The Need To Assess Spatial Variations In Climate Forcings - Suggestions For Future Research

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Solar Influences on Recently Observed Climate Change
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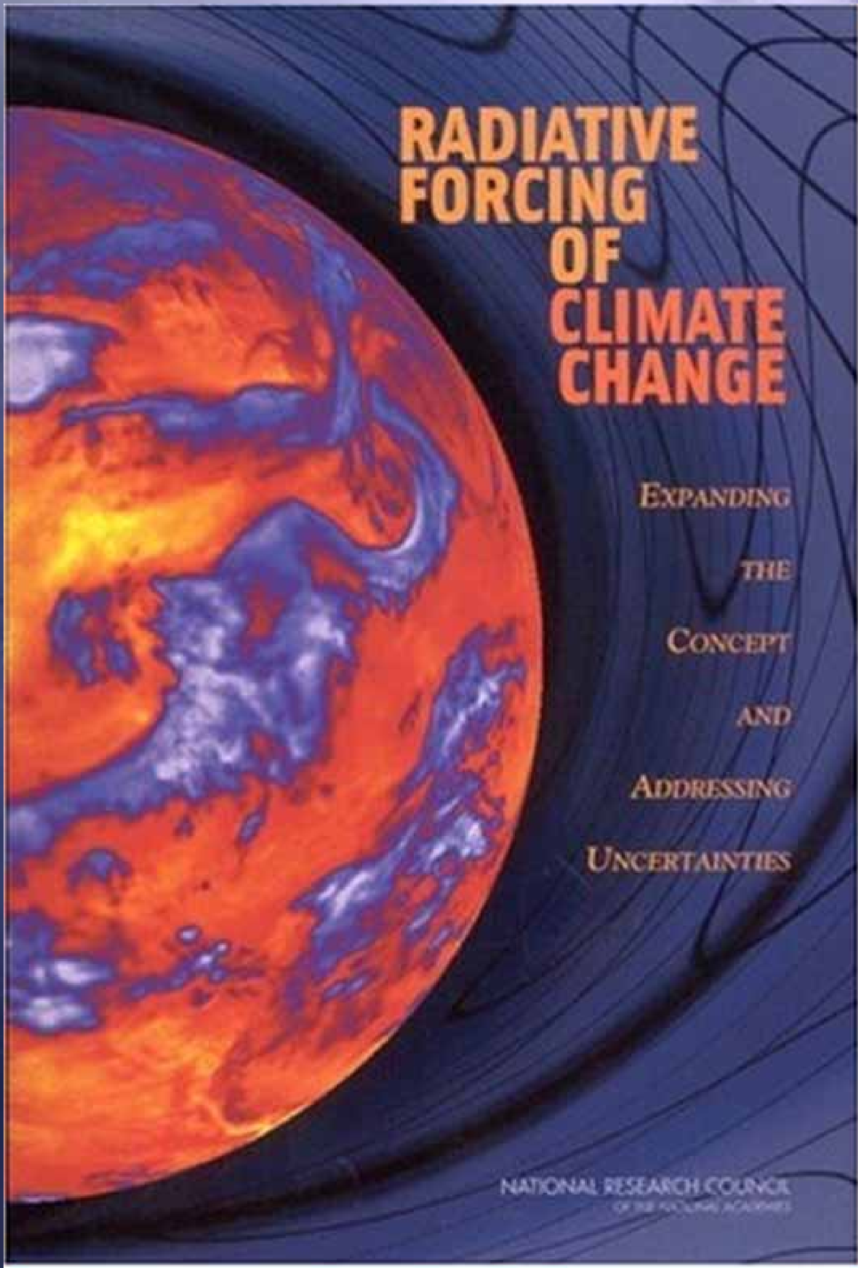
Three Climate Change Hypotheses – Only One Of Which Can Be True

The climate issue, with respect to how humans are influencing the climate system, can be segmented into three distinct hypotheses. These are:

1. The human influence is minimal and natural variations dominate climate variations on all time scales;

2. While natural variations are important, the human influence is significant and involves a diverse range of first-order climate forcings (including, but not limited to the human input of CO_2);

3. The human influence is dominated by the emissions into the atmosphere of greenhouse gases, particularly carbon dioxide.



National Research Council, 2005: Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties, Committee on Radiative Forcing Effects on Climate, Climate Research Committee, 224 pp.

http://www.nap.edu/catalog/11175.html

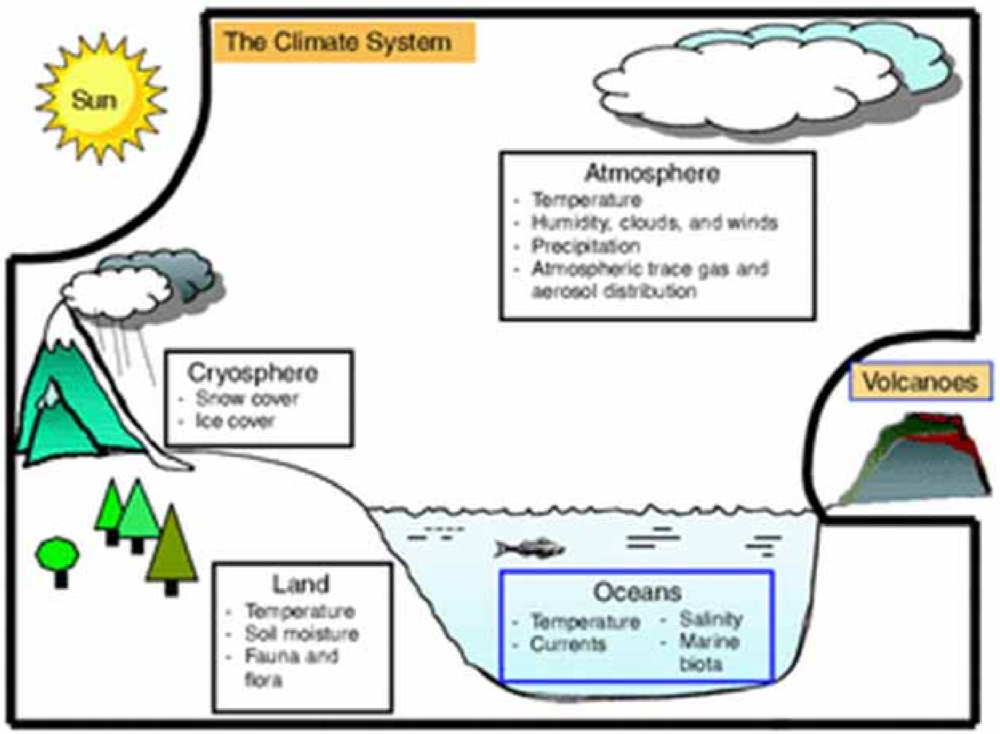


FIGURE 1-1 The climate system, consisting of the atmosphere, oceans, land, and cryosphere. Important state variables for each sphere of the climate system are listed in the boxes. For the purposes of this report, the Sun, volcanic emissions, and human-caused emissions of greenhouse gases and changes to the land surface are considered external to the climate system.

