

The Global Carbon Cycle and Climate: Science and Policy Challenges

Berrien Moore III
University of Oklahoma



***Indian Institute of Science
31 March 2014***

MY APOLOGIES

For being Absent from this most important scientific meeting

The Indian Institute of Science, in collaboration with Space Agencies, is in a leadership position for advancing the possibilities of using science and space-based observations to improve life on Earth.

I look forward to these collaborations in the future.

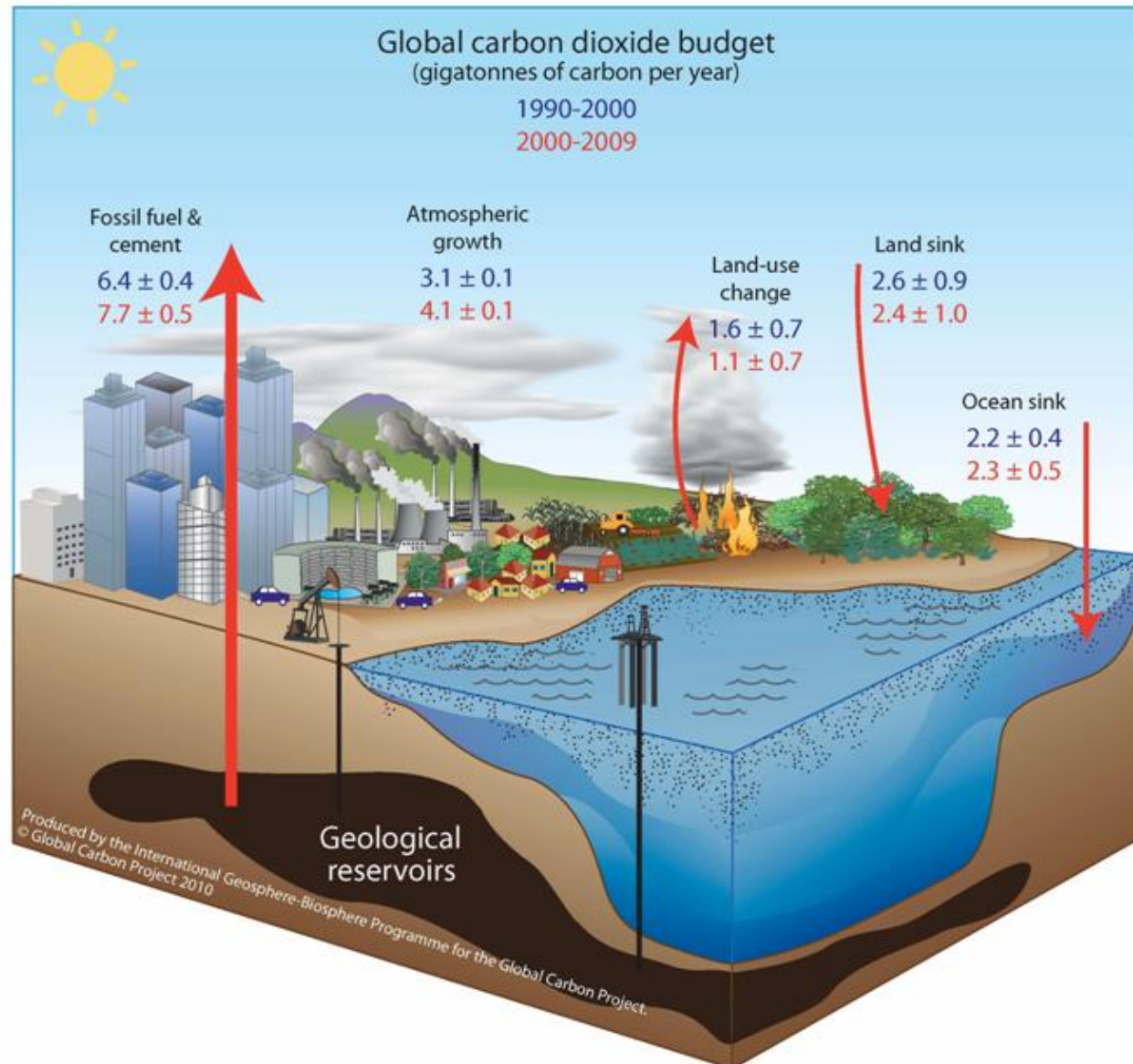
I extend my wishes for a successful meeting, and again, I send my regrets for not being there.

Berrien Moore III

Vice President, Weather & Climate Programs
Dean, College of Atmospheric & Geographic Sciences
Chesapeake Energy Corporation Chair in Climate Studies
Director, National Weather Center

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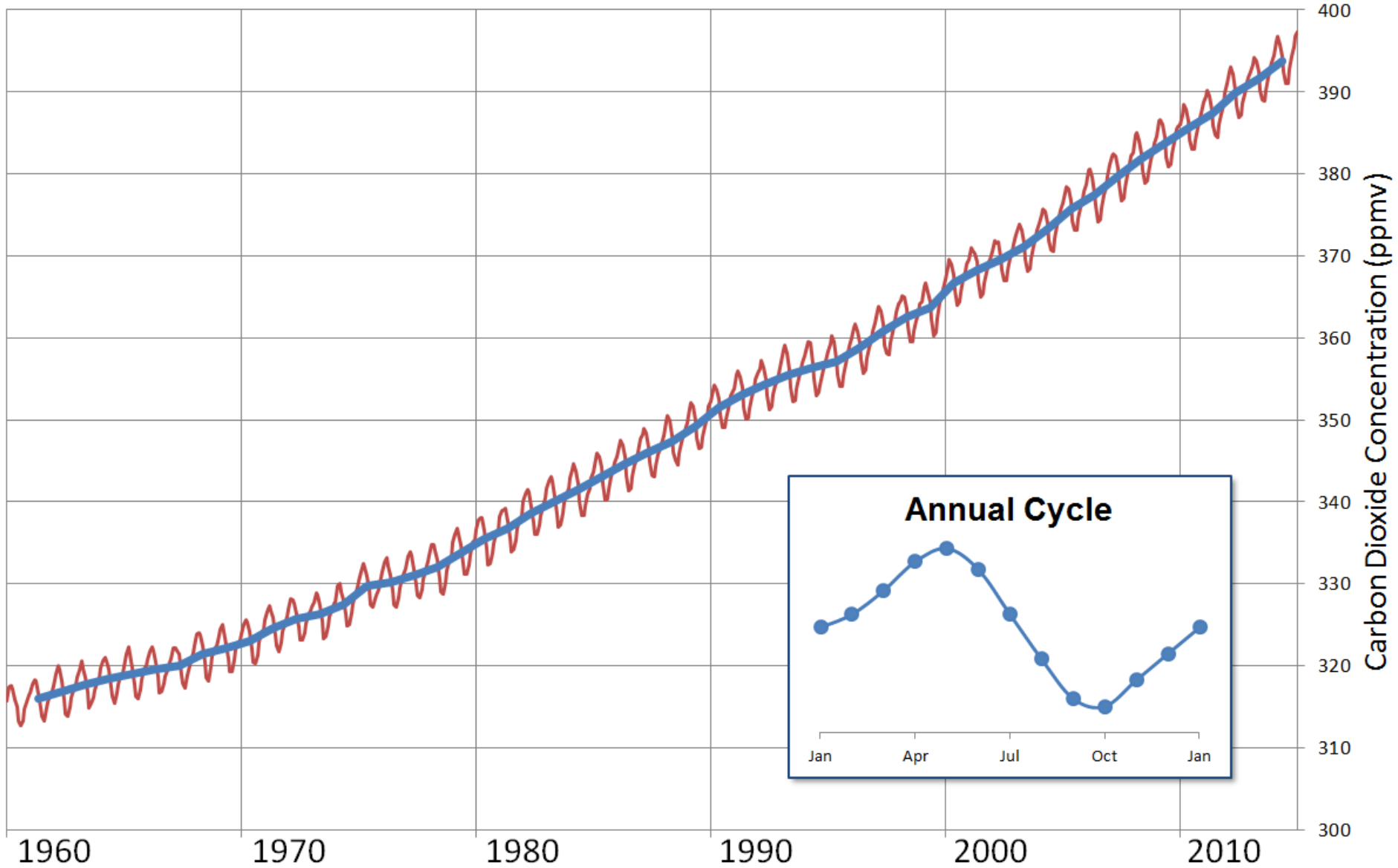
Anthropogenic Global Carbon Dioxide Budget



