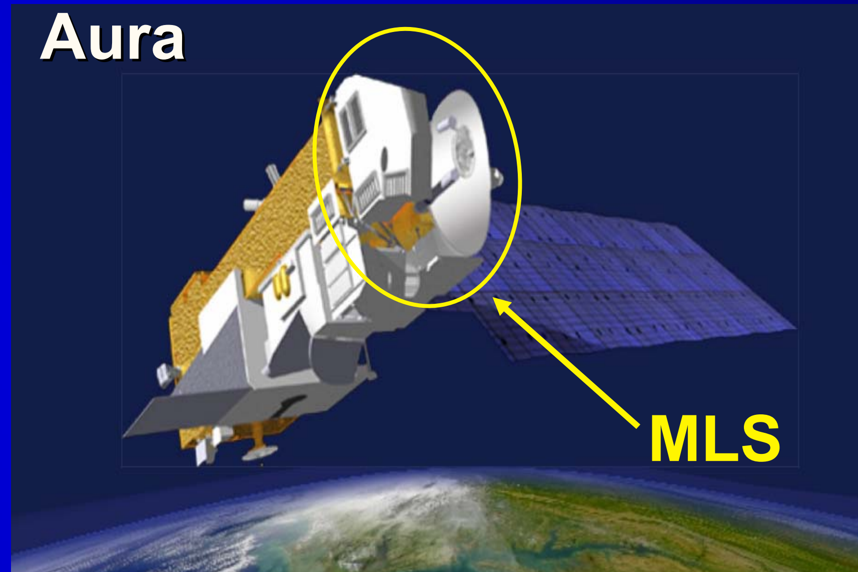

The Microwave Limb Sounder (MLS) on Aura: Science Objectives

presentation at 8 July 2004 Aura pre-launch meeting

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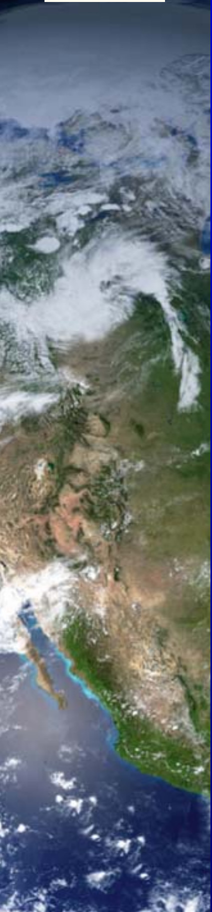
CL #04-2325



Overall Science Objectives of MLS

- Fall under Objective 1.1 of NASA's (2003) Strategic Plan:

"To understand how Earth is changing, better predict change, and understand the consequences for life on Earth."

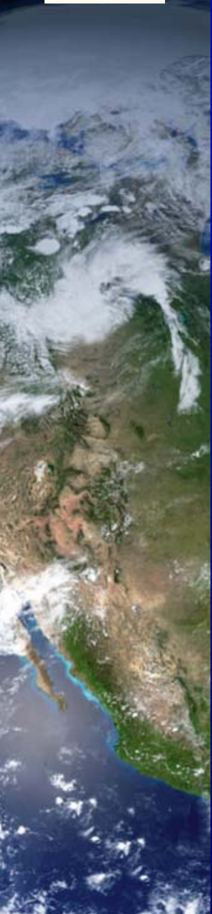
- **Track recovery of the ozone layer**
  - **especially track chlorine and bromine chemistry, and resolve current issues in hydrogen chemistry**
- **Understand aspects of how composition affects climate**
  - **especially through water vapor in the upper troposphere**
- **Quantify aspects of pollution in the <u>upper</u> troposphere**
  - **ozone, carbon monoxide (CO), methyl cyanide (CH_3CN), hydrogen cyanide (HCN); biomass burning injections**

A more detailed discussion of these objectives follows

MLS Science Objectives: Ozone Chemistry - Bromine & Chlorine

Objective: Quantify bromine & chlorine budgets, trends, & impact on ozone.

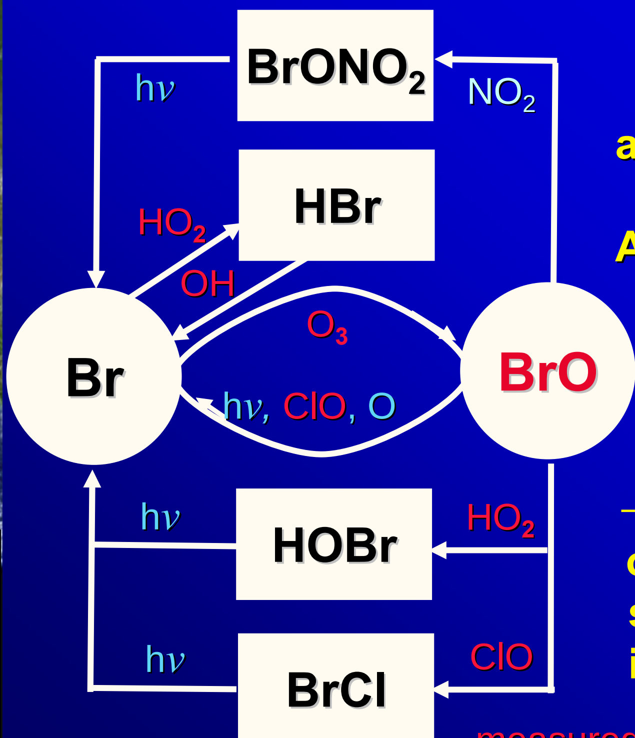
MLS will measure spatial & temporal changes in stratospheric bromine monoxide (BrO), a key reactive bromine gas that destroys ozone.



