Dickensian climate metrology: The ghosts of meteorological observations past, present and future

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Talk outline

- The climate is changing
- The ghost of meteorological observations past: Historical data limitations
- The ghost of meteorological observations present: Ways we can advance our understanding using metrological insights / tools in the here and now
- The ghost of meteorological observations future: What we can do to ensure that future generations have a more robust estimate of climatic changes
- Summary

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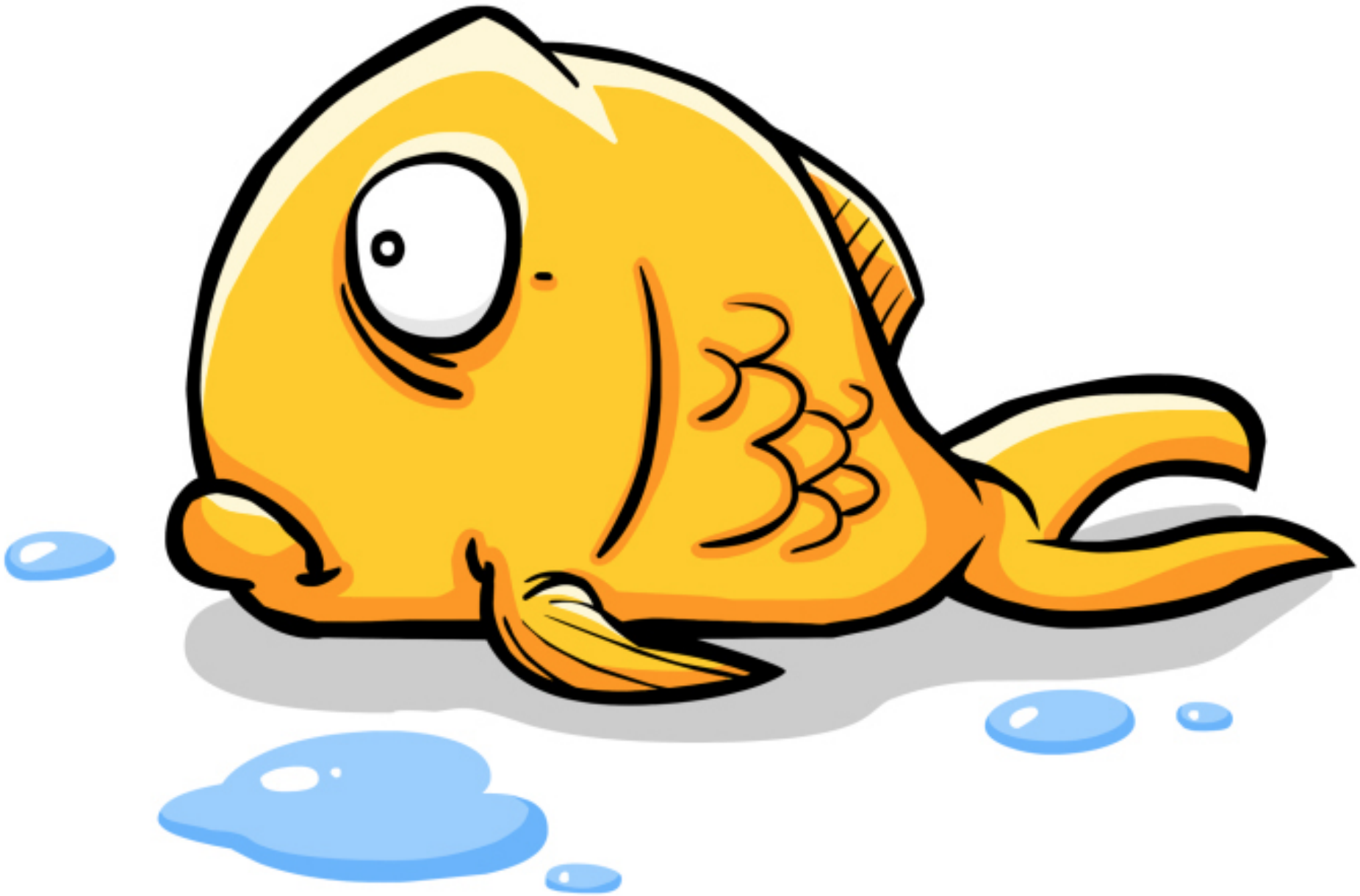
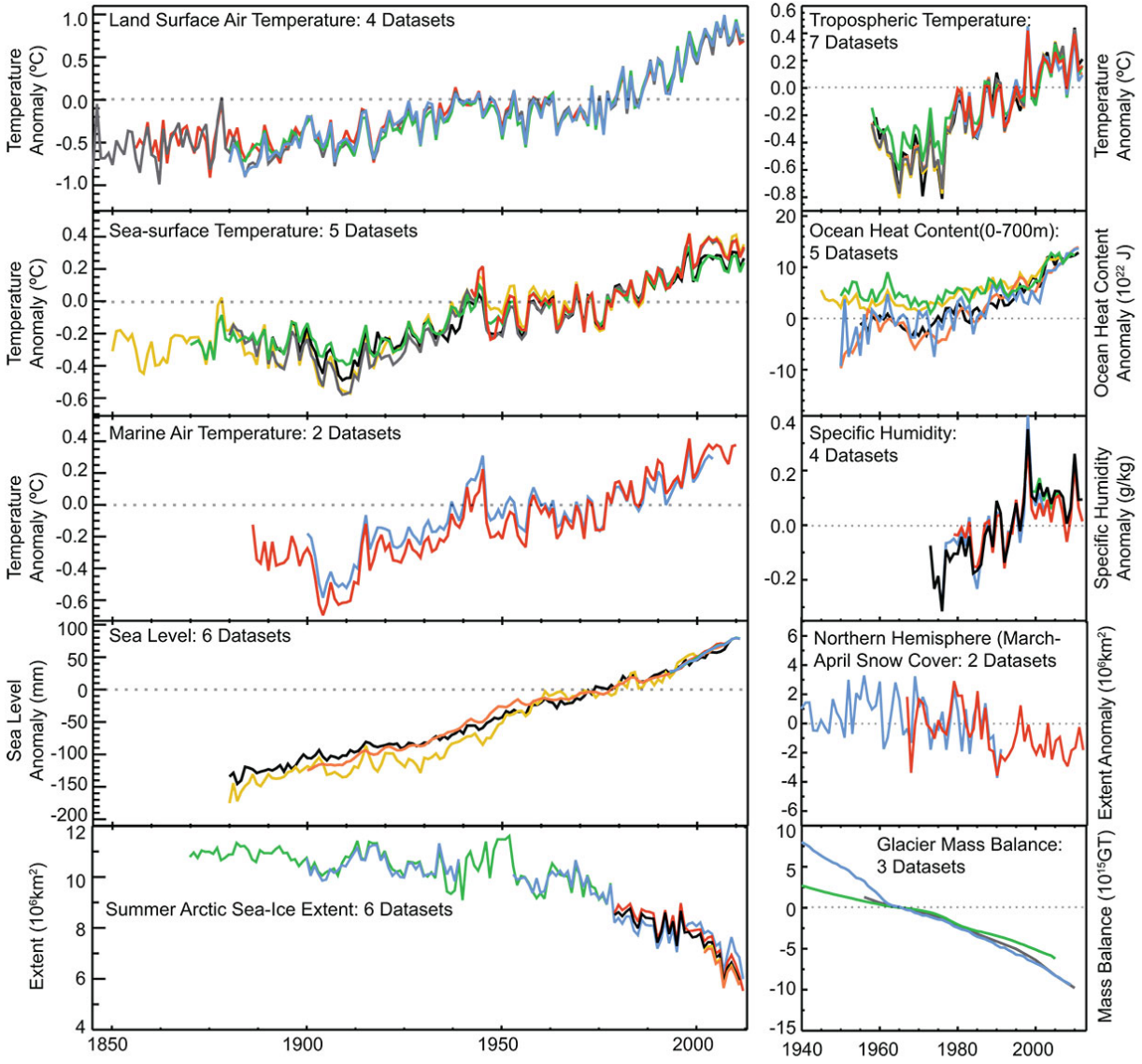
Before that … who am I?

