# **Stable Water Isotopes in CAM5**: Current development and initial results

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# Contributors

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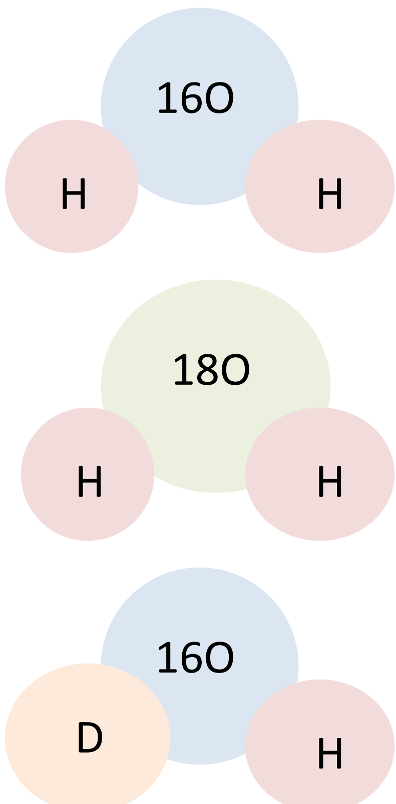
# Isotopes Intro




$$\delta = \left(\frac{R}{R_{ocn}} - 1\right) * 1000$$

Isotopes are atoms with a certain number of neutrons.

Isotopologues are molecules that contain different isotopes.

Three isotopologues for water used in model:

$H_2O$, HDO, $H_2{}^{18}O$

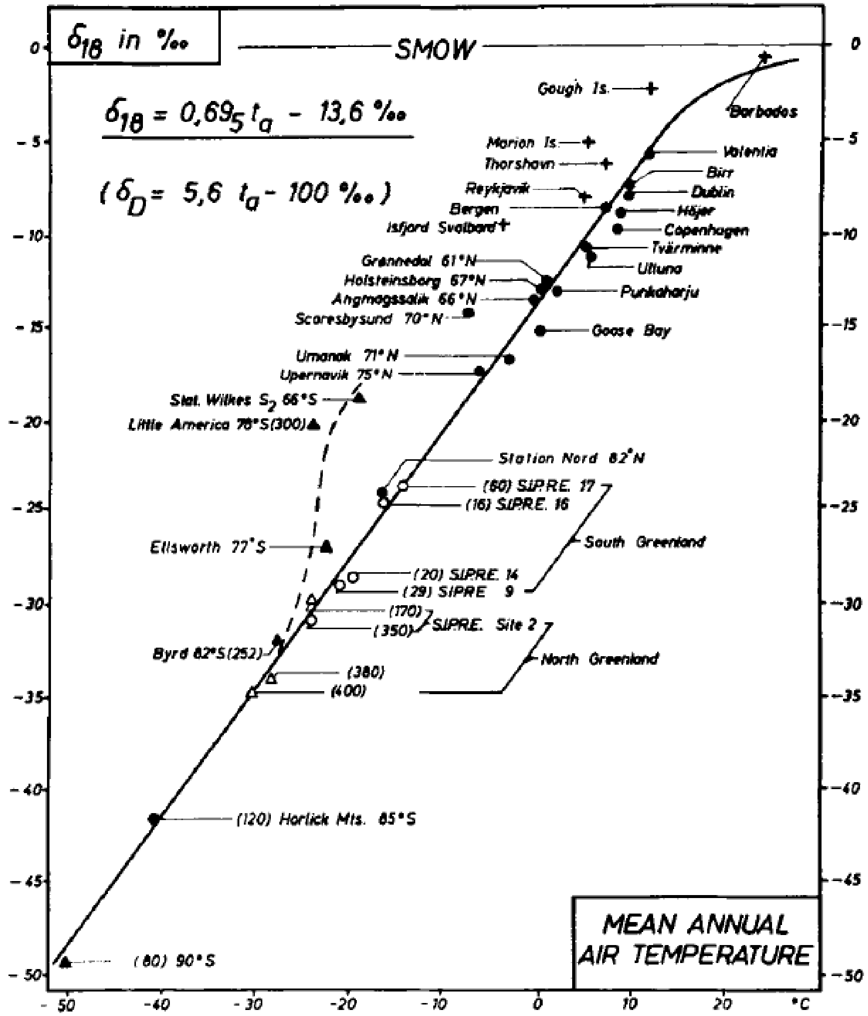
# Isotopes and Paleoclimate

Examples of proxy data[1]:

- Ice Cores
- Sediment Cores
- Speleothems
- Tree Ring and pete-bog cellulose

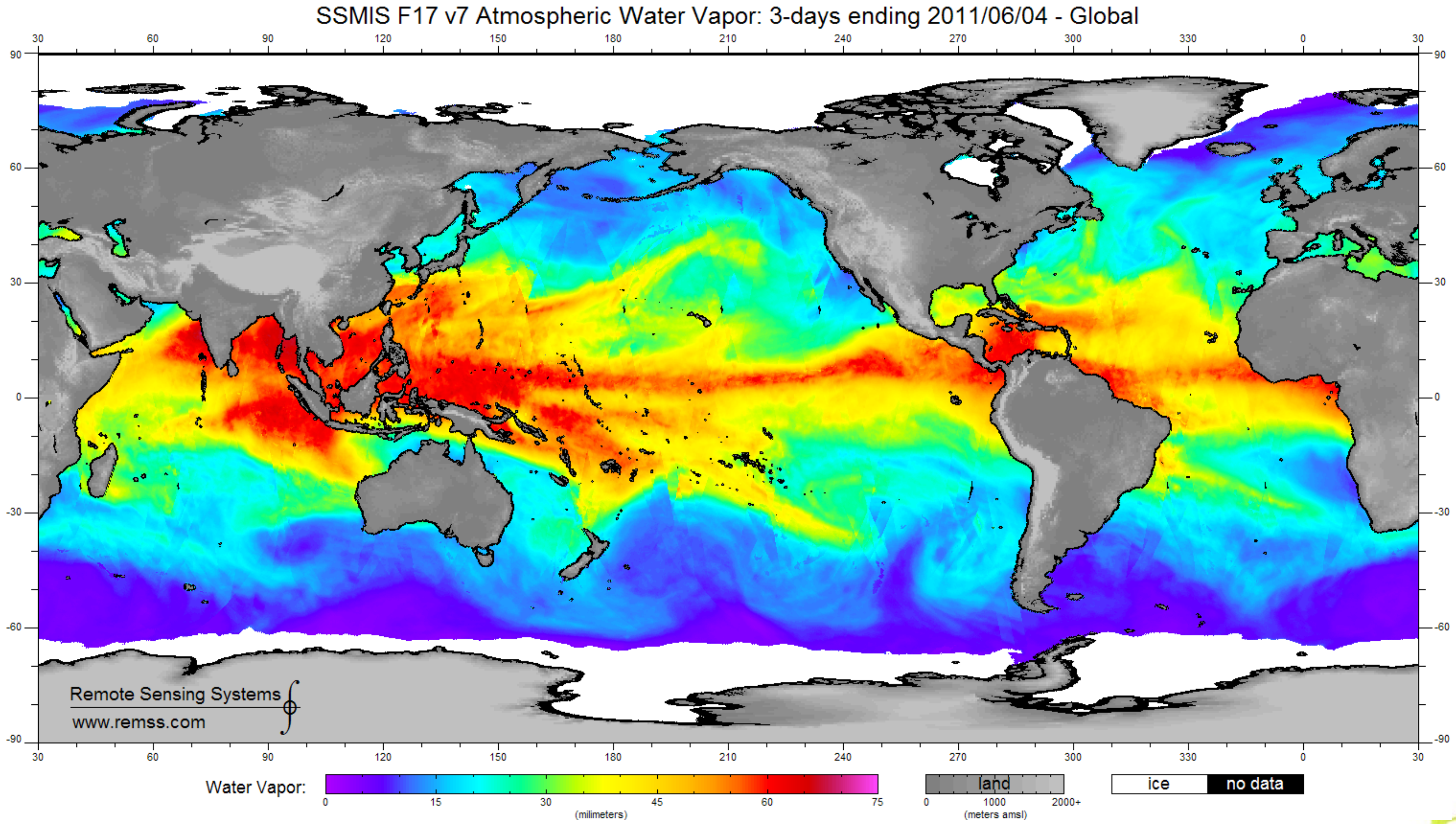
[1]From Sturm et. al., 2010.

