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Pasadena, California

AIRS Science

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AIRS in the context of climate and weather science … and the start of a conversation about AIRS science plans

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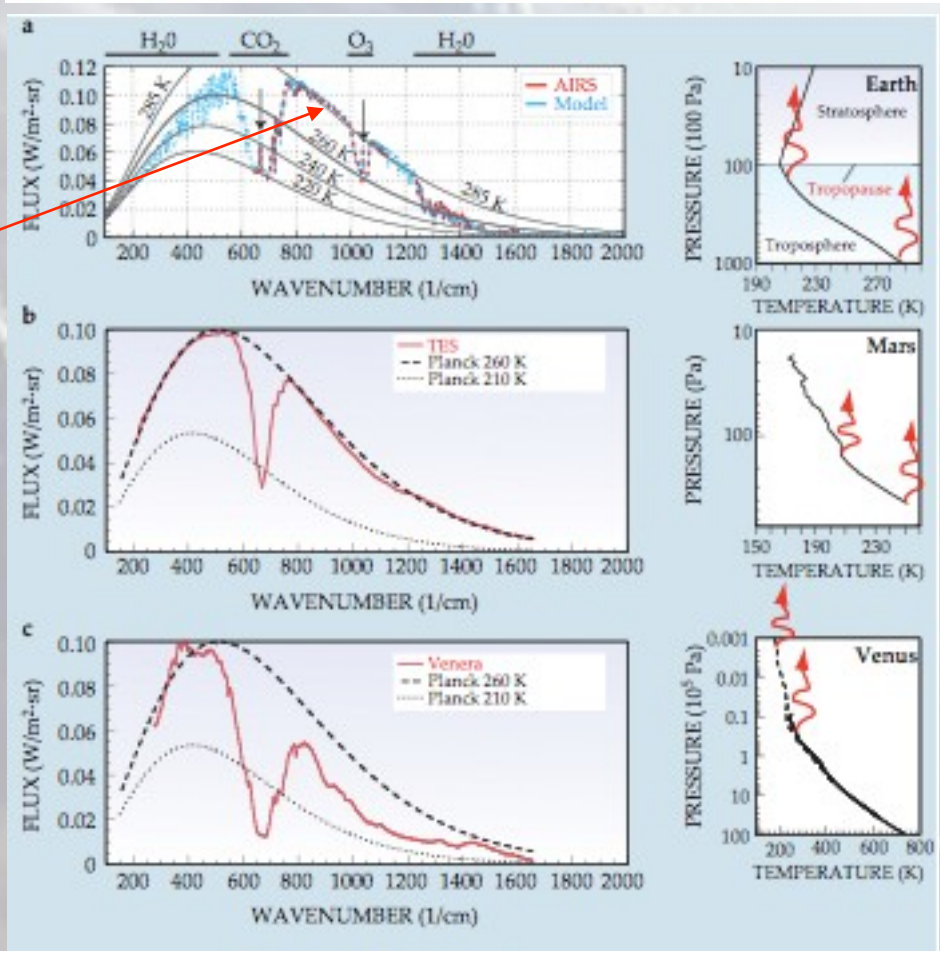
feature article

Infrared radiation and planetary temperature

Raymond T. Pierrehumbert

Infrared radiative transfer theory, one of the most productive physical theories of the past century, has unlocked myriad secrets of the universe including that of planetary temperature and the connection between global warming and greenhouse gases.

