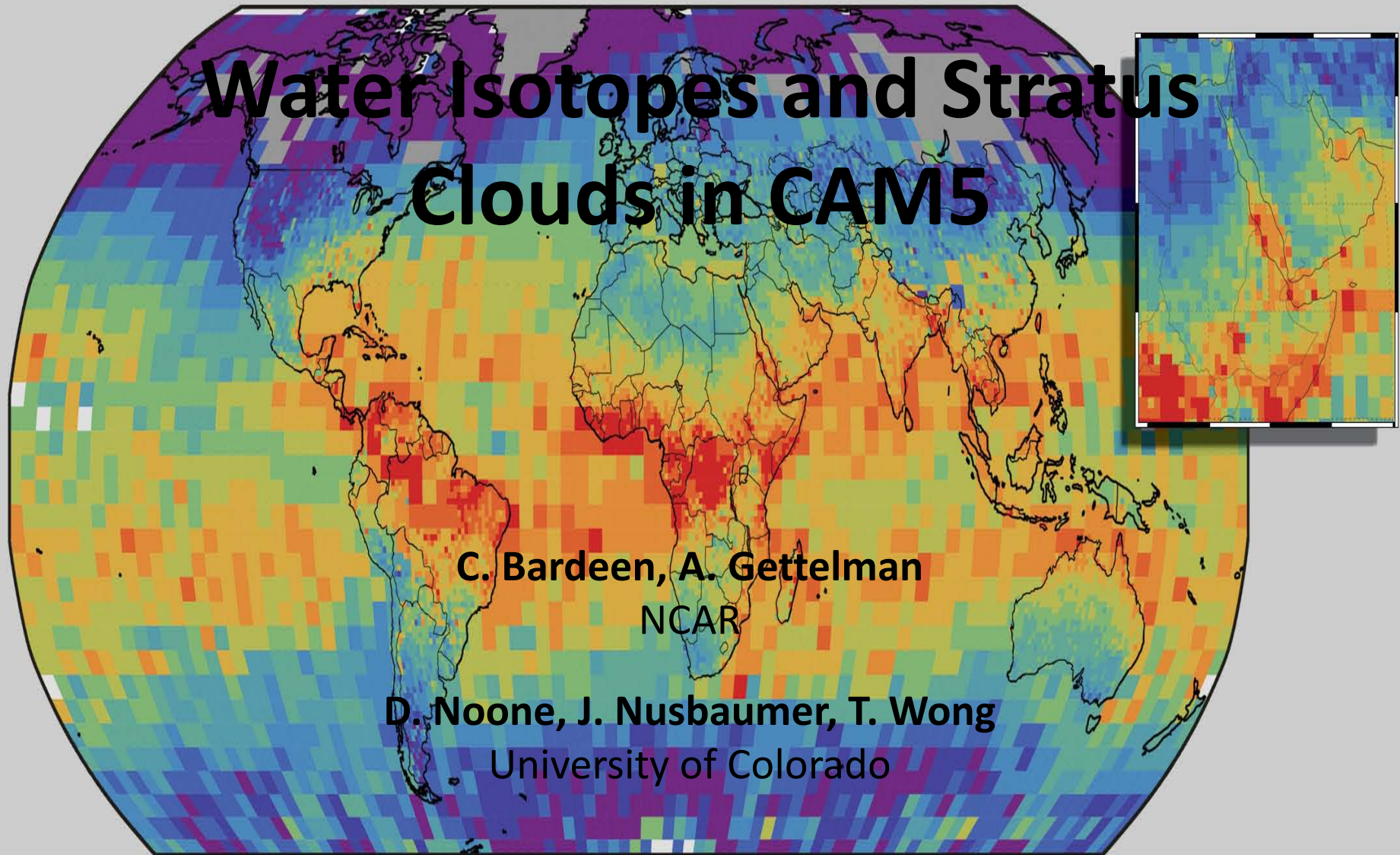


Water Isotopes and Stratus Clouds in CAM5



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Paleoclimate Working Group

