# 1

## *Supplementary Material*

# Assessment of observed changes and responses in natural and managed systems


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# Table of Contents

**This Supplementary Material is in support of Chapter 1. The headings correspond to the sections of the main chapter. The Supplementary Material cannot and should not be read in isolation. It can only be read in association with the chapter.**

## 1.3.2 Hydrology and water resources

**Table SM-1.1.** *Examples from the literature of observed changes in (a) runoff/streamflow and (b) lake levels.*

| Location | Time period | Observed change | Reference |
|---|---|---|---|
| **(a) Runoff/streamflow** | | | |
| Arctic Ocean | 1936-2002 | Increasing annual discharge from six largest Eurasian rivers to Arctic Ocean by 7% due to Arctic Oscillation NAO and warming climate (this increase is not entirely consistent with apparent trends in temperature and precipitation, due to data limitations) | Peterson et al., 2002; Shiklomanov and Shiklomanov, 2003 |
| Sweden | 1807-2002 | No trend in runoff due to increasing temperature offsetting the increasing precipitation | Lindstrom and Bergstrom, 2004 |
| UK | Last 50 years | No trend in annual runoff | Hannaford and Marsh, 2005 |
| Finland | Last 20 years | Increase in discharge | Hyvarinen, 2003 |
| **(b) Lake levels** | | | |
| Bosten Lake, Xinjiang, China | 1980-2000 | Rise in lake level ~4 m due to increasing precipitation and snow-ice melt flow from 3.08×108 $m^3$ to 9.6×108 $m^3$ | Yuan et al., 2003 |
| Daihai Lake, China | 1700-1996 | From 1960 to 1996 lake level decreased 3.85 m due to combined effects of drought and human activities | Zhang and Ruijin, 2001 |
| Lakes, central Italy | Last 20 years | Decline in lake level due to rainfall decrease and water withdrawal | Capelli and Mazza, 2005 |
| Vortsjarv, Estonia | 1884-2000 | Strong water level fluctuation related to the North Atlantic Oscillation (NAO) | Noges et al., 2003 |

**Table SM-1.2.** *Examples from the literature of observed changes in (a) floods and (b) droughts.*

| Location | Time period | Observed change | Reference |
|---|---|---|---|
| **(a) Floods** | | | |
| Global | 1865-1999 | Increase in frequency of floods with discharges exceeding 100-year levels from 29 large river basins more than 200,000 $km^2$ | Milly et al., 2002 |
| Elbe and Dresden, Germany | 1997-2002 | Catastrophic events much larger than 100-year flood, but no increasing trend in flood magnitude in a record from 1827 | Becker and Grunewald, 2003; Kundzewicz et al., 2005 |
| Bangladesh | 1980s-1998 | >50-to-100-year floods from strong monsoons | Chowdhury and Ward, 2003 |
| Yangtze River, China | 1990-1999 | >50-year floods due to El Niño events | Qian and Zhu, 2001 |
| **(b) Droughts** | | | |
| Much of UK | 20th century | No evidence of significant increase in the occurrence of low river flows | Hannaford and Marsh, 2005 |
| Much of Europe | 1911-1995 | No evidence of significant increase in droughts (defined as streamflow below a certain threshold). However, recently Europe has suffered prolonged drought associated with the severe summer heatwave | Hisdal et al., 2001; Hannaford and Marsh, 2005; van der Schrier et al., 2005 |
| Eastern USA | 1941-1999 | Significant increase in annual minimum (202 out of 395 sites) and median (219 sites) daily streamflow around 1970 as a step change related to precipitation increase and NAO | Douglas, 2000; McCabe, 2002; Groisman, 2004 |
| New England, USA | 20th century | No evidence of significant increase in droughts (defined as streamflow below a certain threshold) | Hodgkins et al., 2005 |
| Australia | 2002-2003 | Severe drought due to record high temperature | Karoly et al., 2003; Nicholls, 2004 |
| Sahelian drought | 1981-1993; 1994-2005 | (a) 1981-1993 marked by below average Normalised Difference Vegetation Index (NDVI) and persistence of drought<br>(b) 1994-2005 marked by a trend towards 'wetter' condition, but still far below the pre-1980s wetter condition | Hisdal et al., 2001; Hannaford and Marsh, 2005; Hodgkins et al., 2005; van der Schrier et al., 2005 |

