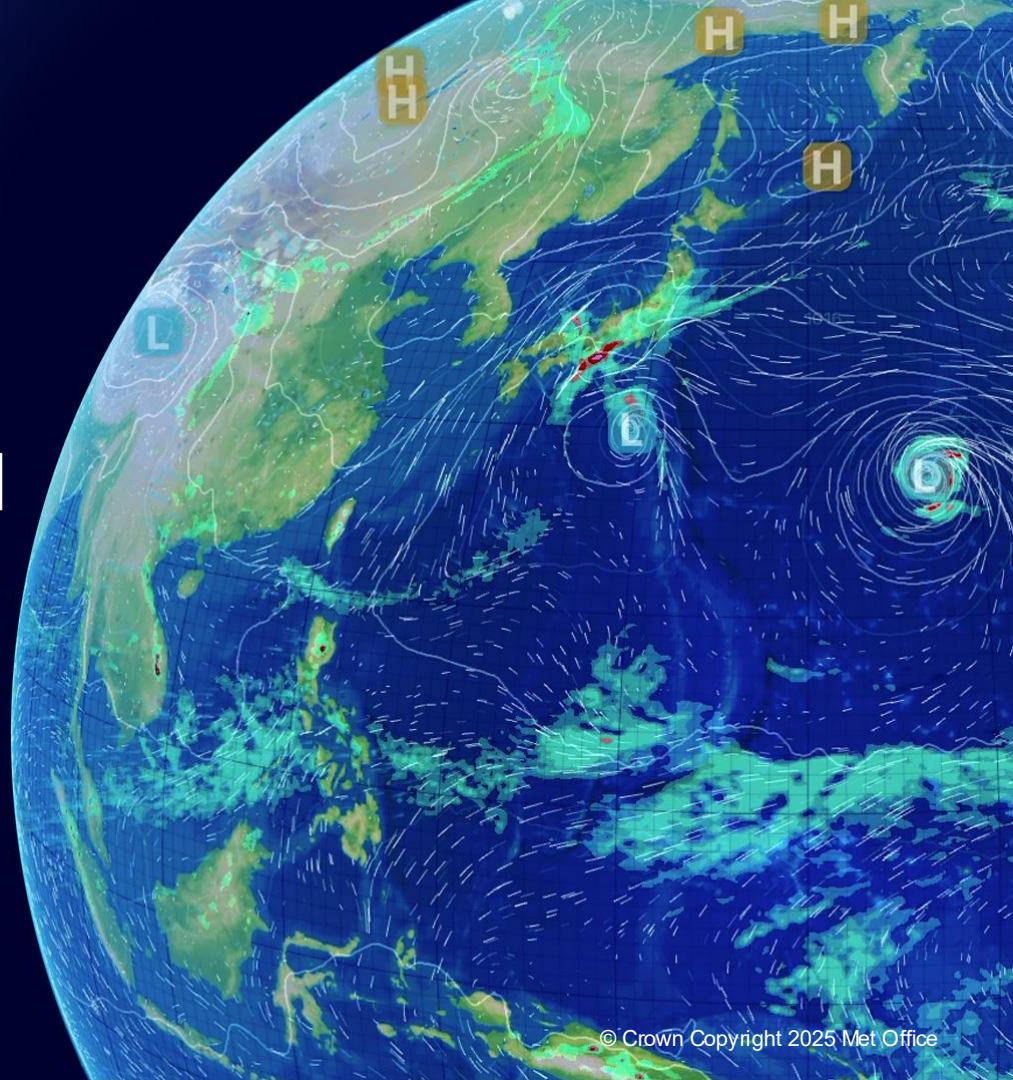


The UK-China Climate Science for Service Partnership (CSSP) and monitoring of humid-heat

Dr Kate Willett

Climate Monitoring Expert Scientist
and CSSP China Senior Supplier



What is the WCSSP Programme?

Through the Weather and Climate Science for Service Partnership Programme, we are **building the basis for services** to support climate and weather resilient economic development and social welfare through strong **strategic partnerships harnessing scientific expertise**.

- Over 50 institutes and organisations involved from around the world
- Over 100 exchange visits & over 400 people trained
- More than 900 publications, cited over 26,000 times
- Developed over 30 new or improved weather and climate service prototypes
- Stimulated over £26 million worth of additional research funding



CSSP Brazil



CSSP China



WCSSP India



WCSSP South Africa



WCSSP Southeast Asia



Work Package 1: Understanding Extremes

Developing the underpinning scientific understanding and capability needed to provide societally relevant information on extreme weather and climate events.

Work Package 2: Exploiting Models

Extending the potential of our modelling systems to understand the climate system and provide societally relevant predictions and projections on a range of hazards and timescales.

Work Package 3: Climate Services

Advancing the scientific and societal understanding, tools and processes to provide societally relevant climate information through needs-driven climate services.



2024 Annual Meeting in Kunming

Supporting the wind energy industry through improved understanding of trends and variability in wind speed

- The **WISTEREA** (Wind Stilling and Energy in Europe and Asia) project is led by University of Reading with visiting scientist from CMA
- It explores observed, reanalysed and modelled wind speed at a range of scales.
- **Key finding:** Observed global stilling is not reproduced by reanalyses. This may be linked to mis-representation of sub-monthly wind speed variation in reanalyses.

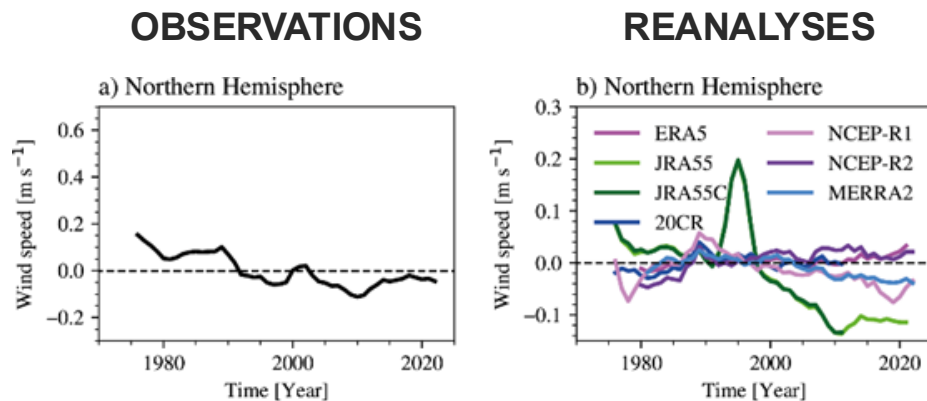


Figure Annual mean wind speed anomaly over land.

