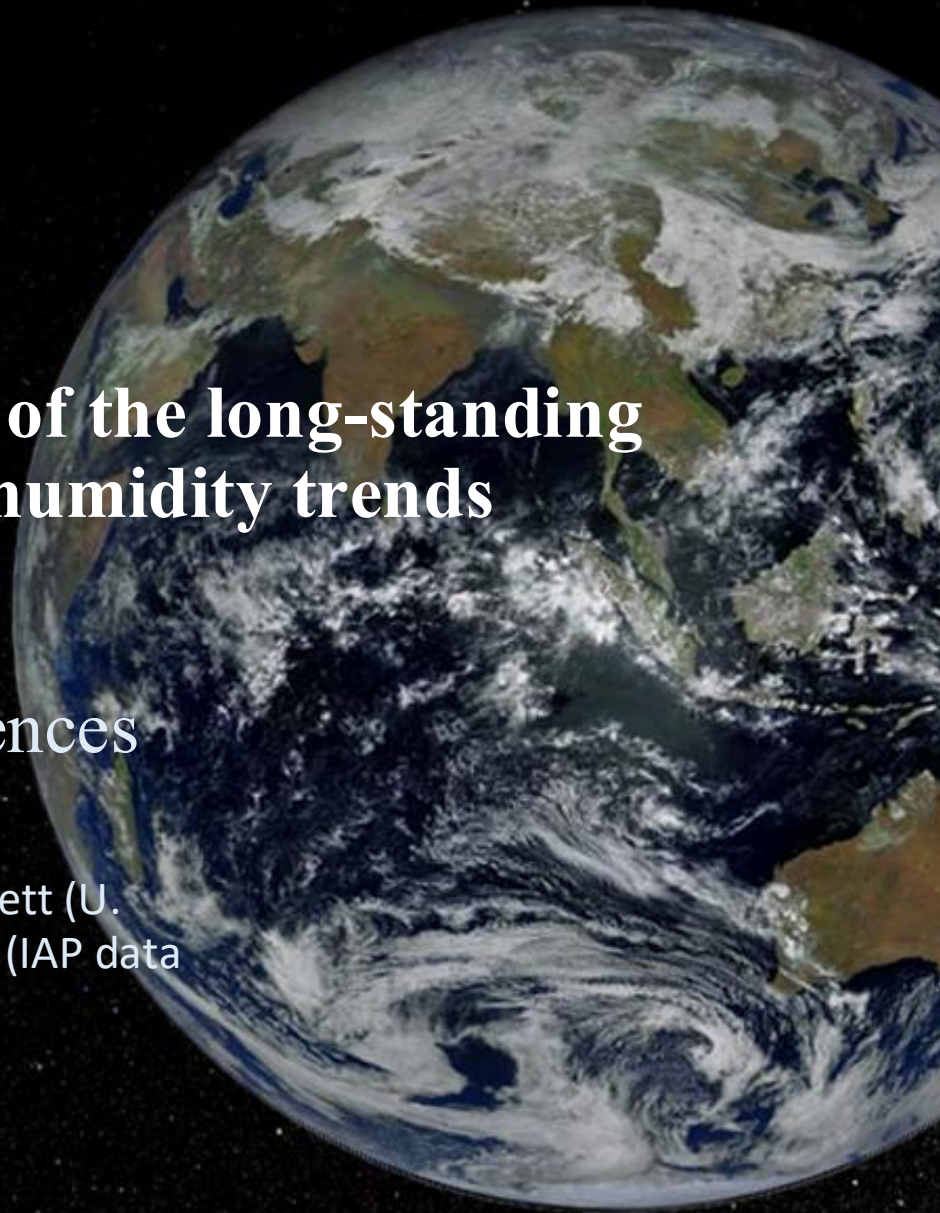
中国气象科学研究院
CHINESE ACADEMY OF METEOROLOGICAL SCIENCES



Undetected observation errors as a major cause of the long-standing observation-model discrepancy on relative humidity trends

Yang CHEN

Chinese Academy of Meteorological Sciences

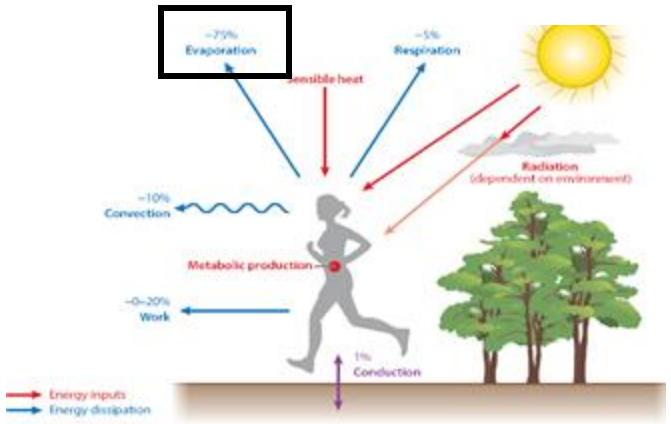
Collaborator: Zhen Liao (CAMS); Yani Zhu (NIMC, data producer); Simon Tett (U. Edinburgh); Kate Willett (UK Hadley Centre, HadISDH producer); Zhen Li (IAP data producer); Panmao Zhai (CAMS)

EPESC—LEADER Science Meeting

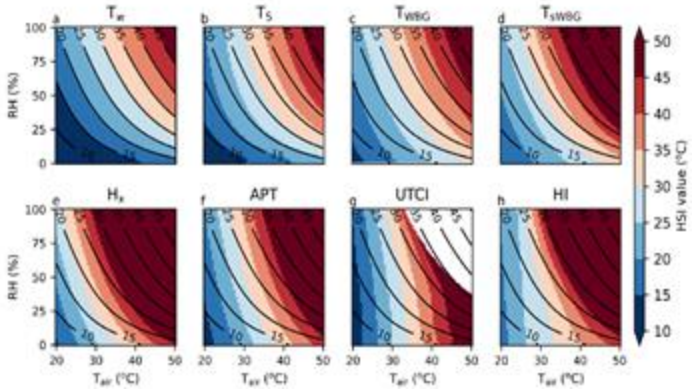
APEC Climate Center - Busan, Republic of Korea, 15—18 July, 2025

