(approximately 360,000 families) experienced damage to their houses. Losses were estimated at over $26 million (USD).

In Ecuador, the annual total precipitation anomalies were about 20% above normal during 2008. With the La Niña event peaking during December 2007, the rainy season over Ecuador experienced its earliest start in the last seven years. During January and February 2008, while La Niña was diminishing, heavy rainfall was registered over most of the country with the coastal regions affected by floods and the central and northern highlands affected by landslides, leading to a state of emergency being declared across the country. During March and April, rainfall remained above normal along the coast and the Andean region, but it was below normal in Amazonia. In May and June, conditions in the coastal region switched to a rainfall deficit, while in the southern and northern highlands heavy rainfall was reported. The second half of the year was characterized by normal conditions in the coastal zone. During the last trimester of 2008, rainfall was above normal in the central highlands and southeastern Ecuador. In the Galapagos Islands, precipitation was significantly below normal in January and February, mostly associated with negative sea surface temperature anomalies; however, precipitation was twice the monthly normal in March and 27% above normal in April. The rest of the year was characterized by normal to slightly below-normal precipitation.

In Peru, significant rainfall was observed in January. Heavy rainfall occurred in the coastal area of Ica (17 mm in 5 days; 4 mm is usually observed for the month) and in the highlands of Arequipa, where more than 80 mm of rain was observed in the first 20 days of the month. In February and March, there was significant rainfall along the northern coast of Peru, resulting in an emergency declared in the flooded areas. In April, cold and dry air moved into the tropical latitudes inducing rainfall and thunderstorms over the southern jungle of Peru, Bolivia, and Amazonia. This also resulted in a significant drop in air temperature over the tropics. In the remaining months, the precipitation was slightly below normal. During 2008, the precipitation over Peru showed a deficit of about 20% compared to the long-term average (1971–2000).

(iii) Notable events

Of 16 tropical cyclones, only Omar passed near the Caribbean coast of Venezuela on 13 and 14 October, intensifying precipitation over much of the country.

2) Tropical South America East of the Andes—J. A. Marengo, J. Baez, and J. Ronchail

(i) Temperature

Most of tropical South America east of the Andes and south of 23°S experienced a warm 2008, with annual mean temperatures 2° to 3°C warmer than normal. Likewise, warm conditions (1° to 2°C above normal) were observed in northern Venezuela, interior Brazil between Amazonia and Northeast Brazil, and in eastern Peru (Fig. 7.11a). Cooler-than-normal conditions (anomalies of −0.5 to −1°C) were observed in southeast Brazil. From January to April, warm temperature anomalies were detected in eastern Amazonia, Northeast Brazil, southern Paraguay, and northern Argentina. In the interior of Northeast Brazil, mean temperatures reached 32° to 34°C, exceeding the mean by more than 4°C. Negative daily maximum temperature anomalies of 2° to 3°C were reported in Uruguay, southern Brazil, and the Brazilian highlands, associated with the penetration of a cold air mass.

In May, negative air temperature anomalies (–1° to –2°C) were observed in the Peruvian Andes and western Bolivia. A cold outbreak, due to an early northward penetration of a polar air mass, occurred in May in southern South America. Very cold temperatures were registered over the Peruvian–Bolivian Altiplano from March to May 2008. Mean minimum temperatures fell considerably to 2.7°, −0.2°, and 3.9°C in La Paz in March, April, and May, respectively. Early frosts and hail resulted in poor harvests in Andean crops (30%–40% below normal) and affected high-altitude hay making, leaving breeders with no alternative food for their herds. Mean maximum temperatures dropped by 3° to 4°C in those regions while minimum temperatures dropped by 1° to 2°C. The sharp falls in temperature were related to two episodes of cold-air penetration, which occurred at the beginning and end of May, with lower temperatures in the highlands of southern Brazil.

In June, colder temperatures (1° to 2°C below normal) were reported over a large area between Paraguay, northern Argentina, and northern Brazil. In July, positive temperature anomalies were detected across almost all tropical South America, east of the Andes. Temperatures 4°C warmer than normal were recorded in eastern Bolivia, Paraguay, northern Argentina, and southern Brazil, making it the warmest July in the last 50 years for many locations. In July, maximum and minimum air temperature anomalies reached 4°C above normal over most of central and southeastern South America, including Brazil. Clearer-than-normal skies also favored

intense overnight heat losses, which in turn lowered minimum air temperatures, especially in west-central and southeastern Brazil. In Campos de Jordão, in the highlands of São Paulo, the temperature fell to −0.2°C on 14 July, and in southern Brazil, some cities experienced three consecutive days with minimums near 0°C from 17 to 19 July.

