# A new precipitation scavenging scheme for WRF-Chem
## (and other Updates)

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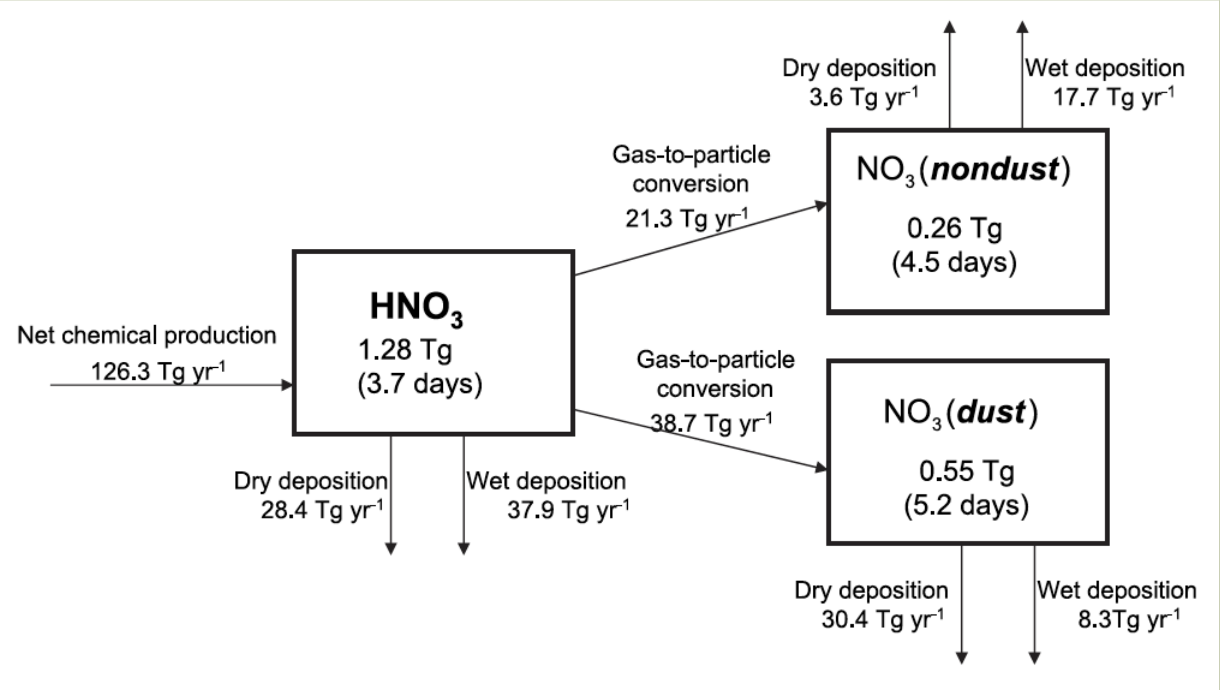
# OVERVIEW

Wet scavenging = important sink for many atmospheric species e.g. $HNO_3$, the most soluble gas, represents nitrogen's final oxidized state and its sinks are physical rather than chemical.




*Global annual average $HNO_3$ budget (Liao et al., JGR 2004)*

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- Large Scale Precipitation Scavenging Scheme from Jessica Neu ("Neu-Scheme") has been embedded and tested in V3.2.
  {Update to V3.3 in progress}
- For gas species ($HNO_3$, $HNO_4$, $H_2O_2$, $NH_3$, HCHO,... )
- For MOZART and MOZCART chemistry options
  (chem_opt = 111 and chem_opt=112)
- Linked to the Thompson microphysics scheme (mp_physics=8)
- Neu-Scheme is also implemented in CAM-Chem

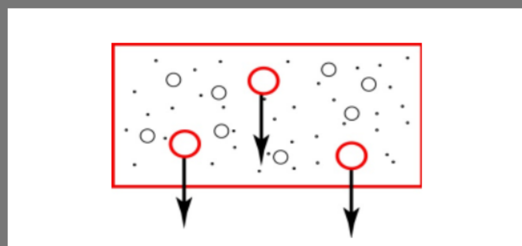
# WASHOUT SCHEME - BASICS

Neu, J. L., and M. J. Prather, Impact of an improved nitric acid scavenging scheme on ozone and oxidative capacity, *Atmos. Chem. Phys*., in preparation.

