Update on New Precipitation Scavenging for CAM / CAM-Chem

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UCI

HNO_3 Uptake on Ice

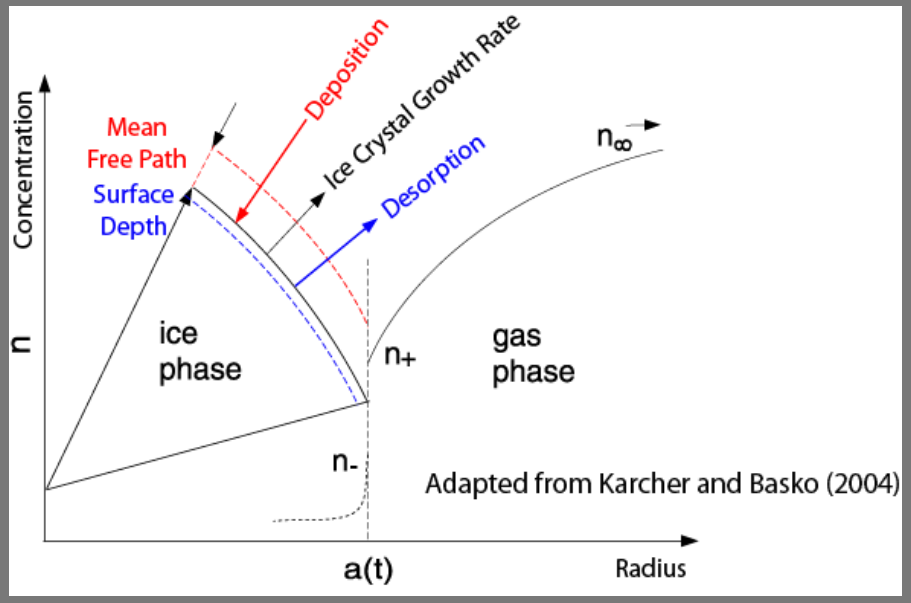
Karcher and Basko (2004)

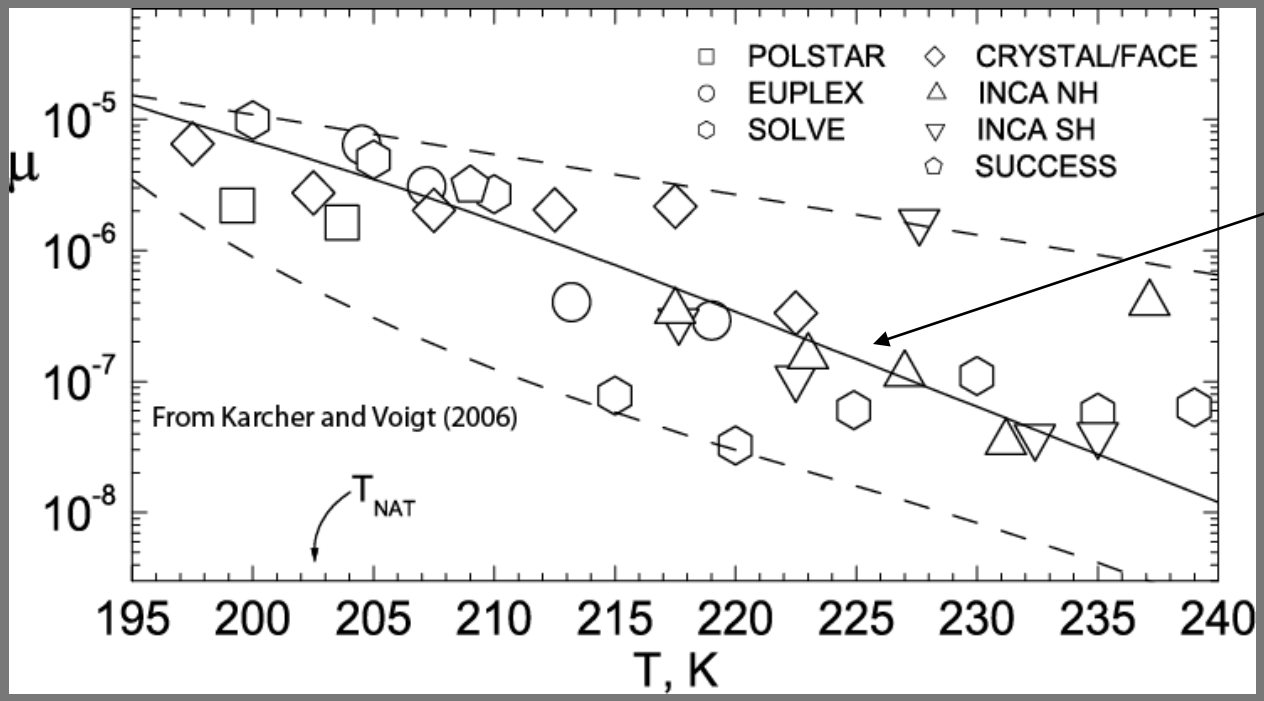
The efficiency of trapping depends on:

1) The probability of surface accomodation

2) The probability of desorption

3) The growth rate of the crystals





Karcher and Voigt (2006)

Best estimate of the trapping efficiency from an empirical fit to the data.

Overlap of Clouds and Precipitation

We assume that precipitating clouds are maximally overlapped, and that if there is precipitation in a layer, at least 10% of that layer has condensed water

Each model level is partitioned into up to 4 sections, each with a gridbox fraction, precipitation rate, and precipitation diameter:

Old Cloud – Area of the gridbox with cloud that also has rain falling from above

Cloud "core" – aged precipitation

New precip is spread evenly between OC and NC

New Cloud – Area of the gridbox with cloud and no rain falling from above

Ambient – Area of the gridbox with rain from above falling through clear sky

Constant rate of evaporation – reduces both area and rain amount

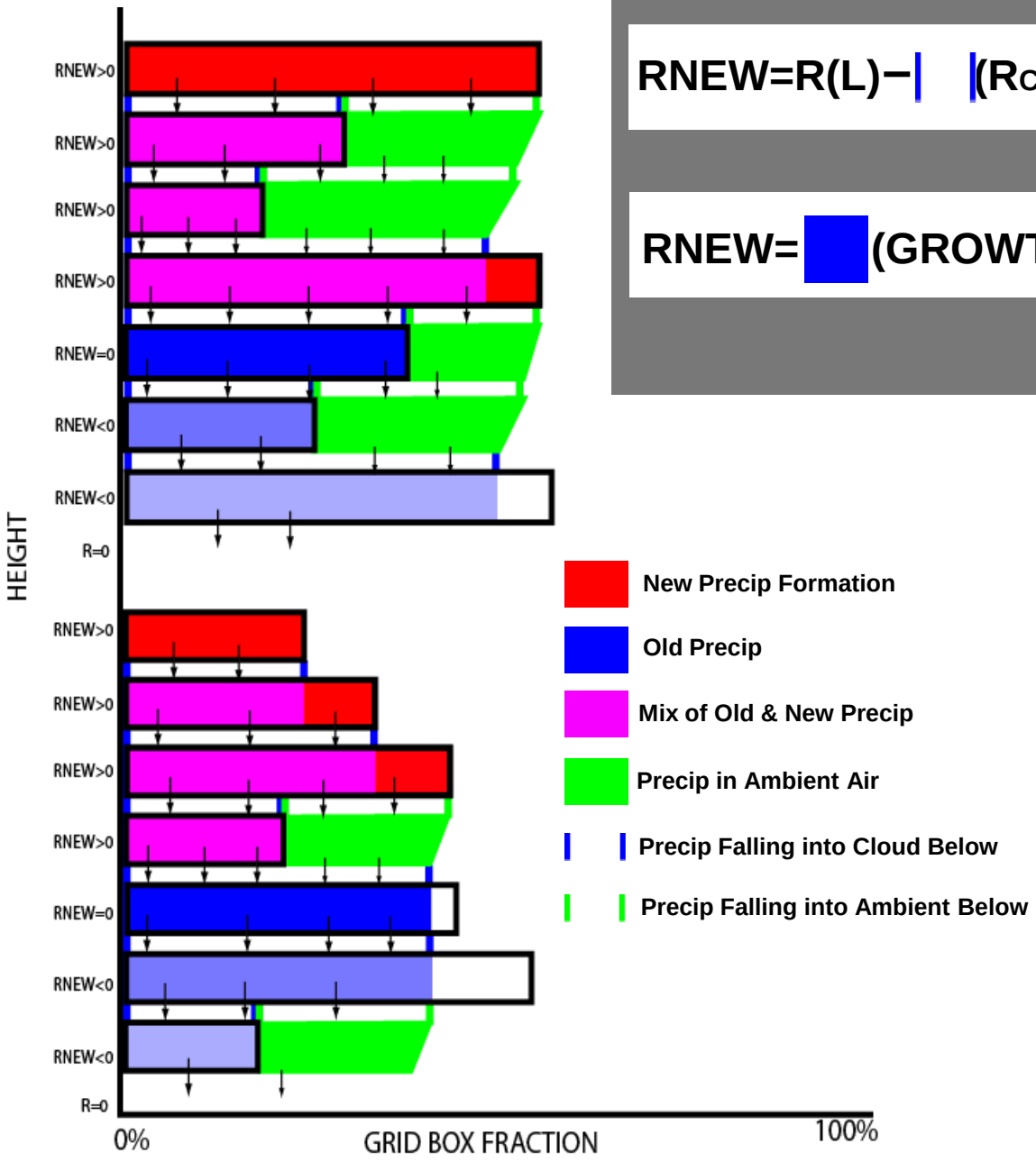
Clear Sky – Area of the gridbox with no cloud and no rain from above

