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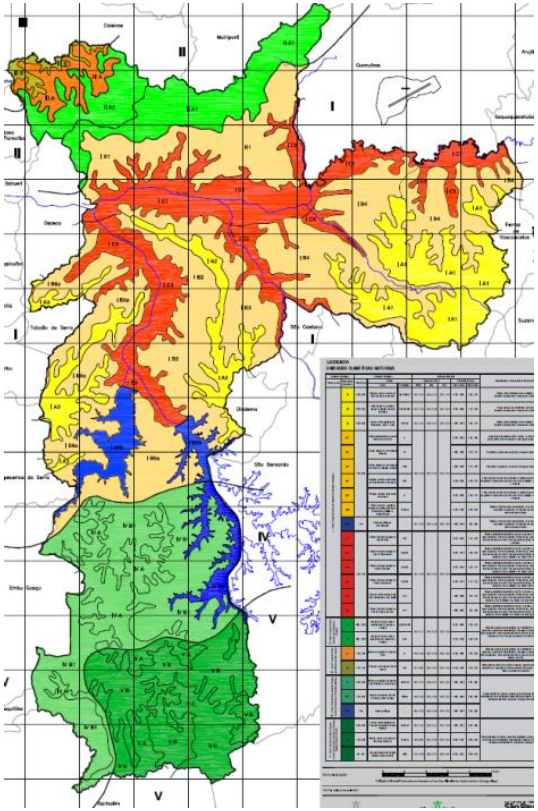
Climate and water resilience in São Paulo city

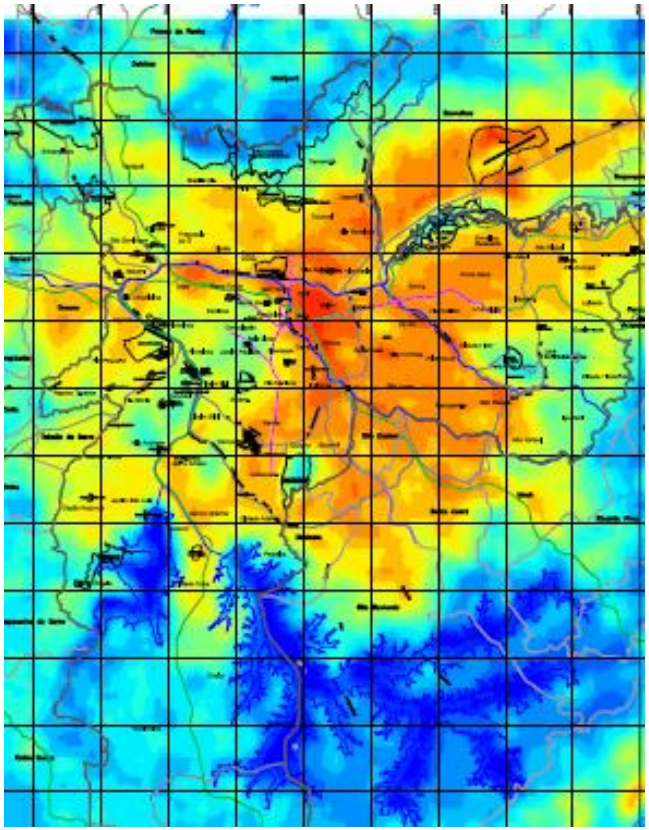
Finnish & Brasil workshop/Fapesp, 28 nov 2016

"As our world becomes urbanized, it becomes more important the understanding of the consequences of both the climatic environment in and around cities and the remnants of the natural world" *W. Wilson* (2011). *Constructed Climates: a Primer on Urban Environments* , University of Chicago Press.

- Options of ecosystem based adaptation
- Predictability and risk

Climate and urbanization in São Paulo





Some controls of urban elements on local climate:

- Materials
- Geometry of street and buildings
- Vegetation
- Antropogenic heat

Natural climatic unities in Sao Paulo (left)
Apparent surface temperature (right)

Source: TARIFA, J. R.; ARMANI, G. 2000. **Unidades climáticas urbanas da Cidade de São Paulo. Atlas Ambiental do Município de São Paulo, Fase I**. São Paulo: Secretaria do Verde e do Meio Ambiente – SVMA/PMSP/Secretaria de Planejamento – SEMPLA/PMSP 2000. 78 p.

Atlas Ambiental do Município de São Paulo. São Paulo: SVMA, 2004. 266p. Ambiental do estado de São Paulo

estimates needs accuracy

How green infrastructure help remediating the warming ?