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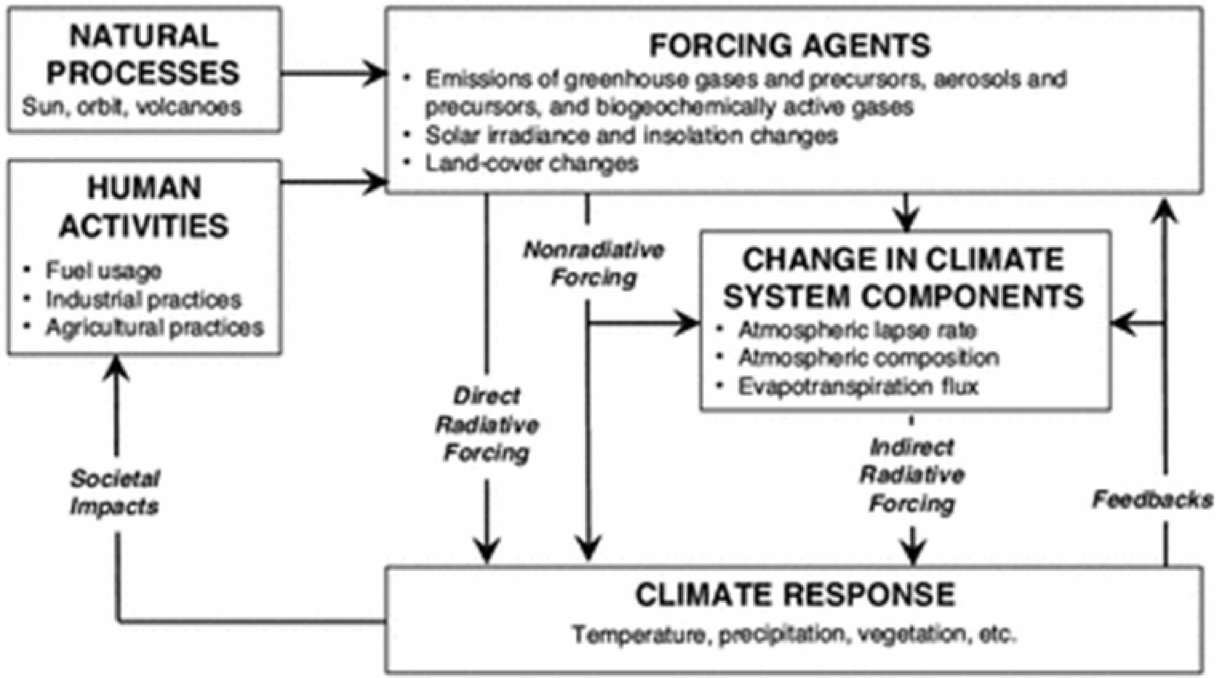


FIGURE 1-2 Conceptual framework of climate forcing, response, and feedbacks under present-day climate conditions. Examples of human activities, forcing agents, climate system components, and variables that can be involved in climate response are provided in the lists in each box.

From: National Research Council, 2005: Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties, Committee on Radiative Forcing Effects on Climate, Climate Research Committee, 224 pp. http://www.nap.edu/catalog/11175.html

Despite all... [its]... advantages, the traditional global mean TOA radiative forcing concept has some important limitations, which have come increasingly to light over the past decade. The concept is inadequate for some forcing agents, such as absorbing aerosols and land-use changes, that may have regional climate impacts much greater than would be predicted from TOA radiative forcing. Also, it diagnoses only one measure of climate change - global mean surface temperature response - while offering little information on regional climate change or precipitation.

from http://www.nap.edu/openbook.php?record_id=11175&page=4

EXPANDING THE RADIATIVE FORCING CONCEPT (NRC 2005 Recommendations)

- → Account for the Vertical Structure of Radiative Forcing
- → Determine the Importance of Regional Variation in Radiative Forcing
- → Determine the Importance of Nonradiative Forcings
- → Provide Improved Guidance to the Policy Community

Determine the Importance of Regional Variation in Radiative Forcing

National Research Council Report

PRIORITY RECOMMENDATIONS

Use climate records to investigate relationships between regional radiative forcing (e.g., land use or aerosol changes) and climate response in the same region, other regions, and globally.

Determine the Importance of Regional Variation in Radiative Forcing

National Research Council Report

PRIORITY RECOMMENDATIONS

Quantify and compare climate responses from regional radiative forcings in different climate models and on different timescales (e.g., seasonal, interannual), and report results in climate change assessments.

Determine the Importance of Nonradiative Forcings

National Research Council Report

PRIORITY RECOMMENDATIONS

Improve understanding and parameterizations of aerosol-cloud thermodynamic interactions and land-atmosphere interactions in climate models in order to quantify the impacts of these nonradiative forcings on both regional and global scales.

Determine the Importance of Nonradiative Forcings

National Research Council Report

PRIORITY RECOMMENDATIONS

Develop improved land-use and land-cover classifications at high resolution for the past and present, as well as scenarios for the future.

Provide Improved Guidance to the Policy Community

National Research Council Report

PRIORITY RECOMMENDATIONS

Encourage policy analysts and integrated assessment modelers to move beyond simple climate models based entirely on global mean TOA radiative forcing and incorporate new global and regional radiative and nonradiative forcing metrics as they become available.

Global Climate Effects Occur with ENSOs for the Following Reasons:

1. Large Magnitude
2. Long Persistence
3. Spatial Coherence

Wu, Z. - X., and Newell, R. E. 1998 Influence of sea surface temperature of air temperature in the tropic. *Climate Dynamics* 14, 275-290.

