

Climate Change

A personal journey into the science and its solutions

Journey into Science & Solutions

TANG Laureate Lecture

Howard Civil Service International House, Taipei
Sept. 22, 2018



Veerabhadran Ramanathan
Scripps Institution of Oceanography
University of California at San Diego

2-4, November 2017. Vatican City

The Pontifical Academy of Sciences



**HEALTH OF PEOPLE, HEALTH OF PLANET
AND OUR RESPONSIBILITY CLIMATE
CHANGE, AIR POLLUTION AND HEALTH**



With unchecked climate change and air pollution, the very fabric of life on Earth, including that of humans, is at grave risk.

Veerabhadran Ramanathan (PAS & UCSD) Monsignor Marcelo Sánchez Sorondo (PAS Chancellor) Partha Dasgupta (PASS & CU) Peter Raven (PAS & MBC) Joachim von Braun (PAS President & UOB) Jeffrey Sachs (UN SDSN) *

Signed by: Stephen Hawking; Gov Jerry Brown; Nobel laureates; 14+ mayors



Climate Extremes and Global Health

New Ways to Make Progress

By Veerabhadran Ramanathan, Marcelo Sanchez Sorondo, Partha Dasgupta, Joachim von Braun, and David G. Victor

the evidence is mounting that climate change will have an extreme impact on human health into the near future.

.....can have widespread impacts on mental health

Journey Begins: Village in South India



*Next to Grand Father's Home (Eraharam, Kumbakonam)
Photo: 2004; Ramanathan*

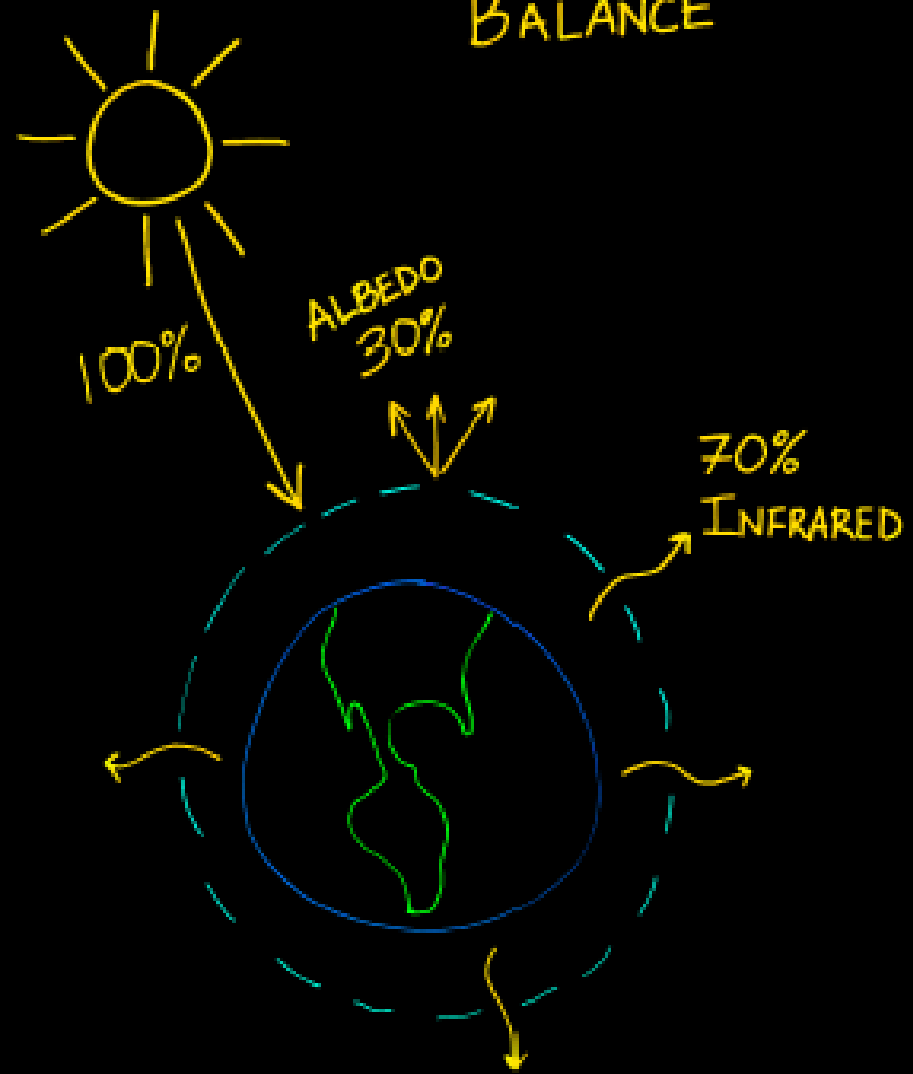


1970: In Pursuit of The IMPALA Dream

Pursuing Chevy Impala to the pursuit of the Common Good.

