Humidity Regime

in the World's

Mega Cities

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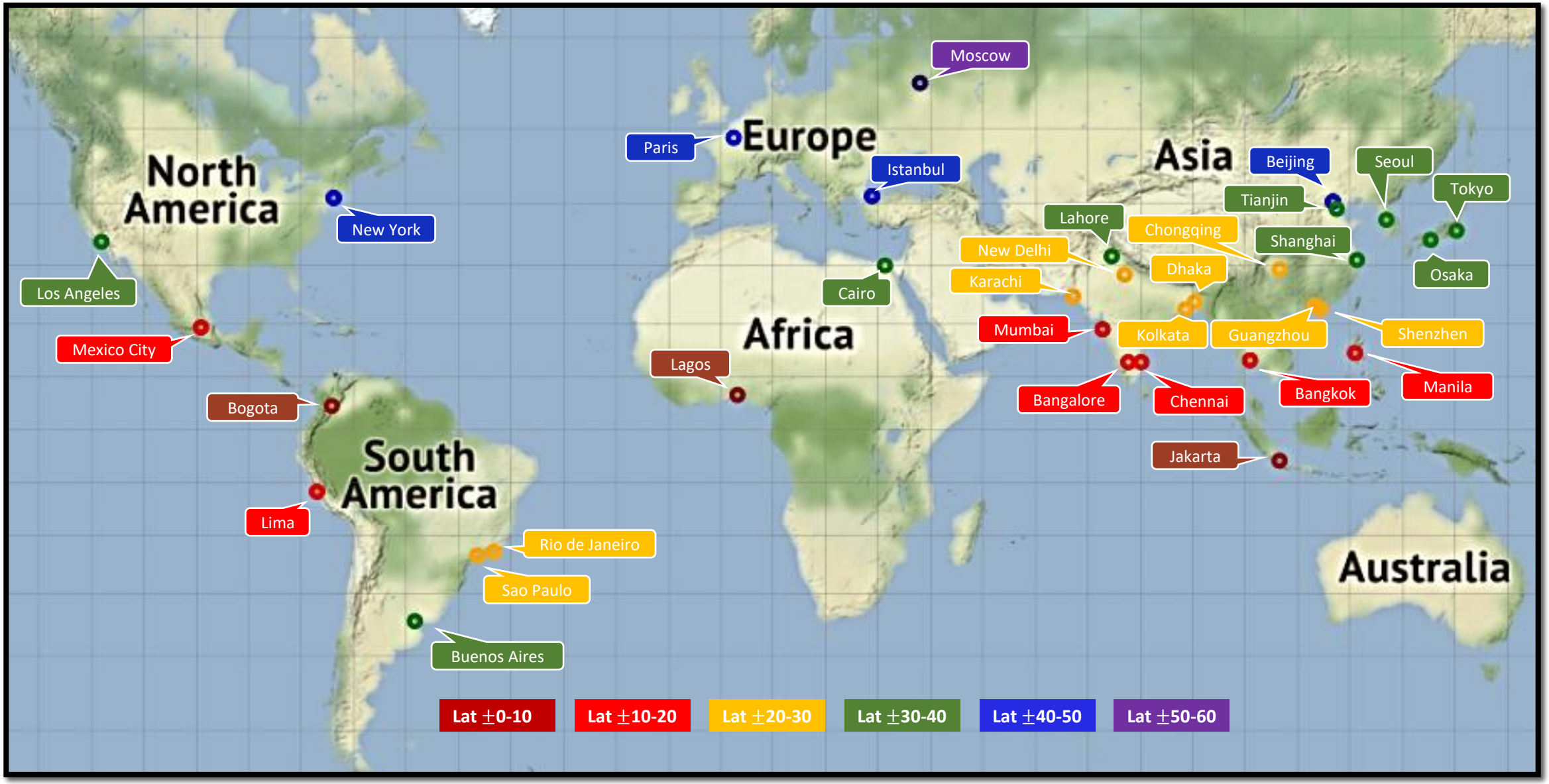
EGU General Assembly, May 24th 2022

33 mega cities with >10m residents



*Kinshasa was excluded from analysis due to insufficient data availability

Research Motivation

- Models capture fairly well actual T and q, however as for RH models still do not entirely manage to fully capture actual changes.