# Isotopes and Paleoclimate




From Dansgaard, 1964.

# Modern Scientific benefits



# Isotope Modeling - Intro

Define water “Tracers” that are governed by the tendency equation:

$$\frac{\partial q_i}{\partial t} = -V \cdot \nabla q_i + D\nabla_h^2 q_i + \frac{\partial}{\partial p}(\overline{\omega' q'_i}) + R_E E - R_C C + R_S S$$

From Noone and Sturm, 2010.

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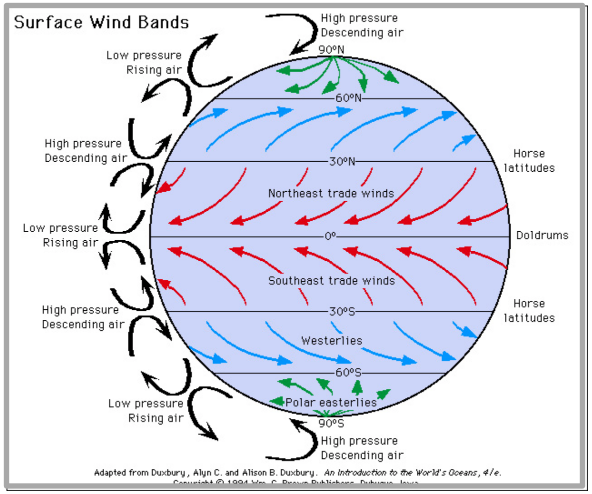
Involves Convection and Cloud physics isotope parameterizations. Definitely non-trivial.

From Noone and Sturm, 2010.

# Advection and Diffusion

CAM5 Automatically handles the atmospheric transport and diffusion of the water isotope tracers, where no fractionation occurs.

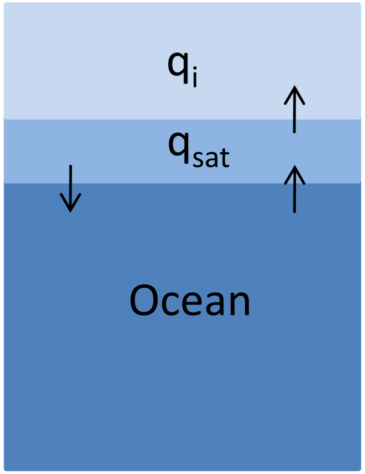
$$\frac{\partial q_i}{\partial t} = -V \cdot \nabla q_i + D\nabla_h^2 q_i + \frac{\partial}{\partial p}(\overline{\omega' q'_i})$$



# Ocean Evaporation

The only addition so far besides the tracers themselves is the ocean evaporation term:

$$\frac{\partial q_i}{\partial t} = R_E E = \rho \eta c \left( \frac{R_{ocn}}{\alpha_{eq}} q_{sat} - q_i \right)$$




Equation from Noone and Sturm, 2010.

# Equilibrium Fractionation

Equilibrium fractionation is the difference in isotopic vapor and liquid abundance after the system reaches equilibrium, approximated by:

$$\alpha_{eq} = \exp(C_1 + \frac{C_2}{T} + \frac{C_3}{T^2})$$

Equation from Majoube, 1971

# Kinetic Fractionation

Kinetic fractionation is the difference in vapor phase and liquid phase isotope concentration while the system is trying to reach equilibrium.

