“... civilization may pass like a cloud or smoke that is scattered by the wind....”
(Cahill 1995)
What we do in this generation will determine the destiny of life on our planet.
Humans have transformed the earth in the last 50 years

City Lights from Space
Fundamental Driver: Increasing population and Earth reaching its carrying capacity.

→ Increased vulnerability to “natural” disasters
Population Increases in Less and More Developed Regions (United Nations data)
Climate change and regional impacts are real

Glacier National Park
1911 and 2000
An ice free Arctic?

1979 2003
Substantial evidence of regional changes in the observed state of the climate system
The frequency, persistence and magnitude of El-Nino events have increased in the last 20 years.

But whether the increase in the number of El Ninos is due to a change in the basic state (e.g., through warming), a change in the form of the phenomena, or natural variability is not known.
Subsidence at Lost Hills, CA from ESA Satellites (ERS-1 & ERS-2)
10 m subsidence 1989-2000
Natural Disaster Prevention and Mitigation

- During 1990’s, natural disasters (floods, droughts, earthquakes, storms, strong winds, torrential rains, and mudslides) hit the world 500-800 times a year and cost more than $600 billion
  - More than previous four decades combined
- Loses by location in the 1990’s
  - 45% were in Asia
  - 30% in US
  - 10% in Europe
- Human impact
  - 2 billion people affected
  - 400,000 – 500,000 killed (more than 2/3 in Asia)
  - ½ deaths from floods, with earthquakes the next-largest killer
What Accounts for the Rise?

- More people
- Many ecosystems are now so frayed that they no longer play a natural cushioning role, e.g. deforestation and wetland destruction
- People migrate to the more disaster-prone coastal zones
- More than ½ the world’s people will soon be living in cities
  - Many new city-dwellers live on vulnerable hillsides and floodplains
- Climate change?
By the year 2050…

There may be 9 billion people…

> 6 billion tons per year of greenhouse gases…

> 60 million tons per year of urban pollutants…

Given these possible scenarios…
We will tax the world’s resources…

Withdrawing 30% of available fresh water…

Converting 65% of frontier forests…

And due to our growing numbers…
We will live increasingly in health and hazard risk areas…

~80% people will live in major urban areas

>25% people near earthquake faults…

~2% will live on coastlines within 1m of mean sea level…
Monsoons in a Warming World: Racing with the Four Horsemen
Who are the Four Horsemen of the Monsoon?

**Uncertainty in:**

1. Natural variability of climate
2. Global warming and climate change
3. Population increase and attendant problems
4. Societal and human response to change and in uncertainty itself
Monsoon regions and global climate change?

- Currently contains the largest percent of planetary population
- Contains countries with most rapidly growing populations on the planet (even without global climate change this is an issue)
- Essentially agrarian economies which are currently susceptible to natural climate variability
Population Density in the Monsoon Regions

- >60% of world’s population resides in monsoon regions
- 10% of world population resides in Ganges Valley
What will happen to the monsoon world if global warming were to occur?

- Monsoons
- Tropical cyclones
- Droughts
- Floods
- Dust Storms

How can we improve predictions of these phenomena?
(1) Uncertainty in Natural Climate Variability

- Year-to-year variability rather small
- Associations with known large-scale climate factors (e.g., El Nino) is uncertain and variable
- Some skill has been achieved in understanding much larger and probably more important intraseasonal variability

- Great uncertainty in future monsoon variability associated with a warming world
Indian Monsoon: Intraseasonal Variability

(b) Central India pentad GPI rainfall for 1999-2002

![Graph showing rainfall for 1999-2002 in Central India](image)
(2) Uncertainty in Magnitude and Regionality of Climate Change and Global Warming

• General consensus that Asian monsoon regions will be wetter and warmer.
• Uncertainty to the degree of increased wetness or the regionality of the changes.
• Uncertainty in the manner in which interannual and intraseasonal variability may change in a warming world.
Some areas are projected to become wetter, others drier with an overall increase projected.
Land areas are projected to warm more than the oceans with the greatest warming at high latitudes.