**Table SM-1.3.** *Examples from the literature of observed changes in physical and chemical water properties.*

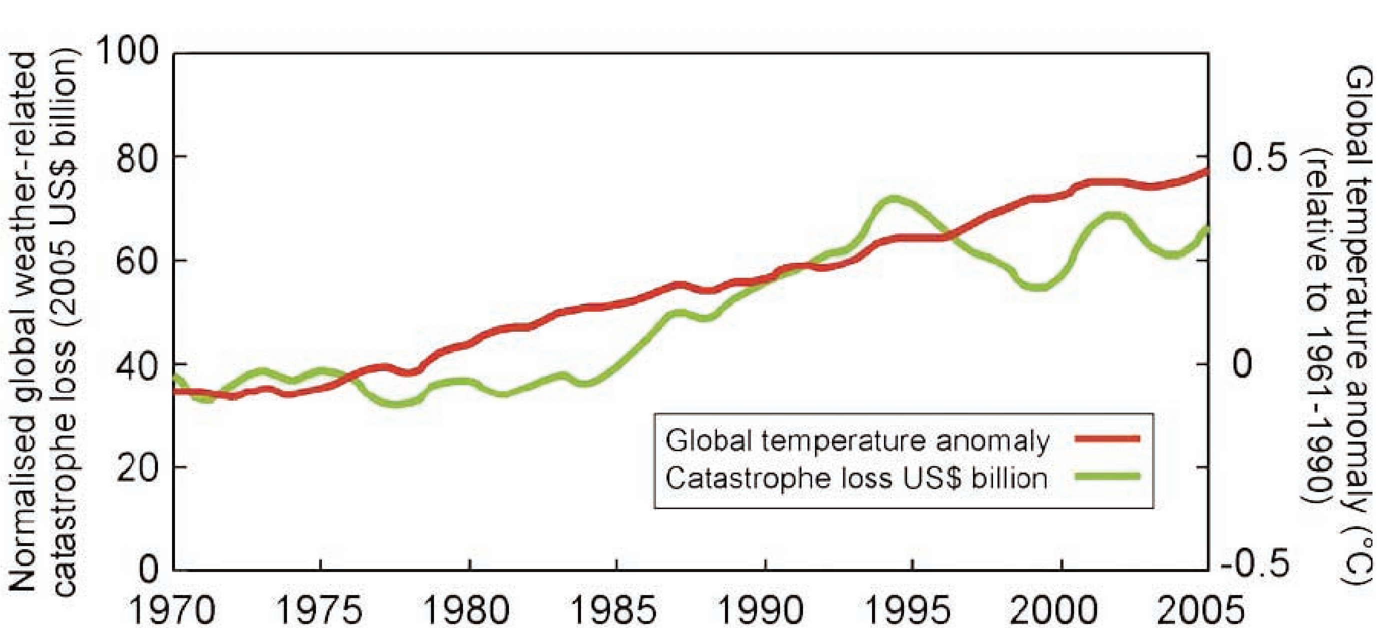
| Location | Time period | Observed change | Reference |
|---|---|---|---|
| 64 lakes/rivers in Europe, North America and Asia | Last 40 years | Surface water temperature warming by 0.2-1.5°C for 17 lakes. Stratified period has advanced by up to 20 days and lengthened by 2-3 weeks with increased thermal stability | Adrian and Deneke, 1996; King et al., 1998; Livingstone and Dokulil, 2001; Carvalho and Kirika, 2003; Livingstone, 2003; Straile et al., 2003; Arhonditsis et al., 2004; Dabrowski et al., 2004; Winder and Schindler, 2004 |
| 8 lakes/rivers in North America, Europe and East Africa | 1991-2003<br>1939-2000 | Decreases in nutrients in surface water and corresponding increases in deep-water concentration because of reduced upwelling due to greater thermal stability | Hambright et al., 1994; Adrian and Deneke, 1996; Straile et al., 2003 |
| Lake Baikal, Russia | Recent decades | Decrease in silica content of 30% related to regional warming | Shimaraev et al., 2004 |
| 27 rivers, Japan | Recent decades | Increase in biological oxygen demand and suspended solids, and decrease in dissolved oxygen due to increase in air temperature | Ozaki et al., 2003 |