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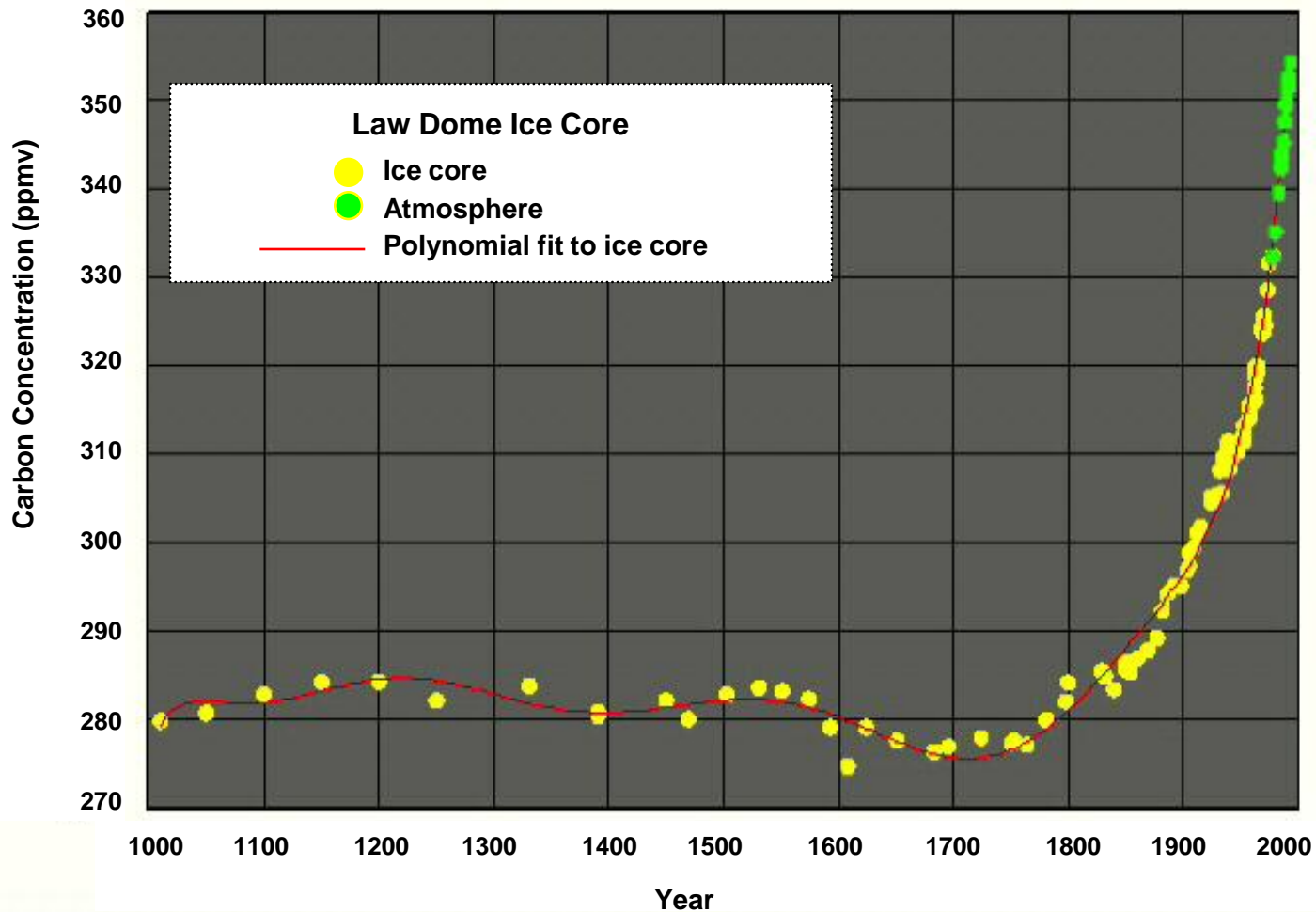
Atmospheric Carbon Dioxide

Measured at Mauna Loa, Hawaii



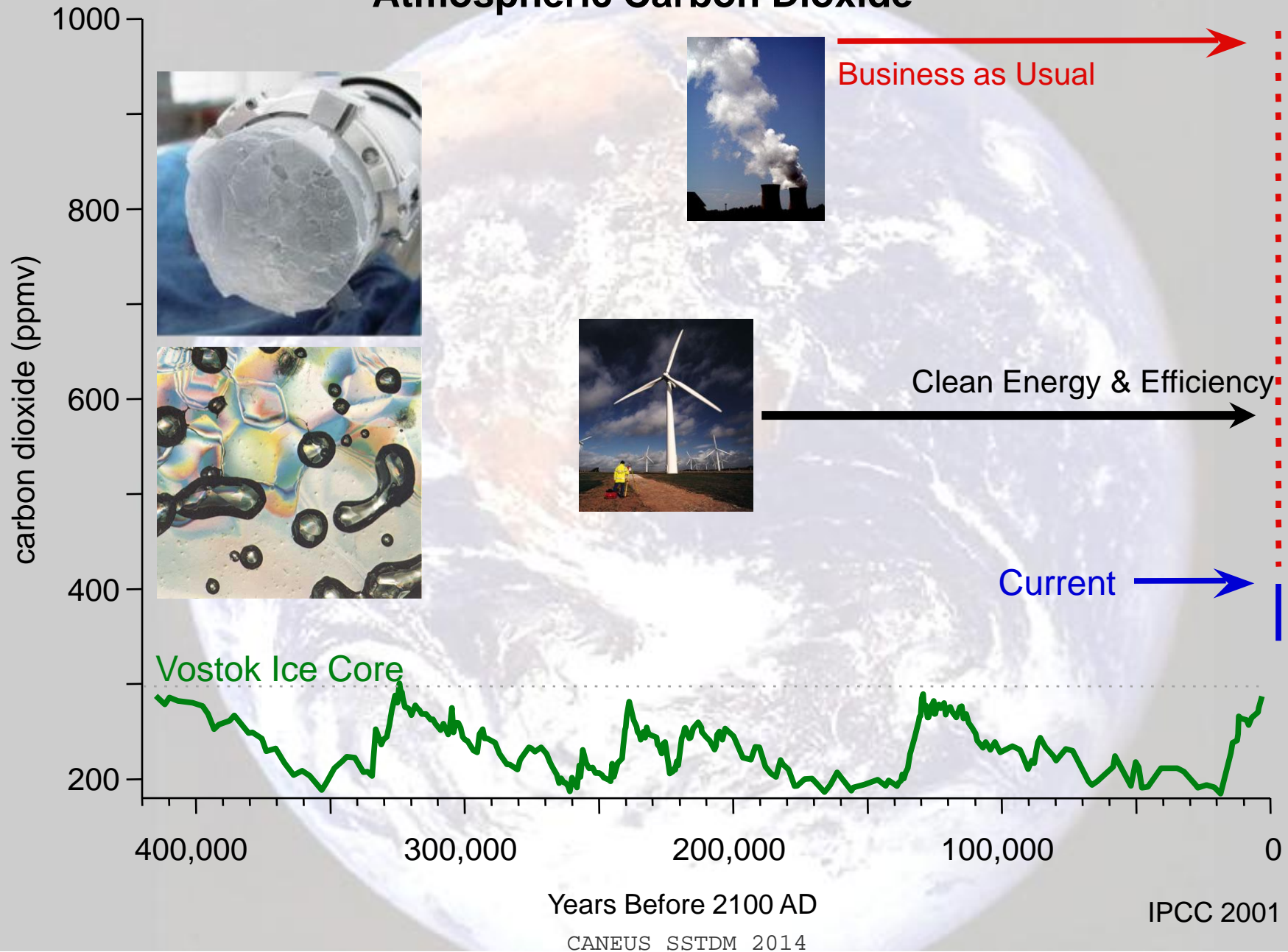
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Historical Atmospheric Carbon Concentration for the Last 1000 Years Extracted from the Law Dome Ice Core



Ethridge, et al., Retif, et al.
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Atmospheric Carbon Dioxide



26 March 2014

Mauna Loa Hawaii

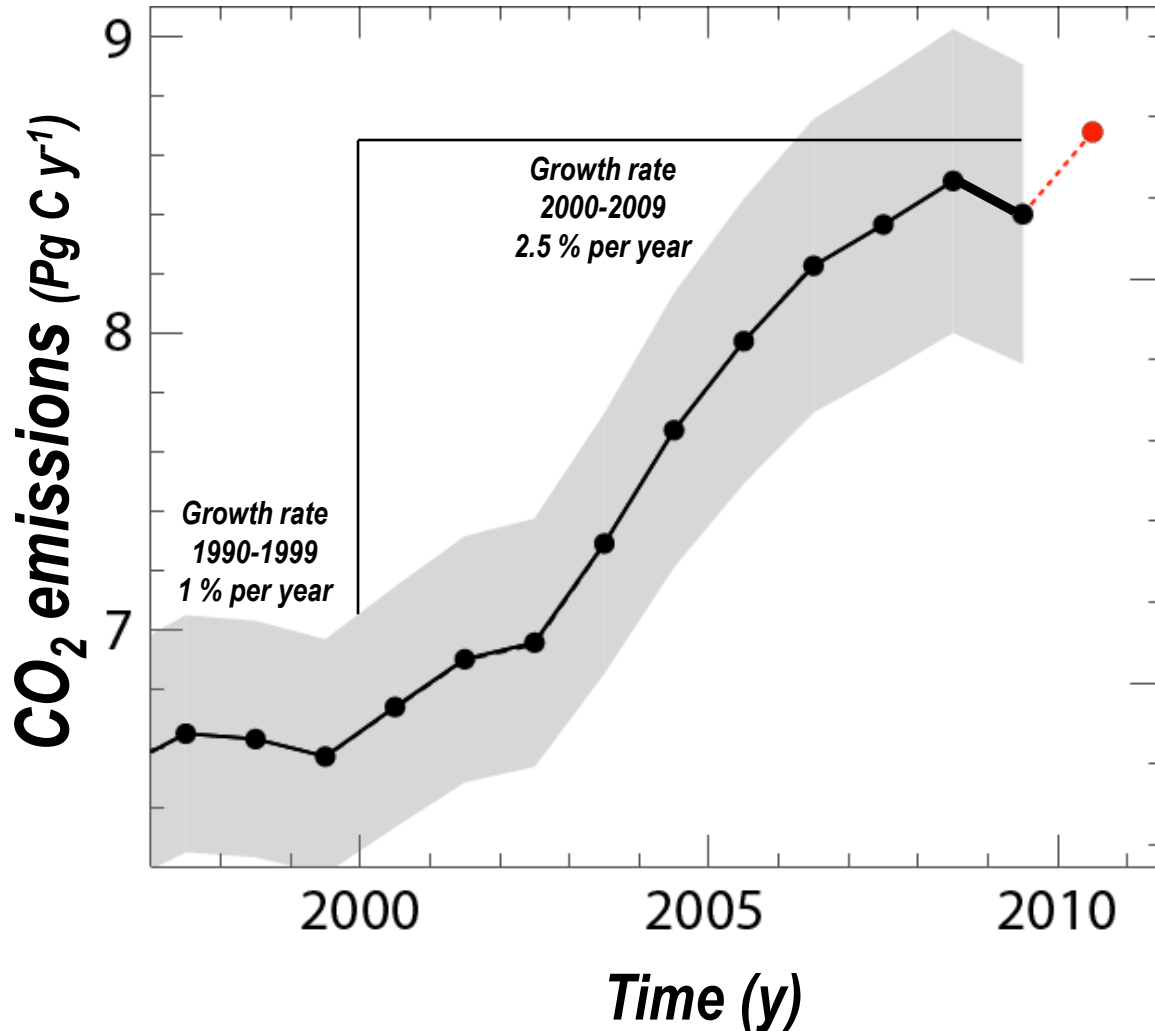
Atmospheric CO₂

concentration:

400.89 ppm

More than 43% above
pre-industrial (~280 ppm)

Fossil Fuel CO₂ Emissions



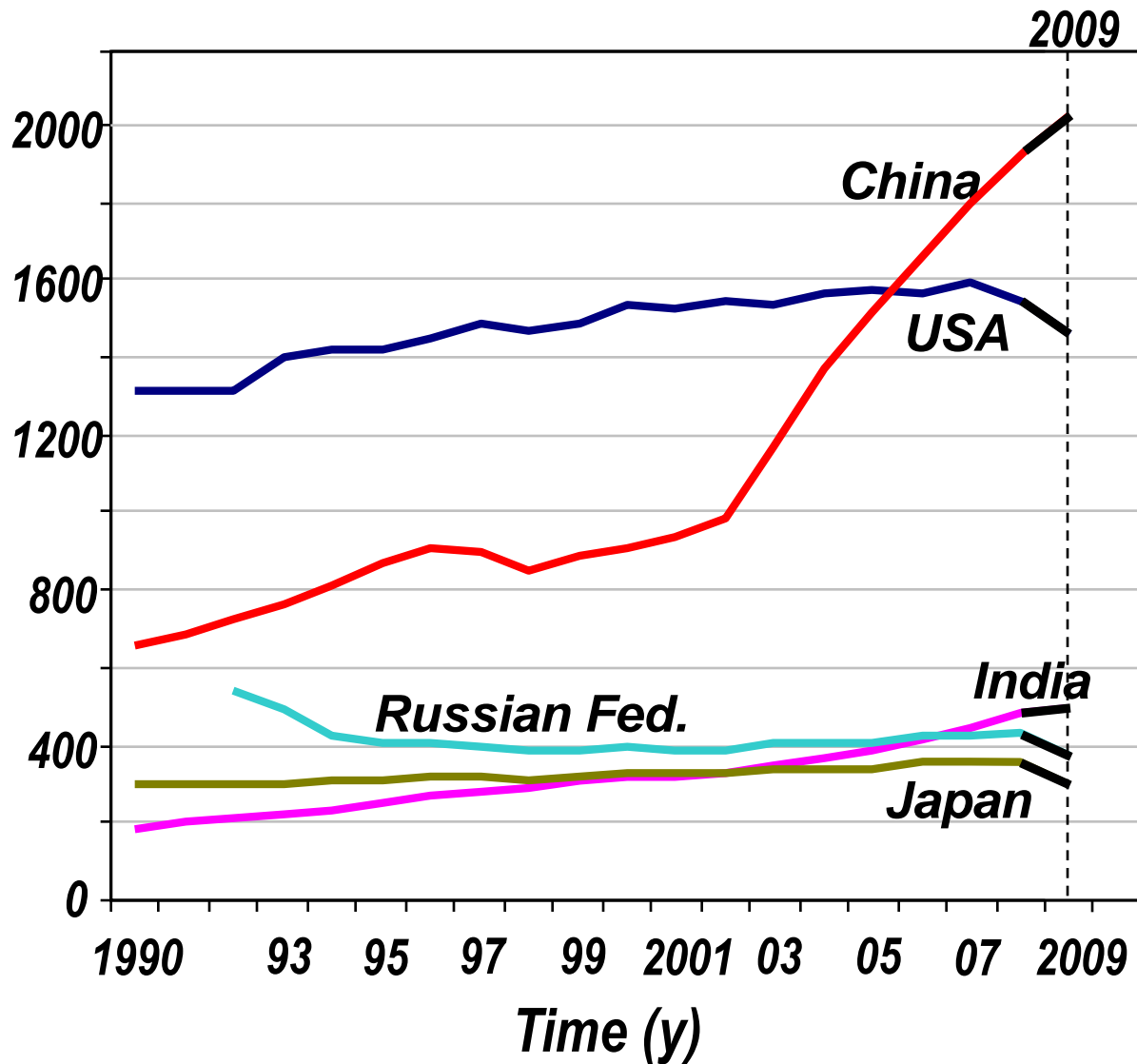
2009:
Emissions: 8.4 ± 0.5 PgC
Growth rate: -1.3%
1990 level: +37%

2000-2008
Growth rate: +3.2%

2010
Growth rate: 5.9%

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Fossil Fuel CO₂ Emissions: Top Emitters



China
CO₂
emission
s in 2010
rose by
10%;
Global
emission
s rose
by 5.9%;
USA by
3.9%

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Fate of Anthropogenic CO₂ Emissions (2000-2009)