- I'm a climate scientist
- Spend most of my time trying to understand how climate has changed and why.
- Lead Author on 5th Assessment Report of the Intergovernmental Panel on Climate Change and third US National Climate Assessment
- Chair of the International Surface Temperature Initiative
- Co-Chair of the Global Climate Observing System Reference Upper Air Network

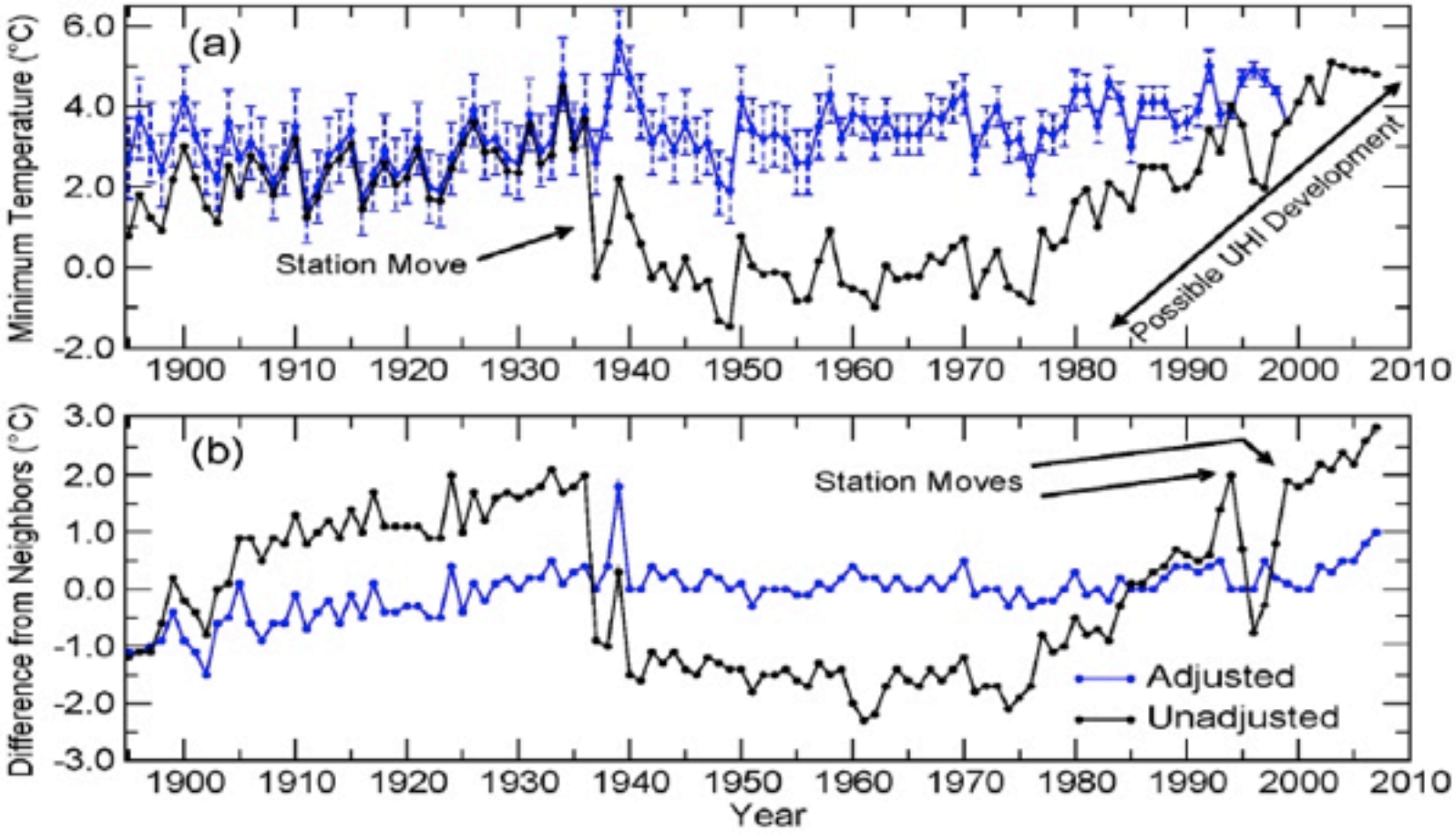



Land Surface Air Temperature: 4 Datasets
Temperature Anomaly (°C)
Sea-surface Temperature: 5 Datasets
Temperature Anomaly (°C)
Marine Air Temperature: 2 Datasets
Temperature Anomaly (°C)
Sea Level: 6 Datasets
Sea Level Anomaly (mm)
Summer Arctic Sea-Ice Extent: 6 Datasets
Extent (10⁶km²)
1850
1900
1950
2000
Tropospheric Temperature: 7 Datasets
Temperature Anomaly (°C)
Ocean Heat Content(0-700m): 5 Datasets
Ocean Heat Content Anomaly (10²² J)
Specific Humidity: 4 Datasets
Specific Humidity Anomaly (g/kg)
Northern Hemisphere (March-April Snow Cover: 2 Datasets
Extent Anomaly (10⁶km²)
Glacier Mass Balance: 3 Datasets
Mass Balance (10¹⁵GT)
1940
1960
1980
2000

The ghost of meteorological observations past

Huge range of instrument types, siting exposures etc. regionally, nationally and globally with many changes over time.