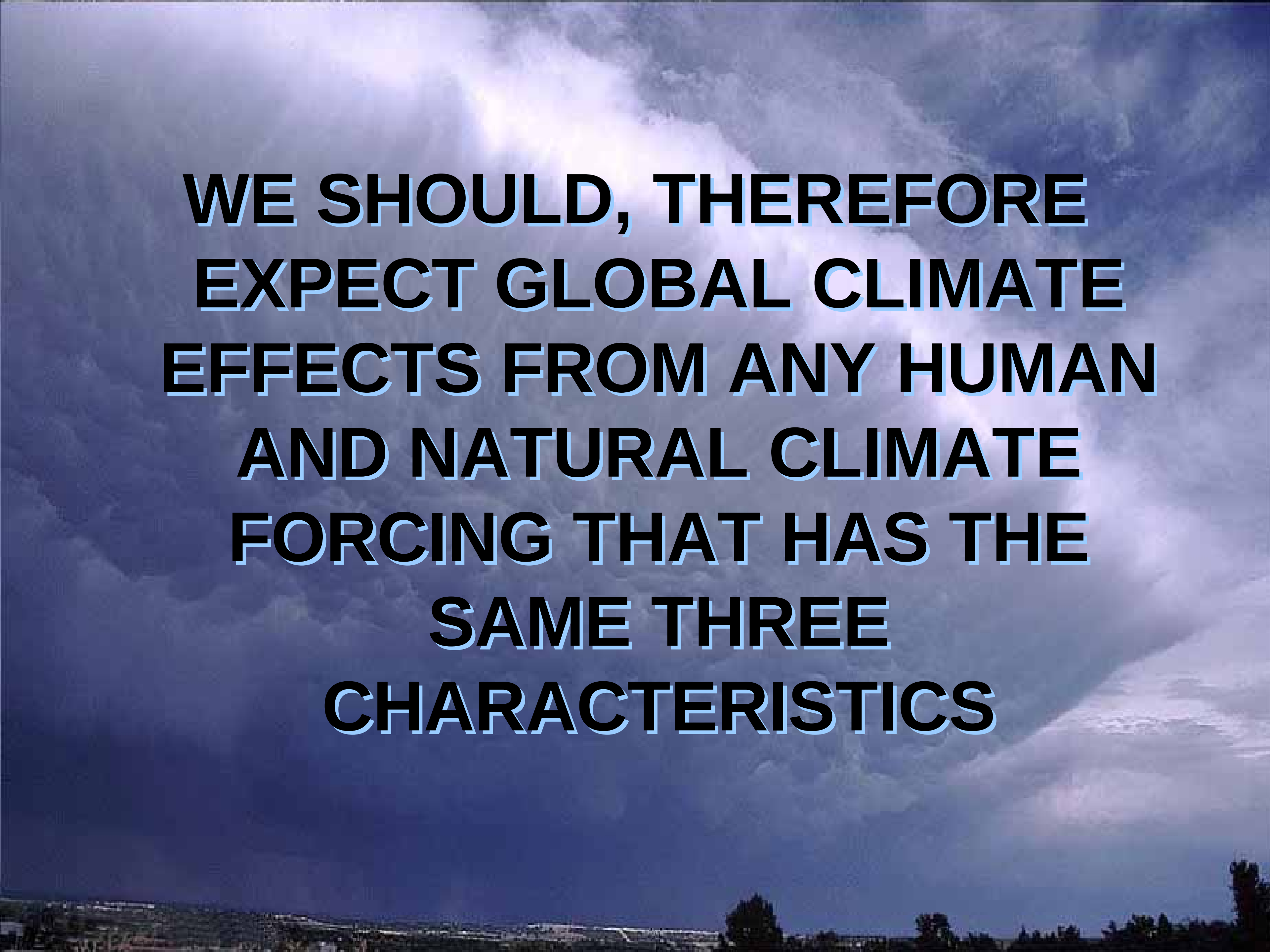
The 2005 National Research Council report concluded that:

"regional variations in radiative forcing may have important regional and global climate implications that are not resolved by the concept of global mean radiative forcing.“

And furthermore:

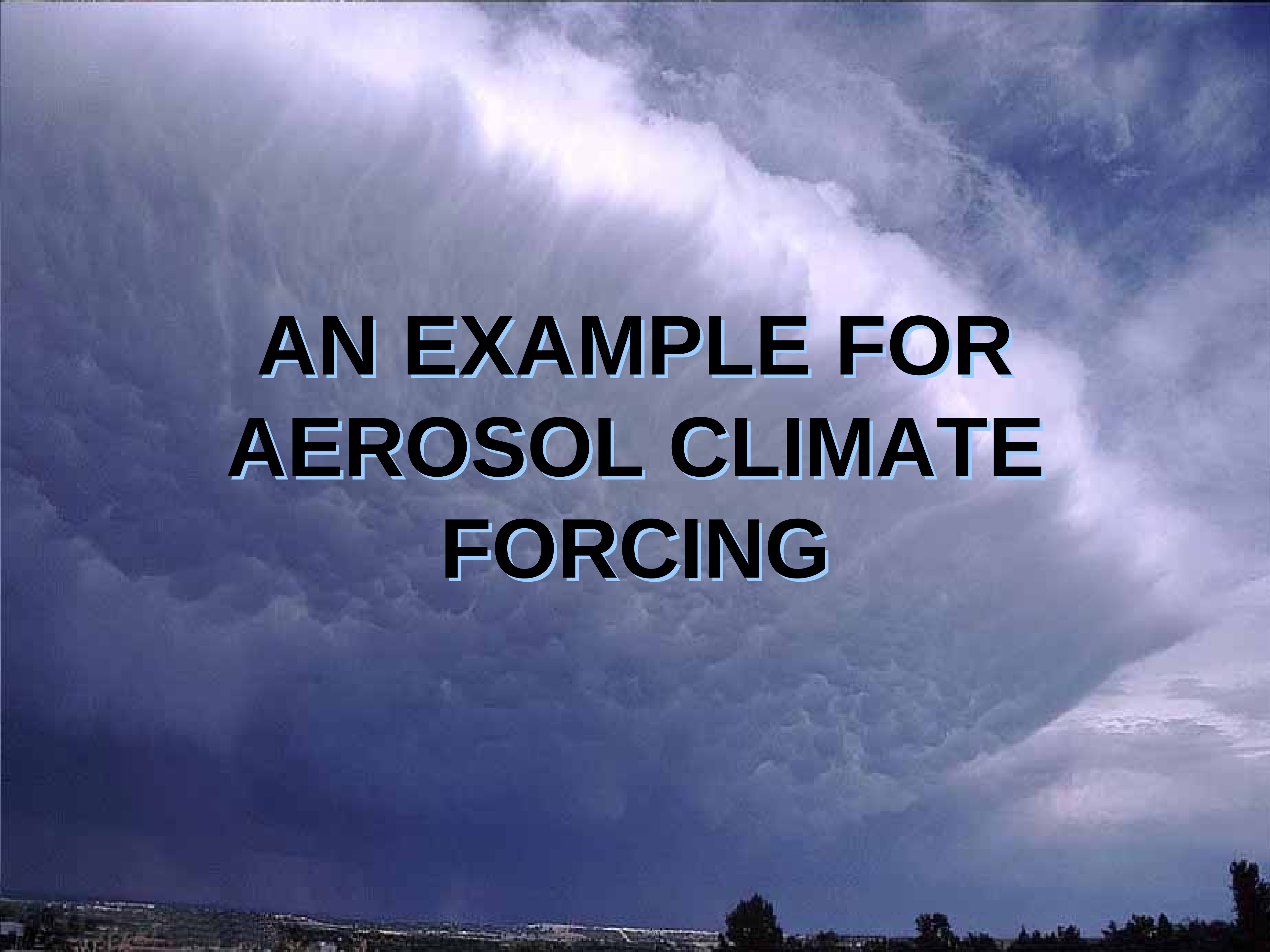
"Regional diabatic heating can cause atmospheric teleconnections that influence regional climate thousands of kilometers away from the point of forcing."

