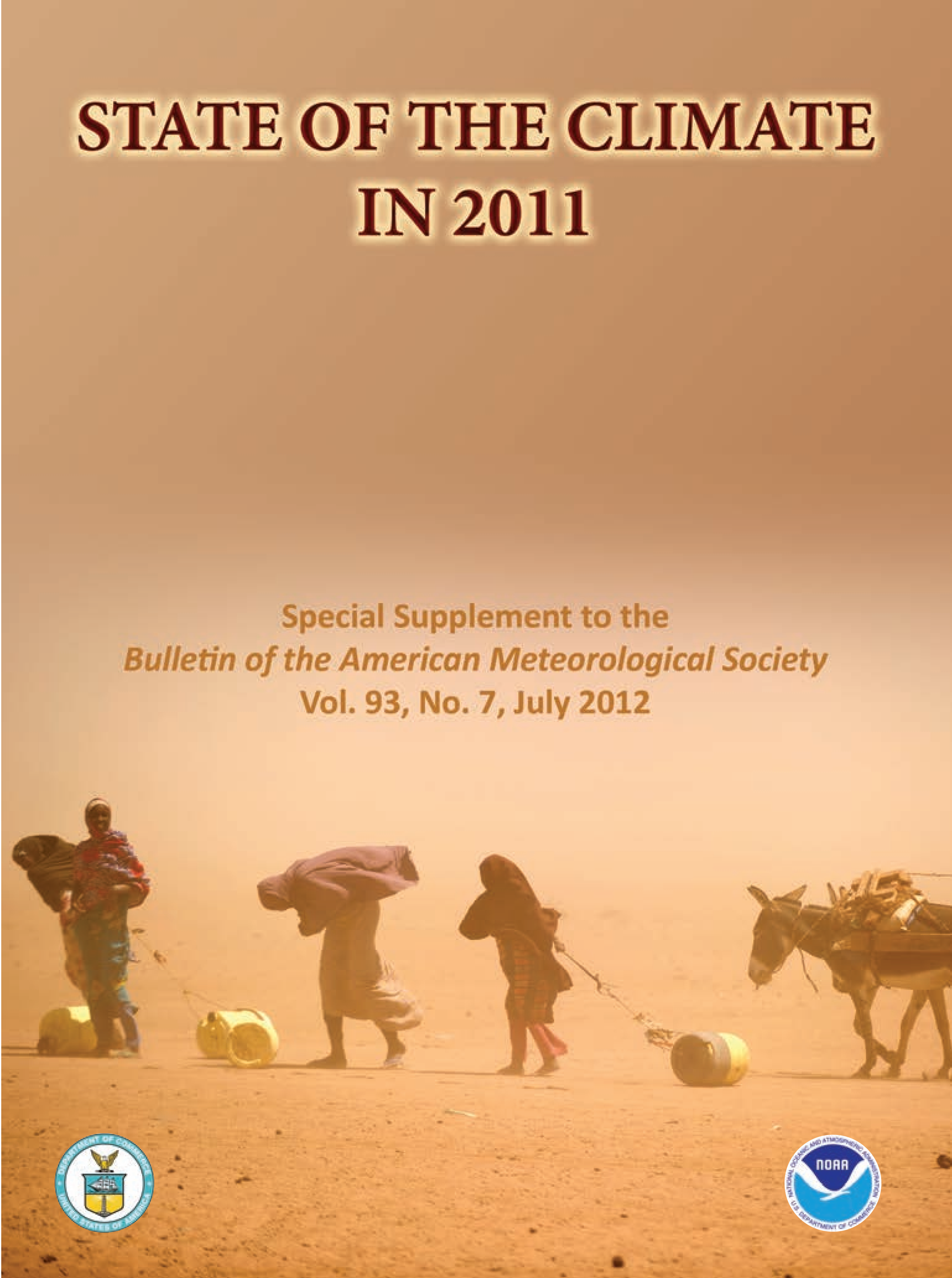
STATE OF THE CLIMATE IN 2011



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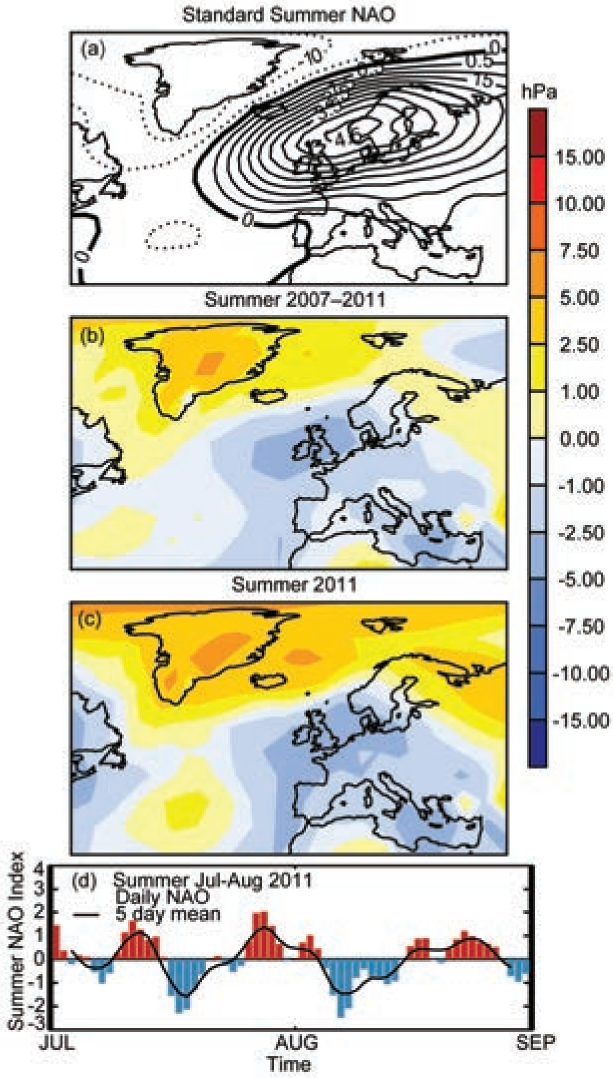

Fig. 2.33. Summer NAO patterns for July to August. (a) Standard pattern in hPa anomalies, (b) and (c) HadSLP2r sea level pressure anomalies (hPa; 1961–90 base period), and (d) daily summer NAO index (Folland et al. 2009) where red bars show the positive phase and blue bars show the negative phase.

In boreal summer, especially July and August, there is a comparable atmospheric circulation pattern to the winter NAO known as the summer NAO (SNAO; Folland et al. 2009). This is more restricted in latitude (Fig. 2.33a) and explains a somewhat smaller fraction of sea level pressure variance. Its southern node stretches from the northeast Atlantic to Scandinavia, such that when the SNAO is positive, this area has an anticyclonic anomaly, bringing generally warm and dry conditions to northwest Europe. There is a corresponding northward shift of the jet stream. Figure 2.33d shows the standardized daily time series of the SNAO index for summer 2011, indicating a neutral mean state. However, this reflected a southward shifted negative southern node (Fig. 2.33c) that gave a rather cool, wet, summer over many parts of the UK, though Scandinavia, while rather wet overall was generally warm (see section 7f for more details). The SNAO shows pronounced multiannual to multidecadal variations like the winter NAO, but uncorrelated with winter NAO variability over the last 150 years. Figure 2.33b shows sea level pressure anomalies in July and August averaged over 2007–11 near Europe. A strong impact of the negative SNAO pattern (-0.66 standard deviations) was wetter than normal conditions over the southern node (not shown). The previous five-year mean (2002–06), including the two very warm UK summers of 2003 and 2006, was by contrast +0.64 standard deviations.