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low relative HDO content

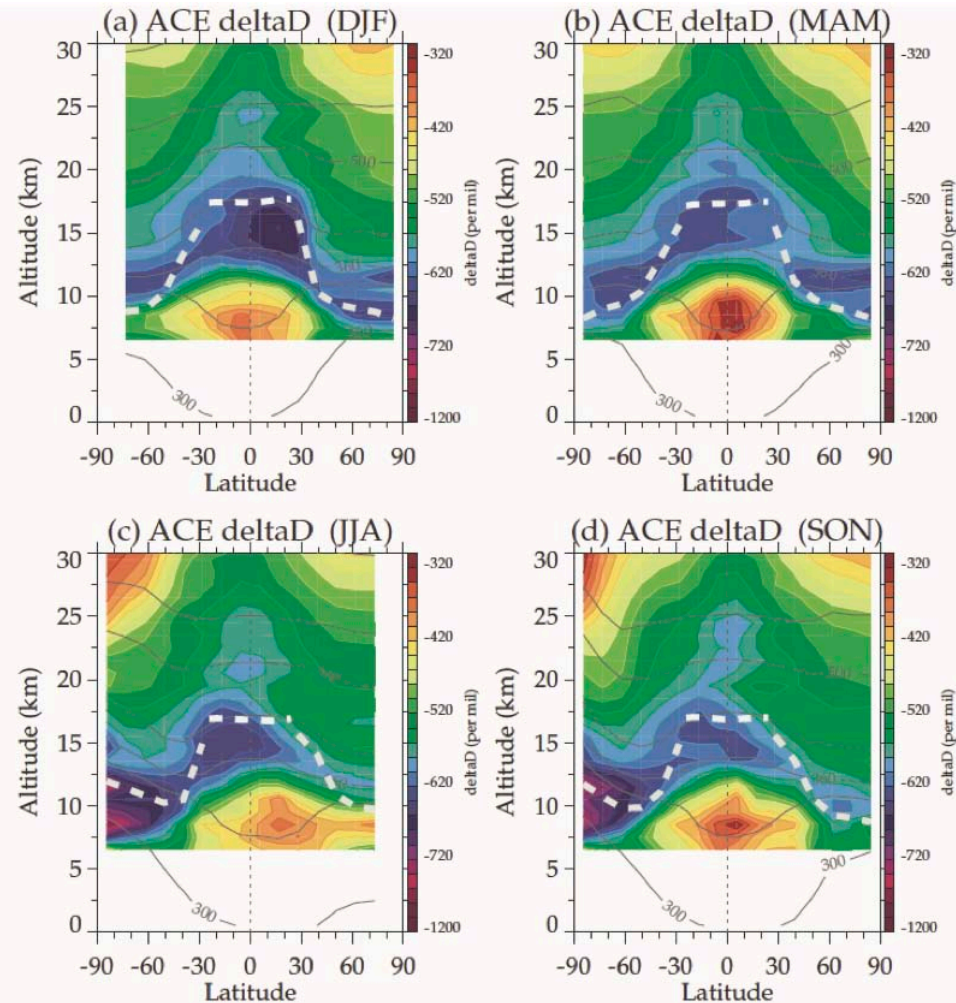
high relative HDO content

[Frankenberg et al.]

