



"Historical" presentation by Dr. Daniel L. Albritton (now retired), former Director of NOAA Aeronomy Laboratory (now the Chemical Sciences Division of NOAA's Earth System Research Laboratory), reporting in early 2001 on the Intergovernmental Panel on Climate Change: 2001 report on Climate.

This testimony on climate change research was presented before the U.S. House of Representatives Committee on Science, 14 March 2001. A detailed account of the hearing was prepared by the NOAA Office of Legislative Affairs.

Since this 2001 presentation, the state of understanding regarding climate science has been updated with the release of the 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). We have left Dr. Albritton's historical presentation on our website to showcase the clear, succinct, and timely hand-drawn information that Dan made famous.

**PAGE 1a**

**PAGE 1b**

**PAGE 2**

**PAGE 3**

**PAGE 4**

**PAGE 5**

**PAGE 6**

**PAGE 7**

**dttext**

CLIMATE CHANGE: WHAT WE KNOW & WHAT WE DON'T KNOW

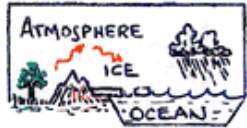
DAN ALBRITTON - NAT'L OCEANIC & ATMOSPHERIC ADMINISTRATION (DOC/NOAA)  
AERONOMY LAB, BOULDER, COLORADO

## ▶ CONTEXT: THE CLIMATE SYSTEM & HUMANKIND

### • CLIMATE CHANGE FORCINGS



### • PHYSICAL PROCESSES



### • PHYSICAL RESPONSES

- CROP YIELD
- COASTAL HABITATION
- FOREST MIGRATION
- ...

### • IMPACTS



### • BIOLOGICAL PROCESSES

---

CLIMATE · OCEANS, GREAT LAKES, and COASTS · WEATHER and AIR QUALITY  
ABOUT US · RESEARCH PROGRAMS · EDUCATION · HOME



PAGE 1a

PAGE 1b

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

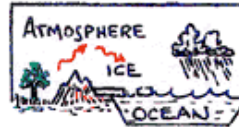
dtext

### ► CONTEXT: THE CLIMATE SYSTEM & HUMANKIND

#### • CLIMATE CHANGE FORCINGS



#### • PHYSICAL PROCESSES



#### ★ THREE MAJOR QUESTIONS:

MY  
EMPHASIS  
TODAY

• HOW WELL DO WE UNDERSTAND THE CLIMATE SYSTEM & OUR ROLE IN CHANGING IT?

• HOW WELL CAN WE CHARACTERIZE THE IMPACTS OF CLIMATE CHANGE?

• WHAT ARE OUR FUTURE OPTIONS?

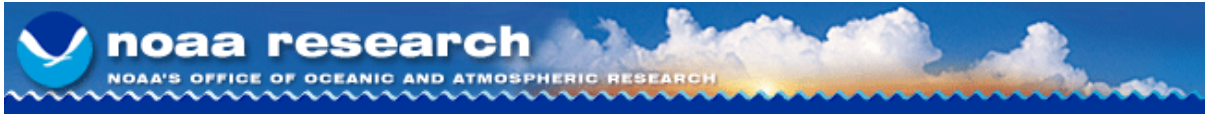
#### • PHYSICAL RESPONSES



#### • BIOLOGICAL PROCESSES

- CROP YIELD
- COASTAL HABITATION
- FOREST MIGRATION
- ...

#### • IMPACTS



- PAGE 1a
- PAGE 1b
- PAGE 2
- PAGE 3
- PAGE 4
- PAGE 5
- PAGE 6
- PAGE 7

dtext

## A SCIENTIFIC STATUS REPORT:



THERE IS A NATURAL GREENHOUSE EFFECT.  
IT KEEPS THE EARTH WARMER THAN  
IT WOULD BE OTHERWISE.



### POINTS...

- IN TERMS OF BASIC PHYSICS:

Ⓐ IT WARMS UP AND...

