EARTH SYSTEM RESEARCH LABORATORY

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Non-CO_2 Climate Gases: *Water Vapor in the Upper Troposphere and Lower Stratosphere*

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with contributions from
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Upper Tropospheric and Stratospheric Water Vapor

Some Key Outstanding Questions:

- What are the trends in UTLS water vapor, and what caused them?
- How will UTLS water vapor change in a changing climate?
- How accurate are the measurements we currently have?
- What are the limits of supersaturation at cold temperatures and how does this impact cloud processes in the UT?
- What are the impacts of aviation (emitting aerosols and water) on the upper tropospheric cloud distribution?
- What is the water vapor feedback in a changing climate?

To address these questions, work at ESRL involves:

1) Development of instruments that measure water vapor from low stratospheric to high tropospheric values.

2) Analysis of measurement quality.

3) Analysis of long-term changes.

4) Microphysical, dynamical, and climate related studies.

Water Vapor Instruments

Campaign instruments

- NOAA Lyman-alpha: flew on balloons and assorted aircraft from 1978-2001.
- Aircraft frostpoint: 2 channel instrument, still undergoing refinement.
- TDL: Maycomm (commercial instrument); flies with UCATS or PANTHER.

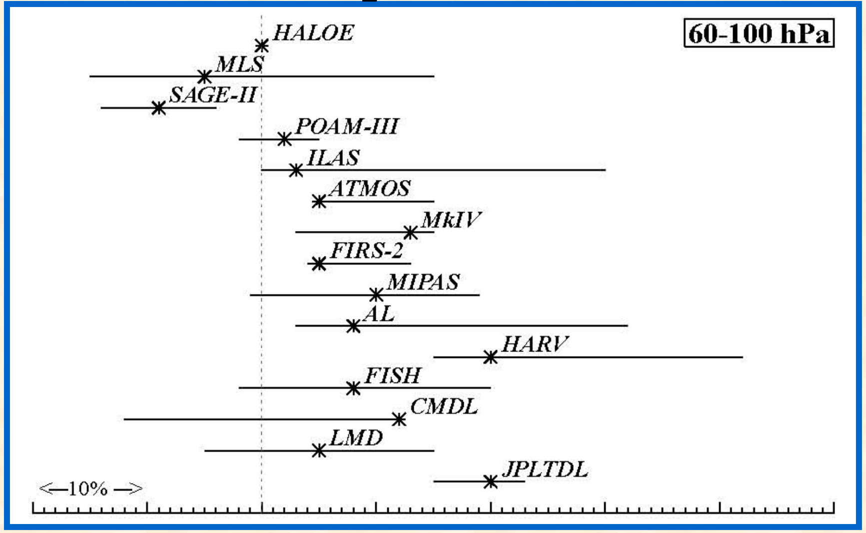
Monitoring instruments (also used for campaign IOPs)

- NOAA Frostpoint: started flying in Boulder in 1981, based on instrument developed by J. Masterbrook at NRL, slight modifications through the years, recent correction of biases published in Scherer et al. 2007 (ACPD).
- CU-CFH: New improved frostpoint balloon instrument, lighter and easier to operate, described in Vömel et al. 2006 (JGR)

Currently Boulder and New Zealand sondings are using the older design, other locations using the new instruments, plans are to eventually change all to the CU-CFH version. Analysis has shown good agreememt between the two instrument versions.