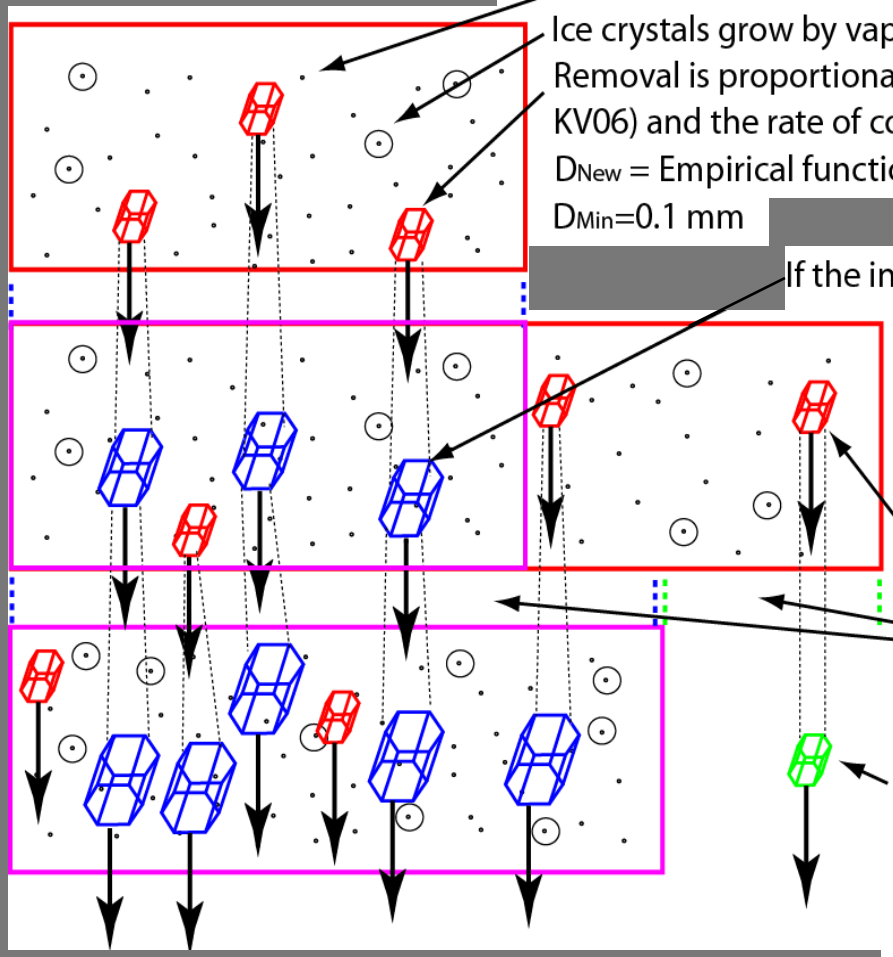
For the next level, we combine the 4 sections and line them up with the cloudy and clear regions below to generate 4 new sections