> Total bromine ≈ 20 pptv (± ~ 20%): 150 times less than total chlorine.
 - **Exact amount of bromine getting into the stratosphere is still under investigation.**

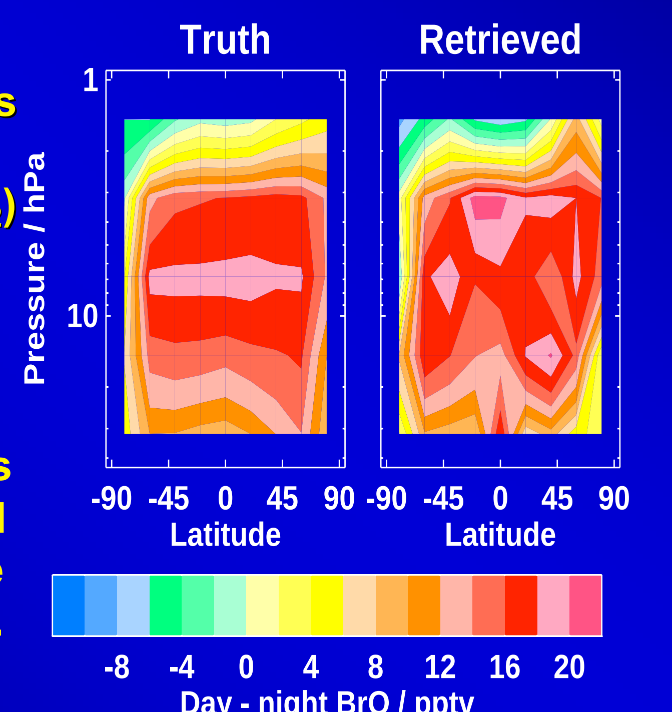
> BrO in the lower stratosphere destroys O_3 much faster (atom for atom) than ClO.
 - Reactive fraction BrO/Bry ≈ 0.5 in lower stratosphere » chlorine fraction in ClO.

Bromine gases & chemical cycles in the stratosphere



Can infer Br_y (total inorganic bromine) and other Br species from BrO & other Aura data (HO_2, NO_2) + models or correlations (e.g., between Br_y and tracers) → constrain models of Br chemistry and sources of bromine in the stratosphere.

Simulated MLS retrieval of zonal mean BrO (~ 23 - 45 km) (Day–Night) monthly average



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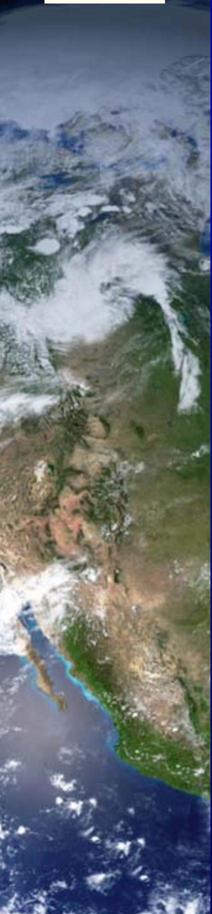
MLS Science Objectives: Ozone Chemistry – Bromine & Chlorine

Objective: Quantify bromine & chlorine budgets, trends, & impact on ozone.



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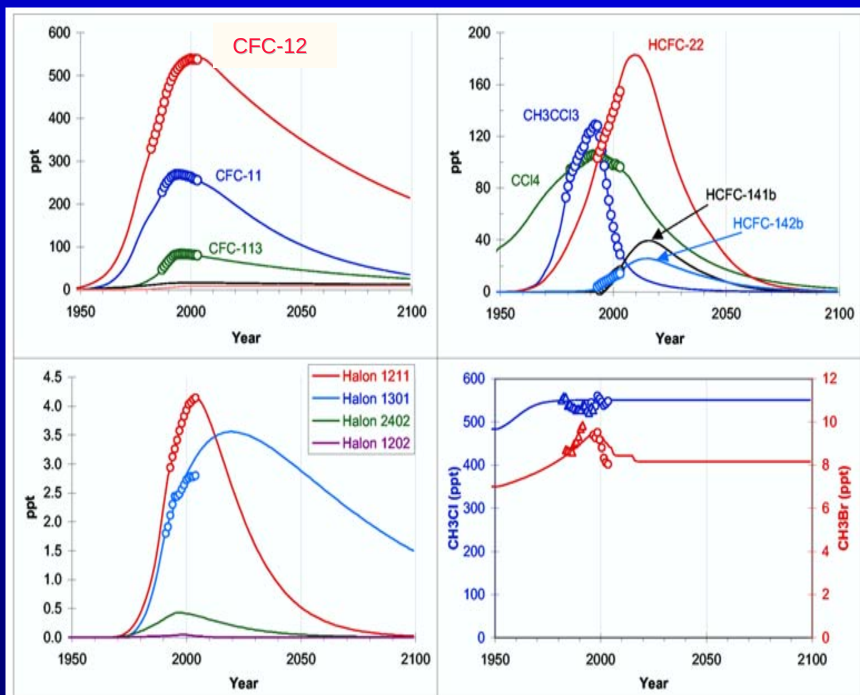
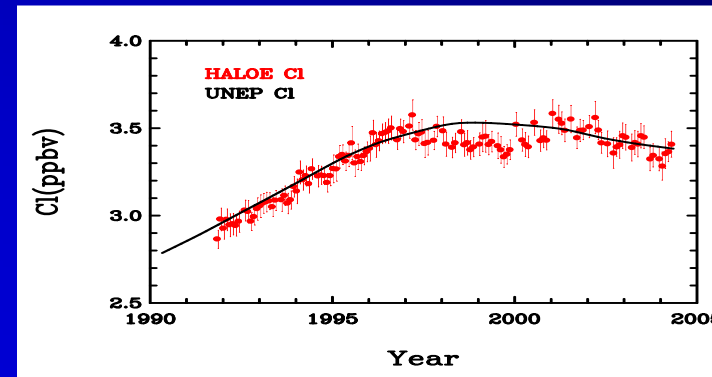
Source Gases for chlorine & bromine