Mayors Summit, Vatican, July 21 2015

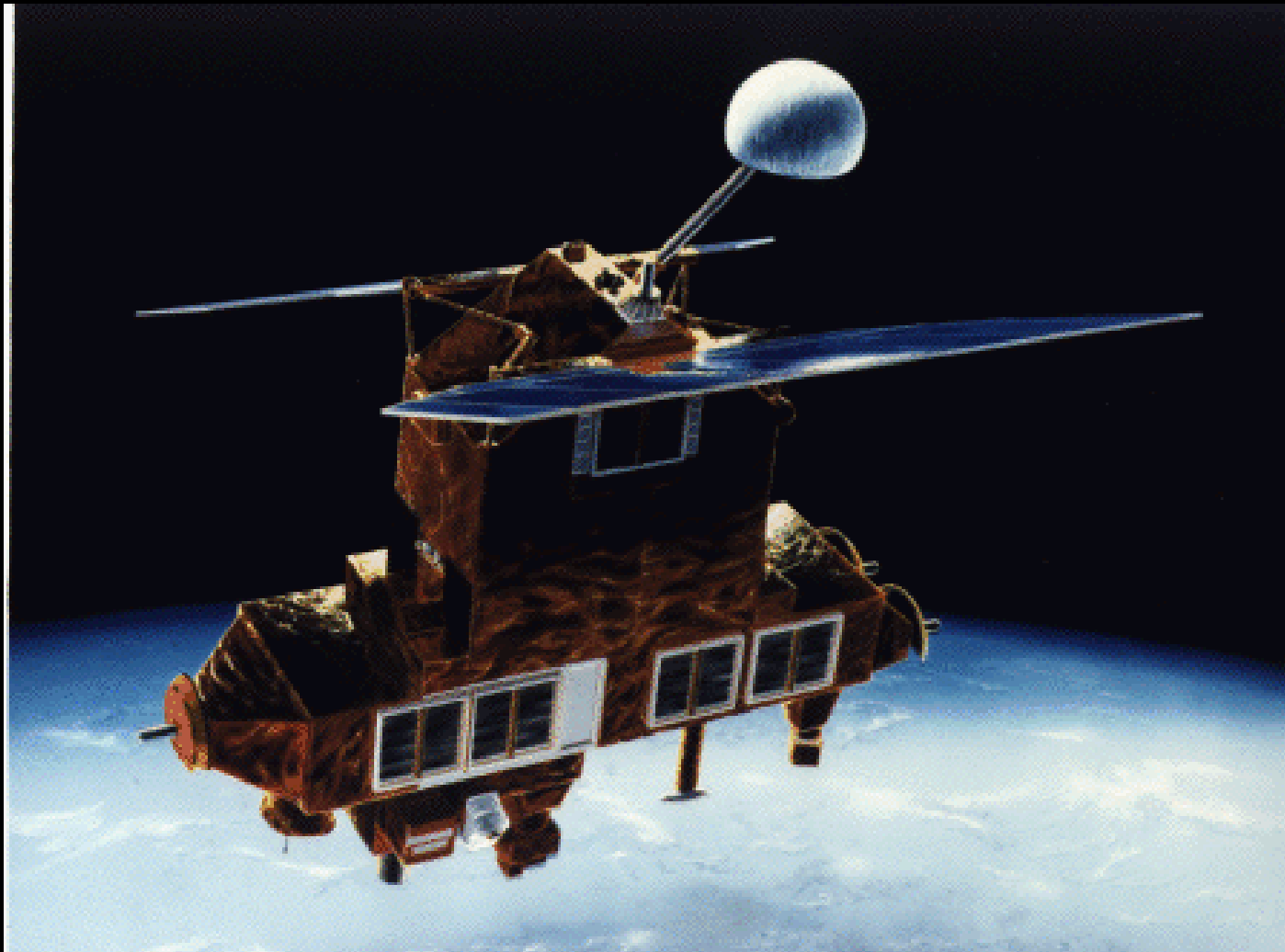
GLOBAL ENERGY BALANCE



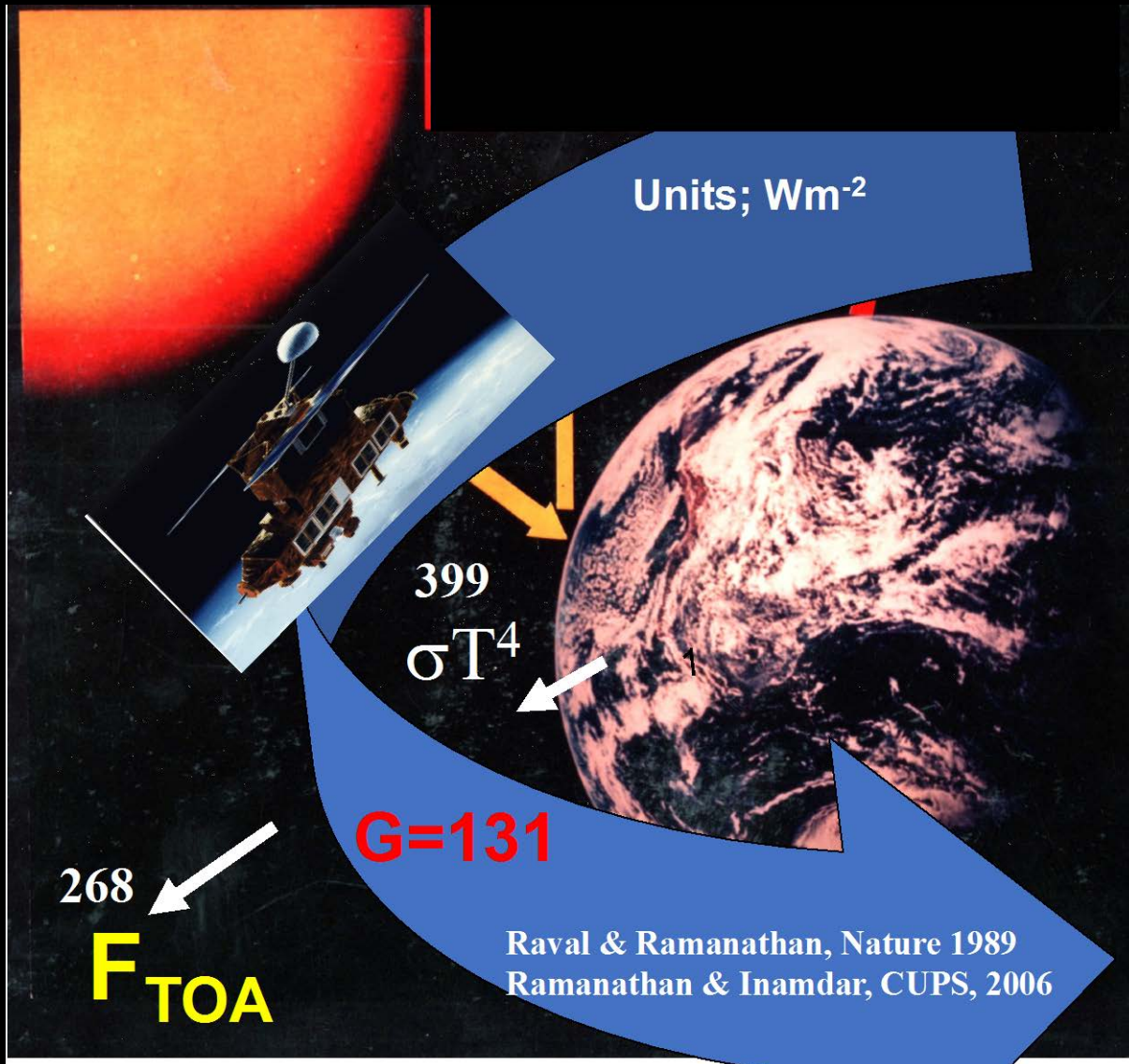
Climate Satellite: Earth Radiation Budget Experiment

Ramanathan, Barkstorm and Harrison, Physics Today, 1989

1975: Led a NASA study to determine the role of clouds & climate feedbacks



Direct Observations of the Greenhouse Effect



Blanket Thicknes:
 $131 Wm^{-2}$

Manmade Blanket
Thickness:
 $3 Wm^{-2}$

Raval & Ramanathan, Nature 1989
Ramanathan & Inamdar, CUPS, 2006

Carbon Dioxide Blanketing the Earth

How much climate pollution is in this thin shell?



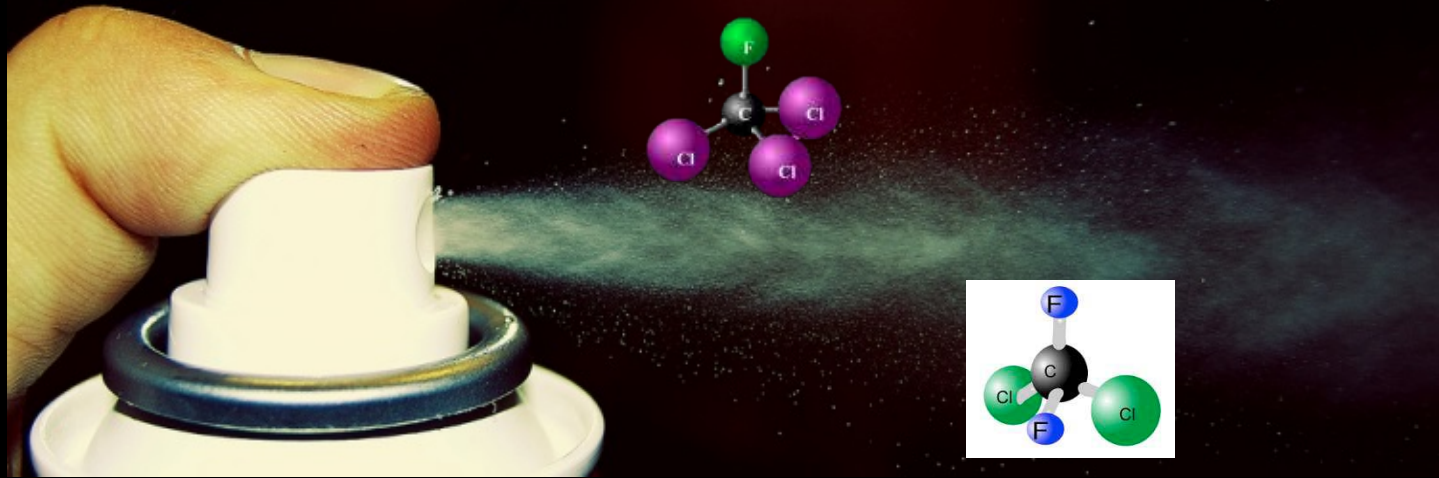
*Atmosphere:
A Thin Fragile Shell*

Added 2,000,000,000,000 tons of CO₂ Since 1750

Greenhouse Effect Due to Chlorofluorocarbons: Climatic Implications

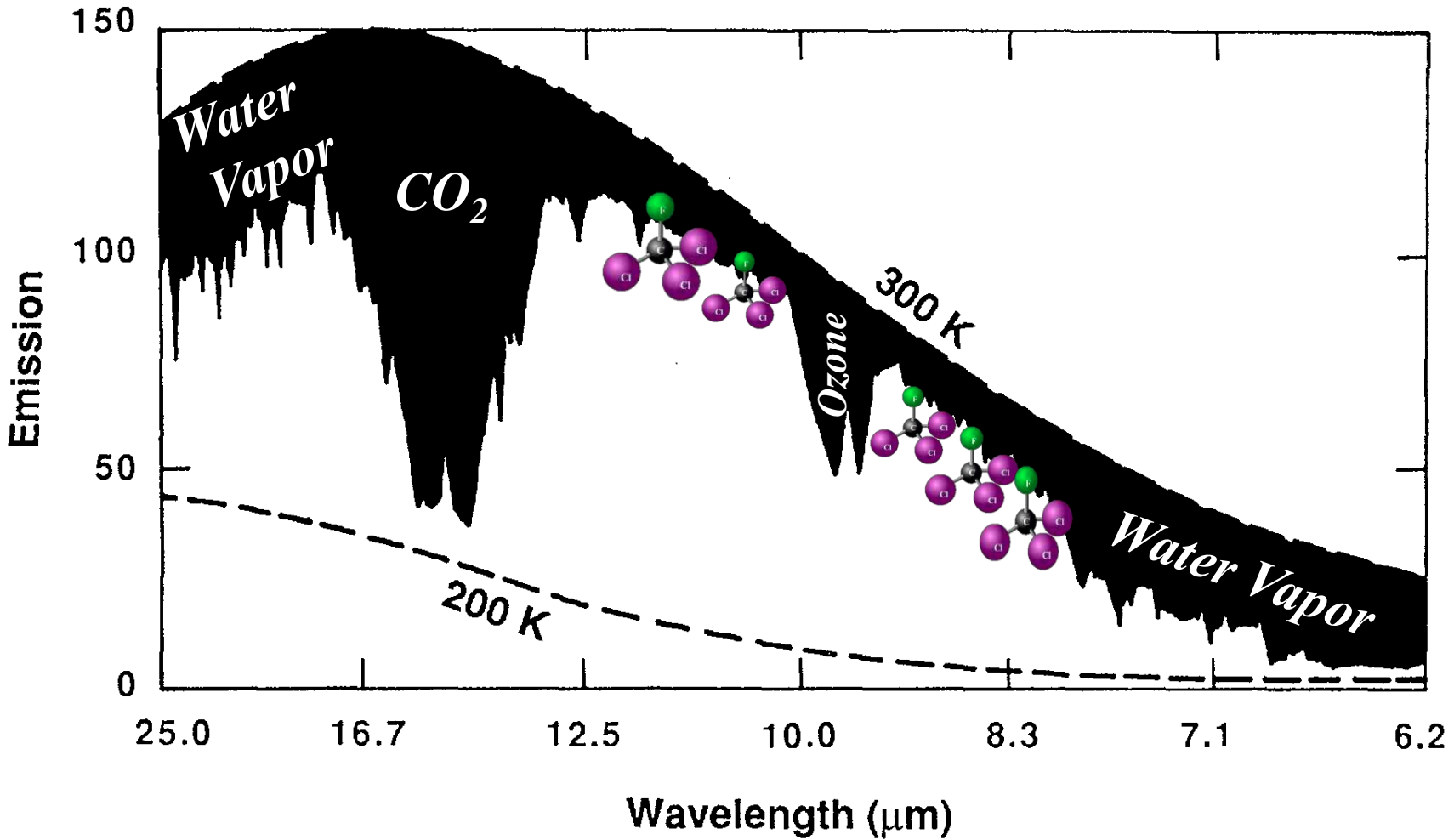
V. Ramanathan

Science, 1975



1975 discovery of Halocarbons as Super-greenhouse gases put Non-CO₂ greenhouse gases on par with CO₂

CFCs [Super Pollutants]: Per ton, 10,000 times more potent than CO2



Indian Ocean Experiment

(1997 to 1999)

PIs: Ramanathan, Crutzen, Mitra & Lelieveld.