Improved prediction of the summer NAO can improve seasonal forecasts of tropical and monsoon rainfall over China

- Met Office seasonal forecasting team and a visiting scientist from CMA.
- The GloSea6 seasonal forecasting model has limited skill in predicting the summer North Atlantic Oscillation (SNAO).
- **Key finding:** GloSea6 has biases in the zonal wind and circumglobal waveguide. Correcting biases and selecting 'best' ensemble members improves prediction of the SNAO and downstream impacts on China.

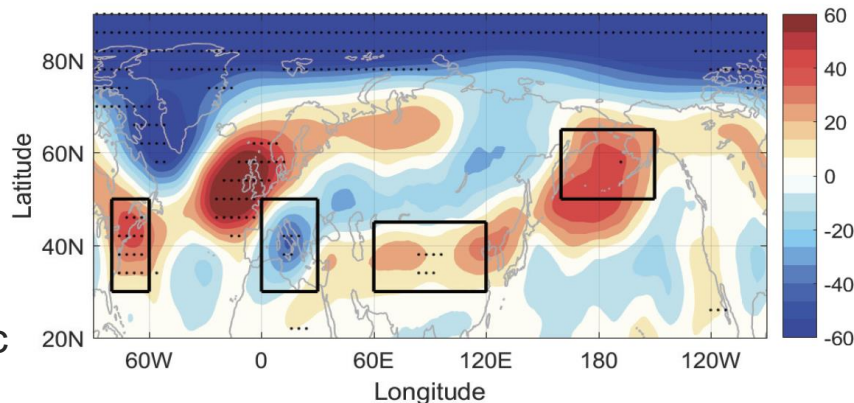


Figure Summer NAO pattern (dipole between Greenland and NE Europe) and circumpolar waveguide, inferred by 250hPa geopotential height anomalies from the ERA5 reanalysis.

Uniting scientists, tea growers, and climate service developers to address the impacts of climate change on the tea industry

- Met Office, Yunnan University of Finance and Economics, Beijing Normal University, CMA and IAP scientists and China and UK stakeholders.
- Greatest benefit from climate services developed in partnership with providers and users.
- **Key progress:** There is some skill in sub-seasonal rainfall forecasts. The team have co-developed decision-making calendars to map out monthly to seasonal decisions, climate hazards, operational risks, and adaptation strategies.



Project Successes Delivering Impact



Over **600 papers published** with **over 20,000 citations**, significantly furthering global knowledge on key climate processes over East Asia and globally.

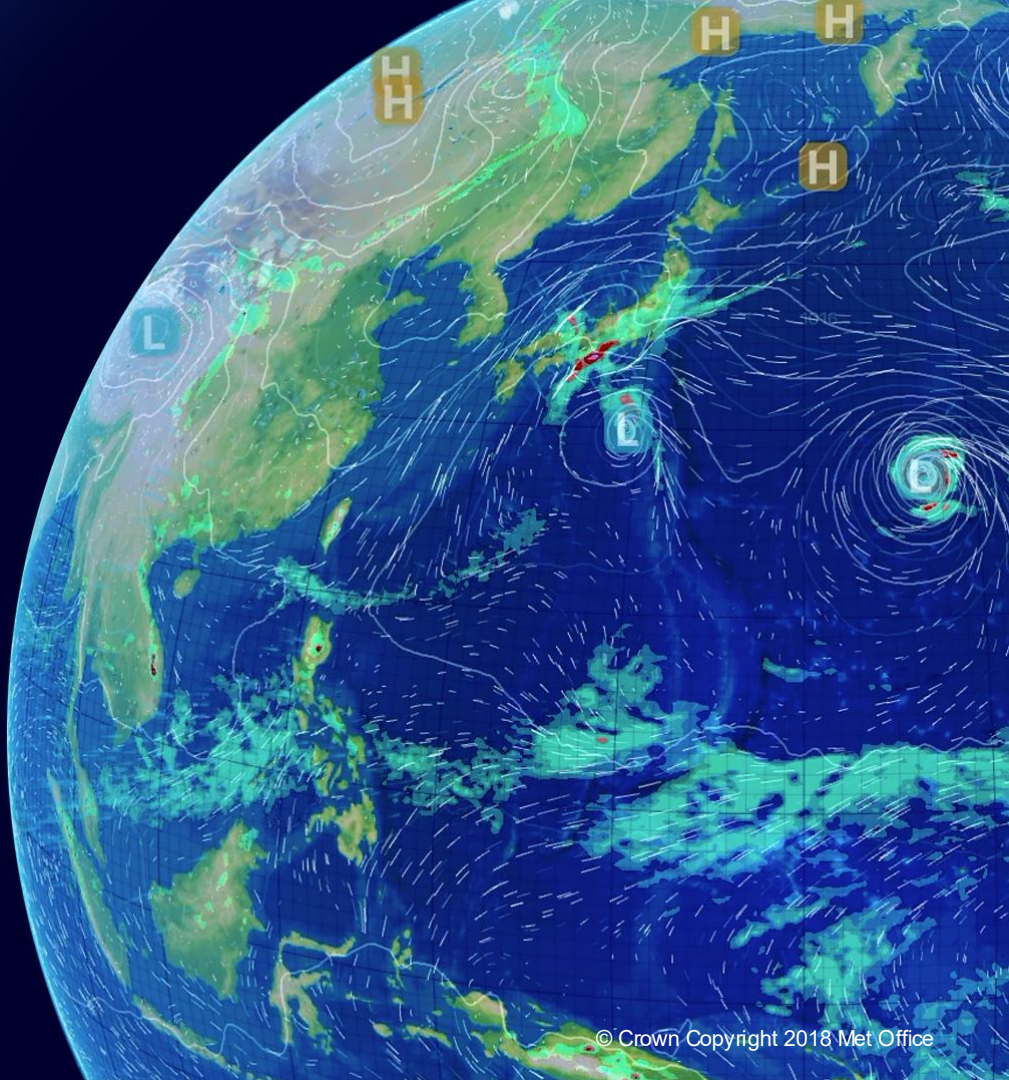
Three Special Issue journals to showcase CSSP China science to the research community within China and the East Asia region.

