June, a cold wave brought cooler-than-average conditions (Fig. 7.15) from southern Brazil to western Amazonia. Four people died in the city of São Paulo due to the cold on 13 June, where minimum temperatures were as low as 3.5°C (average is 12.4°C). On that same day, minimum temperatures were as low as −8.5 C at Urupema, while Rio de Janeiro's minimum temperature was 8.6°C (average is 18.7°C)—the lowest daily June minimum temperature in the last 14 years.

Severe weather, including heavy rains, floods, flash floods, and landslides, severely affected central South America for most of the year (with the exception of December). In central Brazil, heavy rain in January affected more than 67 000 people throughout the state of Mato Grosso do Sul, with 28 municipalities declaring a state of emergency and nearly 1000 people isolated in the Taquarussu district. Recife recorded

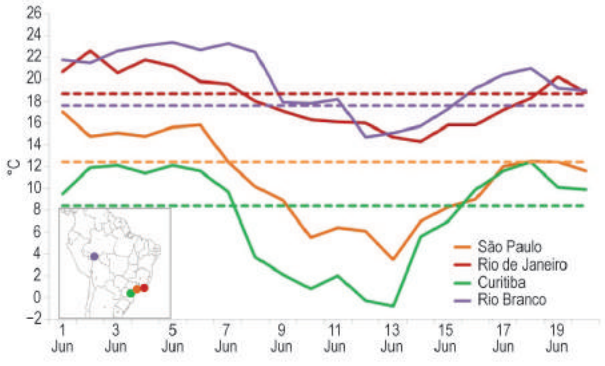

Fig. 7.15. Solid lines represent the mean temperatures (°C) in São Paulo, Rio de Janeiro, Curitiba, and Rio Branco during 1–20 Jun 2016. Dashed lines represent the respective 1981–2010 average (Source: INMET.) Colored dots in the inset map show the locations of the meteorological stations.

SIDEBAR 7.2: DROUGHT IN BOLIVIA: THE WORST IN THE LAST 25 YEARS—J. A. MARENGO, J. C. ESPINOZA, L. M. ALVES and J. RONCHAIL

Rainfall in the central Andes was deficient in 2016. During the January–April growing season (Fig. SB7.3a), rainfall totals were below average in the central and southern Andes of Bolivia and in the southern Chaco region. Oruro received 66.7% of its average precipitation (average: 240 mm) and Cochabamba just 62.1% of its average precipitation (average: 290 mm; Fig. SB7.4). These were the lowest values since the strong 1982/83 El Niño event. Scarce rainfall was also observed in the lowlands, where totals were 20% below average in Trinidad (Beni).

Drought persisted after the dry austral winter season (June–August) and at the end of the year rainfall totals for November–December were about 150 mm month^{-1} below normal. Total precipitation in La Paz and the Altiplano region (Fig. SB7.3b) during September–December 2016 was 25% below normal. Intense drought conditions affected the center and southern parts of the country and the region of Santa Cruz, in the southern lowlands, with deficits surpassing 30% in the Andean regions, which were already affected during the first part of the year (Fig. SB7.3a). The hydrology of the Peruvian side of Lake Titicaca showed low river discharge from October 2016, with the Ramis and Ilave Rivers recording discharge levels of just 3.85 m^3 s^{-1} and 11.6 m^3 s^{-1} compared to their respective climatologies of 17.9 m^3 s^{-1} and 51 m^3 s^{-1}. The water level of Lake Titicaca at Huatajata station dropped to 3807.78 m in December 2016, just shy of tying its lowest level set in September 1996 (3807.39 m). The Desaguadero River (the main outlet of the Lake Titicaca) discharge dropped as well. In the lowlands, a much longer-than-usual flood recession period was observed, especially in the Mamoré River, located downstream from the

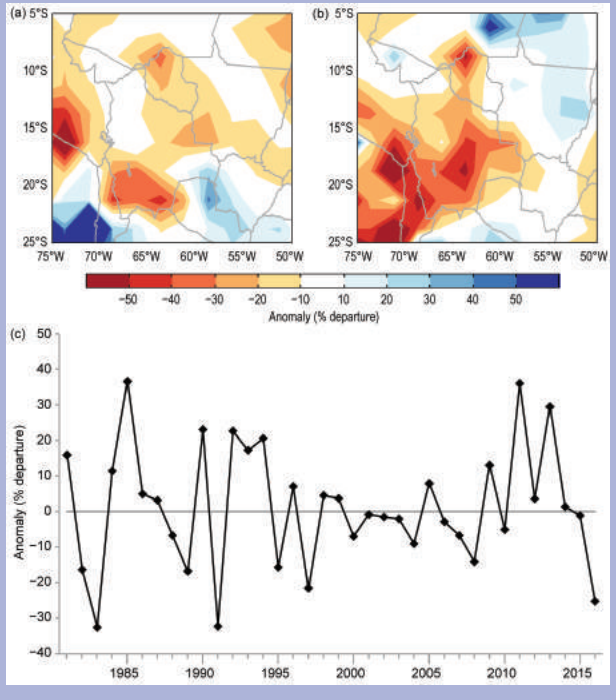

Fig. SB7.3. Precipitation anomaly (%; 1981–2010 base period) maps for Bolivia, derived from the CMAP dataset for 2016: (a) Jan–Apr, and (b) Sep–Dec. (c) Sep–Dec precipitation anomalies (%) near La Paz, Bolivia, during 1982–2016. (Source: Rainfall data is from CMAP, produced by NCEP.)