- Furthermore, in the vicinity of cities there are special conditions influencing the RH – which worth exploring for better understating of current and future trends.

- RH is one of the most important parameters needed to estimate evapotranspiration, as a lower RH encourages evaporation from the soil and water bodies. RH is also important for precipitation formation, human comfort and health, energy consumption, agriculture production and ecosystems

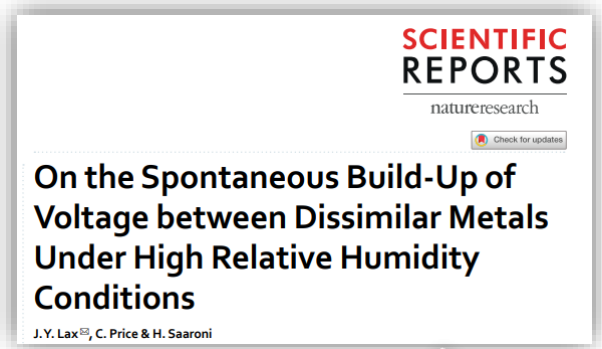
- High RH of $\geq$60% is an important parameter for many aspects, among them is its role influencing the intensity of heat loads on one hand, as well as for novel technologies, for mitigating and adapting to climate change, on the other.

Research Motivation

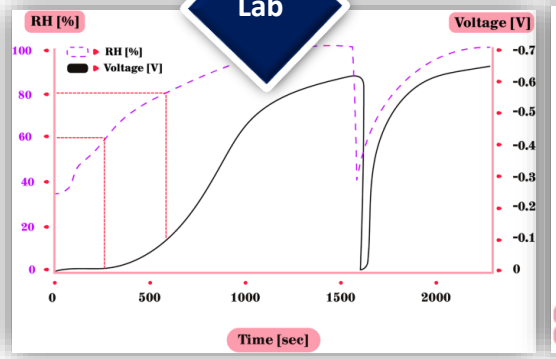
Climate Change Mitigation

Humidity as a source for energy

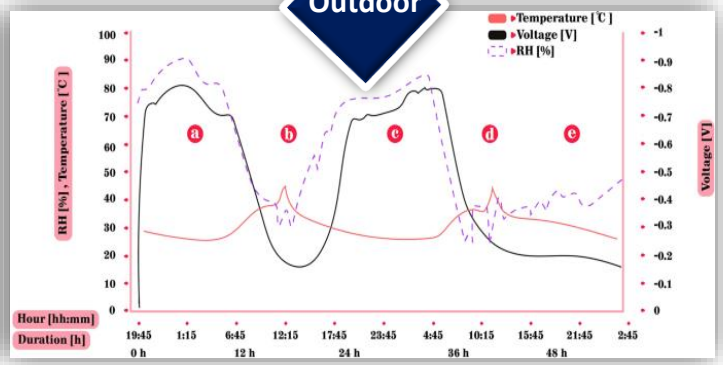