The Indian Ocean Experiment (INDOEX), an international field experiment, has been collecting data since 1996, featuring an intensive field campaign conducted in Spring 1999. For details, see <http://www-indoex.ucsd.edu>.



Participating Institutions

Austria

Universität Innsbruck

Canada

York University, Toronto

Europe

Airborne Platform for Earth Observation

(Geophysica, Falcon)

European Organisation for the Exploitation of

Meteorological Satellites (Meteosat-5)

France

Laboratoire d'Optique Atmosphérique

Laboratoire de Météorologie Dynamique du CNRS

Laboratoire de Météorologie Physique,

Université Blaise Pascal

Laboratoire des Sciences du Climat et de

l'Environnement, CEA-CNRS

Laboratoire Interuniversitaire des Systèmes

Atmosphériques

Service d'Aéronomie

Germany

Forschungszentrum Jülich

GKSS-Forschungszentrum Geesthacht

Institut für Troposphärenforschung

Max Planck Institut für Chemie

Max Planck Institut für Kernphysik

Max Planck Institut für Meteorologie

Meteorologisches Institut der Universität Hamburg

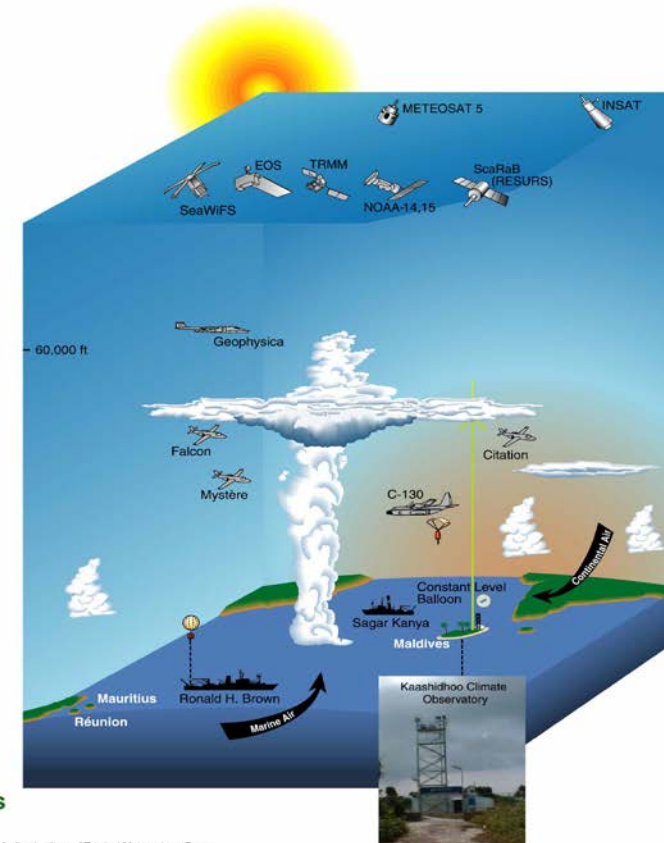
Universität Bremen

India

Antartic Study Centre, Vasco-da-Gama

Indian Institute of Science, Bangalore

Indian Institute of Technology, New Delhi



United States

Center for Clouds, Chemistry and Climate

Arizona State University, Tempe

Atmospheric Research Laboratory

Colorado University, Boulder

Desert Research Institute

Florida State University, Tallahassee

NASA - Goddard Space Flight Center

National Center for Atmospheric Research

NOAA - Atlantic Oceanographic and

Meteorological Laboratory

NOAA - Climate Monitoring and Diagnostics Lab

NOAA - Pacific Marine Environmental Laboratory

North Carolina State University, Raleigh

Oregon State University, Corvallis

Pennsylvania State University, University Park

Scopus Institution of Oceanography

SeaSpace Corporation

University Corporation for Atmospheric Research

University of Alaska, Fairbanks

University of California, Irvine

University of California, Riverside

University of California, San Diego

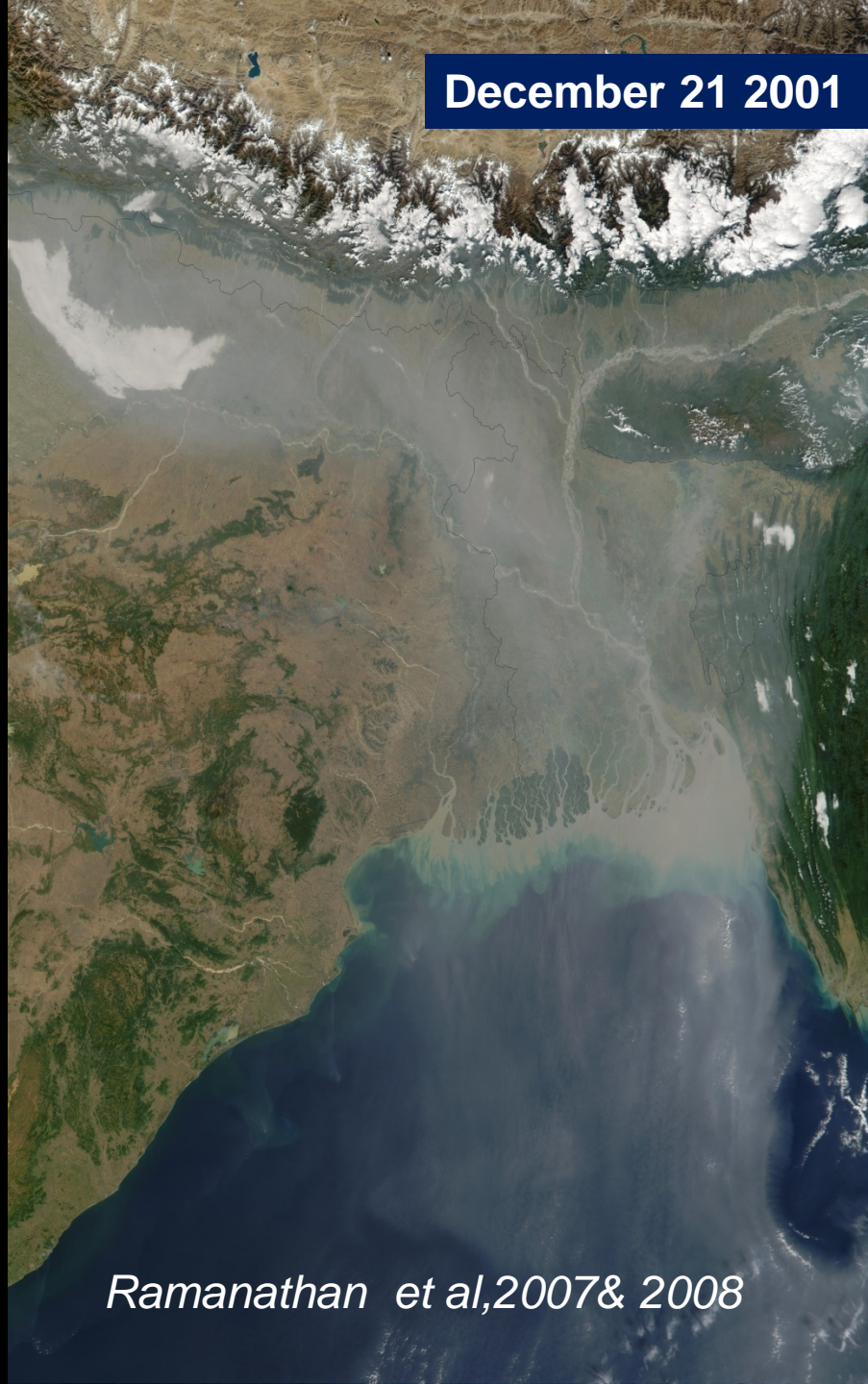
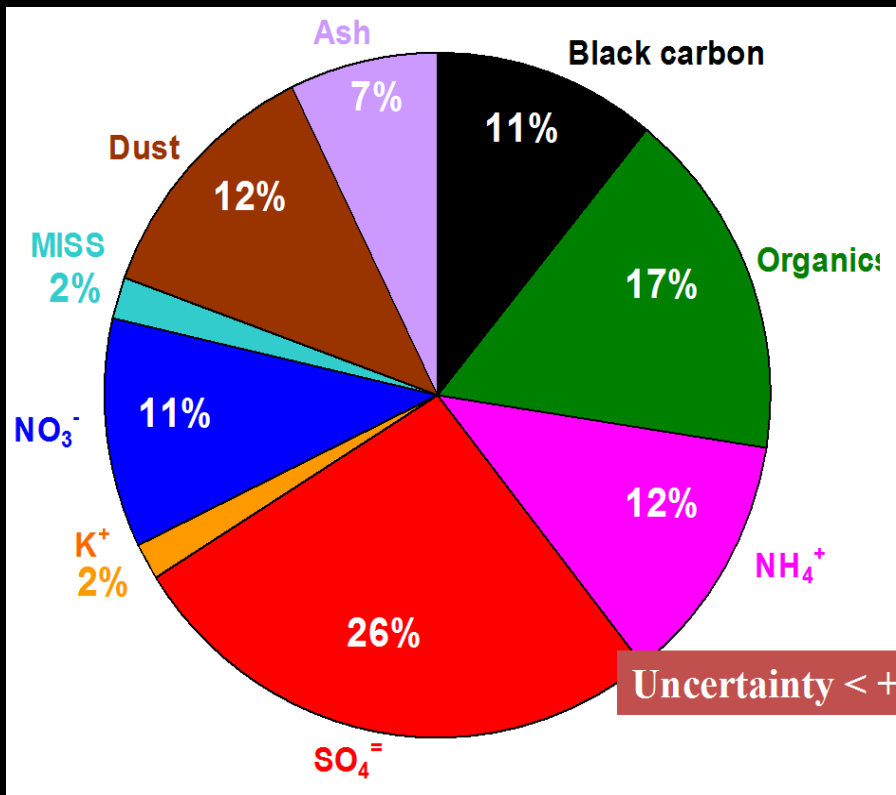
University of Hawaii, Manoa