2) Surface winds

(i) *Land surface winds and atmospheric evaporative demand*—R. Vautard, T. R. McVicar, J.-N. Thépaut, and M. L. Roderick

Land surface winds have a major influence on society and the economy, impacting infrastructure, forests, wind energy production, hydrology, and ecosystems through land-surface exchanges. Long-term wind changes are difficult to characterize because measurements have undergone changes in location, observation protocols, and techniques in many places. Nevertheless, many regional studies concur in declining surface wind speeds in the mid-

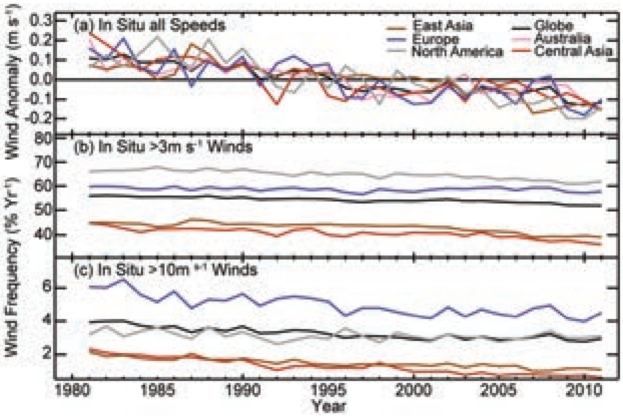

Fig. 2.34. Global and regional average annual mean land wind speed (a) anomalies (1981–2011 base period), (b) frequency of wind speeds > 3 m s^{-1} and (c) frequency of wind speeds > 10 m s^{-1}. Region definitions, means, and trends are shown in Table 2.2. In all panels global data do not include Australian data since the two datasets have undergone different processing procedures, and while the mean Australian anomaly is shown in (a), occurrence frequencies were not calculated for Australia in (b) and (c).

Table 2.2. Global and regional average wind speeds and trends over the 1981–2011 period. Number of stations varies year to year. Global data do not include Australian data since the two datasets have undergone different processing procedures.

Region	Area definition	Mean Wind Speed (m s^{-1})	Trend (m s^{-1} yr^{-1})	Number of Stations
Globe	NA	3.5	-0.0078	1100
Europe	20°W, 40°E; 30°N, 75°N	3.9	-0.0086	410
Central Asia	40°W, 100°E; 30°N, 75°N	2.5	-0.0085	50
East Asia	100°W, 160°E; 30°N, 75°N	2.7	-0.0077	230
North America	17°W, 50°W; 30°N, 75°N	4.1	-0.0105	250
Australia	NA	2.1	-0.0069	44

latitudes and the tropics and increasing winds in the high latitudes (see McVicar et al. 2012 for a global review). A major part of this trend in the Northern Hemisphere appears attributable to land cover changes, including forest growth, reforestation programs, cropland abandonment, and urbanization (Vautard et al. 2010), and also increased aerosol levels (Jacobson and Kaufman 2006).

In 2010, mean land surface wind speeds, as averaged over a site ensemble selected by Vautard et al. (2010), were shown to reach record-low values (Peterson et al. 2011a). Here, the NOAA ISD-LITE database was utilized, quality controlled similarly to Vautard et al. (2010), and augmented with Australian data (McVicar et al. 2008). The quality control leads to an objective selection retaining more than 1000 stations with observations over 1981 to 2011. With this dataset, 2011 constitutes the third weakest land surface winds year (Fig. 2.34a). In each large region of the Northern Hemisphere, mean surface wind speed was also very low, especially over Asia (record low over central Asia, second lowest value over East Asia). Over North America, the mean wind was third lowest and over Europe, sixth lowest. In the Southern Hemisphere, 2011 mean wind over Australia was also record low.

Changes in the mean frequency of surface wind speeds larger than 3 m s^{-1} are shown in Fig. 2.34b. Globally, this frequency for 2011 (51.8%) was a new record low, just below the 2010 value (51.9%). For stronger wind speeds (> 10 m s^{-1}), the 2011 frequency was 25% below the frequencies found ~30 years ago; note the record low in central Asia (Fig. 2.34c). Exactly how these changes relate to wind speeds aloft remains an interesting research question, with potential implications for renewable wind energy (McVicar et al. 2012; Mostafaeipour 2010; Cheng et al. 2012).