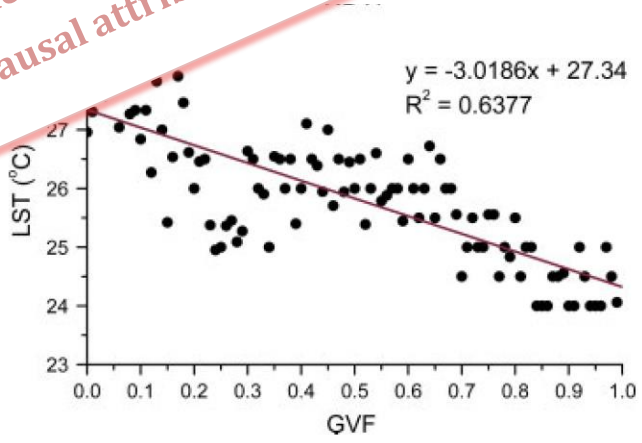
Science AAAS

Global Change and the Ecology of Cities
Nancy B. Grimm, *et al.*
Science **319**, 756 (2008);
DOI: 10.1126/science.1150195

Cool the air by shading, less solar heat absorpion, and higher evapotranspiration
Increase water infiltration and mitigating floods

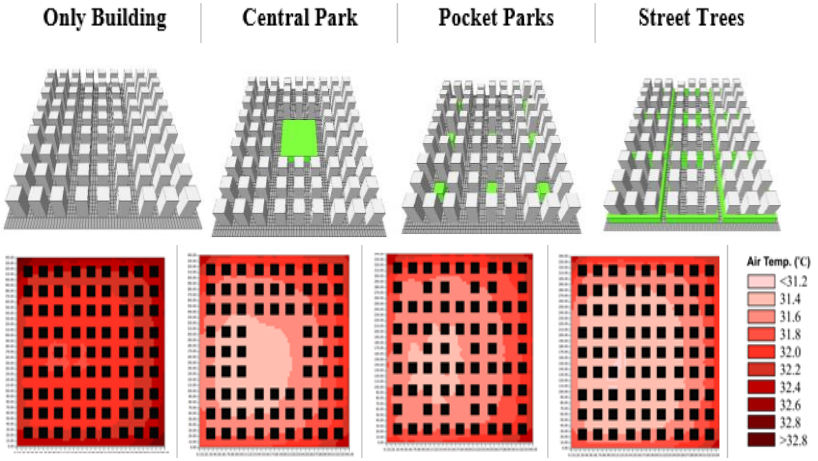
Advantages: reduce electricity demand
Tradeoffs: higher water use, costs of maintenance

issues of scaling and causal attribution



the case of Honkong, China
Land surface temperature VS satellite estimated Green fraction

Source: Hu, Y et al. Influence of land use change on urban heat island derived from multi-sensor data *Int. J. Climatol.* 30: 1382–1395 (2010)



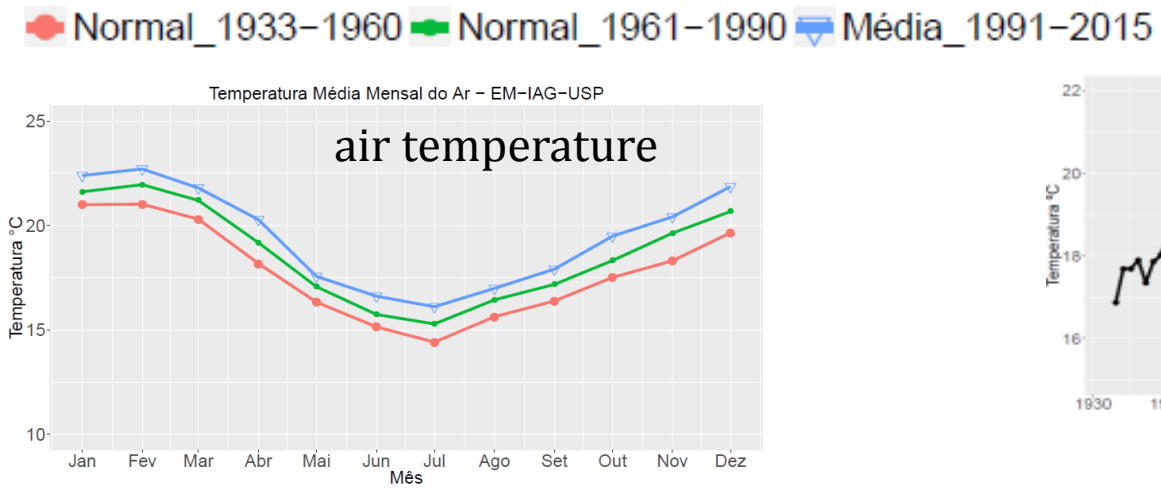
a case in São Paulo: impact in air temperature
Simulation of air temperature using Envi-met model v.4 in São Paulo city, 15h, 16 apr 2016, for spatial scenarios of blocks w/ towers (45m height, 15 floors 20m x 20m).