From August to October almost all of tropical South America was about 1°C warmer than normal, while in September and October, negative maximum and minimum temperature anomalies (1° to 3°C below normal) were detected in southern Brazil and eastern South America. High daily maximum temperatures were detected on 26 August in west-central Brazil (38.4°C at Cacoal; 39.3°C at Diamantino; and 39.6°C at Cáceres). In other regions, minimum temperatures were near normal due to the cloudiness associated with a cold front. However, in November warm temperatures were detected in regions of southern Bolivia, Paraguay, southern Brazil, and northern Argentina, with temperatures 3°C warmer than normal. In November, maximum mean temperature anomalies reached +2° to +3°C over large parts of tropical South America while mean minimum temperatures were 3°C warmer than normal.

(ii) Precipitation

In the tropical region east of the Andes, rainfall was 40% to 60% above normal in the Amazon region and central-southeastern Brazil (Fig. 7.11b), a situation fairly typical of La Niña years. The opposite was observed in central and southern Paraguay, with rainfall 20% to 80% below normal. In Bolivia, heavy rainfall, which began in November 2007, continued into January, causing floods that affected around 25,000 people and resulted in 30 fatalities. More than 10,000 hectares of crops were damaged by the floods, causing an estimated $30 million (USD) in losses. Mudslides destroyed many homes in the capital city of La Paz. In Rio de Janeiro, torrential rain produced floods that affected around 50,000 people and caused four deaths.

As for January, most of the summer and autumn months were characterized by episodes of intense rainfall and floods in large cities such as São Paulo and Rio de Janeiro. In the Peruvian upper Amazon, excessive rains in February produced floods and landslides in various states. The heights of the Ucayali and Madre de Dios Rivers, as well as the Beni and Mamoré Rivers in the lowlands of Bolivia, were all above normal. On the Altiplano, severe flooding and high river levels were detected in the Desaguadero and Pilcomayo Rivers. In tropical Brazil, wetter conditions in the austral summer of 2007/08 resulted in above-normal river levels for the Amazon, Tocantins, and São Francisco Rivers. In northern Paraguay, rainfall was almost twice the normal amount in February 2008; however, for the rest of summer and fall rainfall was deficient.

In Northeast Brazil, the pre–rainy season between January and February was wetter than normal, while the peak of the rainy season from March to May was also normal to above normal. Both March and April were between 20% and 40% wetter than normal. As a consequence, widespread floods killed 15 people, displaced more than 30,000 from their homes, and destroyed corn and bean crops in the Piaui state of Northeast Brazil. In June and July, wetter conditions were observed in northern Brazil and French Guiana, while drier conditions persisted in eastern Colombia and western Venezuela. In August, hailstorms were observed in southern Brazil due to the penetration of a cold front.

Rainfall in the Andean region of Colombia was about 40%–60% above normal between January and September 2008, and, as a consequence of the intense rainfall, about 56% of the country suffered the impacts of the rainfall excesses. Landslides accounted for 70% of deaths and 46% of injuries. In May, dangerous floods caused by torrential rains affected more than 100,000 people, damaged thousands of homes, and were responsible for nine fatalities. In December, rainfall was 20% to 60% above normal over the entire region, and the subsequent overflowing of the Magdalena River broke the retaining wall in the town of Plato (580 km north of Bogotá) and affected about 20,000 people. Power systems and drinking water were restricted in several areas of the municipality.

In areas east of the Andes, a large part of northern Argentina, Paraguay, Uruguay, and southern Brazil experienced a prolonged and intense drought during most of 2008, causing severe impacts to agriculture. From April to August 2008 (including September for Paraguay), Bolivia, Paraguay, and most of northern Argentina were affected by severe rainfall deficits, in some cases 60% to 80% below normal. The presence of a dry air mass that covered most of central and northern South America inhibited the formation of rain and produced above-normal maximum temperatures and, in some areas, a reduction in minimum (overnight) temperatures.

