

Climate change in metropolitan areas: experiences in the metropolitan area of São Paulo and in the city of Santos.

Jose A. Marengo
R&D Director, CEMADEN
Sao Paulo, Brazil
jose.marengo@cemaden.gov.br
www.cemaden.gov.br

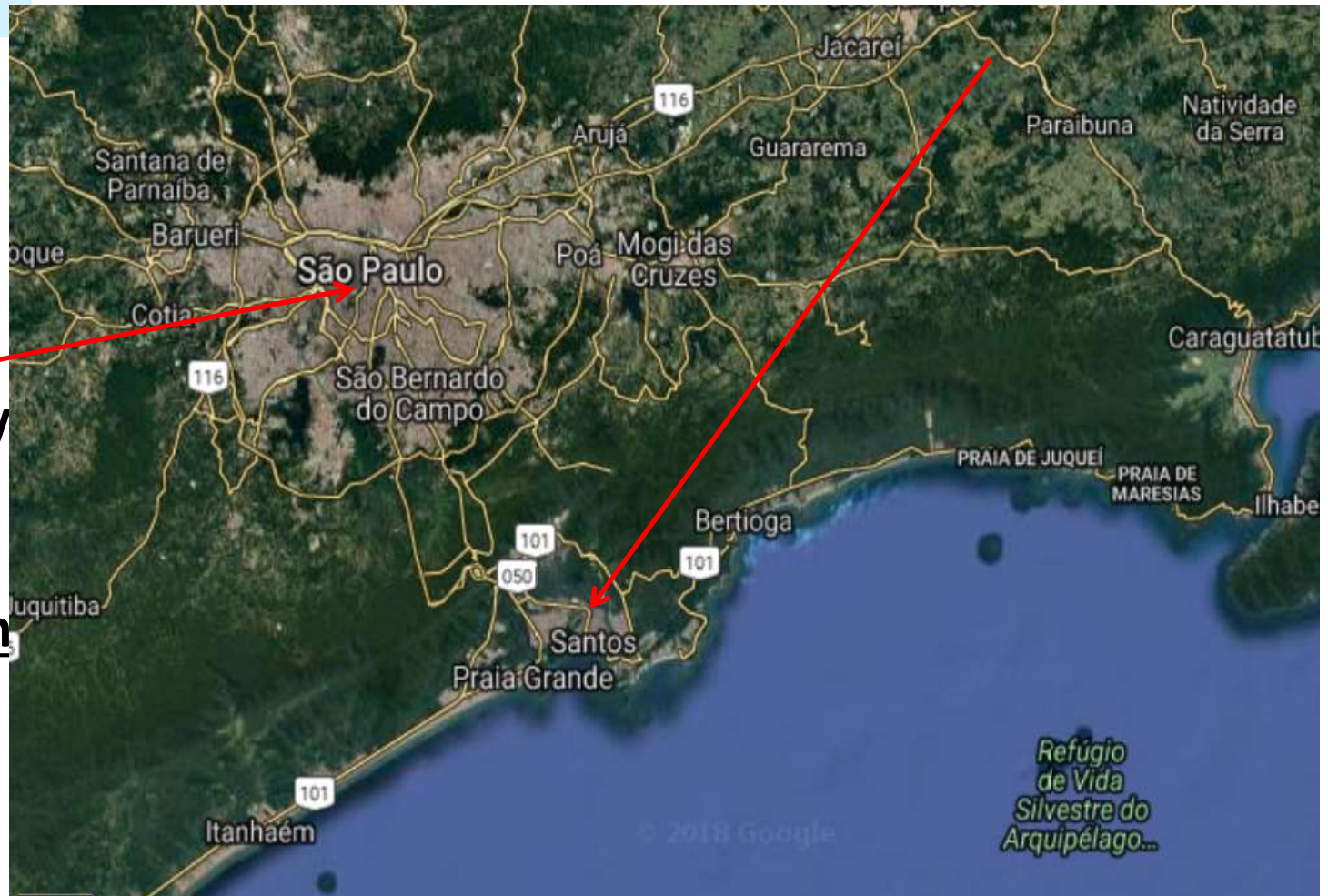




Santos occupies a coastal area of 281 km² .. Total population is 433.966 inhabitants. The Port of Santos is one of the largest in Latin America.

The Metropolitan Area of Sao Paulo (MASP)

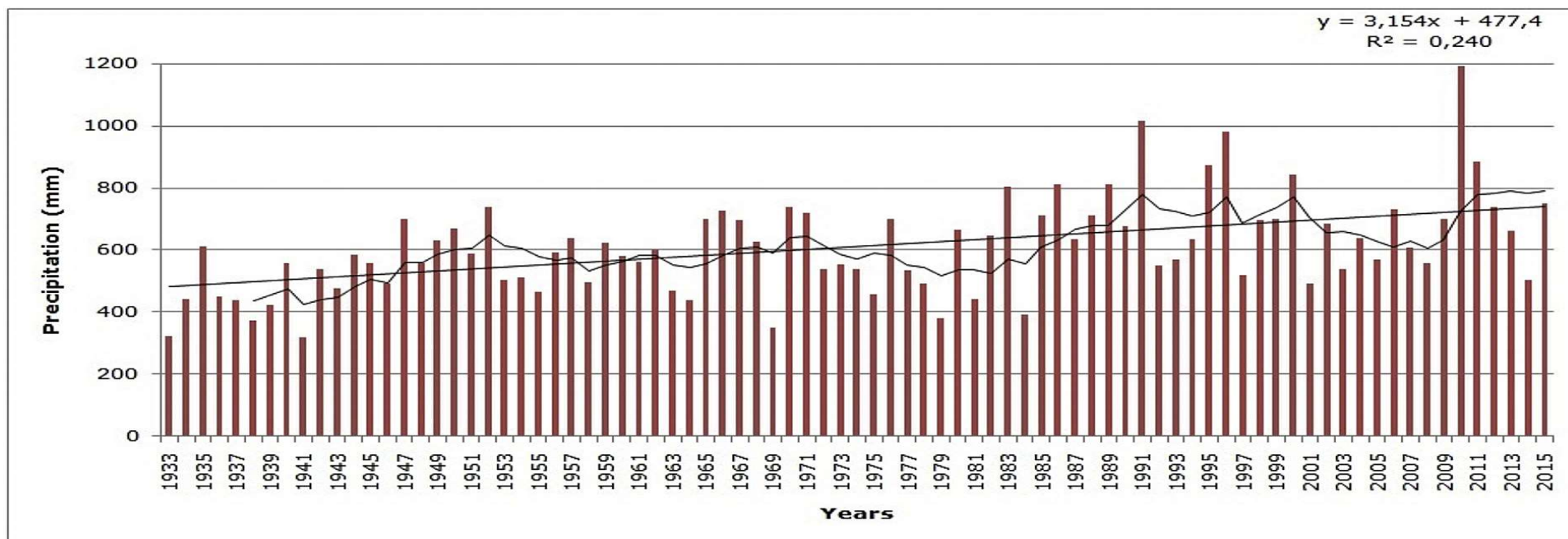
occupies an area of approximately 8,000 km². Total population in the metropolitan area is 19,672,582 inhabitants.