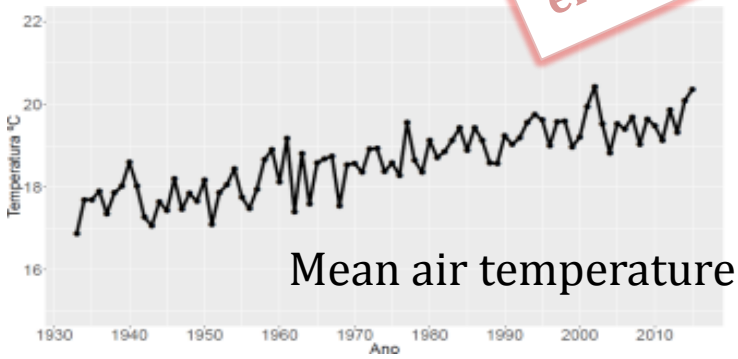
Source: DUARTE, D. ; SHINZATO, P. ; GUSSON, C. ; ALVES, C. . *The Impact of Vegetation on Urban Microclimate to Counterbalance Built Density in a Subropical Changing Climate.* Urban Climate, v. 14, p. 224-239, 2015.

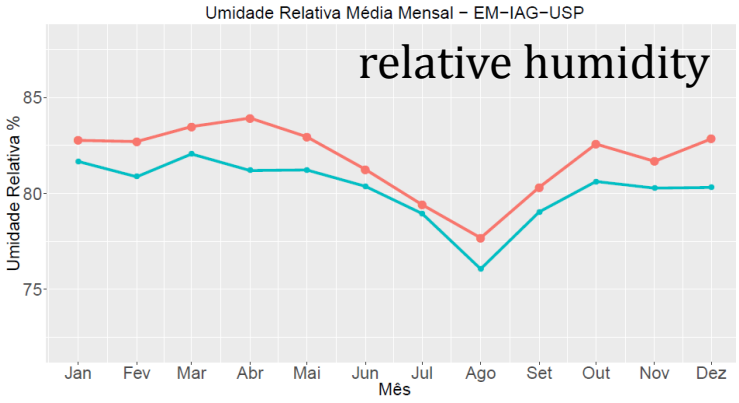
Climate trends in São Paulo

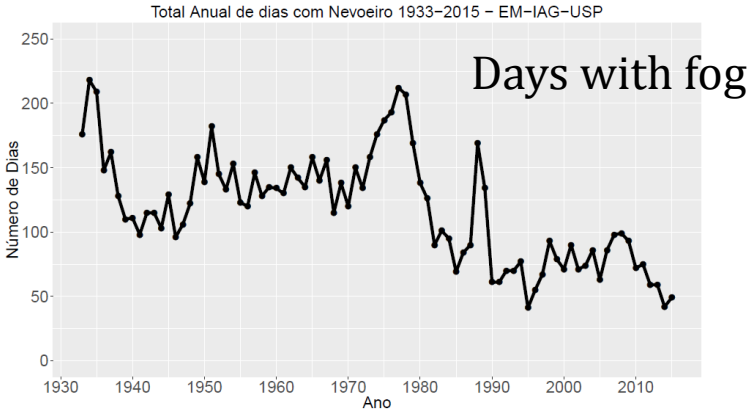
Source: Boletim Climatológico Anual da Estação Meteorológica do IAG/USP/ Seção Técnica de Serviços Meteorológicos – Instituto de Astronomia, Geofísica e Ciências Atmosféricas da Universidade de São Paulo , v18, 2015, São Paulo IAG/USP, 2015