Annual mean temperature change, 2071 to 2100 relative to 1990: Global Average in 2085 = 3.1°C

(IPCC)
But there is substantial uncertainty in the magnitude and regionality of the changes
Uncertainty in Impacts of Population Increase

- Monsoon region has largest population on planet and fastest growing
- Population increase coupled with diminishing arable land creates potential caloric crisis:
- Potential increase of communicable diseases esp. water diseases (malaria, cholera)

Calories available = \( C \times (\text{crop yield}) \times (\text{total arable land}) / \text{population} \)
Impacts of Population Increases

- Reduction of arable land due to urbanization (Bangladesh loses 2% per year)
- Decrease in caloric factor
- Increase of social stresses
(4) Uncertainty in Societal and Human Reaction

- Monsoon nations will face increased stress caused by pressure of population increase coupled with climate change effects (e.g., sea-level), water resource availability, possible increased extreme events.
- How will nations respond?
Consider Bangladesh as an example of a monsoon nation during global warming.
Bangladesh is very low-lying with an average elevation of only a few meters. The delta is susceptible to sea-level variations. In this “coastal” tidal zone (blue), stagnation and damming of flood waters exaggerates and prolongs flooding.
Floods are a Common Feature of Bangladesh

August 2002 floods
Area of Bangladesh that will be lost to cultivation due to sea-level rise in next 50 years
Area of incursions of saline water during winter period reducing winter crop productivity and water quality
Anticipated Changes in Bangladesh

- Population may increase at >2.5%/year rate (25-30 year doubling rate)
- Decrease of 2%/year arable land due to urbanization
- 25% arable land decrease in 50 years due to anticipated inundation
- Significant decrease in caloric factor
- High probability of increase extreme flooding
- Availability of fresh water: the arsenic versus disease dilemma
Bangladesh Stresses in a Warming World

- population increase
- calorie factor: \((\text{yield}) \times \frac{\text{land}}{\text{population}}\)
- arable land
- urbanization & inundation

Graph showing changes over time from 2000 to 2100 with relative units on the y-axis and year on the x-axis.
Is sustainable development even an option in a deltaic region such as Bangladesh during climate change and global warming?
Role of Atmospheric Sciences

• Help with managing environmentally sensitive aspects of societies living ever more closely to the edge
  – Severe weather warnings
  – Medium-range weather forecasts
  – Seasonal outlooks
  – Long-range possible scenarios

• However…
  – Even perfect forecasts and warnings on all time scales would not solve “the problem.”
  – Even if climate does not change, problems will still exist and worsen unless society changes behavior
Atmospheric Science is making progress and society is benefiting
Improving weather and climate models—a great success story!

Anomaly correlation of 500hPa height forecasts

- Northern hemisphere
- Southern hemisphere

Last Millennium Simulation with Paleo-CSM 1.4

- Paleo-CSM 1.4 calibrated to Land et al. (1995), and IPCC AR3
- Proxy reconstruction (Jones et al. 1998)
- Instrumental record (Jones et al. 2006)
- Paleo-CSM 1.4 (natural only, no anthropogenic forcing)

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<table>
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<th>Year (AD)</th>
<th>Observed</th>
<th>Simulated</th>
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- Warmest year: 1990
- Simulations:
  - Pre-industrial
  - Post-industrial

CSM-Forcing:

- 1.0 - 0.7°C colder than observations over 1850s:
- This would represent the largest deviation from observations over the Millenium

Year 2000

- Rainfall (mm)

Year 2002
WRF 48 h Hurricane Ivan Reflectivity Forecast

00 UTC 11 to 00 UTC 13 Sep 04

GOES IR 10:45 UTC 9/14/04 4 km WRF forecast
• **Appreciate** that the monsoon regions of the world are most vulnerable regions to climate change and global warming

• Even if CO2 levels were held at 1990 levels there will be a high probability of societal stress in the monsoon regions

Thus: **appreciate** the problems of population increase even in the absence of global warming
Actions (continued)

- Do not let “uncertainty” be an excuse for inaction
- Let “uncertainty” be the basis of risk analysis of the probabilities of occurrence of events and the basis of reasoned solutions
- Actions must be internationally based through such organizations as the United Nations
- Determine long-term strategies based on risk assessment of possible scenarios
What we do in our generation will determine the destiny of life on our planet.

What we do in the next ten years will determine what is possible in the next fifty.
Thank you