$$\eta = 1 - \alpha_k$$

$$\alpha_k = \frac{(\frac{D}{D_i})^n - 1}{(\frac{D}{D_i})^n + C}$$

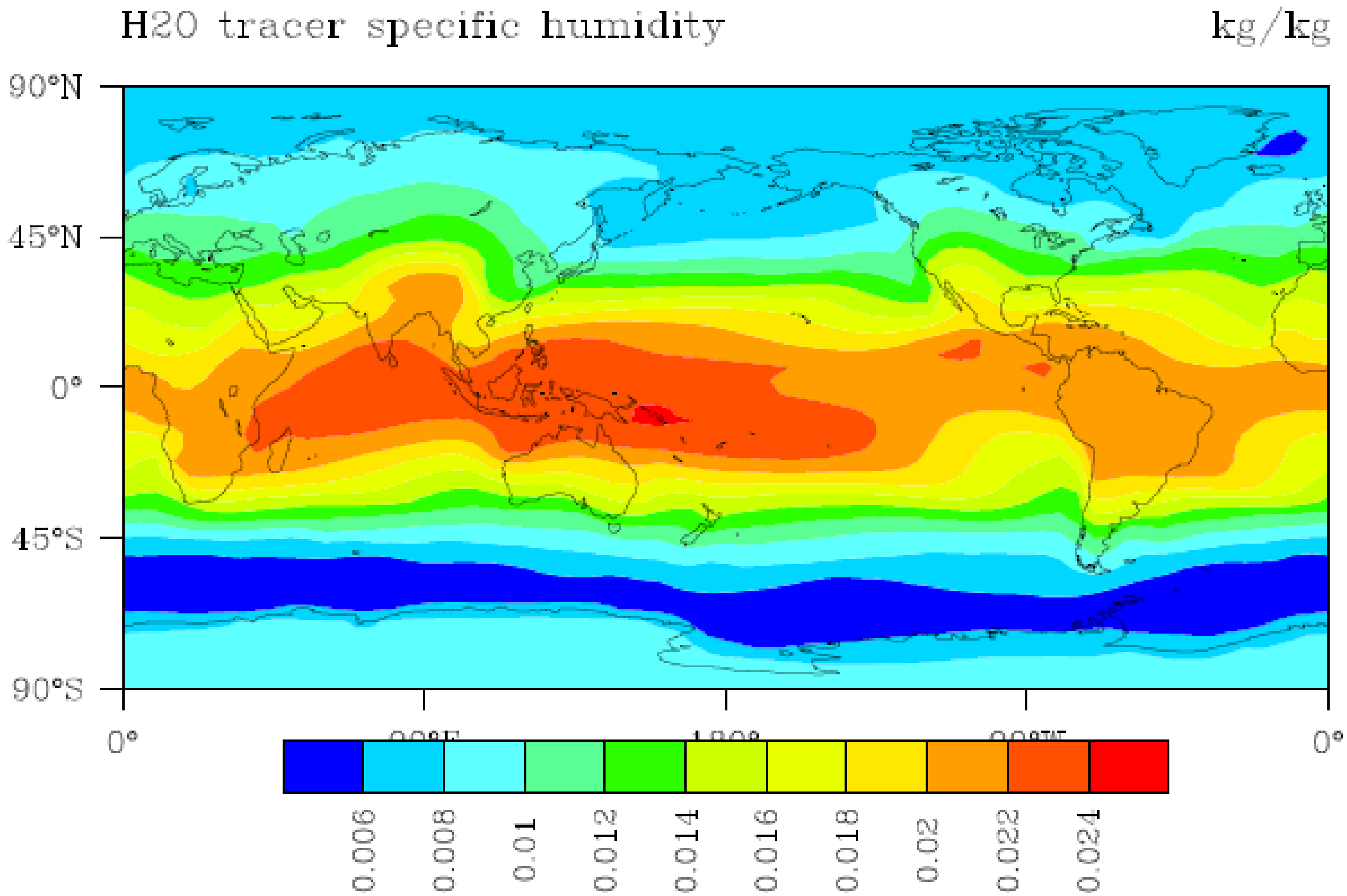
Equation from Merlivat and Jouzel, 1978

# Results

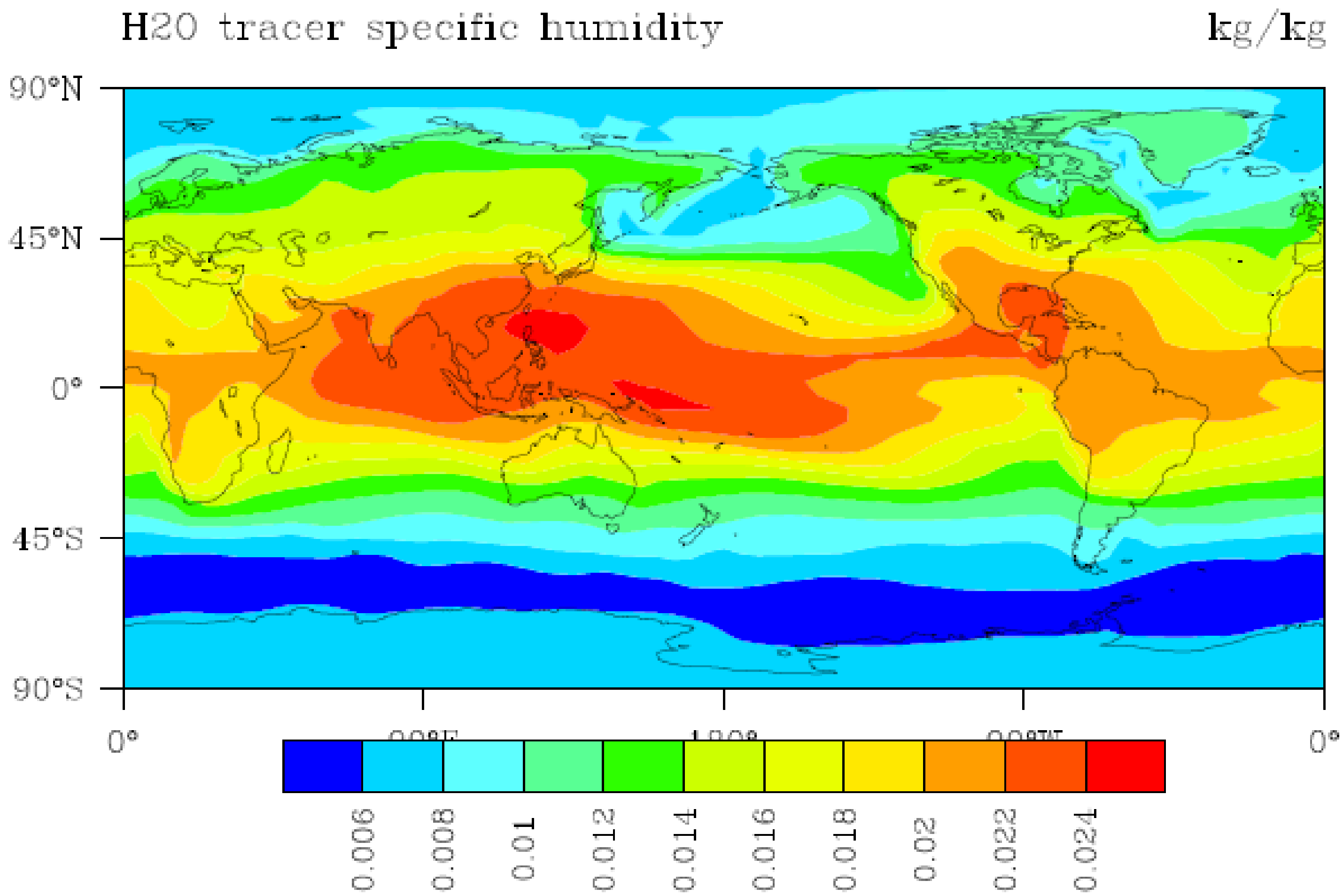
- Ran a CAM5 (F-compset) simulation with water isotope tracers and evaporation physics.