### 1.3.3 Coastal processes and zones

**Table SM-1.4.** *Examples from the literature of changes in storm surges, flood heights and areas, and waves.*

| Type of change | Period | Location | References |
|---|---|---|---|
| More frequent and higher floods due to subsidence, hydrodynamic changes and relative sea-level rise | 1830-2000 | Venice, Italy | Camuffo and Stararo, 2004 |
| Decreasing surges due to shifts in wind direction | 1890s-1910s and 1950s-1997 | Brittany, France | Pirazzoli et al., 2004 |
| Increasing extreme high water levels due to climate variability and sea-level rise | 1975-present | Global | Woodworth and Blackman, 2004 |
| Decrease in mean winter significant wave height | 1958-2001 | Mediterranean Sea | Lionello et al., 2005 |

### 1.3.8 Disasters and hazards




**Errata Figure SM-1.1.** *An example from the literature of one study analysing rising costs of normalised weather-related catastrophes compared with global temperatures. Data smoothed over ±4 years = 9 years until 2001 (Muir Wood et al., 2006).*

## 1.4 Larger-scale aggregation and attribution to anthropogenic climate change

**Table SM-1.5.** *Characteristics of the data used in the aggregation and attribution assessment of Section 1.4.*

1. Database constructed of observations from studies, including information such as:
   a. category and region (according to WGII Chapters),
   b. longitude and latitude of study,
   c. study dates and duration,
   d. direction of change, consistent or not consistent with warming,
   e. statistical significance,
   f. type of impact and system,
   g. whether or not land use was a driving factor.

2. Criteria for inclusion of study in synthesis assessment:
   - published peer-reviewed study,
   - statistically significant trend in change in system related to temperature or related climate variable,
   - changes observed in systems between 1970 and 2004; studies may extend after 2004,
   - studies ending in 1990 or later,
   - duration of study period 20 years or longer.