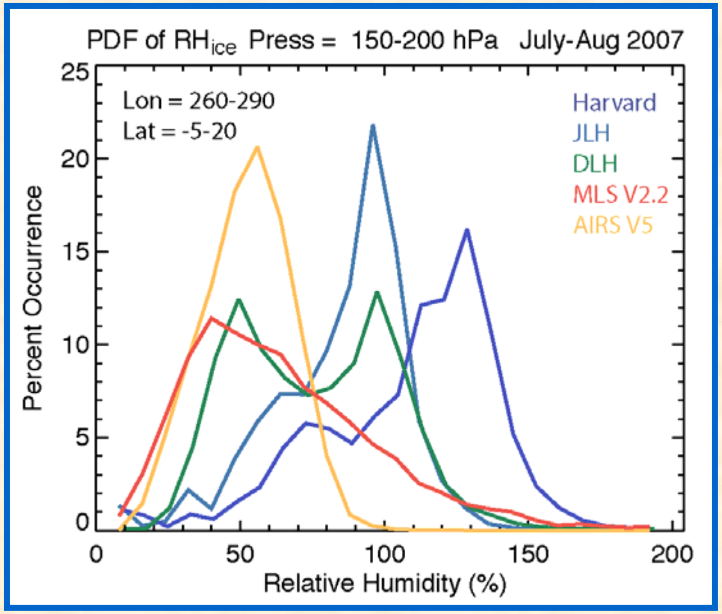
Analysis of Measurement Quality

From SPARC H_2O Assessment (2000)

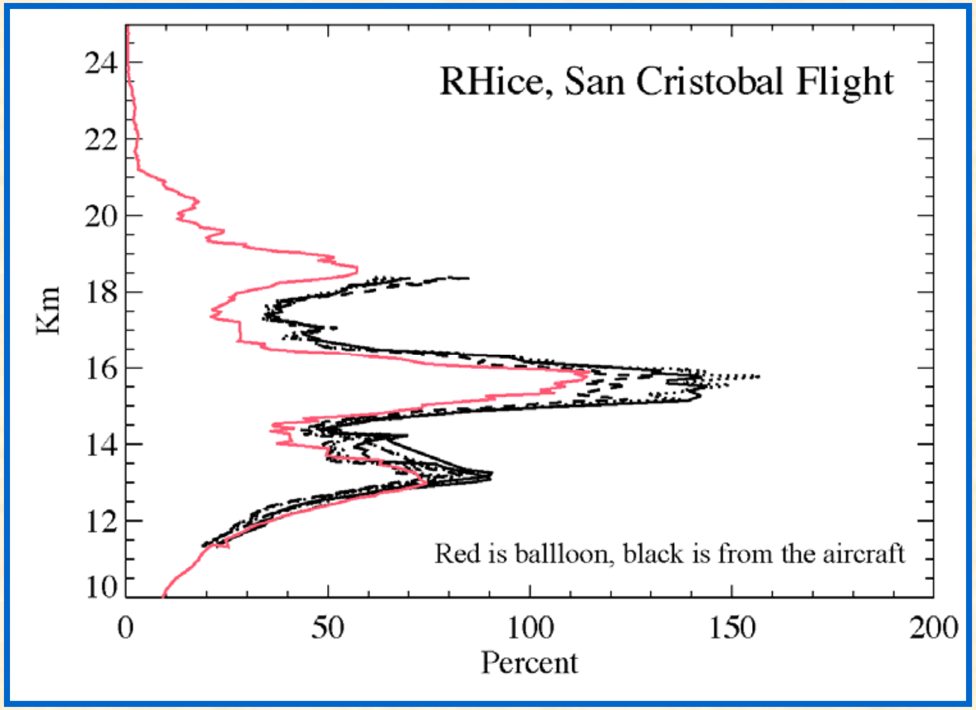


- Significant differences exist between state of the art instruments; these differences can impact interpretations.