Supporting UN Sustainable Development Goals (SDGs) including; SDG 11: Sustainable Cities and Communities, SDG 13: Climate Action, and SDG 17: Partnerships for the Goals, and the World Meteorological Organization "Early Warnings for All" initiative.

Supporting Chinese partners at international climate related events. CSSP China research is informing policy around the world, **with 379 citations in 192 different policy documents**.

HadISDH.extremes climate monitoring product for humid-heat

Met Office **H**adley Centre's **I**ntegrated
Surface **D**ataset of **H**umidity
(**HadISDH**)



Met Office HadISDH humidity

- Gridded (5° by 5°) monthly mean near-surface humidity from 1973 onwards.
- Specific humidity, relative humidity, vapour pressure, wet-bulb temperature, dewpoint temperature and temperature.
- Built from hourly temperature and dewpoint temperature from weather stations over land and ships over oceans.
- Quality controlled and homogenised.

HadISDH dataset available from:

- HadOBS:

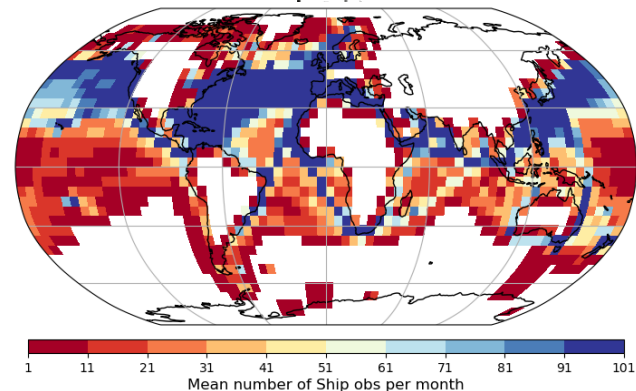
www.metoffice.gov.uk/hadobs/hadisdh

- Climate Dashboard:

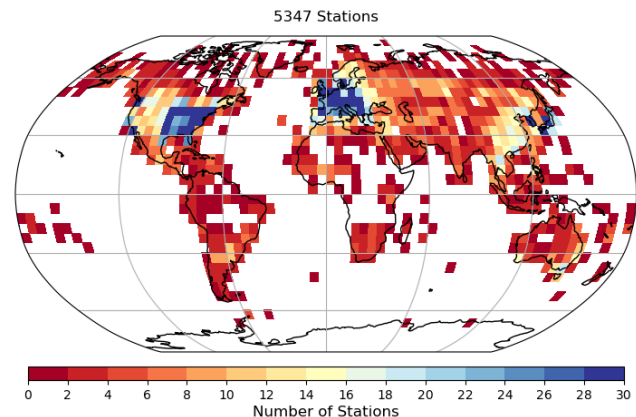
<https://climate.metoffice.cloud/humidity.html>

- CEDA:

<https://catalogue.ceda.ac.uk/uuid/251474c7b09449d8b9e7aeaf1461858f/>

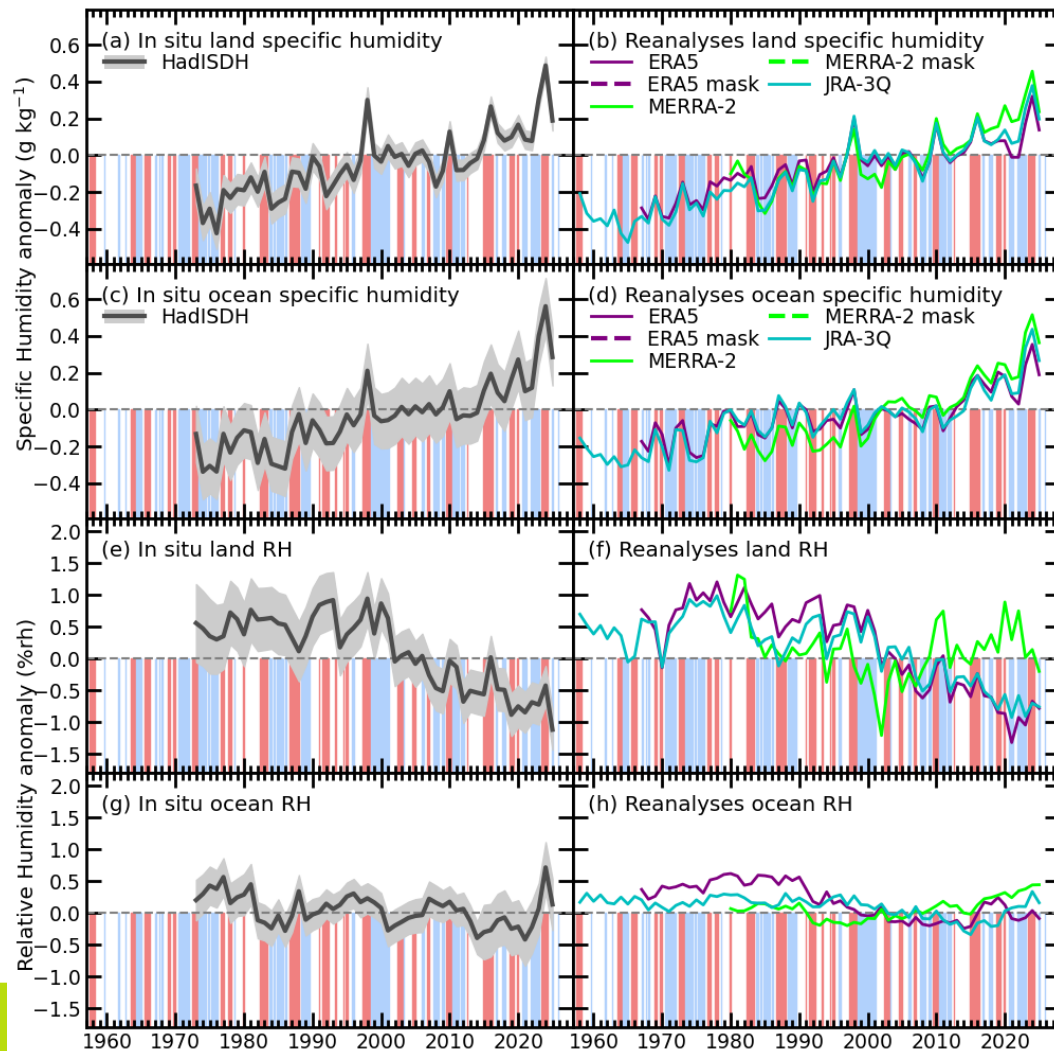


Ship observations per month are sparse outside northern mid-latitudes.