Current understanding on RH changes

Health implications

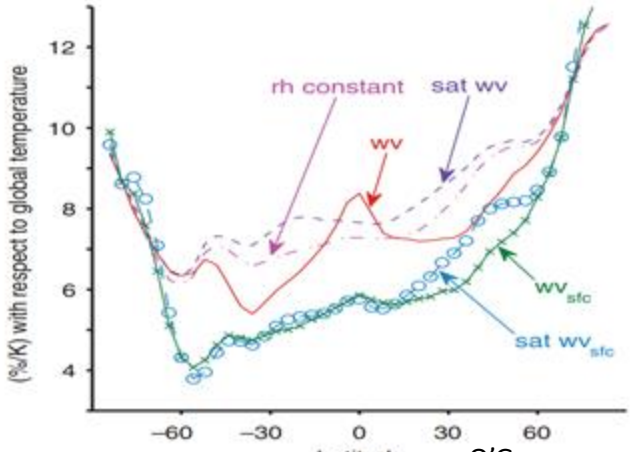


Health implications, Buzan and Huber, 2020



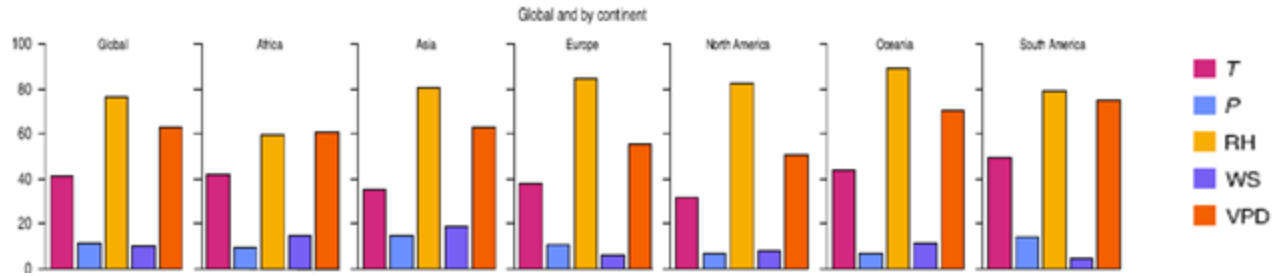
Tens of **humid heat stress indices** with varying sensitivity, Guo et al., 2024

Hydrological sensitivity to climate change

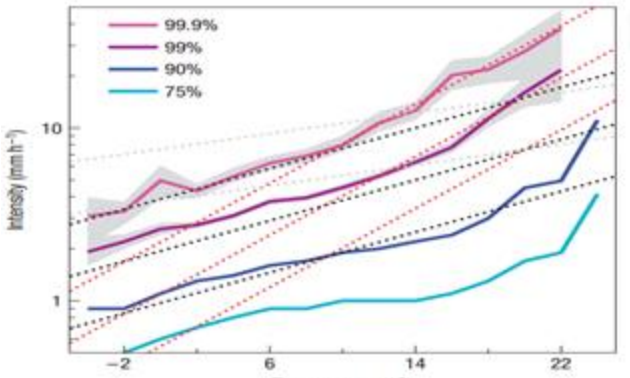


O'Gorman and Muller, 2010

Fire risk implications



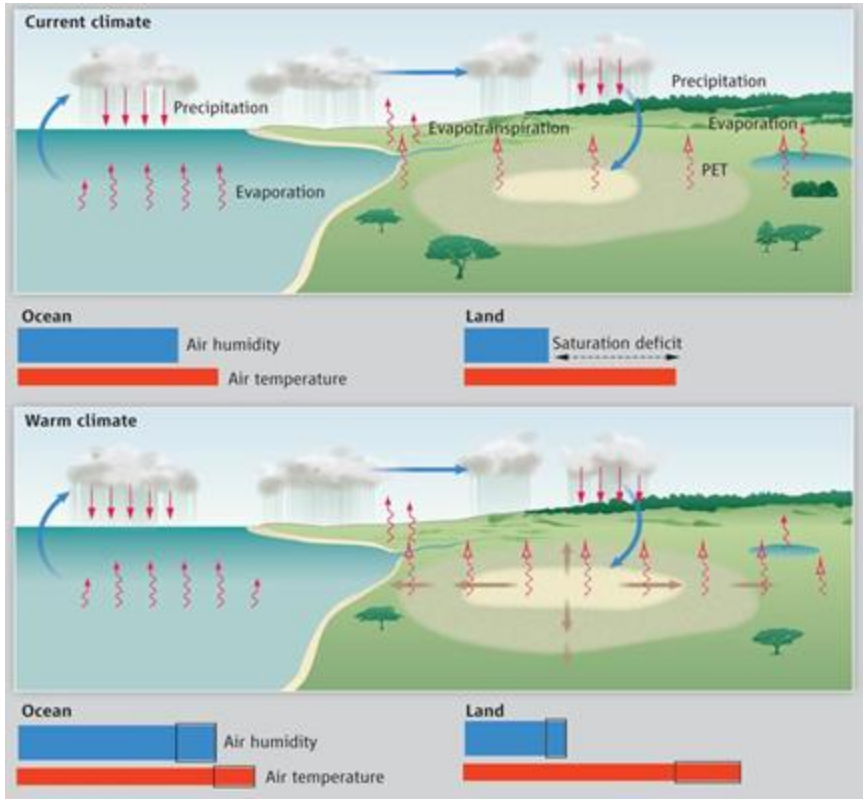
Percentage of significant trends for **fire weather** attributable to trends in FWI input variables (Jain et al., 2022)

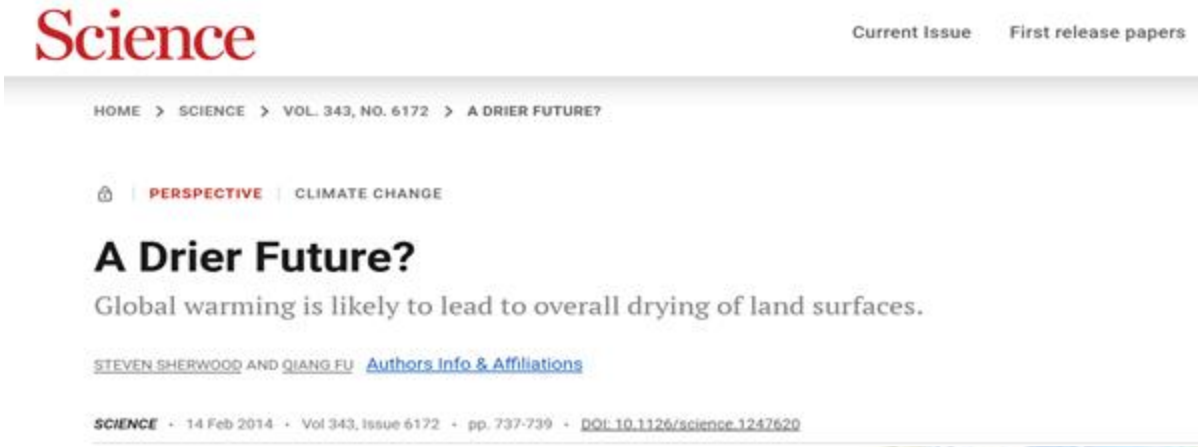


Lenderink and van Meijgaard, 2008

Current understanding on RH changes

- **Theoretically expected decreases in terrestrial RH**




Science

Current Issue First release papers

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PERSPECTIVE | CLIMATE CHANGE

A Drier Future?