- Ran for 3 years with year 2000 initial conditions. It used a Finite-volume dynamical core with 4x5 degree grid resolution. $R_{ocn}$ was set to 1.0.

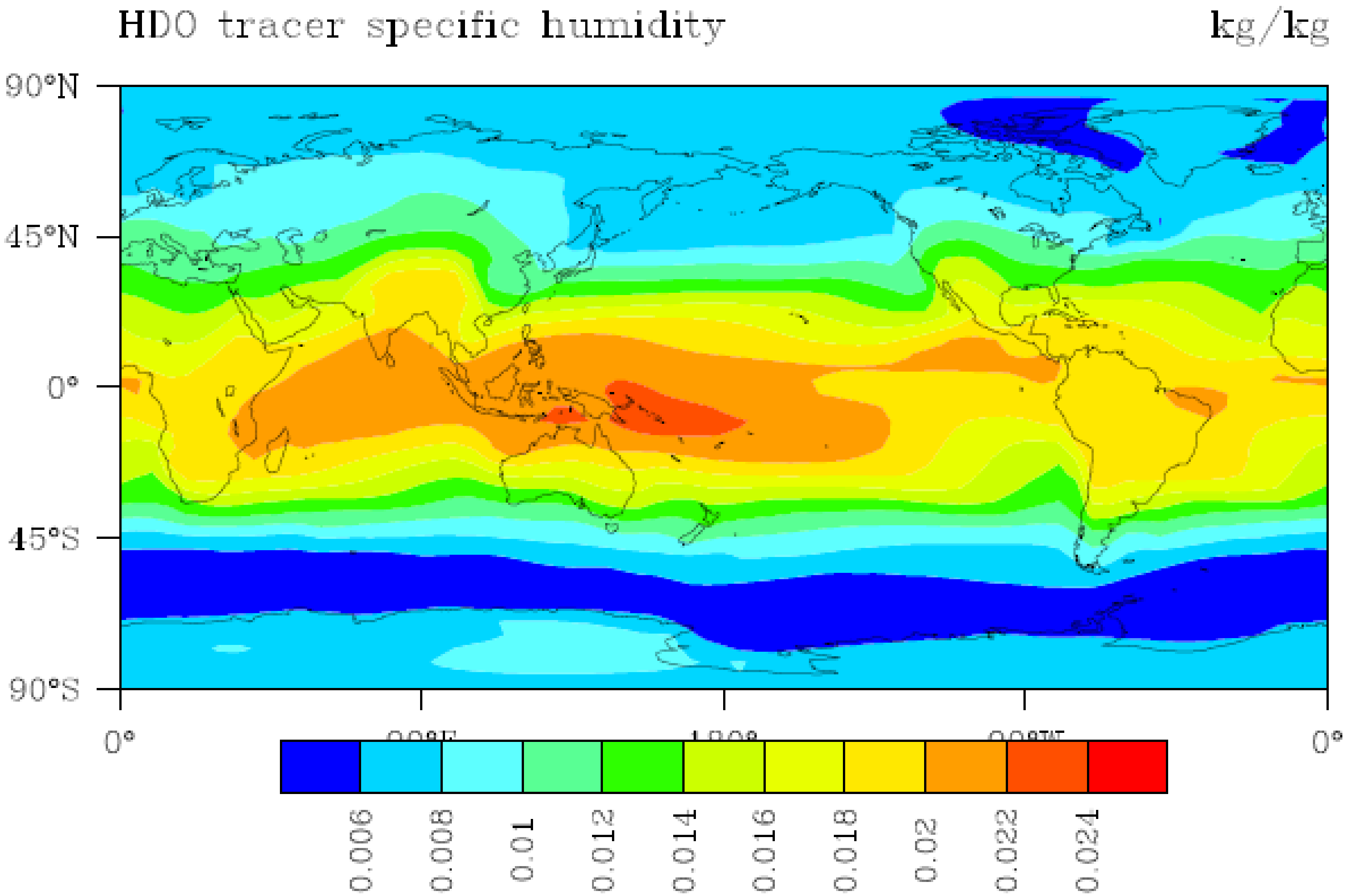
# Results – $H_2O$ tracer (DJF, ~1000 mb)



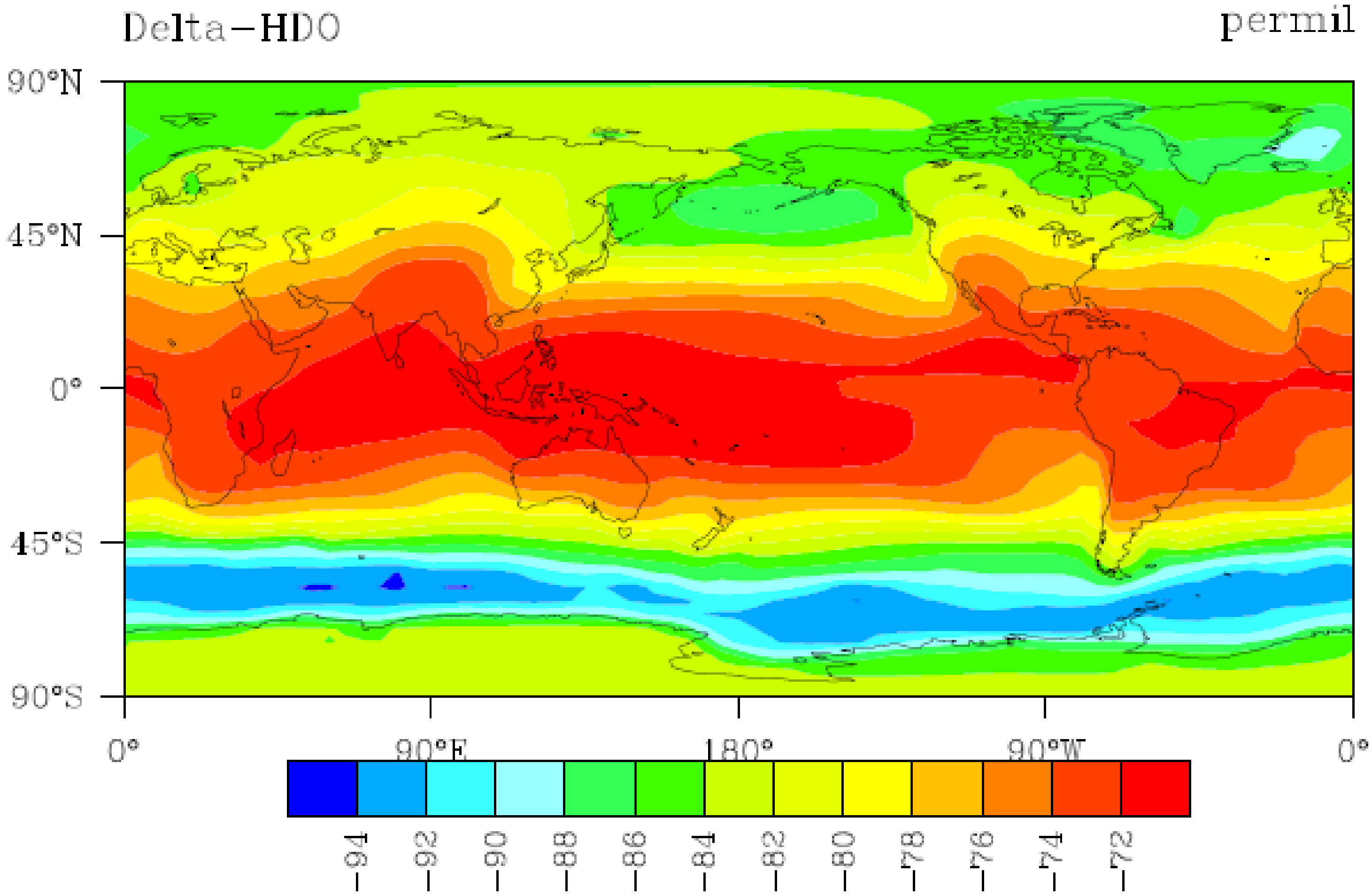
# Results – $H_2O$ tracer (JJA, ~1000 mb)