This regional diabatic heating produces temperature increases or decreases in the layer-averaged regional troposphere. This necessarily alters the regional pressure fields and thus the wind pattern. This pressure and wind pattern then affects the pressure and wind patterns at large distances from the region of the forcing which we refer to as teleconnections.


WE SHOULD, THEREFORE
EXPECT GLOBAL CLIMATE
EFFECTS FROM ANY HUMAN
AND NATURAL CLIMATE
FORCING THAT HAS THE
SAME THREE
CHARACTERISTICS

THE REGIONAL ALTERATION IN TROPOSPHERIC DIABATIC HEATING HAS A GREATER INFLUENCE ON THE CLIMATE SYSTEM THAN A CHANGE IN THE GLOBALLY-AVERAGED SURFACE AND TROPOSPHERIC TEMPERATURES

WHAT IS THE IMPORTANCE OF MORE HETEROGENEOUS CLIMATE FORCINGS RELATIVE TO MORE HOMOGENEOUS CLIMATE FORCING SUCH AS THE RADIATIVE FORCING OF CO_2?



AN EXAMPLE FOR AEROSOL CLIMATE FORCING

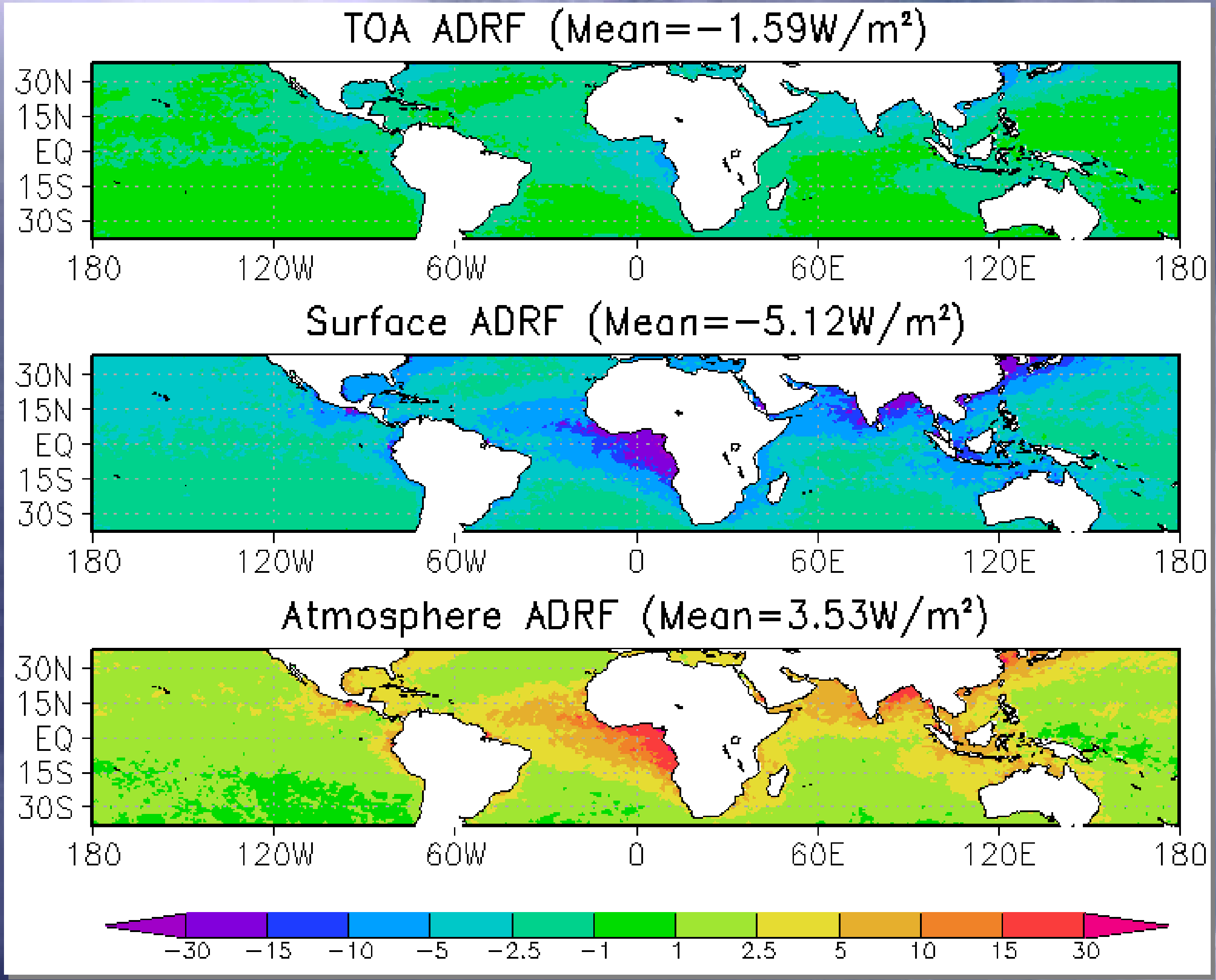


Figure 1. Shortwave aerosol direct radiative forcing (ADRF) for top-of atmosphere (TOA), surface, and atmosphere. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974.
http://climatesci.colorado.edu/publications/pdf/R-312.pdf

