National Aeronautics and
Space Administration

Jet Propulsion Laboratory
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Using Satellites to Understand Climate and Climate Change

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Some Themes

- *Climate*: The long-term behavior of the atmosphere, oceans, and ice sheets.

- *Climate Observations*: Measurements of that system (especially from satellites).

- *Climate Models*: Numerical simulations of the climate system.
  - *Used to forecast future climate*.

Many implications of climate change...

"We seem to be standing by and, frankly, asking for perfectness in science. People are saying they want to be convinced, perfectly."

General Gordon R. Sullivan

Former Chief of Staff, U. S. Army (Ret.)

From *National Security and the Threat of Climate Change*

The Scientific Consensus

Google on "IPCC report"

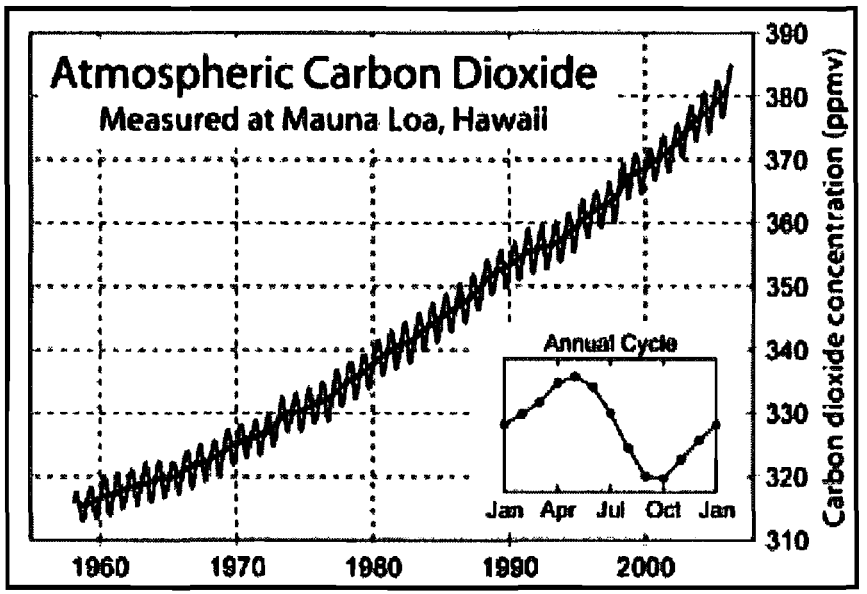
- **see "Working Group 1 Report."**
- **I'll cite this several times tonight.**

Contribution of Working Group I to the
Fourth Assessment Report of the
Intergovernmental Panel on Climate Change

Summary for Policymakers

Three Significant Human Effects on Climate

1. Greenhouse gas emissions
   - Carbon dioxide (CO_2).
   - Also methane, others.
   - About 20 tons CO_2 per person per year in the US.