- Two processes:
  - In-cloud (Nucleation Scavenging or Rainout)
  - Below-Cloud (Impact Scavenging or Washout)

# WASHOUT SCHEME - BASICS

**In-Cloud Scavenging (rainout, nucleation scavenging)**

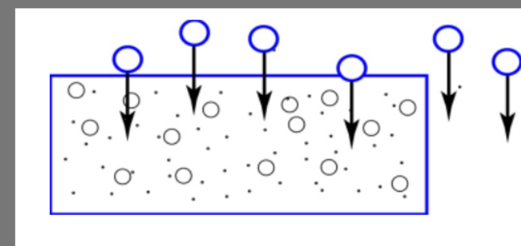


Local uptake by initial cloud droplets and their conversion to precipitation

Scavenging proportional to amount of condensate converted to precipitation

Loss rate depends on cloud water, rate of precipitation formation, and rate of tracer uptake by liquid phase

**Below-Cloud Scavenging (washout, impaction scavenging)**



Collection by falling droplets, either from interstitial / ambient air (most common) or liquid via accretion processes

Scavenging proportional to precipitation flux in the layer

Loss rate depends on precipitation rate and rate of tracer uptake by the liquid phase, mass-transfer rate, or collision rate, depending on species

Both modeled as a first-order loss process: $X_{iscav} = X_i F(1 - \exp(-\lambda \Delta t))$

*Courtesy of Jessica Neu*

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- Partitioning between in-cloud and below-cloud scavenging

# PARTITIONING

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

New precip is spread evenly between OC and NC

**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

**In WRF we use a binary cloud fraction, so each layer is assigned one of the 4 sections.**

Similar to Jakob and Klein (2000)

*Courtesy of Jessica Neu*

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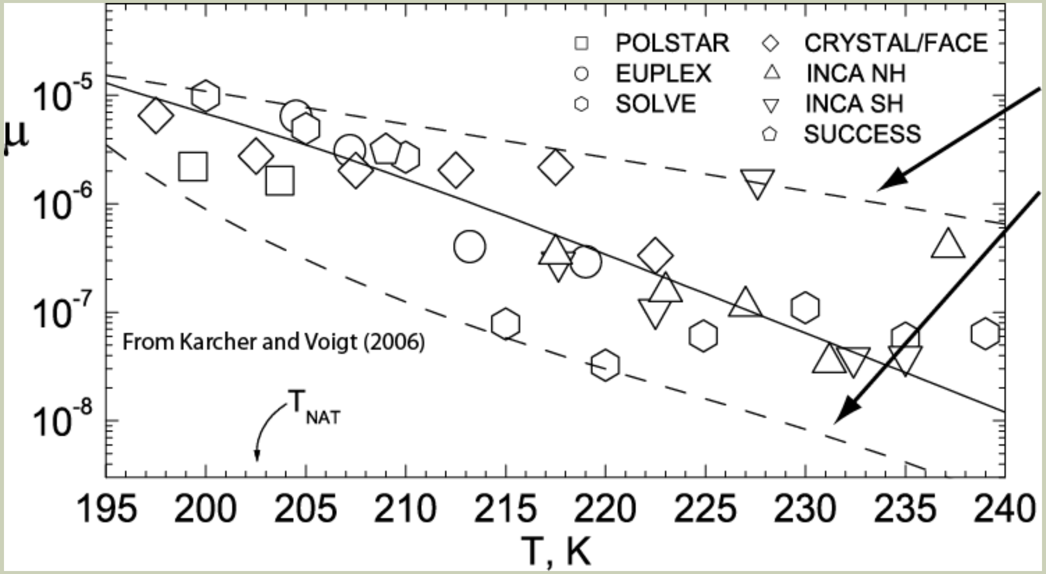
- Transfer of soluble gases into liquid condensate follows Henry's Law (assuming equilibrium between gas and liquid phase)
- Nucleation Scavenging (Uptake by ice) – treated as burial process (tracers deposit on surface along with water vapor and are buried as the ice crystal grows)

# NUCLEATION SCAVENGING

- In-cloud scavenging during ice particel formation is based on the empirical relationship between the $HNO_3$:$H_2O$ molar ratio and temperature (Karcher and Voigt, 2006)
- Below-cloud scavenging is based on a rough representation of the riming process modeled as a collision limited first order loss process.