Global warming is likely to lead to overall drying of land surfaces.

STEVEN SHERWOOD AND QIANG FU Authors Info & Affiliations

SCIENCE · 14 Feb 2014 · Vol 343, Issue 6172 · pp. 737-739 · DOI: 10.1126/science.1247620

- Strong increases in saturated water vapor concentration far exceed growth in actual water vapor concentration;
- Relative humidity (ratio of blue to red bar length) decreases over land, as a result

Current understanding on RH changes

- **Global RH have exhibited strong drying since 2000**

[AR4, CH3] The global trends **[1976–2002]** of nea–surface relative humidity **are very small**. (Dai, 2006);

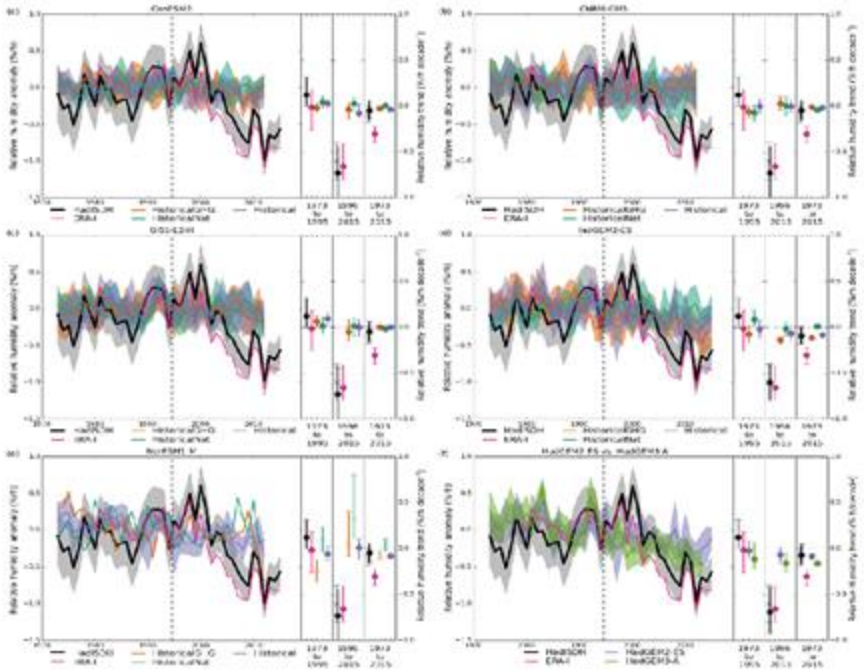
[AR5, CH2, 10] (Ⅰ) The HadCRUH Surface Humidity data set (Willett et al., 2008) indicates **negative or non significant trends [1973–2003]** in relative humidity; **(Ⅱ)**……**fairly widespread decreases** in relative humidity near the surface are observed…; **(Ⅲ) Recent reductions** in relative humidity over not fully understood (Simmons et al., 2010, ERA–40/INTERIM).

[AR6, CH2] (Ⅰ) The global averaged relative humidity **has remained depressed since 2000** (**1973–2019**, Willet et al. 2014, 2020, Dunn et al., 2017; Vicente–Serranao et al., 2018); **(Ⅱ)**……**decreases in relative humidity are significant particularly over the NH mid–latitudes**.

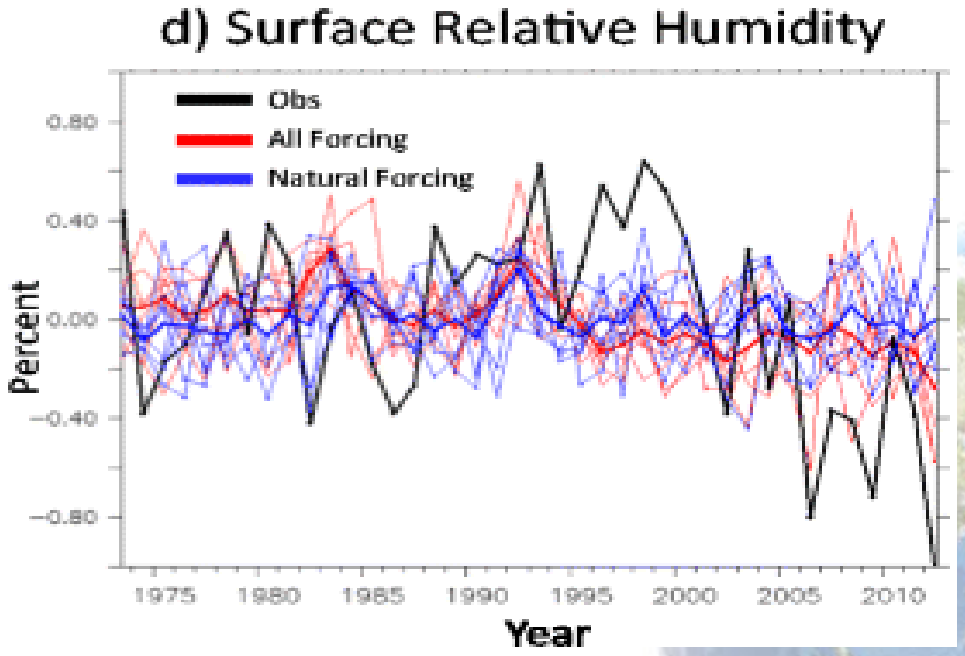
Current understanding on RH changes

- **There is a marked observation—simulation discrepancy**

[AR6, CH3] ……global mean surface relative humidity increased between 1973 and 2000**, followed by a steep decline, with <u>non of the CMIP5 models capturing this behavior</u>** (Dunn et al., 2017);