global and local effects on climat

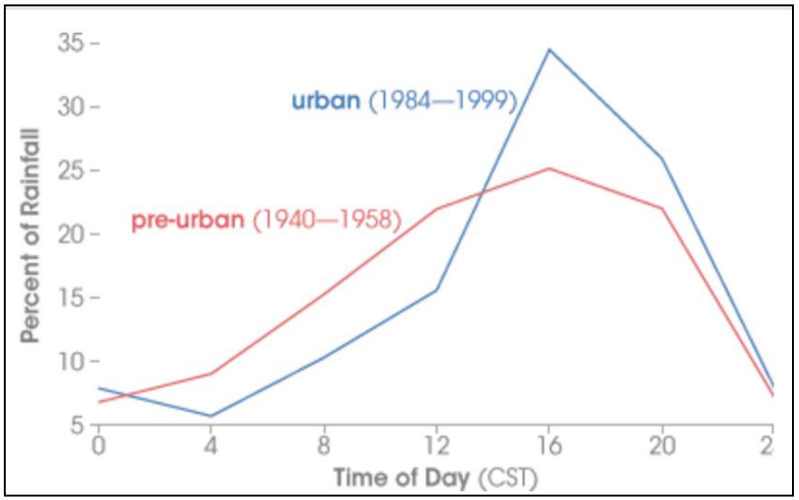








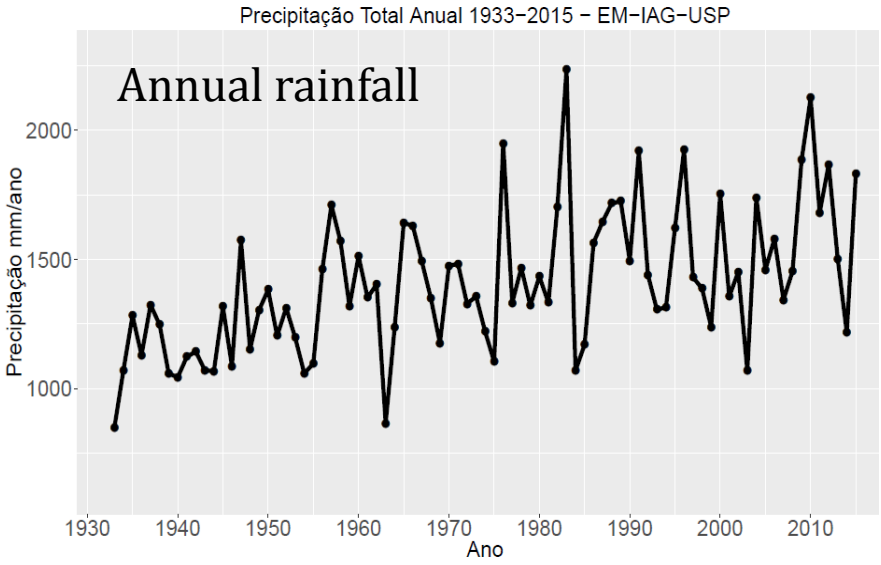
Rainfall changes



the case of Houston city, USA

- rain concentrated in a narrower time window around 4 pm
- warm-season rainfall amount in urban area increased by 25%

- Source: Burian and Sheperd (2005) Hydrological Processes, 19, 2089-1103



the case of Sao Paulo city, Brasil

- natural variability explains only 37% variance of increasing wet season rainfall

Climatic Change
DOI 10.1007/s10584-012-0504-7

Changes in extreme daily rainfall for São Paulo, Brazil

Maria A. F. Silva Dias · Juliana Dias ·
Leila M. V. Carvalho · Edmilson D. Freitas ·
Pedro L. Silva Dias

Likely local and uncleared effects on rainfall

Water yield dependence on Land use

Forested watersheds

- increase water quality (stabilize streambanks, reduce erosion, filter pollutants)
- high-quality habitat for biodiversity
- reduce storm runoff
- more often reduce annual water yield and dry season low flow

- **Deforestation**
- expected to decrease rainfall over large tropical humid areas

- Sources: Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being: synthesis. Washington, DC: Island Press.
- Bruijnzeel, L.A., 1990. Hydrology of Moist Tropical Forest and Effects of Conversion: A State of Knowledge Review. UNESCO, Paris, and Vrije Universiteit, Amsterdam, The Netherlands, 226 pp.

Why care about restoration ?

Water Producer Program (ANA)

Projeto Conservador das Aguas (ANA, Prefeitura Extrema): forest restoration activities to increase water yield in targeted springs through contracts with landowners

