CLIMATE CHANGE 2009

SCIENCE COMPENDIUM

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UNEP

Foreword

The science has become more irrevocable than ever: Climate change is happening. The evidence is all around us. And unless we act, we will see catastrophic consequences including rising sea levels, droughts and famine, and the loss of up to a third of the world's plant and animal species.

We need a new global agreement to tackle climate change, and this must be based on the soundest, most robust and up-to-date science available.

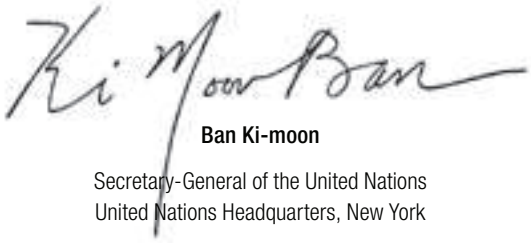
Through its overview of the latest definitive science, this Climate Change Science Compendium reaffirms the strong evidence outlined in the IPCC's 4th Assessment Report that climate change is continuing apace.

In fact, this report shows that climate change is accelerating at a much faster pace than was previously thought by scientists. New scientific evidence suggests important tipping points, leading to irreversible changes in major Earth systems and ecosystems, may already have been reached or even overtaken.

Climate change, more than any other challenge facing the world today, is a planetary crisis that will require strong, focused global action.

As pressures build for an internationally agreed response, we now have a once-in-a-generation opportunity to come together and address climate change through a newly invigorated multilateralism. This will be our chance to put in place a climate change agreement that all nations can embrace – an agreement that is equitable, balanced and comprehensive.

This Climate Change Science Compendium is a wake-up call. The time for hesitation is over. We need the world to realize, once and for all, that the time to act is now and we must work together to address this monumental challenge. This is the moral challenge of our generation.



Ban Ki-moon

Secretary-General of the United Nations
United Nations Headquarters, New York

September 2009

Preface

If governments are to make informed and transformative choices concerning climate change, they require the best and most up to date science.

Two years ago, in 2007, the Intergovernmental Panel on Climate Change's Fourth Assessment Report provided the world with conclusive proof that humans are altering the climate.

It also outlined a range of sobering impact scenarios covering sea-level rise and extreme weather events, as well as the implications for agricultural production, human health, and the marine food chain.

The IPCC's unique, consensus-led process has been at the centre of catalyzing a political response to the phenomena unfolding across the planet as a result of fossil fuel emissions and land use changes.

In a matter of a few weeks' time, governments will gather in Copenhagen, Denmark, for a crucial UN climate convention meeting. Many governments and stakeholders have requested an annual snapshot of how the science has been evolving since the publication of the IPCC's landmark fourth assessment in advance of the panel's next one in 2014.

This Climate Change Science Compendium, based on the wealth of peer-reviewed research published by researchers and institutions since 2006, has been compiled by UNEP in response to that request. The findings indicate that ever more rapid environmental change is underway with the pace and the scale of climate change accelerating, along with the confidence among researchers in their forecasts.

The Arctic, with implications for the globe, is emerging as an area of major concern. There is growing evidence that the ice there is melting far faster than had been previously supposed. Mountains glaciers also appear to be retreating faster. Scientists now suggest that the Arctic could be virtually ice free in September of 2037 and that a nearly ice-free September by 2028 is well within the realms of possibility. Recent findings also show that significant warming extends well beyond the Antarctic Peninsula to cover most of West Antarctica, an area of warming much larger than previously reported.

The impact on the Earth's multi-trillion dollar ecosystems is also a key area of concern. Under a high emission scenario—the one that most closely matches current trends—12–39 per cent of the planet's terrestrial surface could experience novel climate conditions and 10–48 per cent could suffer disappearing climates by 2100.

Rising levels of aridity are also concentrating scientific minds. New research indicates that by the end of the 21st century the Mediterranean region will also experience much more severe increases in aridity than previously estimated rendering the entire region, but particularly the southern Mediterranean, even more vulnerable to water stress and desertification.

