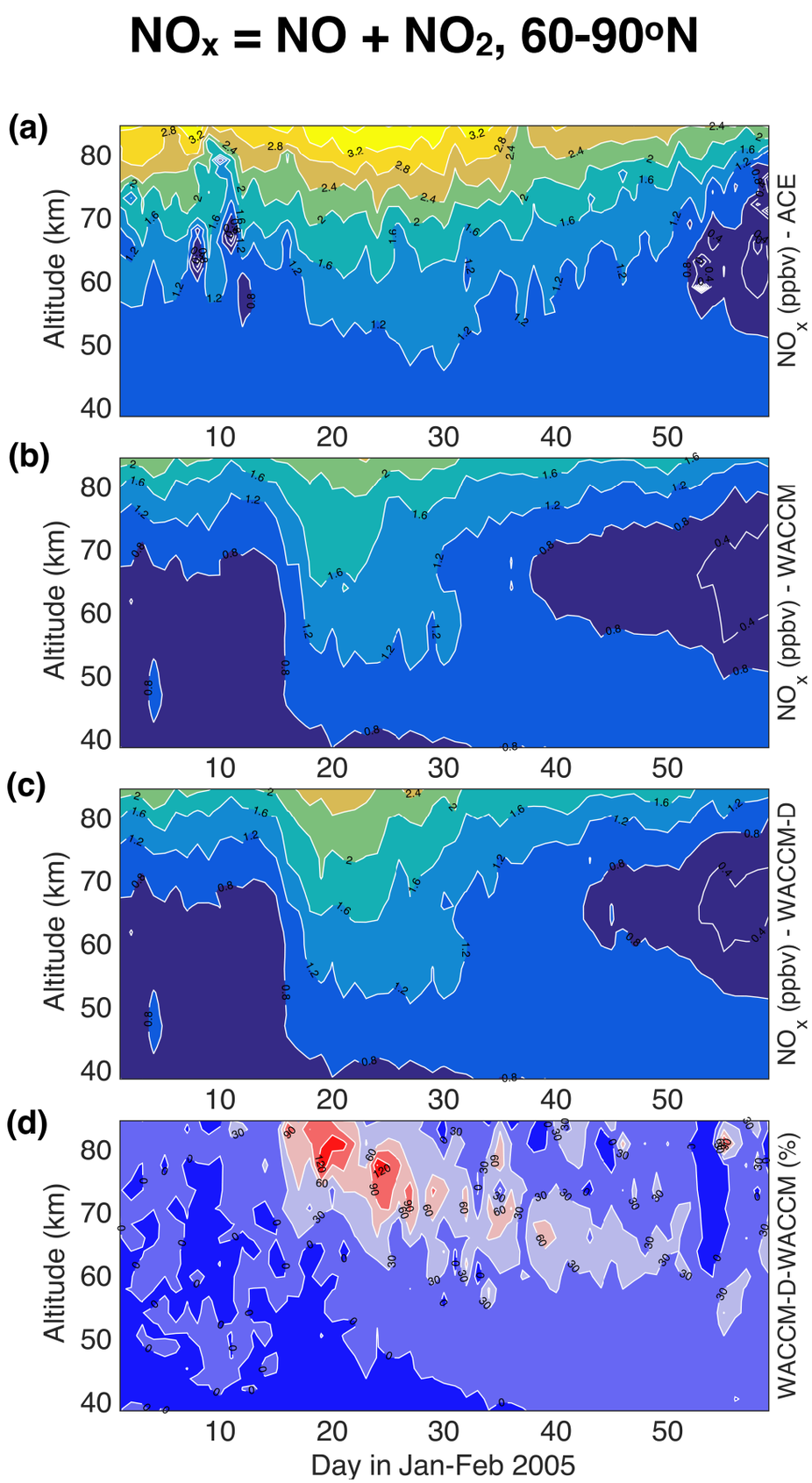


O_3, 60-90°N

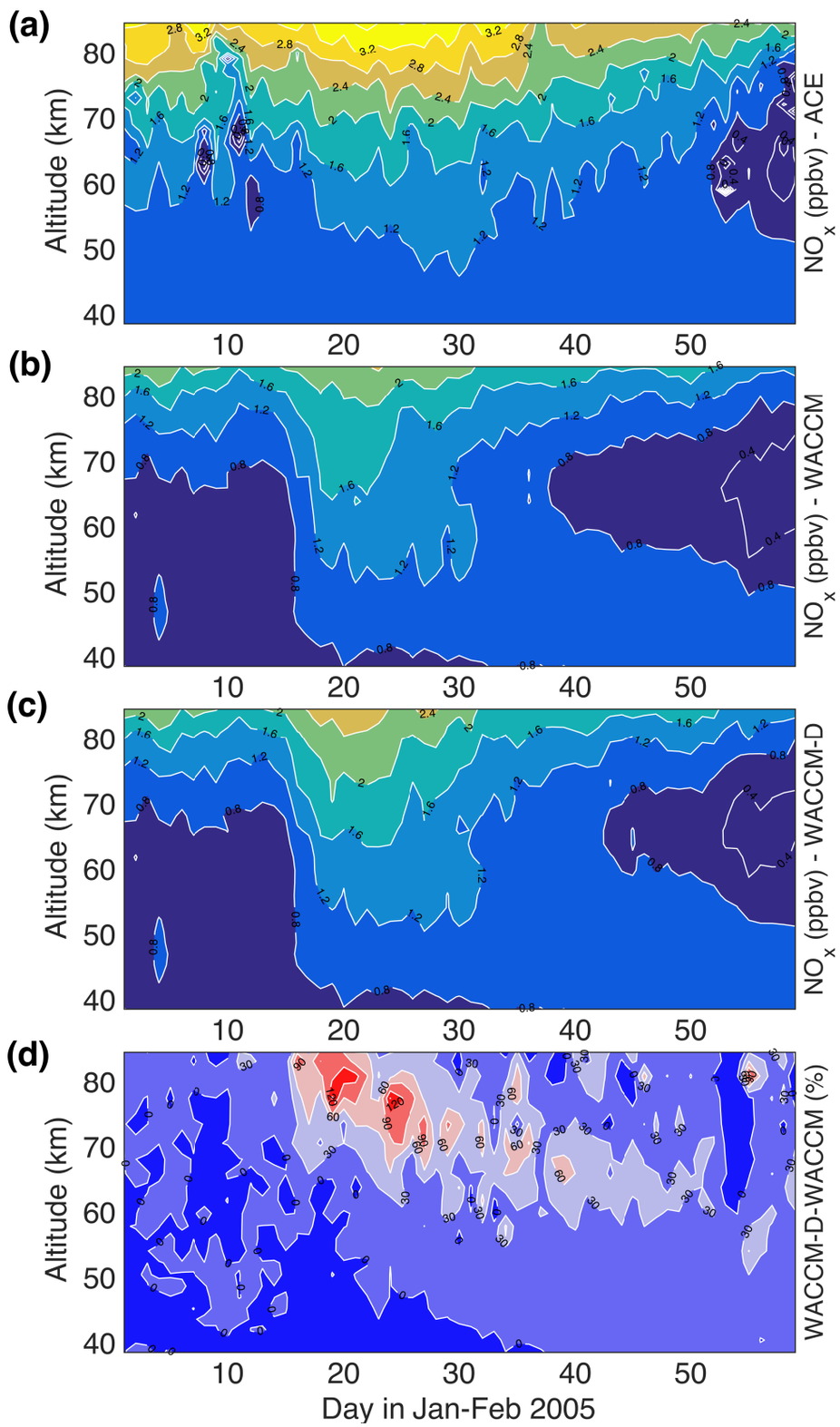


WACCM-D vs MLS and ACE