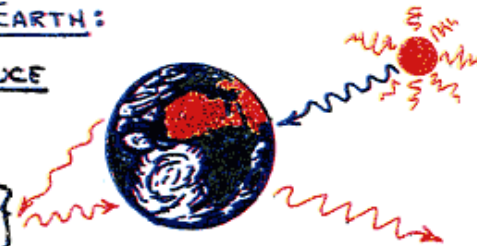


Ⓐ IF AN OBJECT IS BATHED IN VISIBLE LIGHT...

Ⓑ IT EMITS INFRARED LIGHT.

### IN TERMS OF OUR PLANET EARTH:

<u>ATMOSPHERE</u>	<u>ABUNDANCE</u>
NITROGEN	78%
OXYGEN	20
⋮	
★ WATER VAPOR	2%
CARBON DIOXIDE	0.03
⋮	
↑ ⋮ → GREENHOUSE GASES	



- KEY ASPECTS

- > WATER VAPOR & CARBON DIOXIDE HAVE BEEN PART OF OUR ATMOSPHERE FOR MILLIONS OF YEARS.
- > THEIR PRESENCE YIELDS AN AVERAGE SURFACE TEMPERATURE OF ~60°F.
- > WITHOUT THEM, THE AVERAGE WOULD BE ~5°F.

Q: So ... WHAT'S THE PROBLEM?



PAGE 1a

PAGE 1b

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

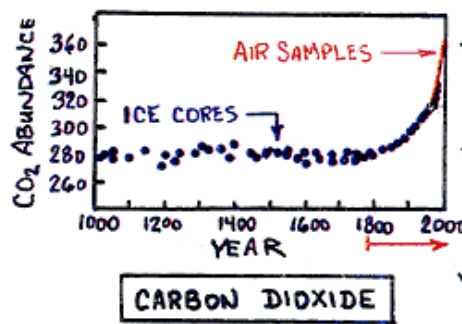
dtext



GREENHOUSE GASES ARE INCREASING IN THE ATMOSPHERE BECAUSE OF HUMAN ACTIVITIES, & THEY ARE INCREASINGLY TRAPPING MORE HEAT.

POINTS...

● IMPECCABLE SCIENTIFIC MEASUREMENTS



"CONFIDENCE INDEX"

31% INCREASE OVER THE INDUSTRIAL ERA.

● OTHER GASES HAVE INCREASED TOO.

- > FOR EXAMPLE: • METHANE (1/3 THE EFFECT OF CO<sub>2</sub>)
- SULFUR (A COOLING TENDENCY)

● THE SOURCES ARE HUMAN-CAUSED.

- CO<sub>2</sub> ~ ALL (COMBUSTION)
- METHANE ~ MOST

Q: BUT, WHAT ARE THE CONSEQUENCES?

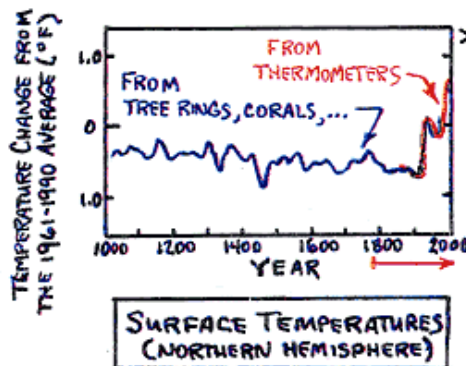
- PAGE 1a
- PAGE 1b
- PAGE 2
- PAGE 3
- PAGE 4
- PAGE 5
- PAGE 6
- PAGE 7

dtext

➡ THERE IS A COLLECTIVE PICTURE OF A WARMING WORLD,  
& HUMAN ACTIVITIES HAVE LIKELY CONTRIBUTED.

POINTS...

- GLOBAL TEMPERATURES: UP 0.7- 1.4° F OVER PAST 100 YEARS



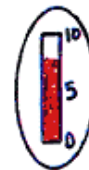
> CONSISTENT WITH THE WARMING:

- GLACIAL RETREAT.
- SNOW-COVER DECREASE.
- FREEZE-FREE PERIODS LENGTHENED.
- SEA-LEVEL INCREASED: 4-8 INCHES.