AIRS spectra



…. and AIRS is central to this story

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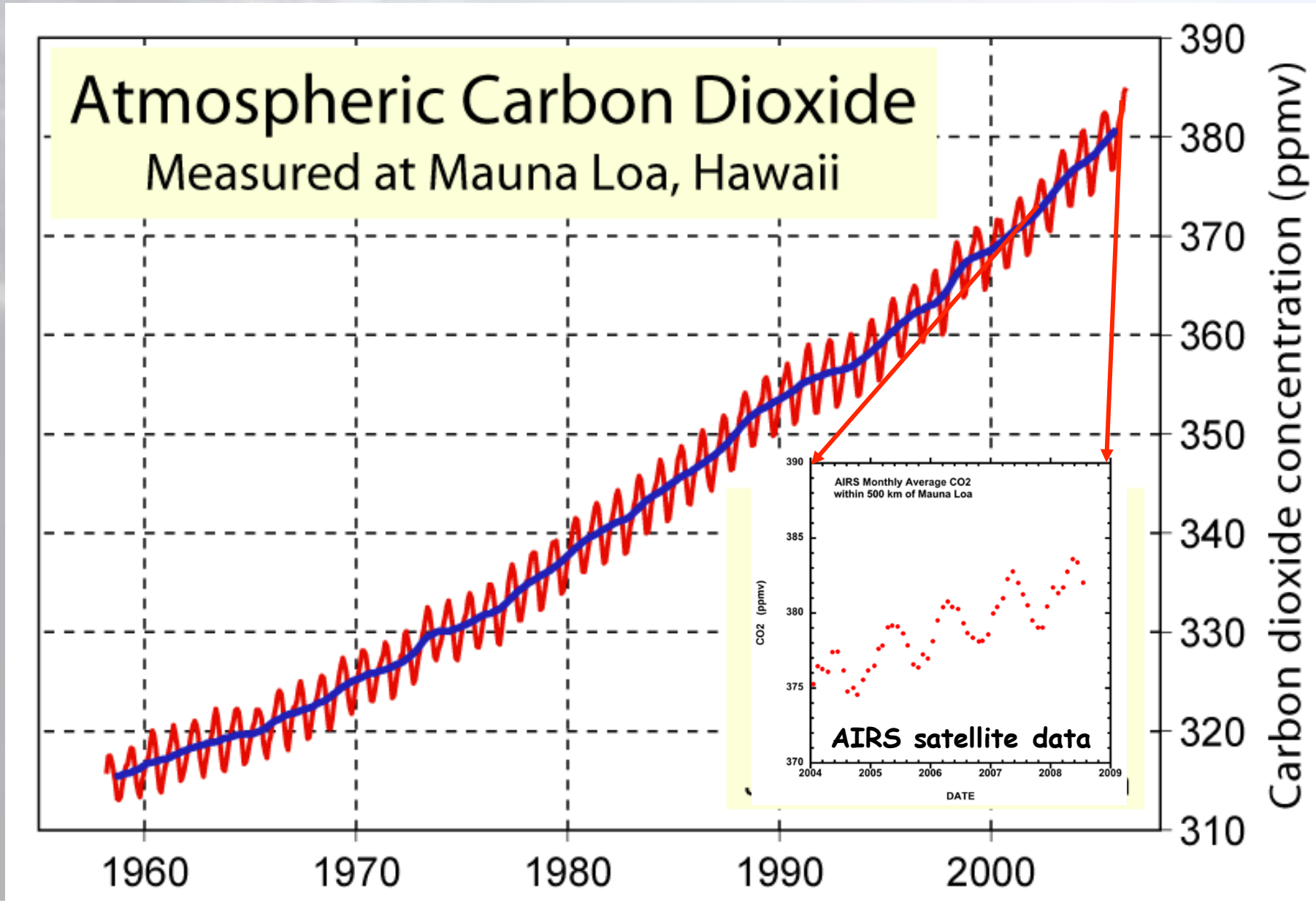
AIRS and an Iconic Measurement