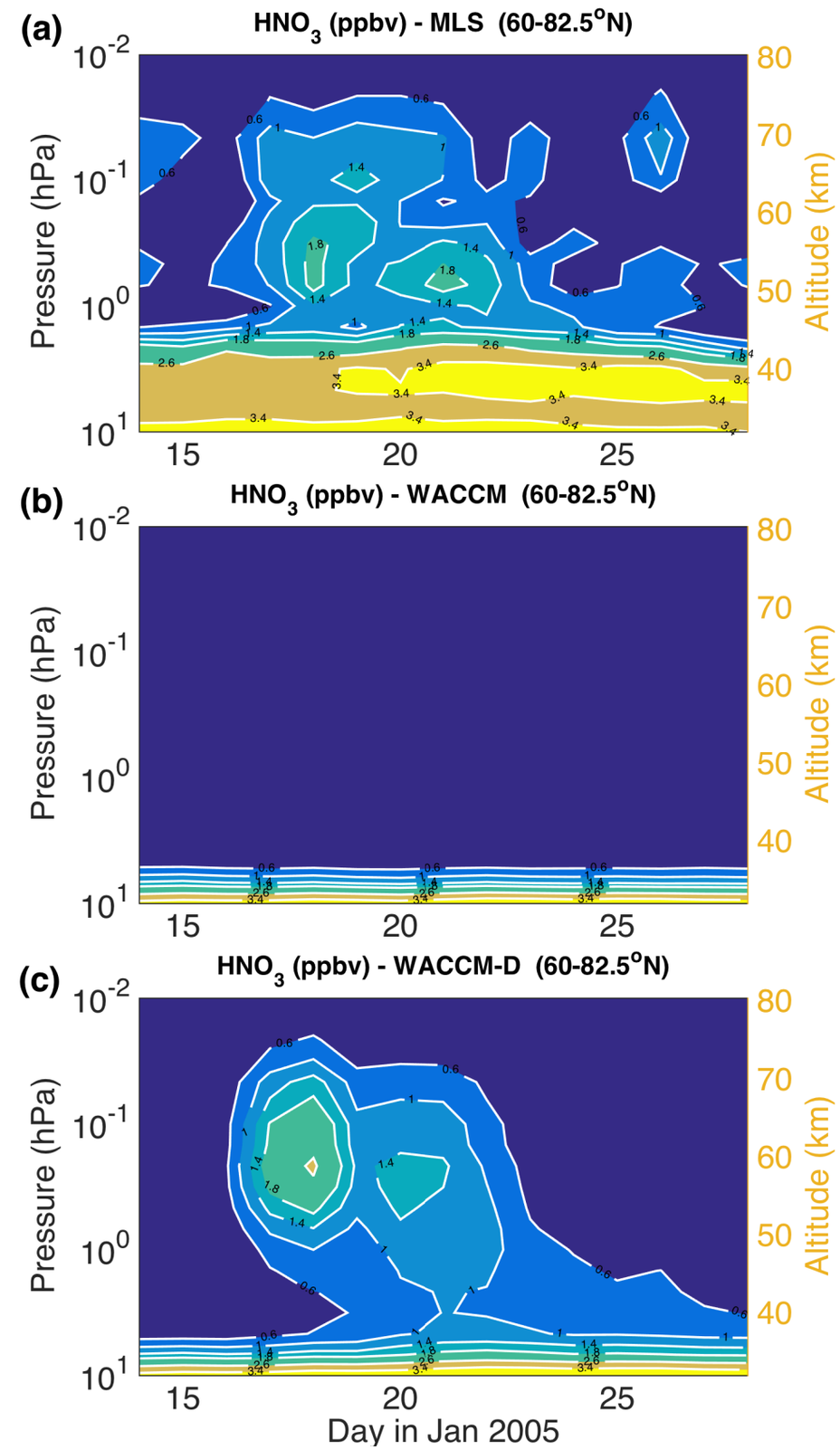


WACCM-D vs MLS and ACE

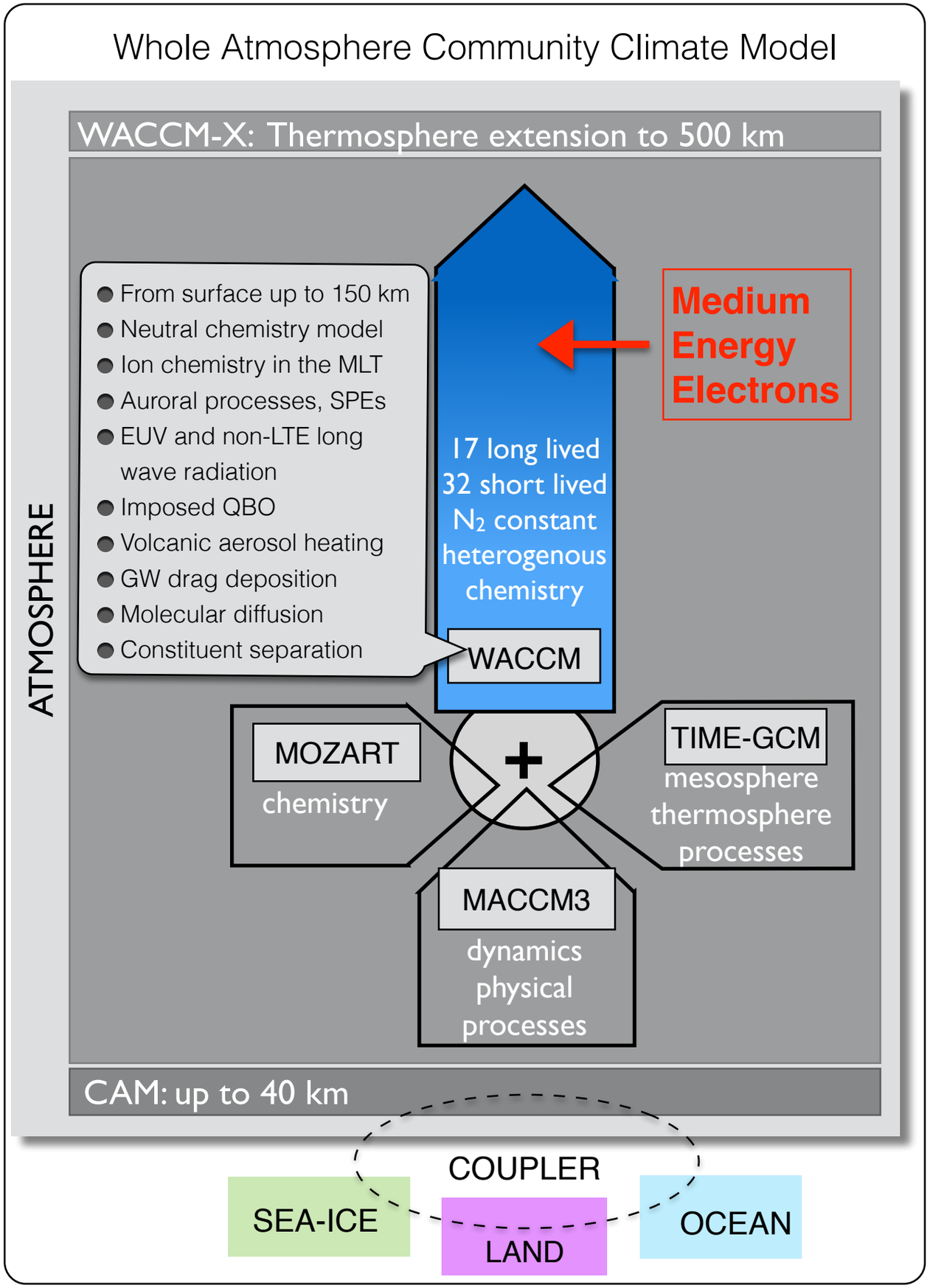
$NO_x = NO + NO_2$, 60-90°N