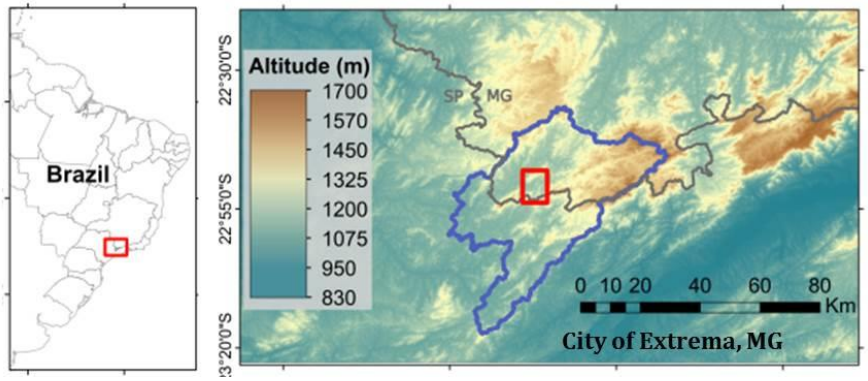
Ecosystem Services

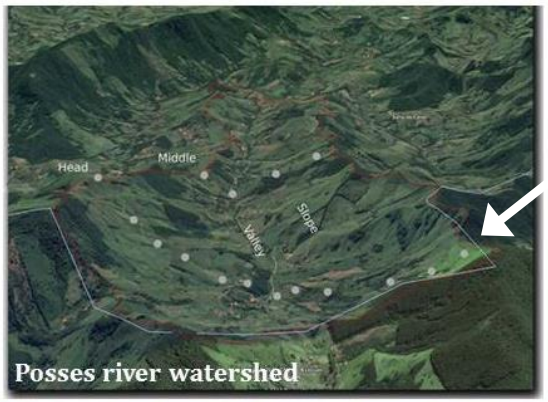
journal homepage: www.elsevier.com/locate/ecoser

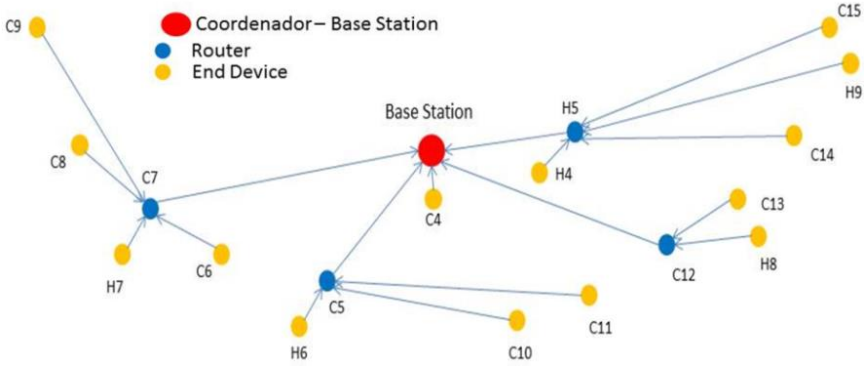
Governing a pioneer program on payment for watershed services: Stakeholder involvement, legal frameworks and early lessons from the Atlantic forest of Brazil

Ryan C. Richards [a,b], Julia Rerolle [c,d], James Aronson [e,f], Paulo Henrique Pereira [g], Helena Gonçalves [h], Pedro H.S. Brancalion [d,*]

Critical zone hydrometeorological team at the headwaters
FAPESP funded Thematic project







Automatic weather station wifi network

Posses river watershed, area 12 km^2, altitude 1350 a 1050 m

18 meteo station Vaisalla WXT, soil moisture DeltaT-PR2 1m depth

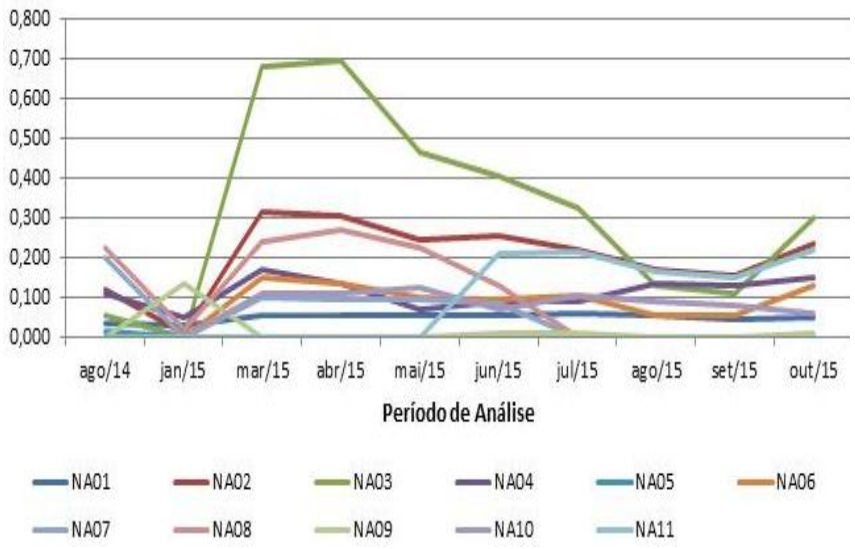
Topology: Base station, router, end devices, WiFi transmission, Transceiver ZigBee, SD card