While the Compendium presents current science, it can never replace the painstaking rigour of an IPCC process—a shining example of how the United Nations can provide a path to consensus among the sometimes differing views of more than 190 nations.

However, I hope the Compendium will provide important insights into the rapidly developing and fast moving realm of climate science so that the choices made by leaders in Copenhagen in December are informed by the best and the latest research available to the international community.

Achim Steiner

UN Under-Secretary General and Executive Director,
United Nations Environment Programme

September 2009

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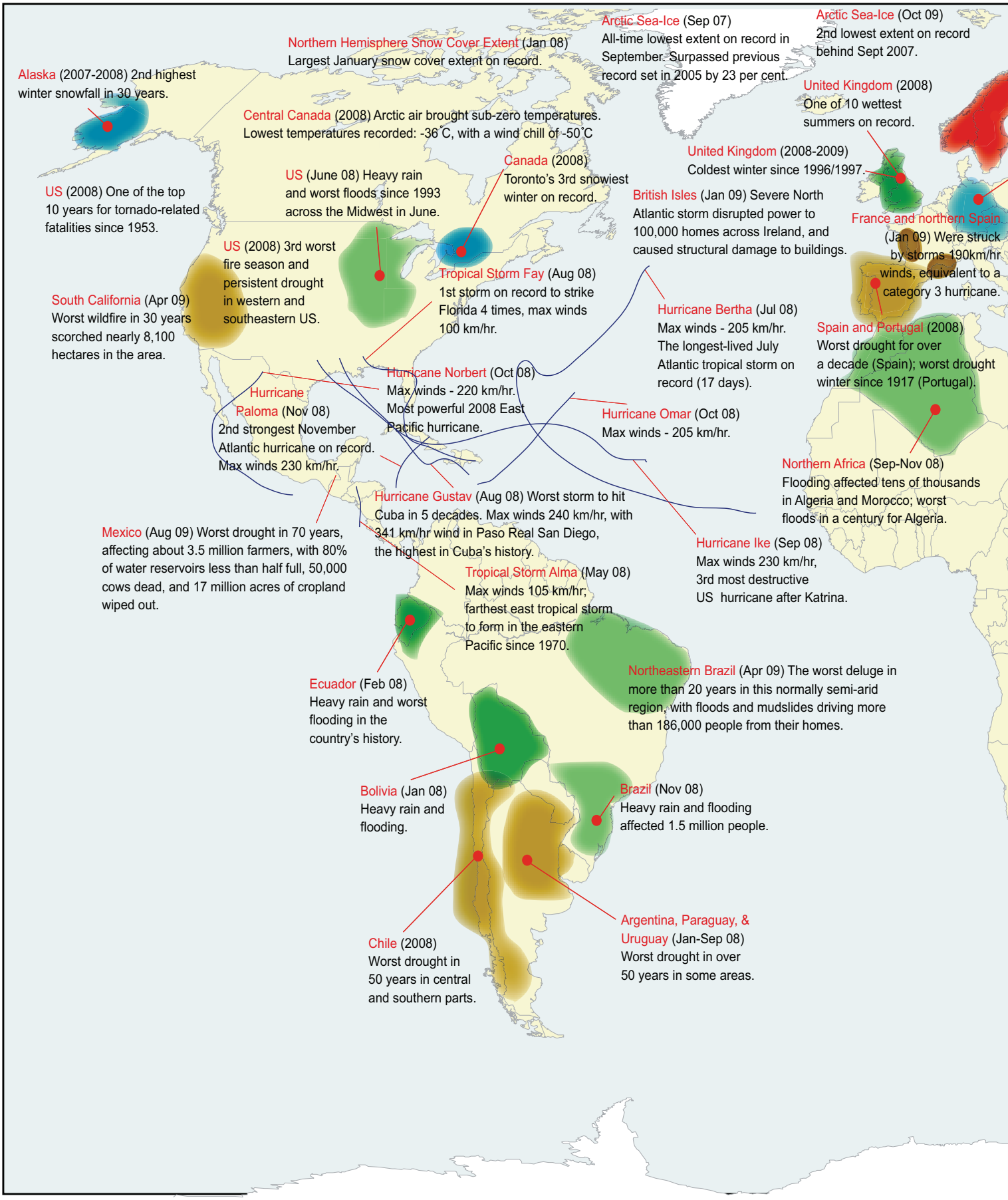
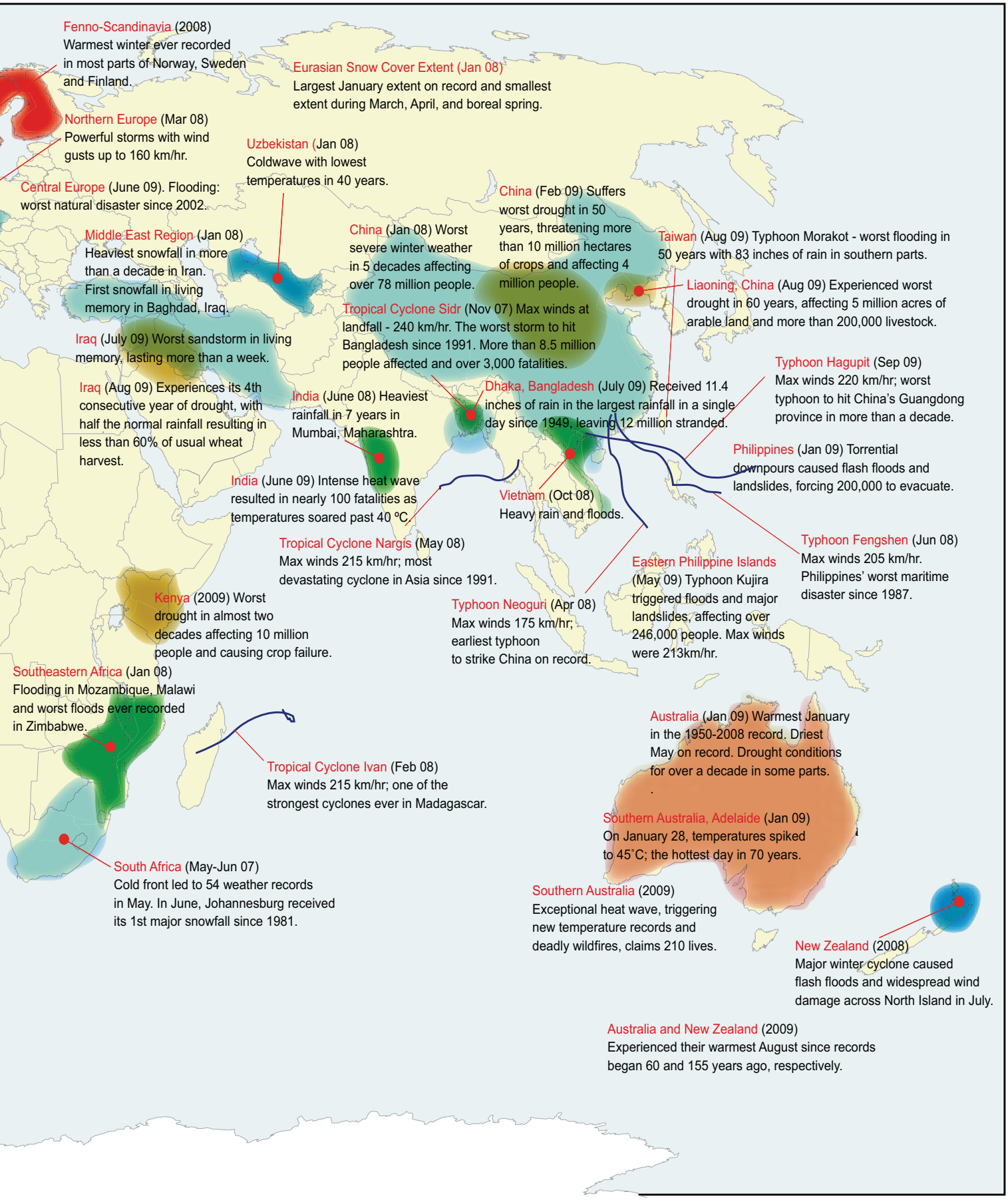
EARTH SYSTEMS