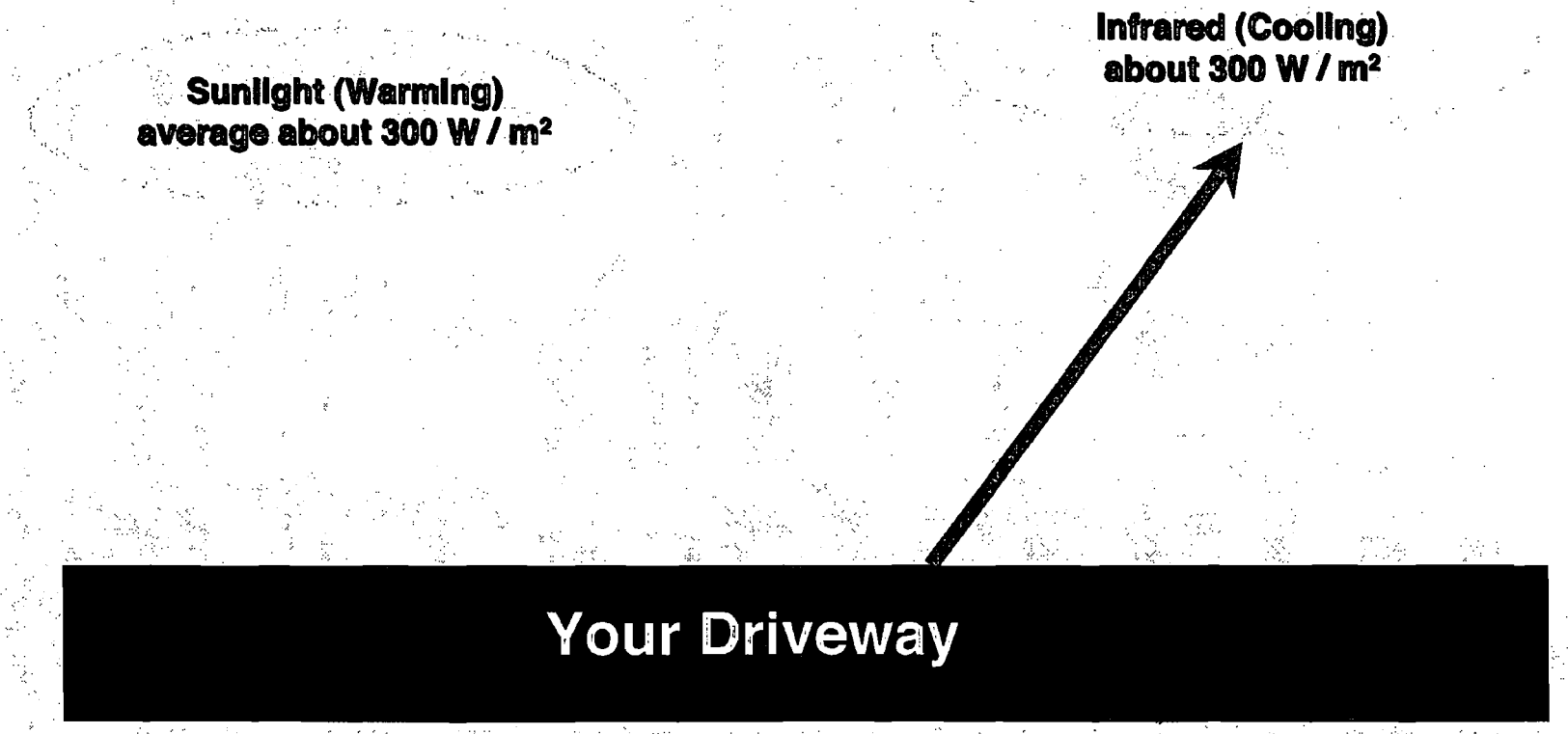


2. Land use practices.

3. Aerosol pollution.

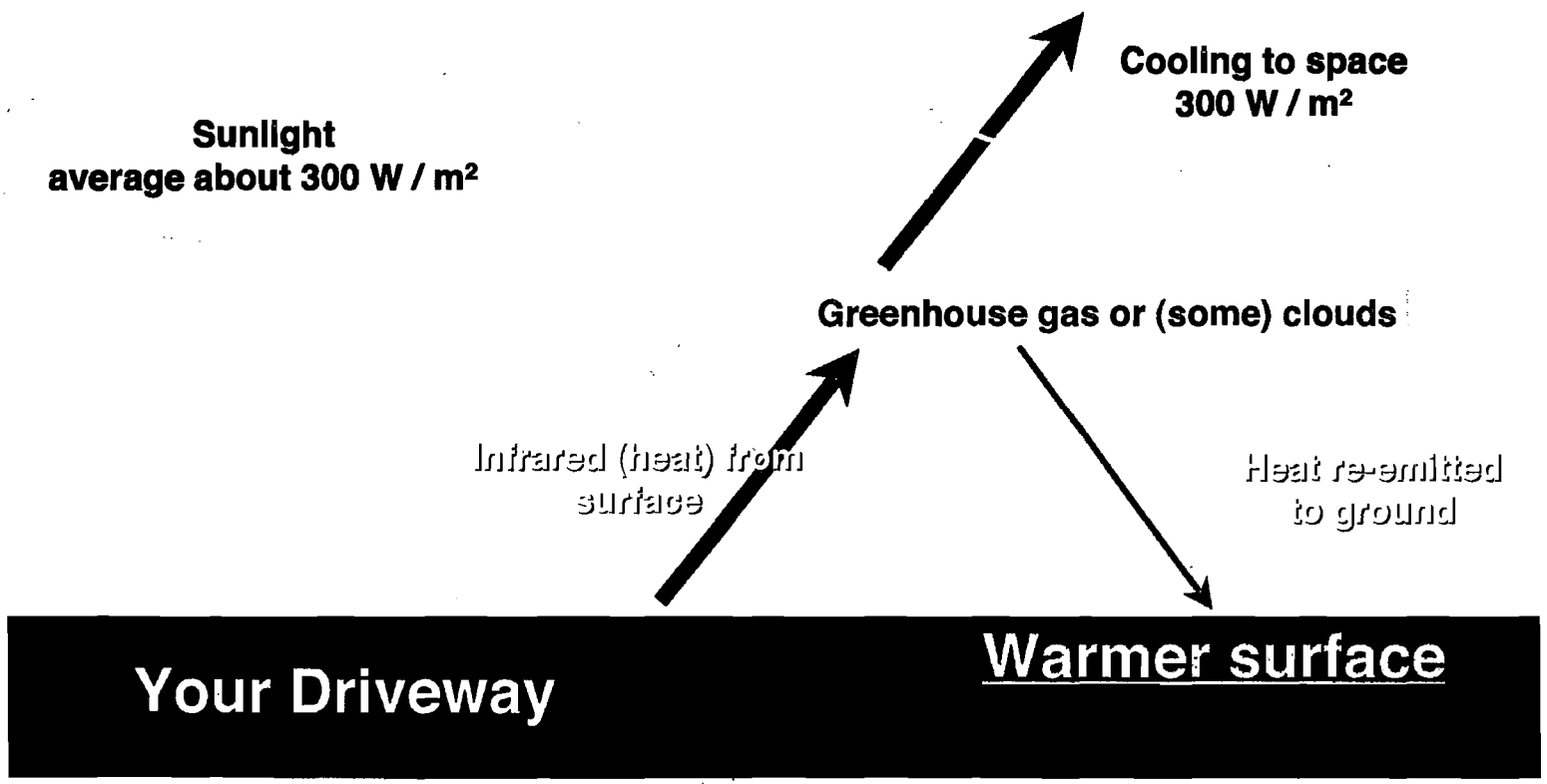
Simple (Radiative) Energy Balance

Long-term balance between incoming and outgoing radiation



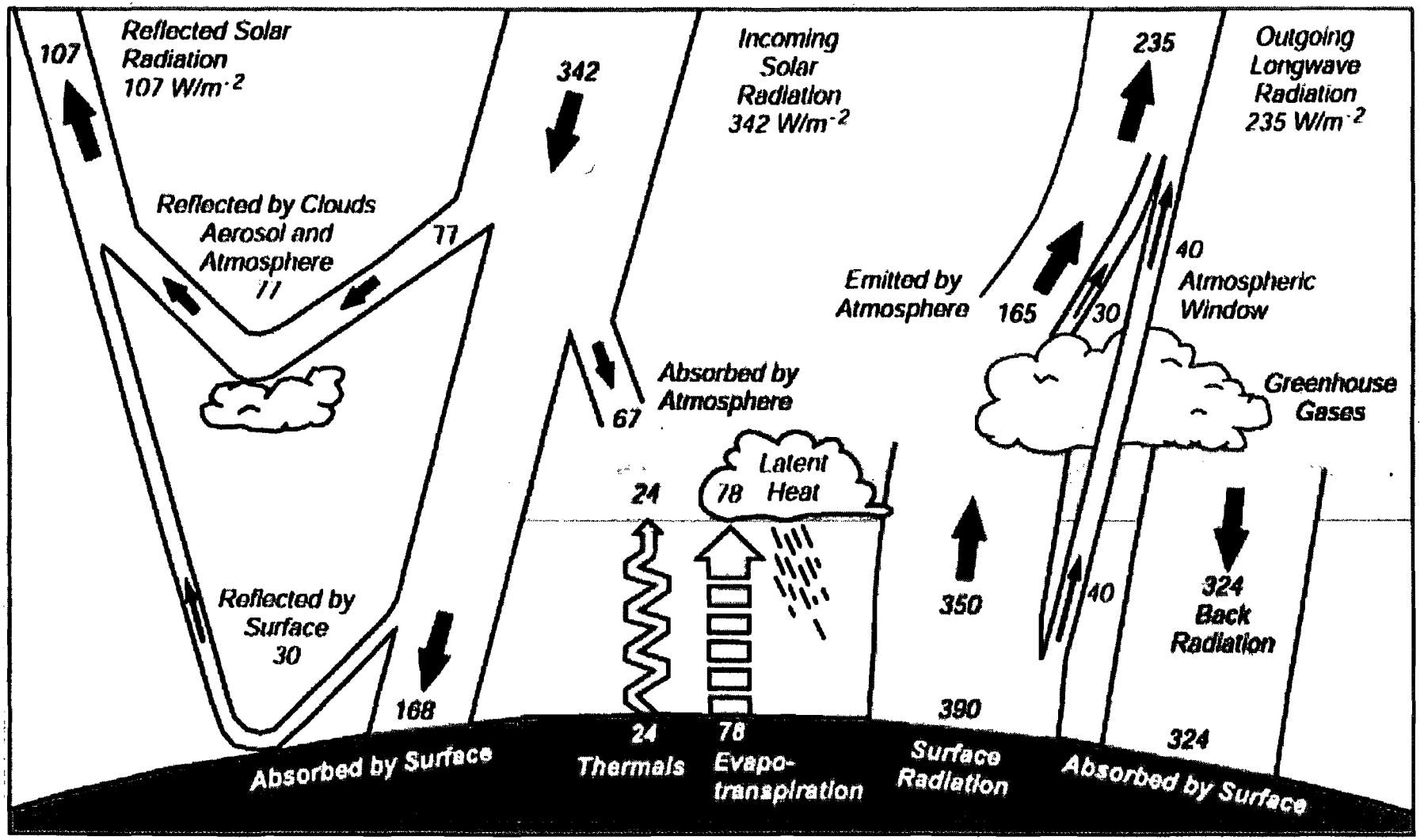
Radiative Balance *with Greenhouse Effect*