The wind anomaly pattern resembled that of 2010 (see Peterson et al. 2011a and Plate 2.1n), with strong negative anomalies over China, eastern North America, Asia, Australia, and western Europe contrasting with positive anomalies found at several high-latitude regions (McVicar et al. 2012, table 2). Over northwest North America and Scandinavia, ERA-Interim (Dee et al. 2011a), reproduced the observed positive anomalies reasonably well, although with smaller magnitude (compare Fig. 2.35 with Plate 2.1n). Negative anomalies are found over central Europe, Asia, and, to a lesser extent, eastern North America. The dissimilarity between reanalysis and observed land wind speed trends has been previously documented in both the Northern (Pryor et al. 2009) and Southern Hemispheres (McVicar et al. 2008). Many global climate models also do not concur with observed land winds (Johnson and Sharma 2010, table 5). On the other hand, reanalyses over oceans are in broad agreement with observations (section 2e2ii).

These anomalies and trends in wind speed bear significance for water resources. The kinetic energy in the wind is small by comparison with the turbulent (latent and sensible) heat fluxes at the surface (Peterson et al. 2011b). Despite this, the worldwide declines in pan evaporation, known as the "pan evaporation paradox" (i.e., declining pan evaporation rates in a warming globe), have been partly attributed to declining wind speeds (Roderick et al. 2007; McVicar et al. 2012, table 7). Reported declines in pan evaporation vary substantially between sites, but in the most intensively studied regions to date (US, China, and Australia), large-scale spatial averages decline at a rate of ~2 mm yr^{-1} yr^{-1} over the last 30–50 years (Fig. 2.36;

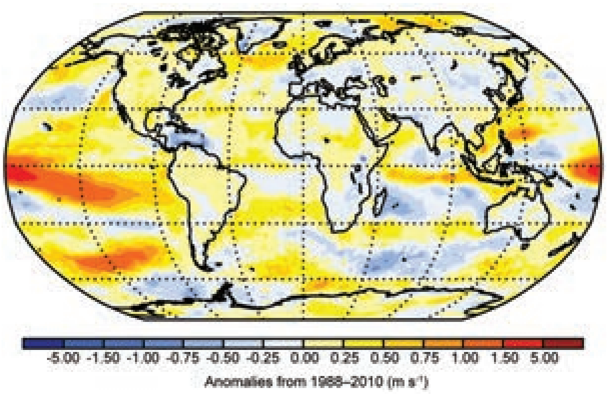

Fig. 2.35. ERA-Interim 2011 anomalies (m s^{-1}; 1988–2010 base period for comparison with Plate 2.1n) for surface wind speed.

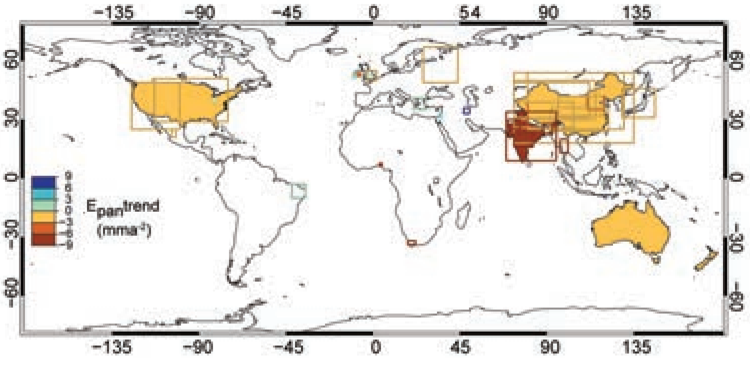

Fig. 2.36. Recent observed rates of pan evaporation trends (mm yr^{-1}) from 55 regional studies. There is incomplete geographic coverage (as shown) and the studies have different start and end dates. (Source: McVicar et al. 2012, Table 5)

McVicar et al. 2012). The hydrological implications of changing atmospheric evaporative demand are geographically variant (see Donohue et al. 2007). In extremely water-limited locations this change will have negligible implications for water resources as evaporation is already limited by water. However, in energy-limited locations and those straddling the energy-limit / water-limit divide (Viviroli et al. 2007), observed trends in atmospheric evaporative demand will have important impacts for water resource availability (Roderick et al. 2009; McVicar et al. 2012).