Significant climate anomalies from 2007 to 2009



Source: NOAA 2007, NOAA 2008, NOAA 2009a


Fenno-Scandinavia (2008)
Warmest winter ever recorded in most parts of Norway, Sweden and Finland.
Eurasian Snow Cover Extent (Jan 08)
Largest January extent on record and smallest extent during March, April, and boreal spring.
Northern Europe (Mar 08)
Powerful storms with wind gusts up to 160 km/hr.
Uzbekistan (Jan 08)
Coldwave with lowest temperatures in 40 years.
Central Europe (June 09). Flooding: worst natural disaster since 2002.
China (Feb 09) Suffers worst drought in 50 years, threatening more than 10 million hectares of crops and affecting 4 million people.
Middle East Region (Jan 08)
Heaviest snowfall in more than a decade in Iran.
First snowfall in living memory in Baghdad, Iraq.
China (Jan 08) Worst severe winter weather in 5 decades affecting over 78 million people.
Taiwan (Aug 09) Typhoon Morakot - worst flooding in 50 years with 83 inches of rain in southern parts.
Liaoning, China (Aug 09) Experienced worst drought in 60 years, affecting 5 million acres of arable land and more than 200,000 livestock.
Tropical Cyclone Sidr (Nov 07) Max winds at landfall - 240 km/hr. The worst storm to hit Bangladesh since 1991. More than 8.5 million people affected and over 3,000 fatalities.
Iraq (July 09) Worst sandstorm in living memory, lasting more than a week.
Typhoon Hagupit (Sep 09)
Max winds 220 km/hr; worst typhoon to hit China's Guangdong province in more than a decade.
Iraq (Aug 09) Experiences its 4th consecutive year of drought, with half the normal rainfall resulting in less than 60% of usual wheat harvest.
India (June 08) Heaviest rainfall in 7 years in Mumbai, Maharashtra.
Dhaka, Bangladesh (July 09) Received 11.4 inches of rain in the largest rainfall in a single day since 1949, leaving 12 million stranded.
Philippines (Jan 09) Torrential downpours caused flash floods and landslides, forcing 200,000 to evacuate.
India (June 09) Intense heat wave resulted in nearly 100 fatalities as temperatures soared past 40 ºC.
Vietnam (Oct 08)
Heavy rain and floods.
Typhoon Fengshen (Jun 08)
Max winds 205 km/hr.
Philippines' worst maritime disaster since 1987.
Tropical Cyclone Nargis (May 08)
Max winds 215 km/hr; most devastating cyclone in Asia since 1991.
Eastern Philippine Islands (May 09) Typhoon Kujira triggered floods and major landslides, affecting over 246,000 people. Max winds were 213km/hr.
Kenya (2009) Worst drought in almost two decades affecting 10 million people and causing crop failure.
Typhoon Neoguri (Apr 08)
Max winds 175 km/hr; earliest typhoon to strike China on record.
Southeastern Africa (Jan 08)
Flooding in Mozambique, Malawi and worst floods ever recorded in Zimbabwe.
Australia (Jan 09) Warmest January in the 1950-2008 record. Driest May on record. Drought conditions for over a decade in some parts.
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Tropical Cyclone Ivan (Feb 08)
Max winds 215 km/hr; one of the strongest cyclones ever in Madagascar.
Southern Australia, Adelaide (Jan 09)
On January 28, temperatures spiked to 45˚C; the hottest day in 70 years.
South Africa (May-Jun 07)
Cold front led to 54 weather records in May. In June, Johannesburg received its 1st major snowfall since 1981.
Southern Australia (2009)
Exceptional heat wave, triggering new temperature records and deadly wildfires, claims 210 lives.
New Zealand (2008)
Major winter cyclone caused flash floods and widespread wind damage across North Island in July.
Australia and New Zealand (2009)
Experienced their warmest August since records began 60 and 155 years ago, respectively.