HNO_3, 60-90°N

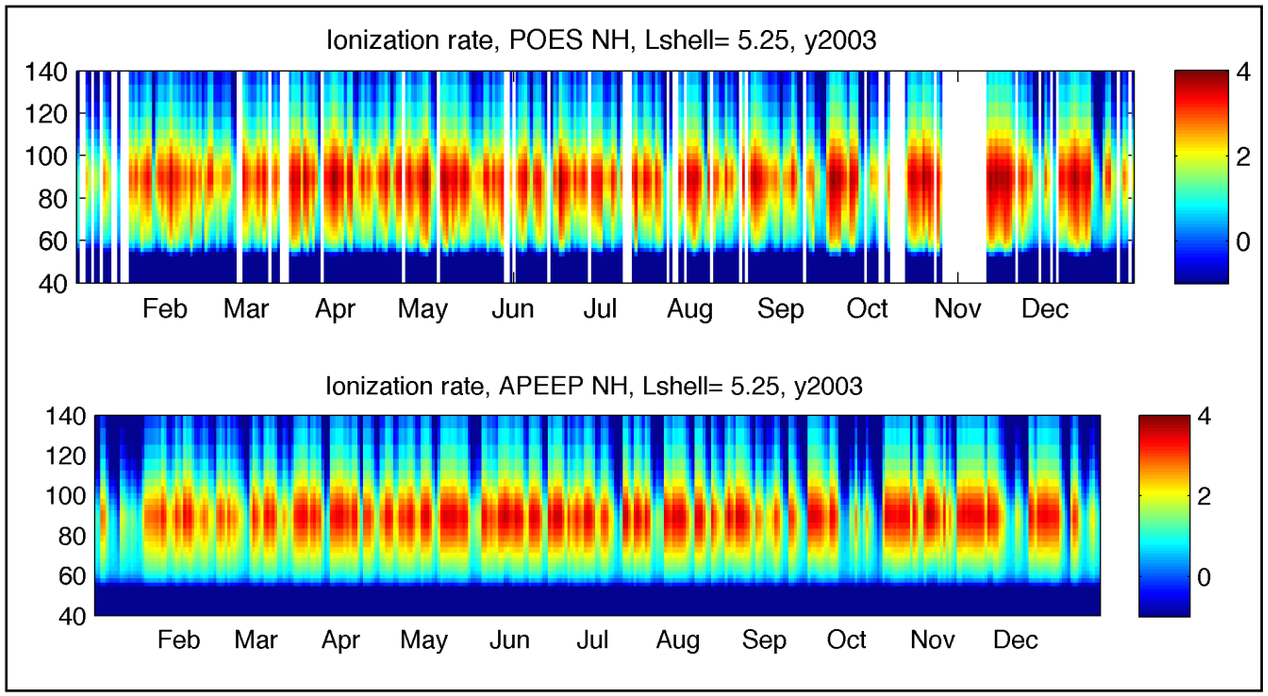


Medium energy electrons



Medium Energy Electrons

- precipitation model for radiation belts electrons based on MEPED/POES
- Ap index as driving parameter (van de Kamp et al., JGR, in review, 2016)