$1.1 \pm 0.7 \text{ PgC y}^{-1}$



$7.7 \pm 0.5 \text{ PgC y}^{-1} +$



$4.1 \pm 0.1 \text{ PgC y}^{-1}$

47%



2.4 PgC y^{-1}

27%

*Calculated as the residual of
all other flux components*

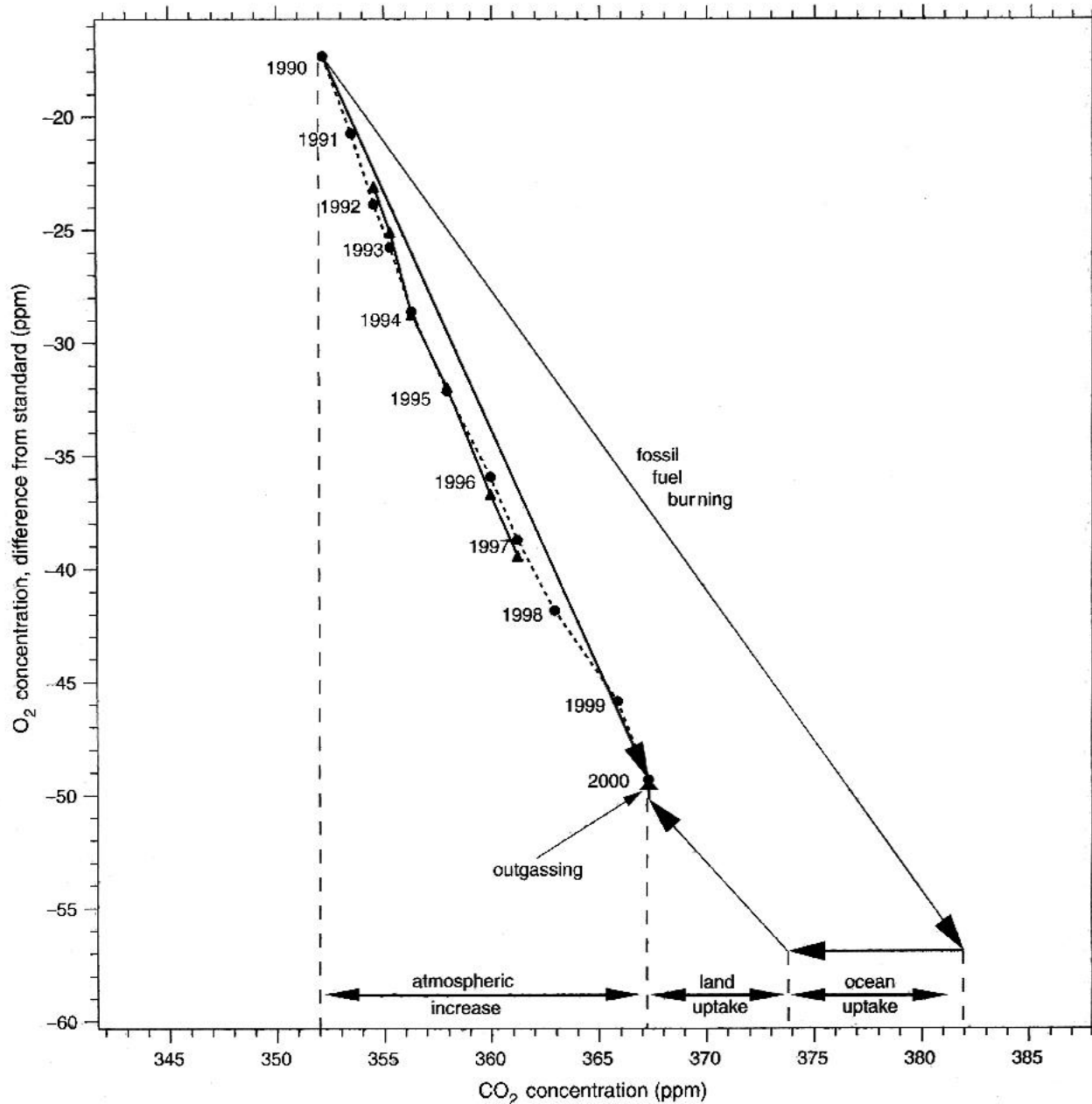


26%

$2.3 \pm 0.4 \text{ PgC y}^{-1}$

Average of 5 models





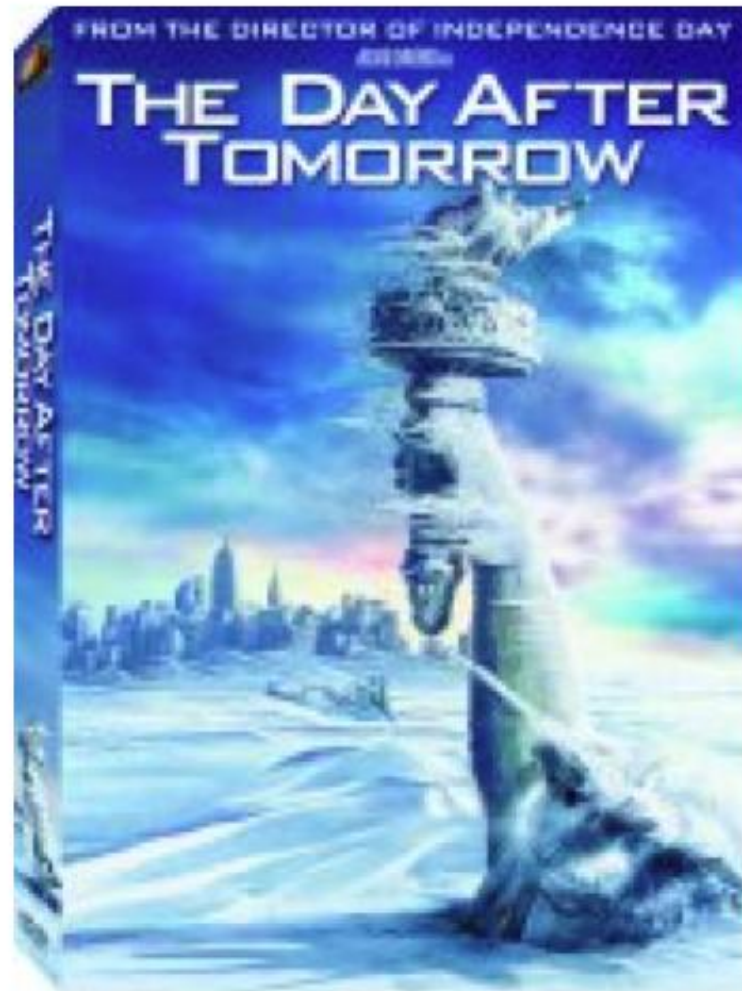
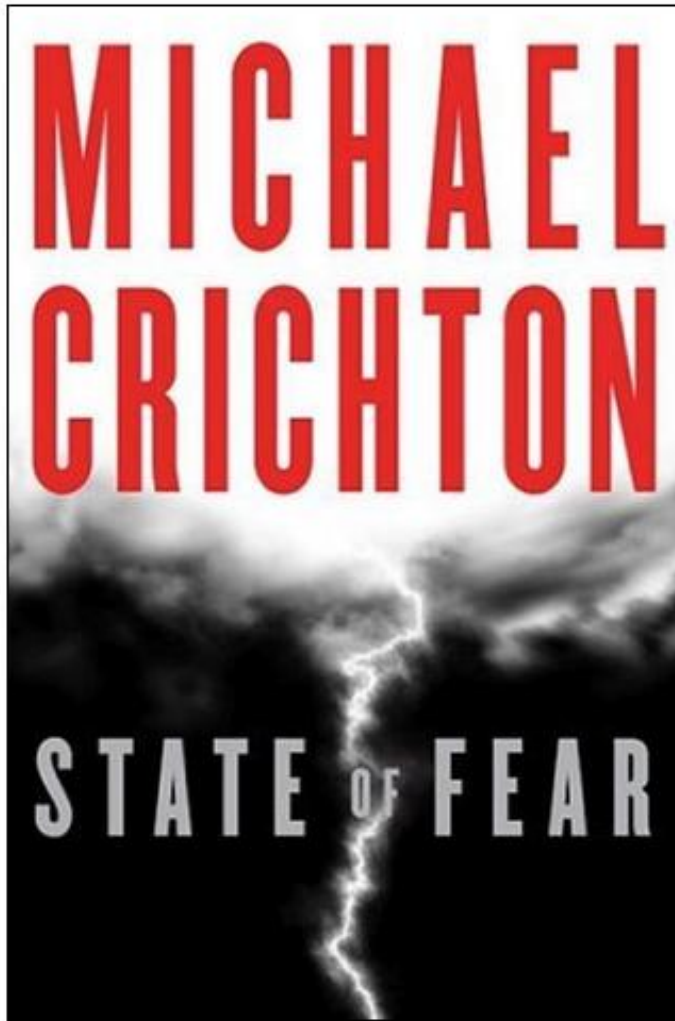
IPCC Third Assessment Report (based on a paper by Ralph Keeling)
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What We Know for SURE

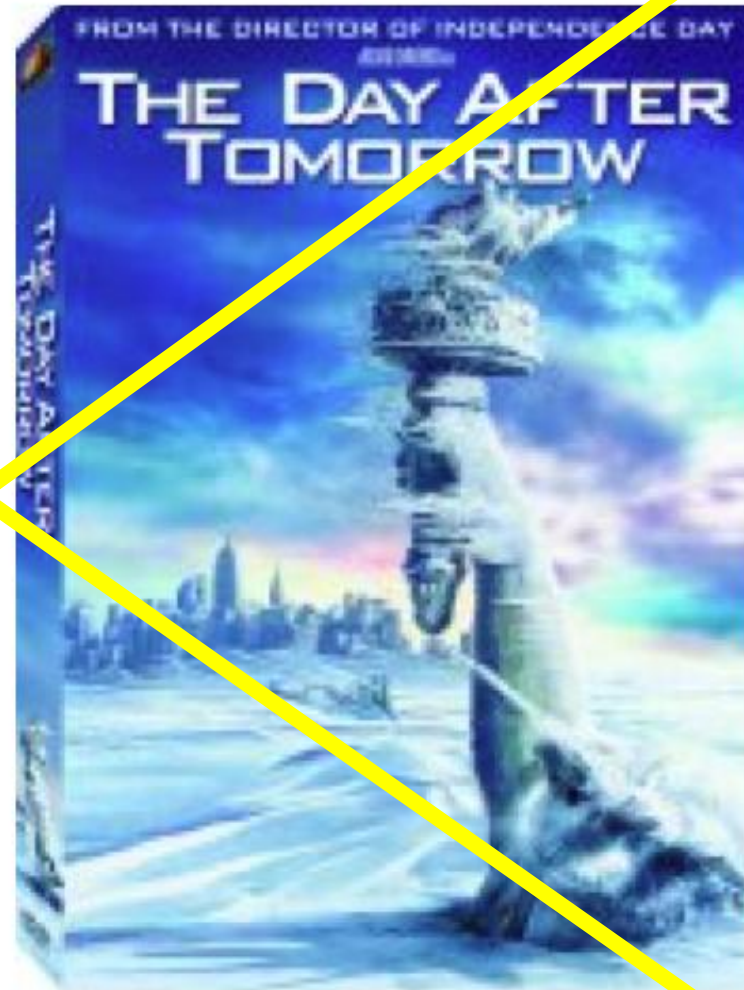
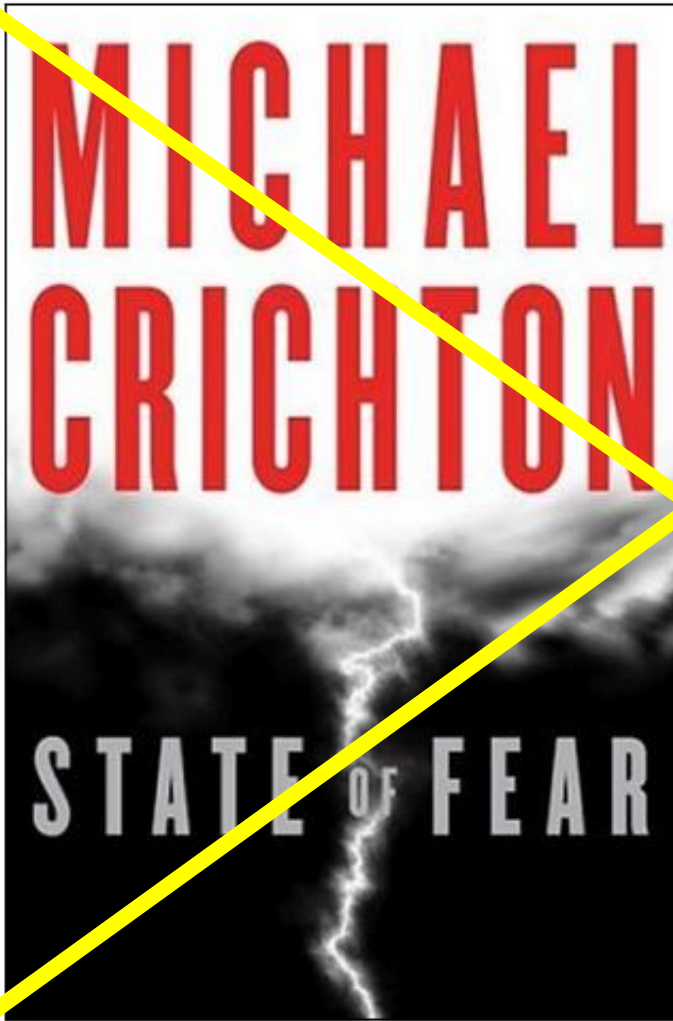
- **CO₂ is a greenhouse gas;**
- **The atmospheric concentration of CO₂ is increasing;**
- **The increase is being caused primarily by fossil fuel burning;**
- **Fossil fuel consumption is at the center of almost all economies;**
- **CO₂ is long-lived in the atmosphere (500+ years), and therefore stabilizing the atmospheric concentration of CO₂ will be difficult.**



*What We **Think** We
Know*



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CLIMATE CHANGE 2001

The Scientific Basis

CLIMATE CHANGE 2007 THE PHYSICAL SCIENCE BASIS



Contribution of
Report of the Int



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



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ipcc

INTERGOVERNMENTAL PANEL ON climate change

CLIMATE CHANGE 2013

The Physical Science Basis

WG I

WORKING GROUP I CONTRIBUTION TO THE
FIFTH ASSESSMENT REPORT OF THE
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE



An increasing body of observations of climatic and other changes in physical and ecological systems gives a collective picture of a warming world.