Earth Systems

A thin veneer of atmosphere, soil, and water covers the surface of the planet. That is the envelope supplying most of the raw material we need to live. Energy from the Sun, with some residual energy still within the planet's core, feeds Earth's dynamic systems that cycle materials within the envelope. Earth System scientists are investigating the energy and material fluxes that determine the systems' dynamics to better understand climate change.

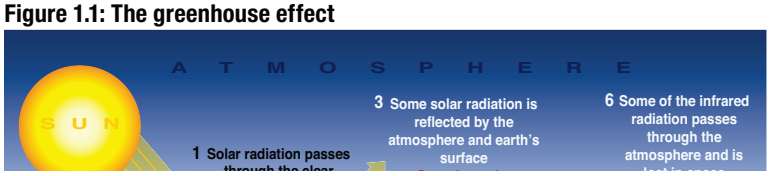
A thin veneer of atmosphere along the arc of the planet seen from a high altitude. *Source: A. Jordan, P. Cullis and E. Hall/NOAA*

INTRODUCTION

This Compendium presents some of the vanguard science and conceptual advances under discussion and published by researchers since 2006 that explores the challenge presented by climate change. Rapidly developing tools—that allow fast and accurate readings of environmental conditions, that compile and analyze data series of increasing complexities at unprecedented rates, and that allow insights into fluxes of energy and material at micro and macro scales—have accelerated the rate at which vanguard science is being produced.

In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) as a scientific body to evaluate the risk of climate change and whether it could be caused by human activity.

Figure 1.1: The greenhouse effect



Based on the findings of the first IPCC assessment, the United Nations Framework Convention on Climate Change (UNFCCC) was negotiated as an international environmental treaty produced at the United Nations Conference on Environment and Development in 1992. The treaty is aimed at stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent 'dangerous anthropogenic interference with the climate system'.

The IPCC produced its second, third, and fourth reports in 1995, 2001, and 2007 respectively, as well as a number of special reports on standardizing methodologies and focusing on particular concerns. The four IPCC Assessment Reports track scientists' growing understanding of Earth System complexities and present consensus conclusions of possible implications. The impressive body of analysis produced by collaboration among thousands of scientists and policy-makers is unrivalled and remains the final arbiter and consensus source of agreed scientific or political canon.

This Compendium serves a purpose different from the IPCC assessments. The questions addressed by the science presented here, simply concern where the frontiers of Earth System Science are evolving. What has been learned in the last few years? What is exciting the researchers and inspiring them to persist in their tests and experiments, their conceptual explorations? What is science telling us now about how climate is changing and why?

Background

Composed of different gases, the atmosphere circulates energy from the equator, where the Sun's radiation arrives most intensely, to the poles via weather systems such as cyclones, storms, and weather fronts. One of the most important circulation systems the atmosphere supports is the hydrologic cycle: Water evaporates from seas, lakes, rivers, soils, ice (sublimation), and plants (evapotranspiration) and moves through the atmosphere to precipitate as rain or snow—the precipitation that falls during monsoons and other events forms streams, rivers, lakes, permeating into soils and then into aquifers and groundwater. Plants send out roots to tap water and minerals in soils and use the Sun's energy to photosynthesize and grow. Snow solidifies into ice sheets and glaciers and in spring ice and snow melt to feed the streams and rivers that provide the water for forests and meadows and fields. Fresh water is delivered to