Courtesy of Pekka Verronen

Proof of concept: OH

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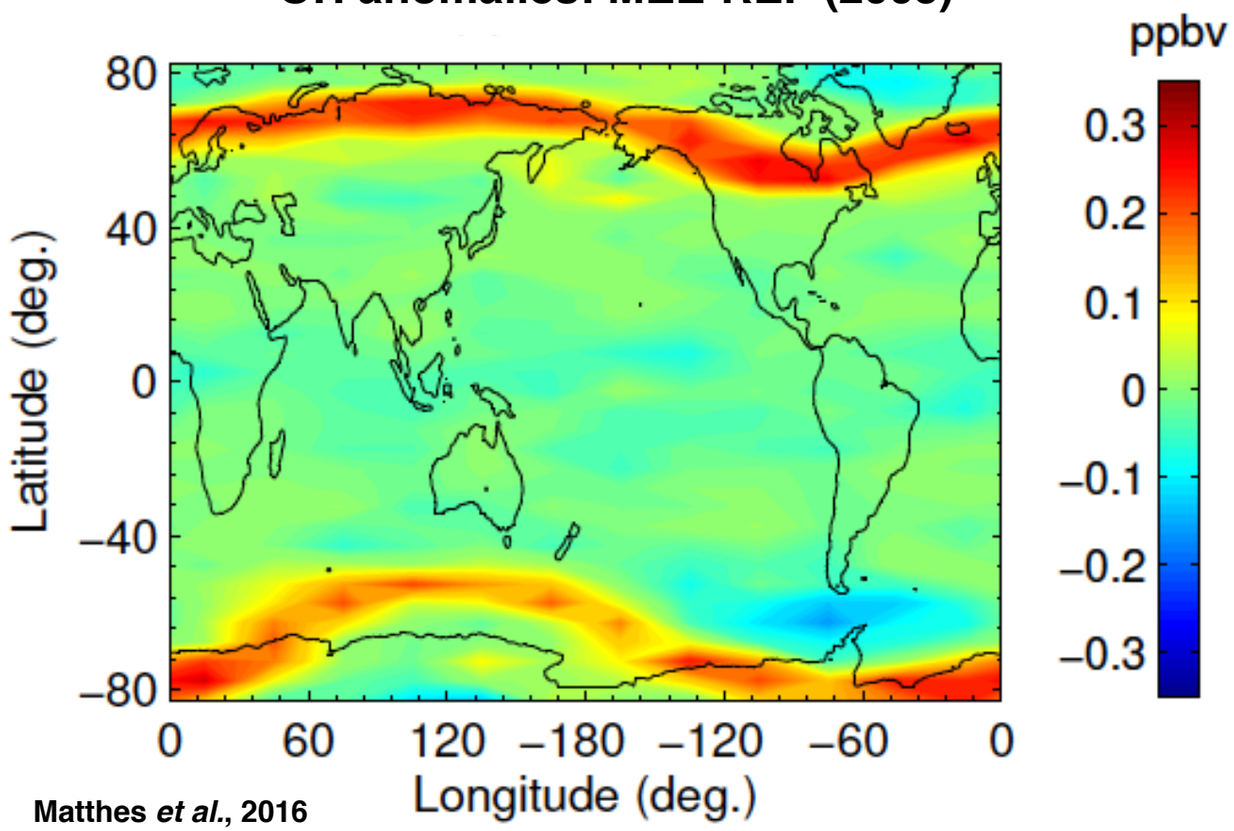
MODEL

OH anomalies: MEE-REF (2005)