Similar to Jakob and Klein (2000)

$$RNEW = R(L) - |(R_{CL_{\downarrow}} \times F_{OC}) - (R_{AM_{\downarrow}}(1-EVAP) \times F_{AM})$$

$$RNEW = (GROWTH \times FOC) + (NEW \times CF)$$





Ice nuclei

Ice crystals grow by vapor deposition, burying HNO3

Removal is proportional to the fraction of dissolved tracer (from KV06) and the rate of conversion of IWC to precip via aggregation

D_{New} = Empirical function of IWC, Precip Rate (Field and Hemsfield, 2003)

D_{Min}=0.1 mm

If the in-cloud precip rate increases, old precip grows by riming

Removal is proportional to the mass of cloud water accreted (= continuous-collection equation integrated over the size distribution) and the dissolved tracer fraction (from KV06).

If the increase in precip rate due to growth < the net in-cloud increase, new precip forms as above

A single D falls into cloud or ambient below

D=const in ambient

Ambient precip evaporates at a constant rate

If the gridbox average precipitation rate decreases in a layer, additional ambient evaporation may occur. Once ambient precipitation is fully evaporated, there may be in-cloud evaporation.

For the liquid phase:

The fraction of dissolved tracer is gvien by Henry's Law (+ dissociation)

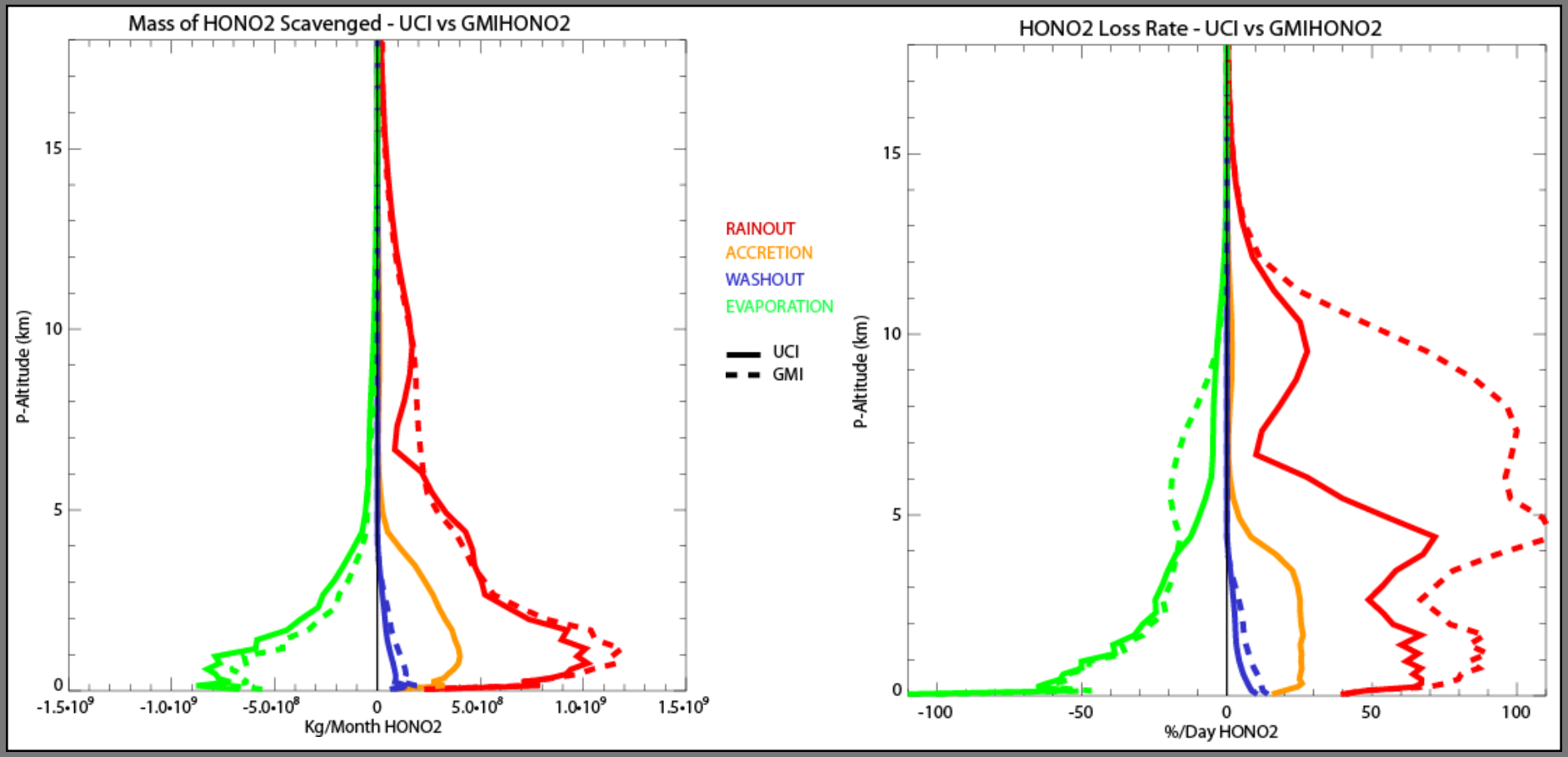
Accretion increases the rain rate, but D remains constant

Below-cloud scavenging includes removal of gas from interstitial air in clouds and from ambient air (washout).