Dunn et al., 2017



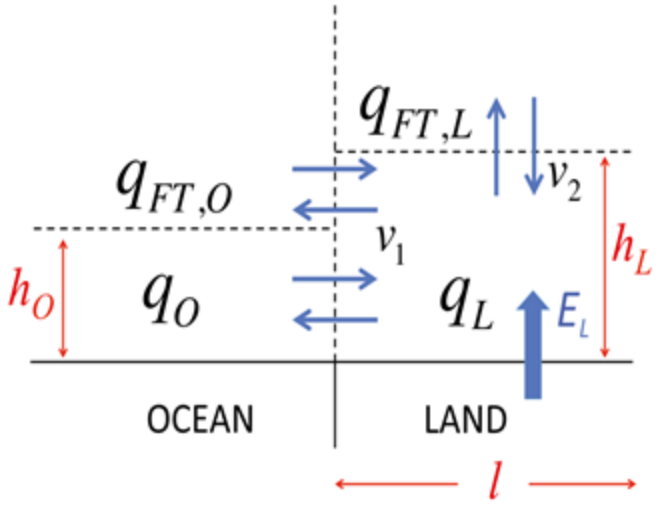
Knutson and Ploshay 2016

Current understanding on RH changes

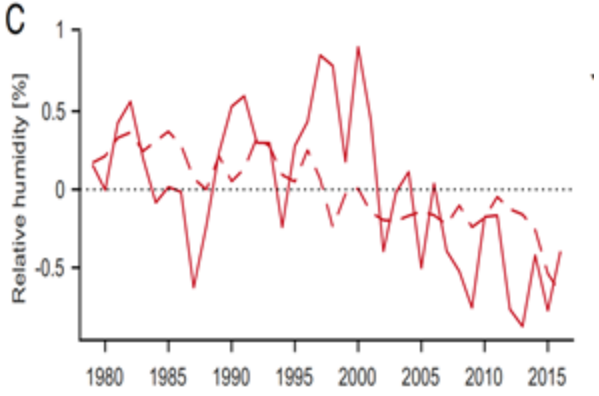
- **Possible theories for the drying**

① Land—ocean warming contrast:
equal changes in moist static energy
equal fractional changes in specific humidity

A conceptual box model

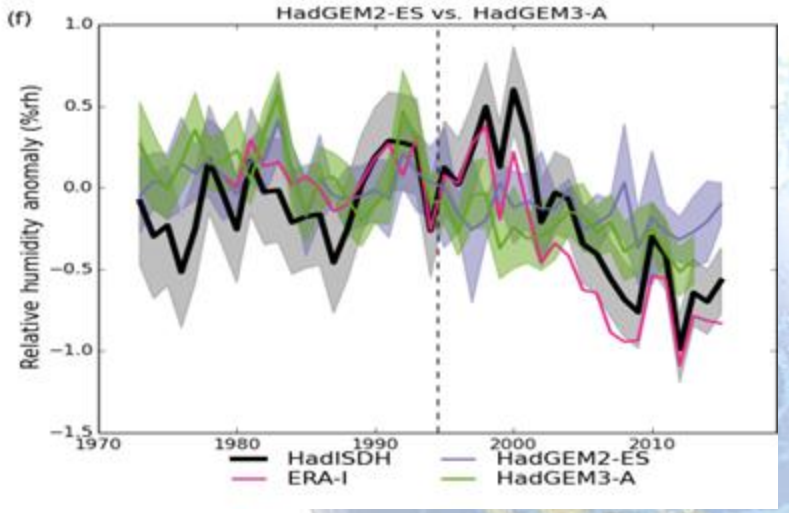


Theory, Byrne & O'Gorman, J. Clim., 2016



Theoretical reconstruction
Byrne & O'Gorman, PNAS, 2017

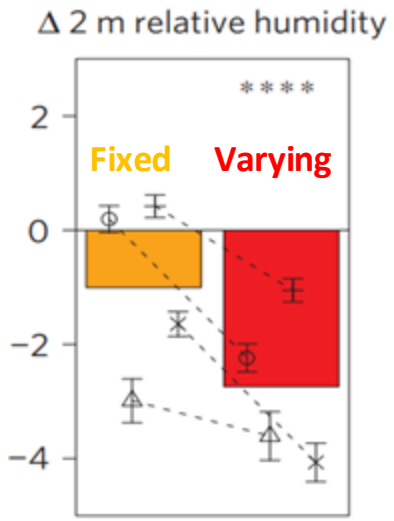
AMIP experiments (Dunn et al. ESD., 2017)



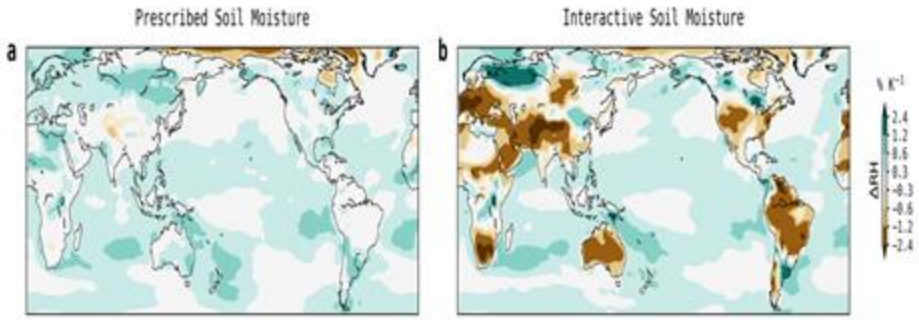
Current understanding on RH changes

- **Possible theories for the drying**

② Land surface process:
Soil moisture and L–A interaction
Plant physiology in response to CO2

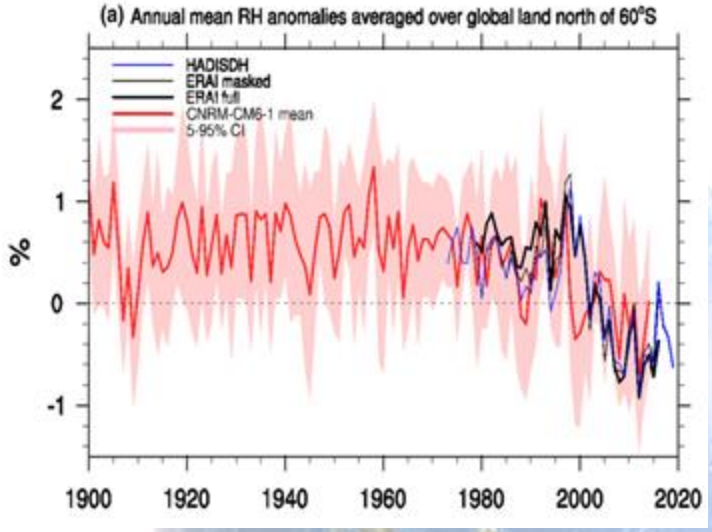


GLACE–CMIP5 MMM, Berg et al., NCC., 2016
(Fixed or varying soil moisture)