Decreases (per international regulations) in total surface sources for bromine and chlorine gases should be reflected (a few years later) in total stratospheric Br & Cl.

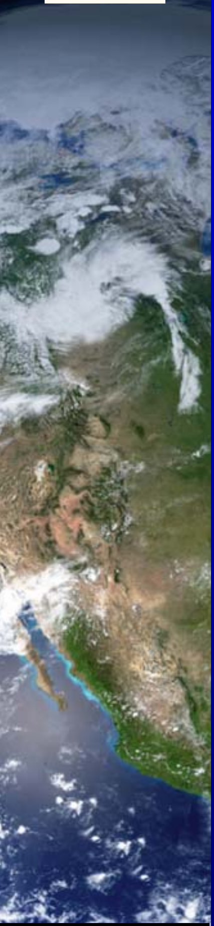


Surface measurements (symbols) and predictions (lines). Figure is updated from WMO Report No. 47 (2003).
(S. Montzka, NOAA CMDL, private communication).

Atmospheric Chlorine (Cl) loading



Valuable HALOE HCl data → global avg. Cl (at 55 km) vs surface Cl (with 5 yr lag).
(James M. Russell III and John Anderson, Hampton Univ., private communication).
MLS will provide daily global profiles of HCl to track chlorine loading and recovery (upper stratosphere) + chlorine partitioning variations and trends (throughout stratosphere and under depleted ozone conditions).
Other useful quantities: ClO/HCl ratio, related Aura data (e.g., HIRDLS $ClONO_2$).



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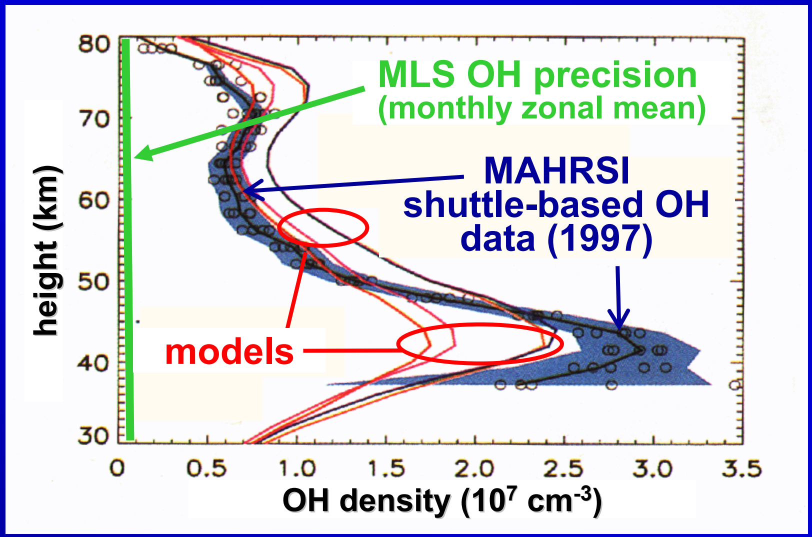
MLS Science Objectives: Ozone Chemistry – Hydrogen Chemistry

Objective: Resolve issues in hydrogen chemistry

- Hydrogen chemistry is dominant mechanism of ozone destruction at the highest and lowest altitudes in the stratosphere



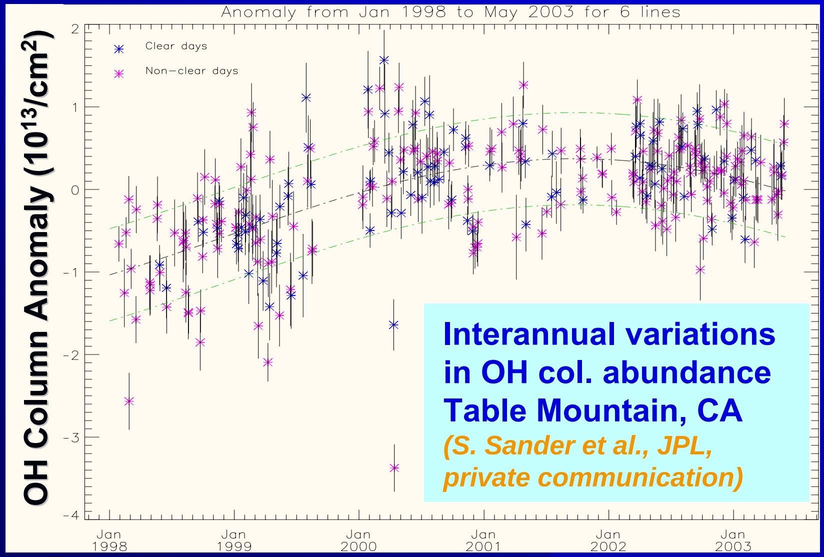
adapted from *Conway et al., GRL (2000)*

"The HO_x dilemma"

OH: Models are inconsistent with previous OH data in altitude region where chemistry seems fairly simple - mainly need to know OH, HO_2, O_3, H_2O, all measured by MLS.