Matthes *et al.*, 2016

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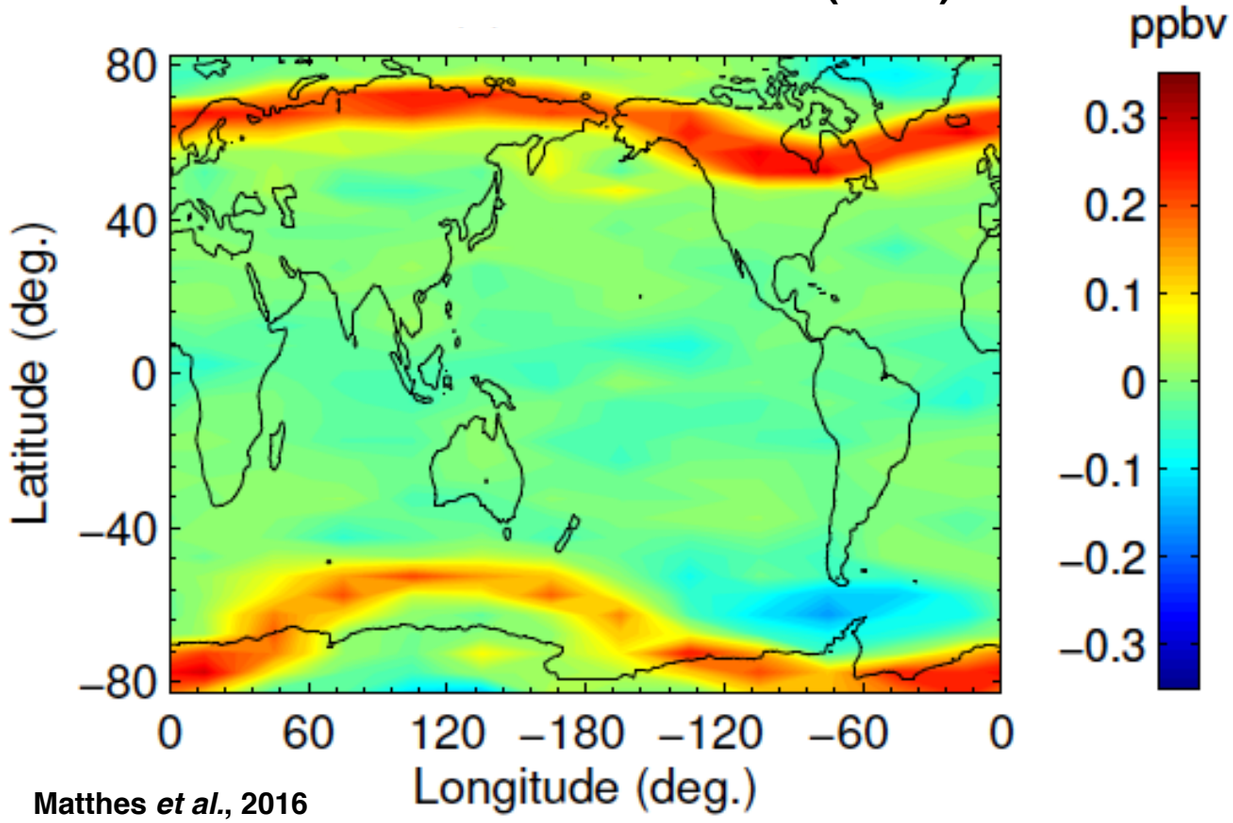
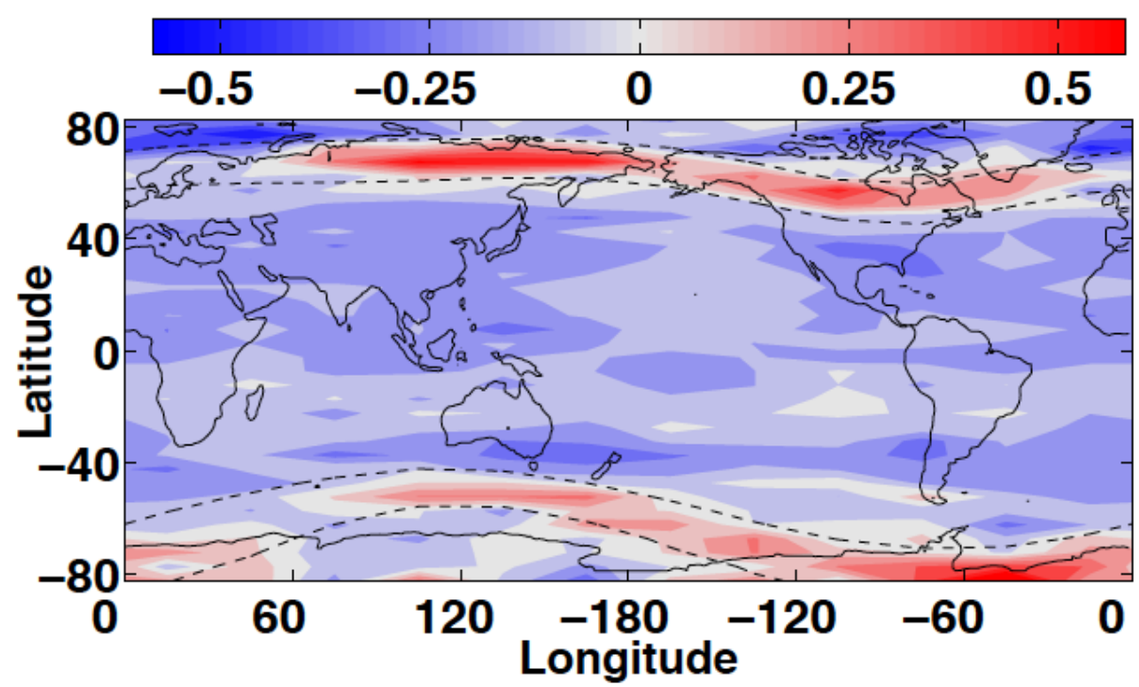