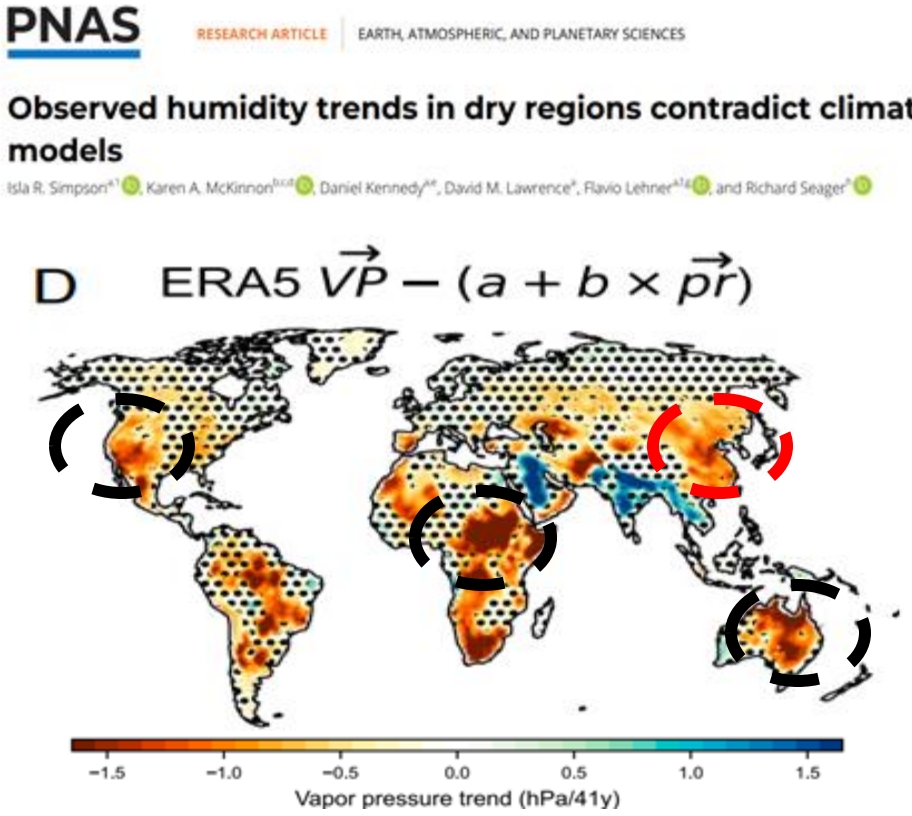
Zhou et al., GRL, 2023

Inclusion of physiological CO2 effect in CNRM–CM6



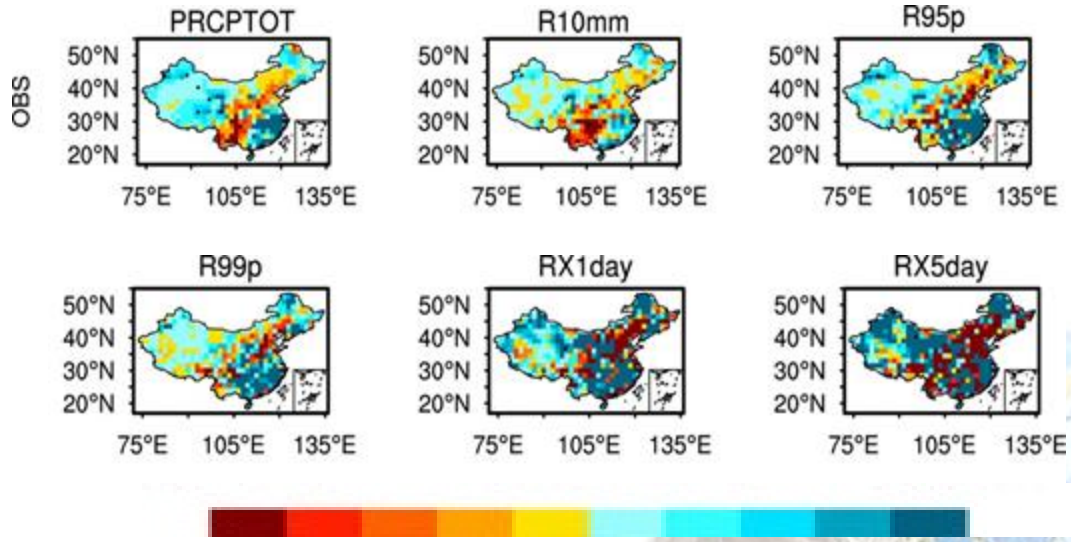
Douville et al., CD, 2020

Current understanding on RH changes



Out—of—model range of humidity decline

Observed (station gauge) Precipitation trends [1961—2014]



