Water Isotopes and Stratus Clouds in CAM5

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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

[Randel et al. 2012]
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)

<table>
<thead>
<tr>
<th>From/To</th>
<th>Vapor</th>
<th>Liquid</th>
<th>Ice</th>
<th>Rain</th>
<th>Snow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor</td>
<td></td>
<td>Activation Condensation</td>
<td>Nucleation Deposition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid</td>
<td>Evaporation</td>
<td>Sedimentation</td>
<td>Bergeron Freezing (I) Freezing (C) Hallet-Mossop</td>
<td>Autoconversion Accretion</td>
<td>Bergeron Accretion</td>
</tr>
<tr>
<td>Ice</td>
<td>Sublimation</td>
<td>Melting</td>
<td>Sedimentation</td>
<td></td>
<td>Autoconversion Accretion</td>
</tr>
<tr>
<td>Rain</td>
<td>Evaporation</td>
<td></td>
<td></td>
<td></td>
<td>Freezing Accretion</td>
</tr>
<tr>
<td>Snow</td>
<td>Sublimation</td>
<td></td>
<td></td>
<td>Melting</td>
<td></td>
</tr>
</tbody>
</table>
Solving for Isotope or Tag

\[
\frac{d\text{ISOTOPE}}{dt} = \alpha \frac{\text{ISOTOPE}}{\text{BULK}} \frac{dBULK}{dt}
\]

- Fractionation Factor
- MG Process Rate
- Isotope Process Rate
- Reservoir Ratio of Source Type
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
    • H$_2$O, HDO, H$_2^{18}$O
  – 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

Qmin = 1e-18

Qmin = 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 Qmin?)
  - 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?