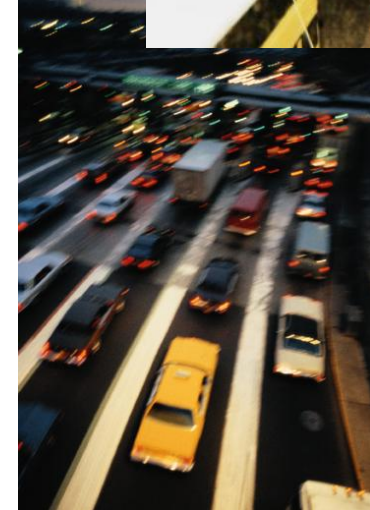


IPCC Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change
CANES - SSTDM - 2014

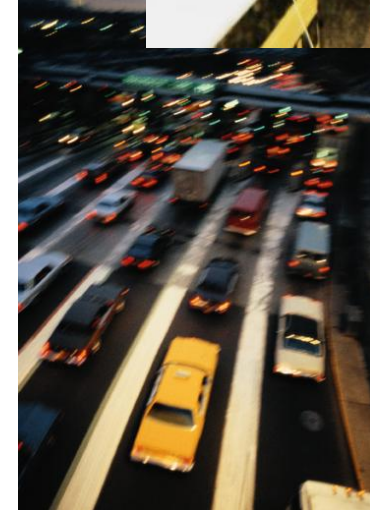
Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.



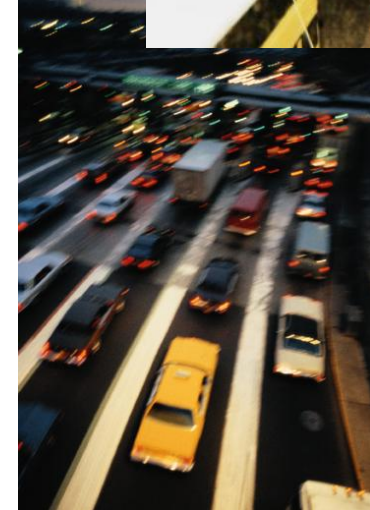
There is new and stronger evidence that most of the warming
observed over the last 50 years
is *likely* attributable to human activities.



Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.



It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century.

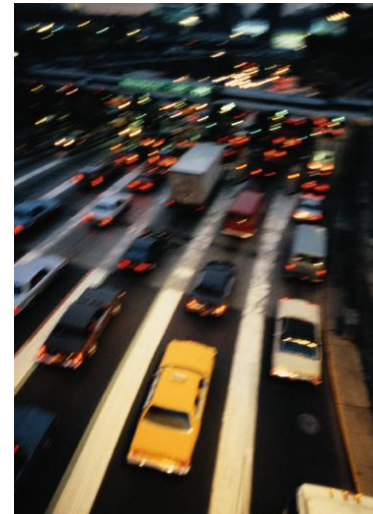


It is **virtually certain** that there will be **more frequent hot and fewer cold temperature extremes** over most land areas on daily and seasonal timescales as global mean temperatures increase. It is very likely that **heat waves will occur with a higher frequency and duration**. **Occasional cold winter extremes will continue to occur**

Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will **very likely** become **more intense and more frequent** by the end of this century...



Globally, it **is likely** that the area encompassed by **monsoon systems will increase** over the 21st century. Monsoon **precipitation is likely to intensify** due to the increase in atmospheric moisture. Monsoon season will lengthen in many



IPCC AR5 Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change



*What We **Need** to
Know*

Fate of Anthropogenic CO₂ Emissions (2000-2009)