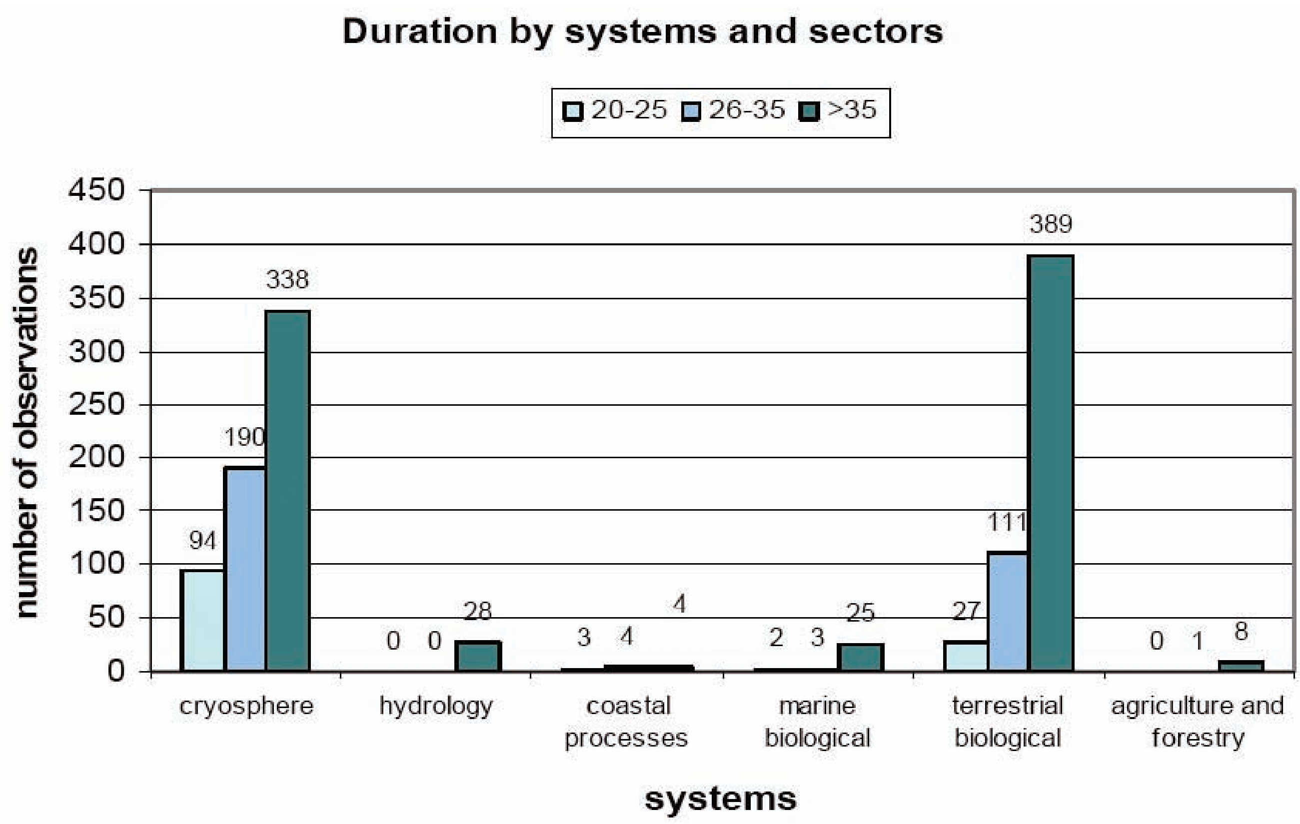



**Figure SM-1.2.** *Duration of time-series (years) of observed changes in natural and managed systems used in statistical analysis of synthesis assessment in Section 1.4.*

**Table SM-1.6.** *Summary of observed impacts of temperature-related regional climate change in chapter synthesis assessment in Section 1.4.*

| | |
|---|---|
| **Cryosphere** | Changes in glaciers, lake and river ice break-up, snow cover and permafrost active layer |
| **Hydrology** | Changes in spring peak discharge and lake levels |
| **Coastal processes** | Changes in storminess and coastal vegetation, shoreline retreat, coastal erosion |
| **Marine, freshwater and terrestrial biological systems** | Changes in phenology, community composition, productivity and synchrony; shifts in latitude/altitude ranges and breeding sites; genetic adaptation |

**Table SM-1.7.** *Comparison of significant observed changes in physical and biological systems with regional temperature changes at the global scale in chapter synthesis assessment in Section 1.4.*

| Temperature cells | Cells with significant observed change consistent with warming* | Cells with significant observed change not consistent with warming | Cells with significant observed change consistent with warming** |
|---|---|---|---|
| **Significant warming** | 49% (2.5%) | 9% (2.5%) | 56% (5%) |
| **Warming** | 31% (22.5%) | 4% (22.5%) | 36% (45%) |
| **Cooling** | 6% (22.5%) | 0% (22.5%) | 6% (45%) |
| **Significant cooling** | 2% (2.5%) | 0% (2.5%) | 2% (5%) |
| **Chi-squared value (significance level)** | | 350 (<<1%) | 104 (<<1%) |

* assuming three-fold null hypothesis; ** assuming two-fold null hypothesis; see text for full explanation

Note: Fraction of 5°×5° cells with significant observed changes in systems (from studies considered in this chapter) and temperature changes (over 1970-2004 from HadCRUT3 – Brohan et al., 2006) in different categories (significant warming, warming, cooling, significant cooling). Expected values shown in parentheses are for the null hypotheses:

(i) significant observed changes in systems are equally likely in each direction,
(ii) temperature trends are due to natural climate variations and are normally distributed,
(iii) there is no relationship between significant changes in systems and co-located warming.