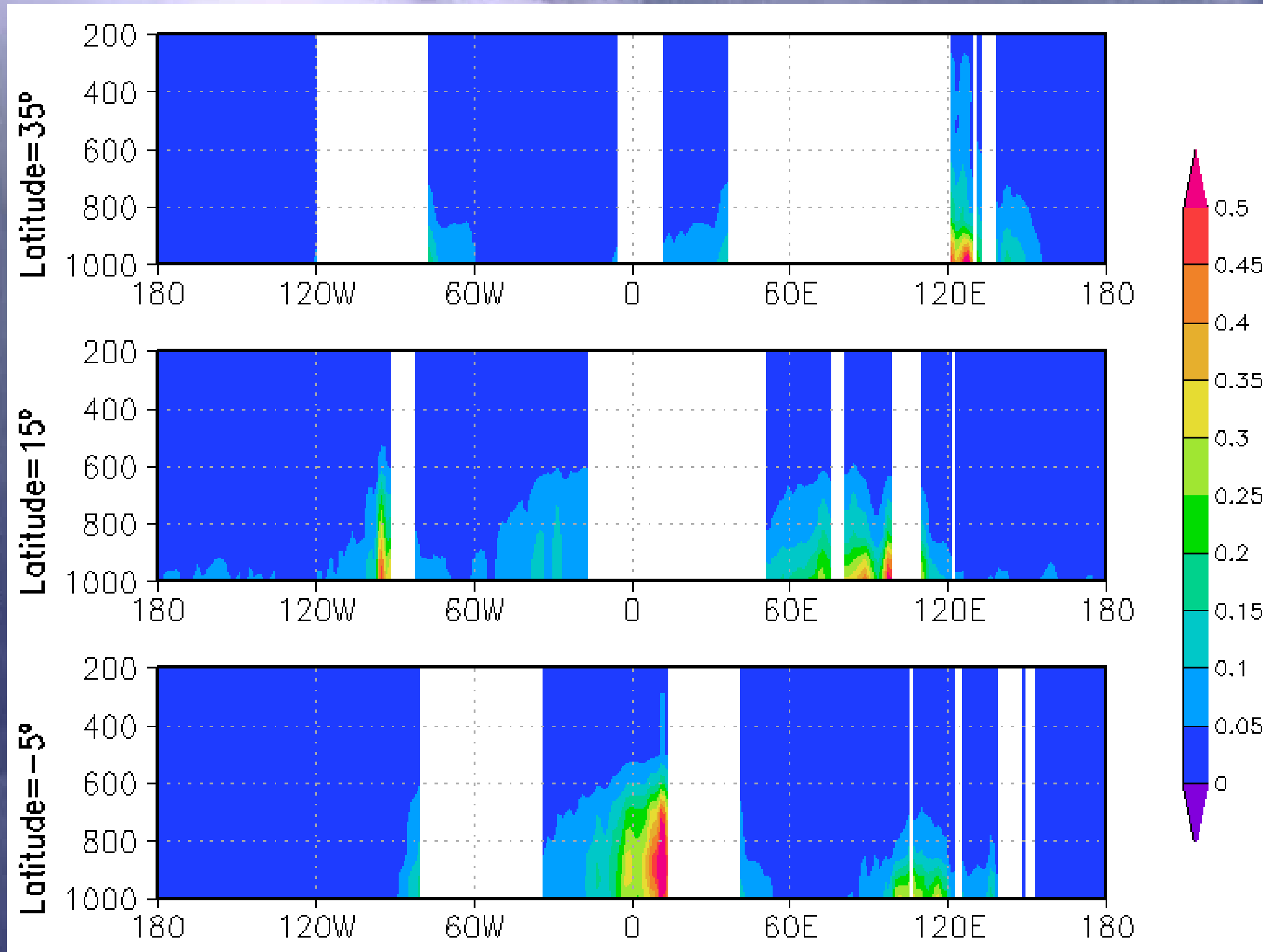


Figure 2. Vertical profile of atmospheric heating rate (K day^{-1}) due to shortwave ADRF. Vertical coordinate is pressure level (mb). From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974.
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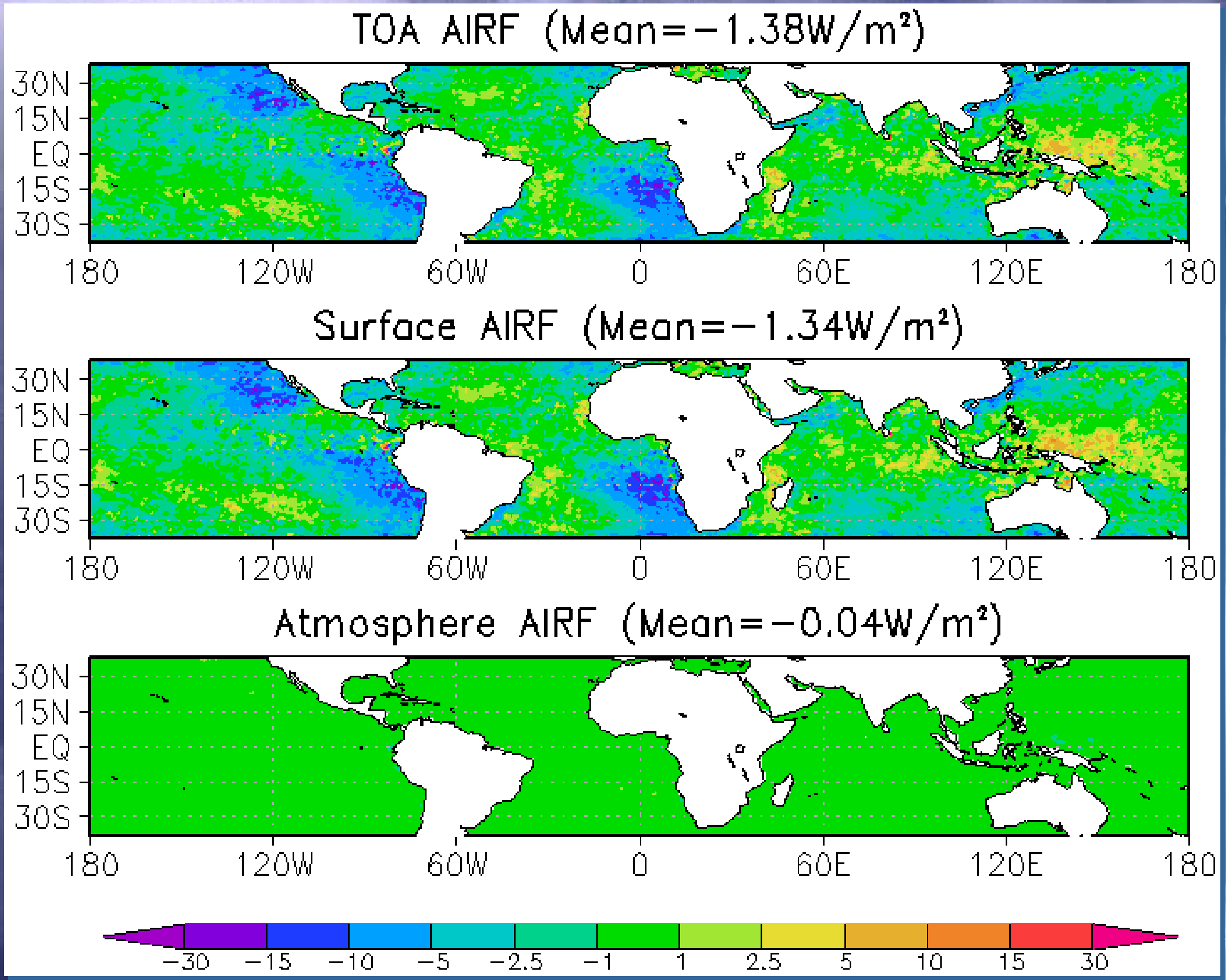