Long-term balance between incoming and outgoing radiation

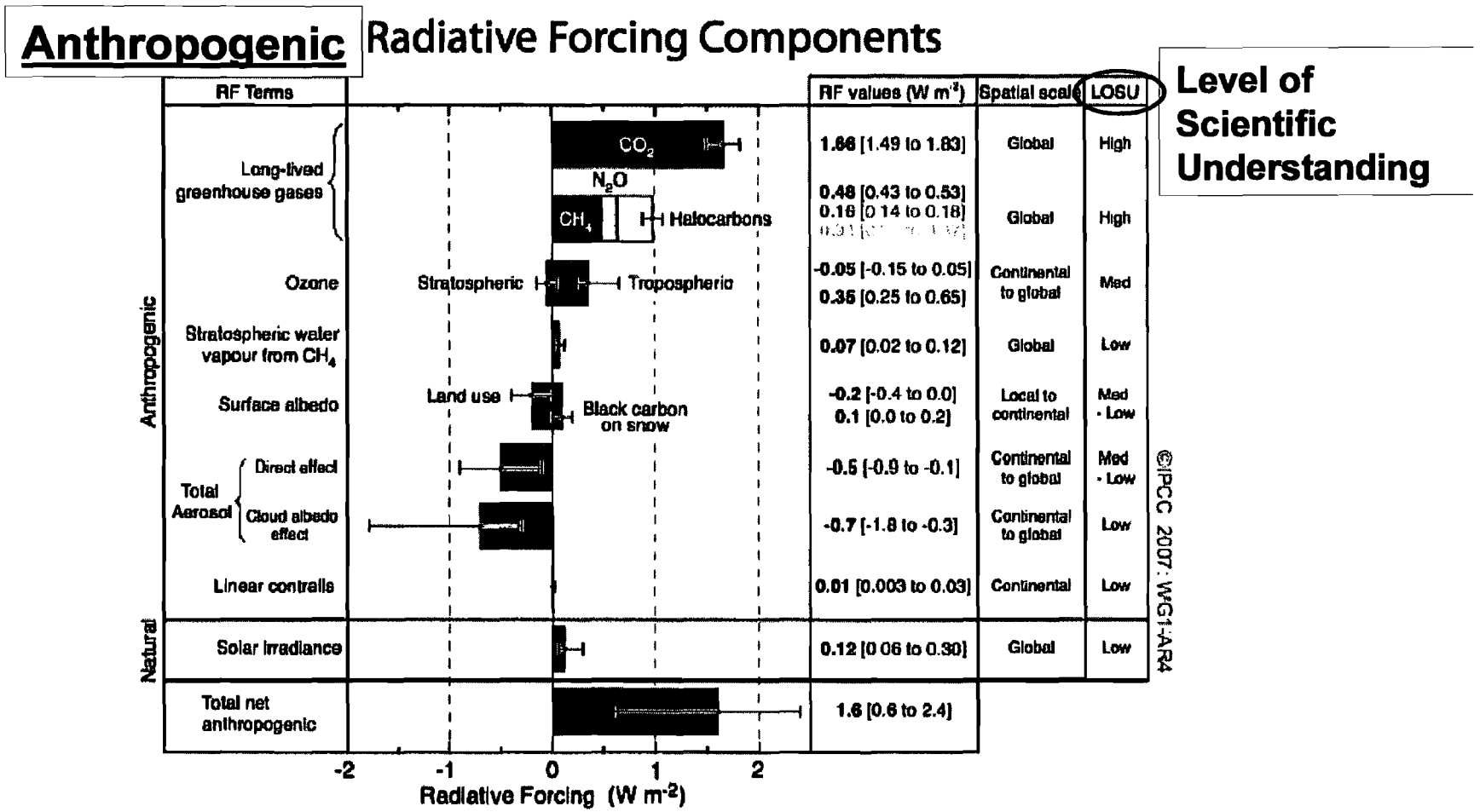


The Earth's Atmosphere and the *Planetary* Energy Balance

Doubled carbon dioxide adds about 3 Watts / m².