**Observed $HNO_3$ : $H_2O$ molar ratios are bounded by:**

**(1) Uptake of all available ambient $HNO_3$ during ice crystal growth, or**

**(2) Pure dilution by deposition of $H_2O$ on ice**

**Trapping efficiency increases with decreasing T**

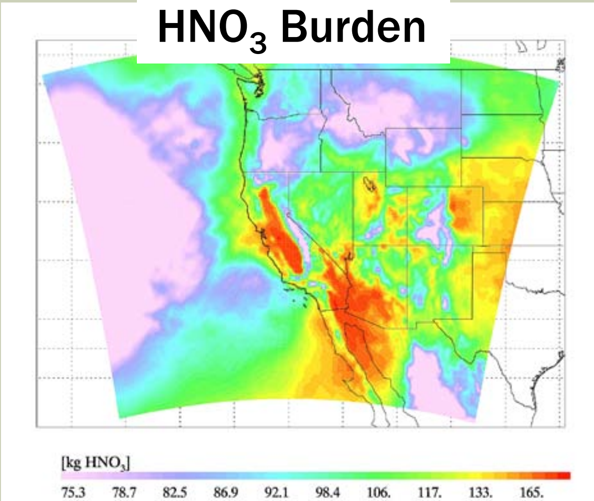
***Courtesy of Jessica Neu***

# WRF-CHEM – Column Integrals

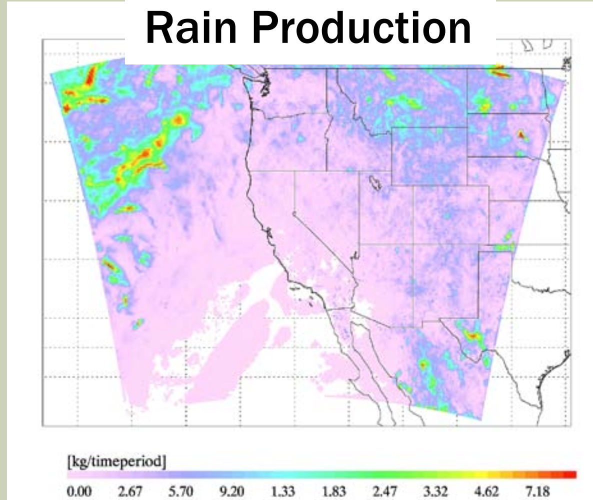
*(MOZCART; 12x12 km²; 06/10–07/10 2008)*

## 1.5 – 10 km

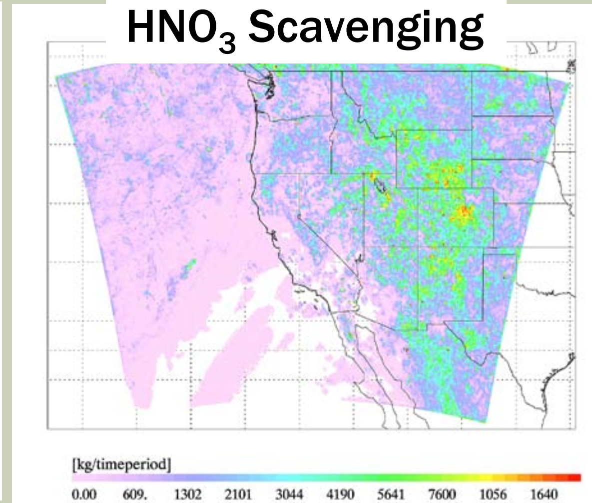
### $HNO_3$ Burden




### Rain Production

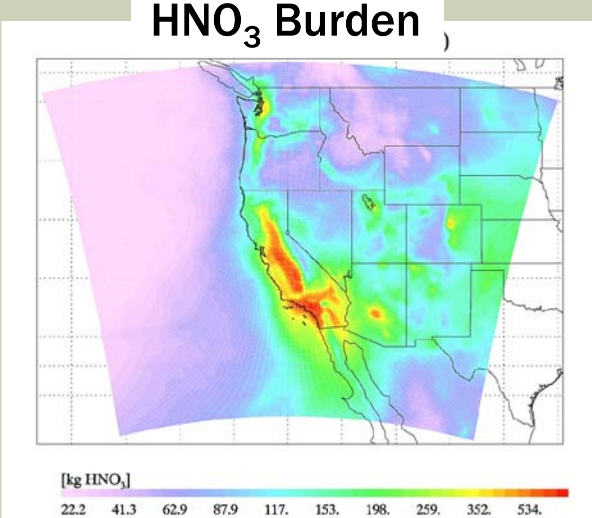



### $HNO_3$ Scavenging




## Surface – 1.5 km

### $HNO_3$ Burden

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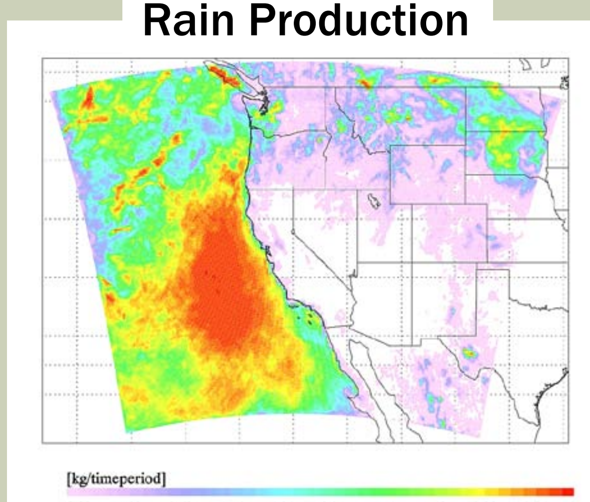