Motivation

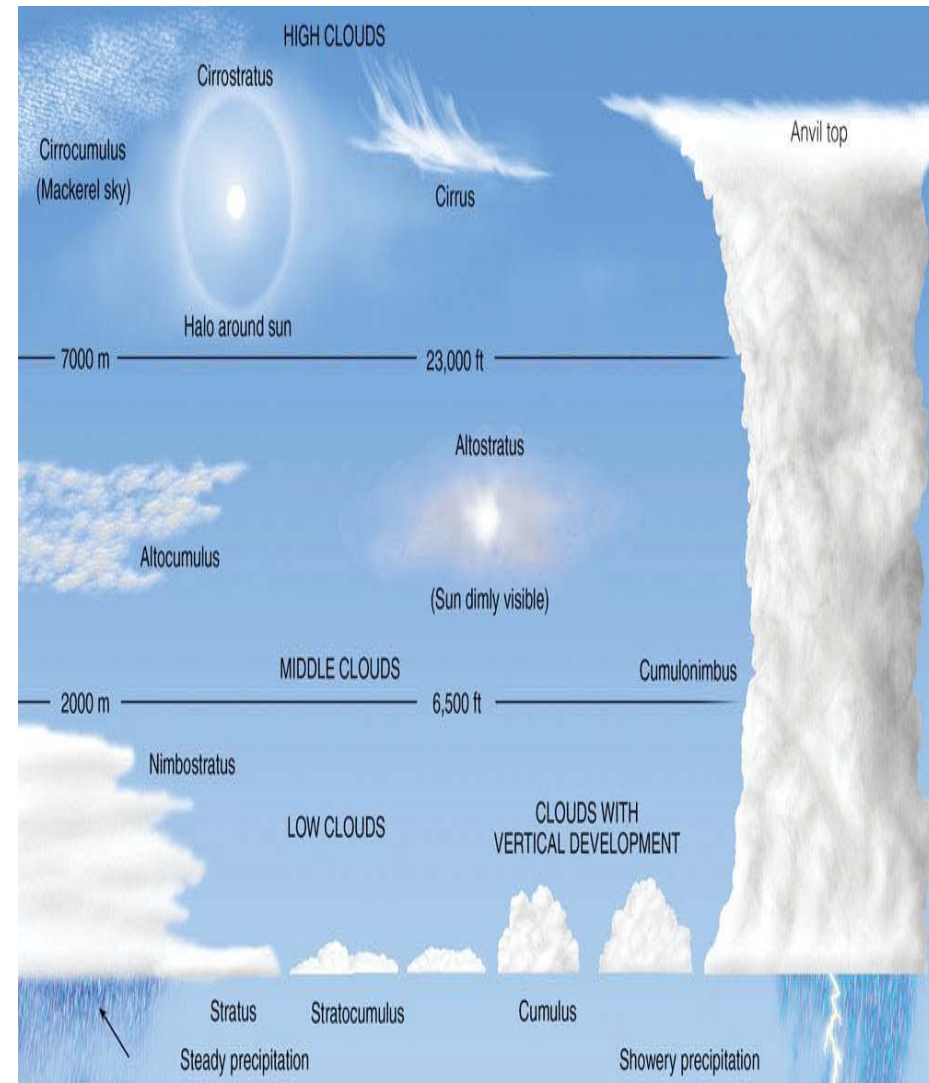
- New Sectional Cirrus Parameterization
- Focused on UTLS
 - Water Vapor
 - Ice Clouds
 - Heating Rates
- Transport
 - Slow Ascent
 - Convection
 - Monsoon Circulation

HDO



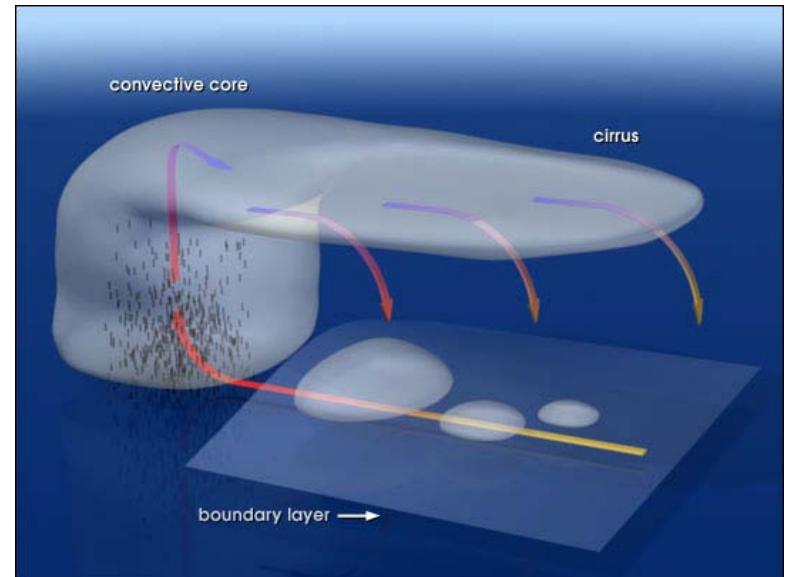
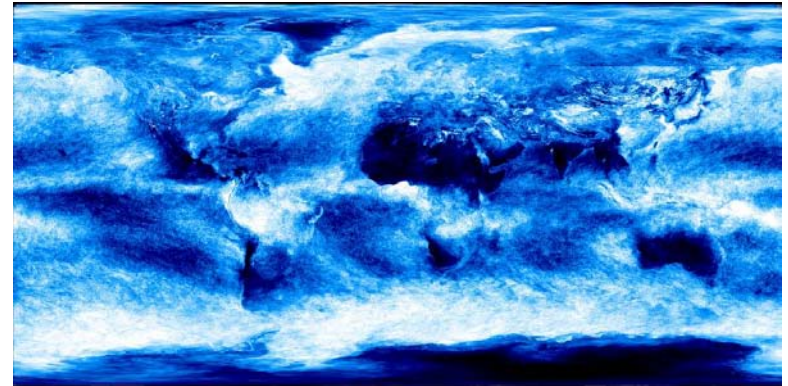
Stratiform Parameterization