Stations give near-global coverage but single-station boxes (red) are common.

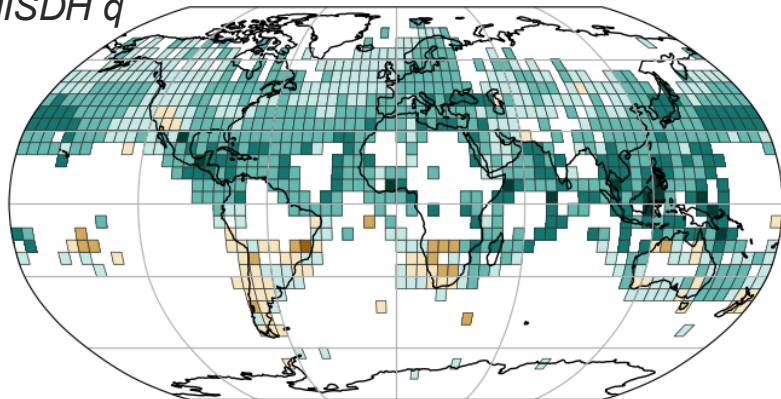
HadISDH global mean trends and variability



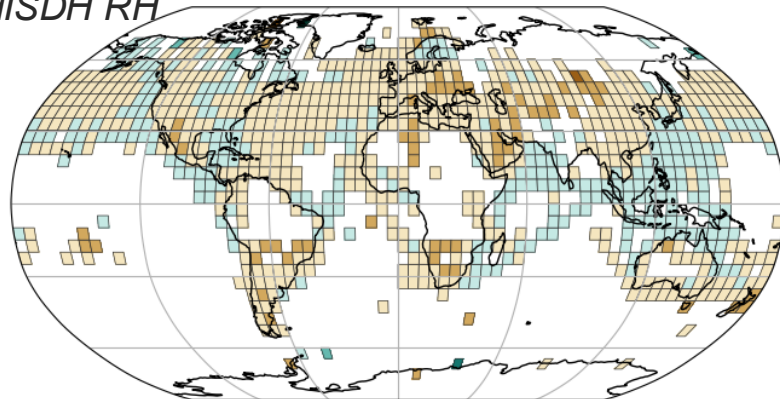
Global annual anomaly timeseries relative to 1991-2020. Produced by Robert Dunn. Near-surface specific humidity is increasing, while relative humidity is decreasing over land.

Decadal trends 1973-2025

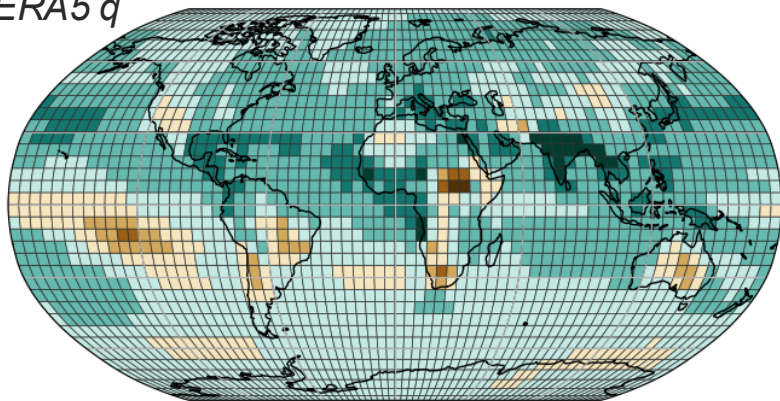
HadISDH q



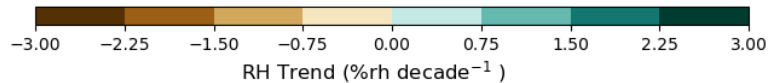
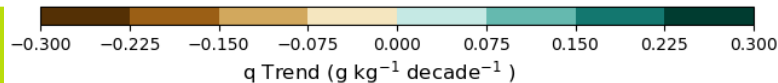
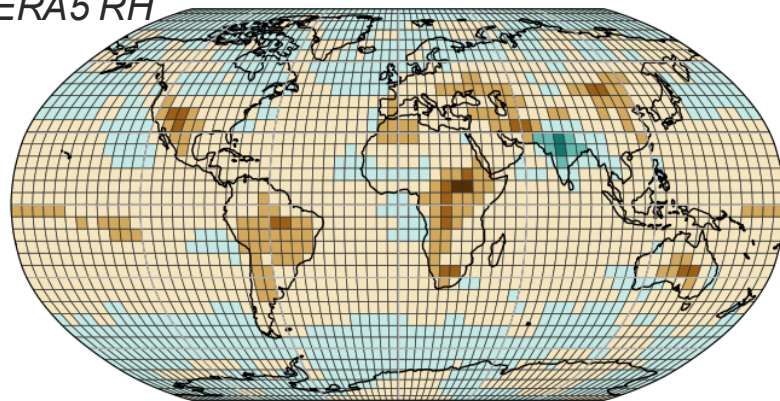
HadISDH RH



ERA5 q



ERA5 RH



Heat extremes can be hot and dry, hot and humid or warm and very humid



It can be useful to know whether heat is humid or dry

Cooling effectiveness differs between humid and dry heat

- Evaporative cooling (sweating, panting) is more effective in hot and dry events (hydration, rest breaks and shade).
- High humidity reduces evaporative capacity of the air. Air conditioning may then be required.

Humid heat events may go undetected

- Temperature-only heat metrics may not detect warm and humid events, which can still impact health, wellbeing and productivity.
- Combined heat metrics, such as the Wet Bulb Globe Temperature (WBGT), mask the contribution of humidity.
- A WBGT of 35 °C could occur in very hot and dry conditions or warm and very humid conditions.