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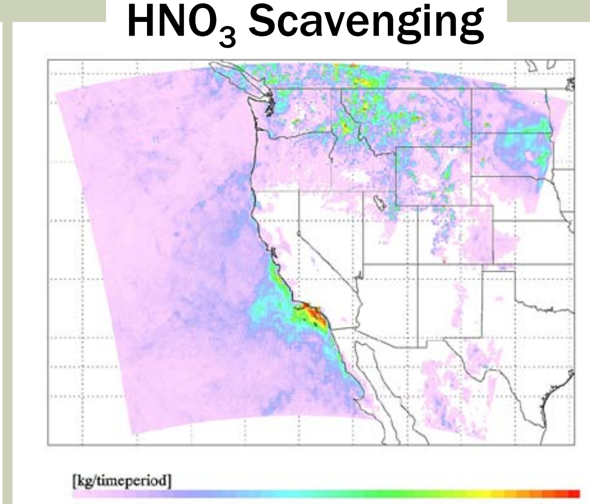
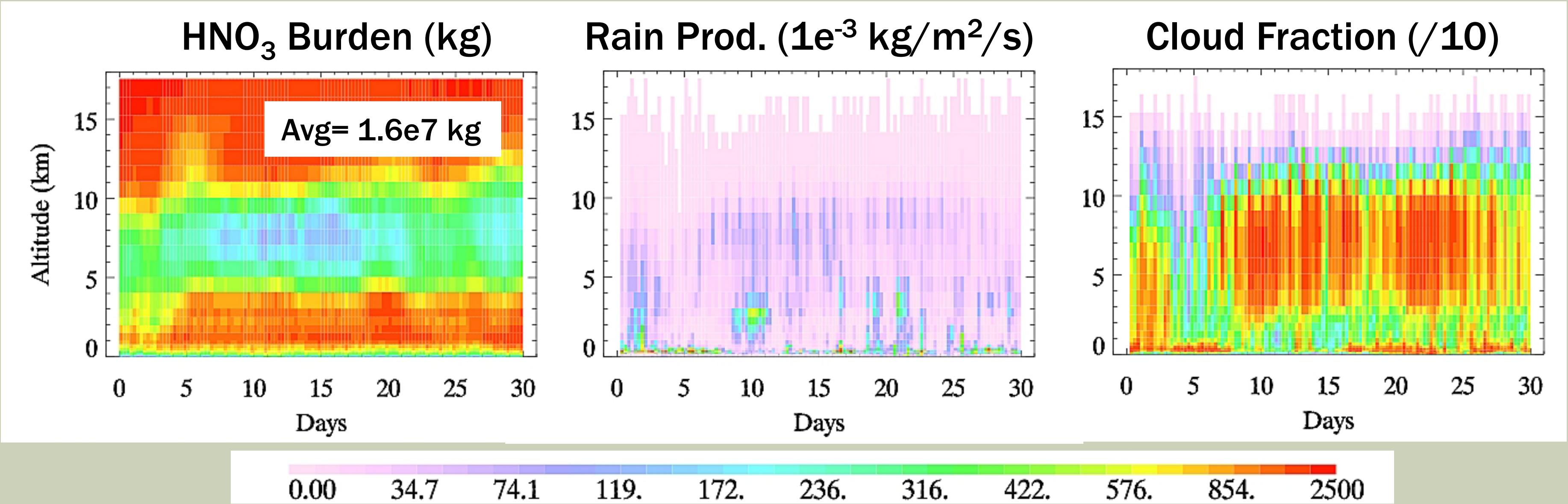