$1.1 \pm 0.7 \text{ PgC y}^{-1}$



$7.7 \pm 0.5 \text{ PgC y}^{-1} +$



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47%



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Average of 5 models





AIRS on Aqua

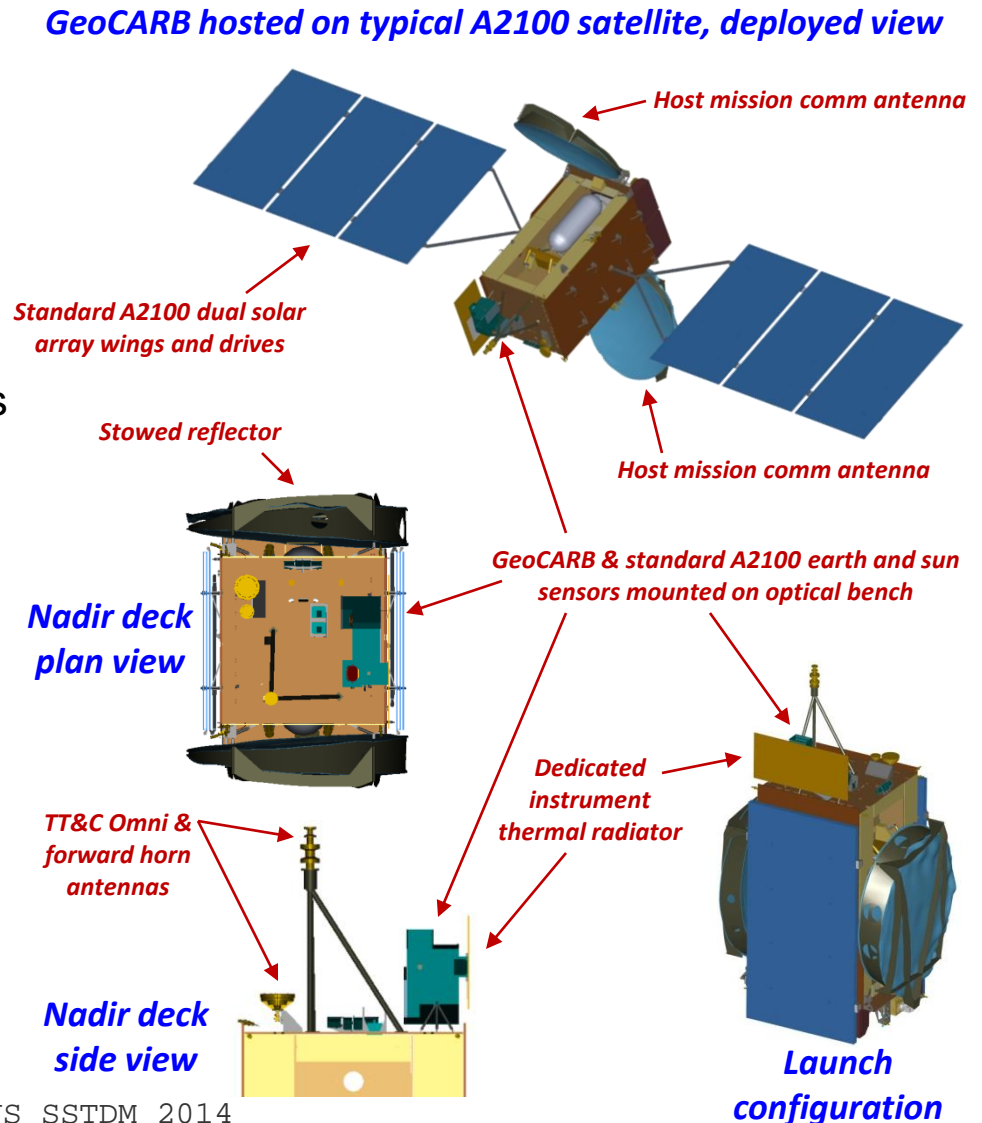
Future Systems

OCO

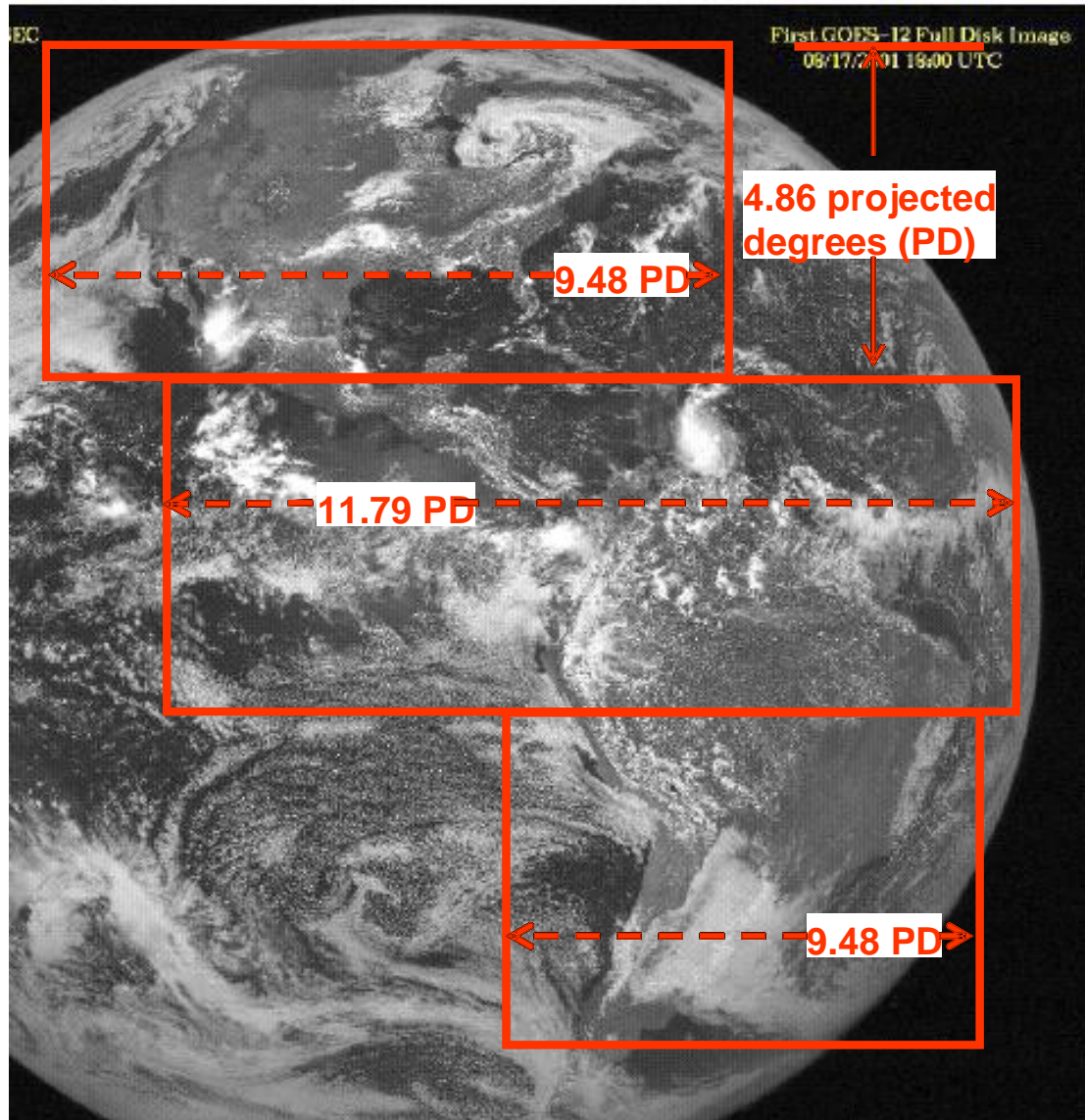
International

Accommodation of GeoCARB on Host Mission

- Hosted on standard A2100 with added interface items to support instrument
 - Mounted directly to nadir deck
 - Data downlink via host channel
 - Standard attitude & orbit control
- Consumes relatively small amount of mass and power (S/C impacts chart)
- Physical accommodation
 - Requires large part of nadir deck
 - No impact on S/C equipment panels
 - Dedicated thermal radiator
- Electrical accommodation
 - Energy via standard 70 V DC power bus
 - On/off, basic health & safety command /telemetry via standard interfaces