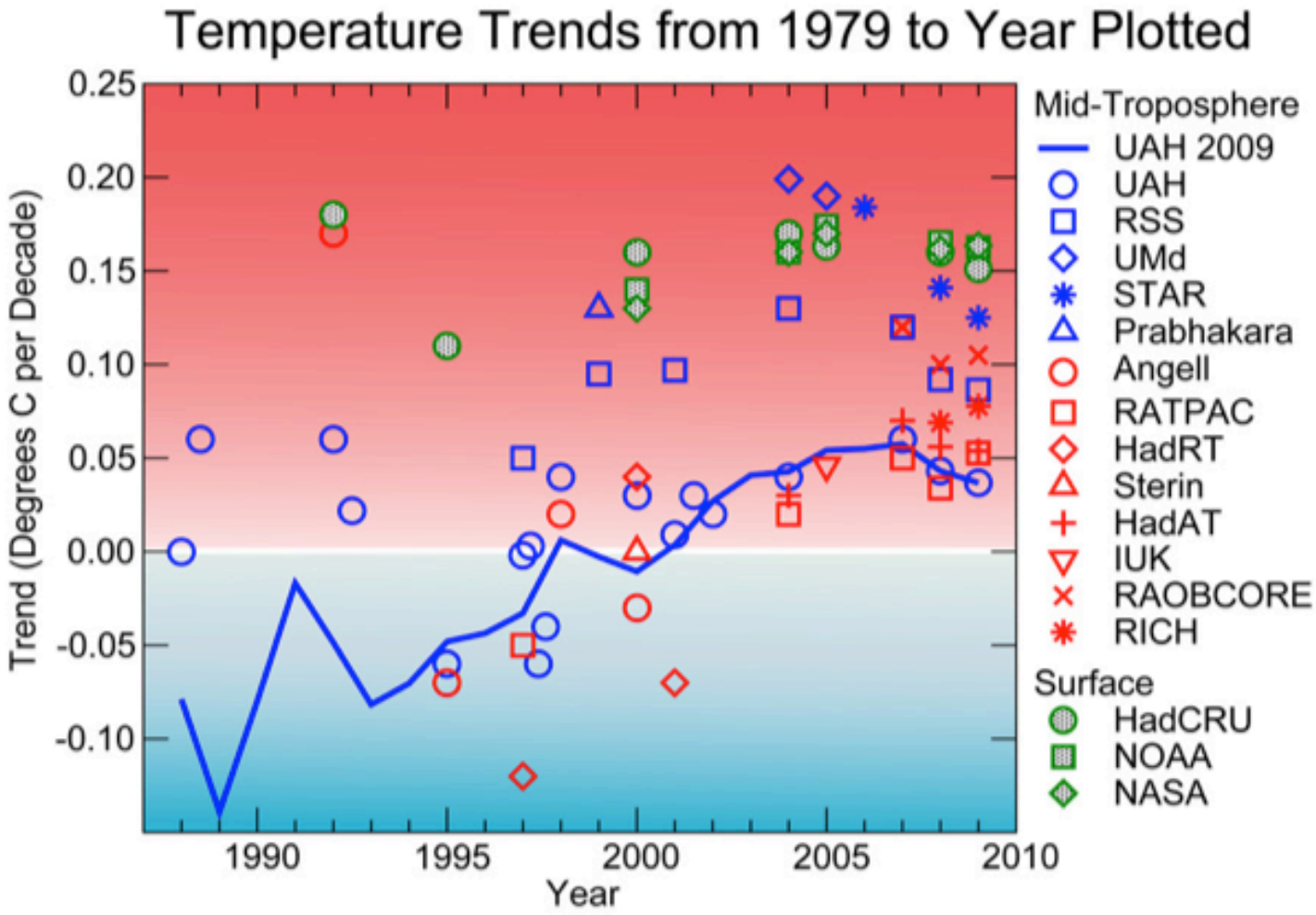
Historical measurement issues have practical consequences



For the surface (similar list would exist for balloon based or remotely sensed data …)

- Station moves
- Instrument changes
- Observer changes
- Automation
- Time of observation biases
- Microclimate exposure changes
- Urbanization
- And so on and so forth …

Historical observational uncertainties have real implications



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What we have at a bottom line

- A lack of traceability to absolute or relative standards for most, if not all, of the historical records
- A lack of comparability between different measurements
- A lack of adequate documentation of the (ubiquitous) changes sufficient to characterize on a station by station basis in an absolute sense their changing measurement characteristics.