University of Maryland, College Park

University of Miami

University of Washington, Seattle

December 21 2001



NASA-MODIS

Ramanathan et al, 2007 & 2008

2 August 2007 | www.nature.com/nature | \$10

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE

nature



**TRAUMATIC
BRAIN INJURY**
Consciousness
raising therapy

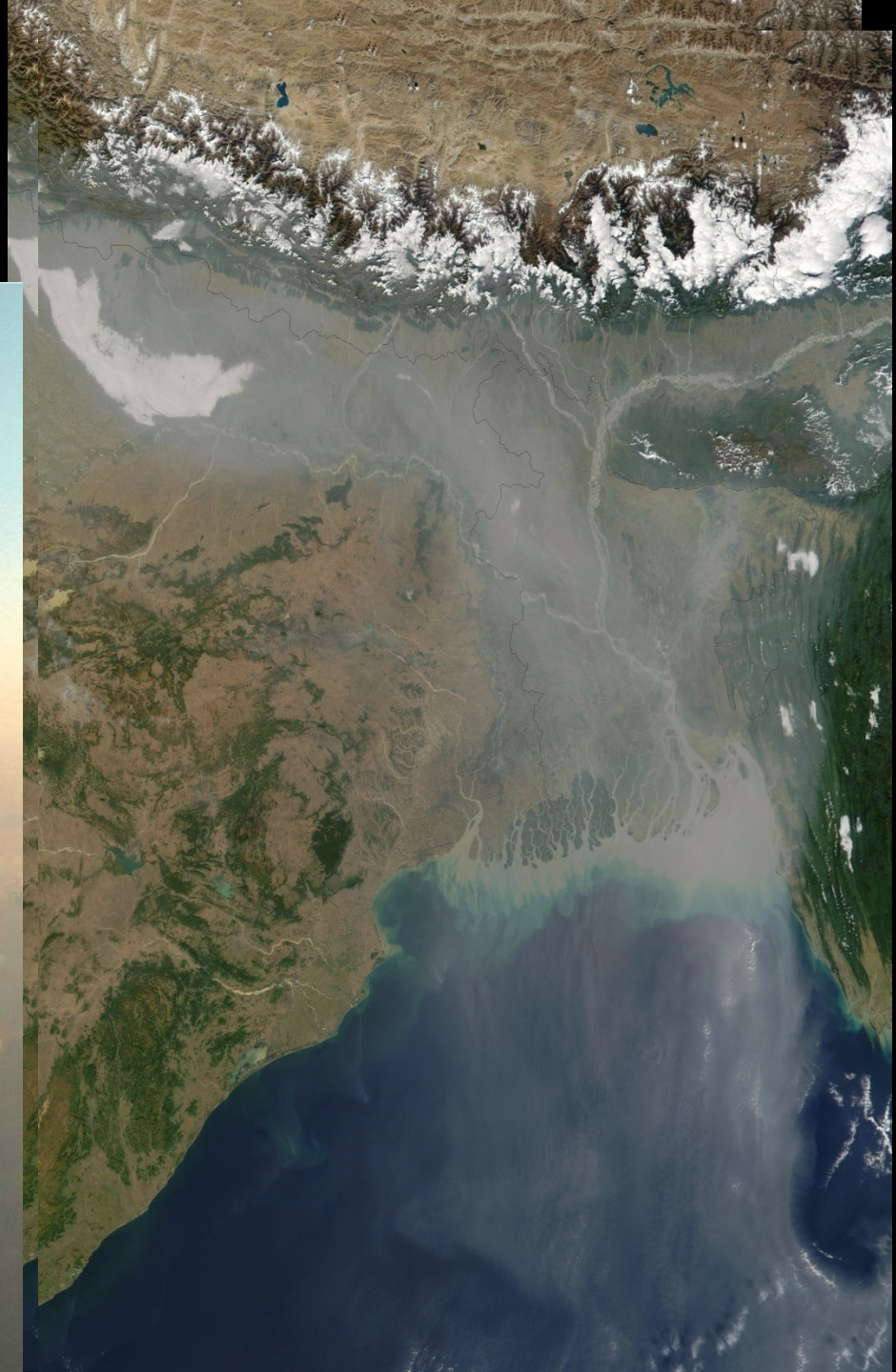
**VERTEBRATE
ORIGINS**
Gone fishing

**EATING IN THE
GREENHOUSE**
Are high-CO₂
crops bad for you?



THE HEAT IS ON

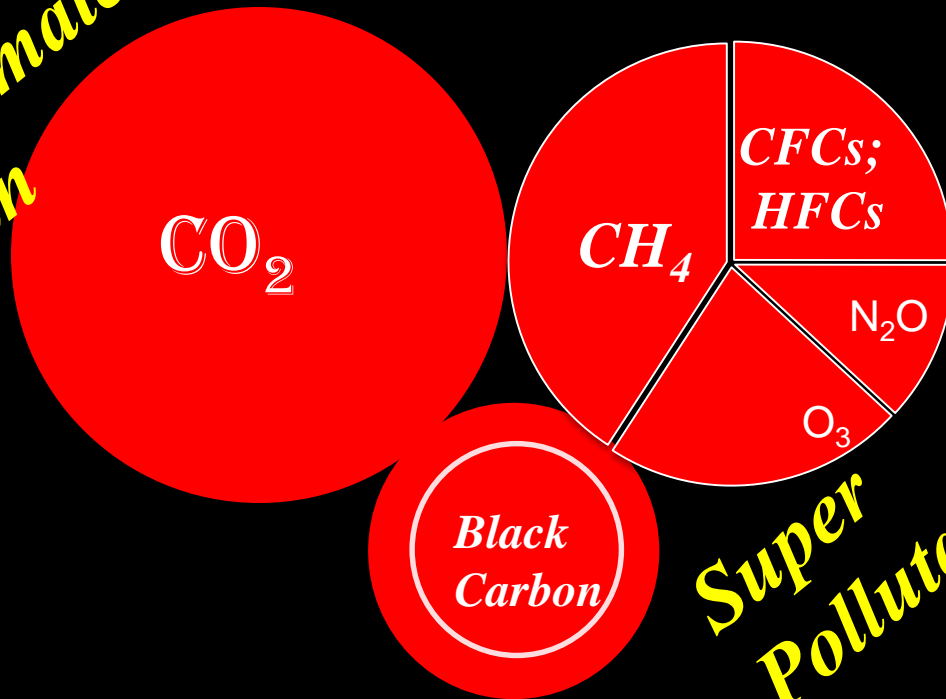
Atmospheric brown
clouds enhance
climate warming



Climate Change Pollutants

Trapped Heat by the blanket

The Climate Villain



Super Pollutants

Data from: IPCC 2007; Ramanathan and Feng, 2008 & Ram and Xu, 2010

Super Pollutants

*Criteria: At least an order of magnitude more potent than
Carbon dioxide*

Super Pollutants: Short-Lived (<15 Yrs)

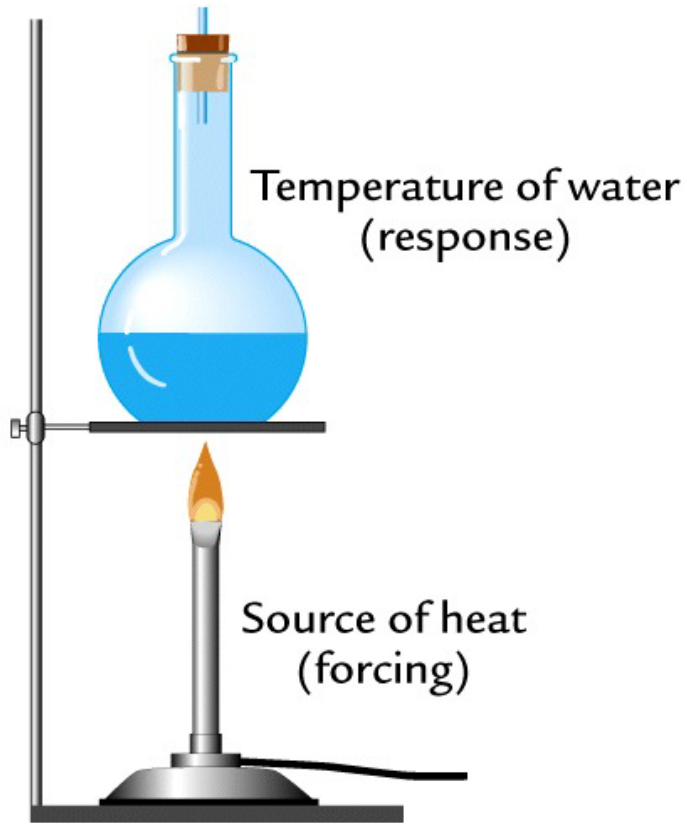
Methane; Black Carbon; Ozone-Troposphere; HFCs

Super Pollutants: Long-Lived (>15 Yrs)