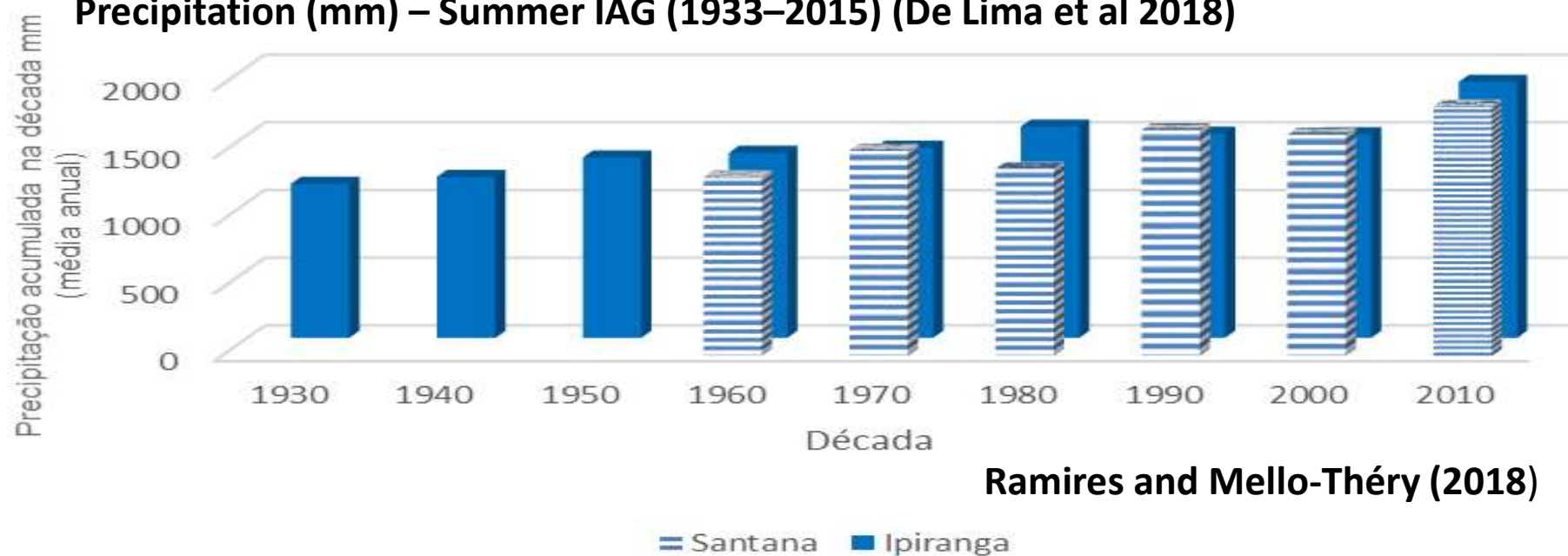
Importance of these cities

-The MASP is the largest pole of national wealth. The region has a Gross Domestic Product (GDP) of R \$ 760.04 billion by 2011. In 2011 it represented 56.32% of the GDP of São Paulo. The MASP is the 12th megacity in the list of the world's largest cities and metropolitan areas by population as of 2016.

-**Santos** is a port municipality located in the Metropolitan Region of Baixada Santista, located on the coast of the state of São Paulo, Brazil. With the greater economic participation of this region, it is home to the largest port in Latin America, the main responsible for the economic dynamics of the city next to tourism, fishing and commerce, occupying the 5th place among non capital more important for the Brazilian economy and 10th placed according to quality of life.



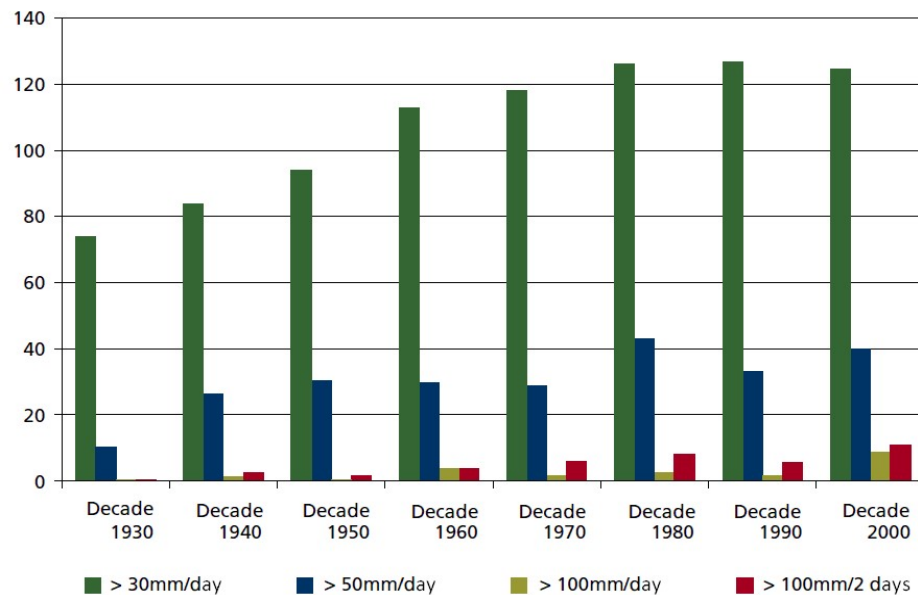
Precipitation (mm) – Summer IAG (1933–2015) (De Lima et al 2018)



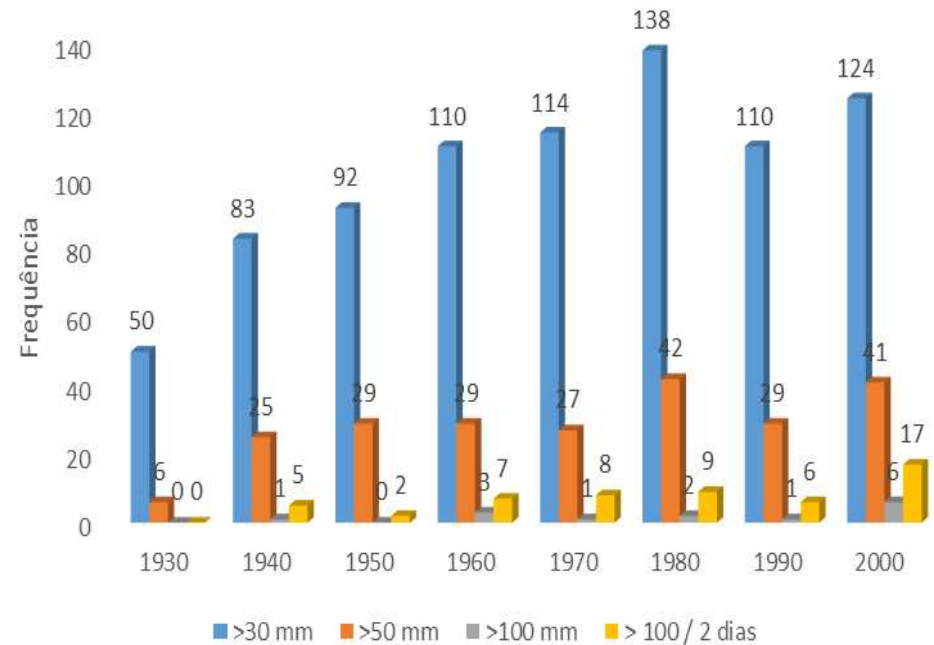
Ramires and Mello-Théry (2018)