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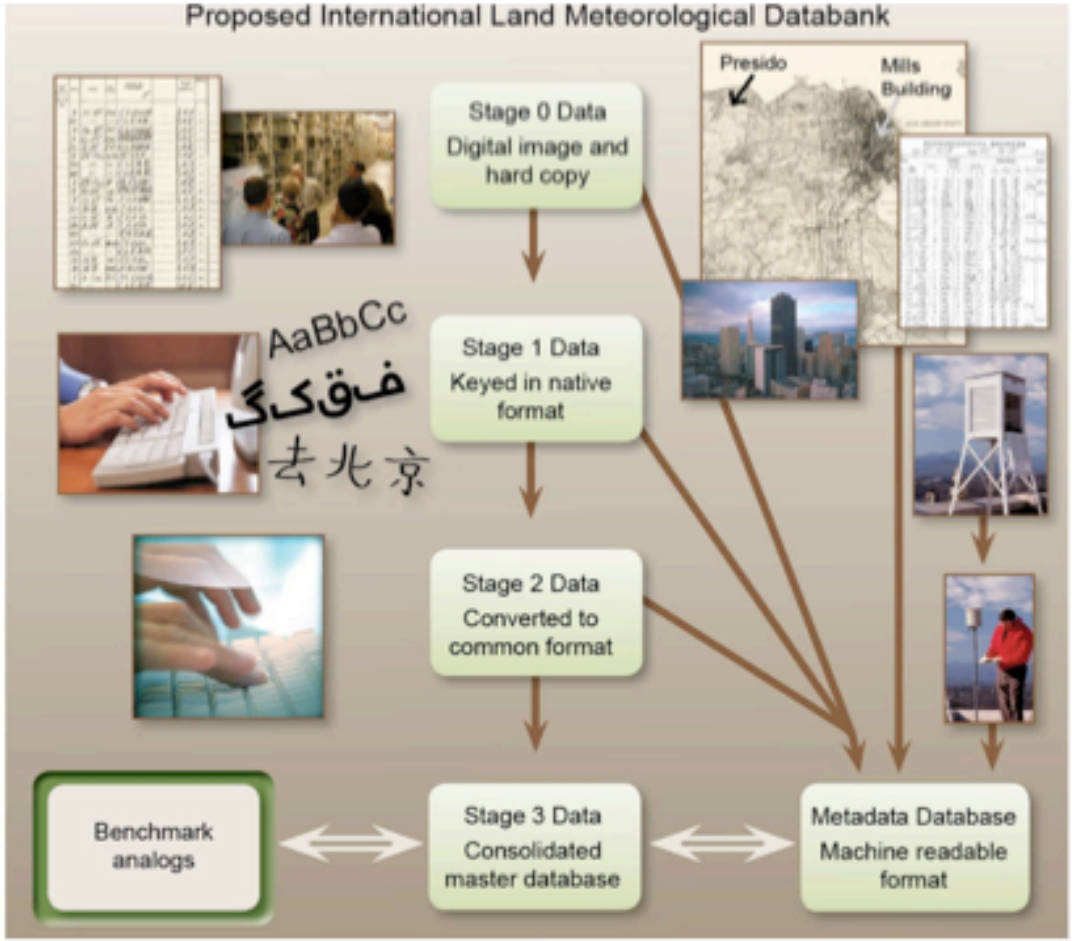
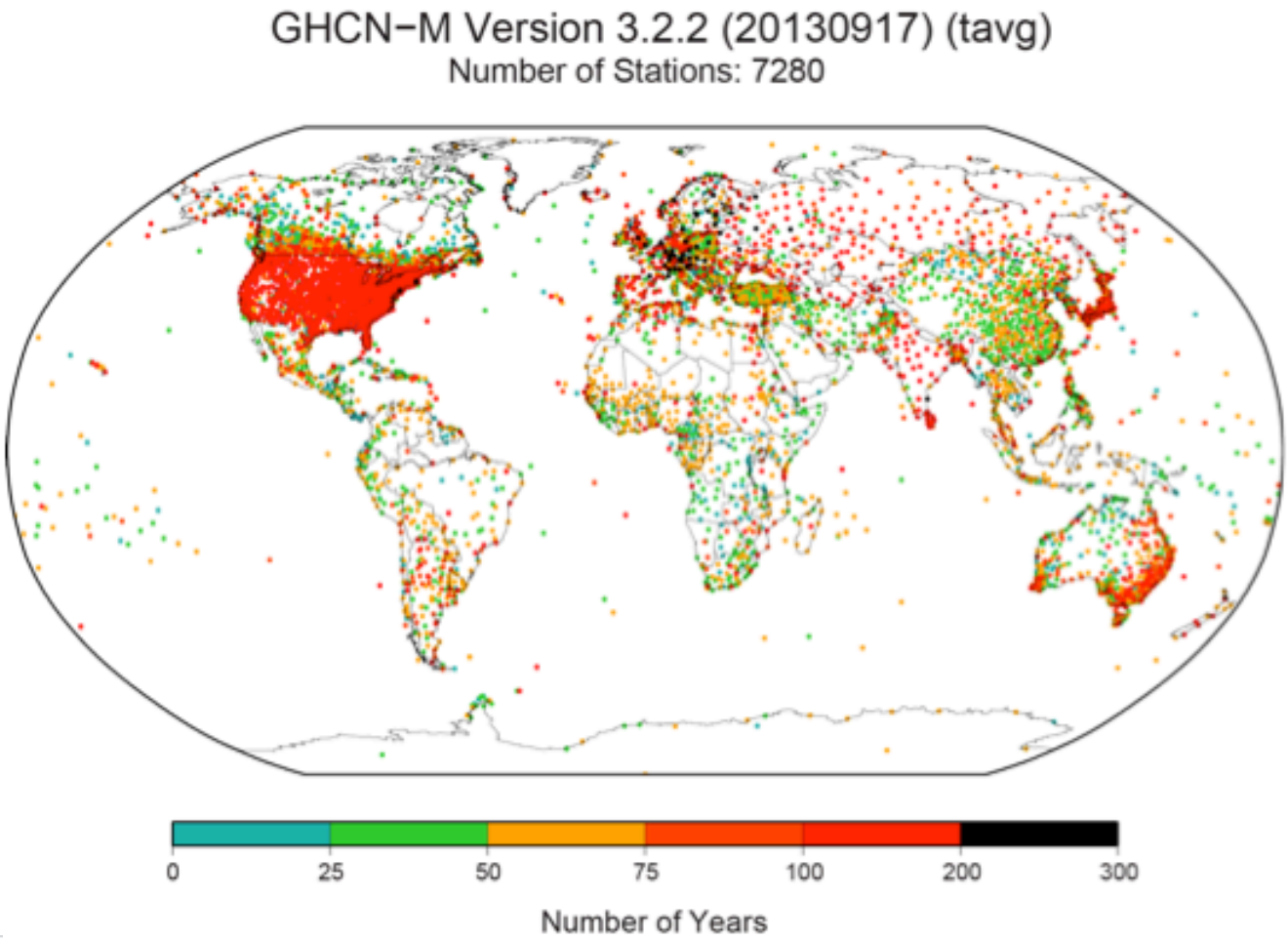
The ghost of meteorological observations present

- We can do better with present observational resources
- Example here is International Surface Temperature Initiative
  - The themes are broadly transferable to other parameters and observational techniques.
- Metrological insights can help us to better estimate the true climate system evolution

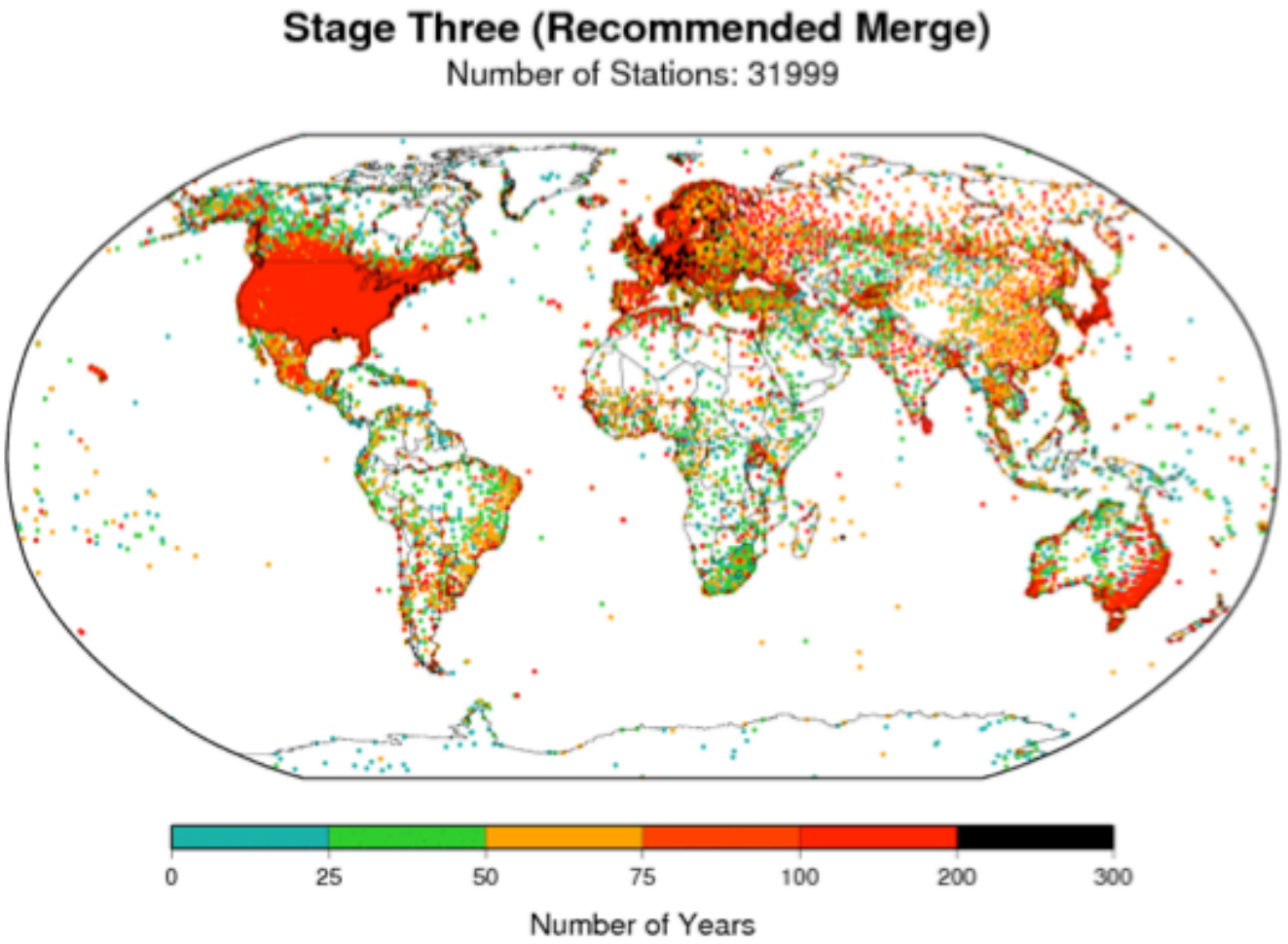
1. Improve data holdings of fundamental basic data