- MG Two-Moment Scheme
[Morrison et al. 2008, Gettelman et al. 2010]
- State Variables
 - Water Vapor
 - Mass
 - Cloud Liquid
 - Mass
 - Number
 - Cloud Ice
 - Mass
 - Number
- Diagnostic Rain & Snow
 - Mass
- Modal Aerosols
- Allows Ice Supersaturation



Cloud Macrophysics

- Revised by Park et al.
- Cloud Fraction
- Liquid Condensation
 - Mass
- Convective Detrainment
 - Mass



Cloud Microphysics

- Morrison-Gettelman Two-Moment Scheme
- Droplet Activation
- Ice Nucleation
- Growth/Evaporation
- Melt/Freeze
- Sedimentation
- Accretion
- Autoconversion
- Precipitation

MG Microphysics Processes

(Ignoring processes that don't change mass or phase)

From/To	Vapor	Liquid	Ice	Rain	Snow
Vapor		Activation Condensation	Nucleation Deposition		
Liquid	Evaporation	Sedimentation	Bergeron Freezing (I) Freezing (C) Hallet-Mossop	Autoconversion Accretion	Bergeron Accretion
Ice	Sublimation	Melting	Sedimentation		Autoconversion Accretion
Rain	Evaporation				Freezing Accretion
Snow	Sublimation			Melting	

Solving for Isotope or Tag

The diagram illustrates the relationship between the change in isotope concentration over time and the mass growth rate, influenced by a fractionation factor and the reservoir ratio of the source type.

$$\frac{dISOTOPE}{dt} = \alpha \frac{ISOTOPE}{BULK} \frac{dBULK}{dt}$$

Labels and arrows pointing to the equation:

- Fractionation Factor** (points to α)
- MG Process Rate** (points to $\frac{dBULK}{dt}$)
- Reservoir Ratio of Source Type** (points to $\frac{ISOTOPE}{BULK}$)
- Isotope Process Rate** (points to $\frac{dISOTOPE}{dt}$)

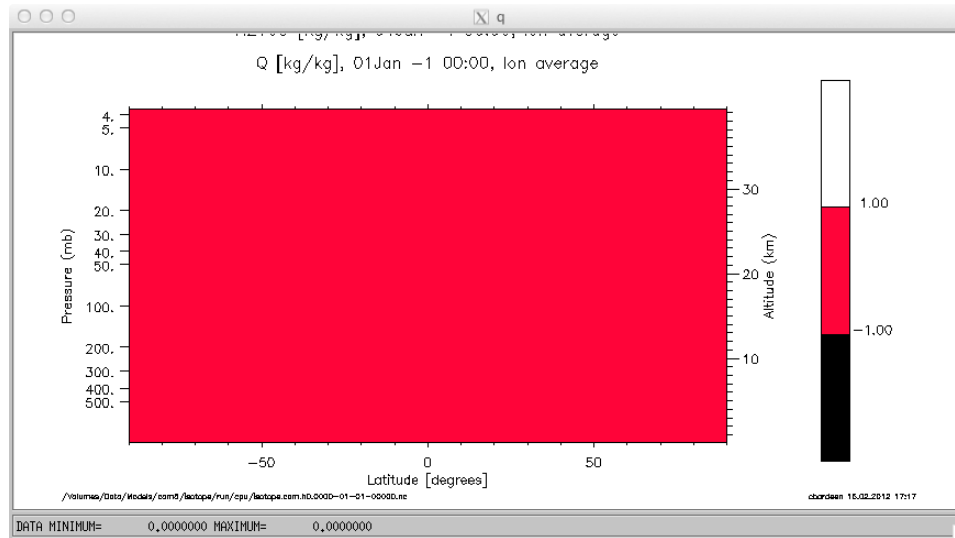
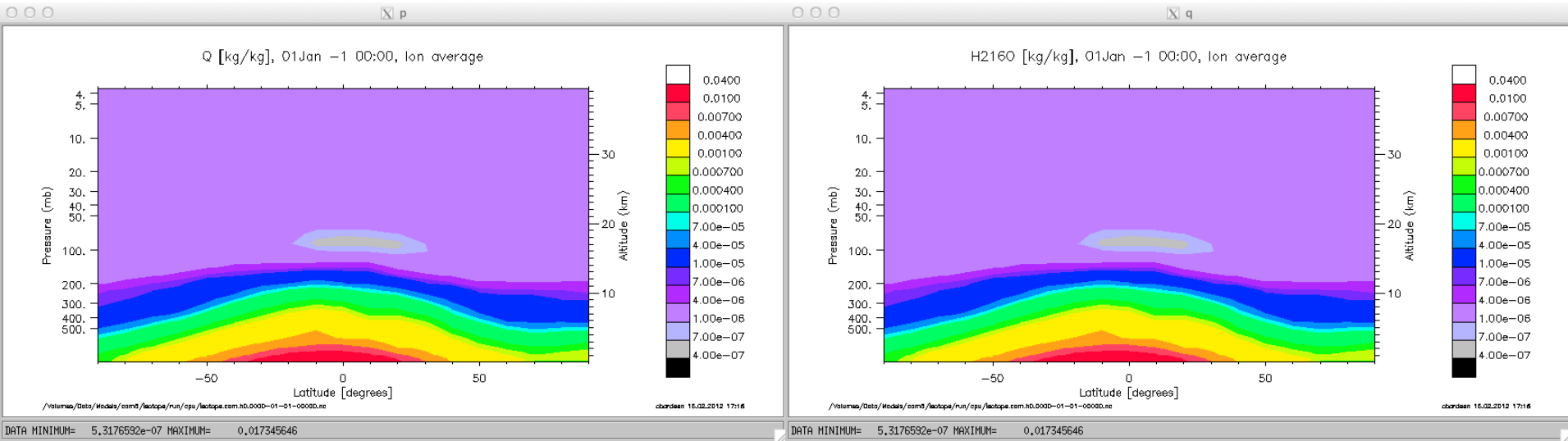
Software Design