How Humans are Contributing
from IPCC report

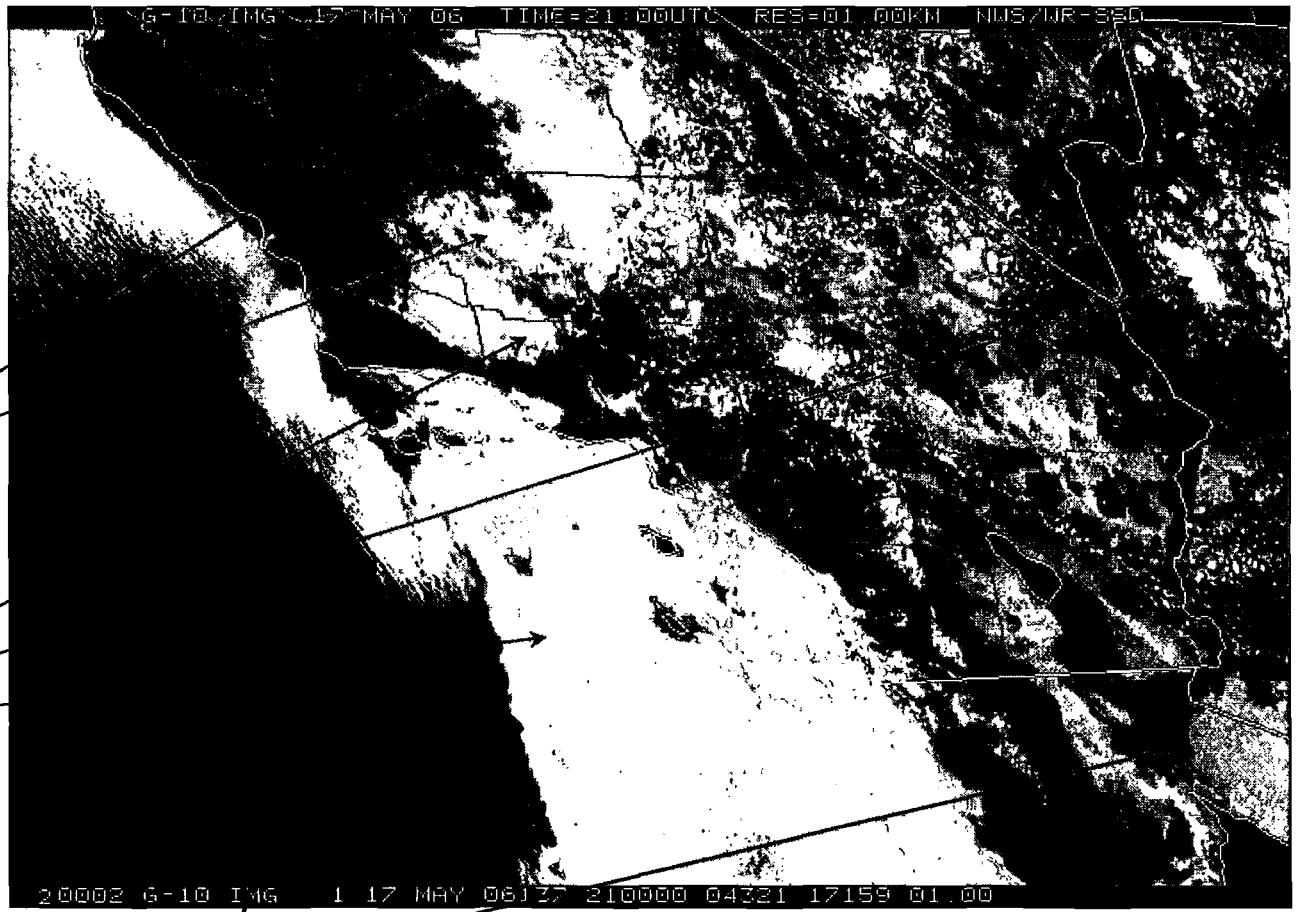


Now the Local Picture

...a snapshot, actually

Wednesday, May 17, 2006

Unusual May conditions: 'marine layer' and thunderstorms over Southern California



High thin clouds warm the surface by absorbing heat radiation

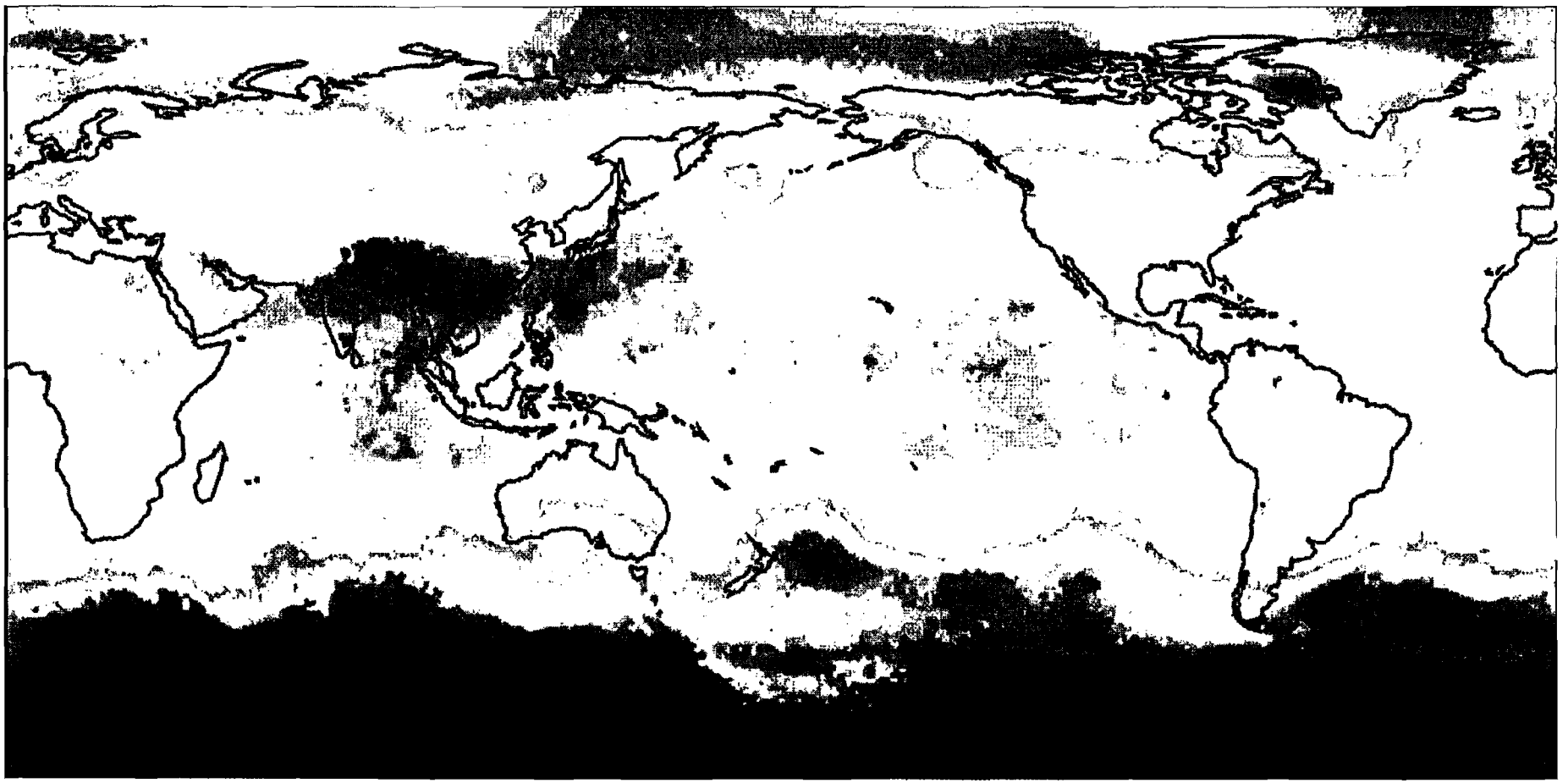
Thick clouds cool the surface by reflecting sunlight