What we had


GHCN−M Version 3.2.2 (20130917) (tavg)
Number of Stations: 7280
0
25
50
75
100
200
300
Number of Years

What we have

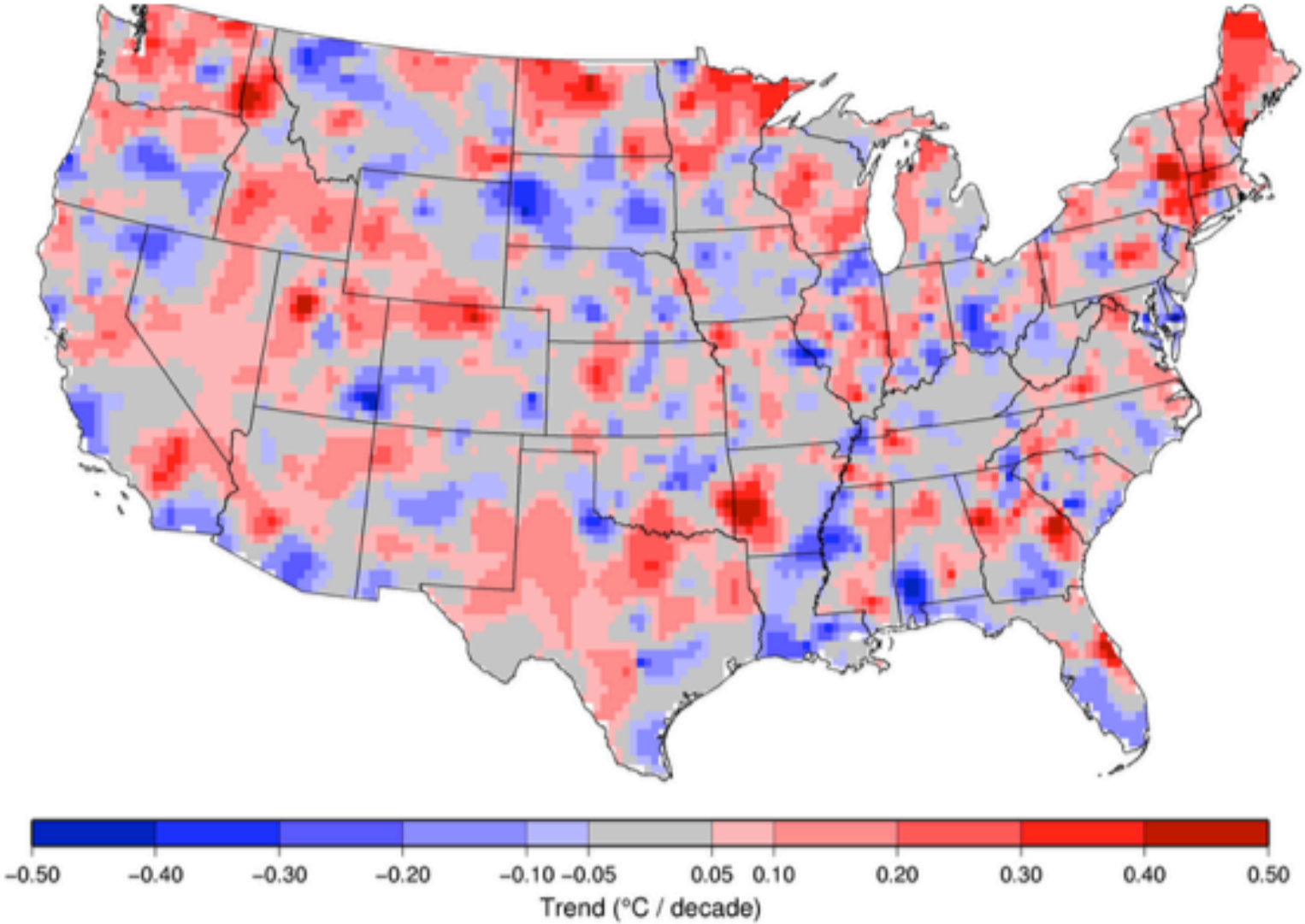

Stage Three (Recommended Merge)
Number of Stations: 31999
0
25
50
75
100
200
300
Number of Years