There are many measures of heat stress

- **WBGT (commonly pseudo-WBGT)**

- ISO standard for evaluating heat stress²
- Thresholds for work/ rest/ clothing/ activity/ water intake (work/sport)^{3,4}
- Includes radiation and wind (or assumes moderate sunshine, light winds)
- Calibrated for specific climates/people/activities

- **Apparent Temperature⁵ - Heat Index / Wind chill**

- **A 'feels like' temperature (general health risk)**
- **Assumes shady conditions, can include wind speed**

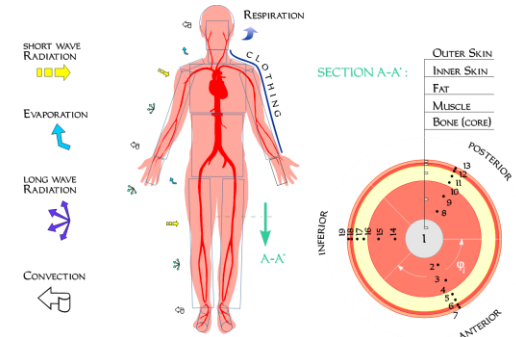
- **Universal Thermal Climate Index (UTCI)^{6,7}**

- **A ‘feels like’ temperature (general health risk)**
- **Includes radiation and wind**
- **Referenced to temperature felt by average person (73.5kg, 14% body fat) walking at 4km/h in 0.3m/s wind speed 50%rh shade**
- **10 thresholds relate to specific physiological responses**

- Wet bulb temperature (T_w)

- Tied explicitly to thermodynamics
- Applicable across all climates
- Not calibrated against impacts, no activity related thresholds

Cat 3	Cat 2	Cat 1	Activity Guidelines
< 82.0°F <27.8°C	< 79.7°F <26.5°C	< 76.1°F <24.5°C	Normal Activities – Provide at least three separate rest breaks each hour with a minimum duration of 3 min each during the workout.
82.2 - 86.9°F 27.9-30.5°C	79.9 - 84.6°F 26.6-29.2°C	76.3 - 81.0°F 24.6-27.2°C	Use discretion for intense or prolonged exercise; Provide at least three separate rest breaks each hour with a minimum duration of 4 min each.
87.1 - 90.0°F 30.6-32.2°C	84.7 - 87.6°F 29.3-30.9°C	81.1 - 84.0°F 27.3-28.9°C	Maximum practice time is 2 h. <u>For Football</u> : players are restricted to helmet, shoulder pads, and shorts during practice. If the WBGT rises to this level during practice, players may continue to work out wearing football pants without changing to shorts. <u>For All Sports</u> : Provide at least four separate rest breaks each hour with a minimum duration of 4 min each.
90.1 - 91.9°F 32.2-33.3°C	87.8 - 89.6°F 31.0-32.0°C	84.2 - 86.0°F 29.0-30.0°C	Maximum practice time is 1 h. <u>For Football</u> : No protective equipment may be worn during practice, and there may be no conditioning activities. <u>For All Sports</u> : There must be 20 min of rest breaks distributed throughout the hour of practice.
≥ 92.1°F ≥ 33.4°C	≥ 89.8°F ≥ 32.1°C	≥ 86.2°F ≥ 30.1°C	No outdoor workouts. Delay practice until a cooler WBGT is reached.



¹ Sherwood 2018 <https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JD028969>

² [https://www.iso.org/standard/67188.html#:~:text=ISO%207243%3A2017%20presents%20a,\(up%20to%208%20h\)](https://www.iso.org/standard/67188.html#:~:text=ISO%207243%3A2017%20presents%20a,(up%20to%208%20h))

³ Grundstein et al., 2015 https://ksi.uconn.edu/wp-content/uploads/sites/1222/2018/08/RegionalWBGT_2015_AppliedGeography.pdf

⁴ Korey Stringer Inst., U. Connecticut <https://ksi.uconn.edu/prevention/wet-bulb-globe-temperature-monitoring/#>

⁵ Steadman 1984 https://journals.ametsoc.org/view/journals/apme/23/12/1520-0450_1984_023_1674_ausoat2_0_co_2.xml?tab_body=pdf

⁶ Blazejczyk et al, 2013 <https://www.researchgate.net/publication/239525964> An introduction to the Universal Thermal Climate Index UTCI

⁷ <https://utci.lobelvia.earth/what-is-utci>

<http://www.elsevier.com/locate/bsc>

HadISDH.extremes wet bulb and dry bulb temperature extremes indices

Gridded global monthly indices from 1973 following Clim pact (<https://clim pact-sci.org/>) methodology:

- **INTENSITY:**

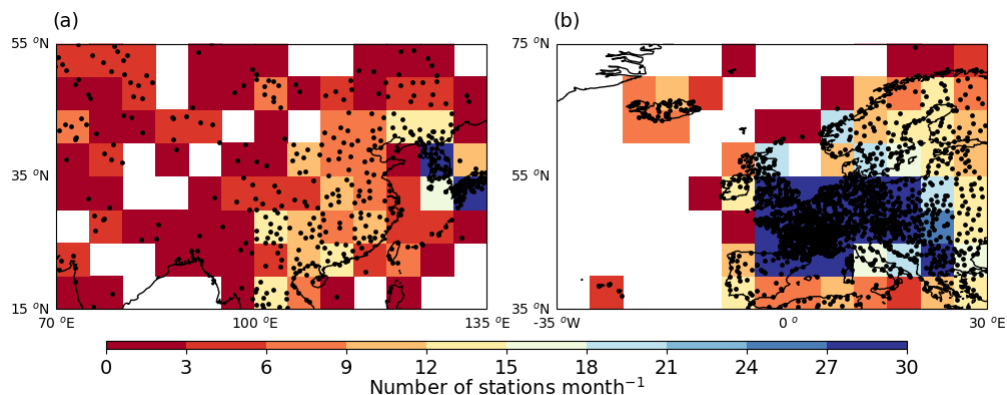
Most extreme day of month
TX, T_wX, TN, T_wN

- **FREQUENCY – RELATIVE EXTREMES:**

Days exceeding percentile threshold per month
TX90p, T_wX90p, TX10p, T_wX10p, TN90p, T_wN90p, TN10p, T_wN10p