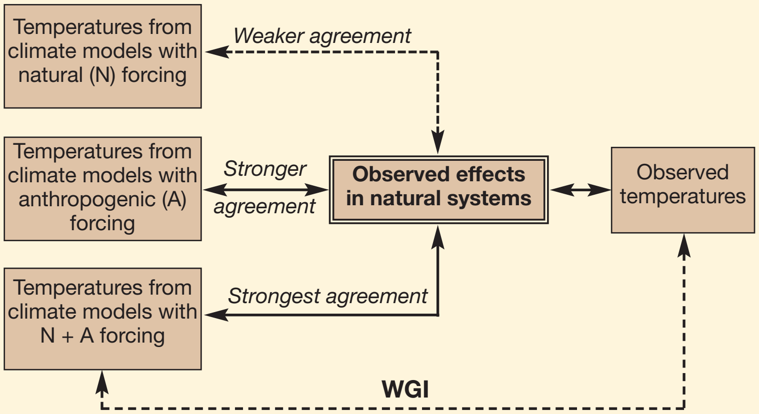
The right-hand column repeats the analysis without assuming point (i) above and only considers significant observed changes in systems that are consistent with warming, in order to avoid the possible effects of publication or research biases.

The significance levels for the chi-squared values relative to the expected distribution are obtained by comparing the locations of the significant observed system changes with regional temperature trends over 35-year periods due to natural climate variability from long control simulations with 5 different coupled climate models; 192 independent 35-year periods were sampled from the control runs, allowing estimation of chi-squared values at about the 1% significance level due to natural variability.

The analysis was repeated using a second global gridded temperature dataset (GHCN-ERSST) and there were no significant differences in the results.

Footnote 1, continued from below Box SM.1 on next page. At each location, all of which are in the Northern Hemisphere, the changing trait is compared with modelled temperatures driven by: (a) Natural forcings (pink bars), (b) anthropogenic (i.e., human) forcings (orange bars), and (c) combined natural and anthropogenic forcings (yellow bars). In addition, on each panel the frequencies of the correlation coefficients between the actual temperatures recorded during each study and changes in the traits of 83 species, the only ones of the 145 with reported local-temperature trends, are shown (dark blue bars). On average the number of years species were examined is about 28 with average starting and ending years of 1960 to 1998. Note that the agreement: a) between the natural and actual plots is weaker ($K$=60.16, $P$>0.05) than b) between the anthropogenic and actual ($K$=35.15, $P$>0.05), which in turn is weaker than c) the agreement between combined and actual ($K$=3.65, $P$<0.01). Taken together, these plots show that a measurable portion of the warming regional temperatures to which species are reacting can be attributed to humans, therefore showing joint attribution (see Chapter 1).

## Box SM.1. Linking the causes of climate change to observed effects on physical and biological systems. In chapter synthesis assessment in Section 1.4



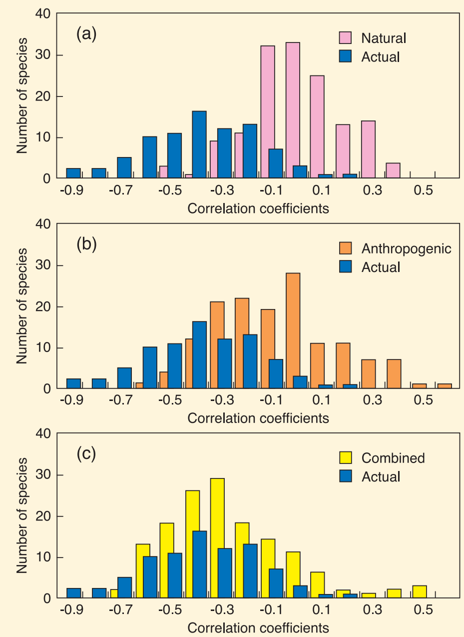

The figure to the left demonstrates the linkages between observed temperatures, observed effects on natural systems, and temperatures from climate model simulations with natural, anthropogenic, and combined natural and anthropogenic forcings. Two ways in which these linkages are utilised in detection and attribution studies of observed effects are described below.