From TC-4, Summer 2007



From Pre-AVE, Winter 2004



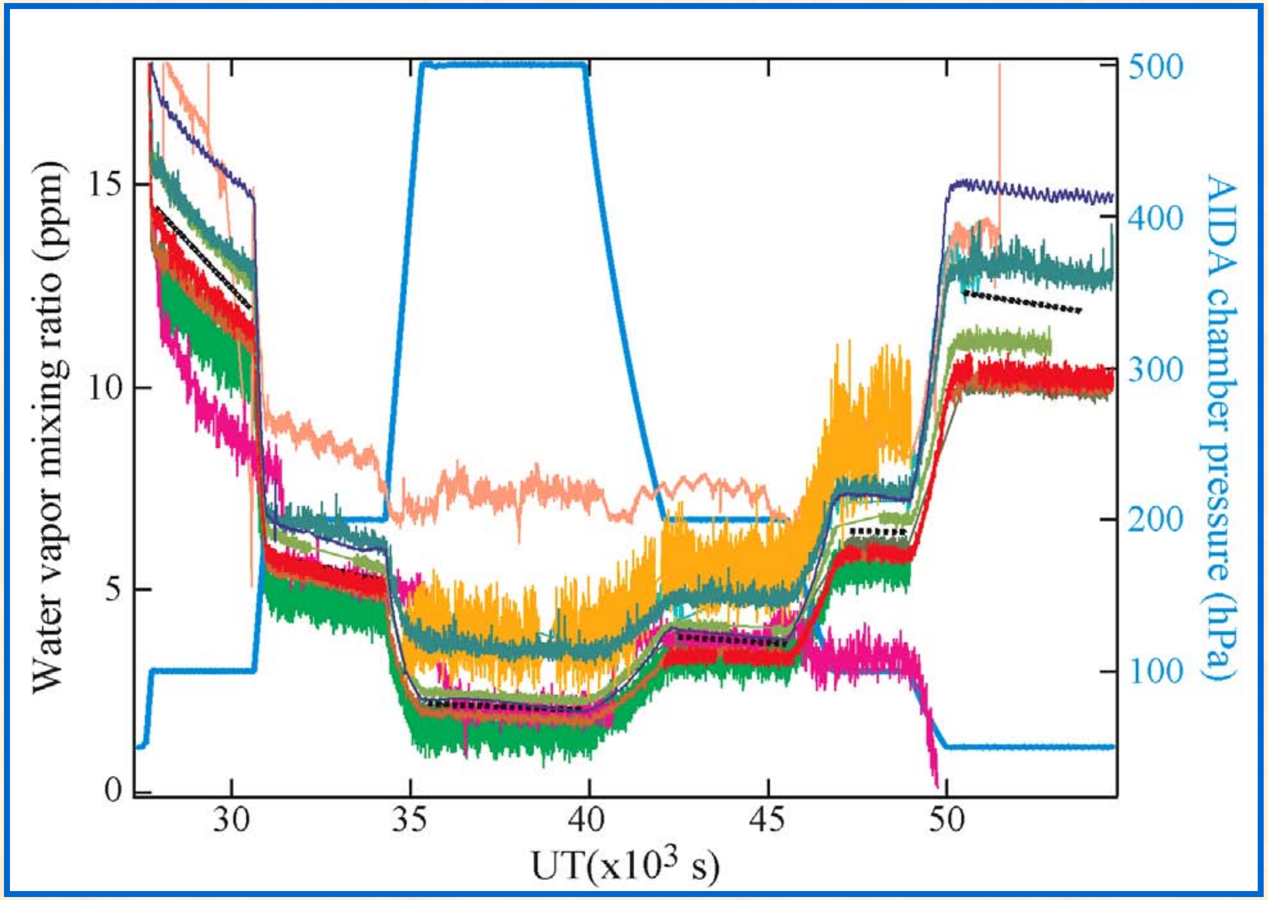
Measurement Intercomparison

AquaVIT: Blind intercomparison experiment at the AIDA aerosol & cloud chamber, involving an international representation of instruments.

NOAA ESRL involvement:

CU-CFH instrument (Holger Vömel)

2 referees (David Fahey and Ru-Shan Gao).