Decreasing

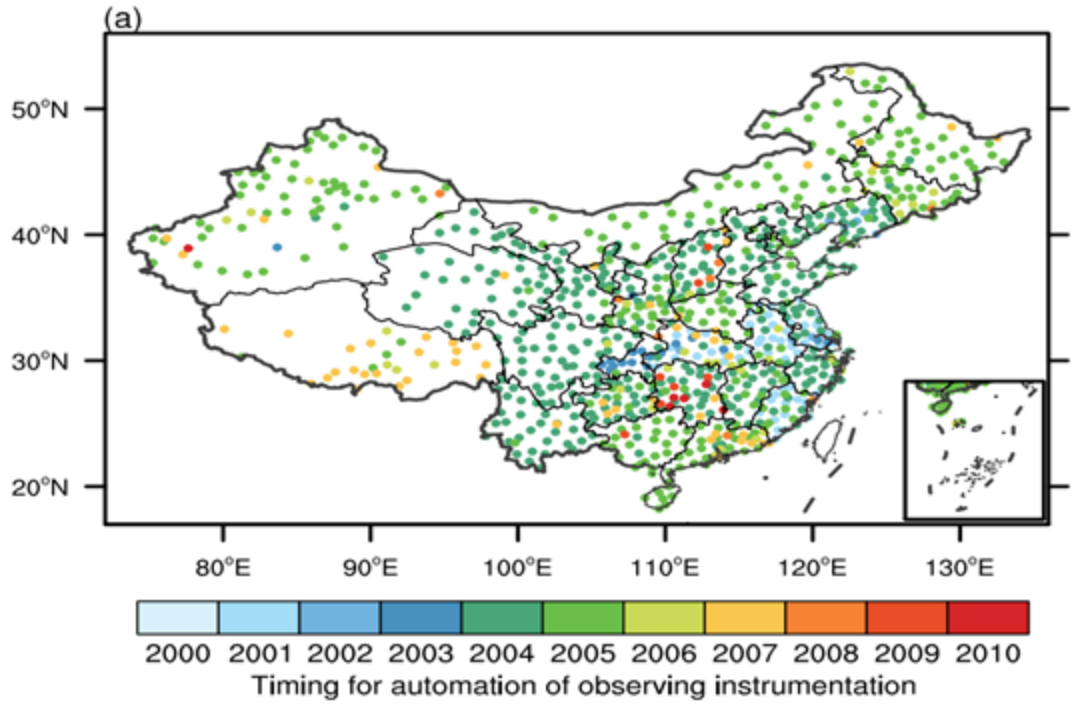
Increasing

Xu et al., Earth Future, 2022

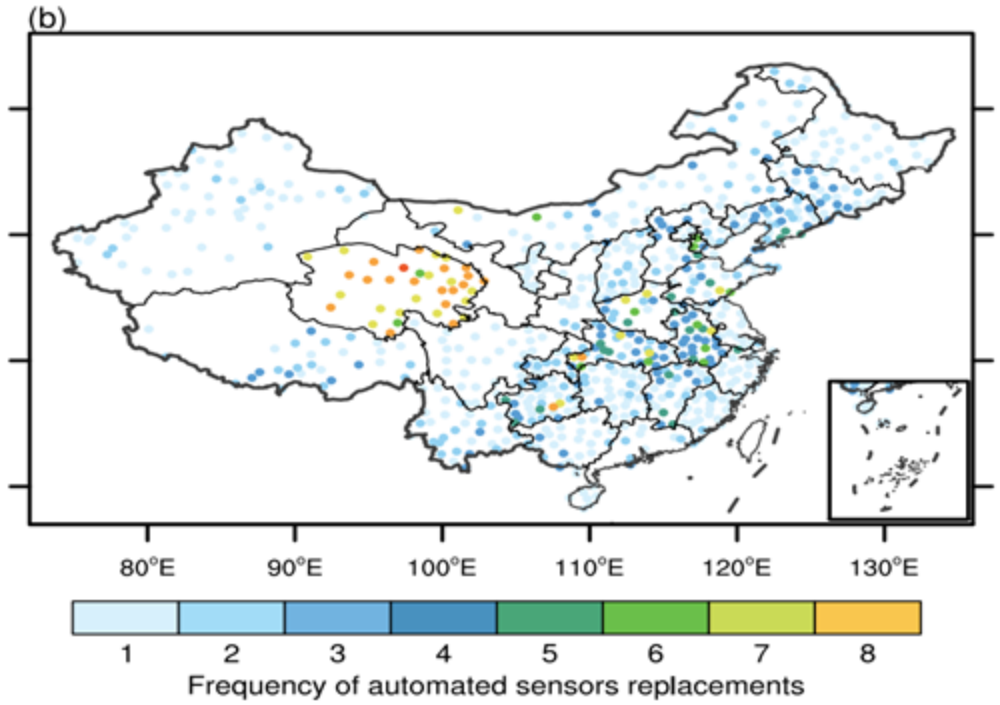
RH data inhomogeneity

- **RH observations might be wrong**

  due to region—wide changes in instrumentation at the (near) same time



Years for instrument automation in the 2000s



Replacements of sensors in the 2010s

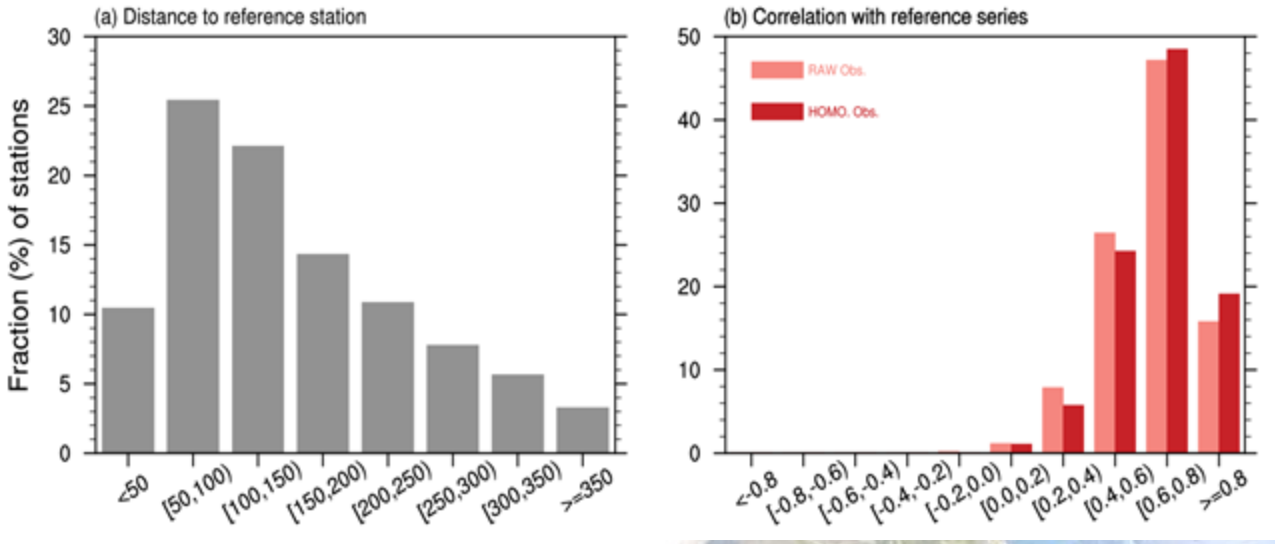
RH data inhomogeneity

- **In the face of region–wide changes in observing instrumentation, metadata is mandatory to inform (neighbor—comparing) homogenization**

a. Penalized Maximal F Test (PMFT) to detect breakpoints, validated against metadata—**sorting out reference series**;

a. Inhomogeneous series adjusted toward the nearest reference station by the penalized maximal t (PMT) scheme **(RHtestV2);**