Figure 3. Shortwave aerosol indirect radiative forcing (AIRF) for top-of atmosphere (TOA), surface, and atmosphere. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974.
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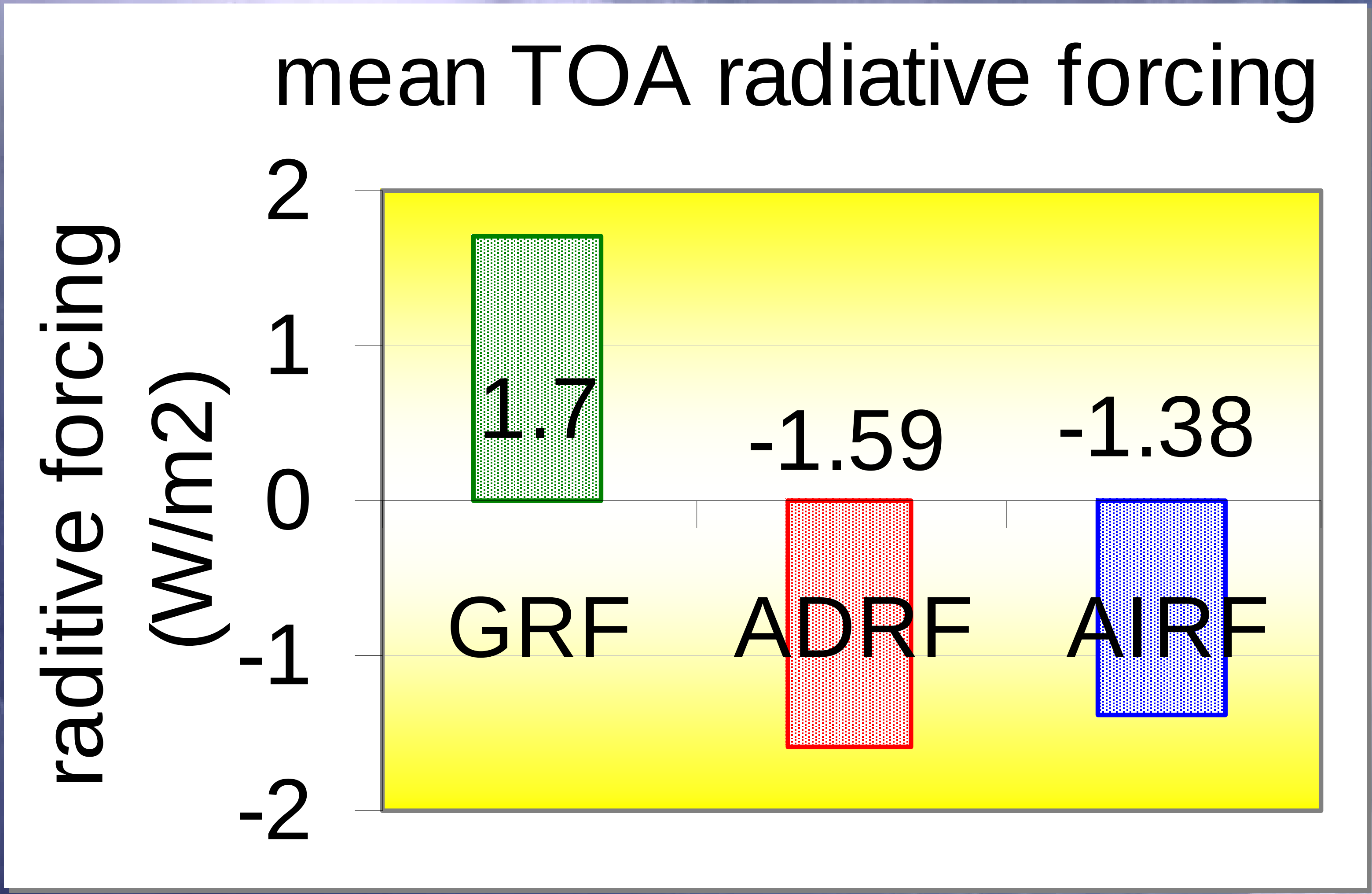

Figure 4. Comparison of Mean TOA radiative forcing between infrared GRF, shortwave ADRF, and shortwave AIRF. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974.
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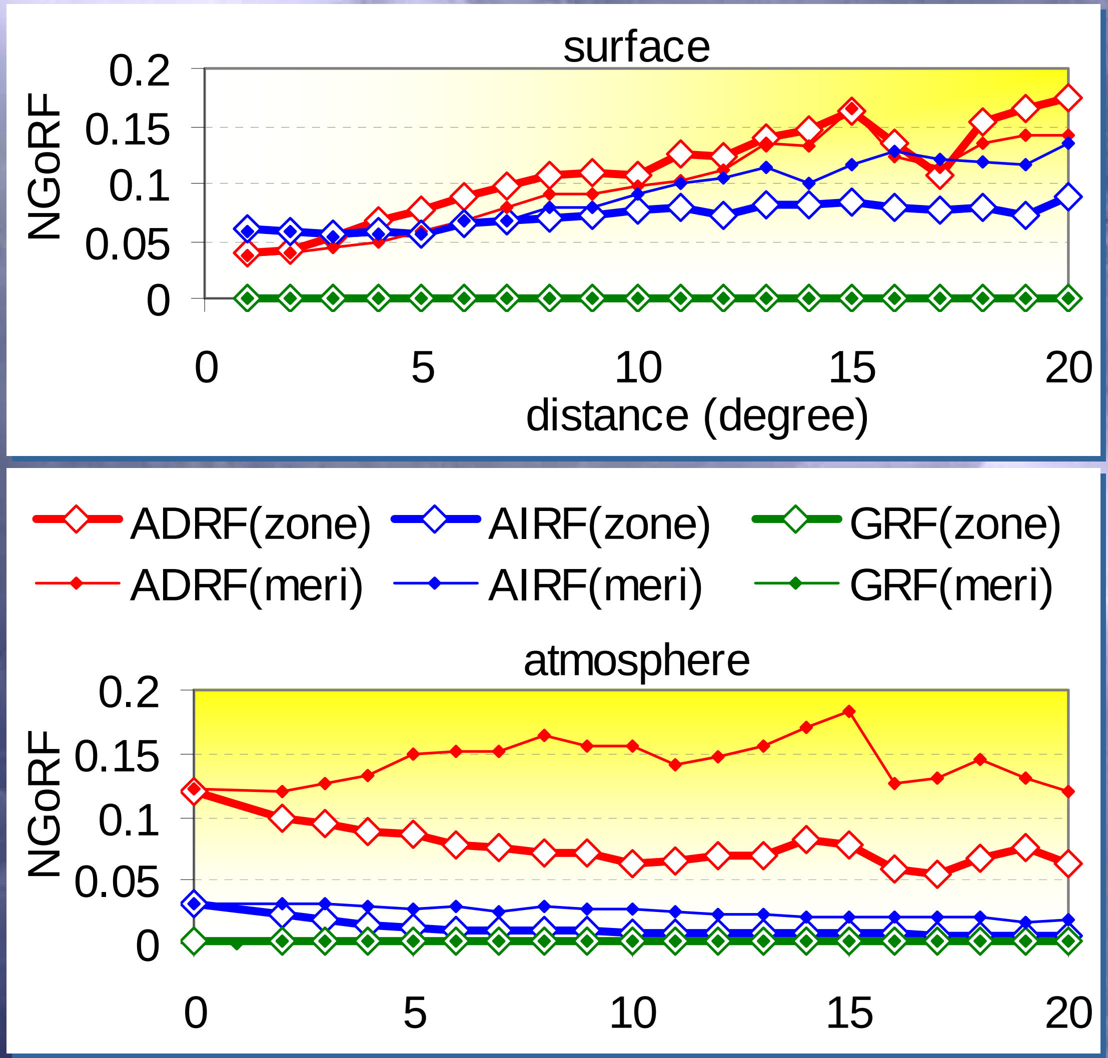

Figure 5. Comparison of the meridional and the zonal component of NGoRF between infrared GRF, shortwave ADRF, and shortwave AIRF for atmosphere and surface. From: Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974. http://climatesci.colorado.edu/publications/pdf/R-312.pdf

In Matsui and Pielke Sr. (2006), it was found from observations of the spatial distribution of aerosols in the atmosphere in the lower latitudes, that the aerosol effect on atmospheric circulations, as a result of their alteration in the heating of regions of the atmosphere, is 60 times greater than due to the heating effect of the human addition of well-mixed greenhouse gases.