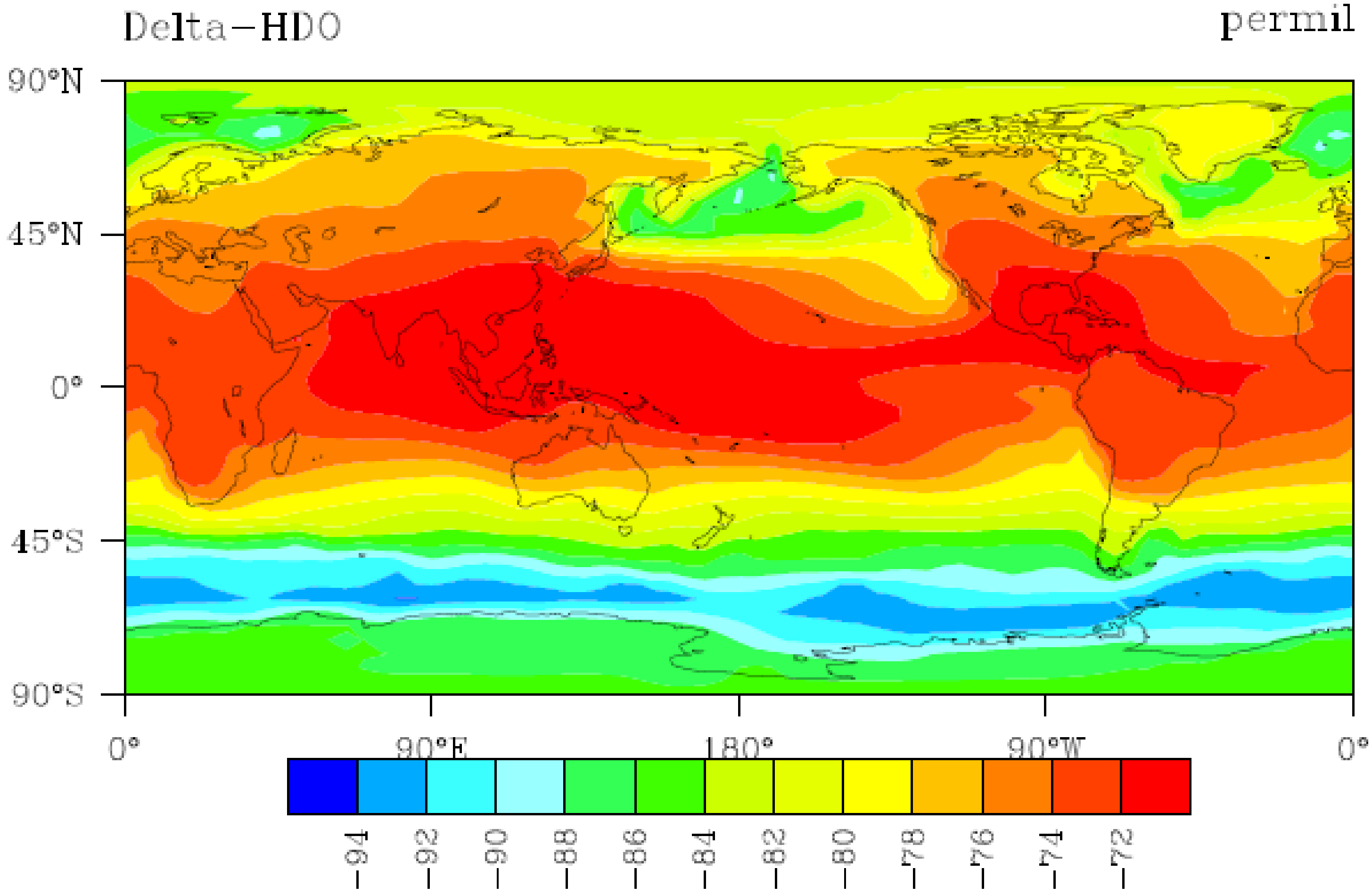
# Results- HDO tracer (no-delta, DJF, ~1000 mb)



# Results – HDO tracer (DJF, ~1000 mb)



# Results – HDO tracer (JJA, ~1000 mb)



# Conclusions

There are several benefits to adding stable water isotopes to the CESM, including paleo-proxy modeling, hydrological tracer studies, and parameterization development.

Work is under way to enable stable water isotopes into CAM5, with some very limited initial results.

# Future Work

Very-short term:  Fix bug in $H_2{}^{18}O$ evaporation scheme.

Short-term:  Add Cloud condensation and evaporation processes to the stable water isotope code.

Long-term:  Add stable water isotopes to the other CESM model components.

Very-long-term:  Add different isotopic systems.