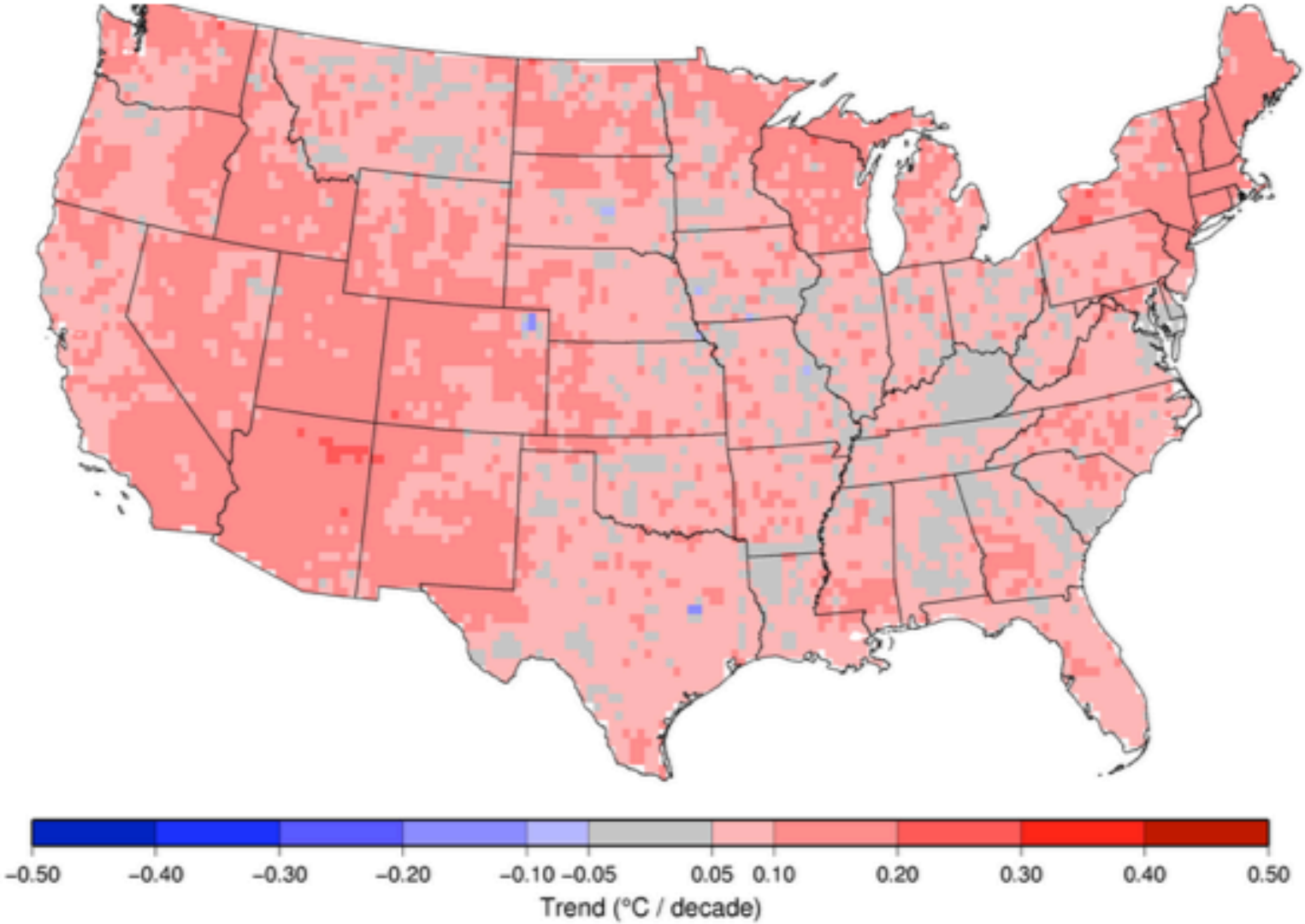
2. Benchmarking (software testing)

- With real world data we do not have the luxury of knowing the truth – we CANNOT measure performance of a specific method or closeness to real world truth of any one data-product.

- We CAN focus on performance of underlying algorithms (AKA software testing)

- Consistent synthetic test cases, simulating real world noise, variability and spatial correlations potentially enable us to do this


−0.50
−0.40
−0.30
−0.20
−0.10
−0.05
0.05
0.10
0.20
0.30
0.40
0.50
Trend (°C / decade)


−0.50
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0.30
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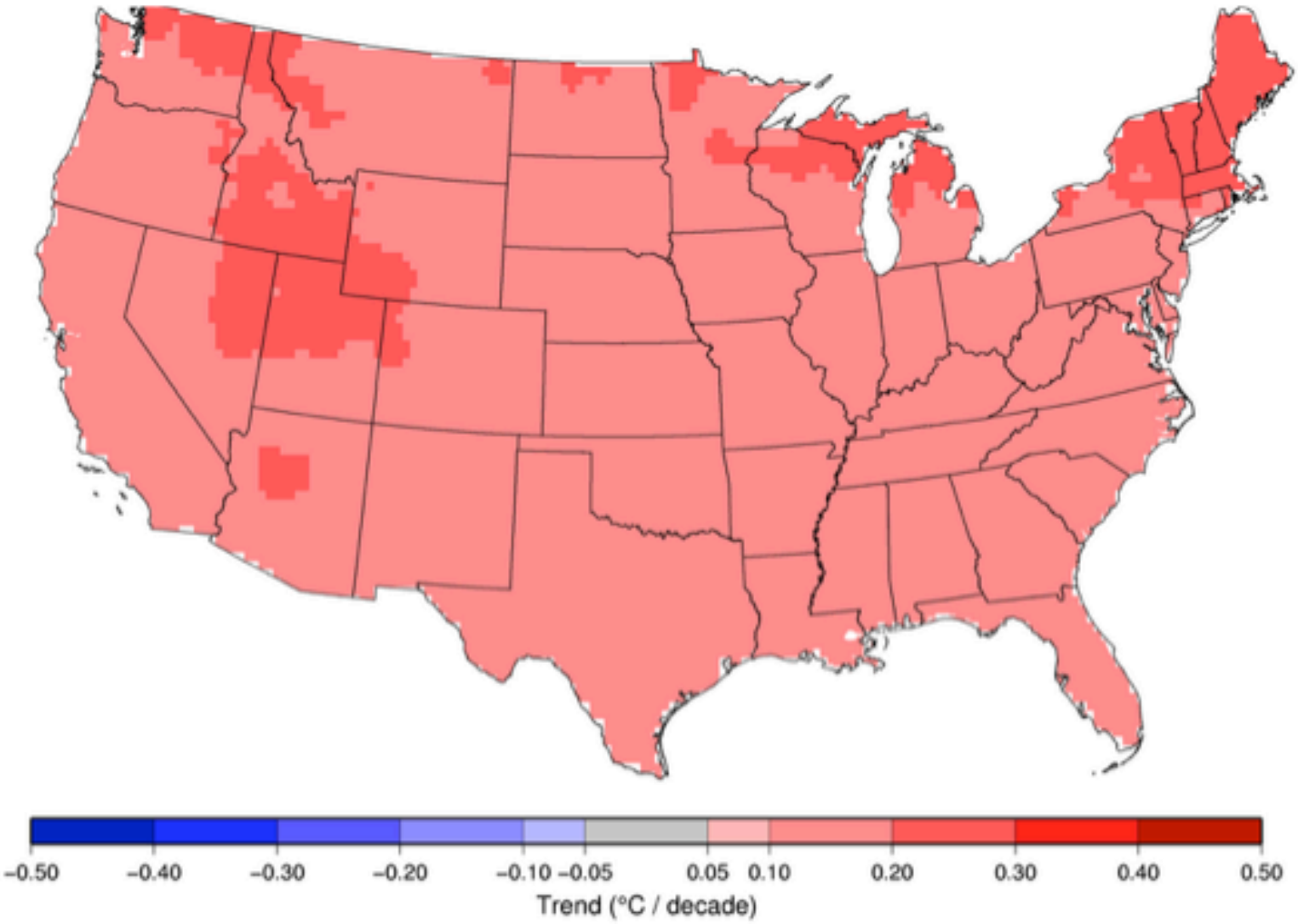
0.50
Trend (°C / decade)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−0.05
0.05
0.10
0.20
0.30
0.40
0.50
Trend (°C / decade)