HO_2: Balloon-borne and ground-based measurements of HO_2 yield larger than expected abundances (by ~30%).

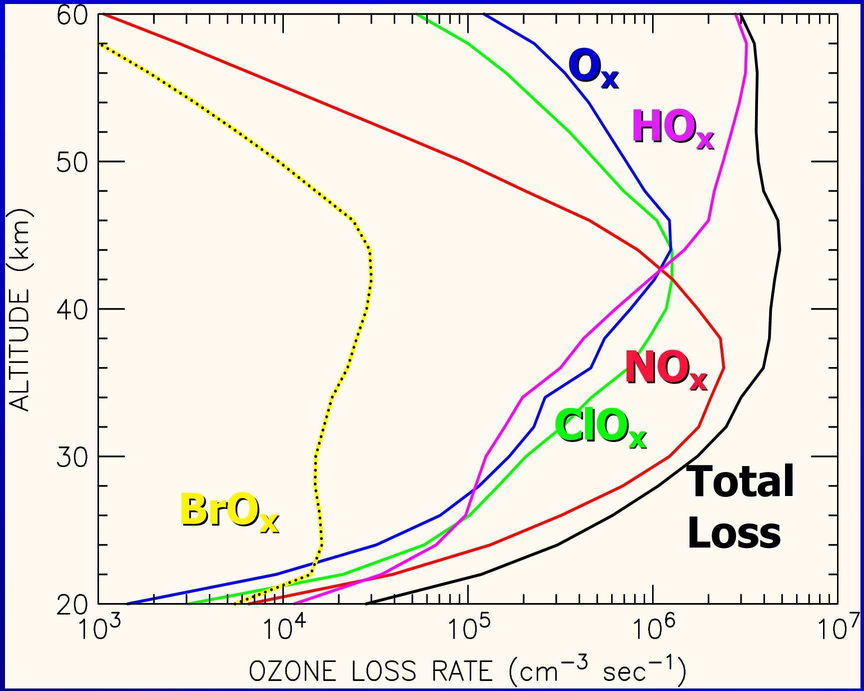
→ Chemistry or Data Issue ?



Column OH: Grd-based col. shows large variability *(Mills et al., GRL, 2002).* Interannual changes at Table Mtn., CA, are larger than the expected combined effects of O_3, H_2O, and solar flux *(Mills et al., JGR, 2003).* The combination of ground-based and MLS measurements will help to understand these variations.

MLS Science Objectives: Ozone Chemistry – Chemical Cycles

Objective: Use measurements of radicals and source species to provide critical global tests of ozone chemistry.



Importance of Chemical Cycles for O_3 Loss
(updated from *Osterman et al., GRL, 1997*)

- MLS → monthly zonal mean distributions for OH, HO_2, ClO & BrO above ~ 20 km.
- HIRDLS & TES measure NO_2.
- Aura instruments will also measure the radical-generating molecules (H_2O, N_2O, CFCs, O_3) in the 'same' air mass (within 15 minutes).
- Can use model radical values on daily basis and average over a month to compare with monthly Aura observations of these radicals.

MLS data combined with the ensemble of Aura products will critically test the completeness of known chemistry over a range of heights and for all seasons.

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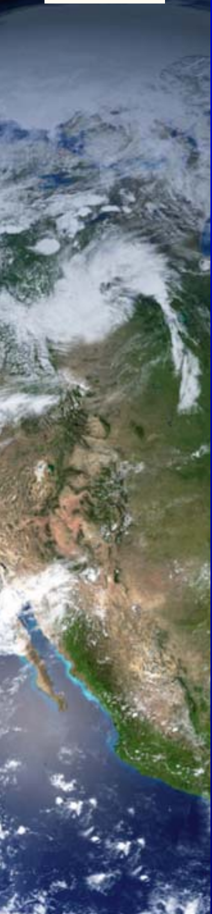

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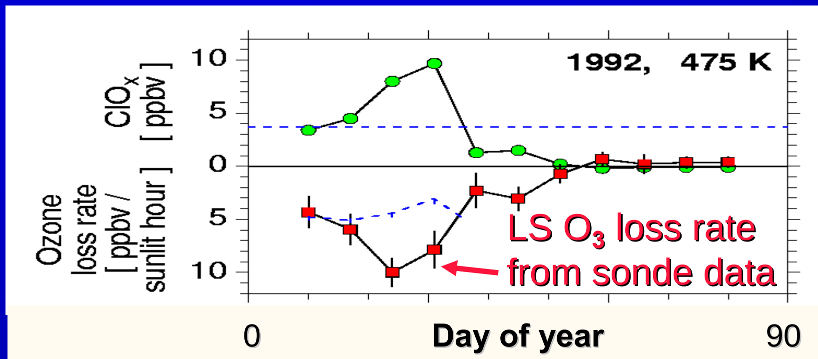
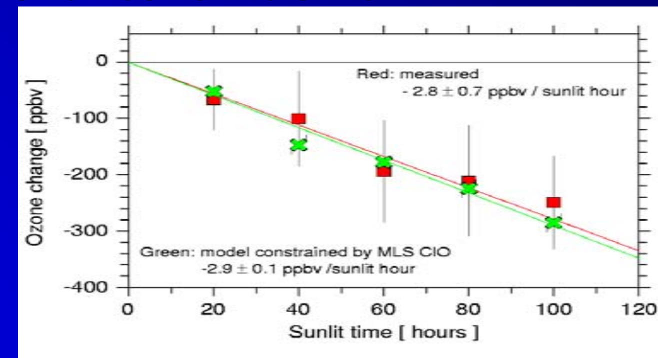
MLS Science Objectives: Ozone Chemistry – Polar Processes