Greenhouse gases warm the surface in clear areas

Back to the global picture: *Temperature*

August 2004 to September 2005, Altitude = 5 km (3 mi)

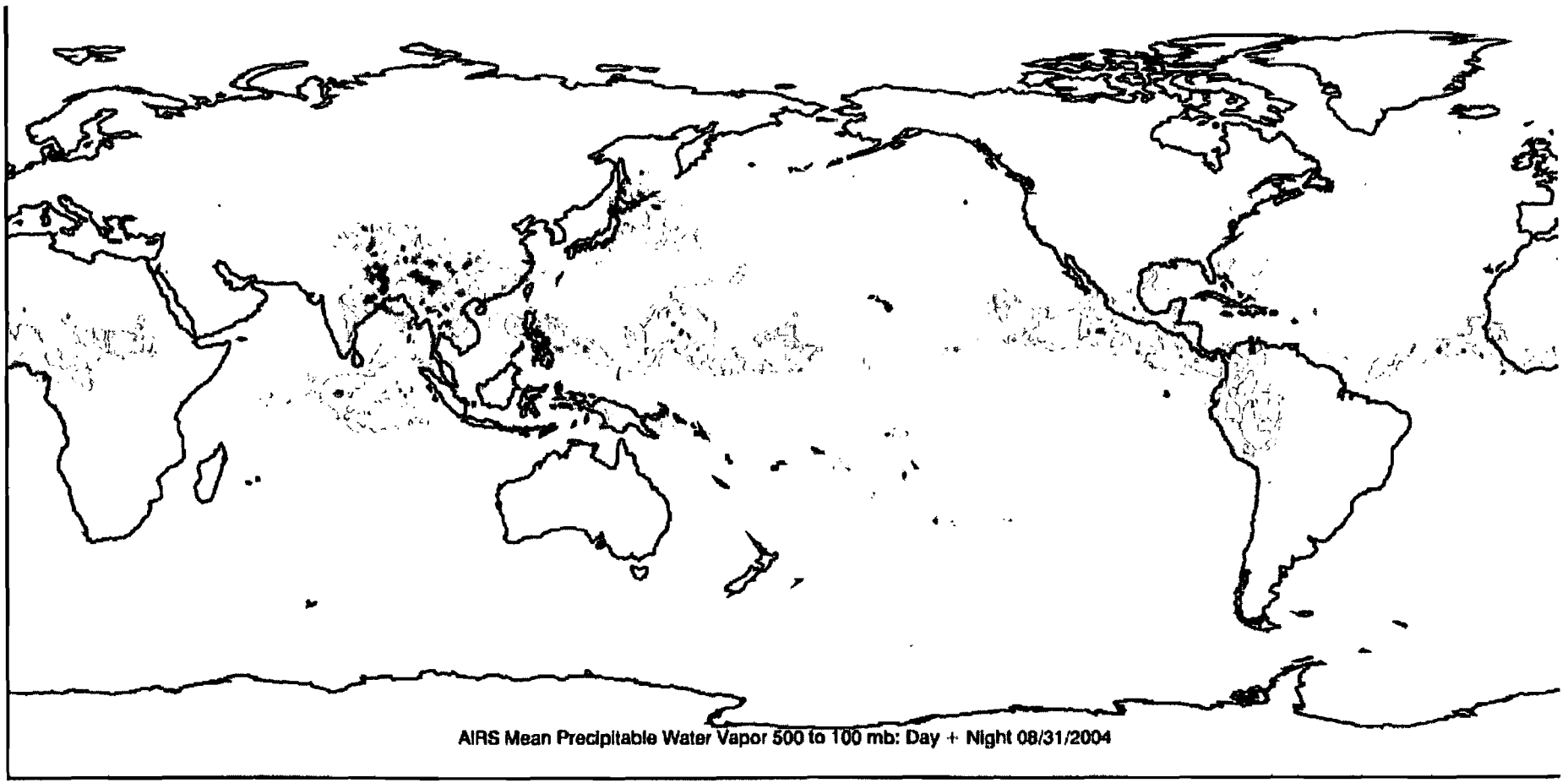
Red = Warm Purple = Cold



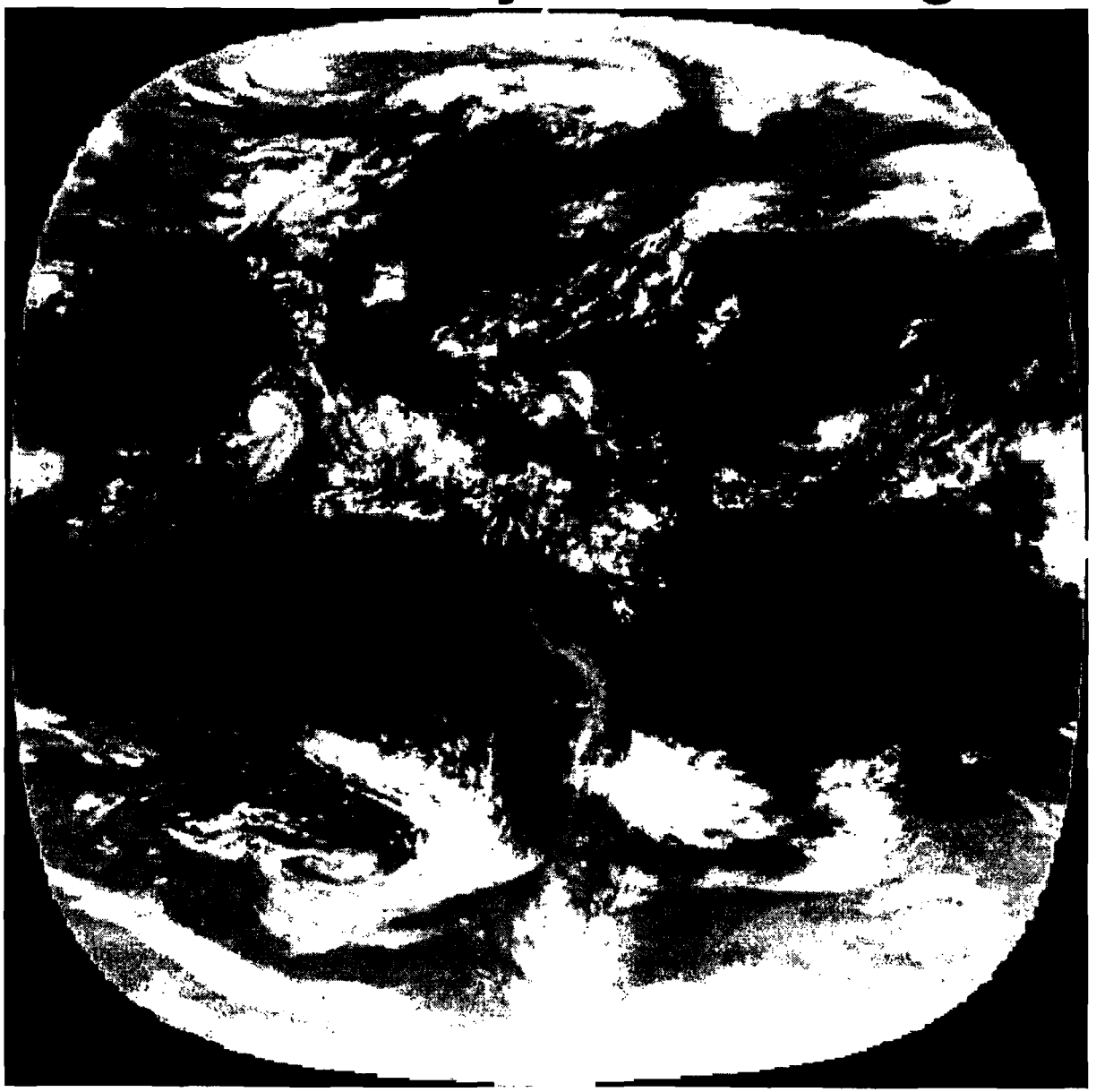
Global Water Vapor as a Greenhouse Gas

August 2004 to September 2005, 5-15 km (3-10 mi) altitude.