# WRF-CHEM – Domain-Wide Statistics



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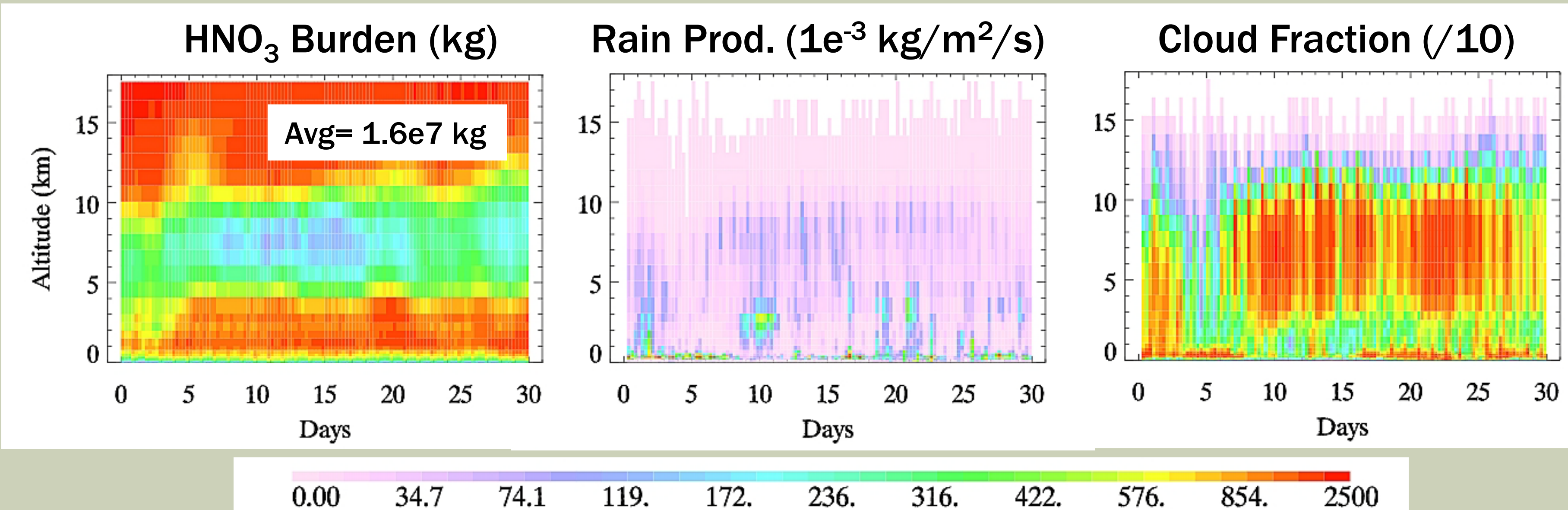
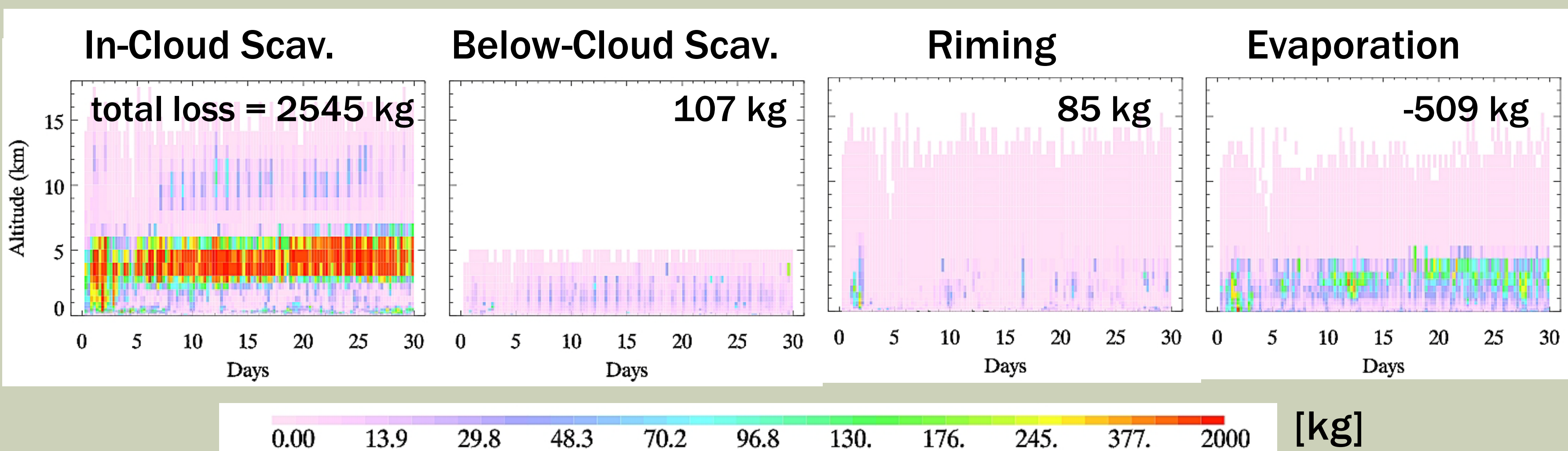