Precipitation (mm) – Annual (per decades (Ipiranga and Santana)-

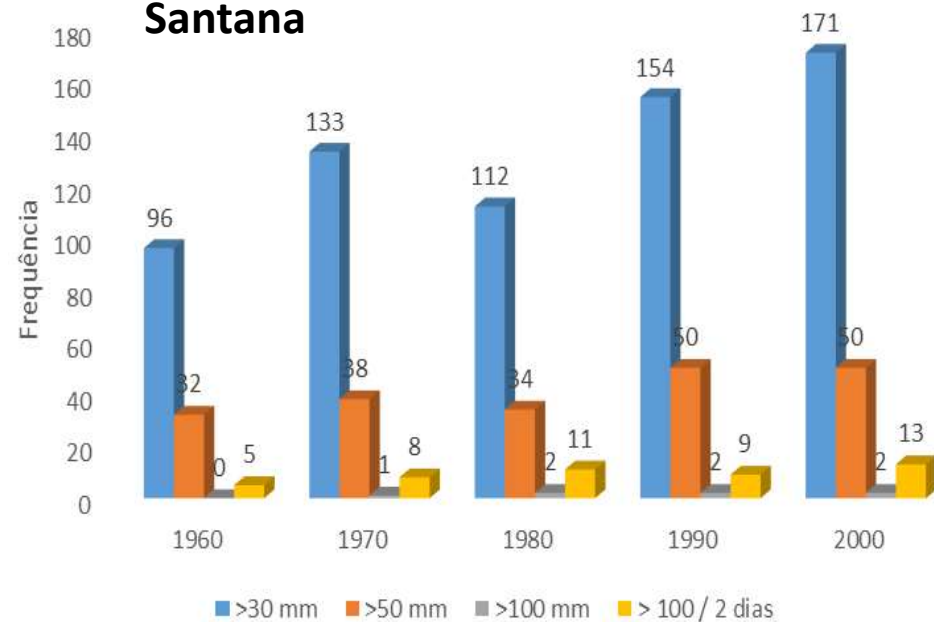
Changes in extreme rainfall in the MASP Area (USP IAG) (Nobre et al 2011)



Ipiranga



Santana



Ramires and Mello-Théry (2018)

1960 ≈ 1990

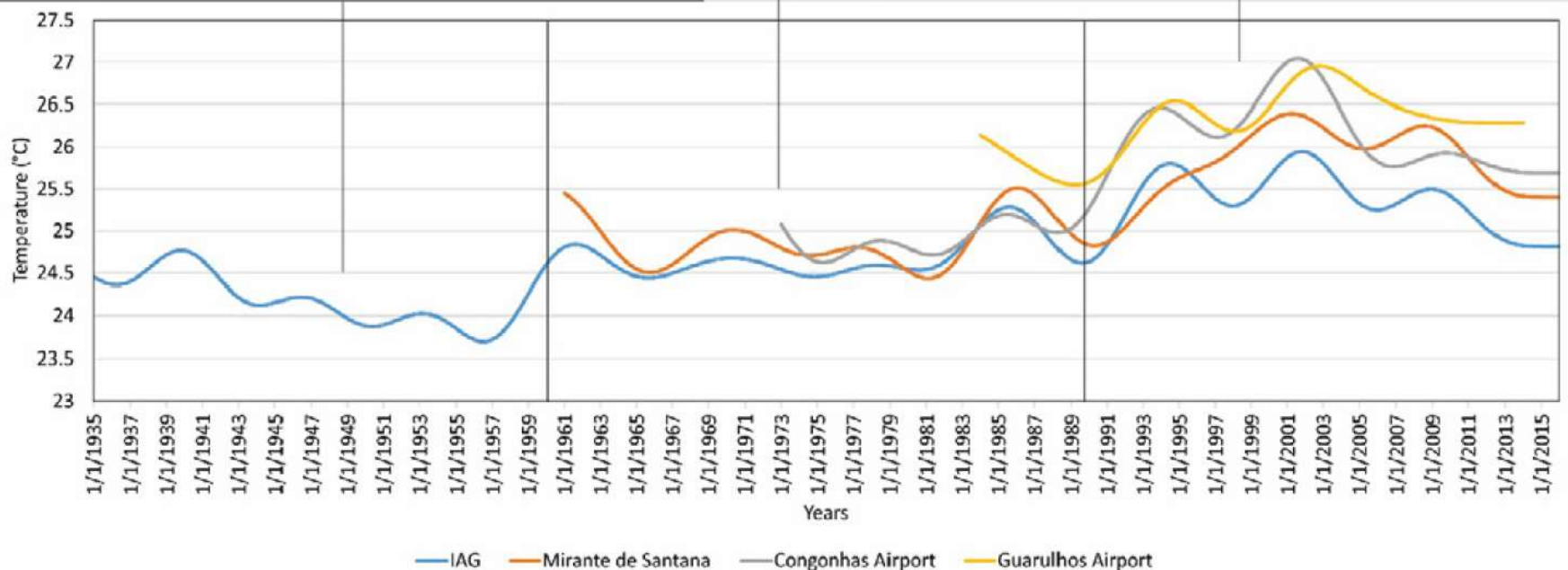
- Accelerated population growth
- The city outskirts begin to grow (rise of slums).
- The Mirante de Santana and Congonhas Airport stations are in areas already densely urbanized.

1930 ≈ 1960

- Pre-metropolitan phase.
- Some of the basic elements of the metropolitan structure are installed.
- Predominantly residential occupation.
- IAG weather station is located in an area of preserved vegetation.

