

flooding in some areas but also favoring rice crops. During the same period, below-normal precipitation was recorded in the highlands. The dry conditions contributed to a higher frequency and intensity of bushfires. In the highlands of Ecuador, precipitation as high as 250% of normal fell during May–June.

In Peru, dry conditions were observed in the northwest region during the first months of 2013, while along the central and southern highlands and somewhat in the Amazonia region, precipitation was above normal. Several historical precipitation records were broken during the rainy season (January–March). During the second half of the year most of the country registered near-normal precipitation.

During 2013, Bolivia observed below-average precipitation, with the exception of the Altiplano (El Alto, Potosí, and Oruro) which had near-average precipitation. In Oruro, the total annual precipitation was 141% of normal in December. In Bolivia's valleys and low lands, precipitation was below normal most of the year with exception of December when precipitation was 116% (valleys) and 194% (low lands) of normal. The northern region of the country showed below-normal precipitation during most of the year. However, monthly precipitation totals of up to 188% of normal were recorded in September.

### *(iii) Notable events*

On 8 February, in Arequipa, Peru, a precipitation record of 125 mm, 500% of normal for the month, was registered. The heavy rain caused eight fatalities and losses of nearly \$35 million US dollars.

During 21–26 July, Peru's Madre de Dios region was affected by strong cold events with temperatures dropping between 10° and 20°C in less than 24 hours. During August, a snow storm affected the Andes region which killed over 25 300 animals, left over 5200 people homeless, and destroyed nearly 140 homes in Apurimac, Ayacucho, Cusco, Huancavelica, Puno, and Junín.

## 2) TROPICAL SOUTH AMERICA EAST OF THE ANDES—J.A. Marengo, L. M. Alves, J. C. Espinoza, and J. Ronchail

Unless otherwise noted, normals and anomalies are based on the 1961–90 average.

### *(i) Temperature*

Across most of the region, the monthly mean temperature was about 1°C warmer than average throughout most of 2013. In the northern Amazon, northern Paraguay, and southern Bolivia temperatures were about 2°C above normal from January–

July. Anomalously low temperatures (1°C below normal) were observed in southern Brazil and southern Paraguay in March.

Temperatures were warmer than normal during much of the winter (June and July), though August was colder than normal. From July to September, 19 cold surges affected southern Amazonia, southern Brazil, and western Amazonia. In Inacio Martins, in the highlands of the state of Parana, Brazil, air temperatures dropped to –4.5°C and, for the first time in 38 years, it snowed in the capital city of Curitiba. In the southern part of the state of Sao Paulo on 24 July temperatures dropped to 4°C, the lowest minimum temperature for that month since 2000. In the city of Rio Branco, in the state of Acre in western Brazilian Amazonia, temperatures dropped to 7.5°C on 25 July, 9.0°C below normal and the lowest July temperature in 15 years.

### *(ii) Precipitation*

During summer and fall 2013, rainfall was well below average between January and May (50–200 mm below average) in northeastern Brazil, continuing the intense drought that started in 2012. Wet conditions prevailed in February (200 mm above normal) over southern Peru and Bolivia. Rainfall episodes in central Brazil were due to the presence of three episodes of the South Atlantic convergence zone (SACZ). Dry conditions (50 mm below normal) prevailed in southern Brazil almost all year long, intensifying during December. Wet conditions prevailed in June from southern Peru all the way to southern Brazil (100 mm above normal) due to several cold fronts impacting the region. Wet conditions were also detected over Bolivia and south of Northeast Brazil in December (100–300 mm above normal). This was due to the presence of the SACZ, while precipitation deficits continued over the core region of the South American monsoon (200 mm below normal).

From March to June many areas of Bolivia had insufficient amounts of rainfall (50–100 mm below normal) and drought severely affected agriculture production. In August, wet conditions (100 mm above normal) left 50 districts of the states of Parana, Santa Catarina, and Rio Grande do Sul under a state of emergency, with 70 000 people affected.

### *(iii) Notable events*

In March, temperatures across the interior of the state of Pernambuco in Northeast Brazil reached 39.5°C, the highest temperature in 2013. On 17 September Brazil's capital, Brasilia, recorded tempera-