# Bibliography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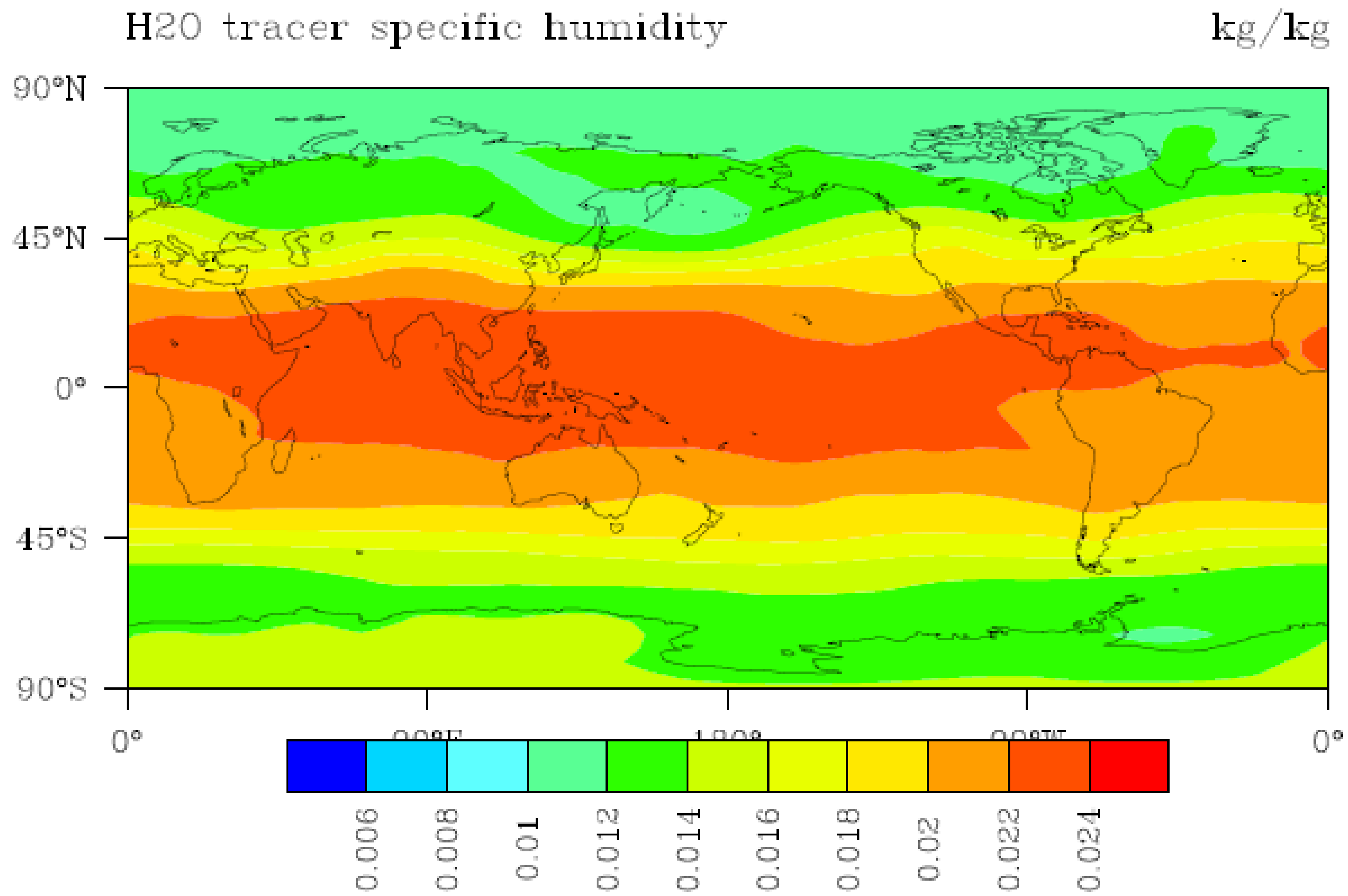
# Questions?

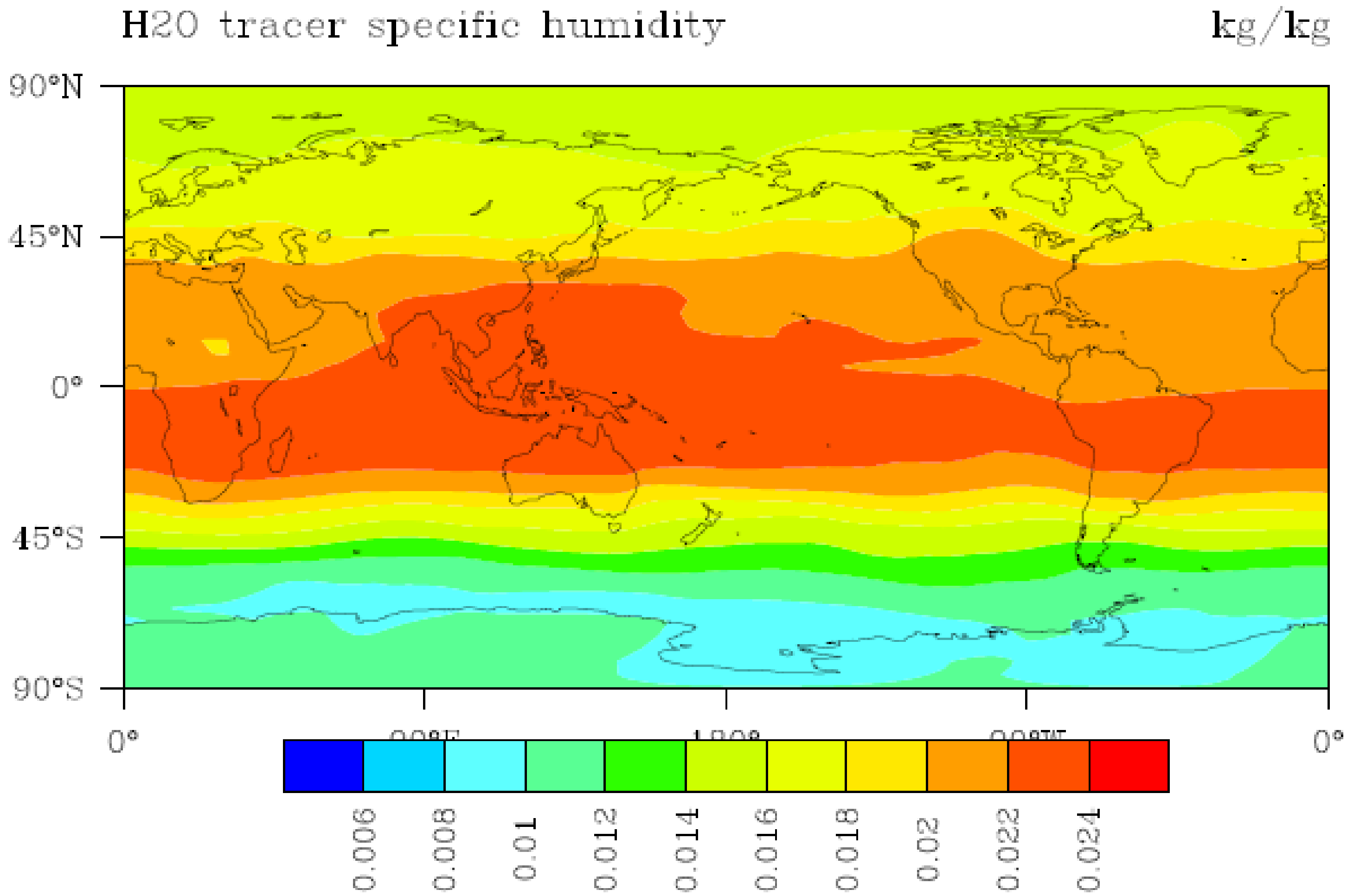
Thanks for listening!