Objective: Refine understanding of lower stratospheric winter polar ozone loss and track its variations

- Improvements (over UARS MLS) include better spatial and temporal coverage, resolution, precision, and additional constituents.



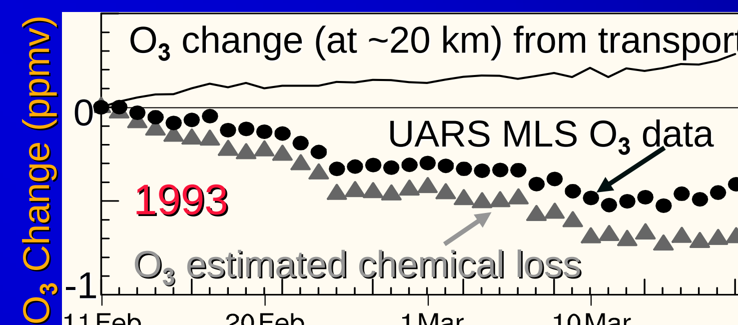
(Rex et al., GRL, 2003)



- Measured and modeled Arctic O_3 loss rates do not 'match' in January

… but do in late winter.

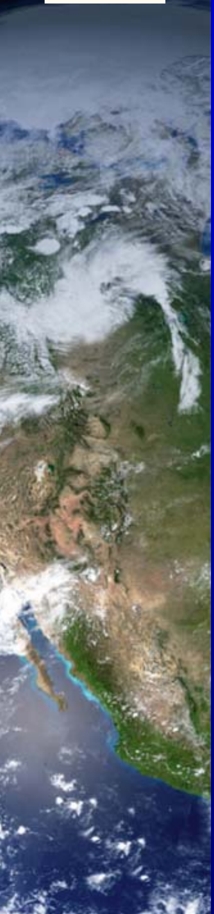
- Uncertainties remain in quantifying the relative contributions of transport and chemical processes in O_3 loss (for polar regions and globally).



Arctic avg. O_3 change *(Manney et al., JGR, 2003)*

In addition to polar O_3 loss studies, we plan to:

- **Further explore issues regarding denitrification & dehydration and their relationship to O_3 loss in both hemispheres.**
- **Track interannual & longer-term variations, especially in Arctic, where temperatures may be near a threshold for larger ozone losses or a delay in recovery (tied to H_2O, polar stratospheric clouds, and climate change).**



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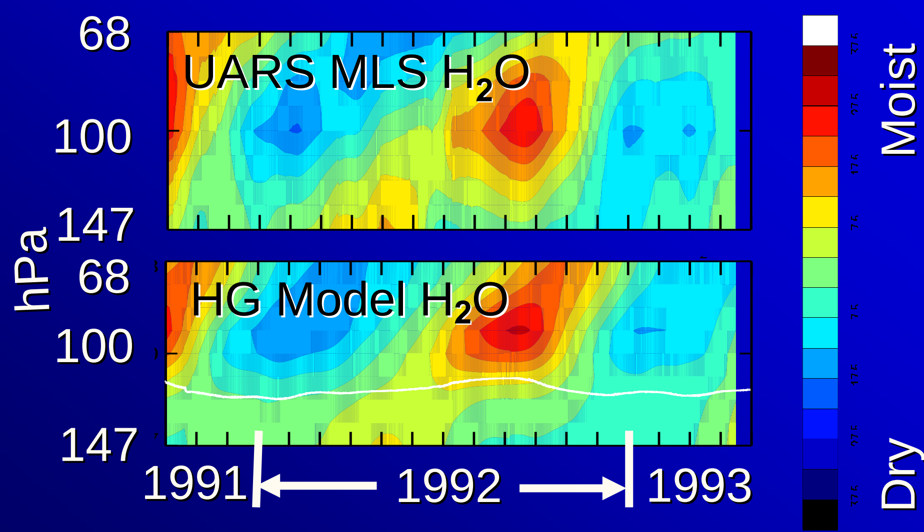
MLS Science Objectives: Water Vapor and Climate

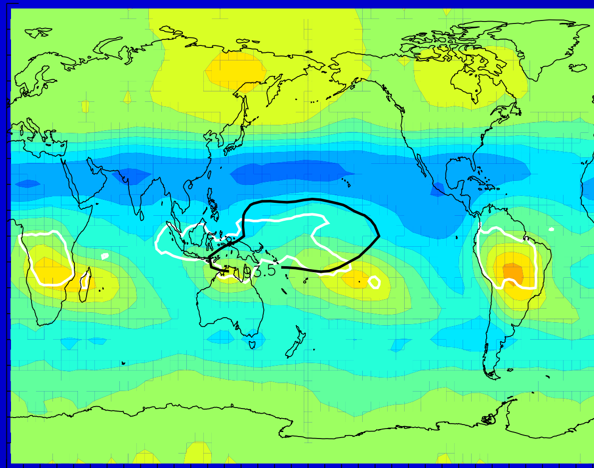
Objective: Understand processes controlling stratospheric humidity