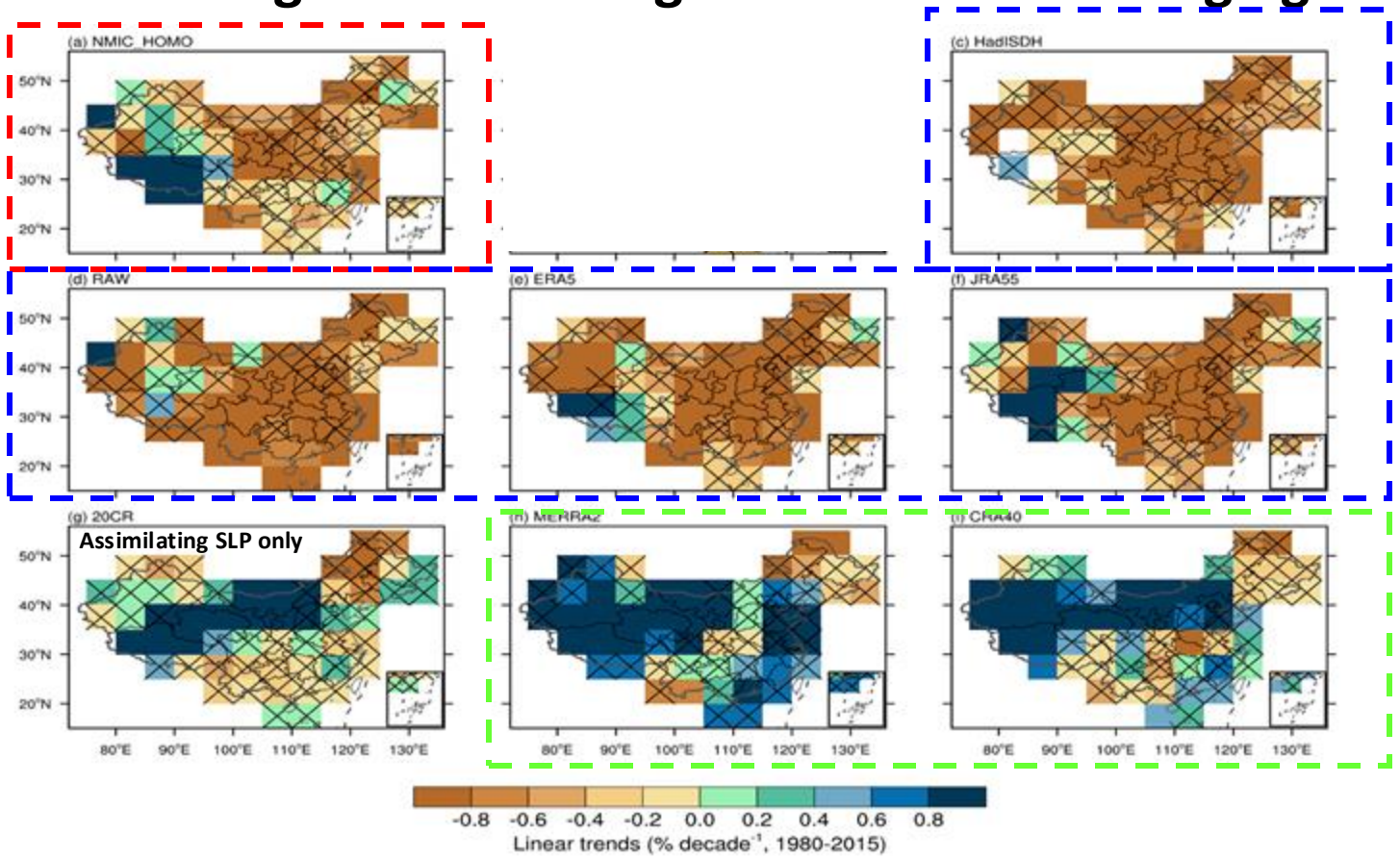
a. Given the matching distance longer than 350km, homogenize the record individually by the 2—year manual—automated obs. difference



The distribution of distance (a) and correlation (b) between inhomogeneous series and the corresponding reference series, in the domain of Eastern China [20-40N, east of 105E].

RH data inhomogeneity

- Severe yet overlooked data inhomogeneity
- Regional–wide changes in observing instruments challenging to homogenize



✕–Insignificance

–Metadata homogenized

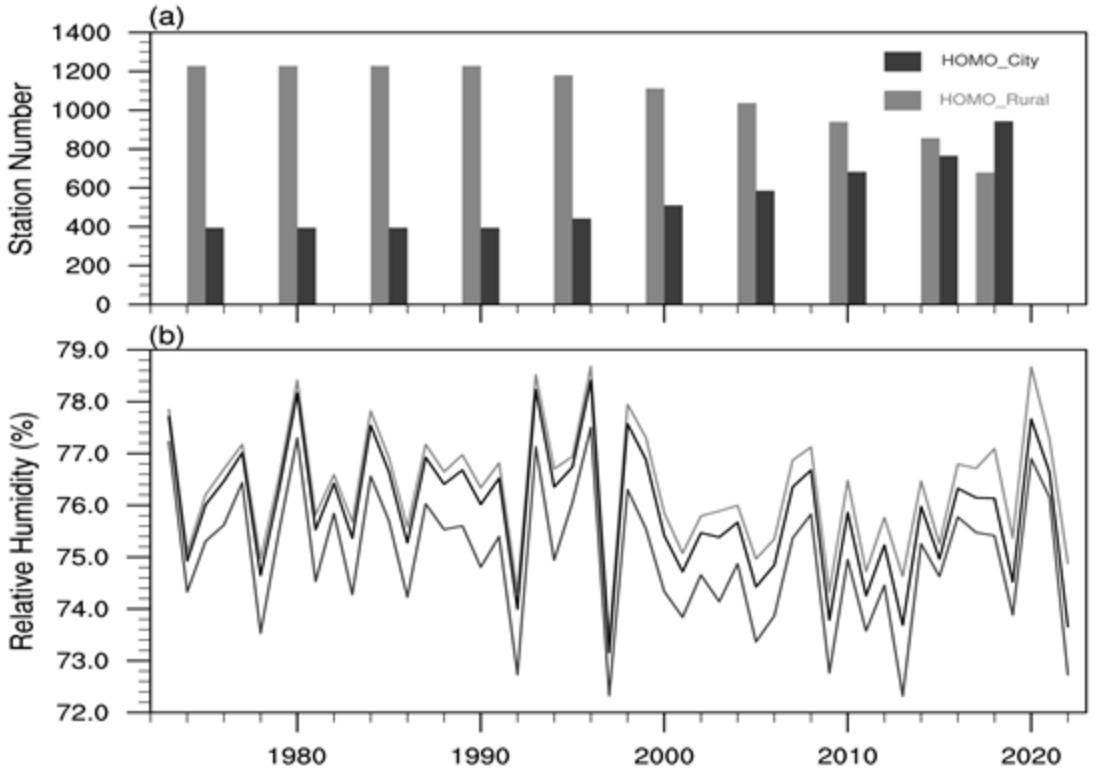
–Other obs. & reanalysis

–MERRA2 & CRA40

RH data inhomogeneity

- **Improved model—observation consistency (~280 ensemble members)**

Eliminating ‘urban dry island’ effect



Variabilities and trends of RH over Eastern China.