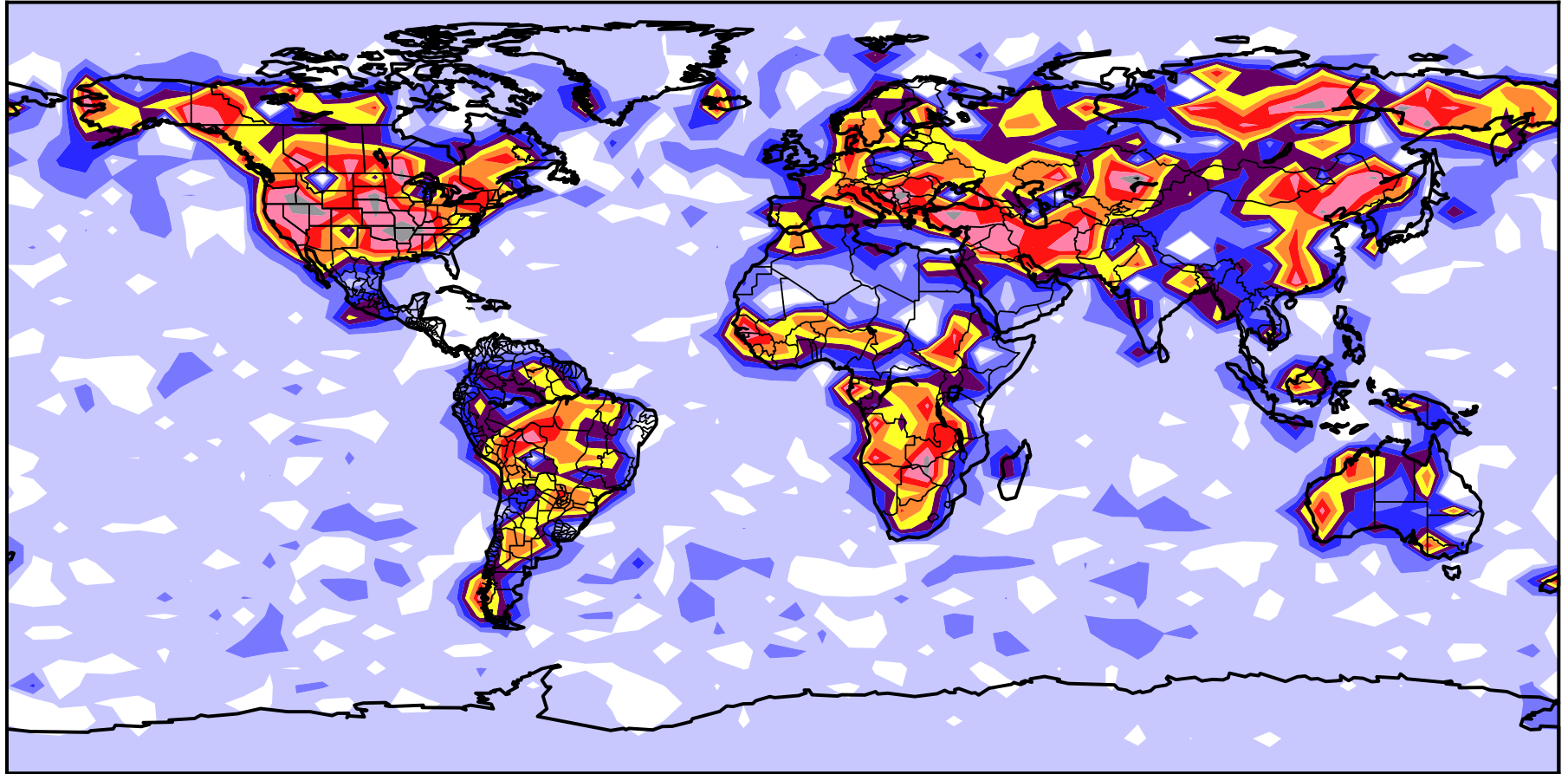


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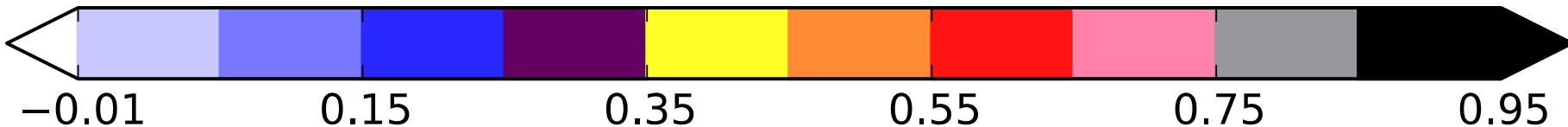
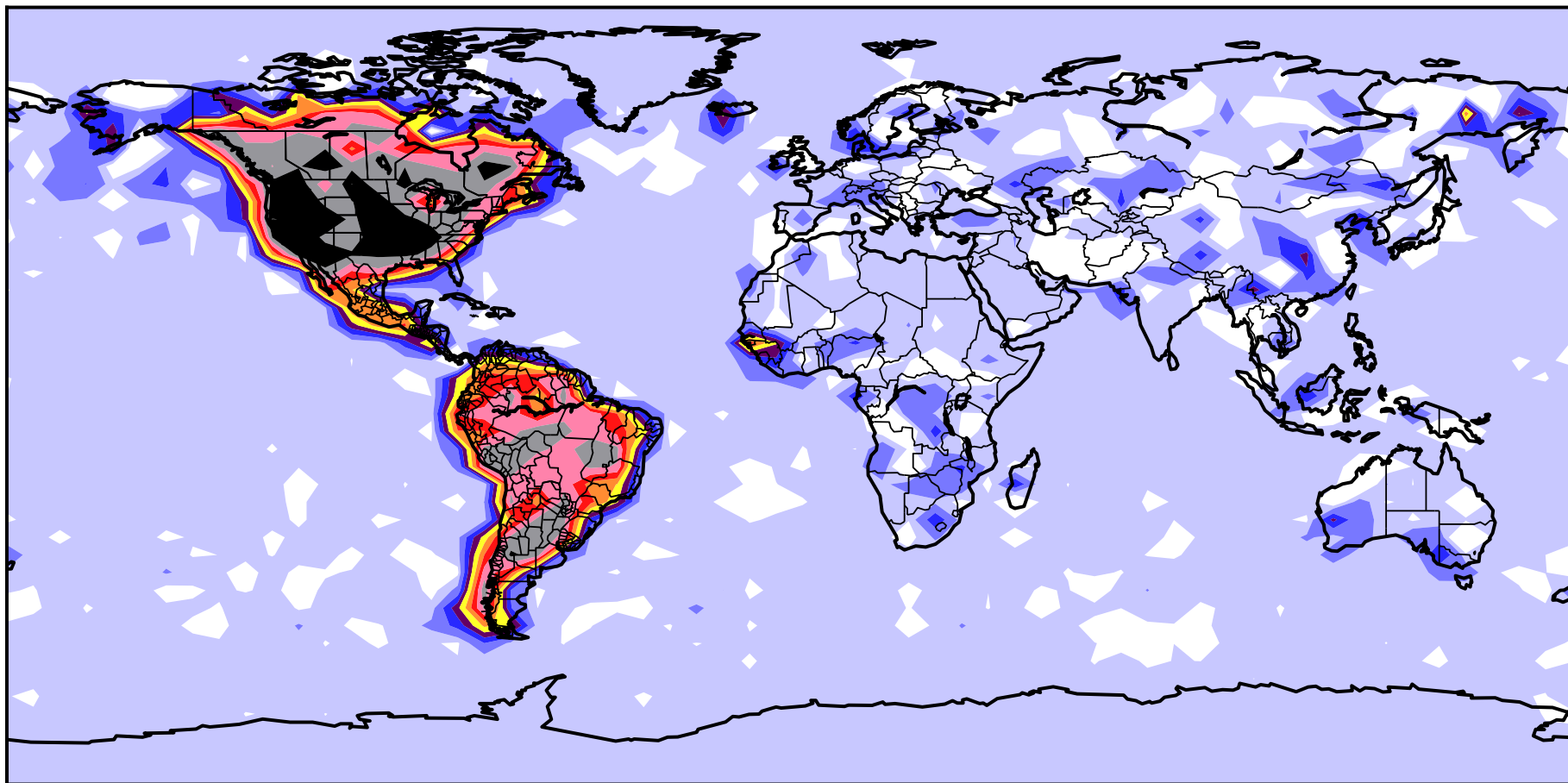
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LEO



CANEUS SSTDM 2014

GEO (95W)



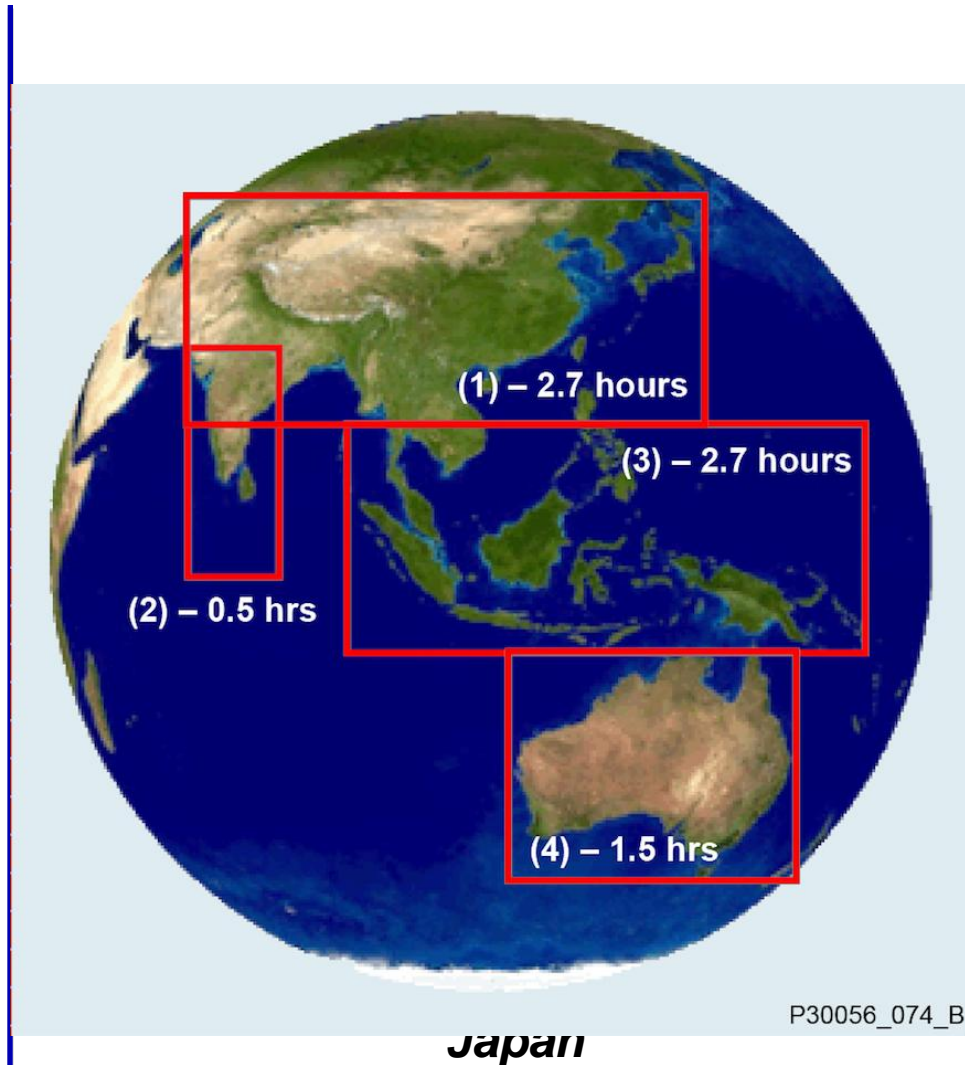
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Increasing the NECESSARY Temporal Coverage of CO₂ and CH₄

- **Monitoring CO₂ and CH₄ over land areas in the viewable hemisphere from a geo-platform**

- **An area of large industrial emissions;**
- **China is the world's largest emitter of anthropogenic CO₂ and CH₄;**
- **India is currently the 3rd largest emitter of anthropogenic CO₂ with potential for rapid growth;**
- **Area could be shifted up to 10 degrees west—multiple communication vendors;**
- **Potential for within region collaboration:**

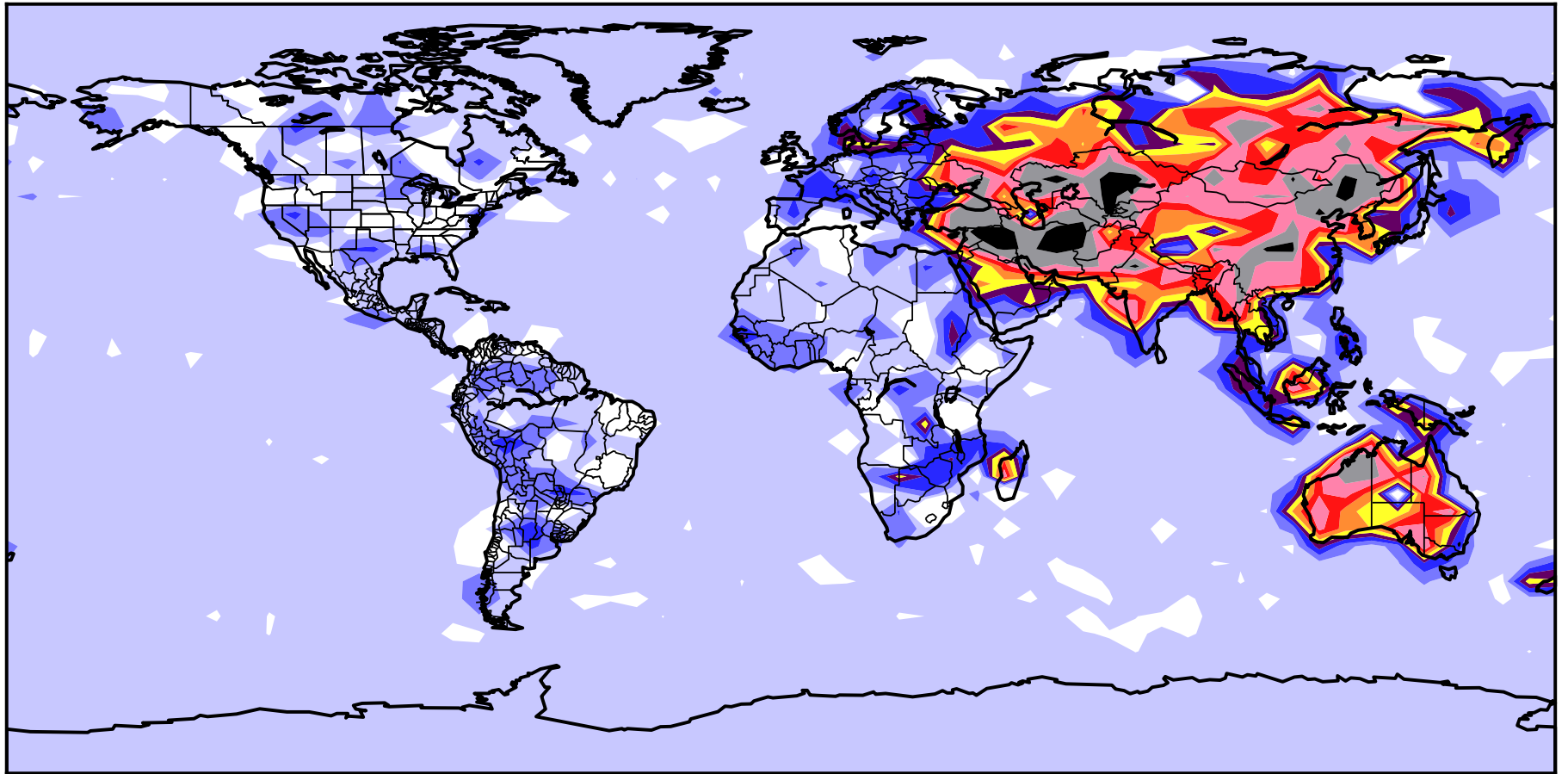
- **Science and Engineering**
- **Ground system, and**
- **accurate ground**