- MOST OF THE WARMING OVER THE PAST 50 YEARS IS LIKELY TO BE DUE TO GREENHOUSE-GAS INCREASES.

REASONS: COMPARISONS OF SIMULATED VS. OBSERVED TEMPERATURES:

- ☑ SIMULATIONS WITH NATURAL AND HUMAN FACTORS MATCH OBSERVATIONS BEST.
- ☑ CORRESPONDENCES INCREASE WITH TIME.
- ☑ PROBABILITY IS LOW THAT A "NATURAL-ONLY" EARTH WOULD HAVE SUCH CORRESPONDENCES.



⊙: WHAT COULD THIS MEAN FOR THE FUTURE?



PAGE 1a  
PAGE 1b  
PAGE 2  
PAGE 3  
PAGE 4  
PAGE 5  
PAGE 6  
PAGE 7

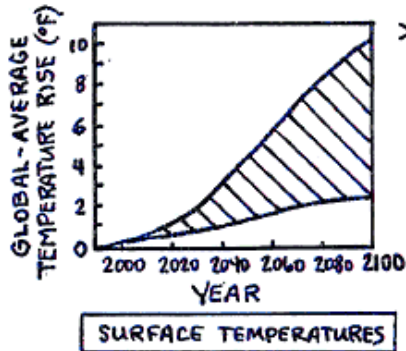
➔ A CONTINUED GROWTH IN GREENHOUSE GASES IS PROJECTED TO LEAD TO VERY SIGNIFICANT INCREASES IN GLOBAL TEMPERATURES & SEA LEVEL.

POINTS ...

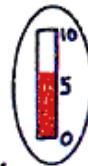
- CO<sub>2</sub> ABUNDANCE WILL LIKELY DOUBLE BEFORE 2100.

> INDEED ... TO STABILIZE AT DOUBLED → CUTS IN EMISSIONS

- PREDICTED CLIMATE RESPONSES



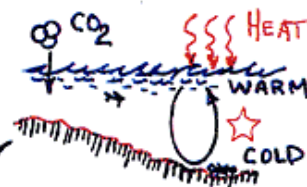
> FOR A RANGE OF FUTURE EMISSION SCENARIOS:  
(NON-INTERVENTION, ECONOMICS, TECHNOLOGY, POPULATION, ...)



- GLOBAL TEMPERATURE RISE 2.5 - 10 °F BY 2100.
- IF SO, THIS WOULD EXCEED THE NATURAL CHANGES OVER THE PAST 10,000 YEARS.
- CORRESPONDING SEA LEVEL RISE: 4 - 35 INCHES BY 2100.

- A GREENHOUSE WARMING COULD BE REVERSED ONLY VERY SLOWLY.

> REASON: THE OCEANS ARE SLUGGISH



Q: BEYOND "GLOBAL AVERAGES"?



PAGE 1a

PAGE 1b

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

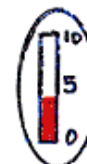
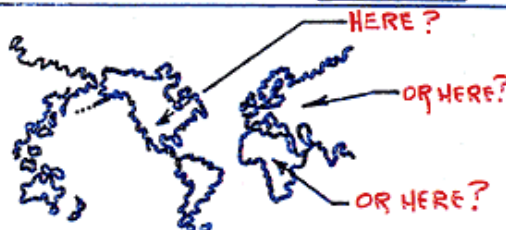
PAGE 7

dtext

➡ IT IS A COMPLEX PLANET & WE HAVE IMPERFECT KNOWLEDGE;  
SO, PREDICTION OF FURTHER DETAILS SUFFERS.

POINTS ...

● WHAT WILL HAPPEN IN PARTICULAR PLACES?



● REGIONAL CHANGES CANNOT YET BE PREDICTED RELIABLY.

> BUT, SOME PROJECTIONS ARE LIKELY ROBUST...

- LAND AREAS WARM MORE THAN OCEANS (N. NORTH AMERICA: 40% ABOVE AVERAGE)
- INCREASED MID-CONTINENTAL SOIL DRYING.

● HOW ABOUT "EXTREME EVENTS"?