- Building on prior work from David Noone with CAM3.0
- Shared Components
 - Water Isotopes (water_isotopes.F90)
 - Isotopic species
 - Fractionation factors
 - Standard Isotope Ratios
 - H₂O, HDO, H₂¹⁸O
 - Water Types (water_types.F90)
 - Phases of water
 - Vapor, Liquid, Ice, Convective Rain, Convective Snow, Stratiform Rain, Stratiform Snow
- CAM Component
 - Water Tracers (water_tracers.F90)
 - Implements CAM Physics Package interface
 - Supports “Water Sets” (1 species, all water types)
 - Calculates tendencies on one or more water sets based upon tendencies to “real” water
- Model Configurations
 - configure –isotope <model>
 - Models: h216o, h216o_hdo, h216o_hdo_h218o
- Namelist Driven
 - Easy to add new species, tags, models

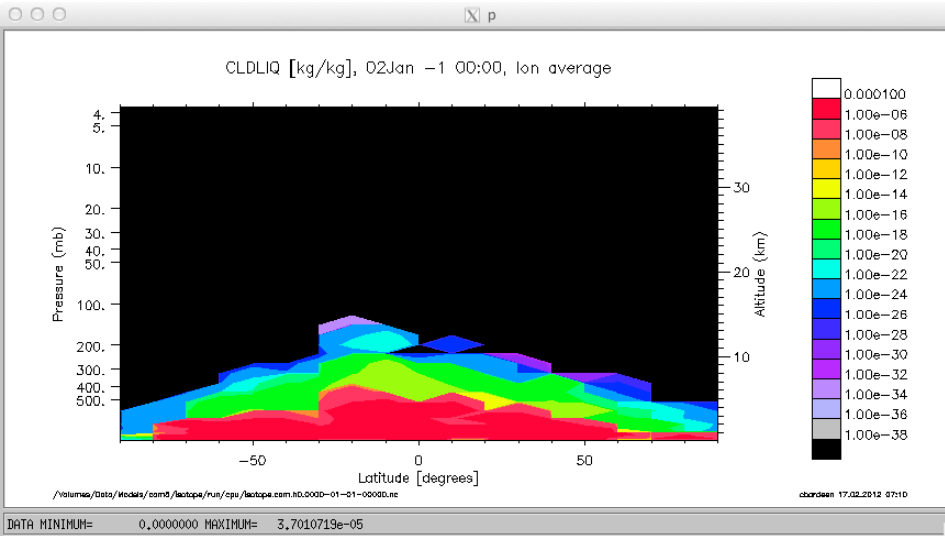
Sample atm_in Namelist

```
&water_tracer_nl
  isotope_model          = 'h216o'
  trace_water            = .true.
  wisotope               = .false.
  wtrc_add_cvprecip      = .true.
  wtrc_add_stprecip      = .true.
  wtrc_check_show_types = .true.
  wtrc_check_total_h2o   = .true.
  wtrc_check_wset        = .true.
  wtrc_detrain_in_macrop = .true.
  wtrc_niter             = 10
  wtrc_names              = 'H216O','H216OL','H216OI','H216OR','H216OS','H216Or','H216Os'
  wtrc_species_names     = 'H216O','H216O','H216O','H216O','H216O','H216O','H216O'
  wtrc_type_names        = 'VAPOR','LIQUID','ICE','RAINS','SNOWS','RAINC','SNOWC'
  wtrc_srfpcp_names      = 'H216OR','H216Or','H216OS','H216Os'
  wtrc_srfvap_names      = 'H216O'
/
```