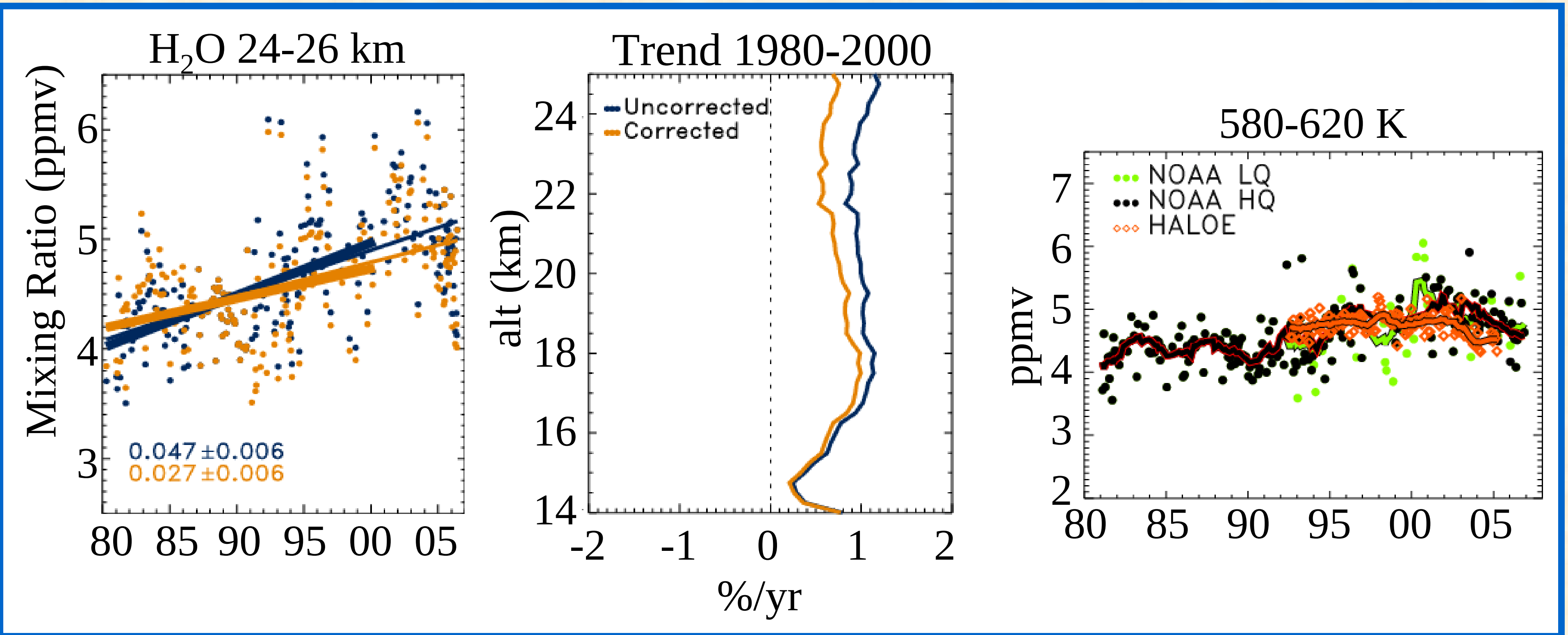


Water Vapor Trends

NOAA FP balloon

- measurements started in Boulder in 1981 (Oltmans)
- older version flew in Washington DC from 1964-1979 (Mastenbrook)
- trends deduced from these two records are ~1%/year above 16 km

  Oltmans et al., GRL, 2000
- Bias corrections applied recently
  - thermister calibration & thermister self heating correction (*Scherer et al., 2007*)
  - trend now ~0.6-0.7%/year, still greater than 0.3%/year from CH_4increases
  - corrections did not improve agreement with HALOE



Microphysical Studies

1) Murphy and Koop (2005): Theoretical reanalysis of the vapor pressure, molar heat capacity, and latent heat of vaporization of ice and liquid water.

- Calculated a simple, accurate expression for saturation vp over ice.