188 mm of rain in just 6 hours on 30 April—57% of the mean climatology for the month (328 mm). The copious rain prompted flash floods and landslides in several locations across the city.

Due to a South Atlantic convergence zone episode on 16 January, above-average rain (+150 mm) was observed in states across northeastern, central, and southeastern Brazil and eastern Bolivia, as well as in western Paraguay and northwestern Peru, causing floods and river overflow. In seven municipalities in the Bolivian department of La Paz, a state of emergency was declared due to intense rainfall that led to overflowing rivers during the first half of the year.

Torrential rainfall, which began in November 2015, continued during January, triggering the overflow of Paraguay's Asunción and Alberdi River levels (7.88 m in Asunción on 1 January and 9.81 m. in Alberdi on 6 January) and displacing more than 65 000 people in Asunción and leading the government to recommend evacuation of the Alberdi city. This was the fourth largest extreme flooding event since 1905, and according to the Meteorological Service of Paraguay, it was related to the 2015/16 El Niño event. This was also an out-of-season event since river levels typically reach their maximum at the end of May or in June–July.

In the Andean region, extreme drought was reported during 2016, leading the Peruvian government Ministry of Agriculture to declare a state of emergency for 17 regions during November and December.

The extreme dry conditions observed in northeastern Brazil contributed to a water crisis where the reservoirs of the San Francisco River were at less than 10% of capacity, leaving small farmers and the driest regions discussed above. At the Guayaramerin station very low levels, ~2 m, were observed from July to November compared to the usual September–October period. The severe dry conditions caused water supply issues for people, cattle, and agriculture in the region.

In November, Bolivia declared a national emergency, with drought affecting five of its nine departments. It was also declared due to the impact of dry conditions stemming from El Niño. Previous droughts were observed during past El Niño years in 1983, 1991, and 1997 (Fig. SB7.3c).

Bolivia's Civil Defense estimated that the drought conditions affected 162 000 families and threatened 607 000 hectares of agricultural land in the Andes and in the Amazonian region of Santa Cruz. About 360 000 head of cattle were lost due to the lack of water and fodder. The association of producers of oleaginous seeds and wheat estimated that in 2016 the production of soy in the lowlands of Bolivia decreased by 20%. The UN Food and Agriculture Organization estimated that the losses in Bolivia were as high as $485 million U.S. dollars (14% of the agricultural gross domestic product in 2015). Drought prompted protests in major cities and conflicts between miners and farmers about the use of aquifers. Water rationing was established for the first time ever in La Paz, affecting one-third of the population and probably more in fast-growing El Alto, the poorest city of Bolivia. The three main reservoirs that provide the city's water were almost dry by the end of 2016. The semiarid highlands surrounding the capital rely mostly on replenishment by rainfall and, secondarily on glacial meltwater (20%–28%), especially during the winter season. But glaciers such as Chacaltaya, which hosted the highest ski resort in the world (17 785 feet) and provided water to La Paz and El Alto, melted completely. In 2005, only a few patches of snow/ice were left, and in 2009 it dissapeared completely (Soruco et al. 2015; Escurra et al. 2014).

Others glaciers have lost a great part of their mass and continue melting. Although the average water use in El Alto is low (52 liters person^{-1} day^{-1}), the critical situation of water supply may worsen as the population migrating to the city increases, especially during drought episodes when food security is no longer guaranteed in the countryside and with the growing demand of water for irrigation for agriculture in the surrounding areas.

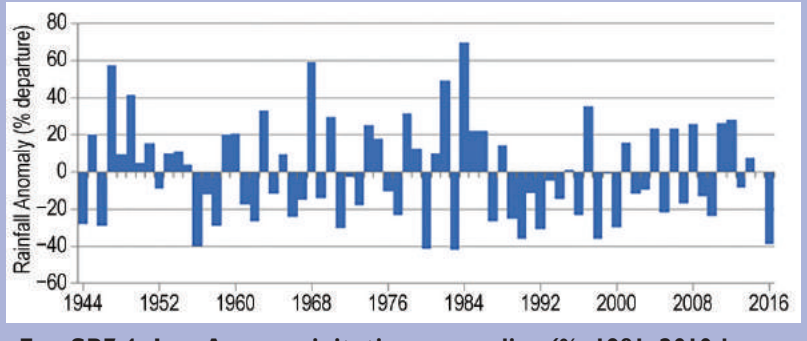

Fig. SB7.4. Jan–Apr precipitation anomalies (%; 1981–2010 base period) for Cochabamba, Bolivia, during 1944–2016 (Source: SENAMHI-Bolivia.)