Outline

- Has the climate warmed?
- Has the climate become wetter?
- Are the atmosphere/ocean circulations changing?
- Has the climate become more variable or extreme?
- Is the 20th century warming unusual?
- Are the observed trends internally consistent?
Introduction

This chapter focuses on 6 questions –

• Has the climate warmed?
• Has the climate become wetter?
• Are the atmosphere/ocean circulations changing?
• Has the climate become more variable or extreme?
• Is the 20th century warming unusual?
• Are the observed trends internally consistent?

The answers to these questions critically depend on the availability of accurate, complete and consistent series of observations.

If conclusions regarding trends cannot always be drawn, it does not necessarily mean that the trends are absent!
From 1901 an equivalent warming of 0.57°C has occurred, with an uncertainty of +/- 0.18°C
The 1910-1945 warming was greatest in, but not limited to, the North Atlantic, Arctic and northern North America. By contrast, the period 1946-1975 shows widespread cooling in the Northern Hemisphere relative to much of the South. Much of the cooling was seen in Northern Hemisphere regions that showed most warming in 1910-1945. Recent warming has been greatest over the mid latitude Northern Hemisphere continents in winter. Over 1901-99 as a whole, warming is seen everywhere except south of Greenland and in a few scattered continental regions in the tropics or sub-tropics.
It is very likely that the surface has warmed relative to the troposphere, and the troposphere has warmed relative to the stratosphere since 1979. There is evidence that the troposphere warmed relative to the surface in the pre-satellite era (1958-1979), though confidence in this finding is lower.
Northern Hemisphere annual snow cover extent has decreased by about 10% since 1966 largely due to decreases in spring and summer since the mid-1980s over both the Eurasian and American continents.

During November 1978 through December 2000, the sea ice extent over the Northern Hemisphere showed a decrease of -2.8% +/- 0.3% per decade.
Mid and High Latitudes: During the 20th Century, annual-zonally averaged precipitation increased between 9% and 16% for the zones 30N to 85N and by about 2 to 5% between 0S to 55S during this time.

Tropics and Sub-Tropics: The increase of precipitation in the middle and high latitudes contrasts with decreases in the northern subtropics.
While the estimated uncertainties in these reconstructed series are substantial, they suggest that the very large 1982-83 and 1997-98 warm events might be outside the range of variability of the past few centuries.
There was an apparent shift in the temperature of the tropical Pacific around 1976 to warmer conditions, discussed in IPCC-1995, which appeared to continue until at least 1998. During this period ENSO events were more frequent, intense or persistent.
Has the Climate Become More Extreme or Variable?

• It is likely that there has been a widespread increase in heavy and extreme precipitation events in regions where total precipitation has increased, e.g., the mid and high latitudes of the Northern Hemisphere.

• New record high night-time minimum temperatures are lengthening the freeze-free season in many mid and high latitude regions.

• The increase of global temperatures has resulted mainly from a significant reduction in the frequency of much below-normal seasonal mean temperatures across much of the globe, with a corresponding but smaller increase in the frequency of much above normal temperatures.

• There is little sign of long-term changes in tropical storm intensity and frequency.
Mann et al calibrated a combined terrestrial (tree ring, ice core, and historical documentary indicators) and marine (coral) multi-proxy climate network against dominant patterns of 20th century global surface temperature. They estimated Northern Hemisphere mean temperature back to AD 1000. The uncertainties (the shaded region in Figure 13) expand considerably in earlier centuries because of the sparse network of proxy data. Taking this into account, Mann et al concluded that the 1990s were likely to have been the warmest decade, and 1998 the warmest year, of the past millennium for at least the Northern Hemisphere.
Are the Observed Trends Internally Consistent?

**Temperature Indicators**

**OCEAN** | **LAND** | **OCEAN**
--- | --- | ---
**LOWER STRATOSPHERE** | **Lower stratosphere: 0.5 to 2.5°C decrease since 1979** |
TROPOSPHERE | **Little or no change since 1979** |
| **0.0 - 0.1°C increase since 1979 - satellites & balloons** |
| **0.2 to 0.4°C increase since ~1960** |
NEAR-SURFACE | **N.H. Spring snow cover extent: since 1987 10% below 1968-86 mean** |
| **1990s warmest decade of the millennium and 1998 warmest year for at least the N.H.** |
| **Marine air temperature: 0.4 to 0.7°C increase since late-19th Century** |
***Sea surface temperature: 0.4 to 0.8°C increase since the late 19th century.*** |
| **Global ocean (to 300m depth) heat content increase since 1940s equal to 0.03°C / decade** |

**Likelihood:**

*** Virtually certain (probability > 99%)
** Very likely (probability > 90% but < 99%)
* Likely (probability > 66% but < 90%)
? Medium likelihood (probability > 33% but < 66%)
Are the Observed Trends Internally Consistent?

**Hydrological and Storm-Related Indicators**

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<thead>
<tr>
<th>OCEAN</th>
<th>LAND</th>
<th>OCEAN</th>
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<tbody>
<tr>
<td><strong>LOWER STRATOSPHERE</strong></td>
<td>* 20% water vapor increase since 1980 (above 18 km)</td>
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<tr>
<td><strong>TROPOSPHERE</strong></td>
<td>Water vapor</td>
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<td>upper troposphere:</td>
<td>*no significant global trends since 1980; 15% increase in tropics (10°N-10°S)</td>
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<td>troposphere:</td>
<td>*many regions with increases since about 1960</td>
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<td>? 2% increase in total cloud amount over the ocean since 1952</td>
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<td><strong>NEAR-SURFACE</strong></td>
<td>?no systematic large-scale change in tornadoes, thunder-days, hail</td>
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<tr>
<td>? 2-3% decrease in subtropics</td>
<td><strong>20th Century</strong> land surface rainfall</td>
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<tr>
<td>? 2-3% increase in tropics</td>
<td><strong>5 to 10% increase in mid-to-high latitude precipitation since 1900, with much of it due to heavy / extreme events</strong></td>
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<tr>
<td><strong>no widespread changes in tropical storm frequency / intensity during the 20th century</strong></td>
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<tr>
<td><strong>no consistent 20th Century change in extratropical storm frequency / intensity</strong></td>
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**Likelihood:**

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