- **How is H_2O removed before entering the stratosphere?**
- **MLS H_2O in tropical tropopause layer (TTL) will have better vertical resolution than UARS MLS + expect longer time series.**
  - **Synergies with planned aircraft campaigns (which can also measure total H_2O).**
- **Does tropical deep convection hydrate or dehydrate the TTL?**
- **MLS measurements that can be made in the presence of cirrus will help answer this question.**

H_2O in the TTL from UARS MLS compared to Holton & Gettelman (HG) "cold trap" model



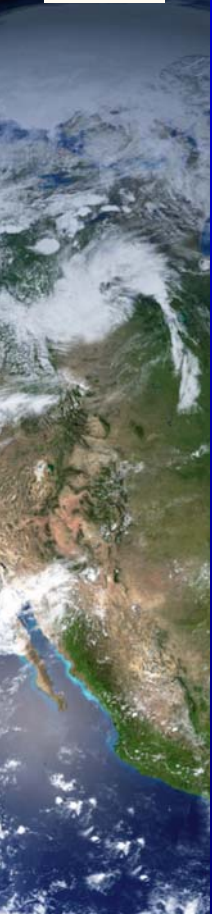
UARS MLS 100 hPa H_2O Winter (DJF) 1992/1993



Figures from *Read et al. (JGR, 2004)*

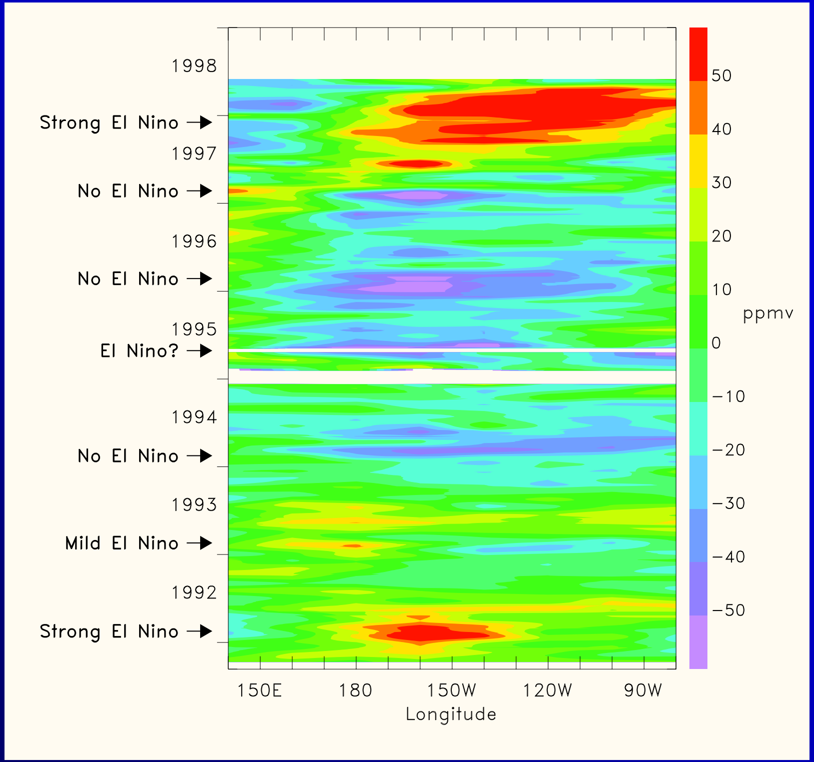
MLS Science Objectives: Water Vapor and Climate

Objective: Better quantify water vapor relationship to climate



- **Understand intra- and interannual changes**
- **MLS can observe changes in upper tropospheric Relative Humidity from El Niño & other variations.**

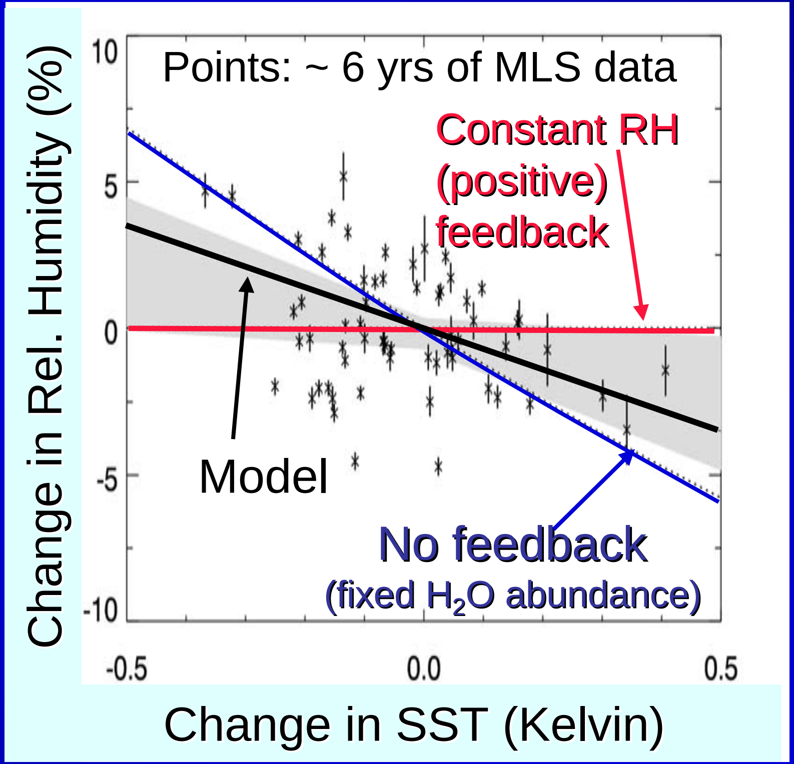
UARS MLS tropical UT (215 hPa) H_2O: Correlation with El Niño