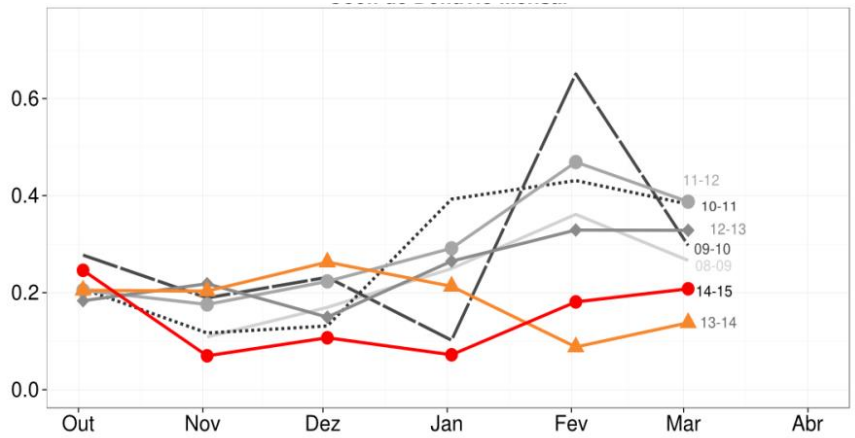
Flux tower (eddy covariance) (Usp)

Water quality, discharge, groundwater (ANA, Cena/Usp, Embrapa Meio Ambiente)

Soil erosion and sediment flux (UFLA)

Hydrological measurements at Posses watershed

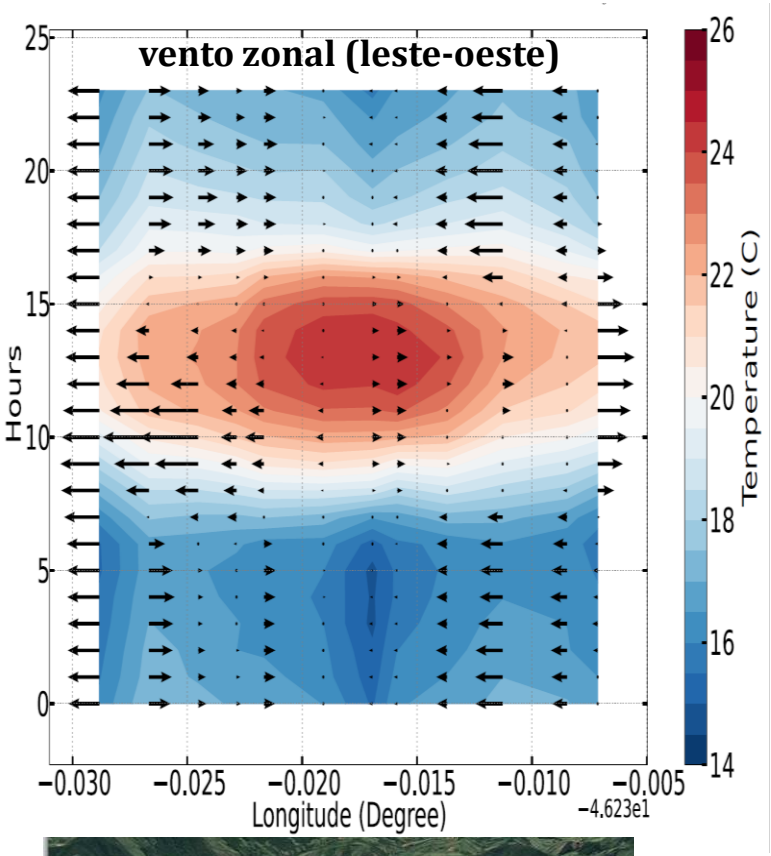


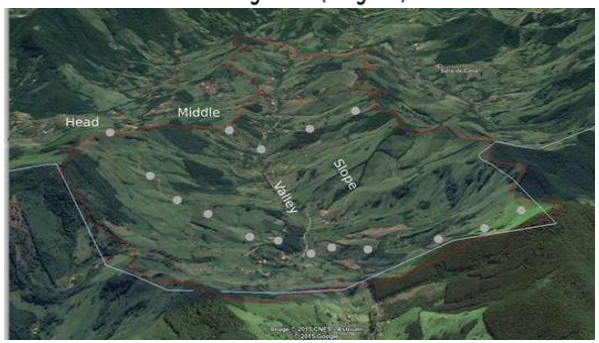


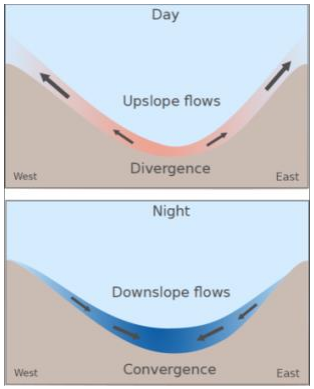
Springflow (L/s) (top)

mean monthly runoff coefficient (discharge / rainfall) (bottom)
Source: Lab. Clima e Biosfera/IAG/Usp (preliminary data analysis)