- **FREQUENCY – SPECIFIC EXTREMES:**

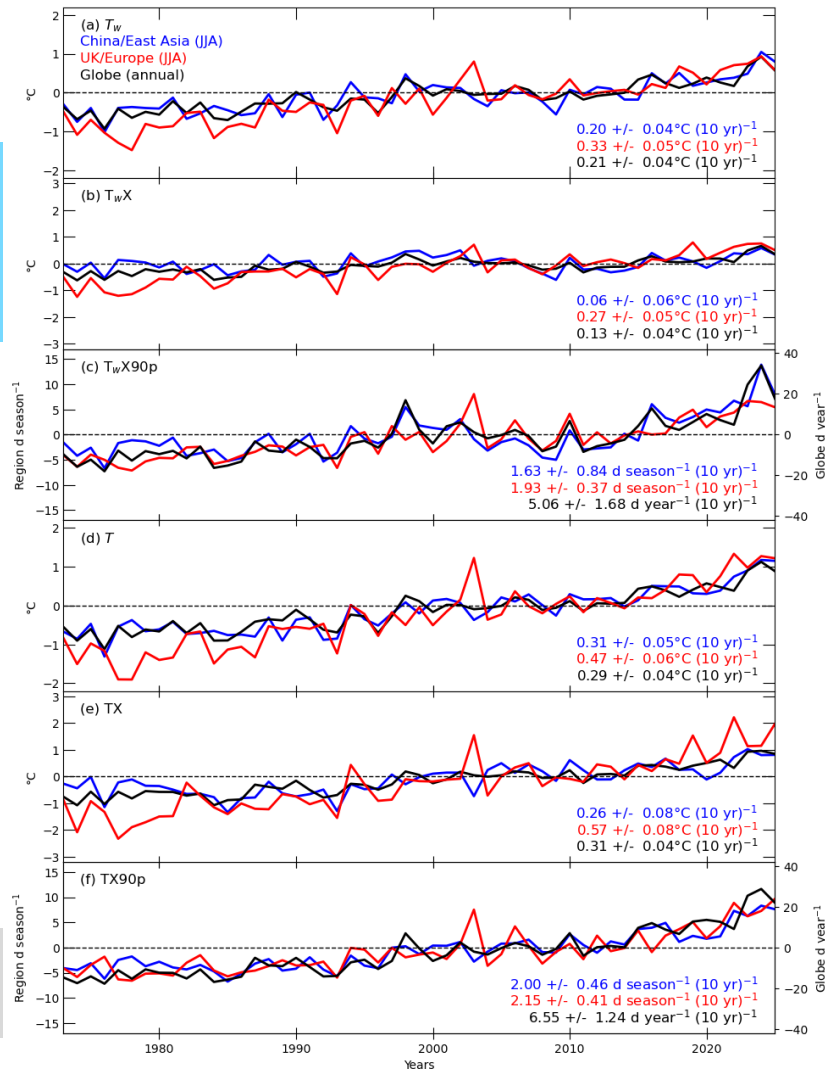
Days exceeding extreme threshold per month
TX25 to TX50, T_wX25 to T_wX35



Station coverage per gridbox over China/East Asia and UK/Europe.

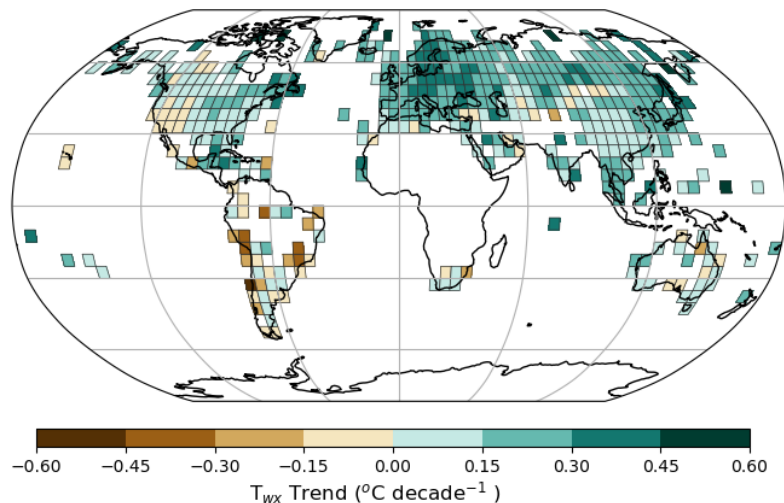
Trends and variability in humid and dry heat extremes

- Humid-heat extremes are **increasing** in intensity (T_wX) and frequency (T_wX90p).
- Humid-heat extremes (T_wX , T_wX90p) are **increasing at a slower rate** than for dry-heat extremes (TX , $TX90p$) for China, UK and the global mean.
- Humid-heat extremes (T_wX) are **increasing more slowly** than mean temperature (T) and humidity (T_w).
- Trends in dry-heat extremes (TX) are **more comparable** with trends in mean temperature (T).

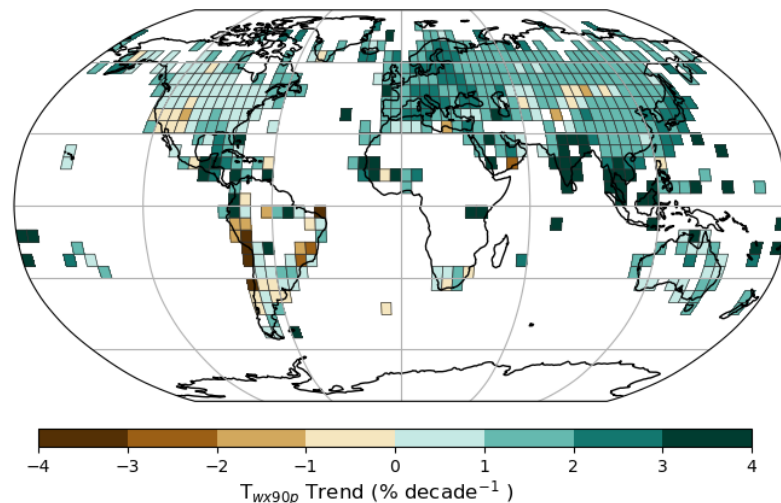


Since the 1970s, humid-heat has increased in intensity and frequency almost everywhere

Humid-heat intensity



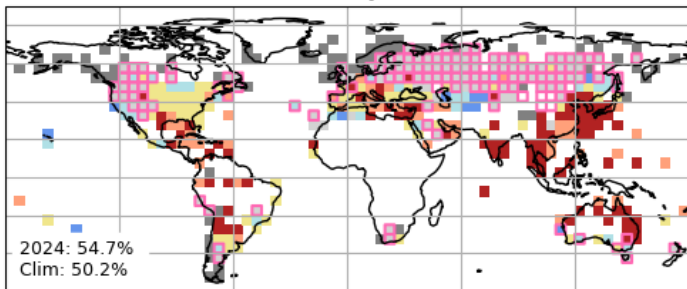
Humid-heat frequency



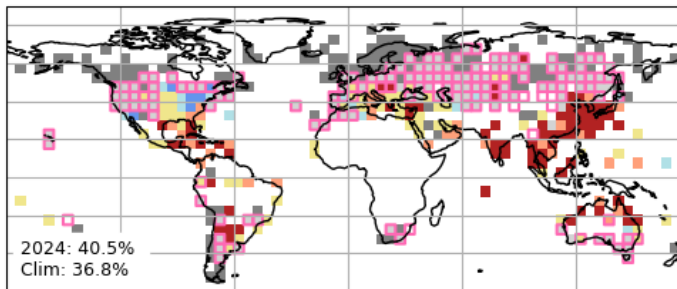
Decadal trends from 1973-2024 of humid-heat indices from HadISDH.extremes.