### 1. Using climate models

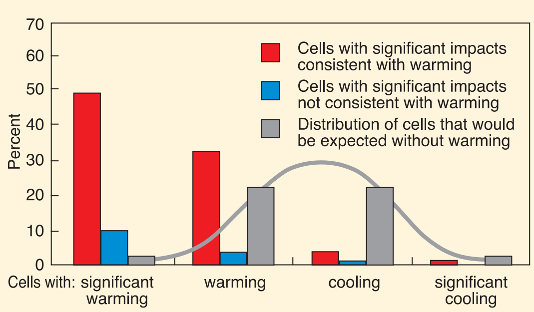
The study of causal connection by separation of natural and anthropogenic forcing factors compares observed temporal changes in animals and plants with changes over the same time periods in observed temperatures as well as modelled temperatures using (i) only natural climate forcing; (ii) only anthropogenic climate forcing; and (iii) both forcings combined.

The panel to the right shows the results from a study employing this methodology[1]. The locations for the modelled temperatures were individual grid boxes corresponding to given animal and plant study sites and time periods.

The agreement (in overlap and shape) between the observed (blue bars) and modelled plots is weakest with natural forcings, stronger with anthropogenic forcings, and strongest with combined forcings. Thus, observed changes in animals and plants are likely responding to both natural and anthropogenic climate forcings, providing a direct cause-and-effect linkage [F1.7, 1.4.2.2].




### 2. Using spatial analysis




The study of causal connection by spatial analysis follows these stages: (i) it identifies 5° × 5° latitude/longitude cells across the globe which exhibit significant warming, warming, cooling, and significant cooling; (ii) it identifies 5° × 5° cells of significant observed changes in natural systems that are consistent with warming and that are not consistent with warming; and (iii) it statistically determines the degree of spatial agreement between the two sets of cells. In this assessment, the conclusion is that the spatial agreement is significant at the 1% level and is very unlikely to be solely due to natural variability of climate or of the natural systems.

Taken together with evidence of significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica [WGI AR4[2] SPM], this shows a discernible human influence on changes in many natural systems [1.4.2.3].

[1] Plotted are the frequencies of the correlation coefficients (associations) between the timing of changes in traits (e.g., earlier egg-laying) of 145 species and modelled (HadCM3) spring temperatures for the grid-boxes in which each species was examined. (Continues at bottom of previous page).

[2] IPCC, 2007: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, Eds., Cambridge University Press, Cambridge, 996 pp.