> A WARMER WORLD → A MORE-VIGOROUS "HYDROLOGICAL CYCLE"  
HEAVIER RAINS, WITH LARGE VARIANCE FROM REGION TO REGION

> HURRICANES: MORE/LESS FREQUENT? MUCH TOUGHER TO CALL.

● SURPRISES?

> CURRENTLY UNKNOWN GEOPHYSICAL PROCESSES ACTIVATED?

> ABRUPT CLIMATE SHIFTS?

POSSIBLE. HERE'S WHY:

- WE ARE ENTERING A NEW REGIME OF CLIMATE PERTURBATION.
- CLIMATE IS A NON-LINEAR SYSTEM.





### CONCLUDING COMMENTS

PAGE 1a

PAGE 1b

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

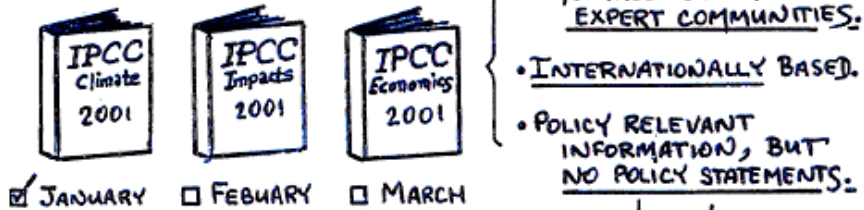
dtext

• BOTTOM LINES → THE VAST-MAJORITY SCIENTIFIC VIEWPOINT:

- THE ISSUE IS A REAL ONE.
- THE FIRST SIGNS OF HUMAN-CAUSED CLIMATE CHANGE HAVE LIKELY OCCURRED.
- SOME DEGREE OF FURTHER CHANGES APPEARS INEVITABLE.
- EXACTLY - WHERE (REGIONS)  
- WHEN (RATE OF CHANGE) IS HARD TO PREDICT,  
- HOW MUCH (MAGNITUDE)
- HUMAN-CAUSED CLIMATE CHANGE WOULD BE SLOW TO REVERSE.

• BASIS OF THIS INFORMATION

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE : 3RD MAJOR ASSESSMENT:



THE LAST BOTTOM LINE: KEY INPUT TO POLICY FORMULATION



Skip to Page 1a,1b Skip to Page 2 Skip to Page 3 Skip to Page 4 section Skip to Page 5 Skip to Page 6 Skip to Page 7

[PG1a, 1b]

## CLIMATE CHANGE: What We Know and What We Don't

Presentation by Daniel L. Albritton, Director of NOAA Aeronomy Laboratory, during early 2001. Dr. Albritton provided additional [testimony](#) on climate change research before the US House of Representatives Committee on Science, March 14, 2001. A [detailed account of the hearing](#) was prepared by the [NOAA Office of Legislative Affairs](#).

CONTEXT: The Climate System and Humankind

### THREE MAJOR QUESTIONS:

1. How well do we understand the climate system and our role in changing it?
2. How well can we characterize the impacts of climate change?
3. What are our future options?

**Climate Change Forcings** create  
**Physical Processes** that cause  
**Physical Responses** that affect  
**Biological Processes** that have  
**IMPACTS** (crop yield, coastal habitation, forest migration)

---

[PG2]

### A SCIENTIFIC STATUS REPORT:

There is a natural greenhouse effect. It keeps the earth warmer than it would be otherwise **Confidence Index=10/10**

#### POINTS:

- IN TERMS OF BASIC PHYSICS:
  - If an object is bathed in **visible** light...
  - It warms up and...
  - It emits **infrared** light
- IN TERMS OF OUR PLANET EARTH THE ATMOSPHERE IS COMPOSED OF::
  - 78% Nitrogen
  - 20% Oxygen
  - \*2% Water Vapor (\*greenhouse gas)
  - \*0.03% Carbon Dioxide (\*greenhouse gas)
- KEY ASPECTS:
  - **Water Vapor** and **Carbon Dioxide** have been part of our atmosphere for **millions of years**.
  - Their presence yields an average surface temperature of ~60 degF
  - Without them the average would be ~5 degF.