Assessing individual years: how unusual was 2024?

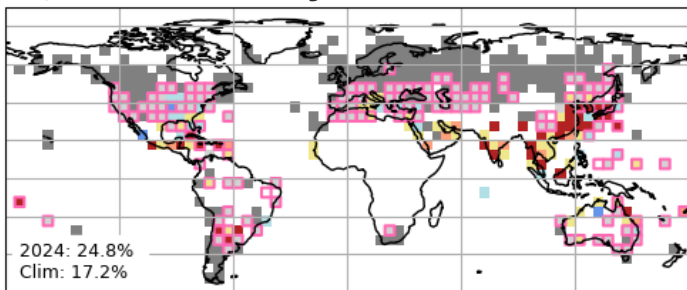
a) 2024 TwX25 **Moderately extreme**



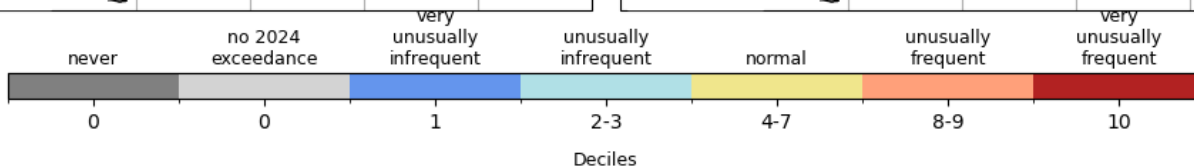
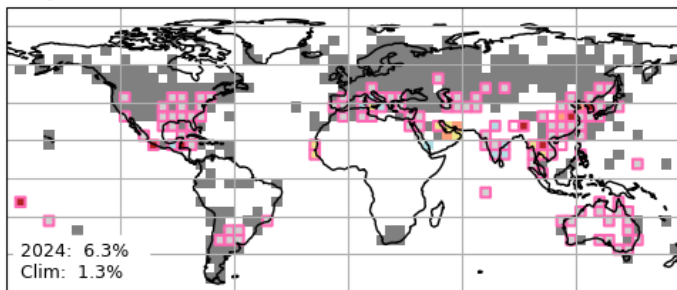
b) 2024 TwX27 **Extreme**



c) 2024 TwX29 **Very extreme**



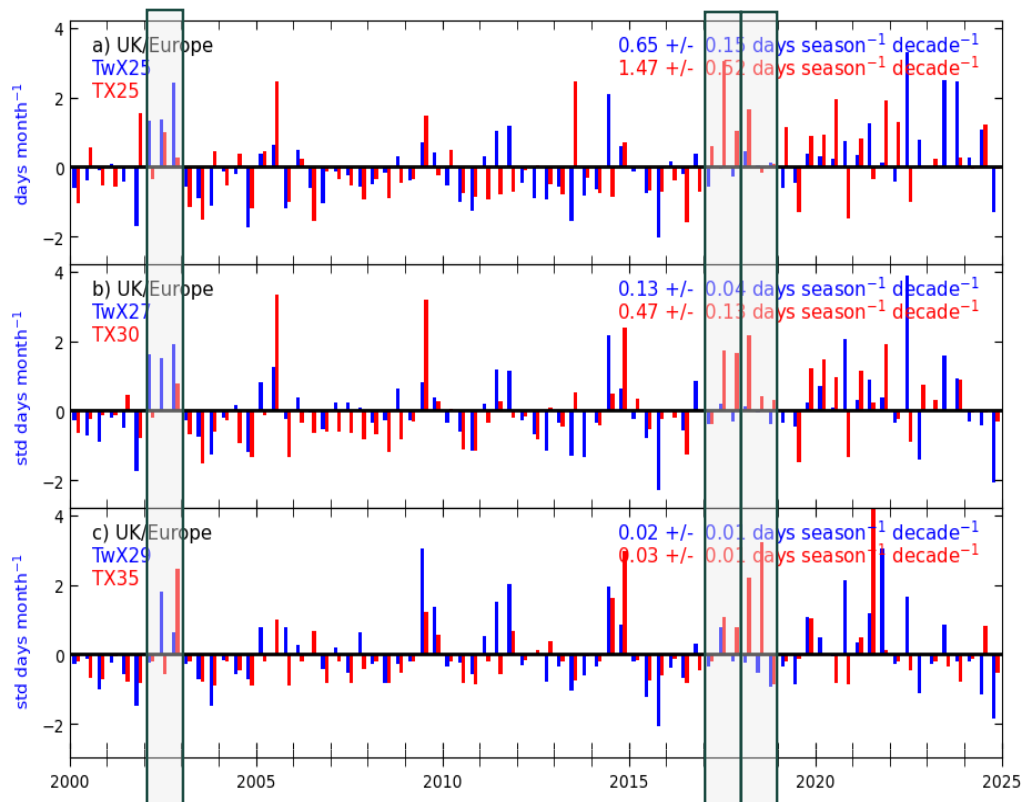
d) 2024 TwX31 **Severe extreme**



Vecellio et al., 2022:
Heat becomes uncompensable [the body gains heat faster than it can off-load] as wet-bulb temperature reaches 31°C, even for young healthy adults.

Number of days during 2024 that exceeded specific thresholds compared to 'normal', as deciles. Pink boxes have had few historical exceedances.

Assessing individual months / seasons: are some more humid than others?



- August 2003: unusually frequent very extreme temperature days (for the UK!) and unusually frequent moderate extreme-extreme humidity.