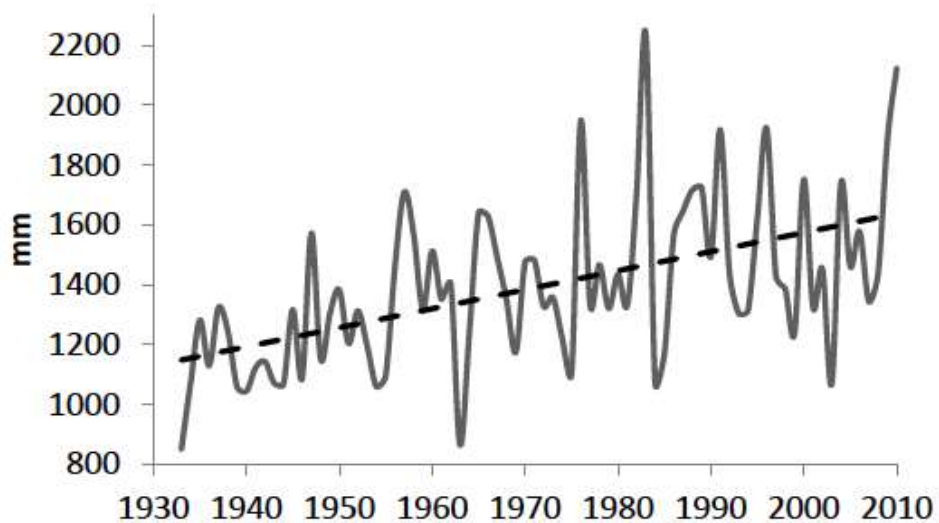
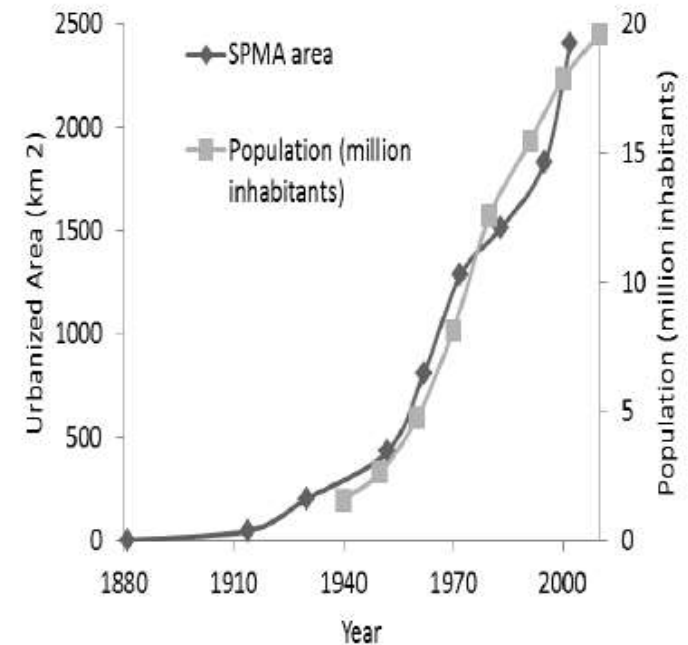
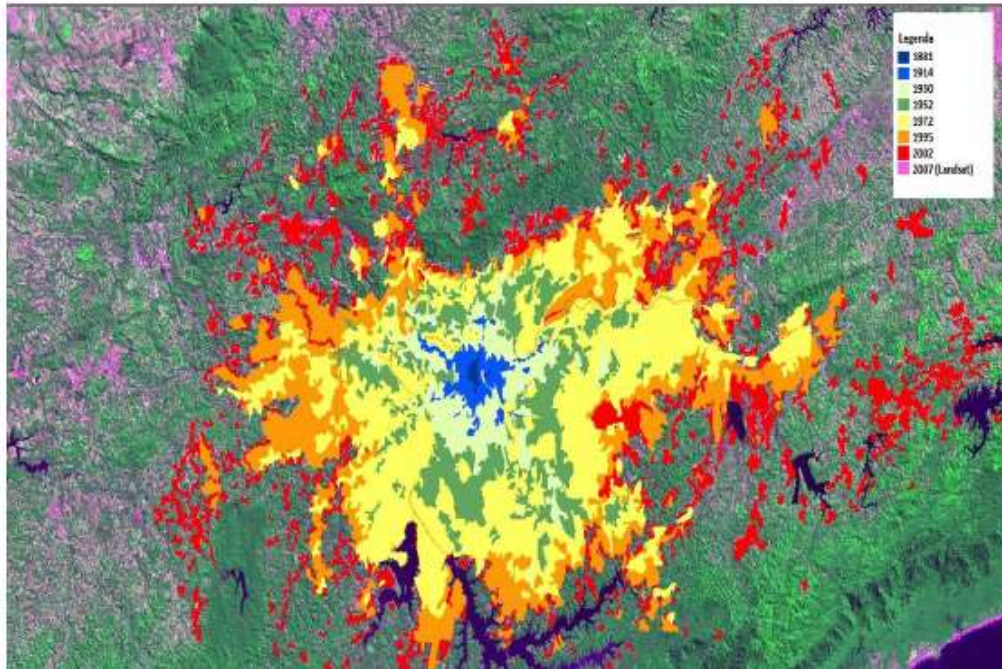
1990 ≈ 2015

- The consolidated urban spot begins to grow at a slower rate.
- Growth continues towards peripheral areas (squatter in protected areas).
- The vicinity of Guarulhos Airport is still growing.



Maximum temperatures (filtered) and major periods of MASP urban growth (De Lima and Magana 2018)

Sao Paulo-The largest urban center in Brazil

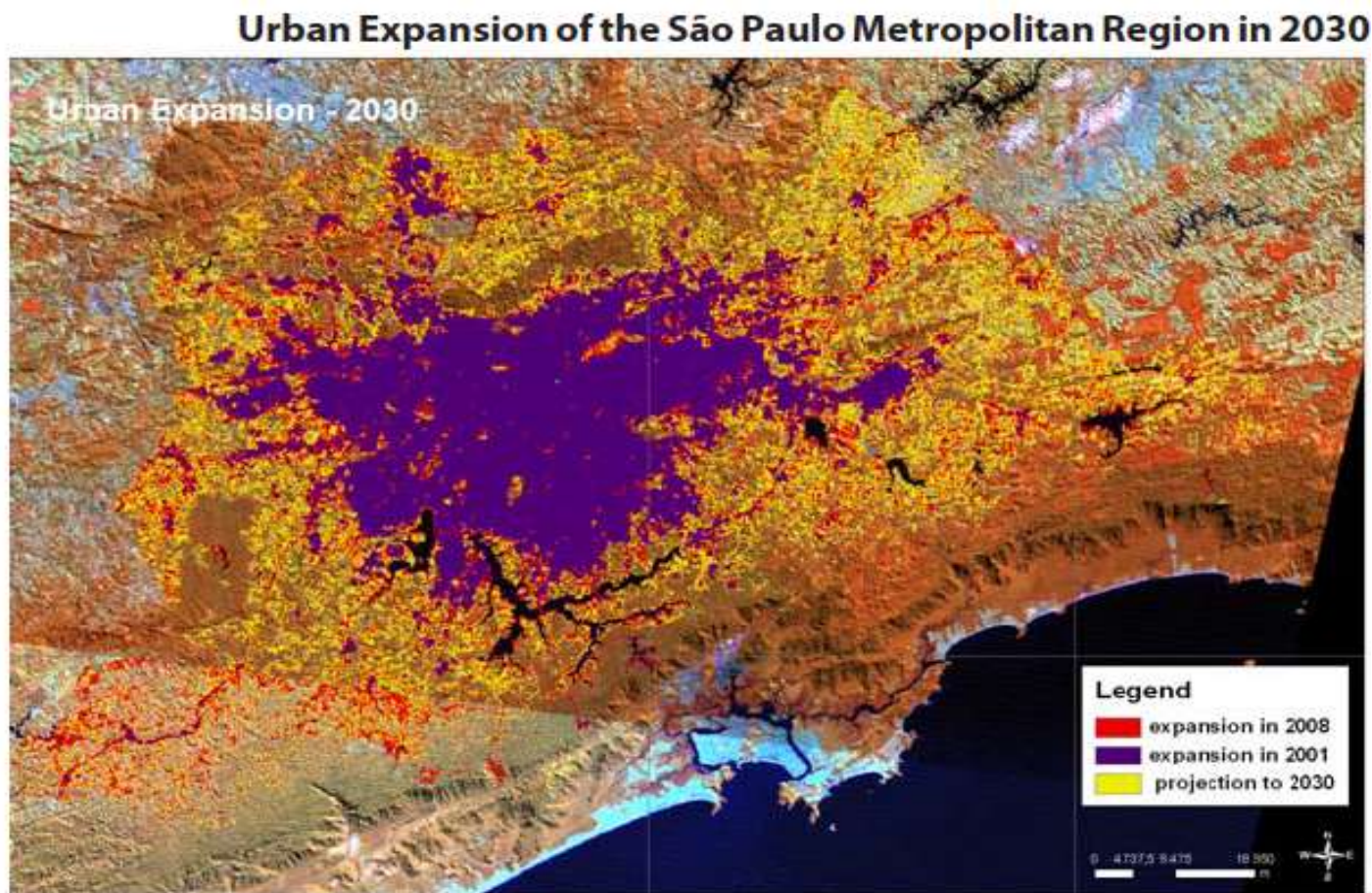


Climate in the MASP has changed:

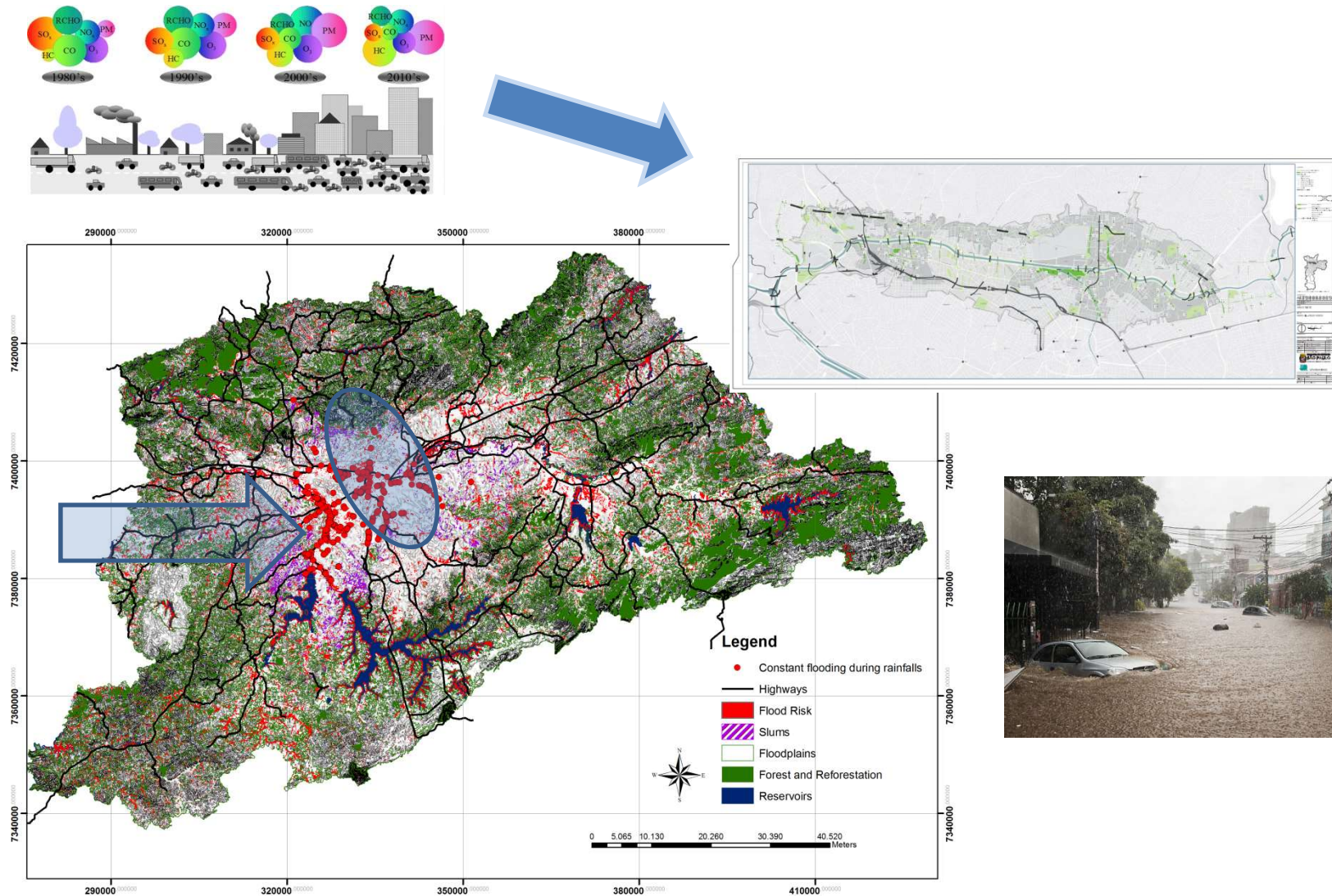
- Air temperature increased about 3°C since 1930
- Monthly and annual precipitation have increased
- Extreme precipitation events have increased in frequency and intensity
- Risk of natural disasters has increase due to increase of vulnerability of population

**Silva Dias, M.A.F., Dias, J., Carvalho, L.,
Freitas, E. e Silva Dias, P.L., 2011**

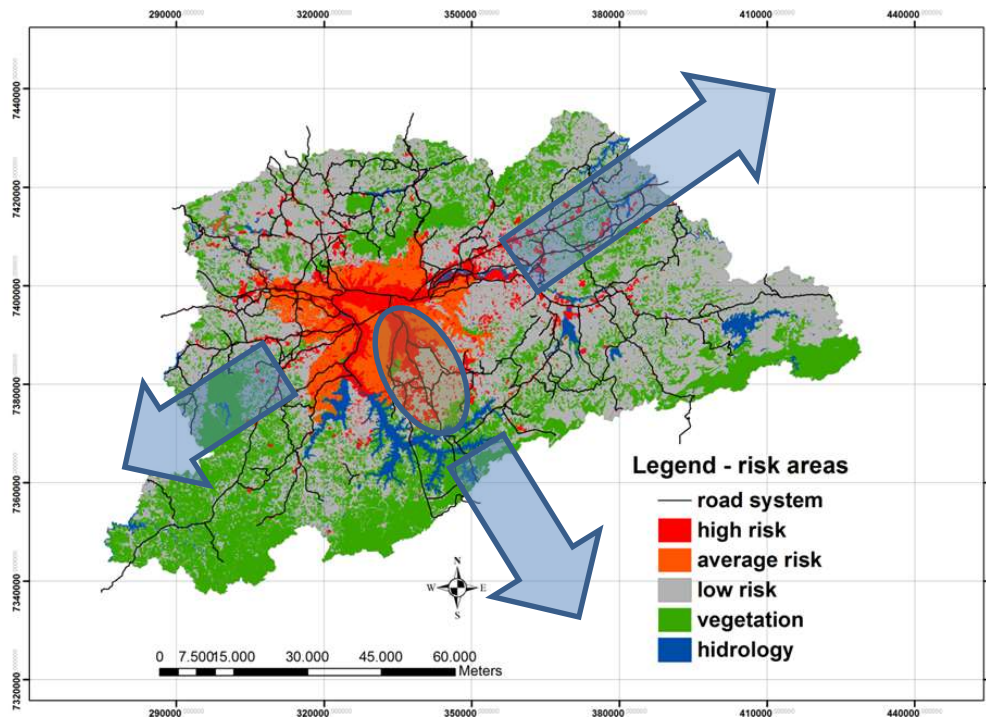
Projections indicate that if the expansion pattern of the MASP continues along historical lines, the urban area in 2030 will be approximately 38 per cent larger than today, with increased risks of floods and landslides affecting the population as a whole, especially the poorest people. More than 20 per cent of these new areas of expansion would be susceptible to and could eventually be affected by natural disasters caused by heavy rains. Approximately 4 per cent of the predicted expansion areas may be at risk of landslides (Nobre et al 2011)



Urban Heat Island – hydrological system were transformed in a kind of heat basin system. Distance from the center. Vulnerability to flood with updated data from 2017 to 2030 in the MASP (Young and Marengo 2018)