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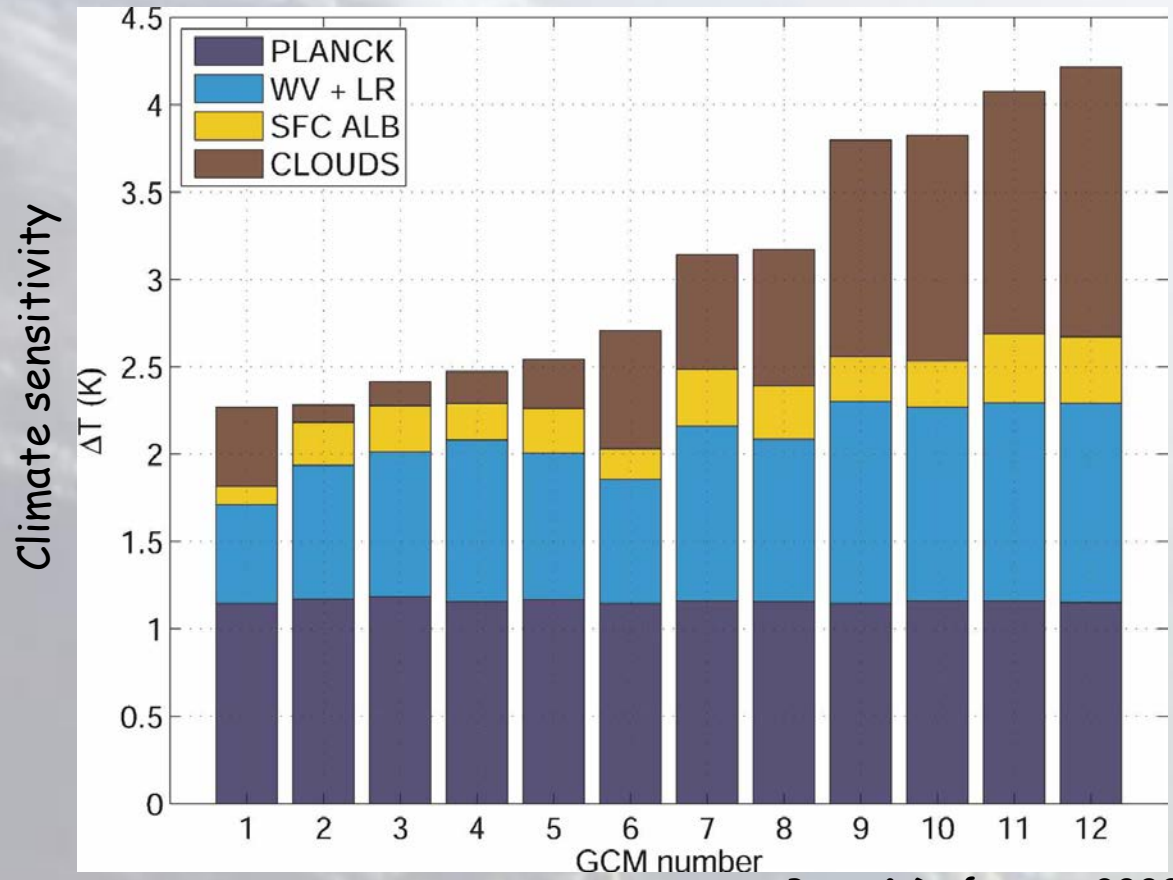
AIRS and Climate Sensitivity



Bony & Dufresne, 2008

AIRS makes essential observations of the processes controlling climate feedbacks: temperature, water vapor, clouds, CO2, ….