RH≥60%



Lab

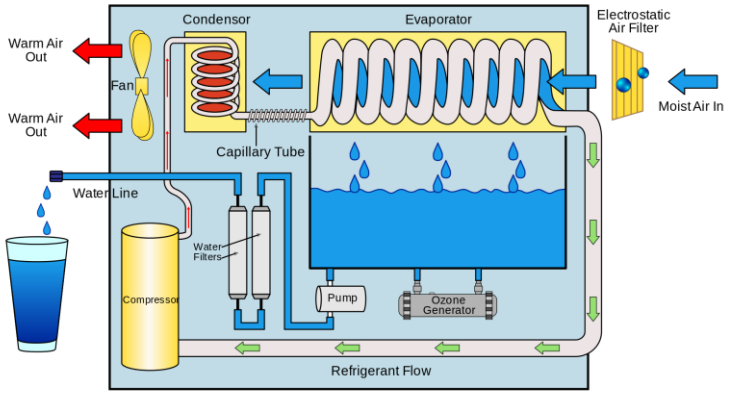


Outdoor



Climate Change Adaptation

Humidity as a source for drinking water



High RH durations

q threshold

T threshold

Lax, J.Y., Price, C. & Saaroni, H. On the Spontaneous Build-Up of Voltage between Dissimilar Metals Under High Relative Humidity Conditions. *Sci Rep* **10,** 7642 (2020). https://doi.org/10.1038/s41598-020-64409-2
Emerging design principles, materials, and applications for moisture-enabled electric generation, eScience, Volume ,1 eussI ,2 ,2022 Pages ,32-46 ISSN ,2667-1417 https://doi.org/.2021.12.009.icse.j/10.1016

Research Methods

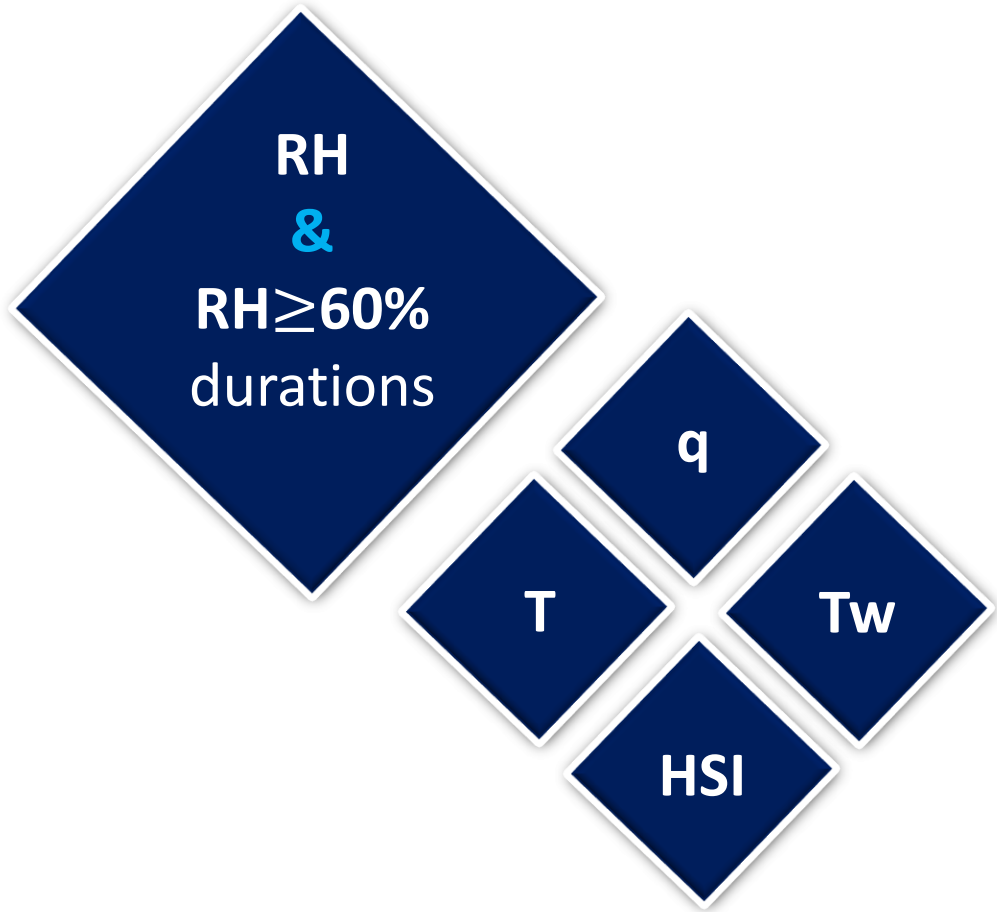
Data taken from observations
(meteorological stations based mainly in cities' airports)

last decade's climatology – 33 mega cities
(RH, RH durations, T, q, Tw & HSI – annual & seasonal mean, std, etc.)