Nitrous Oxide; CFCs

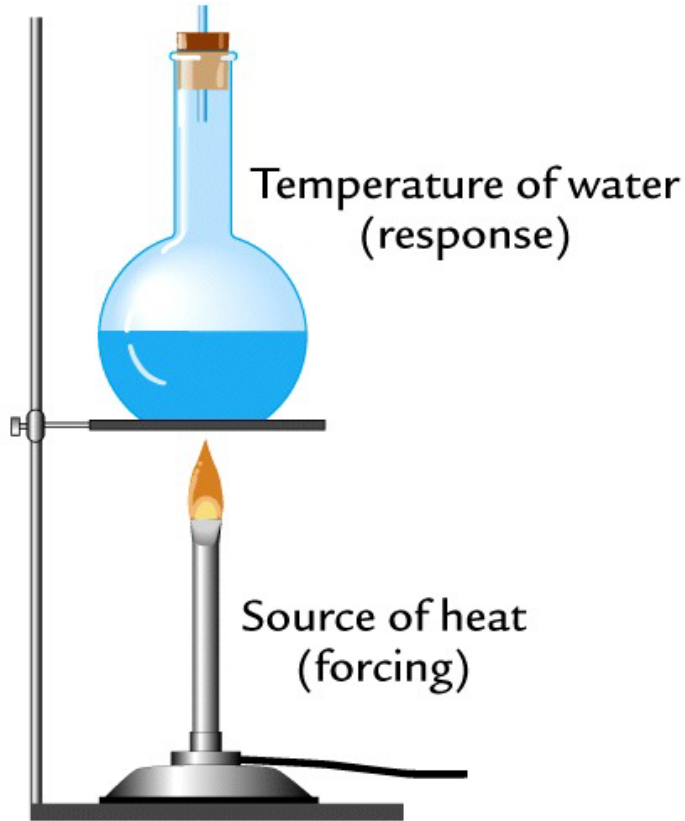
*Super Pollutants contribute about 50%(+/-10%) to
the current warming of planet*

Arrhenius' (1895) Water Vapor Feedback



Arrhenius' (1895) Water Vapor Feedback

Temp Dependence Of Vapor Pressure



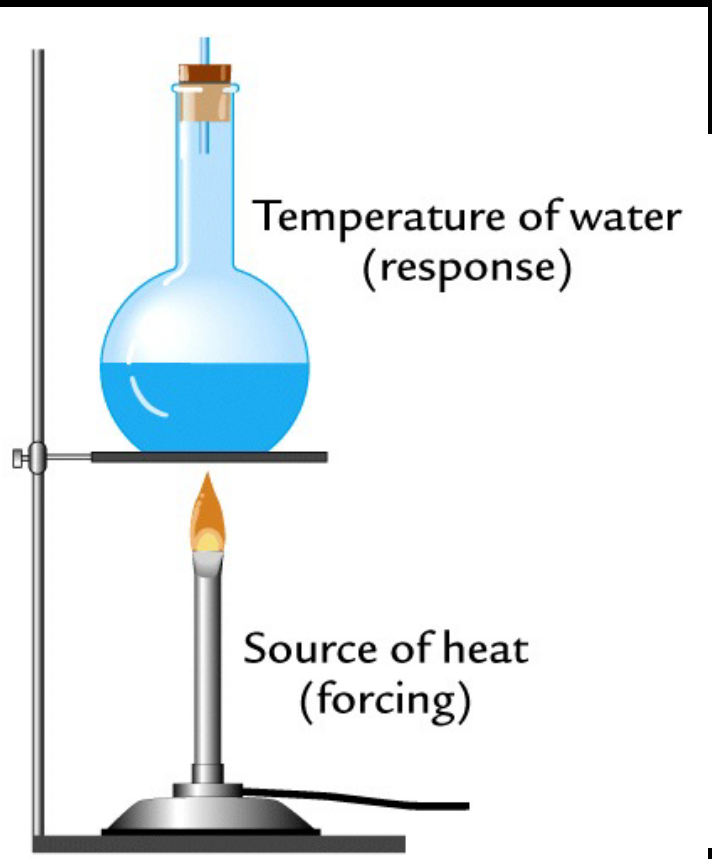
$$e_s : e^{-5400/T}$$

$$\frac{d \ln e_s}{dT} = \frac{5400}{T^2} \approx 0.06$$

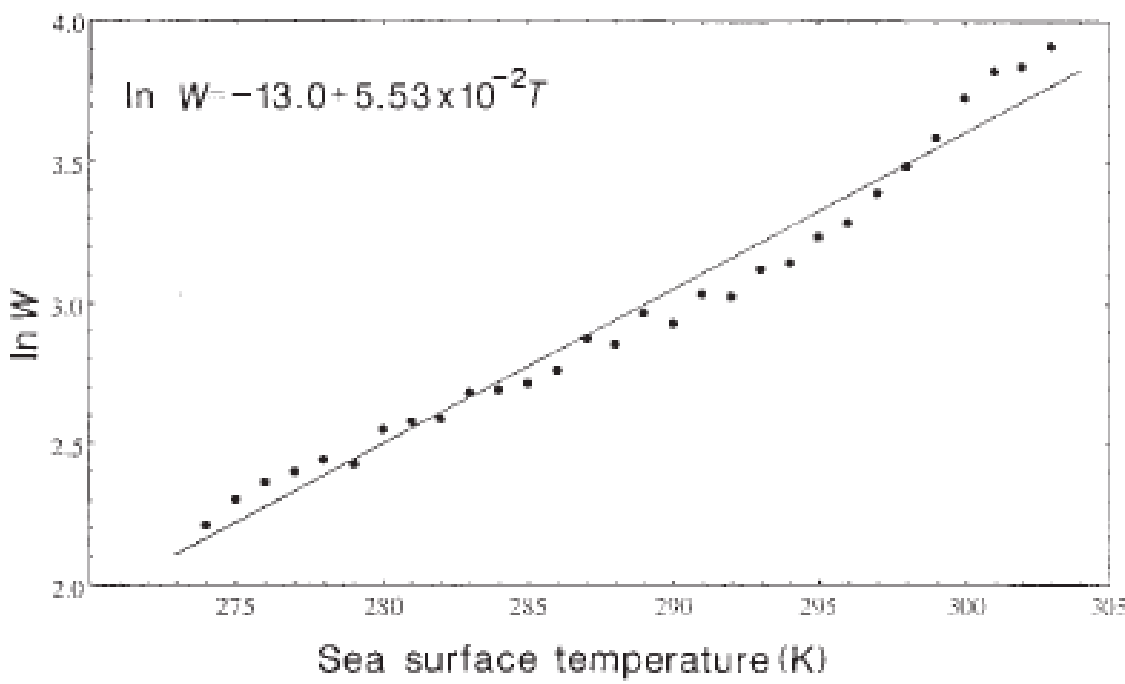
Empirical Evidence Supports The feedback.

Why is Climate Change such a big deal?

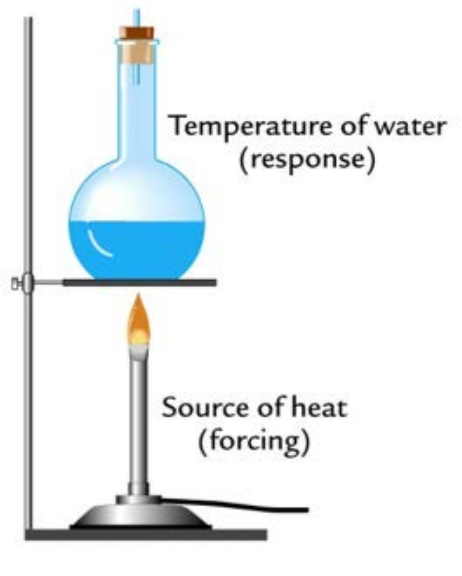
Amplifying Feedbacks: Water Vapor Feedback



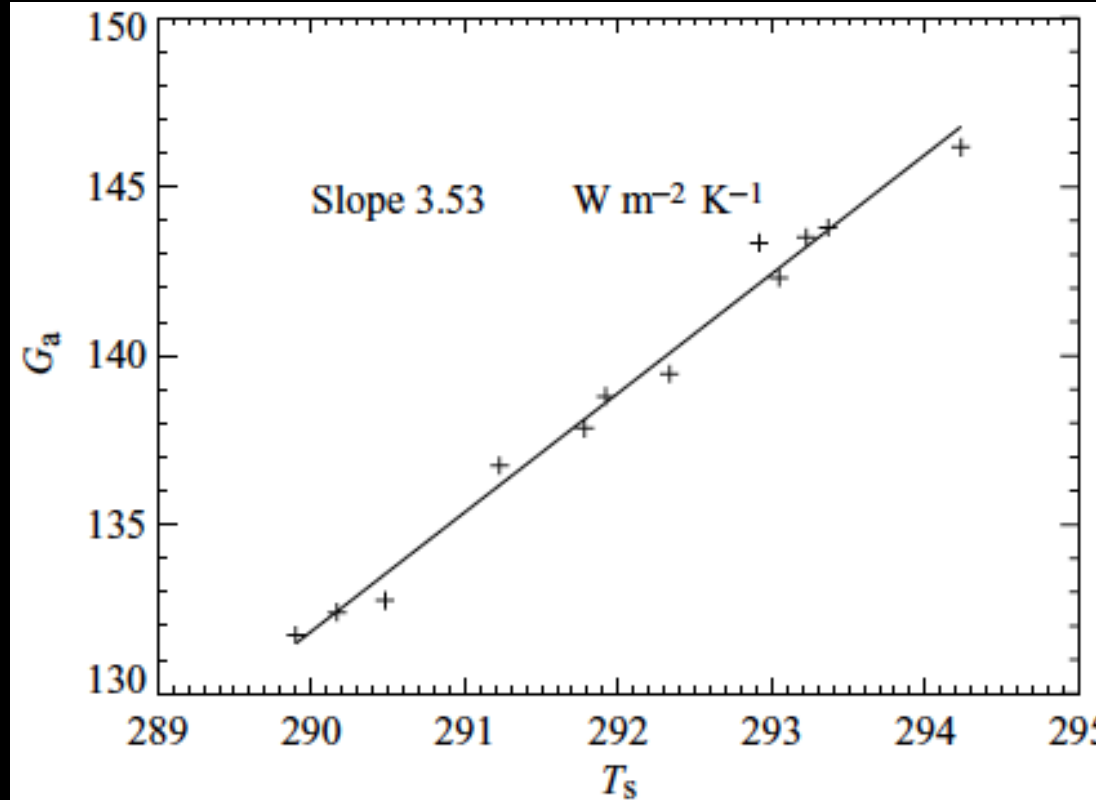
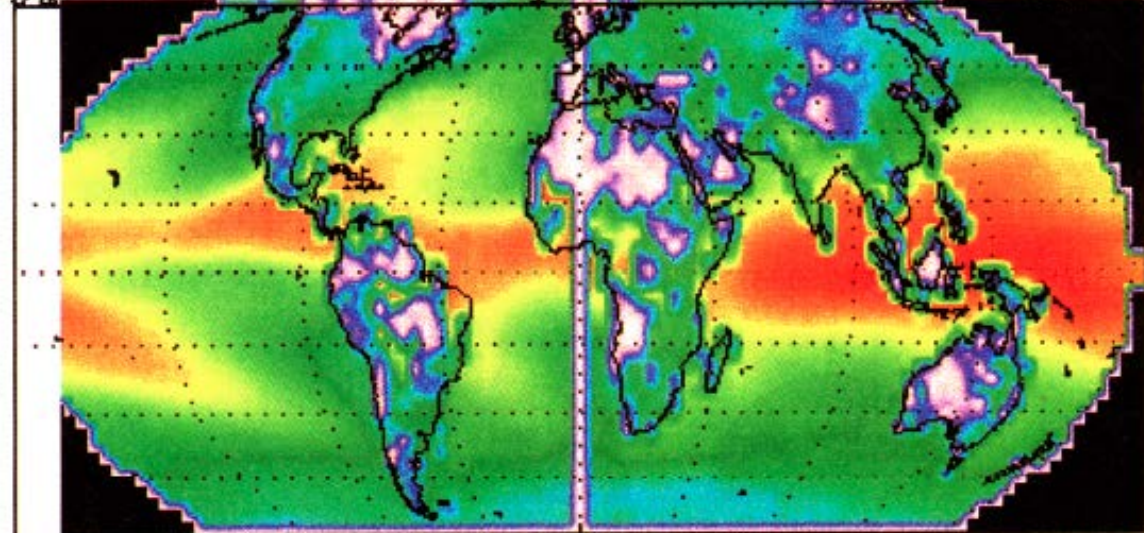
Water vapor data from microwave satellite