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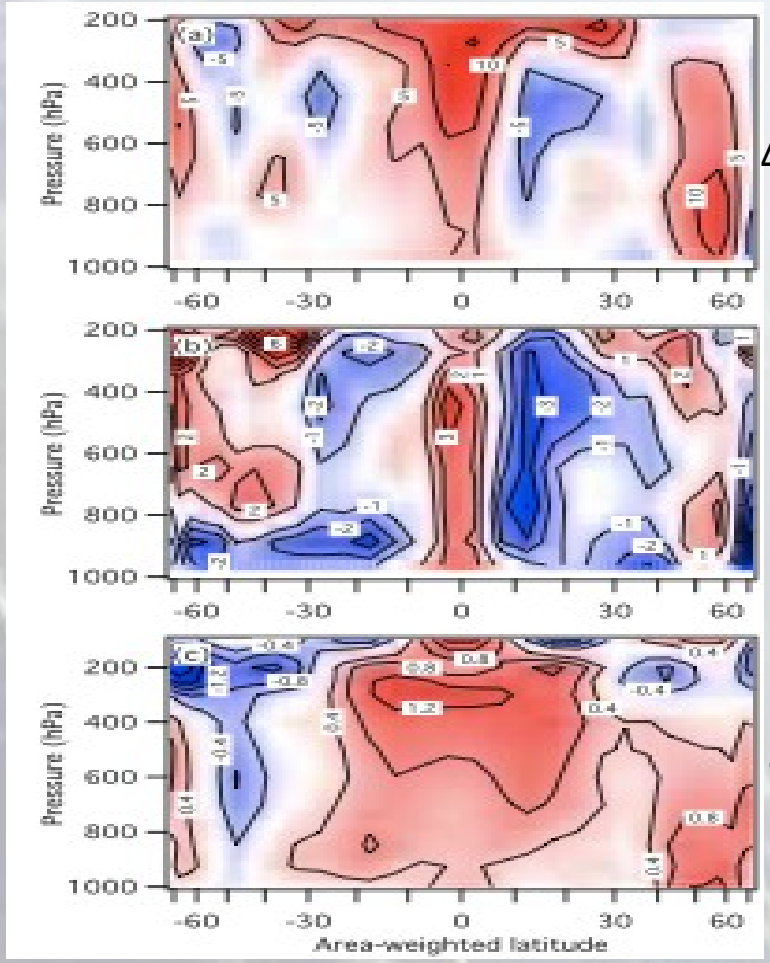
AIRS and Water Vapor Feedback



Δq (%)

ΔRH (%)

ΔT (K)

Dessler et al, GRL, 2008

AIRS confirms estimates of water vapor feedback strength

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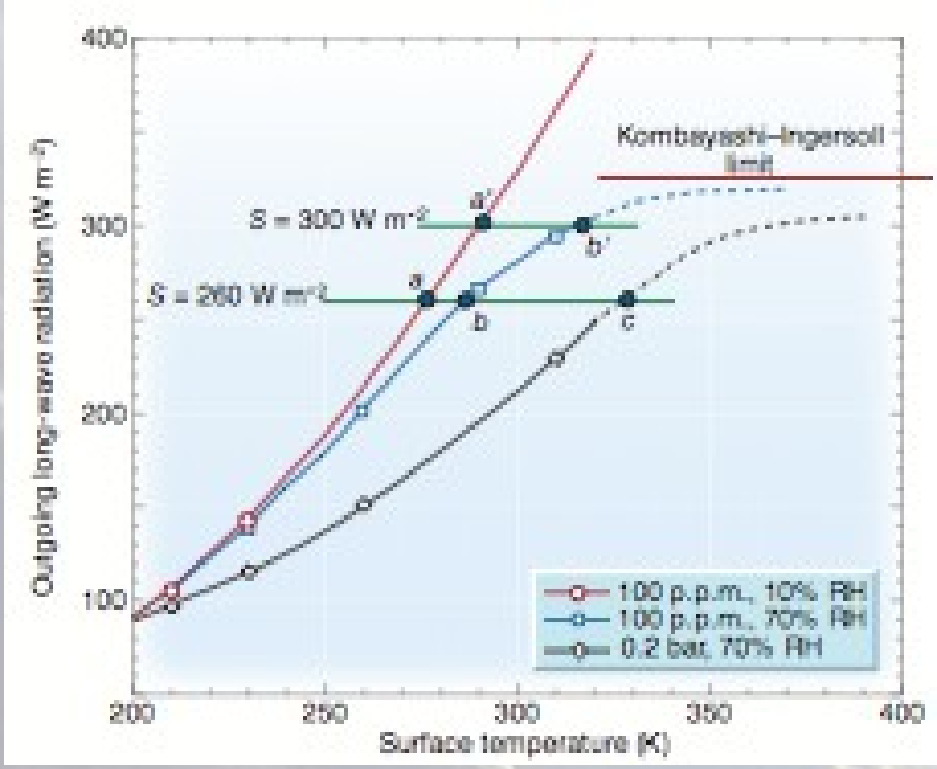
The Ultimate Deep-Climate Problem



Pierrehumbert, Nature, 2002

Variables used to produce these plots are measured by AIRS: profiles of temperature, water vapor and CO2.