Matsui, T., and R.A. Pielke Sr., 2006: Measurement-based estimation of the spatial gradient of aerosol radiative forcing. Geophys. Res. Letts., 33, L11813, doi:10.1029/2006GL025974.

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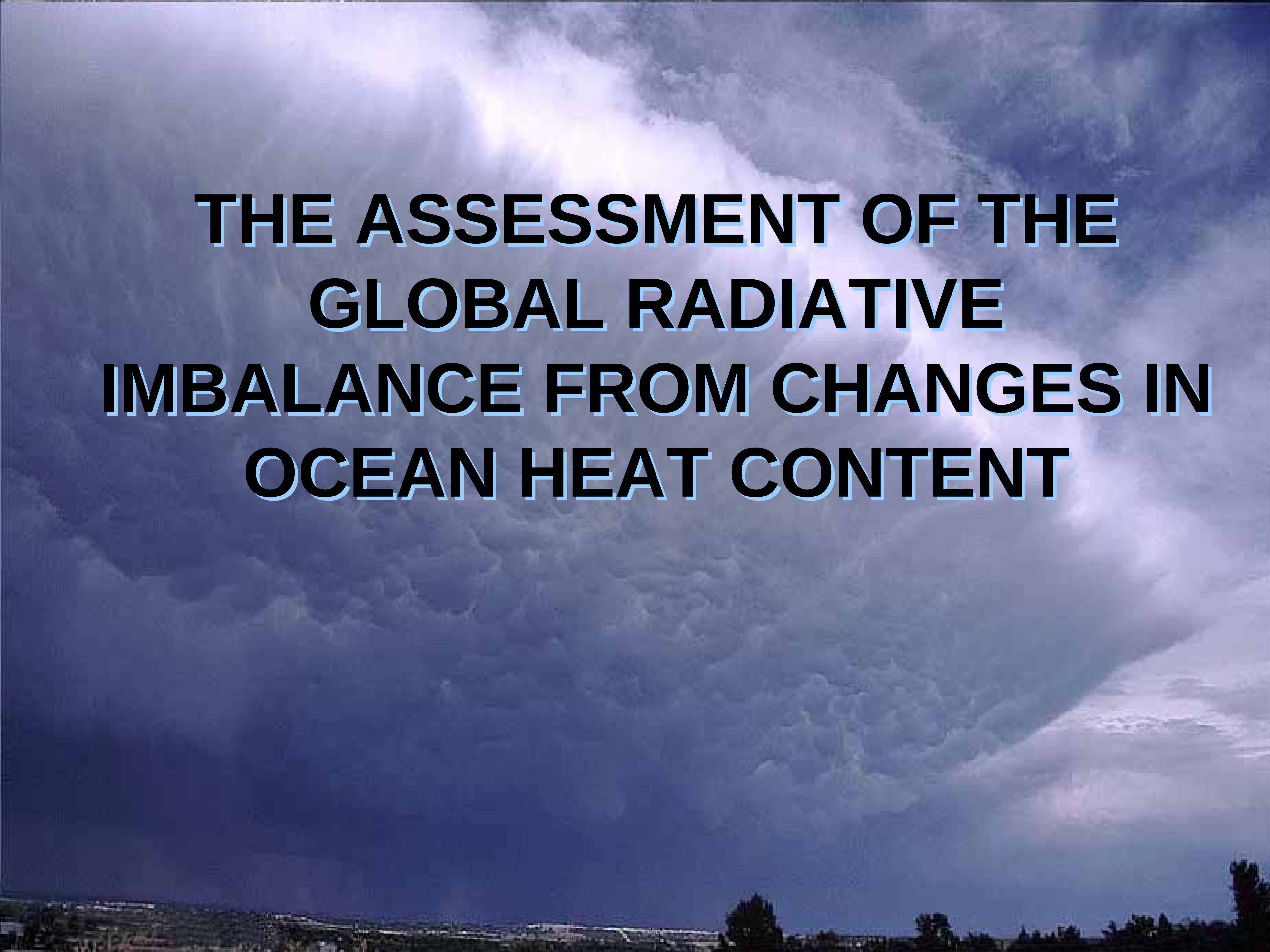
THE ASSESSMENT OF THE GLOBAL RADIATIVE IMBALANCE FROM CHANGES IN OCEAN HEAT CONTENT