Heat stress analysis - 33 mega cities
(Heavy & extreme heat stress durations analysis)

30-40 years annual & hot season trends – 10 cities
(RH, T, q, Tw & HSI – standard simple linear regression)

Cities ranking by suitability for emerging technologies
(As a function of local high RH durations, q & T)

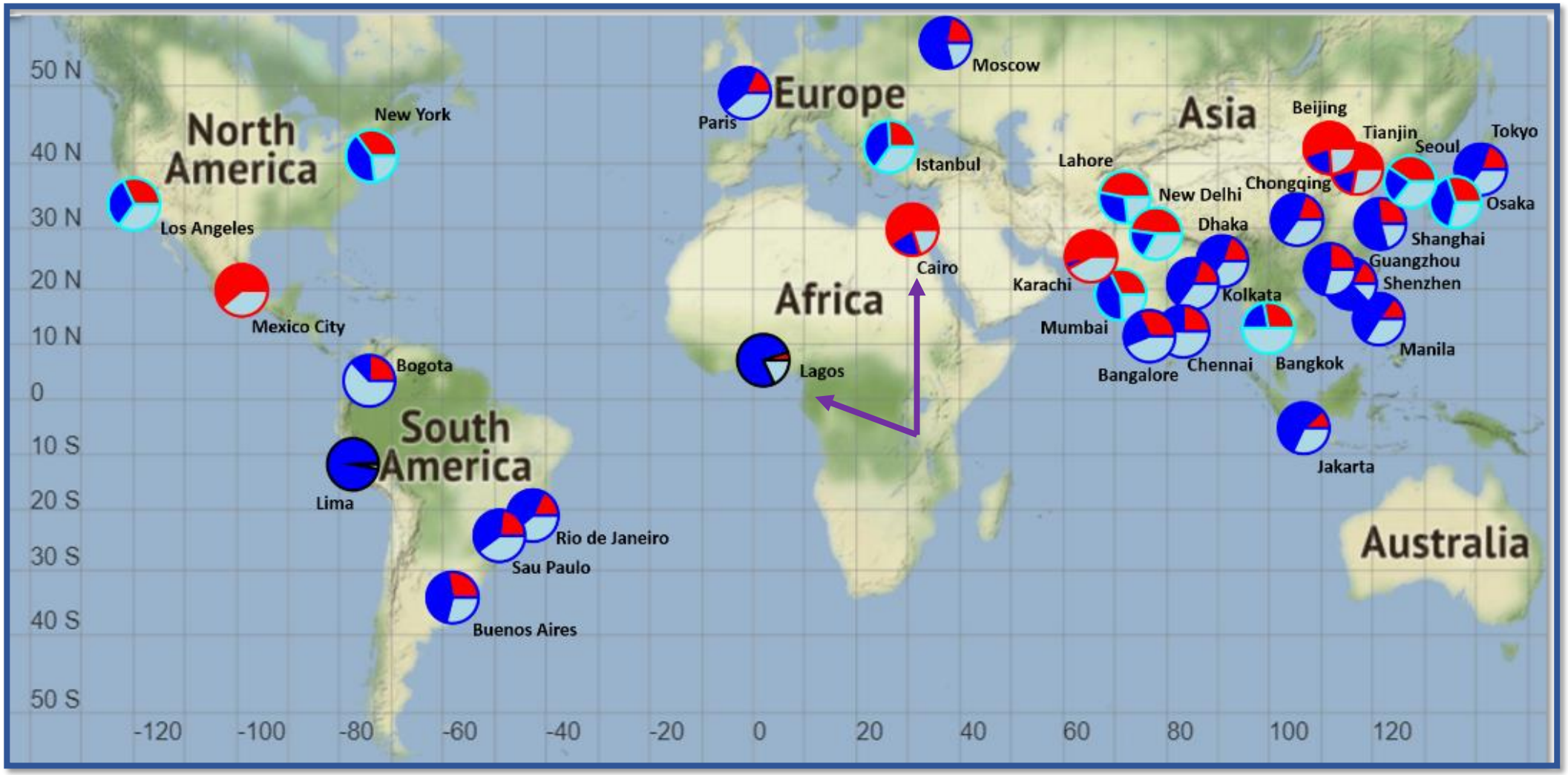


$$Heat\ Stress\ Index\ [HSI, C] = \frac{Temp + Tw}{2}, 'heavy' \rightarrow 28 \leq HSI < 30\ ; 'Extreme' \rightarrow HSI \geq 30$$