Raval and Ramanathan, 1989



g_a : Normalized Atmospheric Greenhouse Effect



$$\beta = 4\sigma(T_s)^3 - dG_a/dT_s$$

$$= 1.9 Wm^{-2}K^{-1}$$

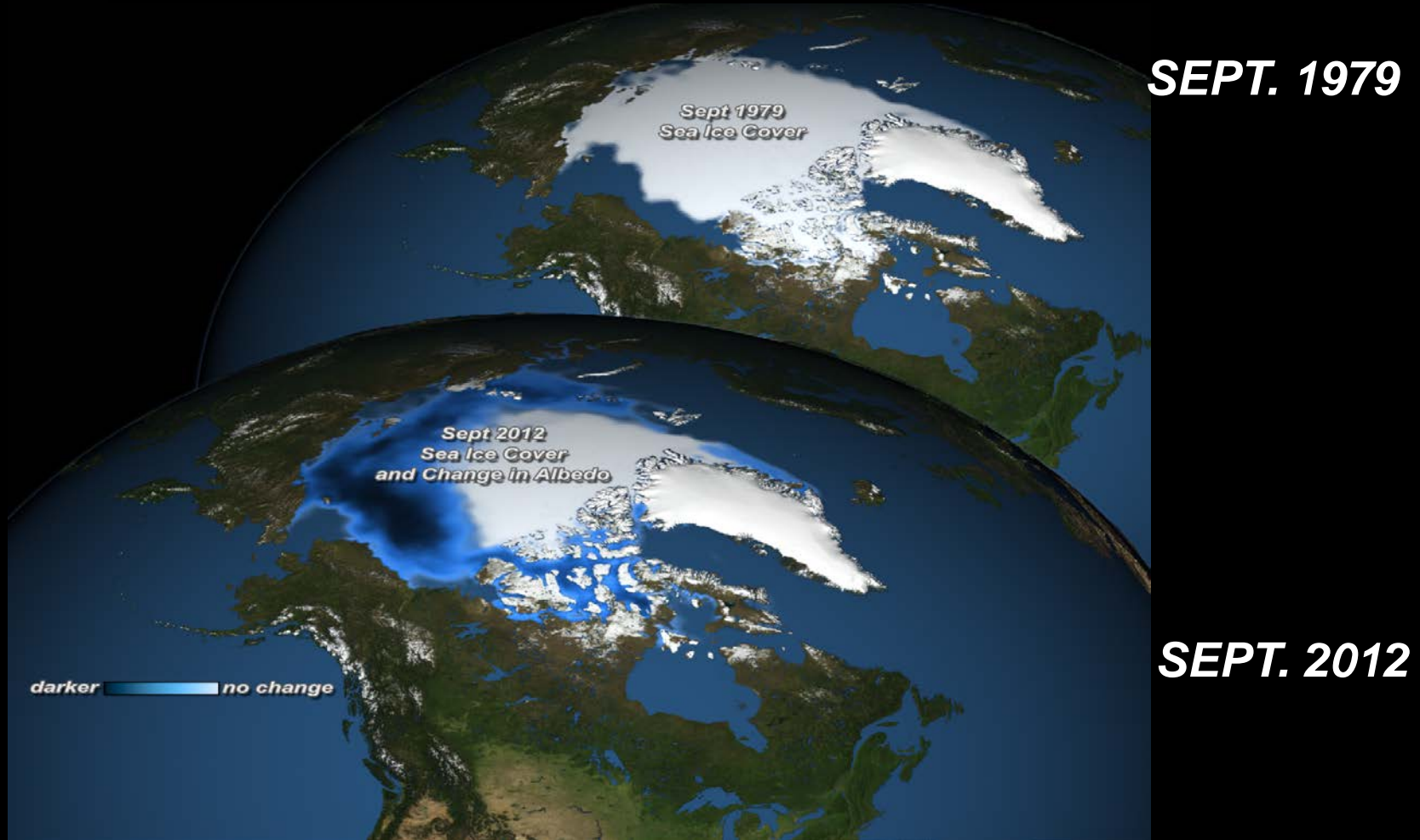
Inamdar & Ramanathan, 1991

Alaska: June 27, 2018



Sea Ice Feedback: Direct Satellite Observations

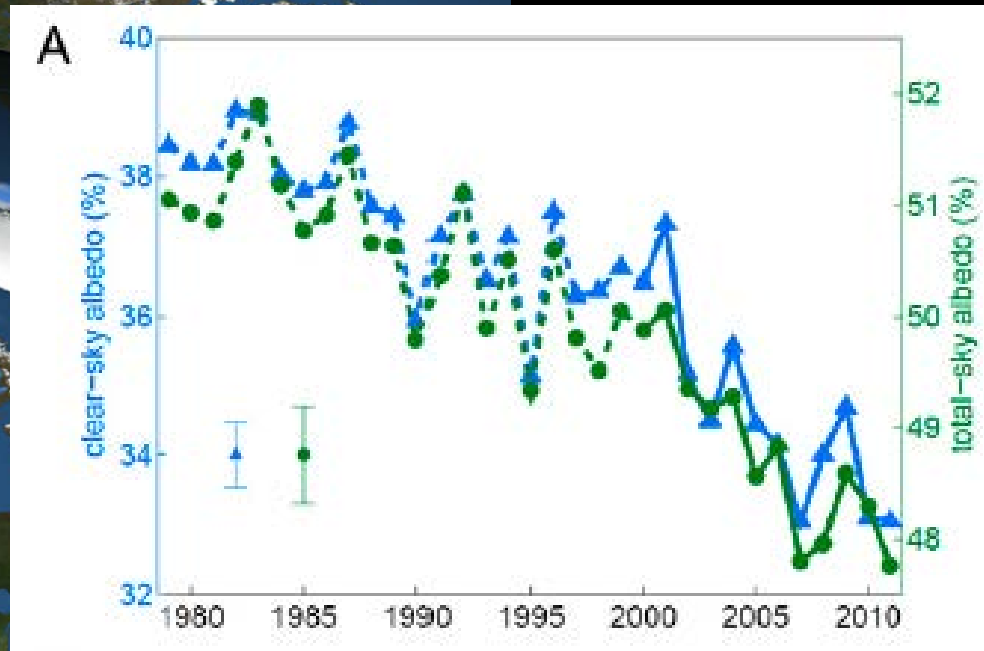
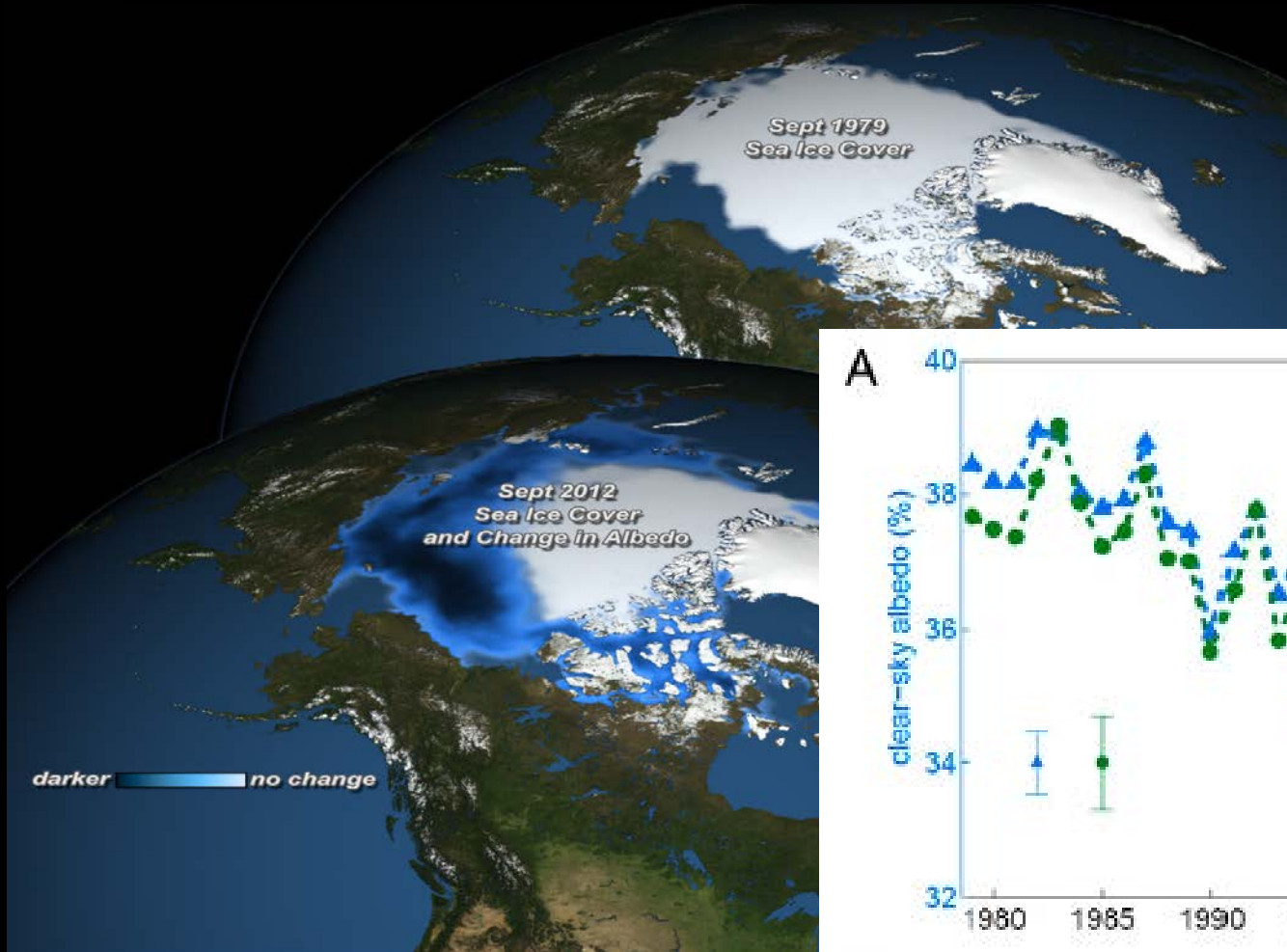
Retreating ice increases arctic solar warming