HOT AND HUMID

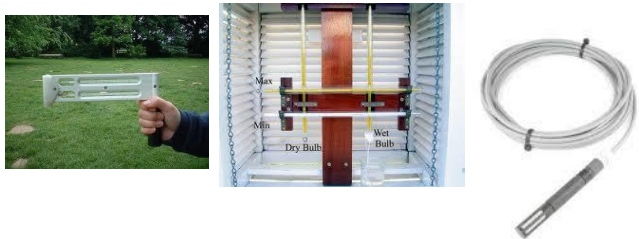
- July 2018: unusually frequent moderate extreme-extreme temperature days without unusual humidity.

WARM AND DRY

- July 2019: unusually frequent very extreme temperature days with without unusual humidity.

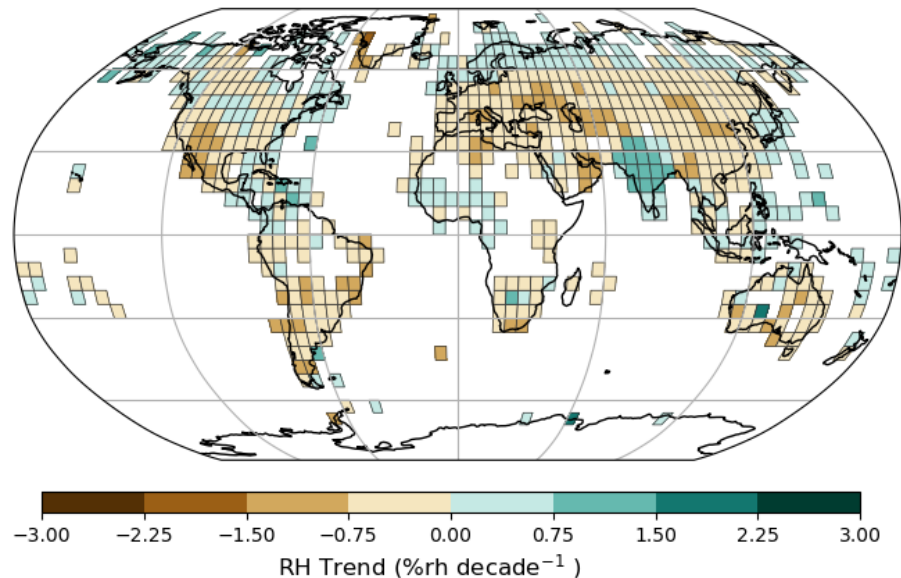
HOT AND DRY

Number of days per month (standardised anomalies) exceeding moderate extreme, extreme and very extreme humid and dry heat thresholds for the UK/Europe region.



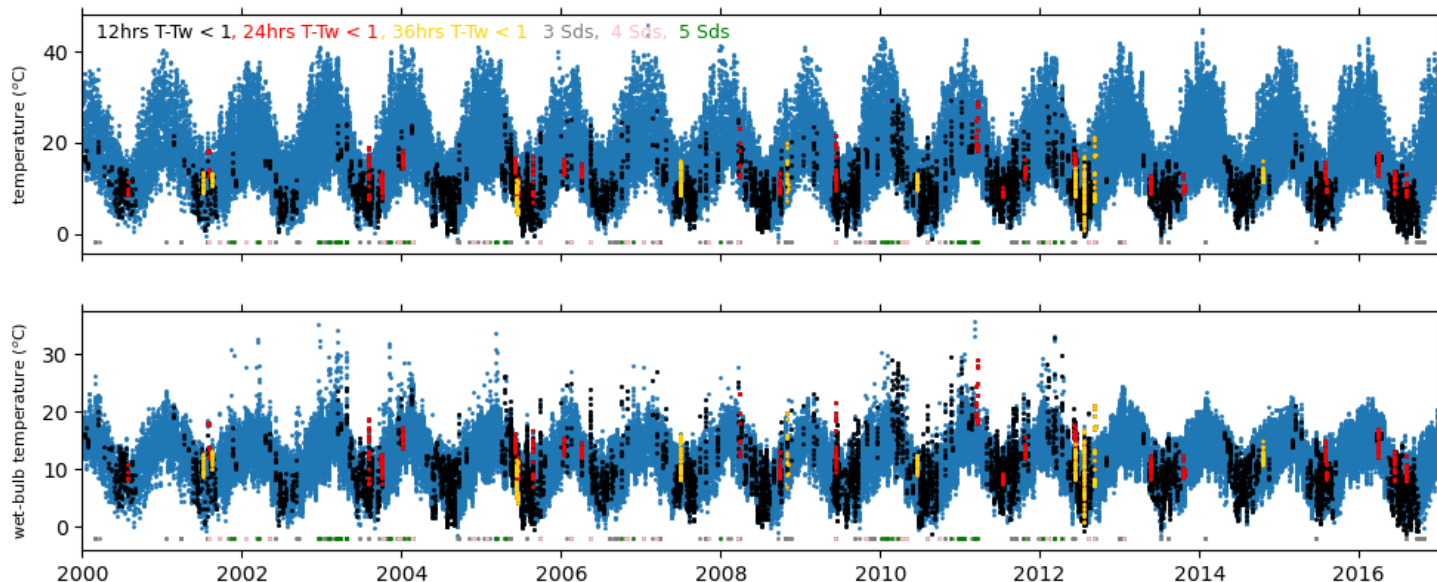
Instrument changes may have contributed to drying trends

- Move from manual wet bulb thermometers to automated Relative Humidity sensors
- More frequent observations from automated sensors
- Possible contribution to observed decrease in RH found over China (Li et al, 2020, Freychet et al., 2020)



Decadal trends in relative humidity (1973-2024) show widespread decreases.

A cautionary note...random error



Hourly T (top) and T_w (bottom) from an Australian weather station.

Black, yellow and red points are **12hr, 24hr and 36hr** continuous periods where T and T_w wet-bulb temperature are within 1°C .

Grey, pink and green dots show outliers of **3, 4 and 5** standard deviations.

The period between 2002-2012 clearly has quality issues that have not been detected by current Quality Control methods.

Humid-heat Summary



It can be useful to know whether heat is humid or dry – warm/humid heat events are harder to detect.

HadISDH.extremes is a global gridded product of humidity and temperature extremes indices, developed under the CSSP China programme.

Since the 1970s there have been widespread (regional and global) increases in frequency and intensity of both humid and dry heat events.

Moderately extreme and extreme humid-heat events have occurred almost everywhere across the globe.

More work is needed to improve coverage, assess remaining inhomogeneity, improve quality control methods and validate severe extremes.