$$Tw\ [℃] = Temp \cdot \arctan\left(0.151977 \cdot \sqrt{((RH + 8.313659)}\right) + \arctan(Temp + RH) - \arctan(RH - 1.676331) + 0.00391838 \cdot (RH^{1.5}) \cdot \arctan(0.023101 \cdot RH) - 4.686035$$

Results

Mega cities RH regime – last decade



Annual Mean RH

- $RH < 60\%$
- $60\% \leq RH < 70\%$
- $70\% \leq RH \leq 80\%$
- $RH > 80\%$

RH distribution

- RH<60%, any duration
- $RH \geq 60\%$ Duration= less than 24h
- $RH \geq 60\%$ Duration= at least 24h

9 out of 33 megacities experience long spells (≥24h) of high RH most of the year

Mega cities 30-40 years trends

City	Duration	30-40 years trend – annual mean				
		RH (%/10 years)	q (g/kg/10 years)	Tw (°C/10 years)	T (°C/10 years)	HSI (°C/10 years)
Buenos Aires	30 Years	-0.77	0.03	**0.17**	**0.31**	**0.26**
Guangzhou		**-1.66**	0.08	**0.24**	**0.51**	**0.42**
LA		0.48	-0.04	-0.08	-0.14	-0.13
Lima		0.17	0.04	0.03	0.01	0.01
Mexico City		-0.65	0.04	0.21	**0.37**	**0.3**
Moscow		**-1.99**	0.06	**0.51**	**0.75**	**0.69**
New York ISP		**-1.19**	0	0.07	0.21	0.18
New York JFK		**-1.55**	**-0.13**	-0.1	0.08	0.04
New York LGA		**-2**	-0.09	0.08	**0.34**	**0.27**
Rio de Janeiro		0.91	0.05	-0.04	**-0.22**	-0.16
Sau Paulo		-1.17	**-0.26**	**-0.21**	-0.05	-0.1
Tokyo		-0.57	0.14	**0.34**	**0.44**	0.41
LA	40 Years	-0.53	0	0.06	0.15	0.12
New York ISP		-0.47	**0.11**	**0.24**	**0.3**	**0.28**
New York JFK		-0.75	0.04	0.12	**0.21**	**0.19**
New York LGA		**-1.84**	-0.04	0.13	**0.37**	**0.3**
Rio de Janeiro		-0.83	-0.22	-0.19	-0.1	-0.11
Sau Paulo		**-2.49**	**-0.39**	**-0.26**	0.1	0
Tokyo		-0.13	**0.22**	**0.4**	**0.45**	**0.43**

Statistically insignificant increasing trend

Statistically **significant** increasing trend

Statistically insignificant decreasing trend

Statistically **significant** decreasing trend

RH decreases in most mega cities.