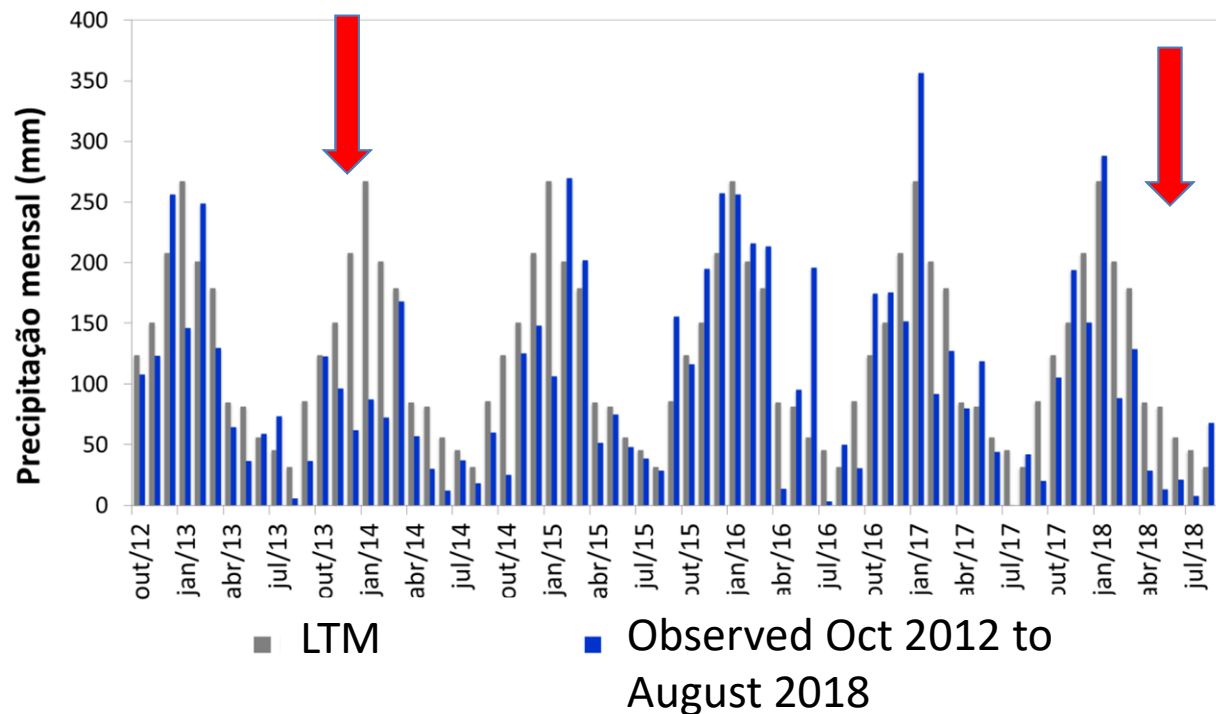


Urban Heat Island – Vulnerability to higher temperatures from urban heat islands in association with air pollution in MASP in 2030 (Young and Marengo 2018)



The Sao Paulo Water Crisis on summer 2014

Source: Sabesp and Cemaden



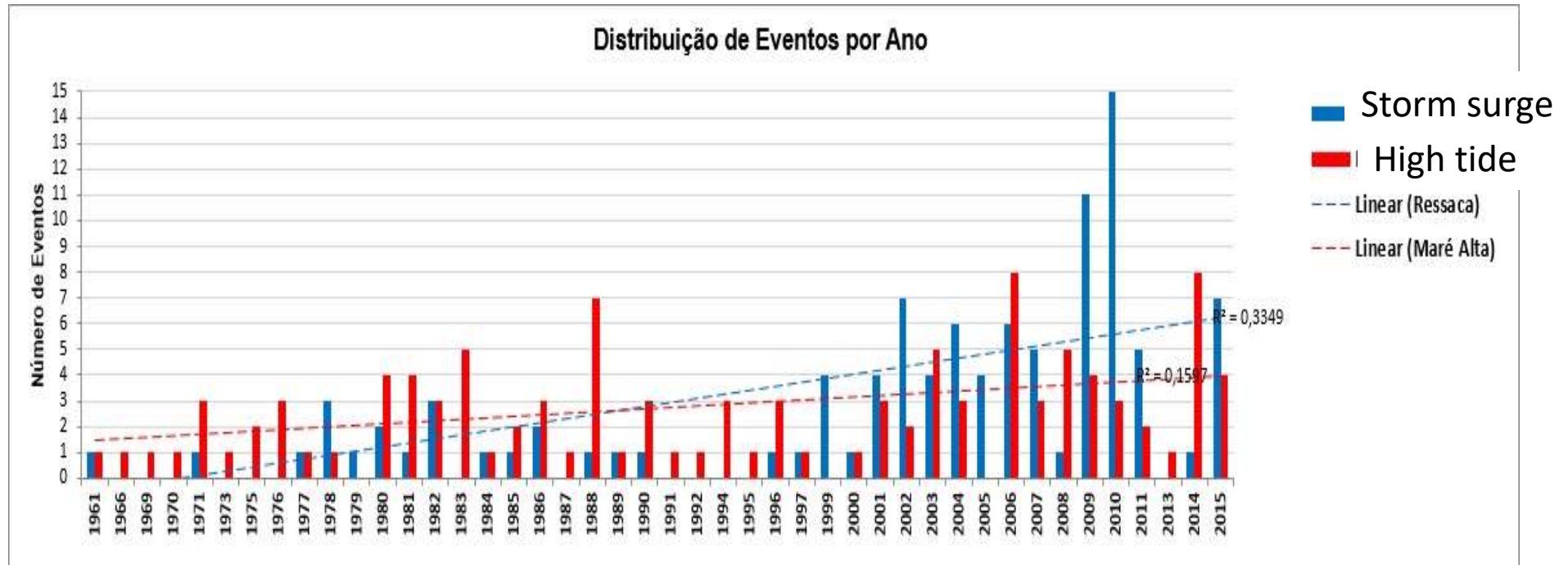
Precipitation – Oct-March

Mean: 1133 mm

2013/2014:	613 mm	(48% below normal)
2014/2015:	879 mm	(15% below normal)
2015/2016:	1257 mm	(07% above normal)
2016/2017:	1079 mm	(8% below normal)
2017/2018:	959 mm	(18% below normal)

The MASP presents today one of the most critical situations in the country with regard to ensuring sufficient water supply in quantity and quality for its population. Declining water resources coupled with increased demand for clean water, population and temperature has already become a political issue in many localities. This situation is becoming more and more aggravated by the constant urban expansion that generates the occupation of peripheral spaces and environmental protection areas, where are located drainage headwaters and important water bodies.