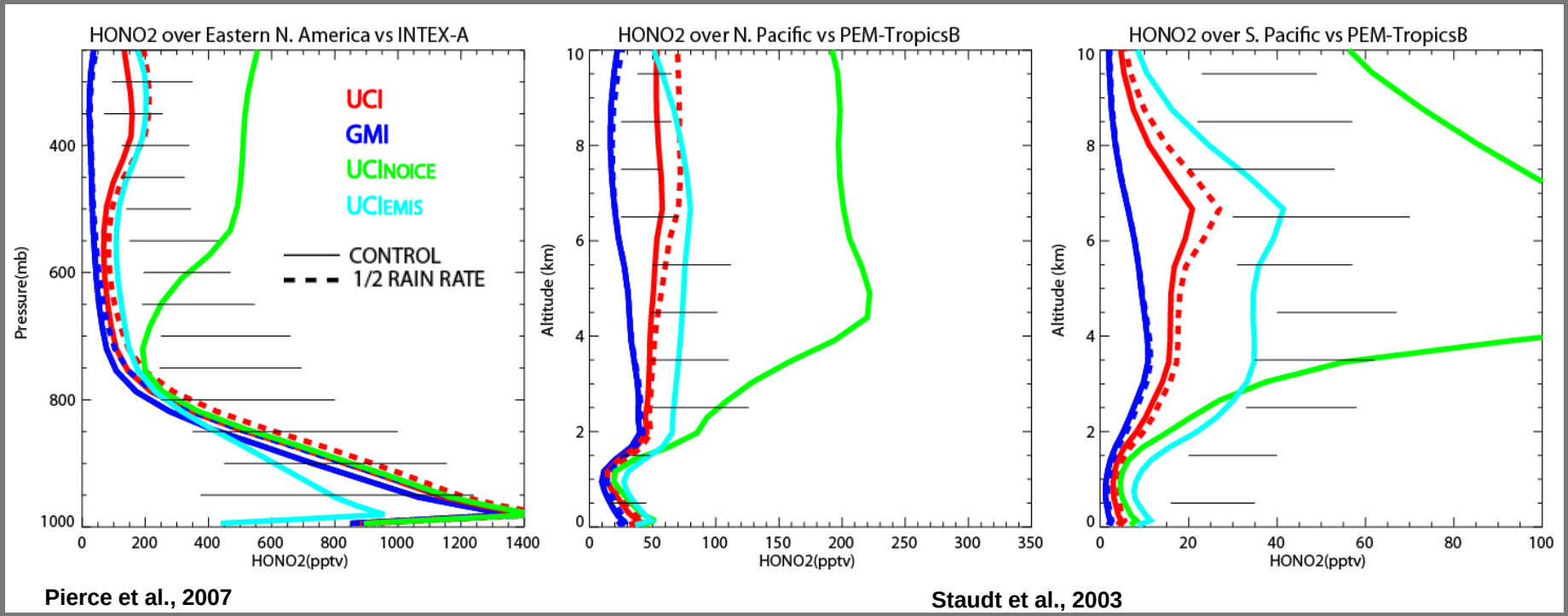
Global Impact of Fractional Scavenging

Compare to “standard” scavenging from Global Modeling Initiative CTM (Liu et al., 2001):

- **If R(L)>R(L+1), then assume new precipitation formation in max(CF, CF_{above})**