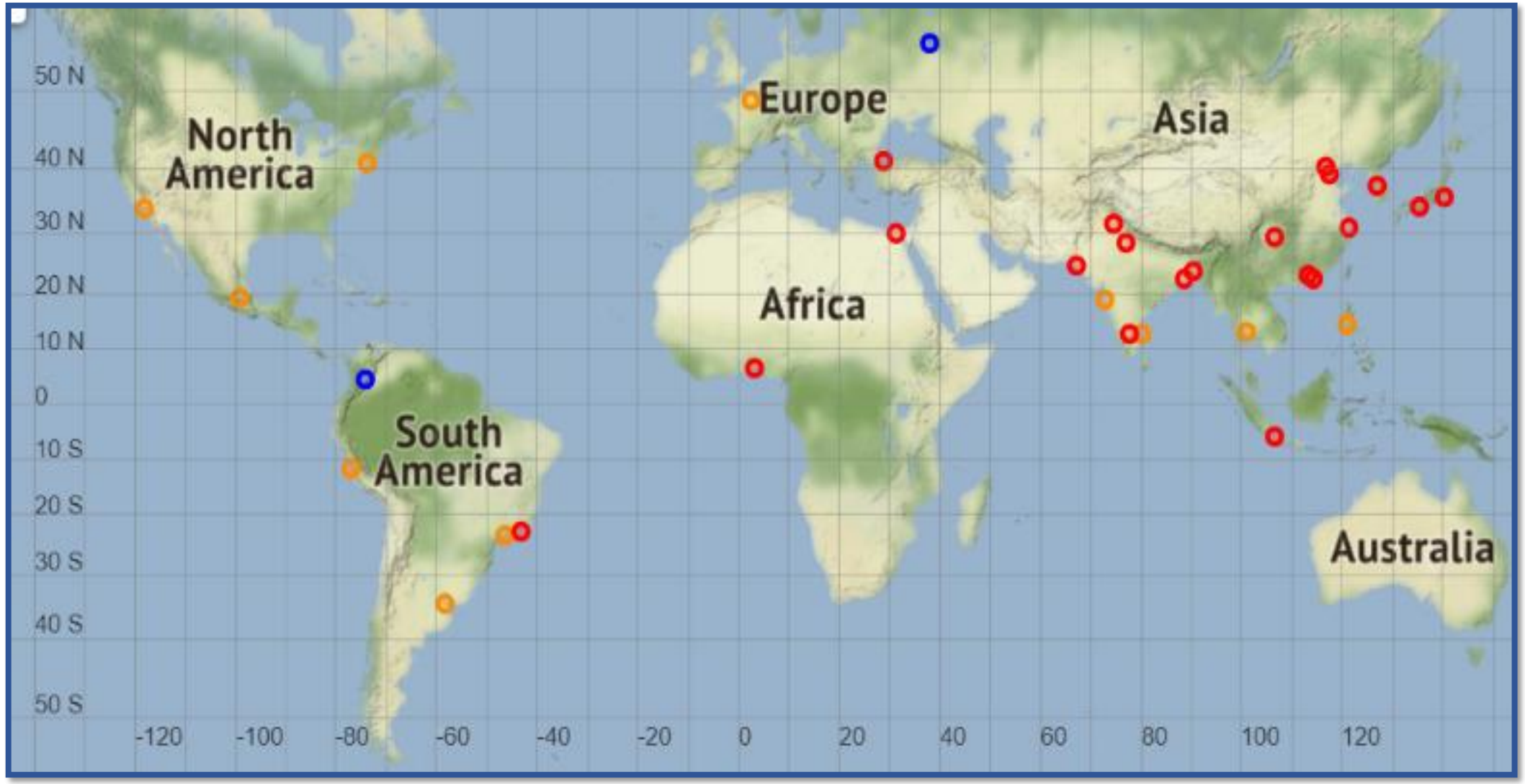
RH decreases faster
than prediction of CMIP5 simulations over land **(-0.05 to -0.25%/ decade),**
as well as compared to average observations **(-0.4 to -0.8%/decade).**

The **expected significant increasing trends in q was not strongly evident** in the mega cities.

As T rises, the **RH decrease is insufficient to prevent heat stress intensification**

Who suffers most from heat stress?