Extremes of dangerous storm surge and high tide events in Santos between 1961-2015, based on newspapers reports (PBMC 2016)



Ponta da Praia-

SE

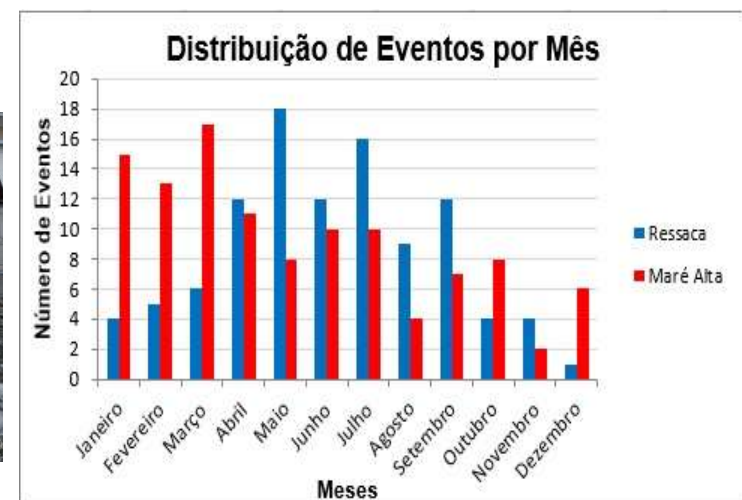


(2005)

NW



(2009)



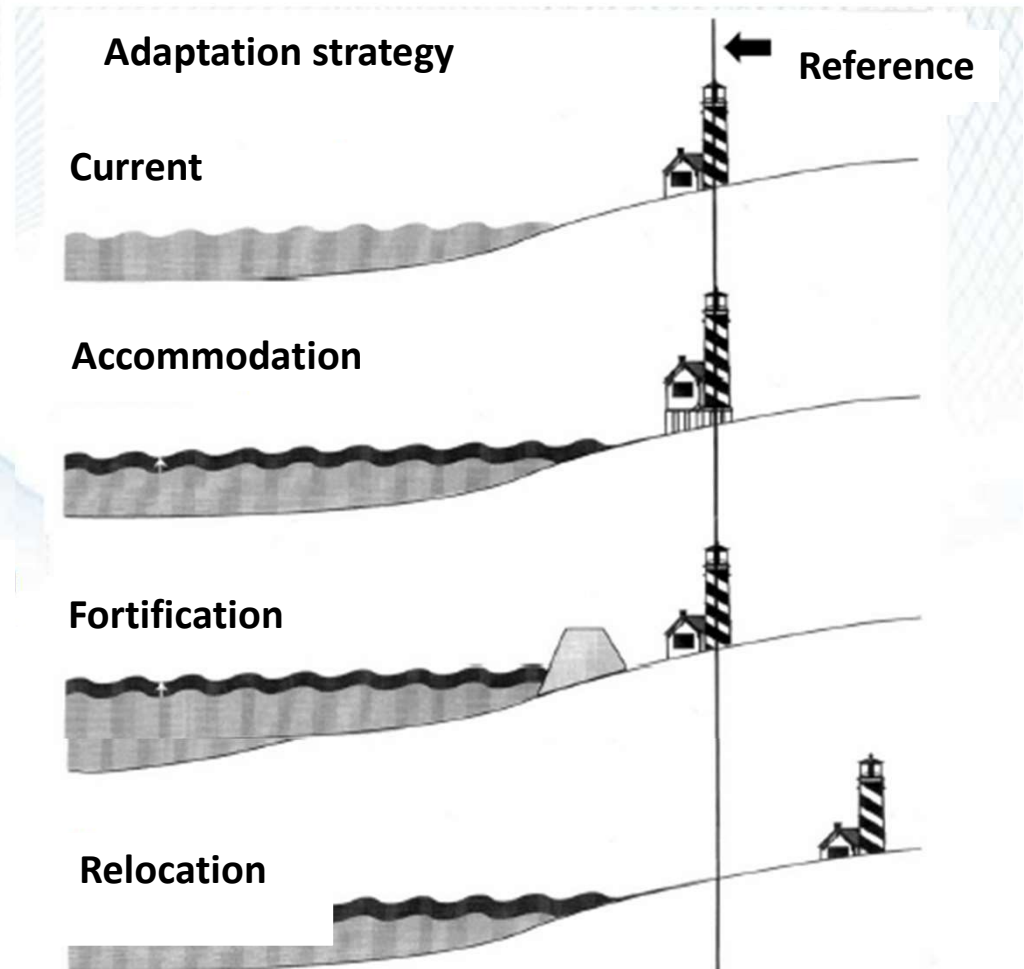
Identification of adaptation options in Santos

Planned Adaptation

Proactive and planned measures to preserve and protect resources in anticipation of impacts.

Reactive Adaptation

Reactive emergency measures implemented after impacts



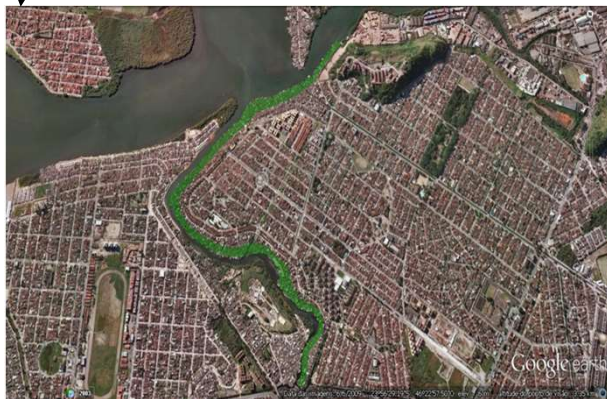
Adaptation measures proposed by the population of Santos in the northwest and southeast (Marengo et al., 2017)



Dredging



Preservation and restoration of Mangroves (EbA)