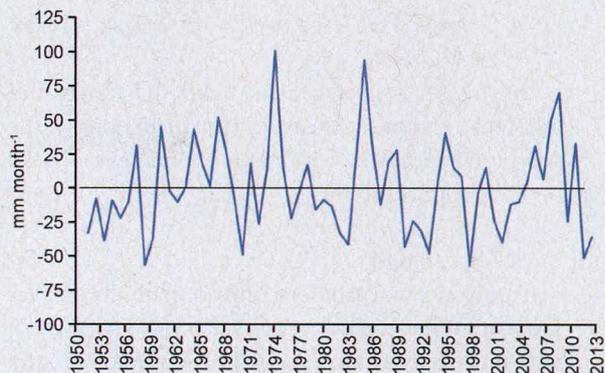
tures as high as 32.6°C (4.1°C above normal) and on 23 September the city of Belo Horizonte experienced temperatures 34.5°C (7.2°C above normal)—the highest daily temperature recorded for each location in 2013. On 11 November temperatures were as high as 34.6°C (8.6°C above normal), the highest daily temperature in 2013 in Sao Paulo, while in Rio de Janeiro the temperature soared to 41.8°C (14.8°C above normal) on 12 November, its highest daily temperature in 2013. On 26 December temperatures reached 38.8°C (9.8°C above normal) in the city of Porto Alegre, surpassing the previous record of 37.7°C set in 2012.

A remarkable cold air surge brought cold temperatures to parts of the tropical South America during 22–25 July. This event produced snow in southern Brazil, and on 24 July the city of Sao Paulo registered its coldest temperature since 1961 (8.6°C).

The wet conditions in southern Peru and Bolivia in February produced floods and landslides that destroyed 3500 houses. By March, wet conditions in the Huallaga River basin (Peruvian Amazon), produced floods that affected 2700 people and the agriculture production in the region. Floods between March and May affected more than 50 000 people in Colombia. On 20 March, heavy rains affected the highlands of Rio de Janeiro, causing damages estimated at \$60 million US dollars. In Petropolis, 300 mm of rainfall were registered during a 24-hour period, compared to just 270 mm typical for all March.

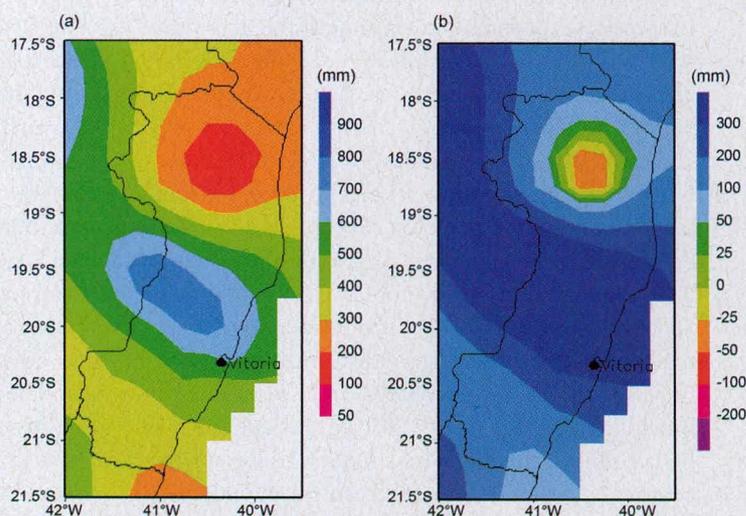
In the city of Salvador in the state of Bahia, on 10 December, torrential rains caused 16 fatalities and more than 800 people were forced to evacuate their houses. Torrential rains caused floods and landslides in southeastern Brazil during 16–23 December, leading to 50 deaths in the Brazilian states of Rio de Janeiro, Bahia, and Espirito Santo.

A state of emergency was declared across parts of northeastern Brazil where residents coped with one of the worst droughts on record. Three consecutive years of drought have had a devastating effect in the region, considered one the country's poorest (Fig. 7.13). The causes of this drought are related to anomalies in the large scale circulation, where warm surface water in the tropical North Atlantic favored an anomalously northward migration of the ITCZ. This reduces the moisture transport from the tropical North Atlantic to the region (Marengo et al. 2013; Nobre and Shukla 1996).



**FIG. 7.13. Rainfall anomaly (mm month<sup>-1</sup>; 1961–90 base period) during the peak rainy season (Feb–May) in Northeast Brazil for 1951–2013. (Source: Global Precipitation Climatology Centre; Marengo et al. 2013.)**

Rainfall in Espirito Santo during December (Fig. 7.14) was the most intense during the last 90 years, according to INMET and INCAPER (Meteorological Center of the state of Espirito Santo), affecting 70 000 people. In the capital, Vitoria, a record-setting total of 669 mm of rain fell in 23 days—more than three times the monthly average of 180 mm. The previous rainiest December in Vitoria was in 1948 with 522 mm. At other stations, rainfall surpassed 700 mm. Within the state, 46 000 people were forced to leave their homes due to flooding. By 25 December, 21 deaths were reported, and floods and landslides affected more than 60% of the state. The cause of the intense rainfall was the very active SACZ over Minas Gerais, Espirito Santo, and Bahia.



**FIG. 7.14. (a) Accumulated rainfall (mm) and (b) rainfall anomalies (mm) in the state of Espirito Santo, Brazil, for Dec 2013. Anomalies are with respect to the 1961–90 base period. (Source: INCAPER-Meteorological Center, state of Espirito Santo.)**

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