Along the year, 31 out of 33 megacities experience some degree of heat stress



Highest heat loads: None Light / mild / moderate heavy / extreme

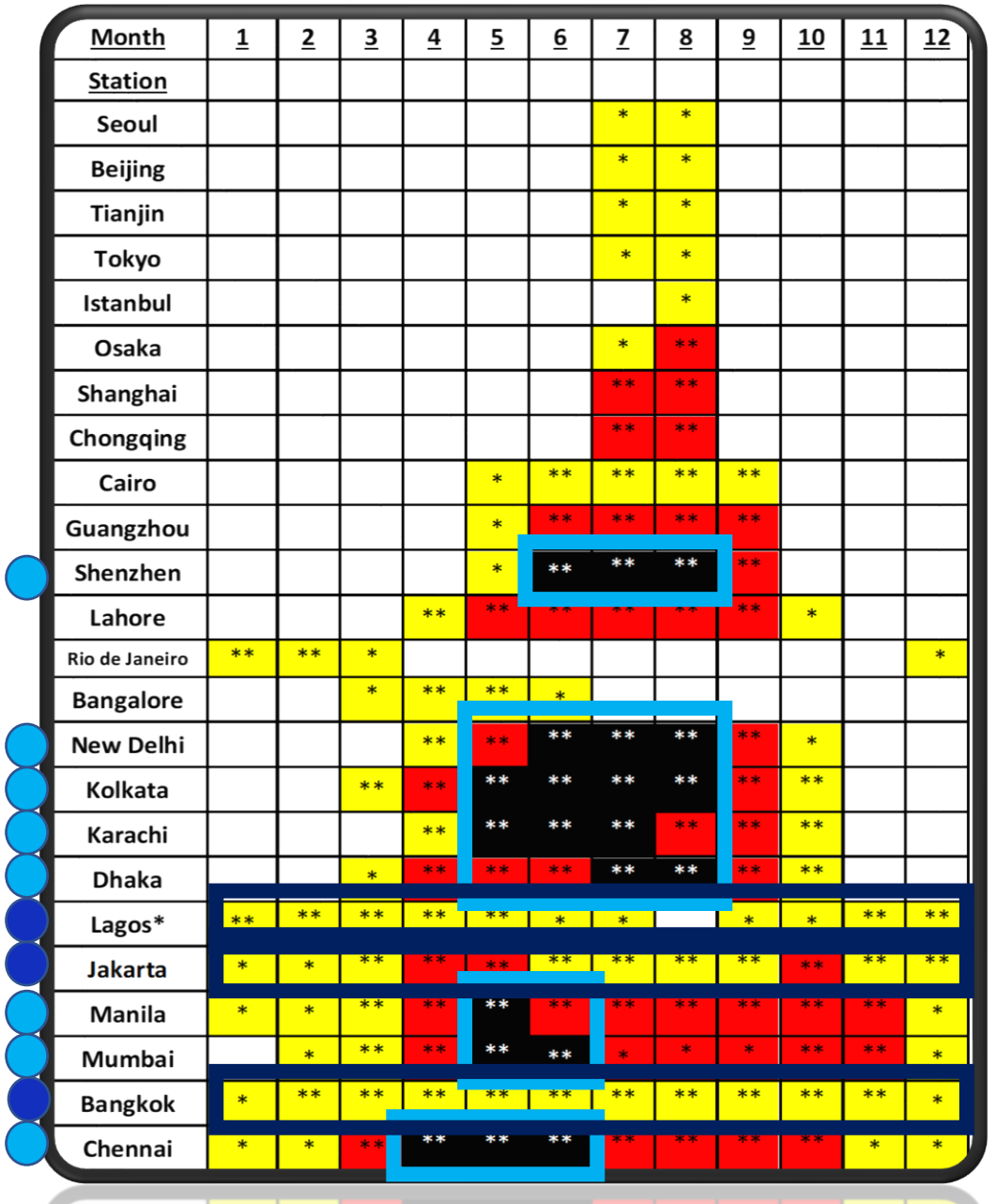
Who suffers most from thermal stress?