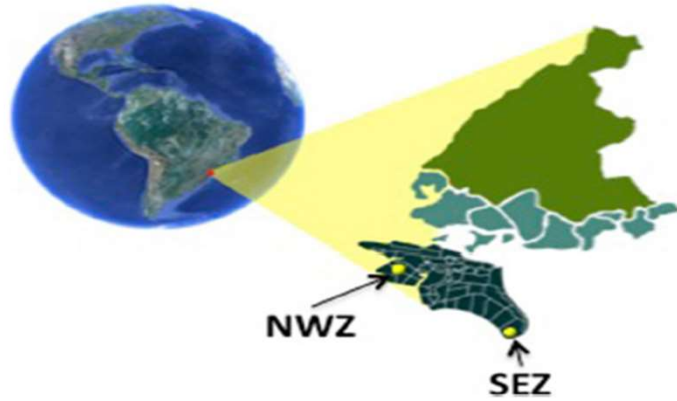
Beach nourishment and dune restoration



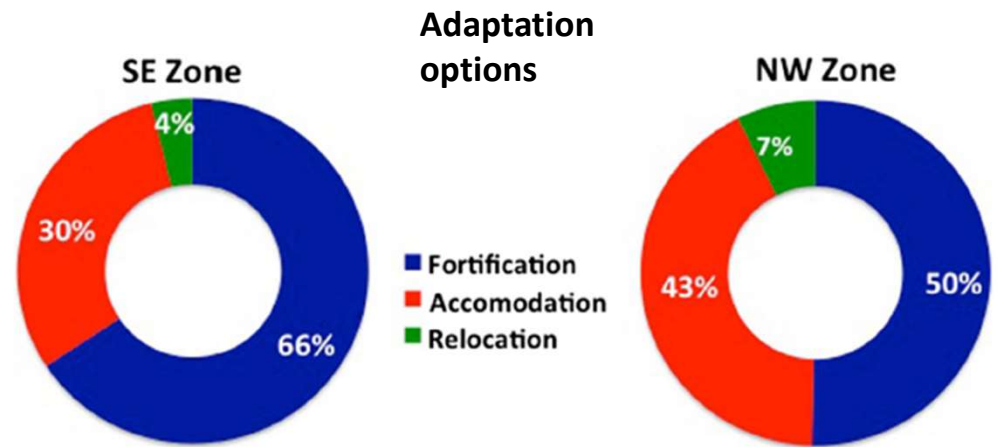
Improve existing sea walls



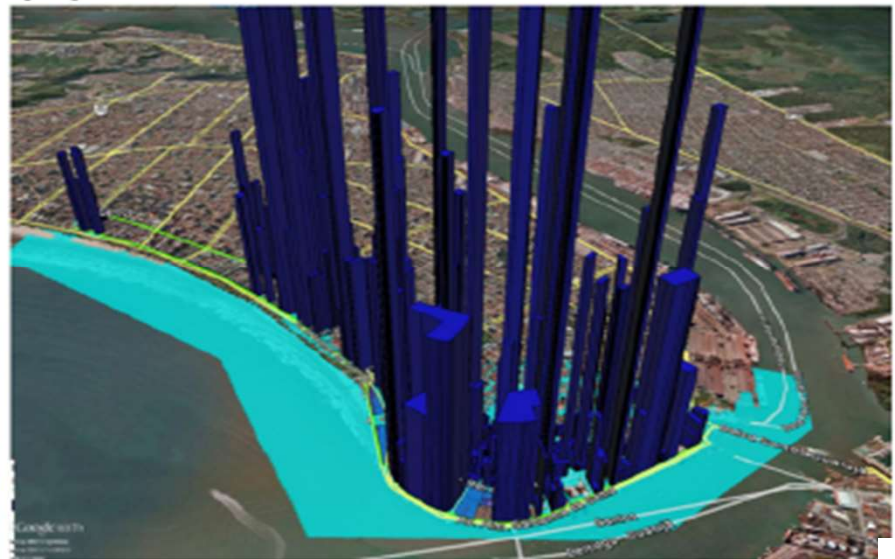
Coastal vulnerability in Santos



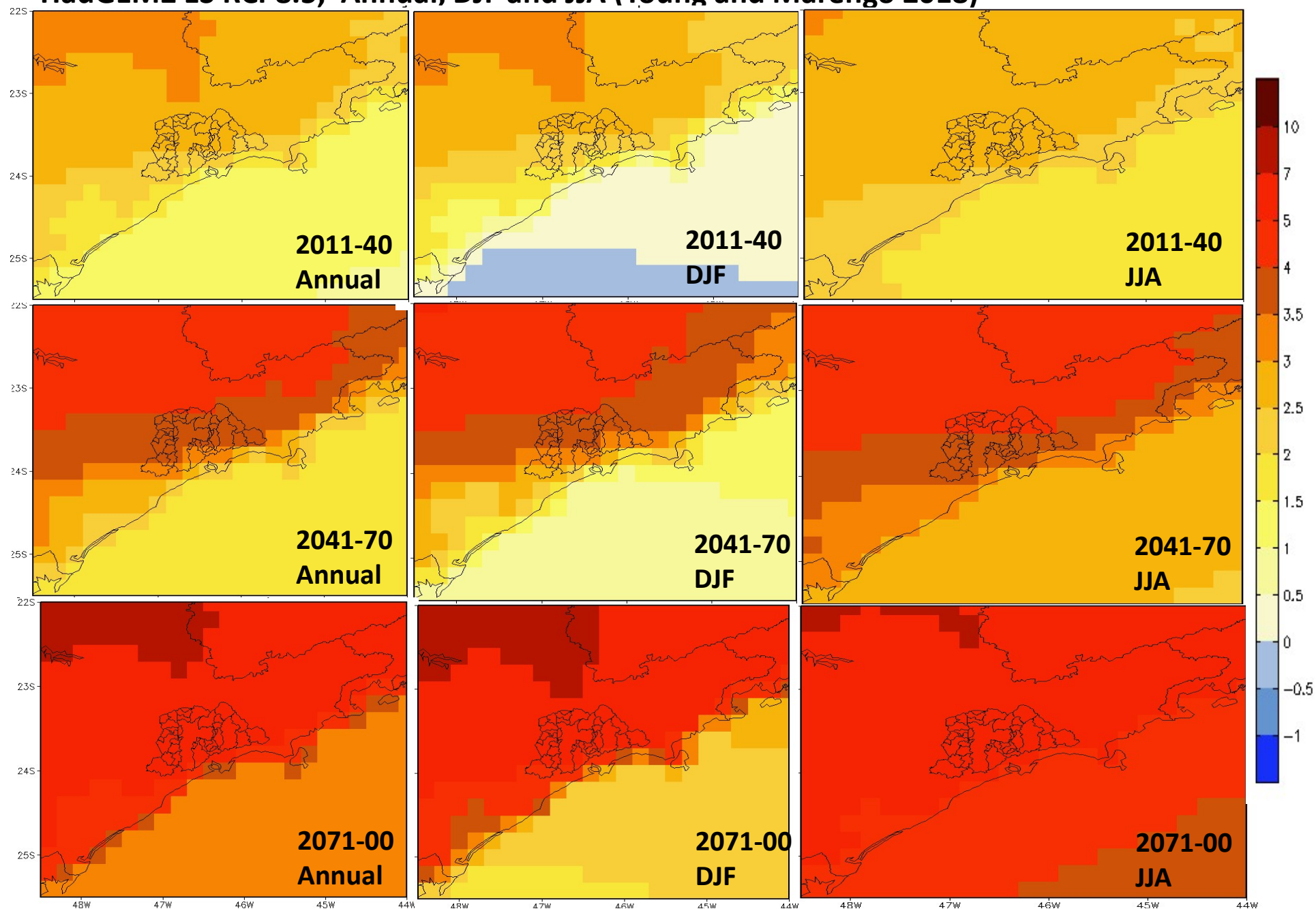
Flood scenarios designed for 2100 and estimated economic losses for a sea level rise of 0.45 m



(B)



Changes in air temperature in the MASP (2011-20140; 2041-2070; 2071-2100) from the Eta-HadGEM2 ES RCP8.5, Annual, DJF and JJA (Young and Marengo 2018)



Vulnerability of Brazilian Megacities to Climate Change: The São Paulo Metropolitan Region (MASP) and Santos

- A major concern of contemporary society in relation to future climate projections relates to possible changes in the frequencies and intensities of extreme weather events. Megacities such as São Paulo have numerous social and environmental problems associated with patterns of development and transformation of space, which have been aggravated by increases in temperature and intensification of extreme weather events. Santos would be affected by intense rainfall due to stronger storms, with high risk of storm surges.
- The risks will grow further due to higher temperatures and the associated increase in the frequency of rainfall events, especially in the summer. Studies project that between 2070 and 2100, an average temperature increase of 2°C to 3°C could double the number of days with heavy rainfall in São Paulo and in Santos

Vulnerability of Brazilian Megacities to Climate Change: The São Paulo Metropolitan Region (MASP)

- The MASP, which already suffers from floods every summer, may experience an increased number of days with heavy rainfall by the end of the 21st century.** Total rainfall of over 30 mm/day has the potential to cause severe flooding. Total rainfall above 50 mm/day, virtually nonexistent before the 1950s, now usually occurs two to five times a year in São Paulo. **Santos would experience SLR and more storm surges affecting coastal areas**
- Projections indicate that if the expansion pattern of the continues along historical lines, there will be an increased risks of floods and landslides affecting the population as a whole, especially the poorest people.** Impacts on population and infrastructure would be higher and adaptation strategies are needed to avoid impacts on vulnerable sectors of these cities. Mitigation action are needed (e.g. the Paris agreement 2015)