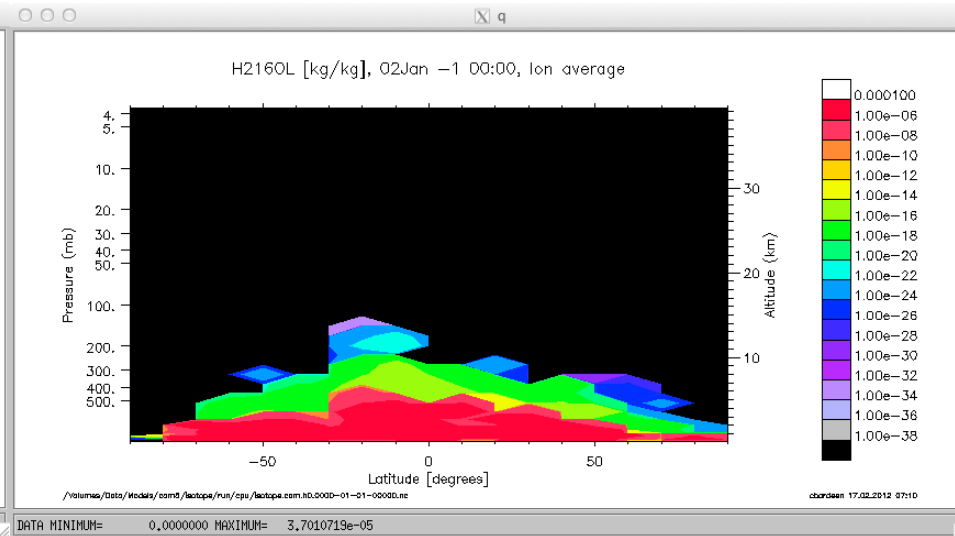
Water Vapor



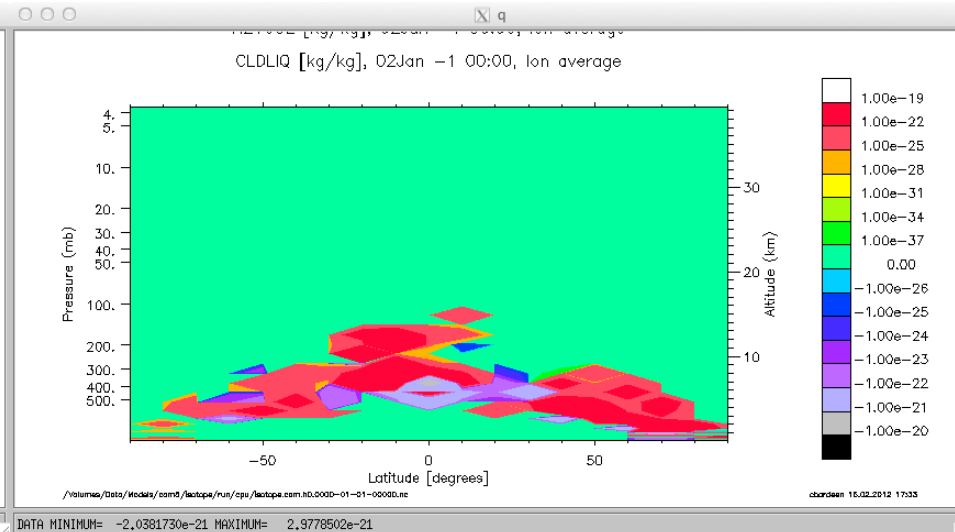
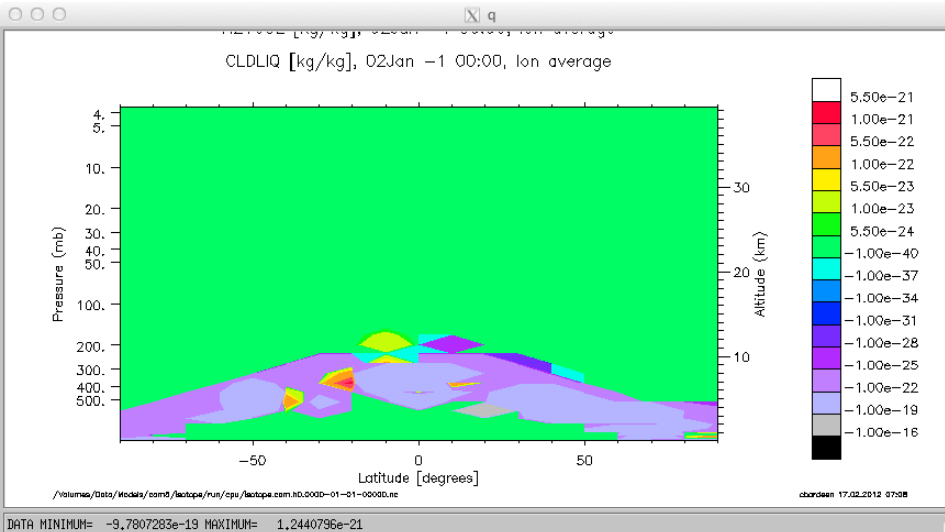
Cloud Liquid