Heat load

*	Heavy
**	Extreme

Heavy / extreme heat load duration

	At least 1 hour
	Mostly > 12h
	Mostly > 24h



Shenzhen

New Delhi

Kolkata

Karachi

Dhaka

Manila

Mumbai

Chennai

Lagos

Jakarta

Bangkok

Mega cities ranking for novel humidity reliant technologies

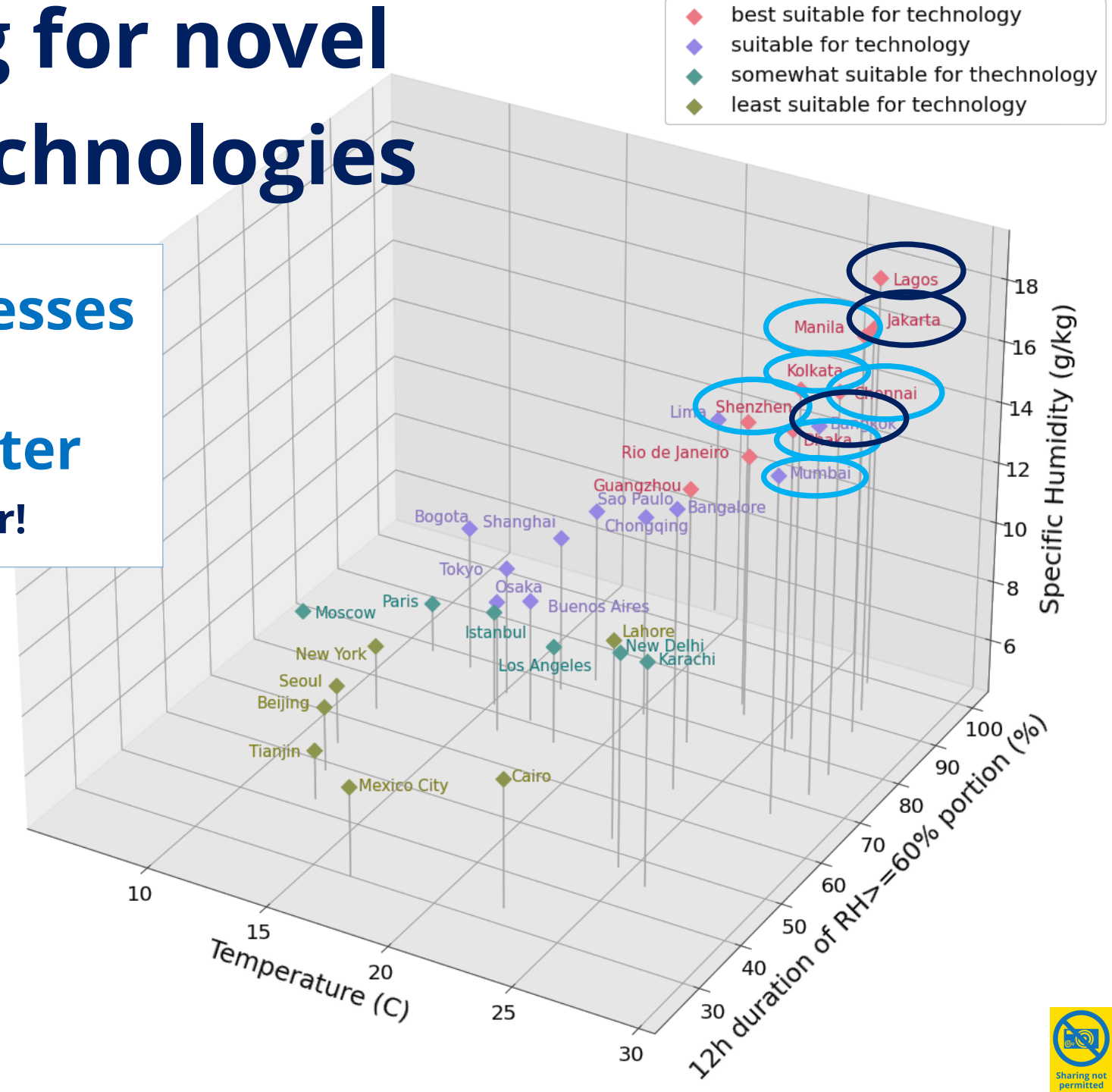
Cities with highest heat stresses

are in most cases

best suited for energy & water

extracting technologies from humid air!

Shenzhen	Lagos
Kolkata	Jakarta
Dhaka	Bangkok
Manila	
Mumbai	
Chennai	



Thank you.

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