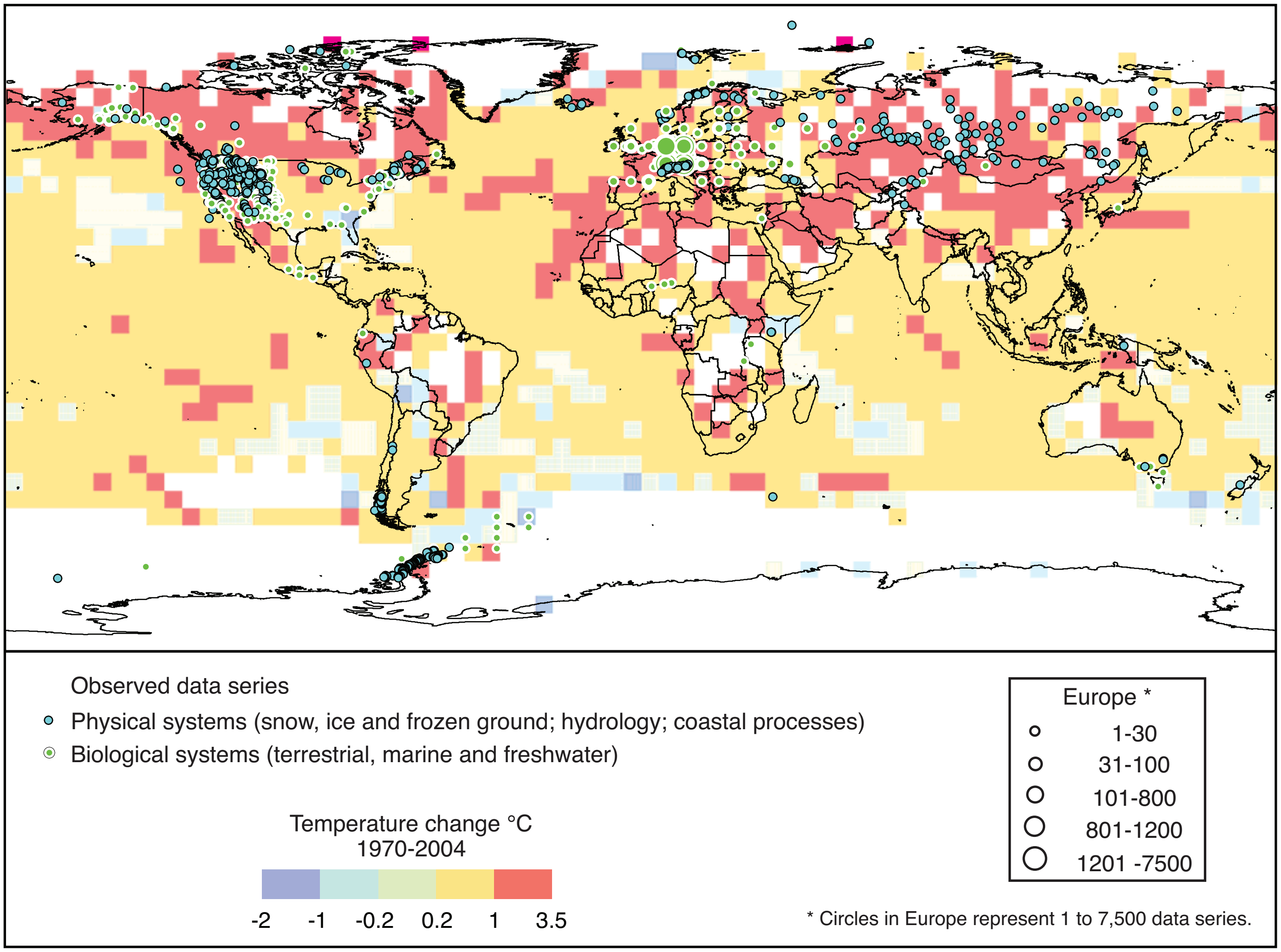



**Figure SM-1.3.** *Observed changes in physical systems (cryosphere, hydrology and coastal processes) and biological systems (marine and freshwater biological systems, terrestrial biological systems) for studies ending in 1990 or later with at least 20 years of data used in chapter sysnthesis assessment in Section 1.4. Dots represent about 75 studies, which have >29,000 data series (of which ~27,800 are from European phenological studies of flora and fauna). Observed trends in surface air temperature and sea-surface temperature 1970-2004 (HadCRUT3 Brohan et al., 2006). White regions do not contain sufficient observational climate data to estimate a trend.*