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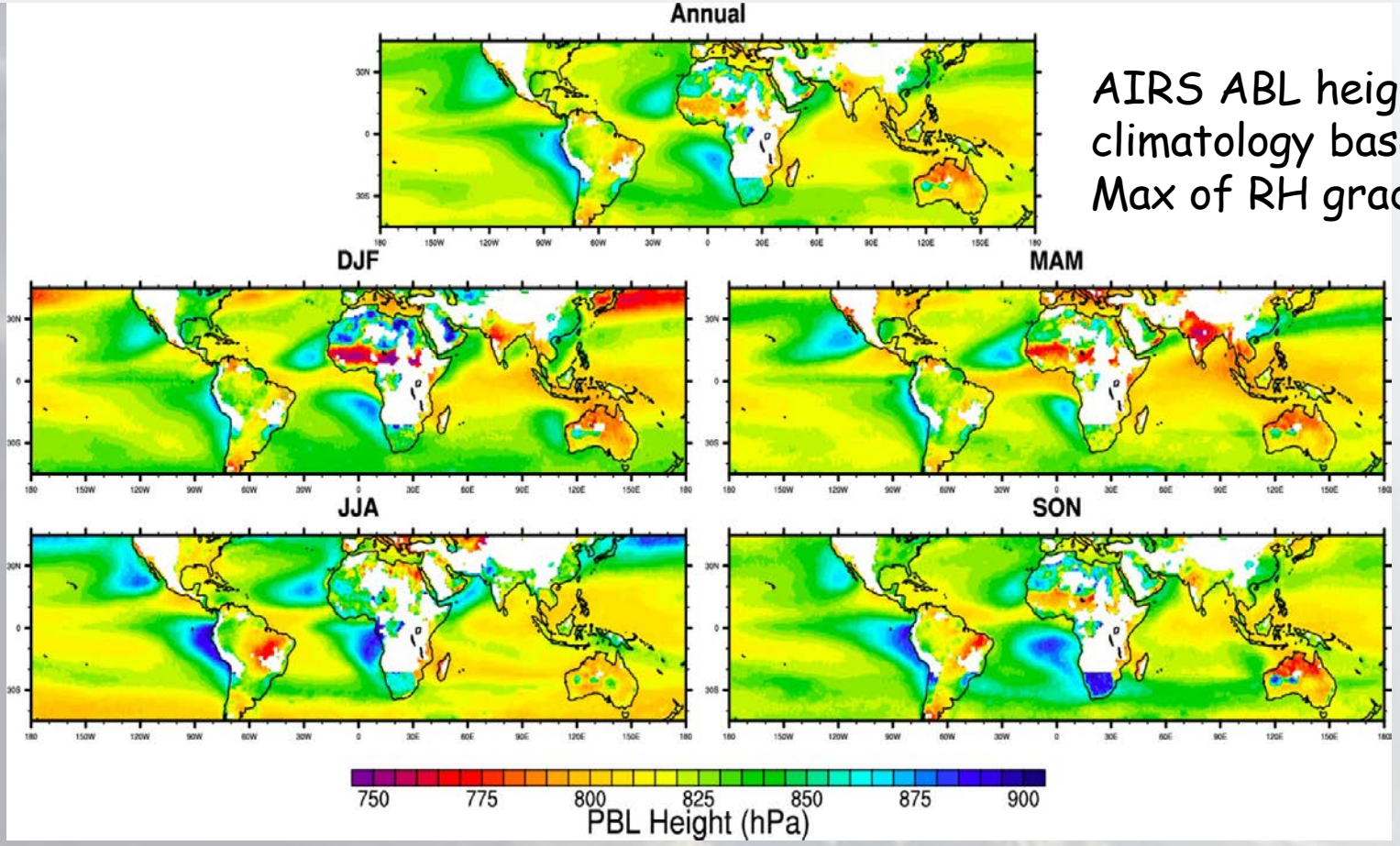
AIRS and the atmospheric boundary layer