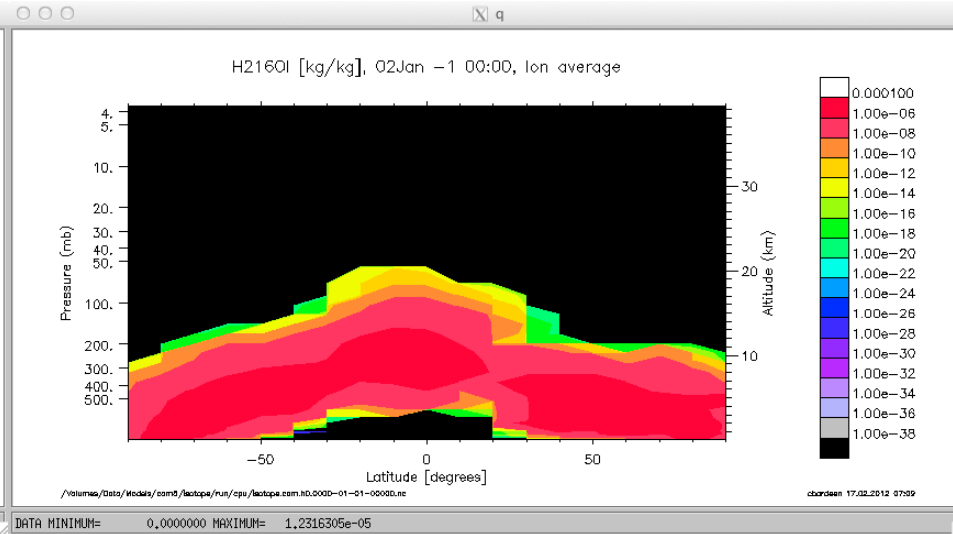
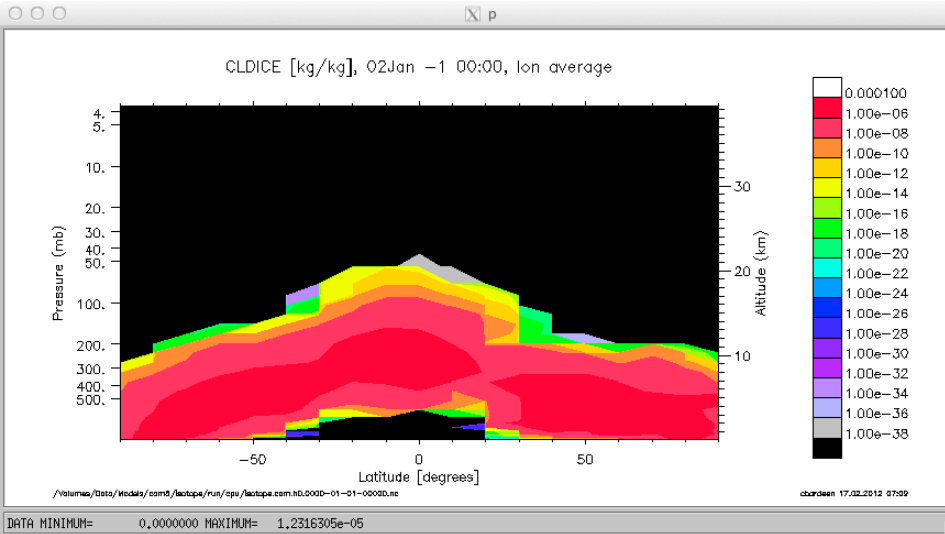
$Q_{min} = 1e-18$