Summaries

✓ The instrumentation change—introduced RH inhomogeneity is non–trivial across Eastern China, also very likely the case at a global scale;

✓ Inter—data consistency does not necessarily exclude artifacts;

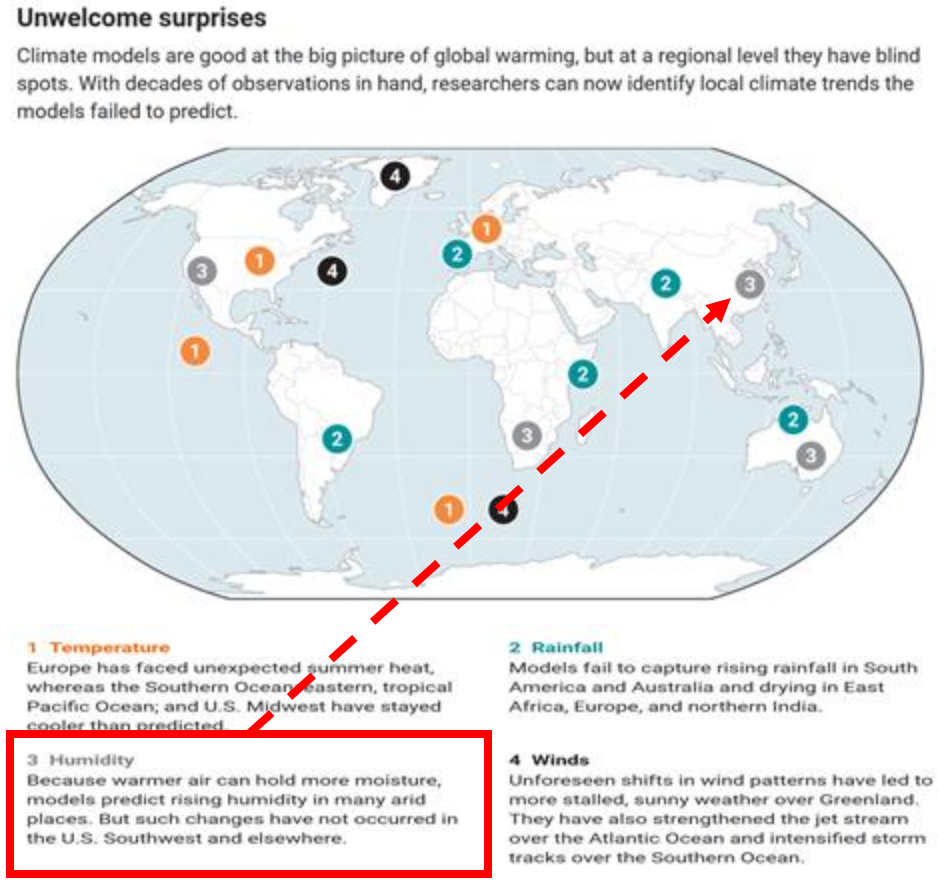
✓ The improved observation—model consistency could be leveraged as an effective constraint in estimating forced changes in RH and compound events (Friday, 14:00, Session D2 (cont.): Extreme event attribution, Part II)

✓ Zhu, Y., Chen, Y.*, …, et al. Metadata—informed homogenization of relative humidity observations across China. *(Invited, submitted)*

E-mail: ychen@cma.gov.cn

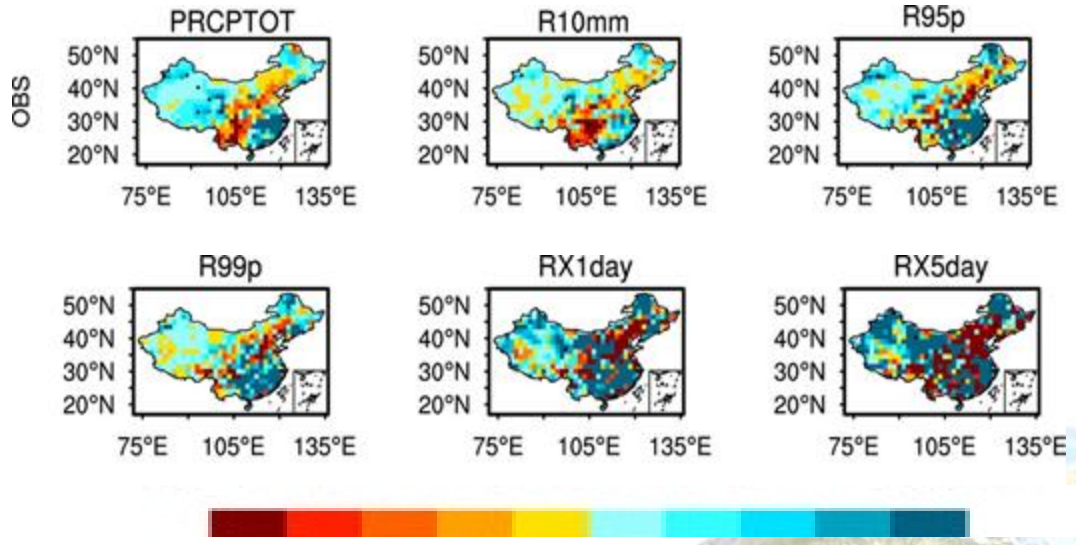
Thank you!

Current understanding on RH changes



Paul Voosen, Science, 2025
Shaw et al., Front in Climate 2024
Simpson et al., PNAS, 2023

Observed (station gauge) Precipitation trends [1961—2014]



Xu et al., Earth Future, 2022