- **If R(L)<R(L+1), then washout and / or evaporate in CF_{above}**
- **No separate ice treatment**



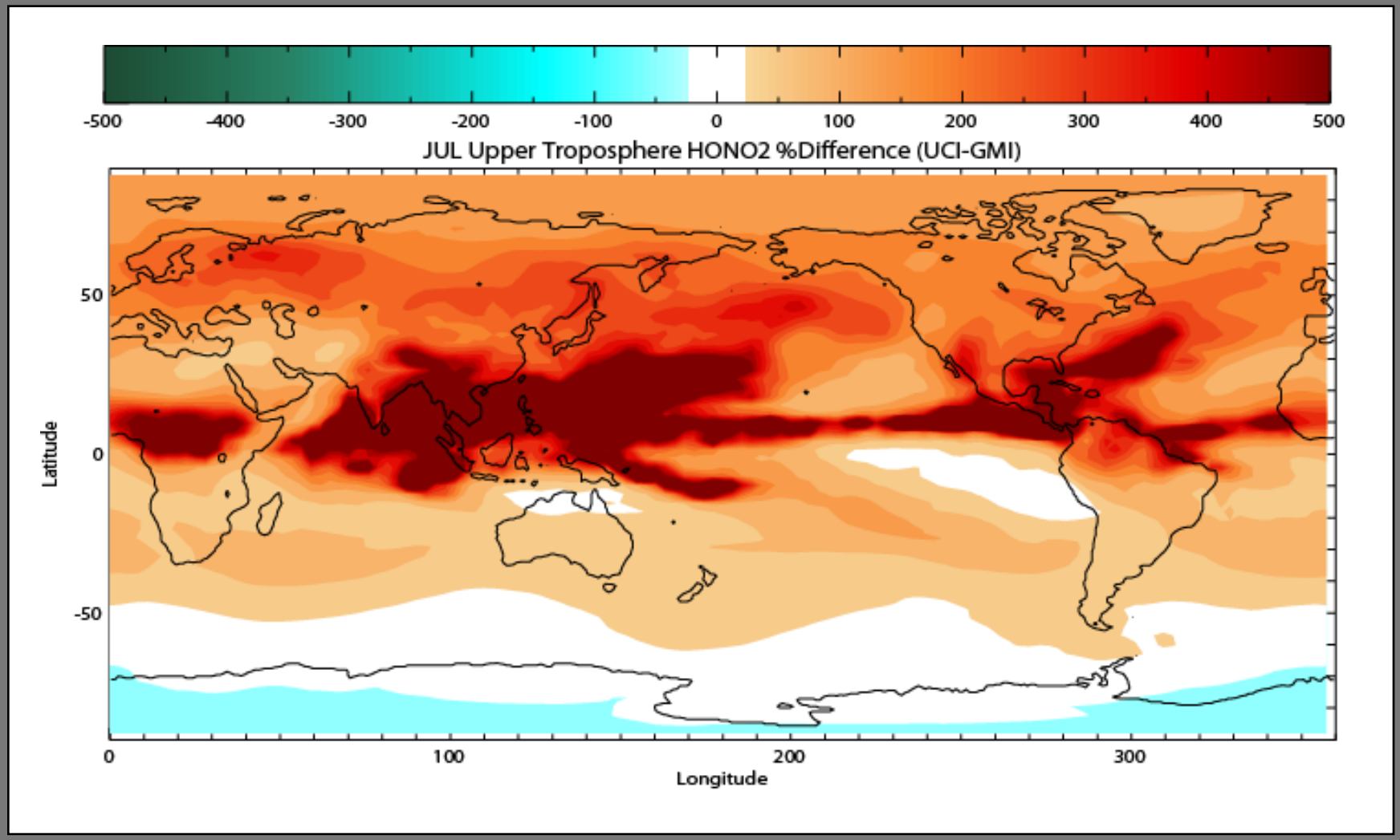
The flux through scavenging is almost identical, but the loss rates are much smaller for UCI_{scav}