Tan = Drier **Blue = Wetter**



Clouds in August 2005
Geostationary Infrared Image



Climate Feedbacks

1. "Ice-albedo feedback"
   - Why the Arctic is warming quickly.

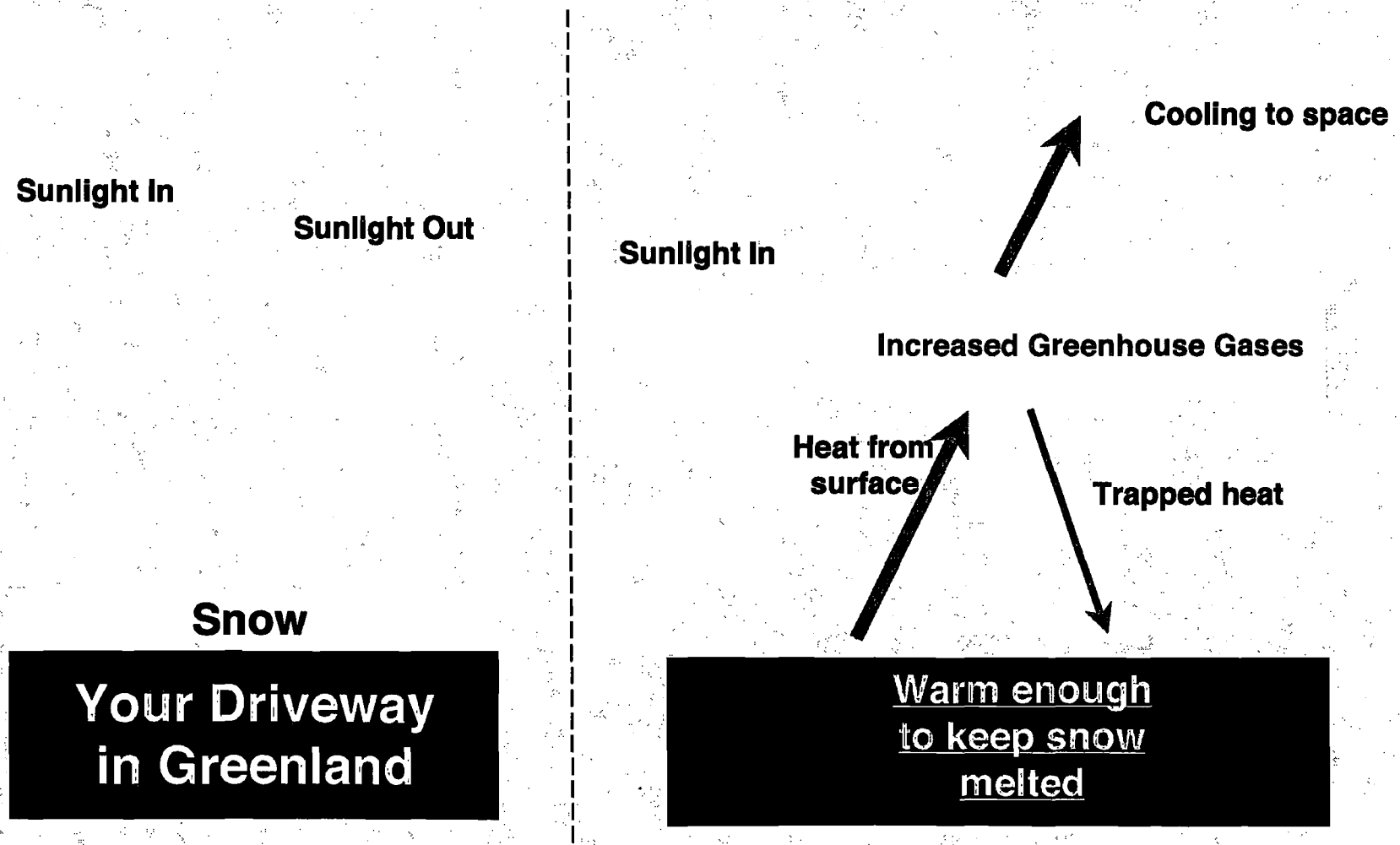
2. Cloud feedbacks
   - The largest source of uncertainty in climate prediction.

Others are important, especially water vapor feedback.

...but I won't talk about them.