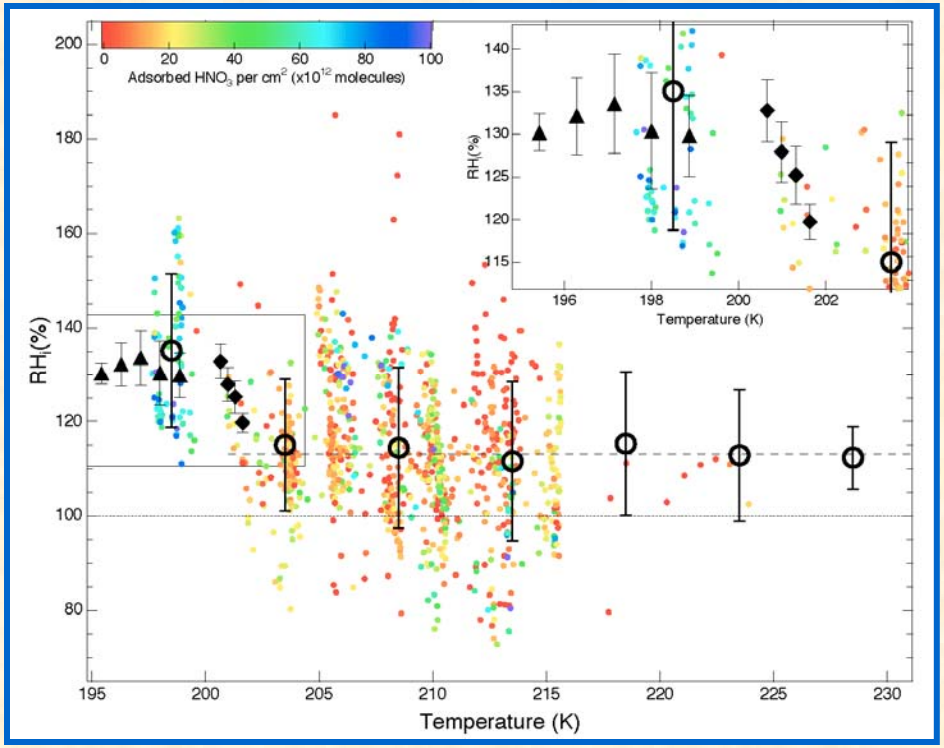
$$p_{\text{ice}} = \exp(9.550426 - 5723.265/T + 3.53068 \ln(T) - 0.00728332T); \quad T > 110\,\text{K}.$$

- Noted problems with previous estimates of saturation vp over supercooled water, and provided an expression valid for 123-332K.

$$\ln(p_{\text{liq}}) \approx 54.842763 - 6763.22/T - 4.210\ln(T) + 0.000367T + \tanh\{0.0415(T - 218.8)\}(53.878 - 1331.22/T - 9.44523\ln(T) + 0.014025T)$$

2) Gao et al (2004):

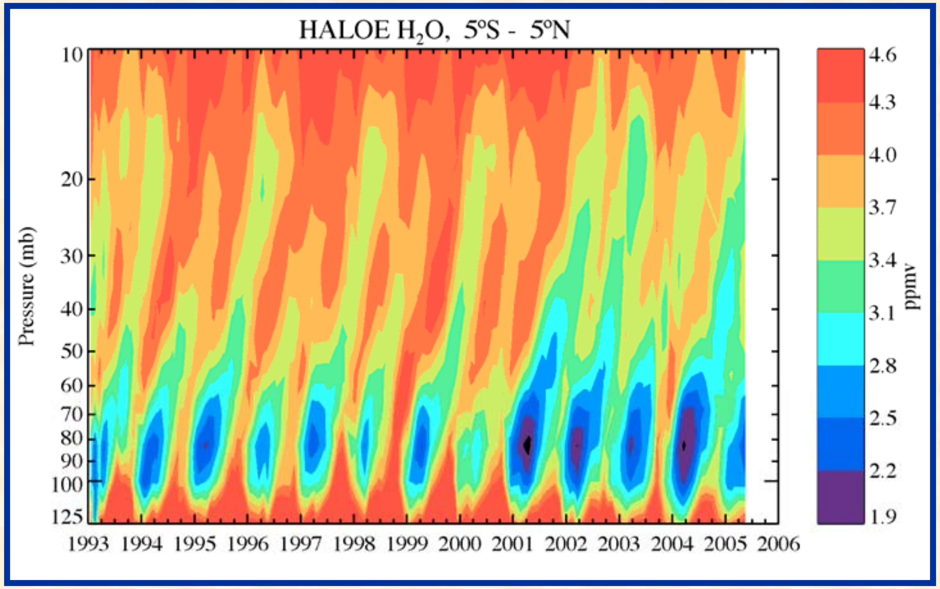
- Sharp increase in RHice inside clouds at 202K
- Hypothesized that this is due to the presence of a new class of nitric acid containing ice particles.