Pierce et al., 2007

Staudt et al., 2003

UCI$_{scav}$ matches aircraft campaign profiles better than GMI$_{scav}$, especially in remote regions



UCI-GMI % Difference for HNO3 in the Upper Tropopshere

Wet Deposition in CAM

In the PHYSICS module – called from TPHYSBC, AEROSOL_WET_INTR

Wet deposition for rain only. Convective and stratiform rain are handled separately, but within the same subroutine.

CLDDIAG – estimates the fraction of the box with precip

WETDEPA – Aerosol wet deposition, uses solubility factors

WETDEPG – Gas phase wet deposition for sulfur chemistry (SO2, H2O2), uses Henry's Law

Wet Deposition in CAM-Chem

Aerosols scavenged in PHYSICS module. Aerosols must be scavenged before convection, because only the fraction remaining in interstitial air is transported.

Aerosols called from TPHYSBC, MZ_AEROSOLS_INTR (uses namelist)

Rain only.

WETDEPA – Same as CAM, solubility factors set by MOZART

Gases scavenged in CHEMISTRY module.

Gases called from CHEMISTRY, MO_GAS_PHASE_CHEMDR

Uses the sum of rain and snow production / evaporation + convective precip production.

MO_SETHET – Gas phase wet deposition with Henry's Law (inlcudes SO2 unless CAM sulfur chemistry is used). Giorgi and Chameides (1985).

Saturation factors!

New Wet Deposition

Goal is to have a single wet deposition routine for aerosols / gases, CAM / CAM-Chem, use logical flags or scavenging indices for snow vs rain, kinetically-limited vs solubility limited, etc.

Will go in the physics module

The routine is written for large-scale precip (TOTPRECP, TOTEVAPR, LCWAT, CLDST)

Uses the actual evaporation rate from CAM (CTM version uses constant evaporation rate)

Outputs the scavenging tendency and fraction remaining in interstitial (not currently done for gases).

Uses a table with effective Henry's Law constants for gases (from MOZART dry dep routine)

Interface with physics is done.

Open Issues

Scavenging by convective precip – Use old routines, or add convective parameters to input for new routine?

Aerosols – solubility factors, collection efficiencies. Modal aerosols?

Interface with MO_GAS_PHASE_CHEMDR – if we move scavenging to physics, will have to change the interface with chemistry.

Microphysics – The new microphysics generates grid-box averaged TOTPRECP and TOTEVAPR just for wet dep. Could use explicit terms directly from microphysics.