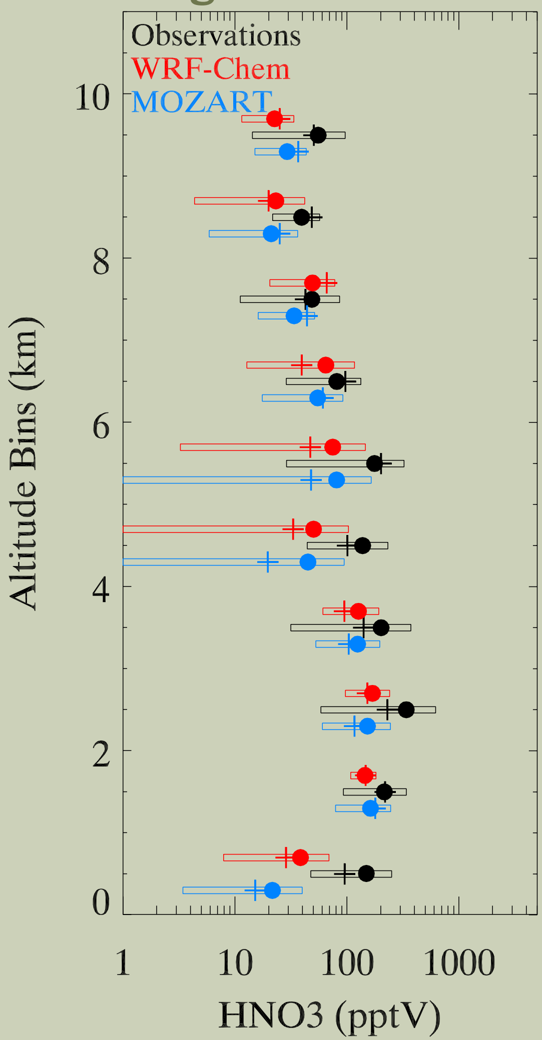




*(Total Loss ~ 0.98 Tg/year; Burden and Loss in the order of 1-2% of global budget studies)*