The Poles: Ice-albedo Feedback

Albedo means 'reflectivity'



Consequences of ice-albedo feedback

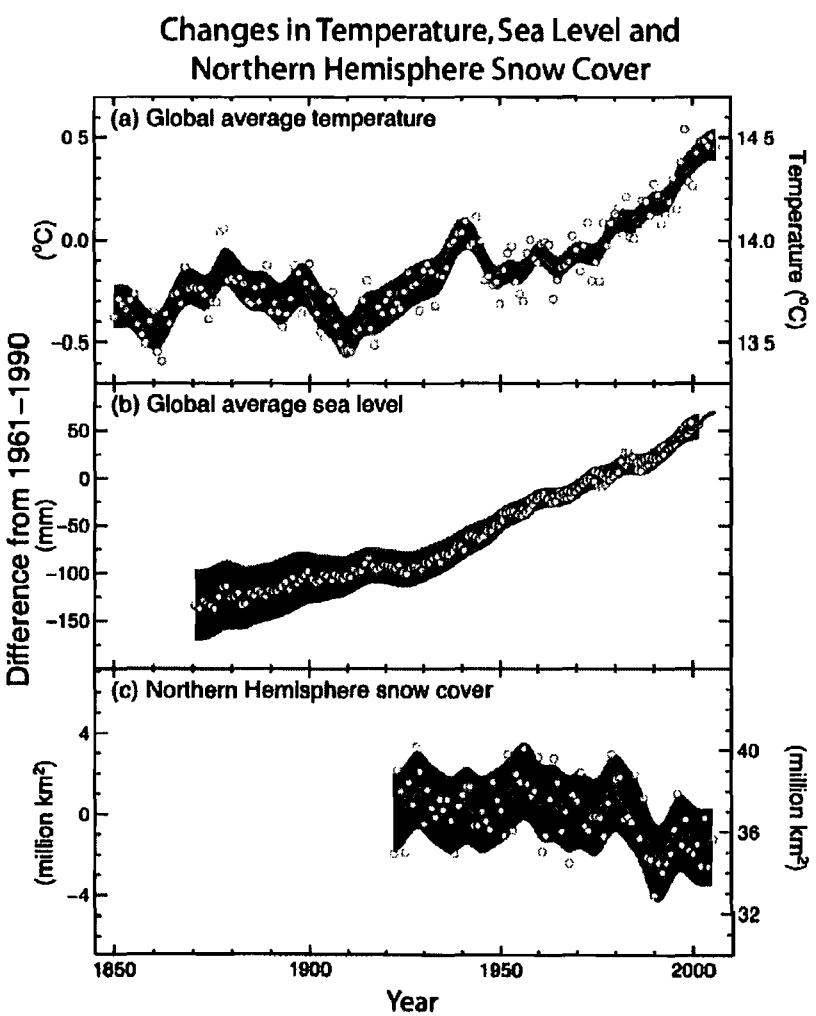
- **Decrease in Arctic snow and summer sea ice.**
- **Retreat of Greenland and Antarctic ice sheets.**
- **Melting permafrost.**
- **Northward movement of tree line.**

"Arctic Sea Ice Melting Faster, A Study Finds"
***New York Times*, May 1.**

"Climate scientists may have significantly underestimated the power of global warming from human-generated heat-trapping gases to shrink the cap of sea ice floating on the Arctic Ocean, according to a new study of polar trends..."

What the IPCC report says:

Arctic:



Antarctic:

"Antarctic *sea ice* continues to show interannual variability and localized changes but *no statistically significant average changes, consistent with the lack of warming reflected in average temperatures across the region* [my italics]."

The Latest on the Antarctic

NASA Press Release of 15 May 2007:

"NASA FINDS VAST REGIONS OF WEST ANTARCTICA MELTED IN RECENT PAST

WASHINGTON - A team of NASA and university scientists has found clear evidence that extensive areas of snow melted in west Antarctica in January 2005 in response to warm temperatures. This was the first widespread Antarctic melting ever detected with NASA's QuikScat satellite and the most significant melt observed using satellites during the past three decades. The affected regions encompass a combined area as big as California."

Finally... Cloud Feedbacks

Remember, clouds generally do two things:

1. **Reflect sunlight back to space (cooling).**

2. **Act as a greenhouse 'substance' (warming).**

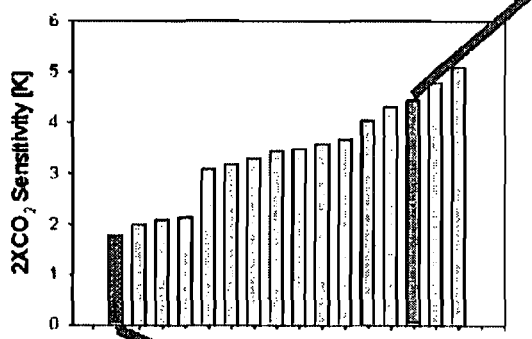
FROM THE IPCC REPORT:

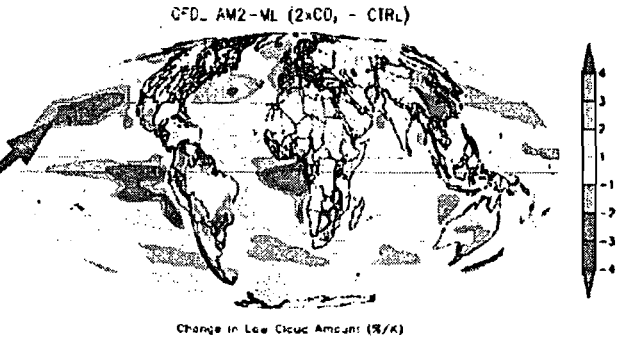
"Cloud feedbacks remain the largest source of uncertainty [in future climate forecasts.]"

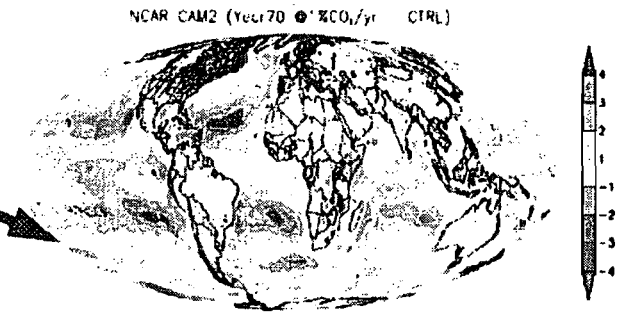
Also in 1990, 1995 and 2001 reports!

IPCC Climate Models and *Cloud Feedback*

IPCC model predicting larger warming from doubled CO_2







IPCC model predicting smaller warming from doubled CO_2

The maps show:

Blue = Fewer clouds reflecting sunlight.

Red = More clouds reflecting sunlight.