Climate spatial variability in the watershed

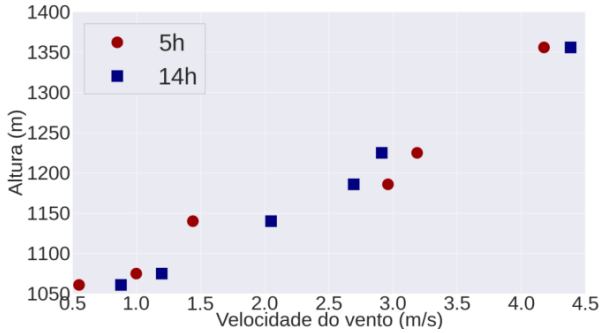






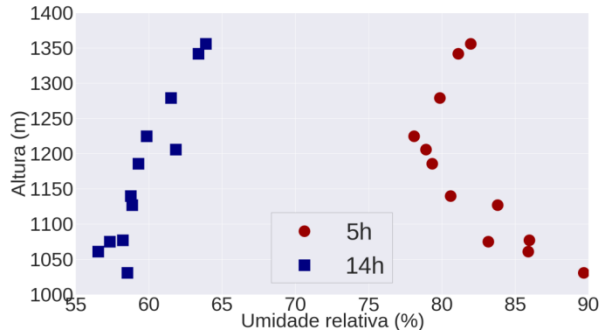
- Divergence with upslope flow in the morning
- Convergence with downslope flow in the night

- Source: Martin et al (2016) (in prep)



changes with height:

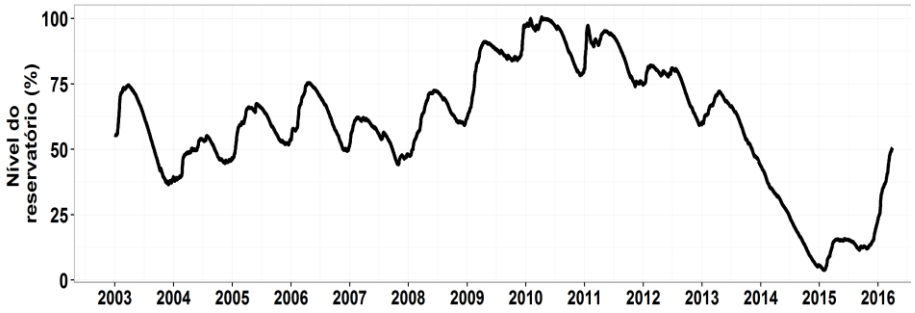
- Wind speed



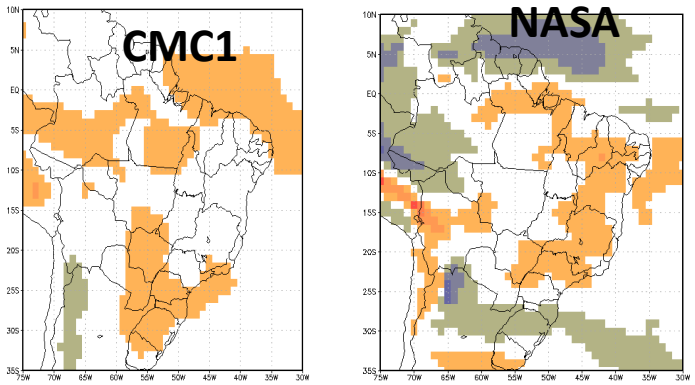
- relative humidity

Water yield dependence on climate variability and climate change

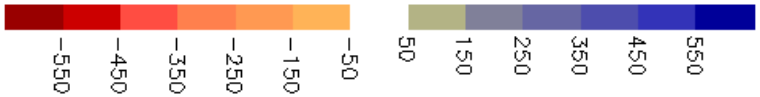
Water excess in 2010 and déficit in 2014.