# WRF-CHEM – Comparison to Observations

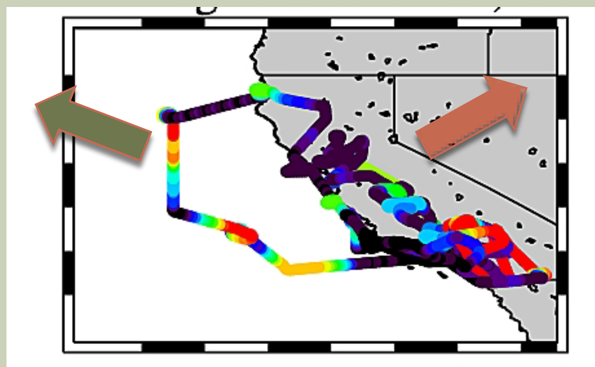
## NASA ARCTAS-CARB

### Flight over Ocean

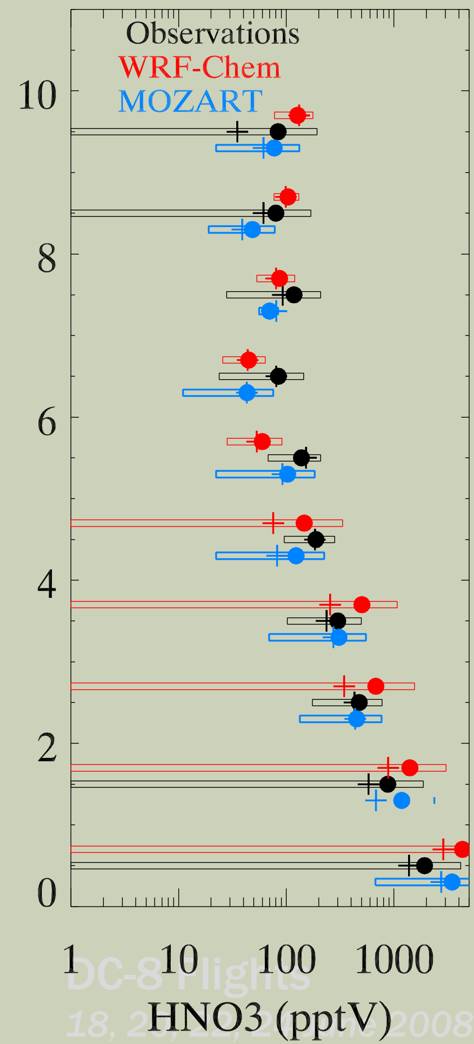



### DC-8 Science Flights:

**18, 20, 22, 24 June 2008**

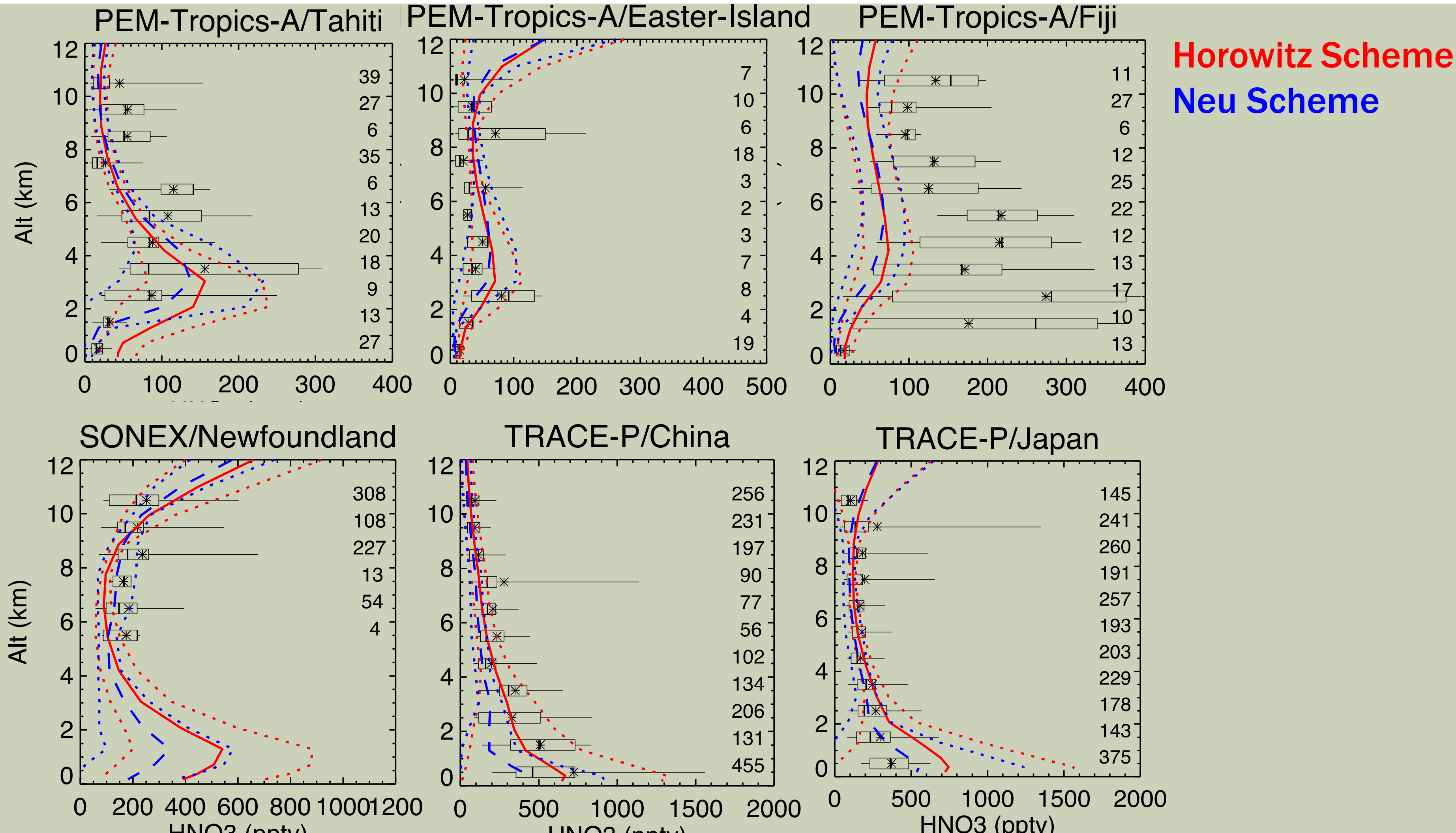


### Flights over Land




*Jacob et al., The Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) mission: design, execution, and first results, Atmos. Chem. Phys., 2010*