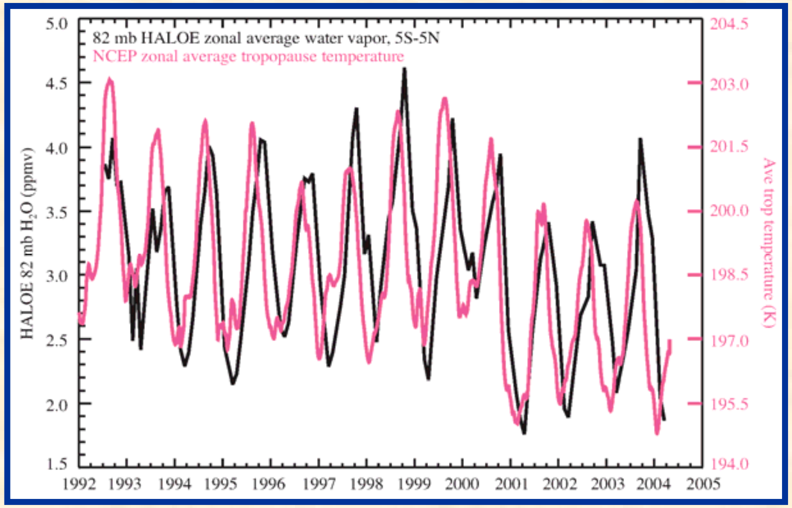


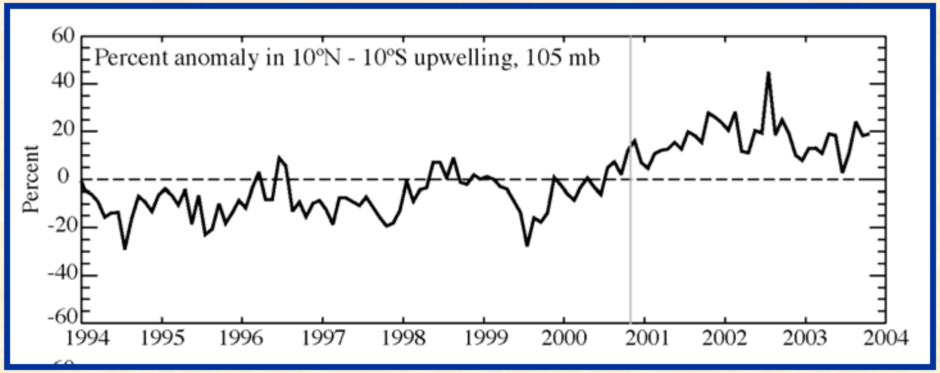
Recent Tropical Water Vapor Changes, Inferences About Mechanisms