Pistone, Eisenman, Ramanathan, PNAS, 2014

Sea Ice Feedback: Direct Satellite Observations

Retreating ice increases arctic solar warming



Pistone, Eisenman, Ramanathan, PNAS, 2014

Judging a Theory by its Predictions

SCIENCE

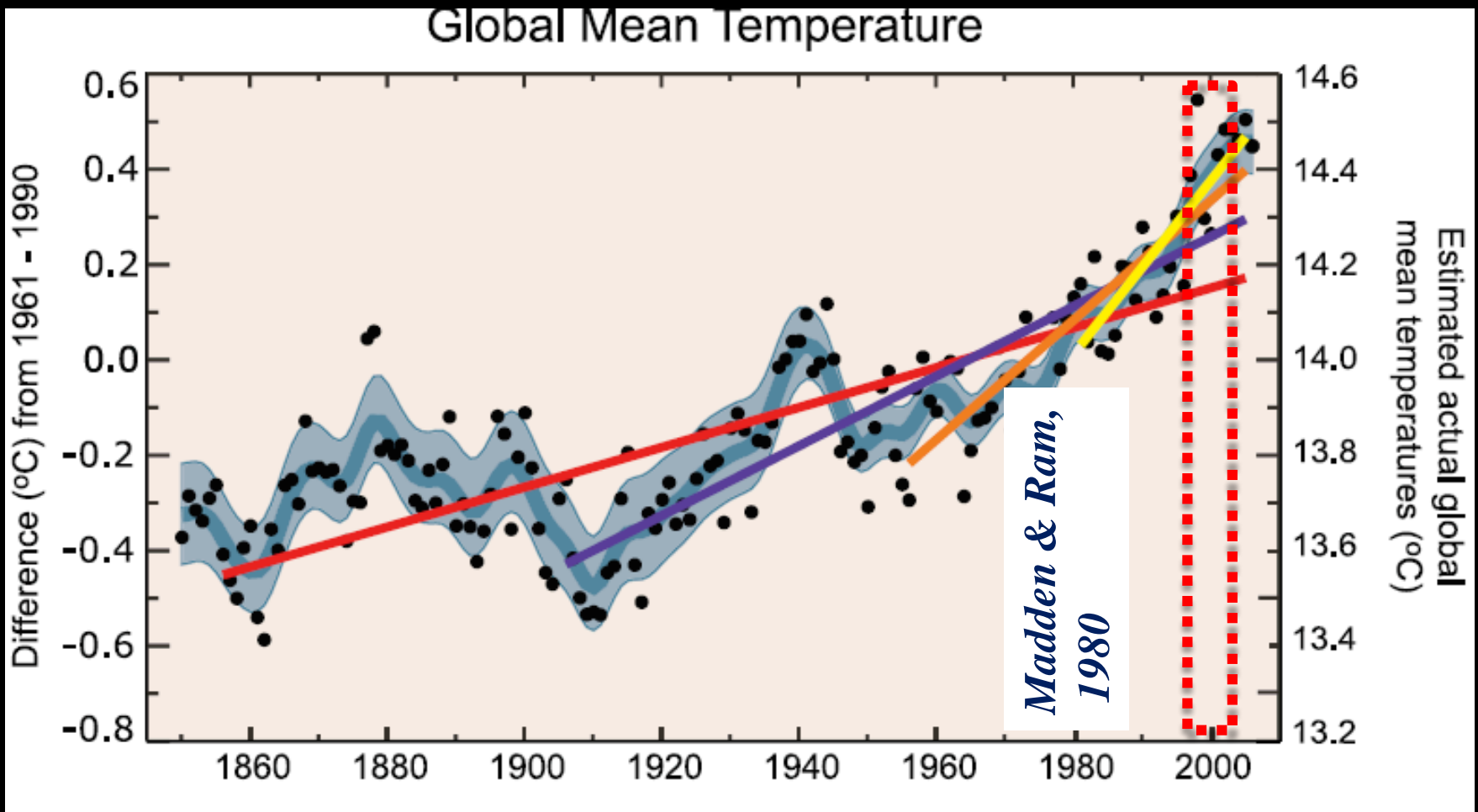
15 AUGUST 1980

Prediction

*Warming Due To CO₂ Should Be Detectable By
Year 2000*

Verification of the 1980 prediction

"Unequivocal" Warming of the Planet: IPCC, 2001 & 2007



BENDING THE CURVE

EXECUTIVE SUMMARY

Ten scalable solutions for carbon neutrality and climate stability

2010



2Tt

1.5°C
2030s



3Tt

2°C
2050s



*Crossing
Thresholds*

1.5°C before 2030

2°C before 2050

2°C World: Impacts

- *1.5 Billion Exposed to Deadly Heat*
- *600 million exposed to vector borne diseases*
- *Severe wide spread droughts and water shortages*
- *Mass Displacement & Migration*
- *Mora et al; Lelieveld et al; Cook et al,2014; Forman and Ramanathan, 2018*

*Because of coupled non-linear feedbacks,
5% probability of exceeding 3°C by 2050.*

Xu and Ramanathan,2017

From Science to Solutions

BOTTOM THREE BILLION
Forced by Poverty to Rely On 18th Century Technologies



The 3 Billion Contribute Only About 5% of CO₂ emissions

The Pontifical Academy of Sciences (2004).



..... International In Scope, Multi-racial In Composition, And Non-sectarian In Its Choice Of Members.