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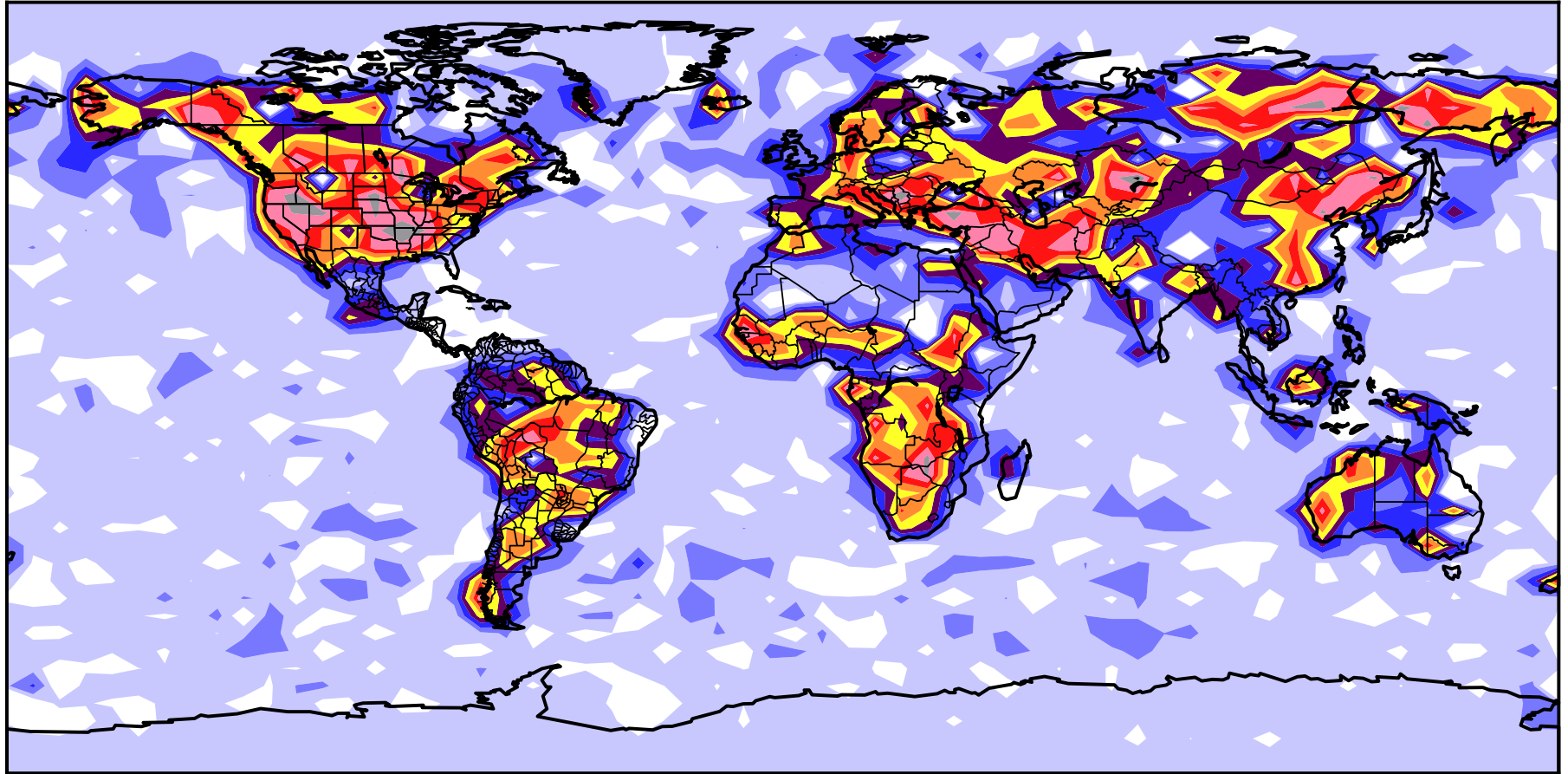
CANEUS SSTDM 2014

GEO (110E)



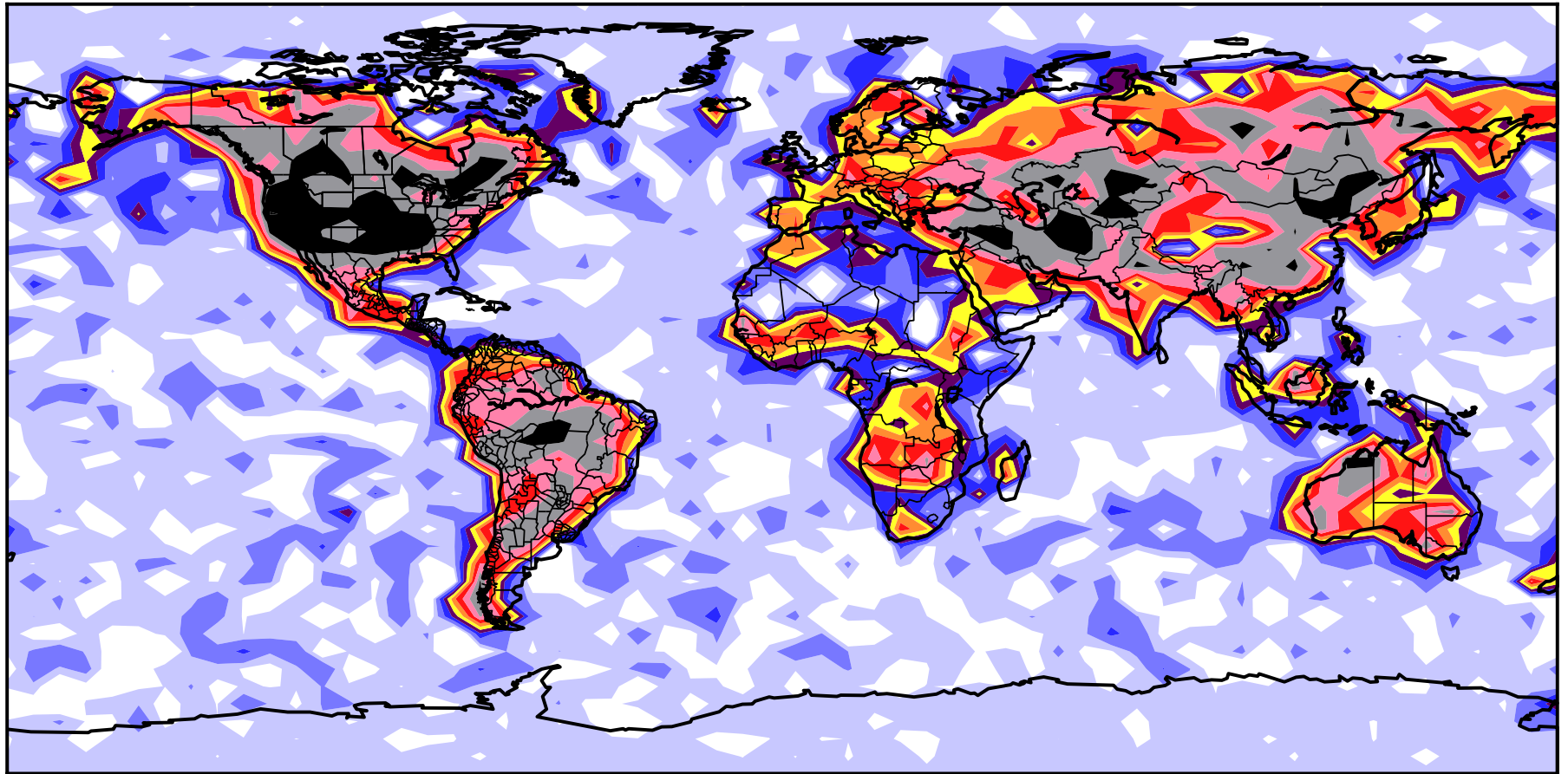
CANEUS SSTDM 2014

LEO



CANEUS SSTDM 2014

LEO + GEO (95W & 110E)



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“One thing that is clear based upon my own career in industry and government is that when faced with major challenges of high technological content in a time of austerity, the last thing one should under-fund is R&D...to do so is the equivalent to removing an engine from an overloaded aircraft in order to reduce its weight.”

Norman R. Augustine

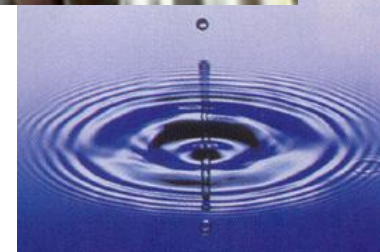
Retired Chairman and CEO, Lockheed Martin Corp.

Former Undersecretary of the Army

Excerpt from “A BUSINESS PLAN FOR

AMERICA’S ENERGY FUTURE”

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