In August 2008, two cold fronts produced intense rainfall in southern and southeastern Brazil. In Paraguay, the states of Alto Paraguay, Boquerón, and Presidente Hayes were affected by a severe drought (rainfall

INTENSE RAINFALL AND FLOODS CLAIM AT LEAST 120 LIVES IN SOUTHERN BRAZIL—J. A. MARENGO

In southern Brazil, 22 to 24 November saw heavy rainfall over Santa Catarina state, which caused severe floods and deadly mudslides. Around 1.5 million people (a quarter of Santa Catarina's total population) were directly impacted, with 69,000 people left homeless, 120 fatalities reported, and a state of emergency declared. Mudslides and flooding caused by the storms blocked almost all highways in the region and cut off water and electricity to many thousands of homes. Most of the fatalities were caused by mudslides that swept away homes and businesses. The storms broke a stretch of pipeline that carries Bolivian natural gas to southern Brazil and forced the suspension of the fuel supply to part of Santa Catarina and to the entire neighboring Rio Grande do Sul state. Some cities reported looting of supermarkets and pharmacies by hungry and desperate flood victims. This event has been described as the region's worst hydrometeorological disaster since at least 1862.

The meteorological causes were associated with an atmospheric blocking over the South Atlantic that formed in the preceding week. High rainfall was linked to the intensification of the subtropical Atlantic high, which produced a steep pressure gradient along the coast that favored strong moisture transport from the ocean to the continent. Over land, a cyclonic vortex at the middle levels of the atmosphere between eastern Paraná and Santa Catarina favored the ascent of the moist air along the Sierra do Mar mountains. This unusual combination of phenomena favored the intensification of rainfall along the coastal region of Santa Catarina (Fig. 7.12). Unofficial estimates of the losses due to this extreme rainfall event and subsequent floods and landslides are of the order of $350 million (USD).

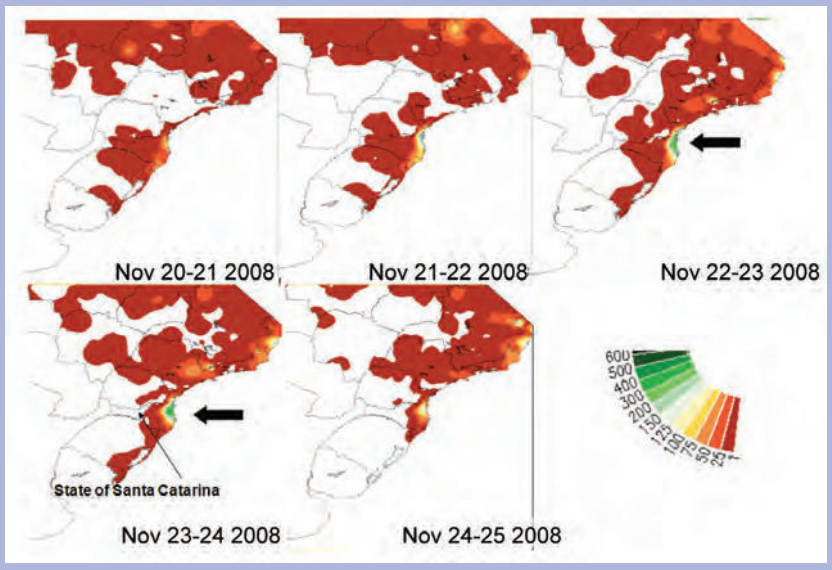

FIG. 7.12. Accumulated precipitation (mm) in southern Brazil during 20–25 Nov 2008. (Source: CPTEC/INPE.)

80%–100% below normal), and by September 2008 the government had declared a regional emergency (Paraguayan Chaco), with thousands of families, as well as cattle and agriculture, strongly affected.

3) SOUTHERN SOUTH AMERICA—P. Aceituno, M. Bidegain, J. Quintana, M. Skansi, and M. Rusticucci

(i) Temperature

Temperatures above the 1971–2000 average were observed over most of southern South America during 2008, with mean anomalies of between +0.5 and +1°C (Fig. 7.11a). Mean temperatures in July were more than 3°C above average over large parts of northern Argentina, Paraguay, northern Uruguay, and southern Brazil, making this month the warmest of the last 50 years for many locations. Mean temperature anomalies larger than 3°C were also reported during November, when the average daily maximum temperature in central Argentina and southwestern Uruguay was more than 4°C above the climatological mean. For many cities in southeastern South America, including Montevideo and Buenos Aires, this was the warmest November in the last 50 years.

The annual mean temperature for 2008 was also above average along the extratropical west coast of the continent southward from 30°S, with annual mean anomalies of 1.0°C in the region from 35° to 41°S. Above-average daily maximum temperatures were prevalent during the early (January to March) and late (September to December) parts of the year. Most were associated with rainfall deficits and clear sky conditions. In the region from 39° to 46°S, monthly mean maximum temperature anomalies were above +2.0°C during January and March and above 4.0°C