$Q_{min} = 0.$

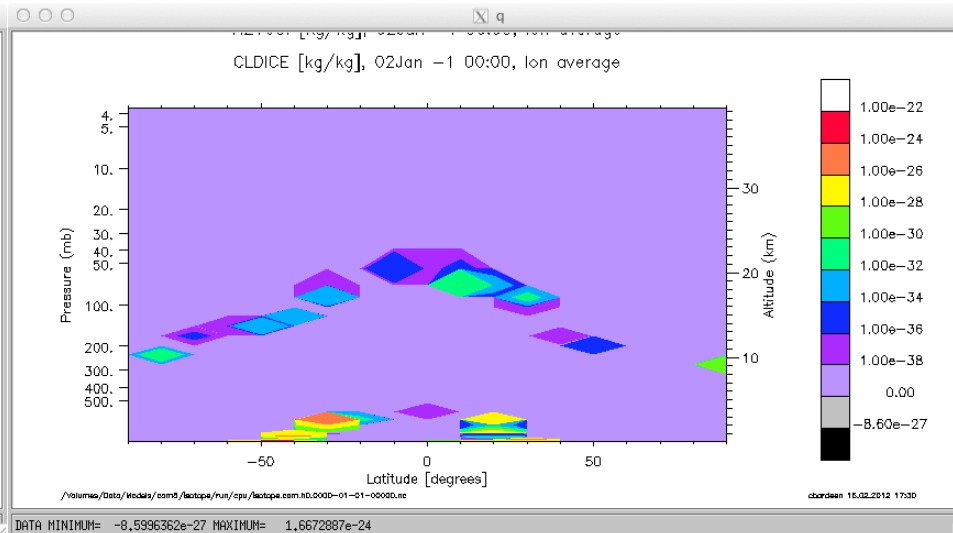
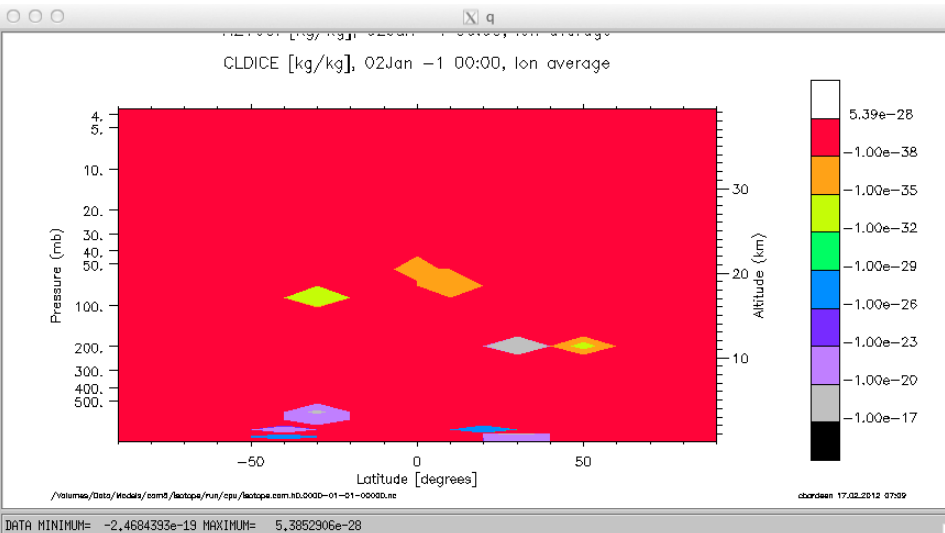


Cloud Ice



Qmin = 1e-18

Qmin = 0.



Summary/Future Work

- Still in early stages, but we have implemented a basic framework in CAM for water isotopes and tags linked with stratiform processes, that conserves overall mass to 1 part in 10^{14} .
- Short Term
 - Integrate stratiform & convective code for water tracers
 - Rework ice/liquid sedimentation rates
 - Look for small differences in ice & water fields (application of Q_{min} ?)
 - Implement vapor – liquid isotope equilibrium
 - Test fractionation (HDO and HDO & $H_2^{18}O$ models)
 - Test water tagging
 - Couple precipitation to surface models
- Longer Term
 - Integrate with prognostic precipitation (MG2)
 - Integrate with WACCM5
 - Add HDO from CH_4
 - Integrate with CAM5/CARMA cirrus
- Coordination
 - Hugh Morrison, Michael Levy, Others?