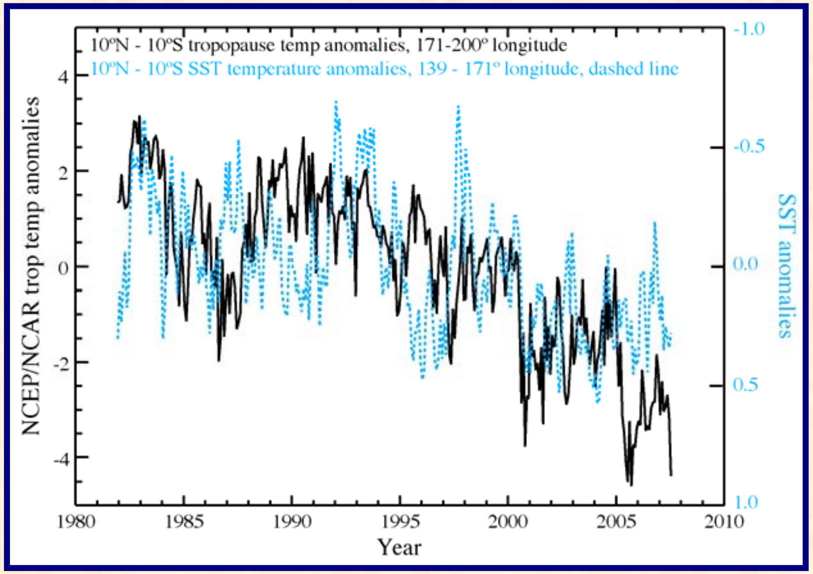
Rosenlof and Reid, Trends in the temperature and water vapor content of the tropical lower stratosphere: The sea-surface connection, paper in press at JGR, #2007JD009109.

Combination of satellite H_2O, SST, and temperatures from the NCEP reanalysis gives insight into dynamical processes.