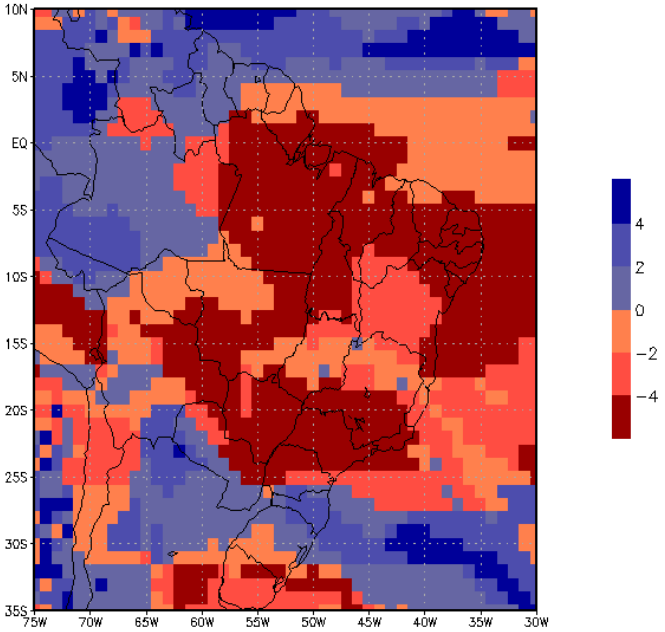


% of total volume at Jaguari-Jacareí water reservoir



Predicted rainfall anomaly (mm) summer DJF 2013/2014





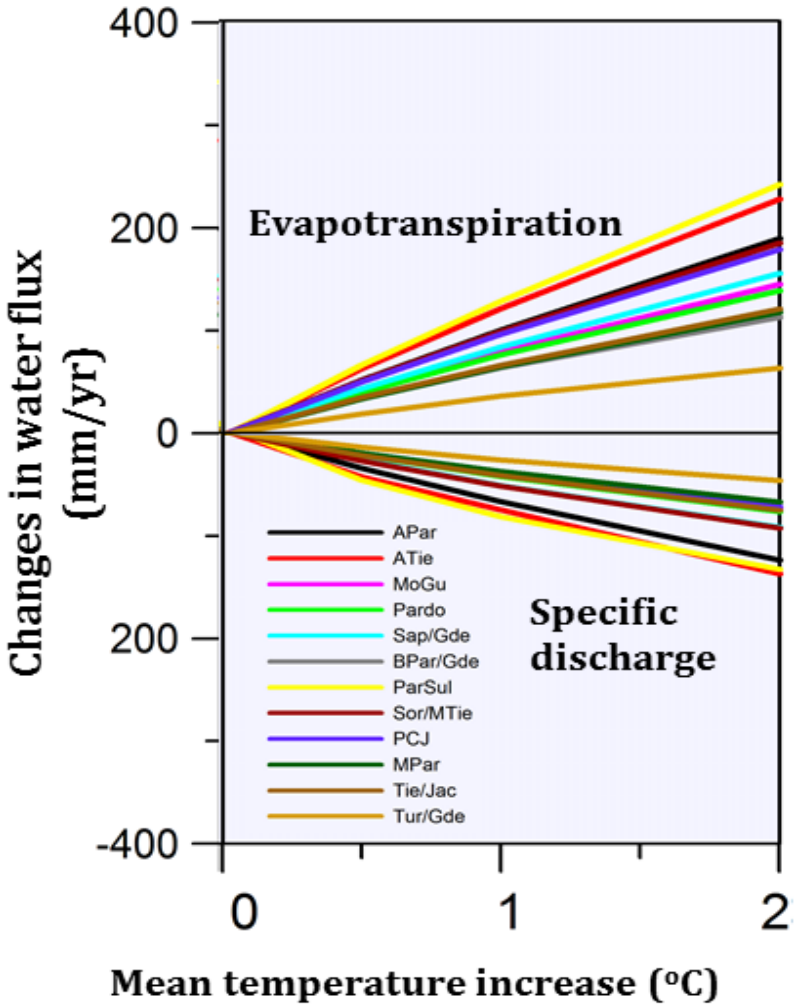
Number of models out of 5 with seasonal forecast of rainfall below average (-) / above average (+) for DJF 2013/2014 using NMME (Kirtman et al. 2014 Bulletin of American Meteo. Soc.)

Water yield dependence on climate variability and climate change

Runoff simulation using a surface vegetation - atmosphere model (SiB2) (Fonte: Domingues et al., 2014, IAG/Usp)

Simulation domain: São Paulo state UGRHI (sub-basins) res 0,25º deg, time step 1 h, 1 year

Climate forcing
Baseline with climate observations, and additional crescent warming up to 2 ºC above average



Final remarks

Some research priorities

How green infrastructure is helpful to mitigate current and future urban problems ?

Concile green and grey infrastructures to optimize benefits.

- Accurate quantification of ecosystem services, their benefits and tradeoffs
- Improve predictability systems