Matthes *et al.*, 2016

OBSERVATIONS

MLS OH anomalies: 2005-2009

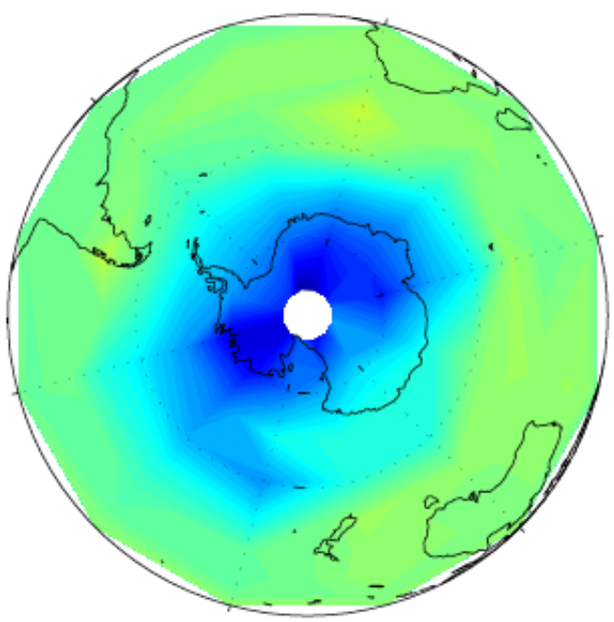


Andersson *et al.*, 2014

Ozone relative changes % (winter, SH)

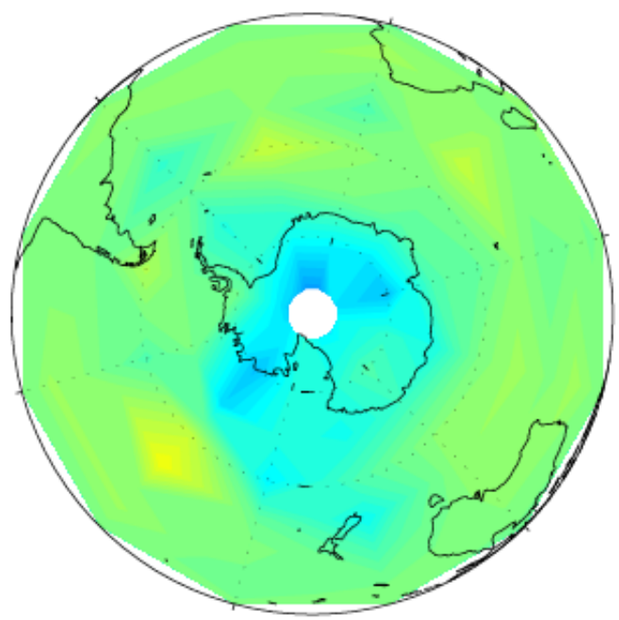
MODEL

2005, MEE-REF

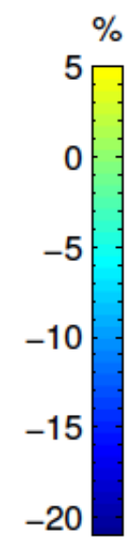


(c) SH ozone 2005

2009, MEE-REF



(d) SH ozone 2009



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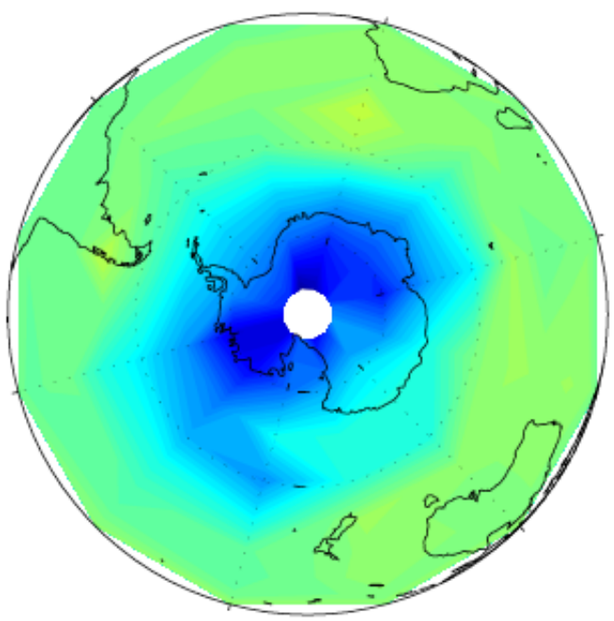