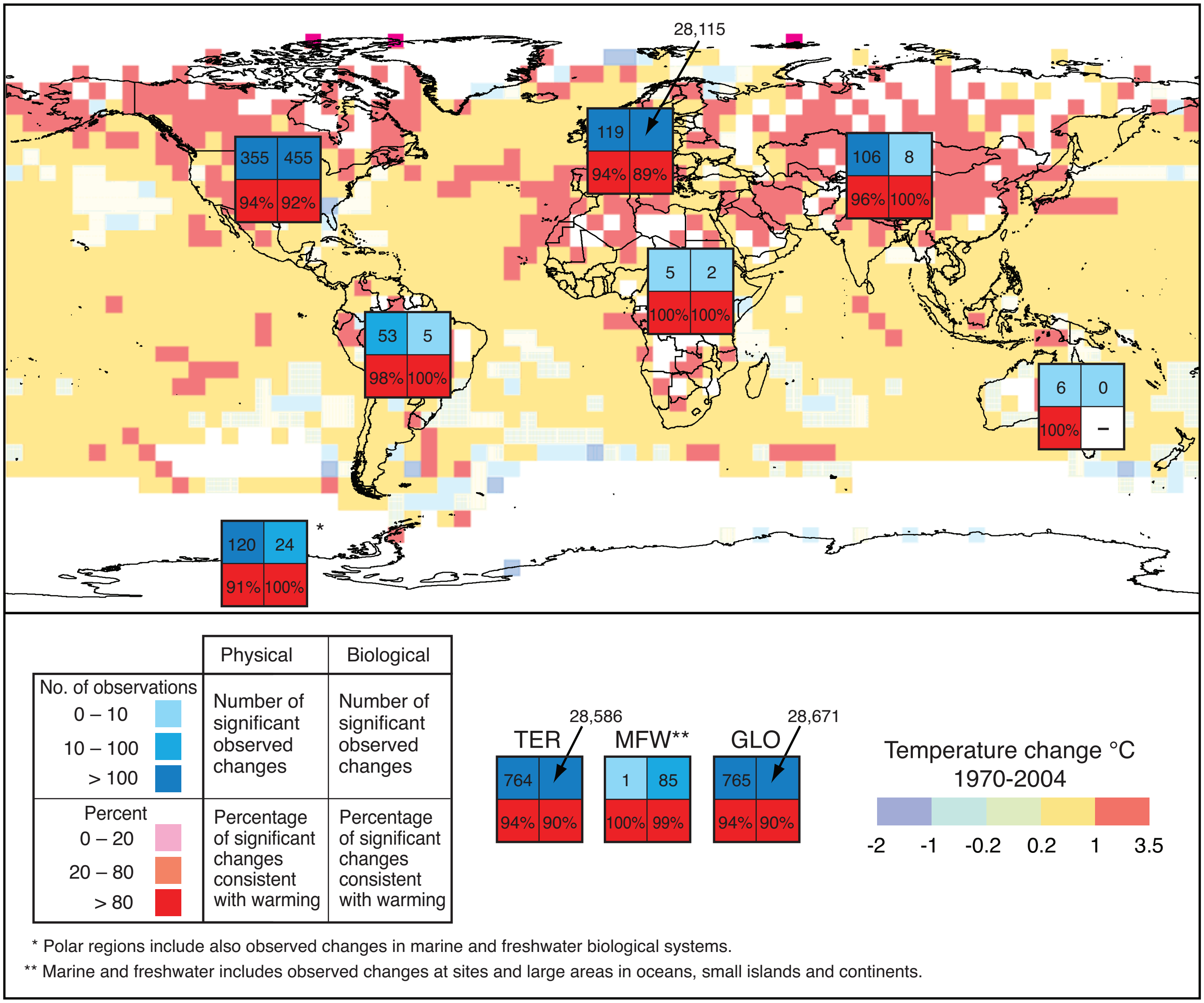



**Figure SM-1.4.** *Changes in physical and biological systems and surface temperature used in chapter synthesis assessment in Section 1.4. Background shading, and the key to the bottom right, show changes in gridded surface temperatures over the period 1970-2004. The boxes, and the key to bottom left, show the continental-scale changes in physical (left-hand column) and biological (right-hand column) systems calculated from individual series with at least 20 years data in the 1970-2004 period; the top row shows the number of observed series matching the length criterion that show a significant trend and the bottom row shows the percentage of these in which the trend is consistent with warming. At the global scale TER = Terrestrial; MFW = Marine and Freshwater, and GLO = Global.*

**Table SM-1.8.** *References of studies that fit the criteria selected for global synthesis assessment in Section 1.4.*

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| | | | |
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