Need multiple approaches

- Structural uncertainty is the key
  - Raw data is far from traceable to international measurement standards.
  - Data artifacts are numerous and have myriad causes
  - Metadata describing station histories is patchy at best and often non-existent
  - Data is discrete in both space and time
  - No “how to” … rather very many cases of “it may work …”
  - Multiple subjective decisions required even in automated procedures (thresholds, periods, test type etc.)
  - Different approaches may have different strengths and weaknesses
  - No single dataset can answer all user needs

– There is a definite role for metrologically based analyses of the holdings!

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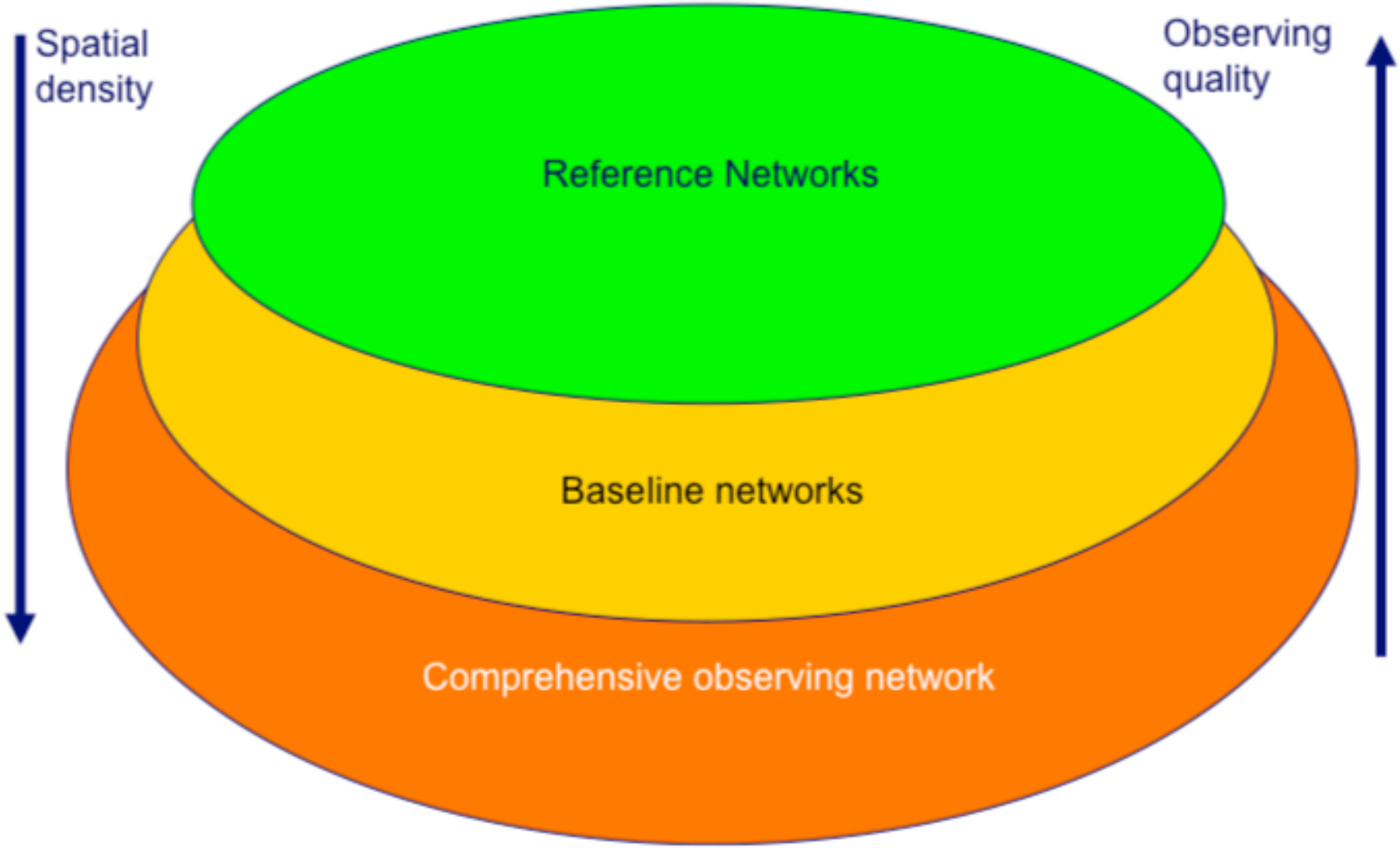
The ghost of meteorological observations future

- Does it always have to be this way?
  - No, with a little effort and joined up thinking
  - We *do not* need perfect measures everywhere
  - We *do* need a sufficient set of well characterized measurements to be able to have a chance to understand the remainder of the observations
  - Reference quality measurements e.g. US Climate Reference Network and GCOS Reference Upper Air Network, are required on a sustained basis.
  - Need a truly multi-point system
    - Don't rob Peter to pay Paul

- Example below is for GRUAN
  - Again the underlying principles are broadly transferrable


Spatial
density
Observing
quality
Reference Networks
Baseline networks
Comprehensive observing network

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Reference networks can …

› Provide long-term measurement series in their own right

› Constrain measurements from more globally complete measurement systems by providing a finite set of well characterized tie-points