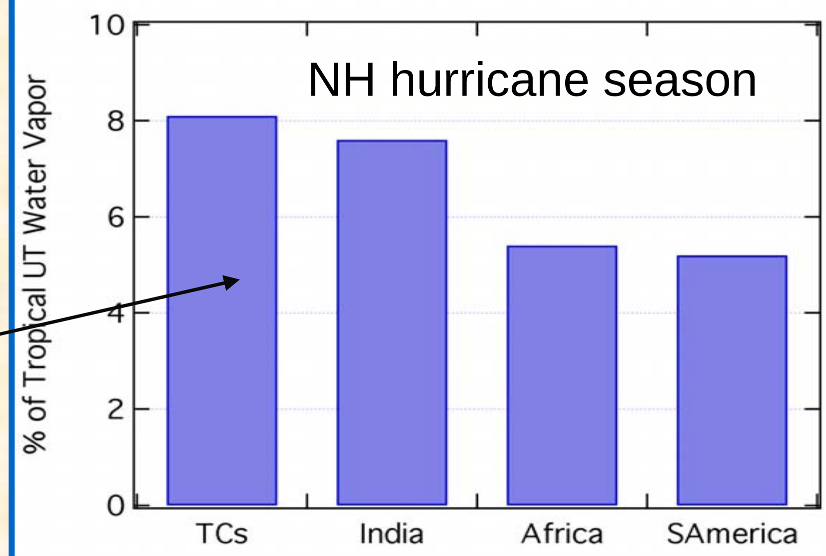


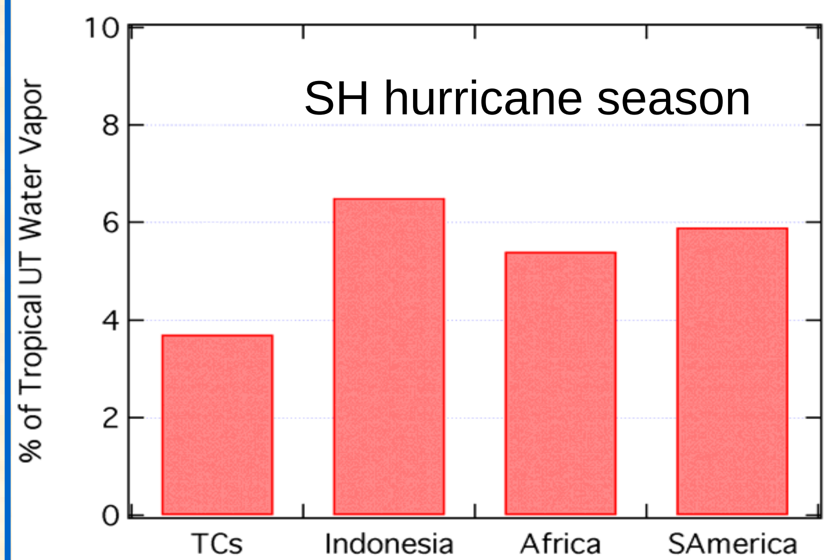


Comparing Tropical UT H_2O Source Regions for 150-300 hPa

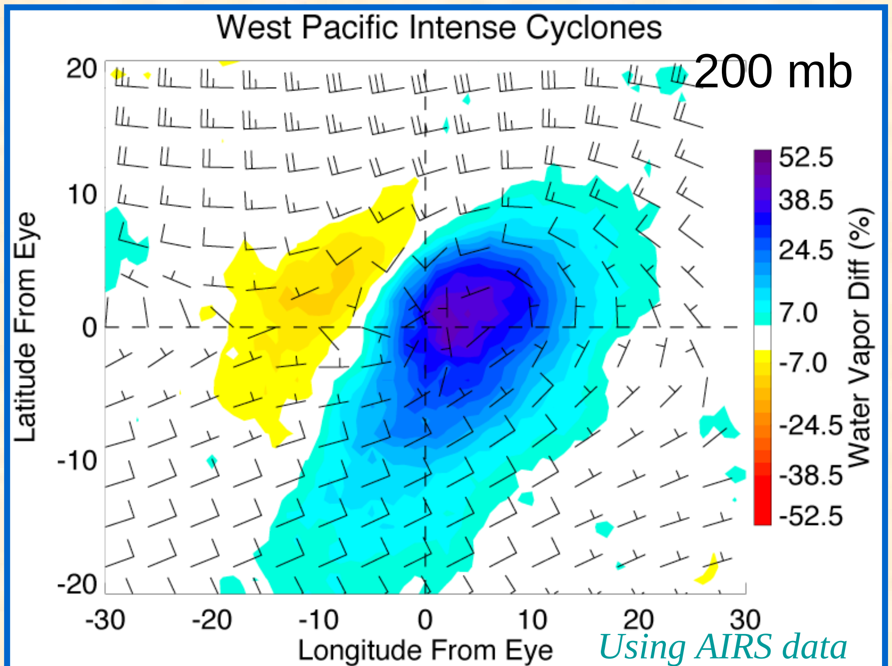
Ongoing Analysis: Tropical storm impact on the water vapor budget of the upper troposphere.

in May-Oct, TCs are a comparable source to the Asian monsoon.





Composite for Intense (catagory 3-5) Cyclones in the Western Pacific Basin



see Ray and Rosenlof, JGR, 2007

NOAA Water Vapor Process Research Initiative

- Examine issue of measurement accuracy
  - Instrument intercomparison
  - Lab analysis (of frost point technique)
  - New instrument development
  - Calibration and standards work
- Extend monitoring network
  - More measurements in tropics and high latitudes
- Continued data analysis
  - Process studies
  - Model studies

Summary

Instrument Development:

New balloon instrument completed and deployed worldwide.

Measurement Quality:

Steps taken to address in situ measurement differences.

Bias corrections applied to past data.

Long-term changes:

Reanalysis of Boulder data shows significant increase still present, and is larger than can be explained by methane increases.

Microphysical, dynamical and climate related studies:

Reassessment of saturation vapor expressions.

Postulated that nitric acid on particles affects supersaturations observed in clouds.

Analyzed a recent abrupt change in tropical tropopause temperatures and stratospheric water and hypothesized links to surface conditions.