Global and smooth boundary layer height climatology from space (1st time)



AIRS ABL height climatology based on Max of RH gradient

AIRS has untapped information about boundary layer structure

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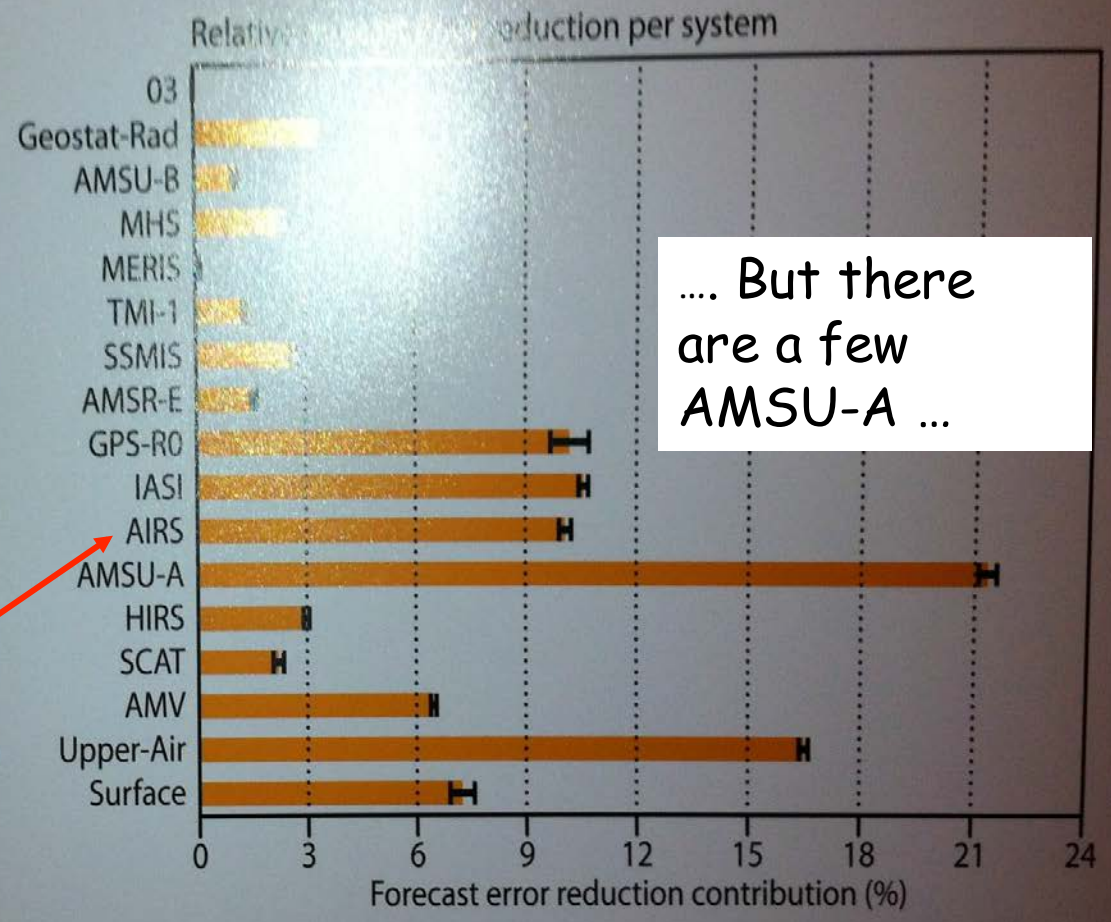
AIRS and Weather Prediction