# Supplemental slides

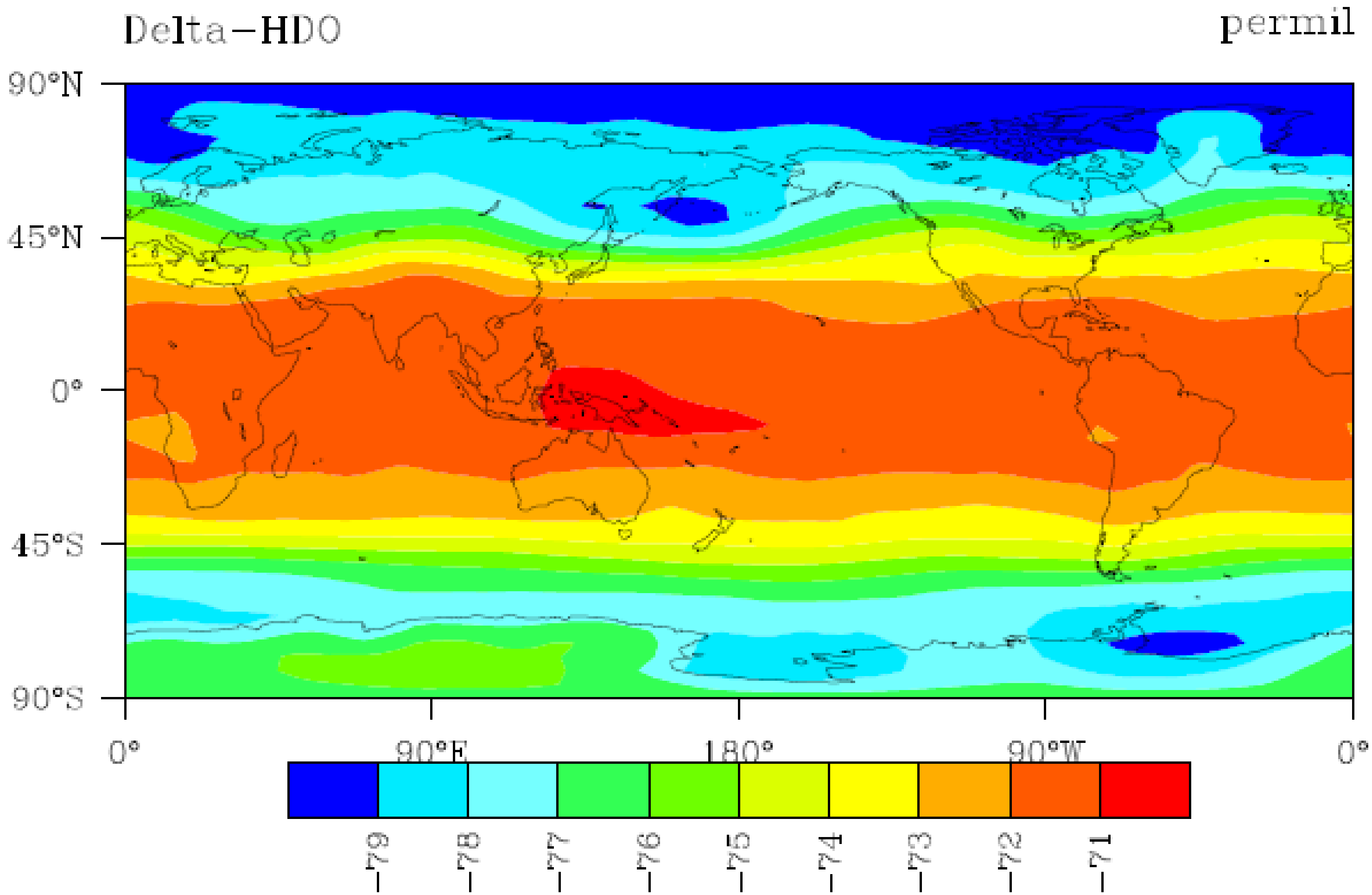
# Results – $H_2O$ tracer (DJF, ~500 mb)