Conclusions

1. **Models with more reflective clouds show less warming.**
2. **Models with more 'greenhousy' clouds show more warming (not shown).**

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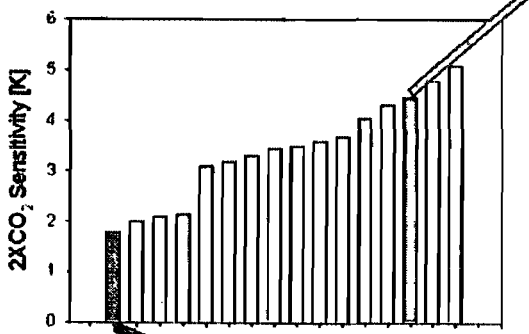

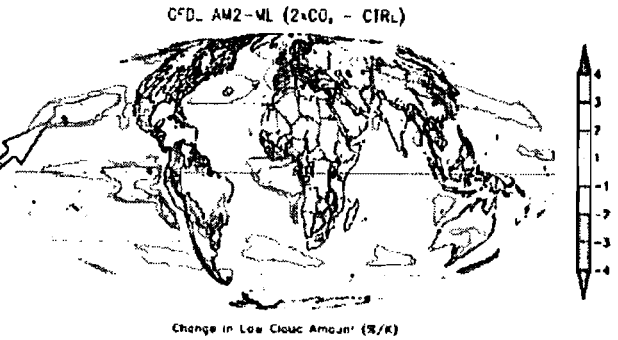

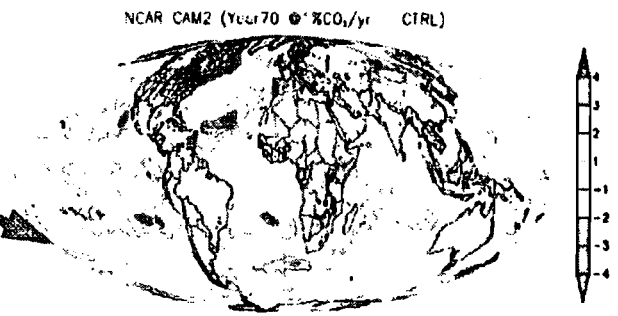

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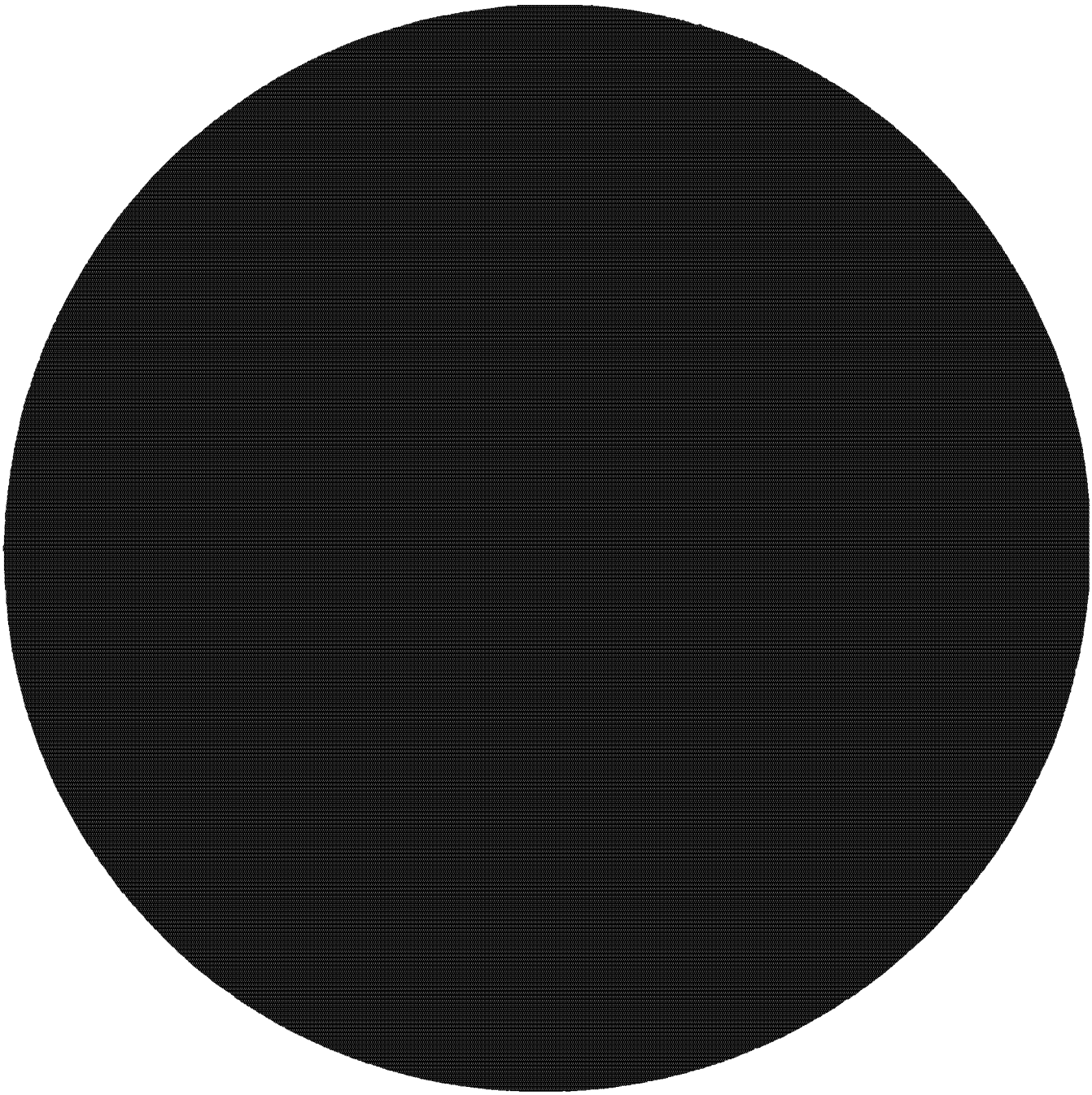
Summary

- **Humans are a major factor in climate change.**
- **We understand some climate responses**
  - ***Basic greenhouse effect.***
  - ***Ice-albedo feedback in the Arctic.***
- **Some responses are a puzzle**
  - ***The Antarctic.***
  - ***How strongly clouds will amplify (or mitigate) human influences.***
  - ***Aerosol-cloud interactions.***
- **Climate observations are key to resolving these issue.**
- **Climate models are only as good as our understanding of climate processes.**

Supplemental Material

- ***National Security and the Threat of Climate Change***

  http://securityandclimate.cna.org

- ***Intergovernmental Panel on Climate Change***
  - **See "Working Group 1 Report" at http://www.ipcc.ch**

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