ECMWF latest results: WCRP OSC, Denver, 24-28 Oct. 2011

Forecast sensitivity

There are many techniques and metrics to measure the value of the observing system, but forecast sensitivity can provide information on the impact of each observation on a chosen target, usually a 24-hour forecast of tropospheric mass, wind and moisture. This measure shows that AMSU-A is the single most valuable source of data, though the hyperspectral sounders, GPS radio occultation and conventional upper air observations are still important.

Global mean impact of data on reduction of error of a 24-hour forecast using forecast sensitivity. The forecast sensitivity technique is complementary to full observing system experiments. Note that conventional upper air includes all aircraft as well as radiosondes.



…. But there are a few AMSU-A …

AIRS plays key role in improving current weather prediction…

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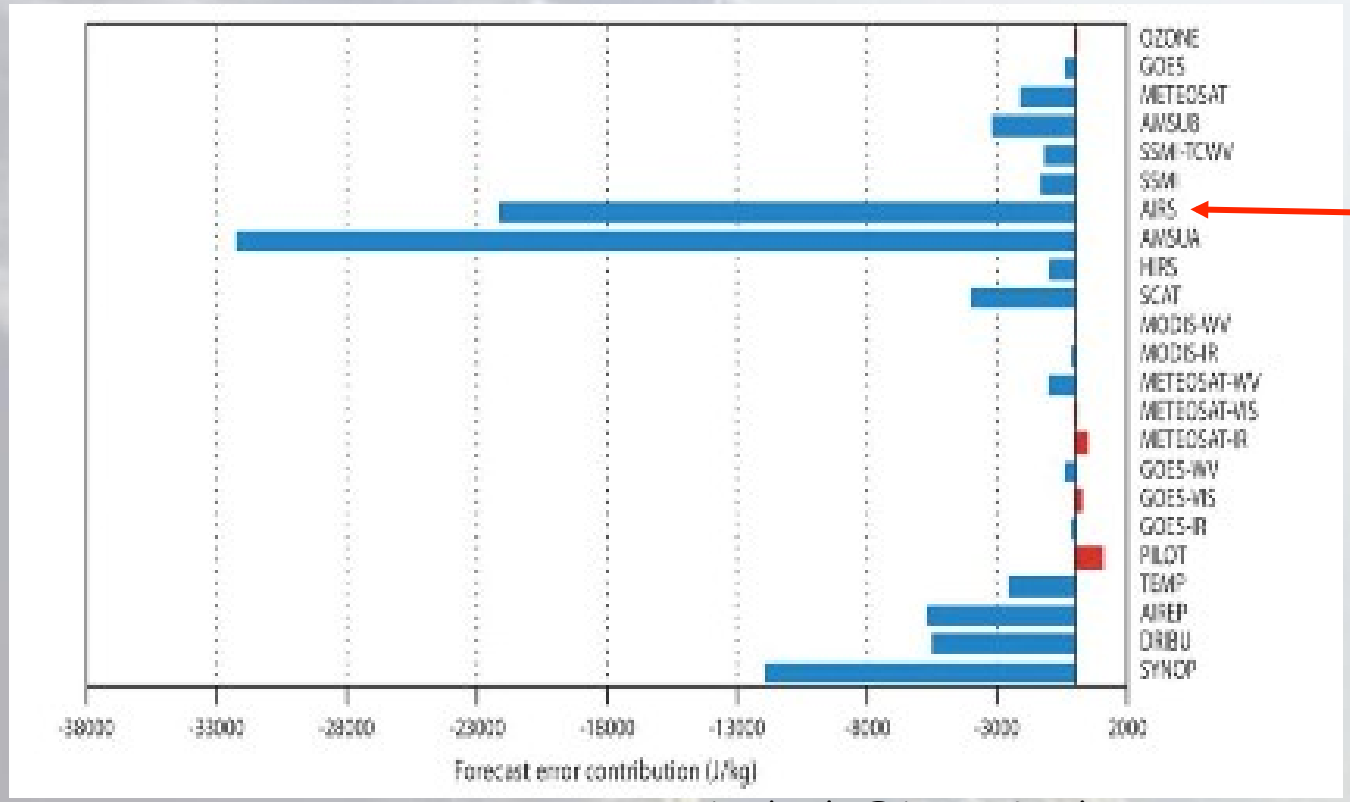
AIRS and Weather Prediction