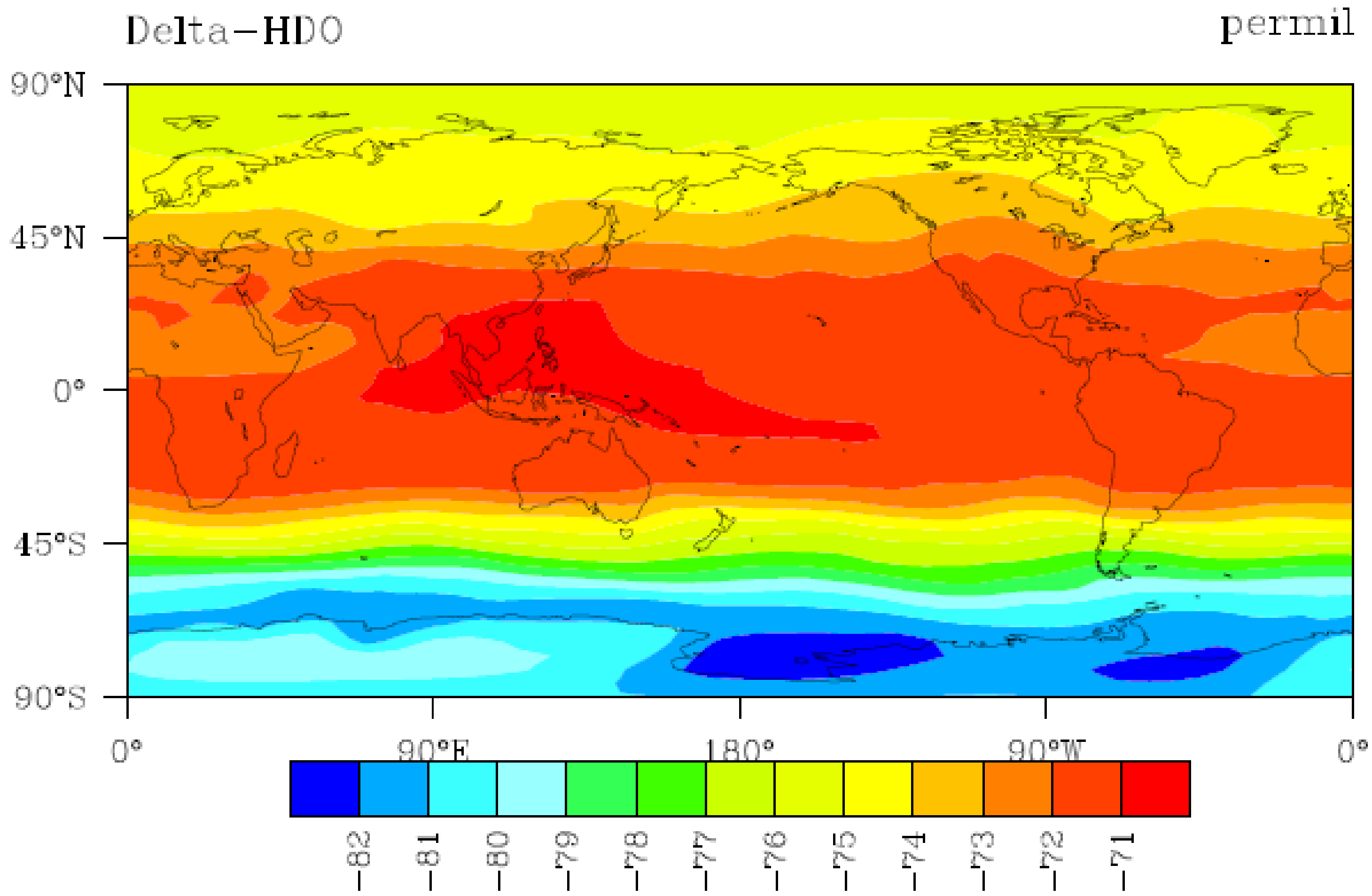
# Results – $H_2O$ tracer (JJA, ~500 mb)



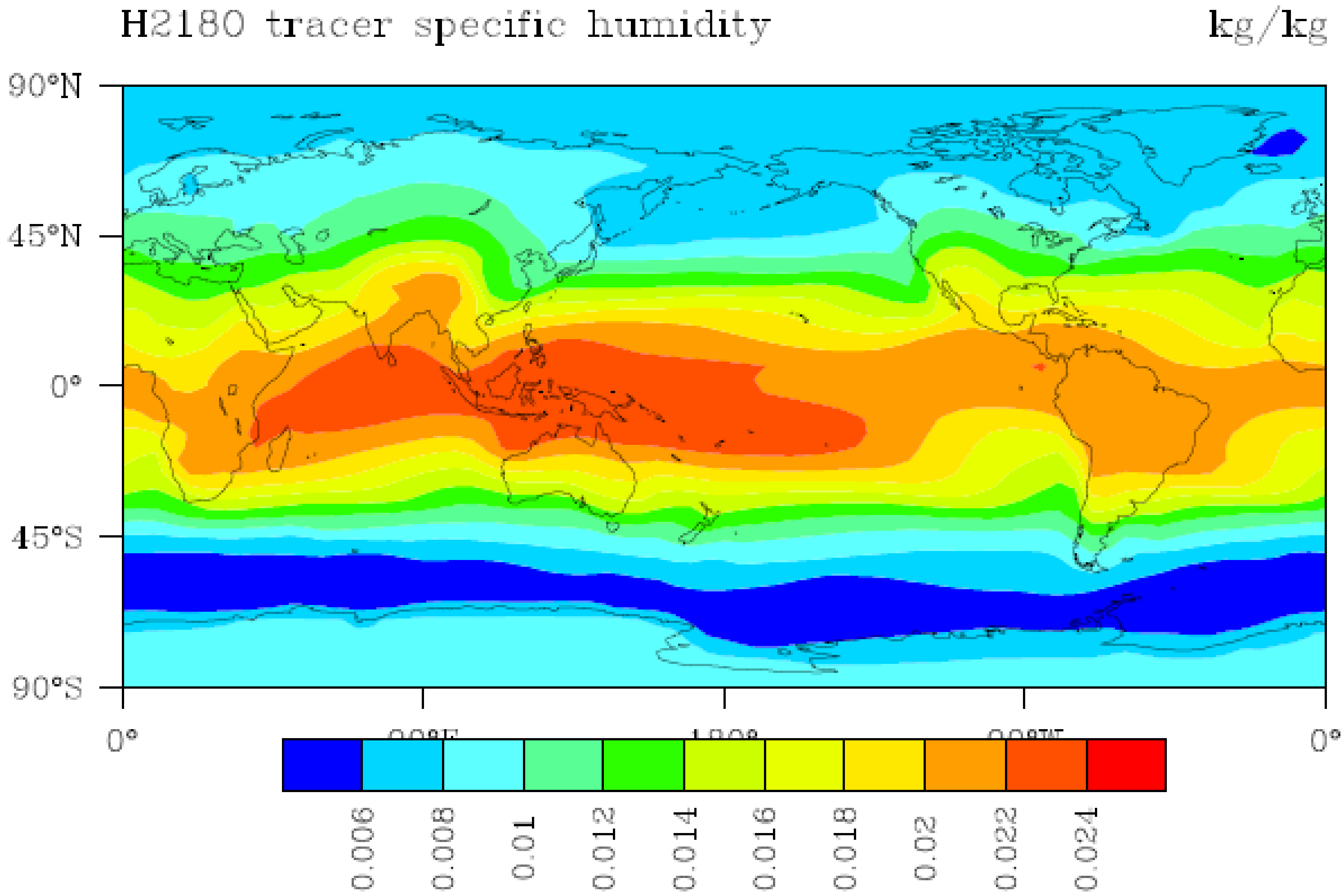
# Results – HDO tracer (DJF, ~500 mb)



# Results – HDO tracer (JJA, ~500 mb)



# When things go wrong…



# When things go wrong…