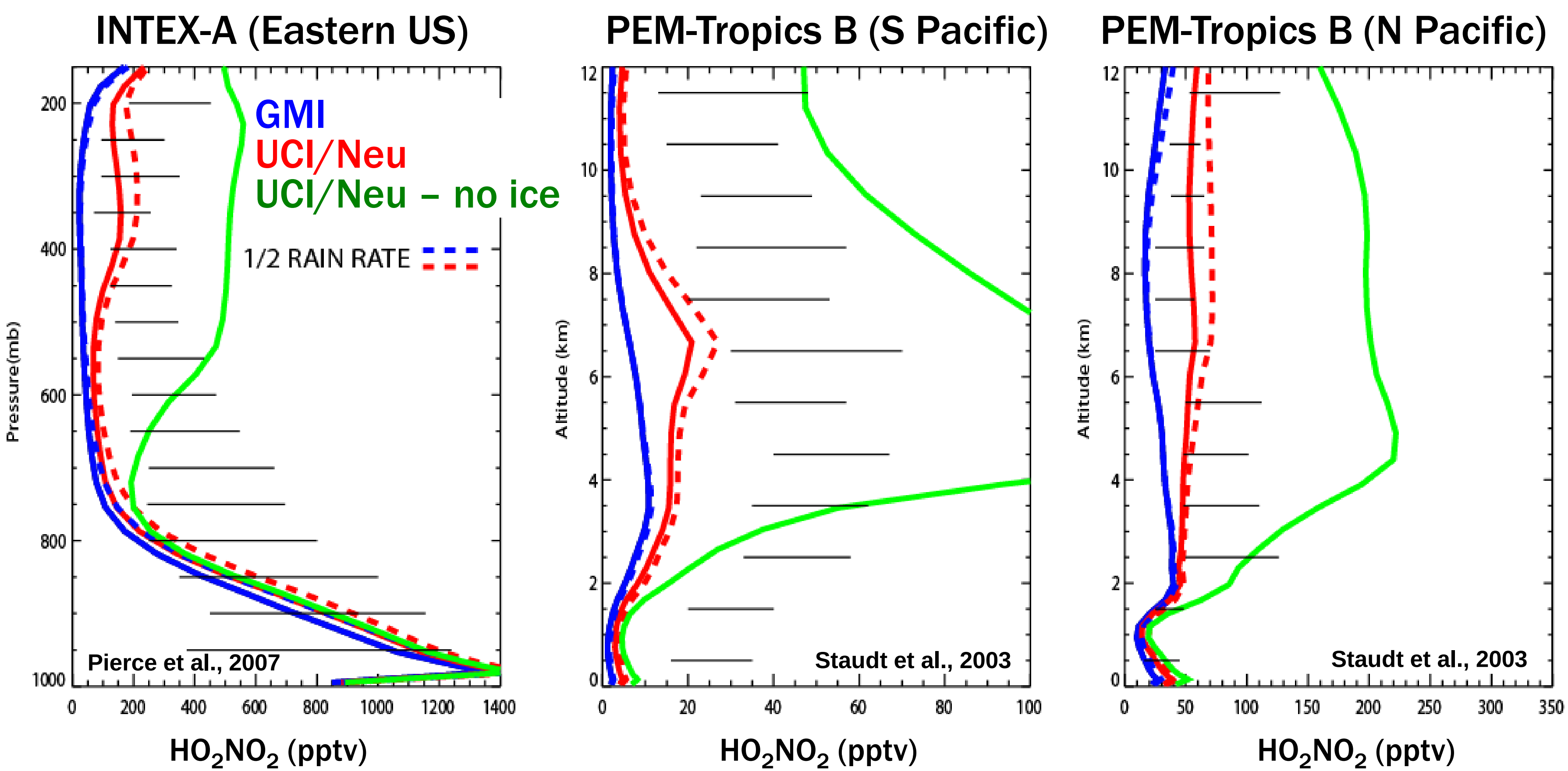
# CAM-CHEM – Neu versus previous scheme




*Courtesy of Jean-Francois Lamarque*

# COMPARISON TO OTHER SCHEMES

## Compare UCI (University of CA, Irvine) CTM with Neu scheme to Global Modeling Initiative (GMI) CTM




UCI<sub></sub>scav matches aircraft campaign profiles better than GMIscav, especially in remote regions.

Observations clearly contradict simulation with no ice scavenging

Global Mean Change in tropospheric $O_3$ between Neu and Neu-no ice about 10% (2.5 DU)

*Courtesy of Jessica Neu*

# OTHER UPDATES

- **Upper Chemical Boundary Conditions**
  Chemical UBC are taken from WACCM climatology for past, present and future (previous talk by M. Barth et al.)
- **Reduced Chemistry**
  (Howeling et al., 1998); useful for long climate runs and compatible with CAM-Chem (collaboration with J. Fast, JPL)
- **Aircraft Tracking Tool**
  Enable output for specified locations and times
- **Fire Emissions Preprocessor "Fire_Emis"**
  For creating wrffirechemi_<domain> files when running WRF-Chem with online plume rise.
  Emissions based on NCAR Fire Model (FINN; C. Wiedinmyer).
  Download from *http://www.acd.ucar.edu/wrf-chem/*

# SUMMARY

- Wet Scavenging Scheme based on work by J. Neu has been implemented in WRF-Chem and will be made available with the next release.
- Currently for MOZART and MOZCART chemistry options, but could be extended to other chemistry options.
- Also for upcoming release:
  - Upper chemical boundary conditions from climatology
  - Reduced chemical mechanism
  - Tracking Tool for outputting fields along flight tracks
- Now available to community: Fire_Emis Preprocessor for creating wrffirechemi_d<domain> files from NCAR Fire Model FINN.