Waters et al. (J. Atmos. Sci. 1999)

- **Quantify the water vapor feedback in climate change**
- **MLS upper tropospheric H_2O data should help better predict the surface temperature rise from increasing CO_2 emissions.**

MLS **H_2O (215 hPa)** vs Sea Surface T



Minschwaner & Dessler (J. Climate, 2004)

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MLS Science Objectives: Water Vapor and Climate - Clouds

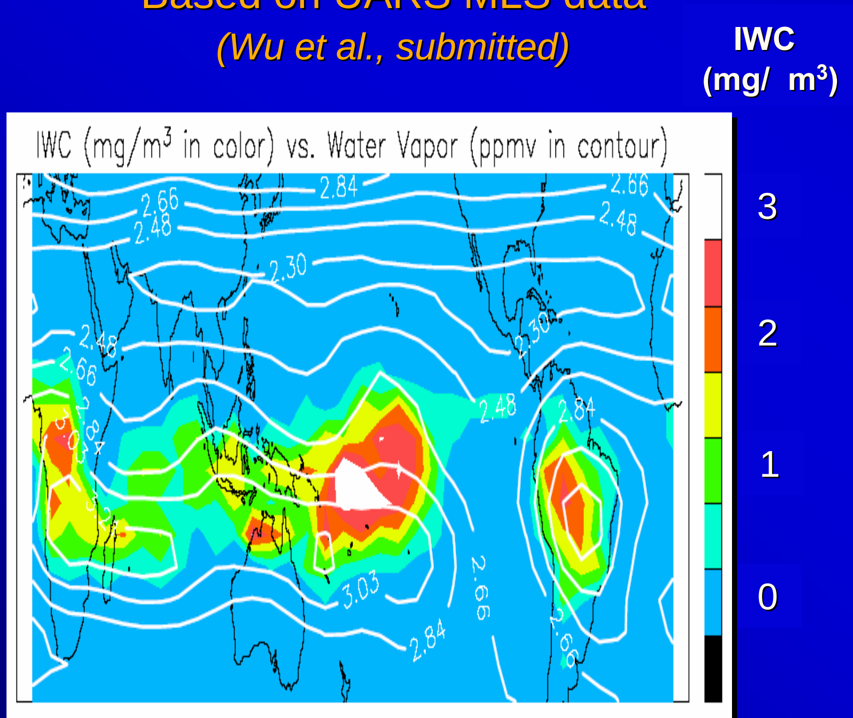
Objective: To accurately measure global cloud Ice Water Content → improve climate models

Ice Water Content distribution

Jan.-March 1992

Based on UARS MLS data

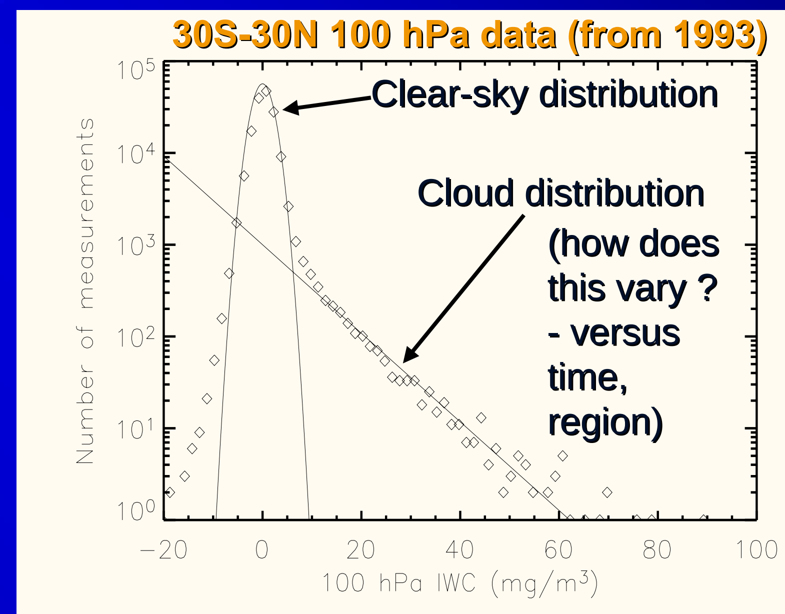
(Wu et al., submitted)



More detailed statistics

Histogram of cloud occurrence for different ice water contents

UARS MLS data *(Wu et al., submitted)*



- Inaccuracy in knowledge of cloud Ice Water Content: worse than 100%!
  - require assumptions about ice particle properties (e.g., sizes, shapes).
- Can reduce these uncertainties in the future by analyzing multi-frequency measurements from MLS, the A-train (e.g., CloudSat), & other instruments.