BENDING THE CURVE

EXECUTIVE SUMMARY

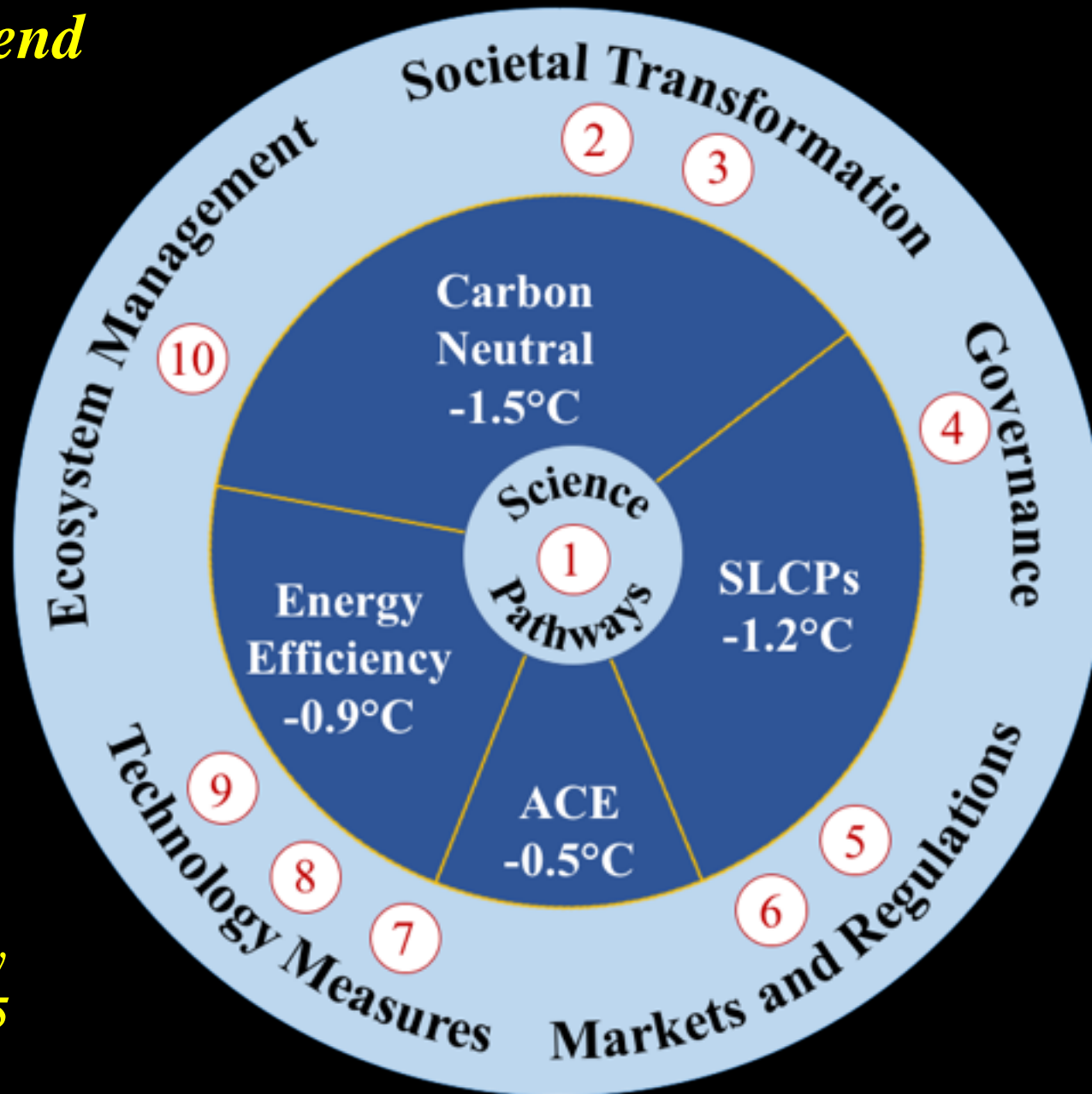
Ten scalable solutions for carbon
neutrality and climate stability

Carbon Neutrality Initiative of The University Of California

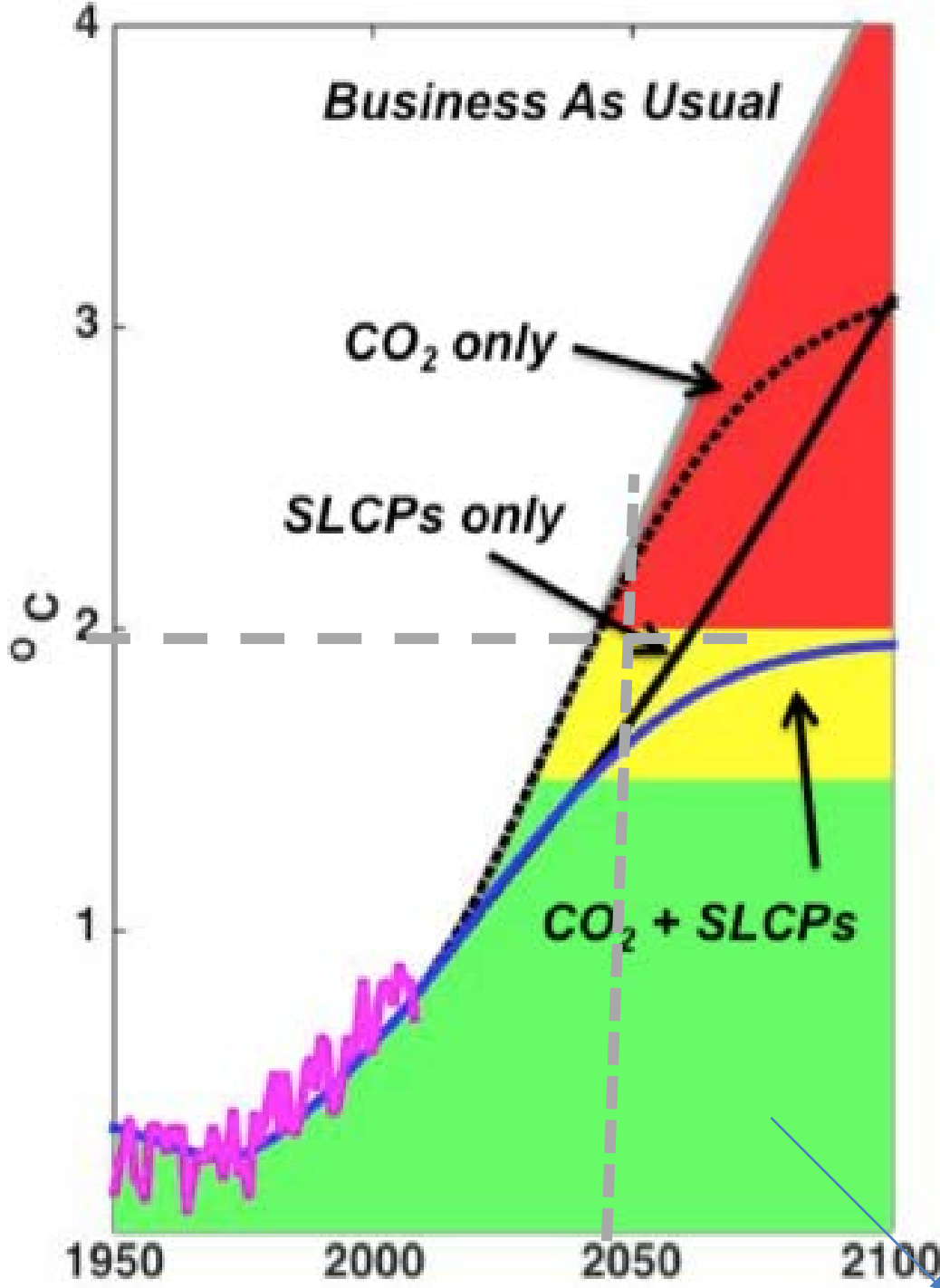
UC- Fifty

*[http://uc-
carbonneutralitysummit
2015.ucsd.edu/_files/Be
nding-the-Curve.pdf](http://uc-carbonneutralitysummit2015.ucsd.edu/_files/Bending-the-Curve.pdf)*

Six Clusters and Ten Solutions to Bend The Curve



*Ramanathan & 50 faculty
from Univ California, 2015*



Mitigation of super Pollutants is a practical and proven measure to:

- *keep the warming well below 2C until at least 2050.*

Adverse Impacts on People

Avoided impacts by reducing warming from 2⁰C to 1.5⁰C

- *Heat Extremes : Exposure reduced by 1.7 billion people ¹*
- *Heavy Precip : Reduces record rainfall by a third ²*
- *Droughts : Exposure reduced by 37% (>250 million people) ^{3,4}*

1) Dosio et al, 2018; 2) Betts et al, 2018; 3) Gerten et al, 2013; 4) Arnell et al, 2018

<http://climateanalytics.org/blog/2018/hot-dry-or-flooded-more-weather-extremes-beyond-1-5c-warming.html>



**CLIMATE &
CLEAN AIR
COALITION**
TO REDUCE SHORT-LIVED
CLIMATE POLLUTANTS

- *67 National & Sub-National Partners*
- *70 non-state partners*



California's SB 1383

*Accelerate emission reductions for all Super Pollutants
(80% for BC; 40% for Methane; 100% for HFCs)*

Societal Transformation



project surya
Fighting Climate Change Now



Rural Women as Climate Warriors



Societal Transformation *UCs Climate Solutions Course*
Education One Million Climate Warriors



We will Provide you the tools to bend the curve

*Societal
Transformation*

*An Alliance Between Science,
Religion & Policy*

July 21, 2015 Summit For City Mayors, Vatican

Why do we need Religions to fight climate change?

Finding ways to develop a sustainable relationship with our planet requires..... ultimately also a moral revolution. Religious institutions can and should take the lead on bringing about such a new attitude towards Creation.

Dasgupta and Ramanathan, SCIENCE, 2014

Omaha, Nebraska.

February 21, 2018



*From pursuing Chevy
Impala to the pursuit of the
Common Good*

Declaration of the Mayors
21 July 2015



*From pursuing Chevy
Impala to the pursuit of the
Common Good*

Declaration of the Mayors
21 July 2015



BENDING THE CURVE

LEADING THE TRANSLATION OF RESEARCH INTO SOLUTIONS



*Chairs:
Houlton & Ramanathan*

Coming together to solve climate change.

Caltech



CSU Bakersfield



CALIFORNIA STATE UNIVERSITY EAST BAY

FRESNO STATE

University Community Leadership

HUMBOLDT STATE UNIVERSITY

CAL STATE LA



CALIFORNIA STATE UNIVERSITY MONTEREY BAY

California State University Northridge

CAL POLY POMONA



SACRAMENTO STATE



SAN DIEGO STATE UNIVERSITY

SJSU SAN JOSE STATE UNIVERSITY



CALIFORNIA STATE UNIVERSITY SAN MARCOS

COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK



Lawrence Livermore National Laboratory



BERKELEY LAB

Stanford University

Berkeley UNIVERSITY OF CALIFORNIA

UC DAVIS

UC IRVINE

UC MERCED

UCLA

UNIVERSITY OF CALIFORNIA Office of the President



UC RIVERSIDE

UCSB

UNIVERSITY OF CALIFORNIA SANTA CRUZ

UC San Diego

UC San Diego Extension

USC University of Southern California



California Collaborative for Climate Change Solutions