(ii) Ocean surface winds—C. Mears

Surface wind speed over the oceans has been monitored continuously by satellite-borne microwave radiometers since the launch of the first Special Sensor Microwave/Imager (SSM/I) satellite in late 1987. These instruments make measurements of upwelling microwave radiation to infer the surface roughness of the world's oceans, and thus the surface wind speed (Wentz 1997). Since the first SSM/I instrument, a number of additional microwave imaging sensors have been launched and intercalibrated to the accuracy necessary for climate studies (Wentz et al. 2007). Globally-averaged ocean surface winds (Fig. 2.37) exhibited a maximum in 1988–89, followed by a minimum in 1991, and an increasing trend from 1990 to 2007. In 2008–09, global ocean wind speed fell slightly, followed by recovery in 2010–11. Reanalyses show a steady increase over time, with some variability between the products. The earlier record (up to early 1990s) is less certain than later times due to fewer simultaneous satellite observations and calibration uncertainty for the first two SSM/I instruments.

Global anomalies for 2011, relative to the 1988–2010 base period, showed large positive anomalies in the central tropical Pacific, the South Pacific east of 180°W, and in the North Atlantic near 55°N. The latter coincided with the positive phase of the NAO (Hurrell et al. 2003; section 2e1) during the cool season months in 2011. Strong negative anomalies occurred east of Madagascar, in the Caribbean Sea, and in the mid-latitude North Pacific (Fig. 2.38; Plate 2.1n).

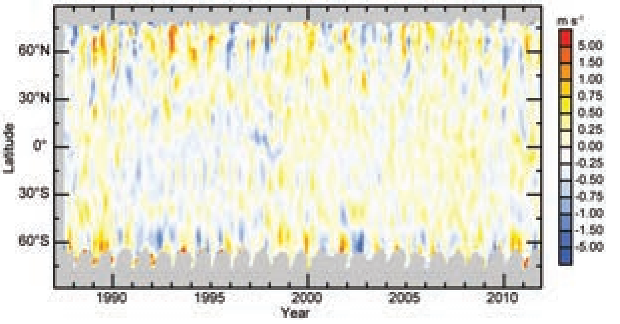

Fig. 2.38. Satellite radiometer monthly mean anomaly (m s^{-1}; 1988–2010 base period) surface wind speed over the ice-free oceans averaged by latitude. Data have been smoothed in time to remove variability on time scales shorter than four months. Gray areas indicate regions where data are unavailable.

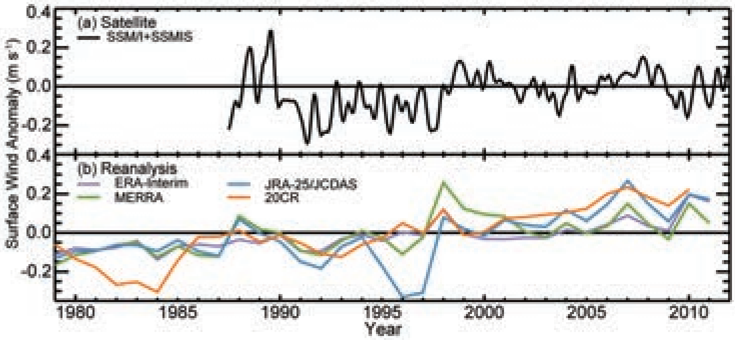

Fig. 2.37. Surface wind speed anomalies (m s^{-1}; 1988–2010 base period) over the global ice-free oceans as measured by Remote Sensing Systems from satellite-borne microwave radiometers (available online at http://www.remss.com) and reanalyses products as described in Fig. 2.1. The satellite time series has been smoothed to remove variability on time scales shorter than four months.

f. *Earth radiation budget at the top-of-atmosphere*—T. Wong, P. W. Stackhouse Jr., D. P. Kratz, P. Sawaengphokhai, A. C. Wilber, and N. G. Loeb

Analyses of the Clouds and the Earth's Radiant Energy System (CERES; Wielicki et al. 1998) instrument data taken from the combined NASA Terra and Aqua

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