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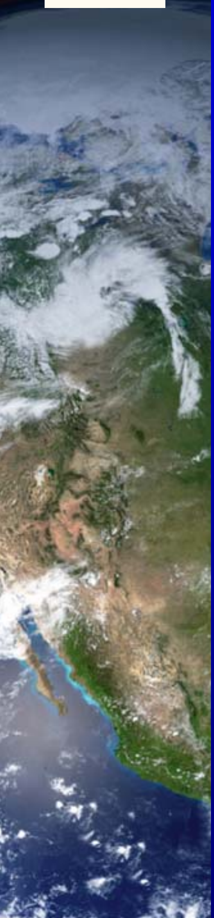

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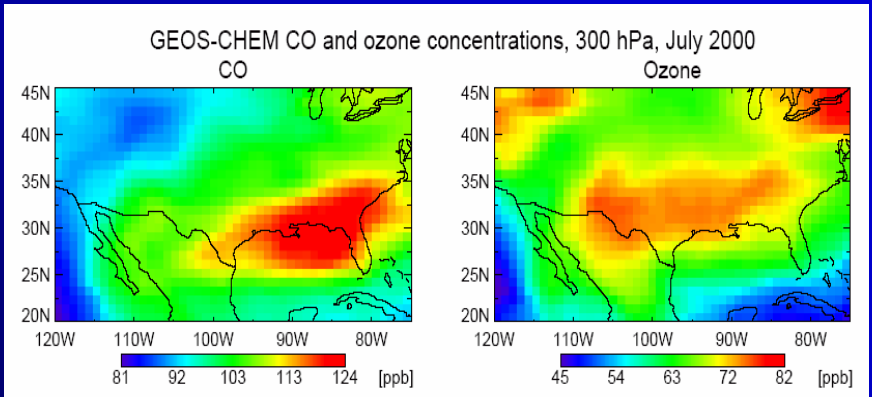
MLS Science Objectives: Tropospheric Pollution

Objective: Quantify aspects of pollution in the upper troposphere

- **MLS will measure the following upper tropospheric species (+ H_2O):**
  - **Ozone** (tropospheric pollutant & important greenhouse gas in UT)
  - **CO** (a good tracer of anthropogenic pollution)
  - **CH_3CN & HCN**, biomass burning tracers. MLS sensitive only to **large enhancements** above background. [UARS MLS detected enhancement in CH_3CN from forest fire, injected into lower stratosphere *(Livesey et al., 2004)*.]
- **These data complement tropos. data from TES, OMI, HIRDLS, aircraft**
  - Expect pollution + long-range transport in UT (e.g., from convection, warm conveyor belts, 'pollution train').
  - Couple to goals of *INTEX* aircraft/ground campaigns (2004 & 2006).

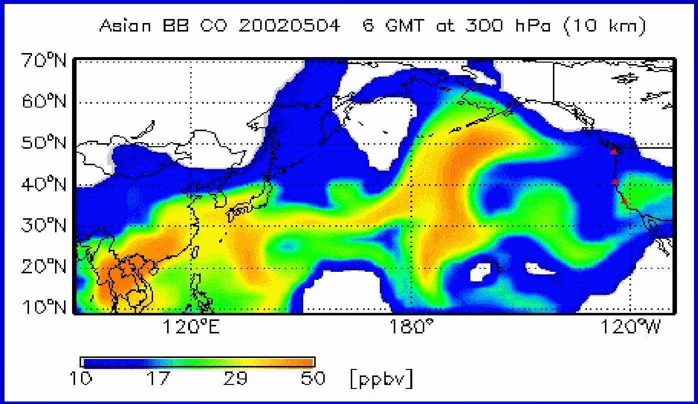
Caveats: MLS sensitivity (~20, 30 ppbv for CO, O_3 at 200 hPa & worse at lower alt.) + sampling issues → need useful 'averaging' (+ validation) of the MLS UT data.



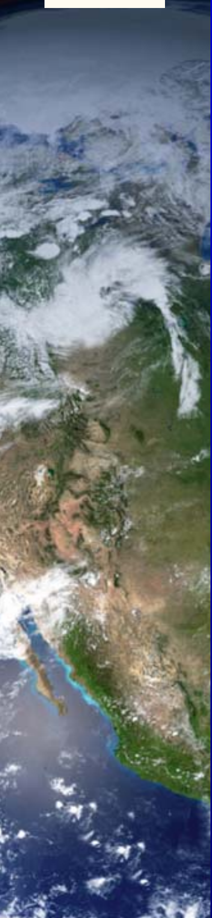
Simulated CO, O_3 *(Li et al., JGR, sub., 2004)*

How are O_3 and CO correlated?

How do models and data compare?



Intercontinental pollution transport illustration (CO biomass burning component only) *(Q. Li, JPL, private communication., 2004)*



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Microwave Limb Sounder (MLS): Science

Summary and Acknowledgements

MLS will contribute to important areas of atmospheric research:

[Thanks for inputs to this talk mainly from those listed below]

- **Ozone Chemistry**
  - Bromine and chlorine — [N. Livesey, S. Montzka, J. Russell]
  - Hydrogen Chemistry — [H. Pickett, S. Sander]
  - Chemical Cycles — [H. Pickett, R. Salawitch]
  - Polar Processes — [G. Manney, M. Santee]
- **Water Vapor and Climate**
  - Water Vapor — [W. Read]
  - Cloud Ice — [D. Wu]
- **Tropospheric Pollution** — [M. Filipiak, Q. Li]

Thanks to Joe Waters and the whole MLS team (at JPL and Edinburgh University), the Aura Project, JPL, and NASA for helping get us to this stage & the eagerly awaited Aura launch.