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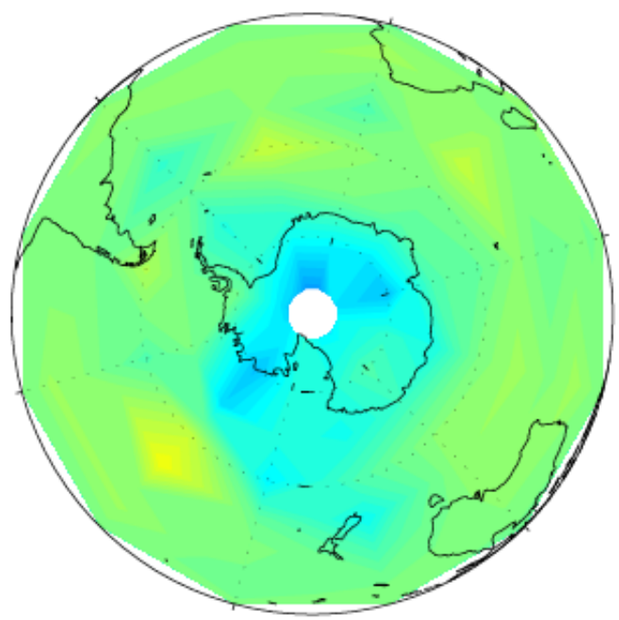

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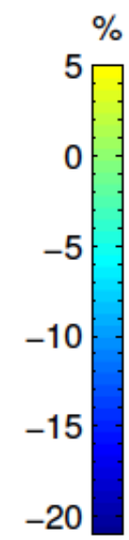
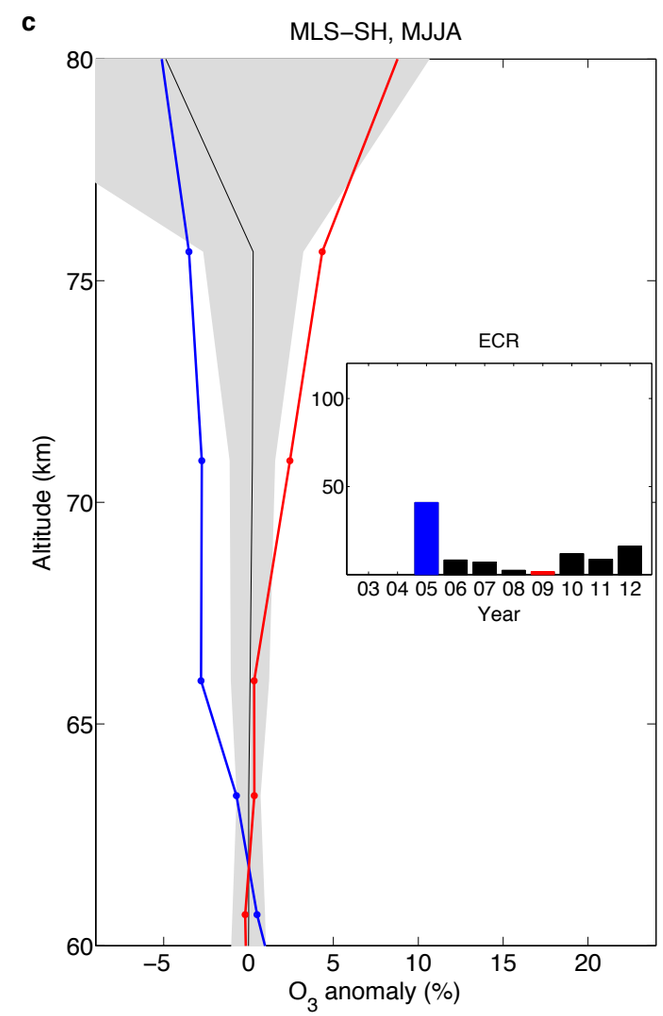


OBSERVATIONS

MLS



Andersson et al. 2014

Summary

- **WACCM-D** incorporates D-region ion chemistry to reproduce the neutral atmospheric effects caused by EPP in the polar region

- Including ion chemistry scheme in the model significantly improved the response of important neutral species to the energetic particle precipitation

- Including medium energy electrons in the models is necessarily in order to fully understand Sun-Earth connection through the particle precipitation

- WACCM-D will be official 'compset' in CESM 2.0 release -> FSDWD
- Medium energy electrons (Ap model) will be part of solar forcing for CMIP6