#### Q: So, what's the PROBLEM?

[PG3]

Greenhouse gases are increasing in the atmosphere because of human activities, and they are increasingly trapping more heat.

**POINTS:**

- IMPECCABLE SCIENTIFIC MEASUREMENTS **Confidence Index=9/10**
  - The abundance of Carbon Dioxide increased 31% over the industrial era between 1800 and 2000, as measured by ice cores and air samples
- OTHER GASES HAVE INCREASED TOO
  - Methane (one-third the effect of Carbon Dioxide)
  - Sulfur (a cooling tendency)
- THE SOURCES ARE HUMAN-CAUSED
  - Carbon Dioxide ~all (combustion)
  - Methane ~most

**Q: But, what are the CONSEQUENCES?**

[PG4]

There is a collective picture of a warming world, and human activities have likely contributed.

**POINTS:**

- GLOBAL TEMPERATURES ARE UP 0.7 - 1.4 degF OVER PAST 100 YEARS (recorded by thermometers rather than tree rings, corals, etc.)  
Consistent with the warming:
  - Glacial retreat
  - Snow-cover decrease
  - Freeze-free periods lengthened
  - Sea-level increased 4-8 inches
- MOST OF THE WARMING OVER THE PAST 50 YEARS IS LIKELY TO BE DUE TO GREENHOUSE-GAS INCREASES **Confidence Index=8/10**  
Reasons: Comparisons of **simulated** vs **observed** temperatures:
  - Simulations with natural and human factors match observations best
  - Correspondences increase with time
  - Probability is low that a "natural-only" earth would have such correspondences

**Q: What could this mean for the FUTURE?**

[PG5]

A continued growth in greenhouse gases is projected to lead to very significant increases in global temperatures and sea level.

**POINTS:**

- CARBON DIOXIDE ABUNDANCE WILL LIKELY DOUBLE BEFORE 2100  
Indeed...to stabilize at doubled would require cuts in emissions
- PREDICTED CLIMATE RESPONSES **Confidence Index=6/10**  
For a range of future emission scenarios (non-intervention, economics, technology, population,...)
  - Global temperature rise of 2.5 - 10 deg F by 2100
  - If so, this would exceed the natural changes over the past 10,000 years
  - Corresponding sea level rise of 4 - 35 inches by 2100
- A GREENHOUSE WARMING COULD BE REVERSED ONLY VERY SLOWLY  
Reason: The oceans are sluggish

## Q: Beyond "GLOBAL AVERAGES"?

---

[PG6]

It is a complex planet and we have imperfect knowledge; so, prediction of further details suffers.

### POINTS:

- What will happen in **particular** places? **Confidence Index=4/10**
  - Regional changes cannot yet be predicted reliably
  - Some projections are likely robust...
    - Land areas warm more than oceans (N. North America: 40% above average)
    - Increased mid-continental soil drying
- How about "extreme events"?
  - A warmer world means a more vigorous "Hydrological Cycle" (**heavier rains**, with large **variance** from region to region)
  - Hurricanes: more or less frequent? Much tougher to call
- Surprises?  
Currently unknown geophysical processes activated? Abrupt climate shifts? Both possible because
  - We are entering a new regime of climate perturbation
  - Climate is a non-linear system

---

[PG7]

## CONCLUDING COMMENTS

### BOTTOM LINES - THE VAST MAJORITY SCIENTIFIC VIEWPOINT

- The issue is a real one
- The first signs of human-caused climate change have likely occurred
- Some degree of further changes appears inevitable
- Exactly **where** (regions), **when** (rate of change), **how much** (magnitude) is hard to predict
- Human-caused climate change would be slow to reverse

## BASIS OF THIS INFORMATION:

- Intergovernmental Panel on Climate Change: Third major assessment
  - Prepared by the expert communities
  - Internationally based
  - Policy-relevant information, but no policy statements

## THE LAST BOTTOM LINE: KEY INPUT TO POLICY FORMULATION

---

### ILLUSTRATIONS