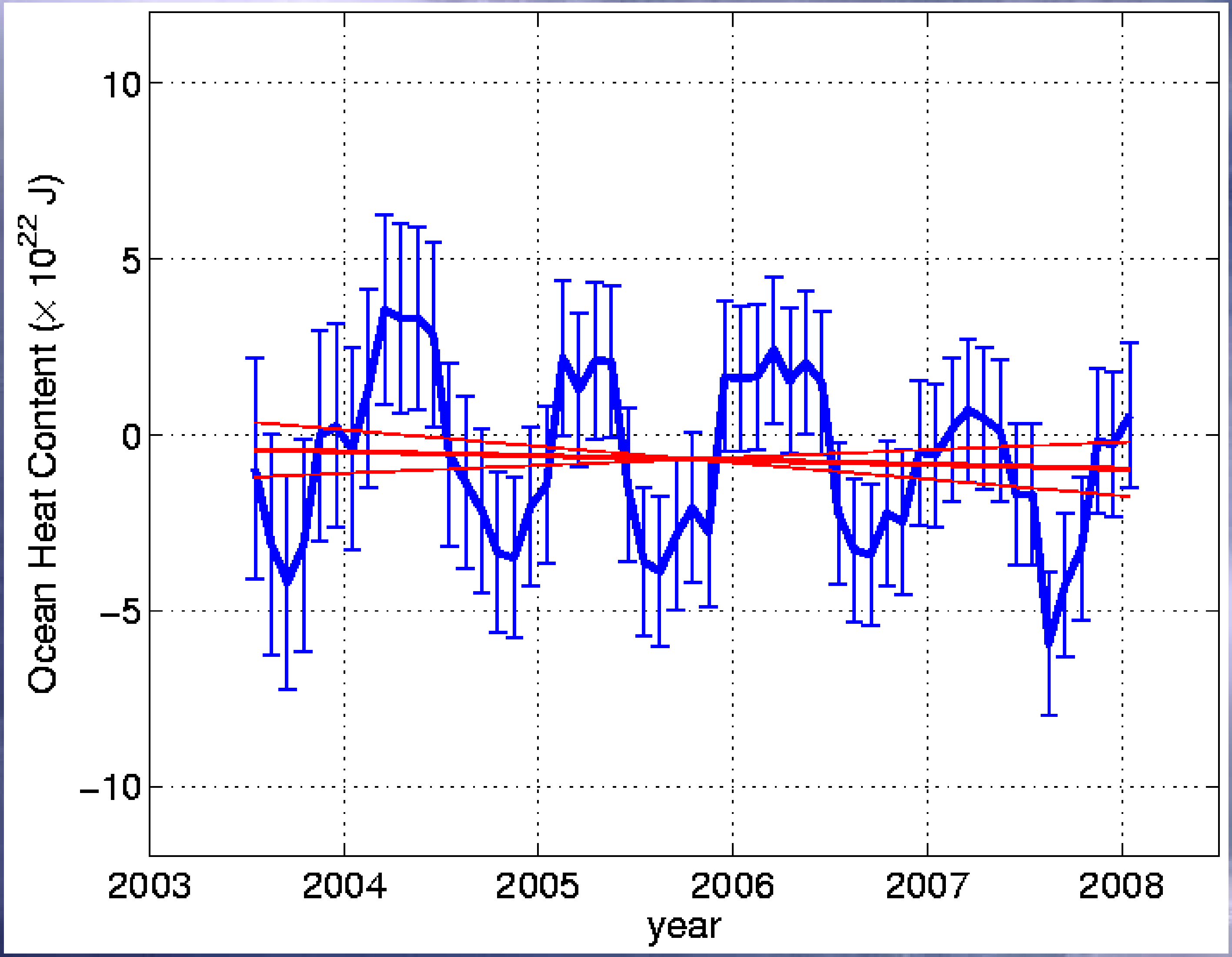


Figure 1: Four-year rate of the global upper 700 m of ocean heat changes in Joules at monthly time intervals. One standard error value is also shown. (Figure courtesy of Josh Willis of NASA's Jet Propulsion Laboratory).

Global Radiative Forcing

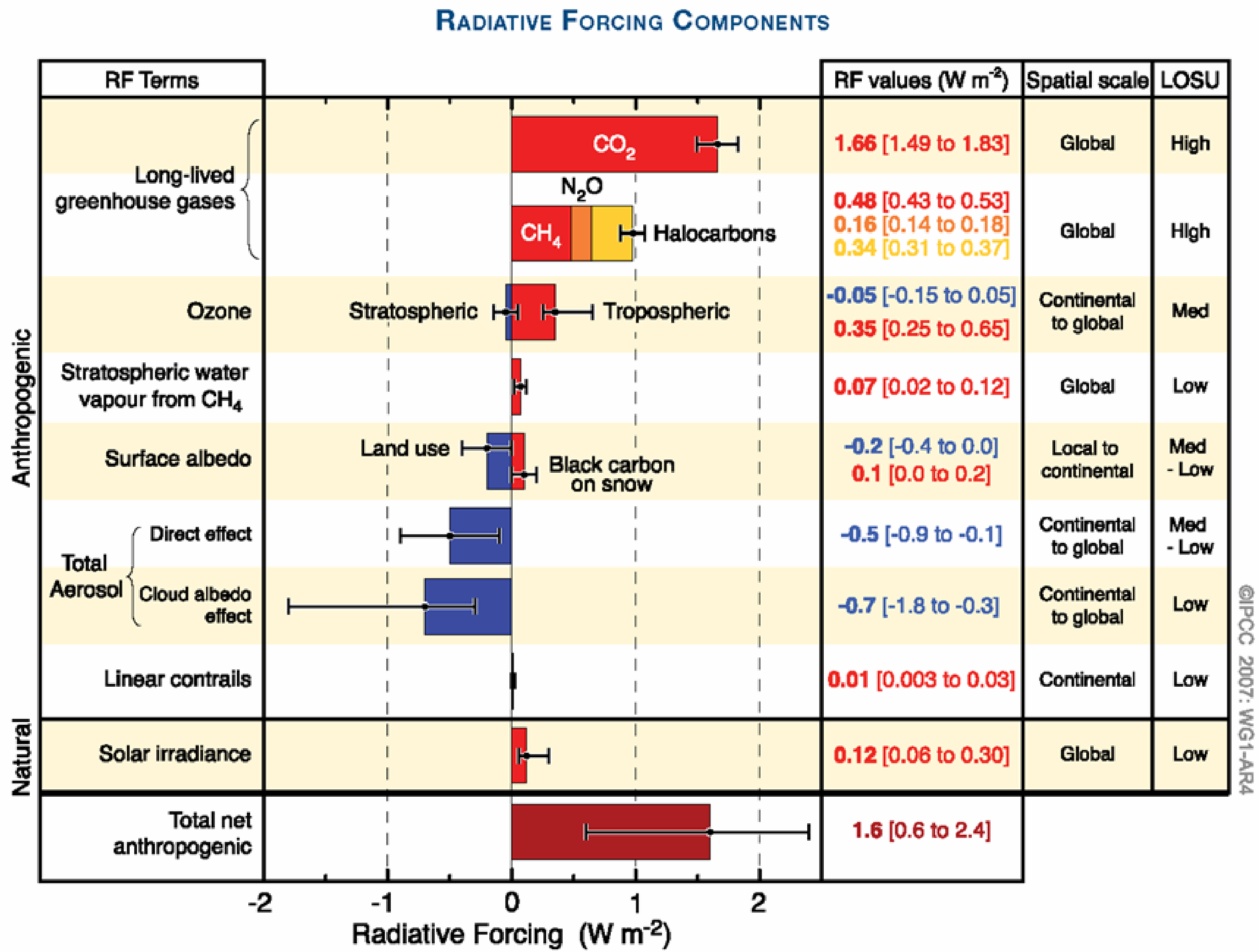


Figure SPM.2. *Global average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. The range for linear contrails does not include other possible effects of aviation on cloudiness. {2.9, Figure 2.20}*

2007 IPCC Total Radiative Forcing = 1.72 (0.66 to 2.7) Watts per meter squared

Best Estimate of Total Radiative Imbalance (1993-2005) = 0.33 (0.10 to 0.56) Watts per meter squared

If the IPCC Forcing is accepted as the current forcing, than the net global radiative feedbacks are negative!

IN CONCLUSION

1. Solar forcing is spatially and temporally distributed across the Earth.

2. Natural and human effects alter the spatial and temporal distribution of this solar forcing.

3. The diabatic heating pattern that results is a major control on the weather at all time periods.

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Background Photograph Courtesy of Mike Hollingshead

http://www.extremeinstability.com/index.htm