ECMWF observation sensitivity - NH Summer 2006



AIRS

Cardinali, ECMWF Tech. Memo, 2009

Taking into account last few years: AIRS even more essential

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Key problem: … what about clouds?

For the last decades we have not been able to properly assimilate/retrieve cloud and cloud-related observations in weather prediction models … Why?

Serious difficulties in dealing even with a simple "assimilation" problem:

1) Assume we have information on mean T and q in a grid-box;
2) We wish to introduce new cloud fraction and liquid water information;
3) How should T and q be changed/adjusted to new cloud info?

Cloud data-assimilation/retrieval problem needs to be solved to take full advantage of current and new sounders

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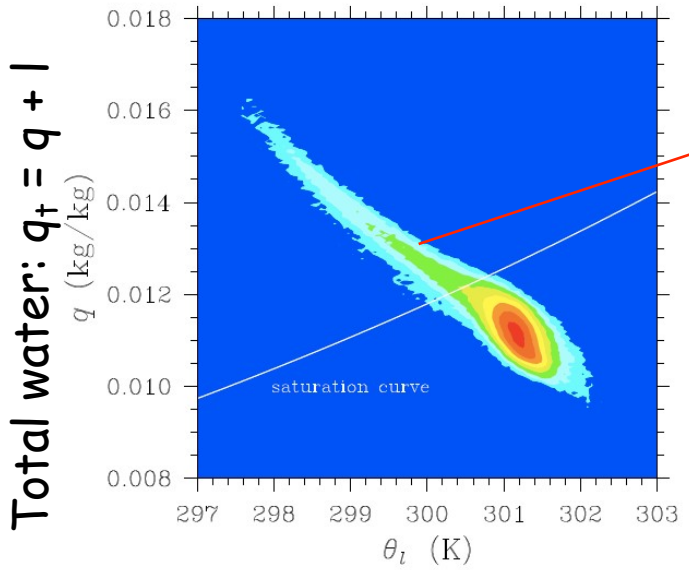
PDF-based Methods to Retrieve/ Assimilate Cloud Thermodynamics

PDF cloud models are based on the pdf of q_t or on the joint pdf of q_t and θ_l



Values larger than saturation are cloudy

$$a = \int_{q_s}^{+\infty} p(q_t)\,dq_t$$

a = cloud fraction

$$\bar{l} = \int_{q_s}^{+\infty} (q_t - \overline{q_s})\,p(q_t)\,dq_t$$

With Gaussian distribution we obtain cloud fraction and liquid water as a function of Q:

$$a = \frac{1}{2} + \frac{1}{2} erf\left(\frac{Q}{\sqrt{2}}\right)$$

$$\frac{l}{\sigma} = aQ + \frac{1}{\sqrt{2\pi}} e^{-Q^2/2}$$

$$Q = \frac{q_t - q_s}{\sigma}$$

Global observations of PDFs of thermodynamic properties are essential

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Summary

- AIRS is culmination of two hundred years of IR science and technology
- AIRS is central to understanding climate and climate change
- AIRS plays significant role in improving weather prediction
- Need for PDF methods to assimilate/retrieve cloud thermodynamics
- Potential of AIRS for environmental applications

Start of community conversation about AIRS science plans

All feedback welcome