› Serve to improve process understanding

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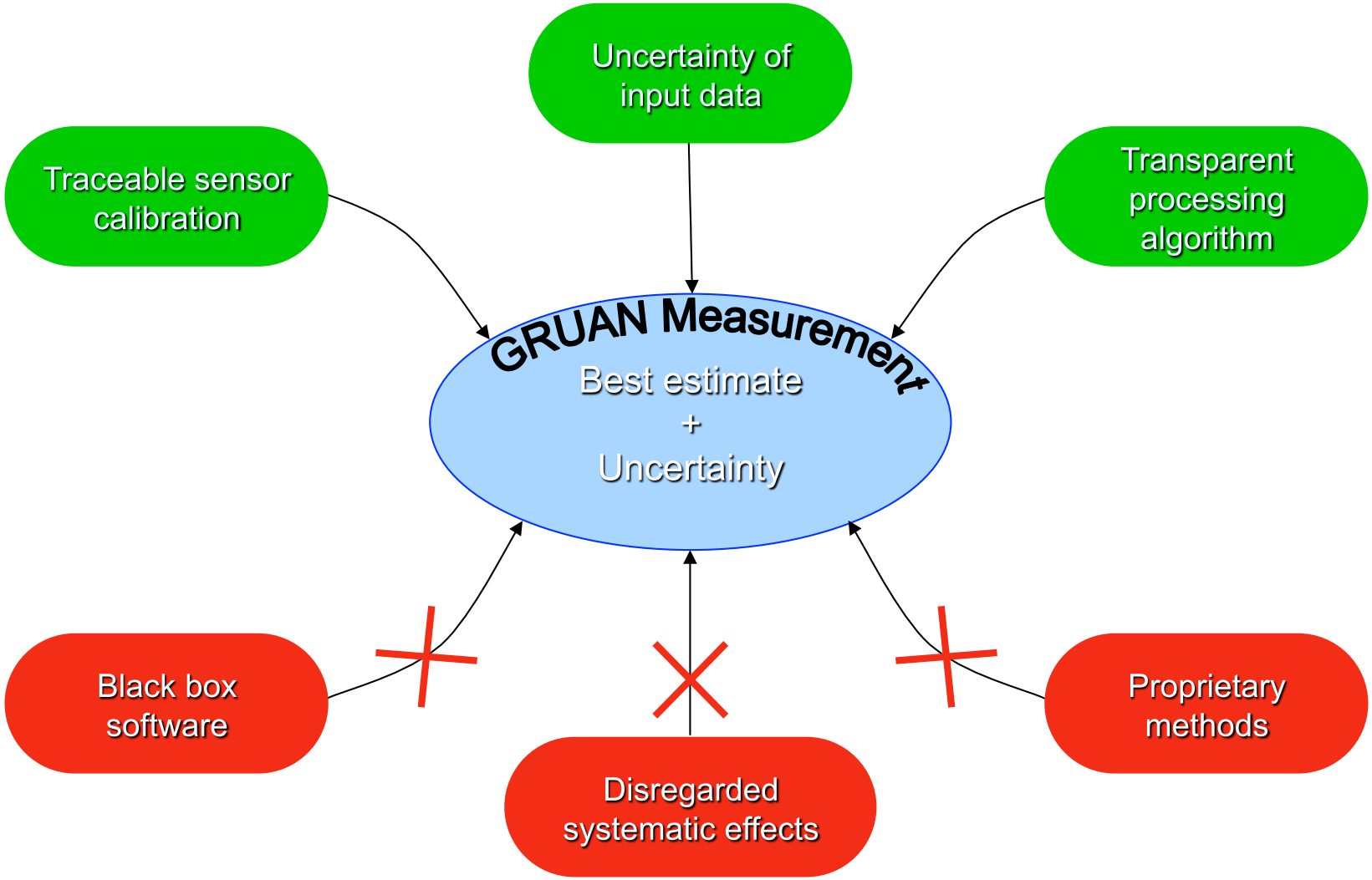
A reference quality observation

- ✓Is traceable to an SI unit or an accepted standard
- ✓Provides a comprehensive uncertainty analysis
- ✓Is documented in accessible literature
- ✓Is validated (e.g. by intercomparison or redundant observations)
- ✓Includes complete meta data description

Establishing reference quality



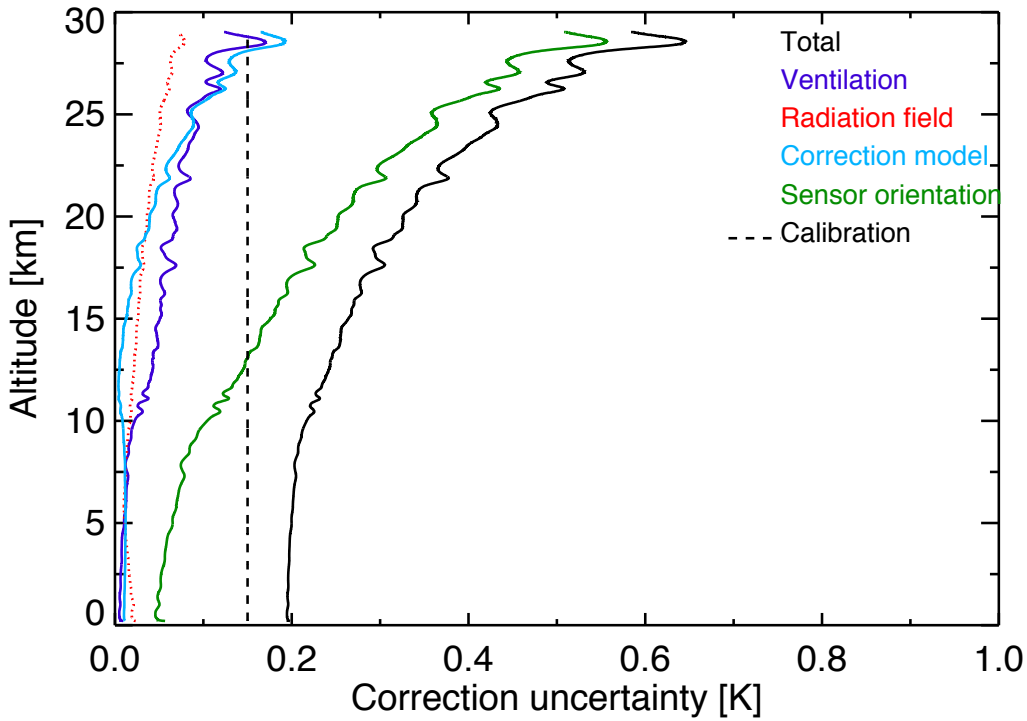
Literature:

- Guide to the expression of uncertainty in measurement (GUM, 1980)
- Reference Quality Upper-Air Measurements: Guidance for developing GRUAN data products, Immler et al. (2010), Atmos. Meas. Techn.

Example – RS92 radiosonde

Sources of measurement uncertainty:

- Sensor orientation
- Unknown radiation field
- Lab measurements of the radiative heating
- Ventilation
- Ground check
- Calibration
- Time lag



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Still a long way to go …

- Bring in extra data streams
  - Frostpoint hygrometers
  - Lidars
  - Radiometers
- Expand the network
  - Truly global
  - Sufficient stations to characterize climate
- Maintain the network for decades to come
  - We need continuous and high quality measurements
- Do science with the network measurements
  - Funding will only be secure if we show reference measurement networks are truly valuable. Saying so does not make it so.

Summary

- No question as to the trajectory of the climate system
- Significant ambiguity in the details as a result of past measurement practices
- We can do better in the here and now in estimating the past changes using metrological insights (and statistical, climatological etc.)
- We can also instigate and maintain measurements that better assure the future through instigating traceable and comparable reference measurement networks
- It is unambiguous that metrology has a key role to play in all of this
- And the good news is that there are many potential ways to get involved
- So, let's make sure that happens ☺

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Q&A