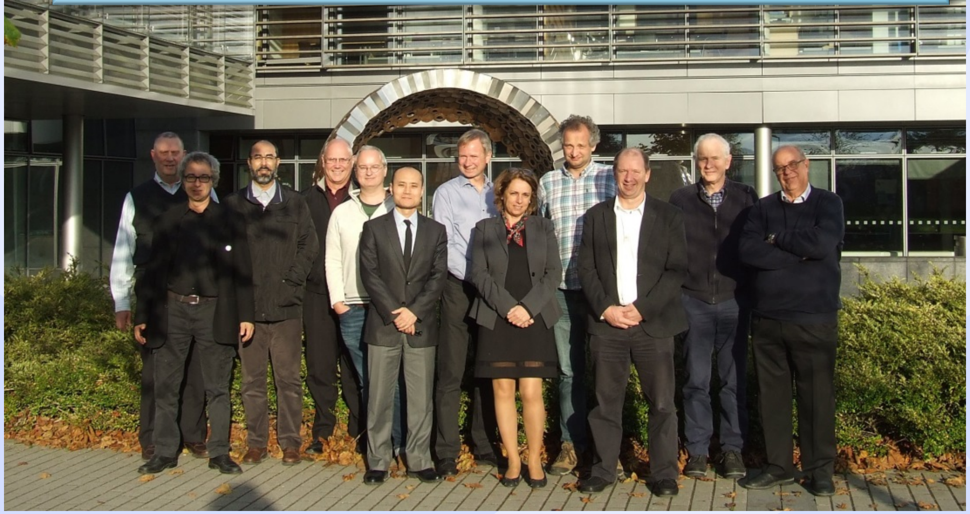
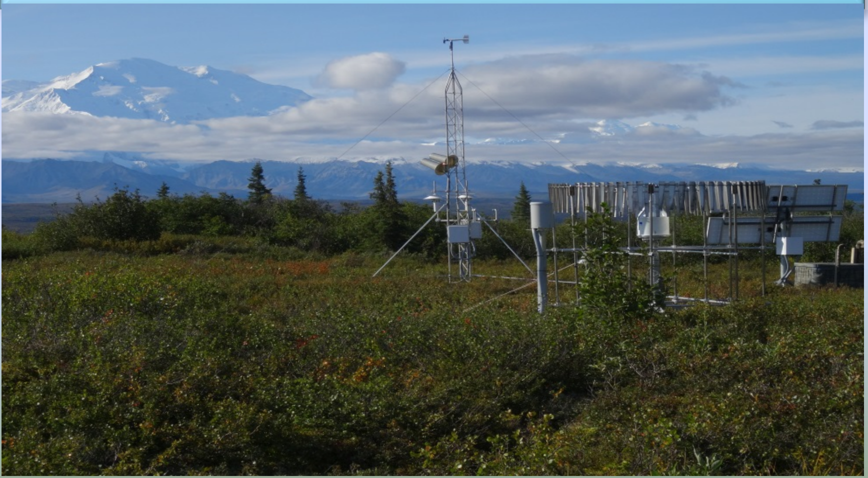
GCOS Surface Reference Network (GSRN) Task Team Report to the AOPC-23 Meeting
6-March-2018; Darmstadt, Germany

GSRN TT Initial Meeting from 1-3 Nov 2017; Maynooth University; Dublin, Ireland



USCRN Station in Denali National Park Alaska



Presented by:
Howard J. Diamond, PhD
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Co-Chair – Nigel Tapper, PhD
Monash University; Melbourne, Australia

Agenda

- Background and Charge to the Task Team
- U.S. Climate Reference Network (USCRN) and GCOS Reference Upper Air Network (GRUAN) as potential models to build on
- Report from the GSRN Task Team from 1-3 November 2017 in Dublin, Ireland
- Work Plan and Path Forward (and some personal thoughts)
- Summary

GSRN Task Team Membership

- Co- Chair – Howard Diamond – USA
- Co-Chair and TOPC Rep – Nigel Tapper - Australia
- AOPC Representative – Phil Jones – UK
- GRUAN Representative – Peter Thorne – Ireland
- GSN Representative – Tim Oakley – UK
- CBS/WIGOS/CIMO Representative – Andrew Harper – New Zealand
- NMHS Representative – Jiankai WANG – China
- BIPM Representative – Andrea Merlone – Italy
- Climate Scientist Representative – Victor Venema – Germany
- Satellite – (Bojan Bojkov – Germany)
- Region I Representative – Rachid Sebbari – Maroc
- GCOS Secretariat – Caterina Tassone
- WMO Secretariat – Peer Hechler

GCOS Surface Reference Network Task Team Meeting
Maynooth University in Dublin, Ireland; 1-3 November 2017

Background

- AOPC-22 (Exeter, UK, March 2017) agreed on the creation of a dedicated task-team to scope a potential GCOS global surface reference network.
- The potential for such a network has been proposed by GCOS AOPC and by the Commission for Climatology.
- Build on paper accepted in the Intl Journal of Climatology, "Towards a global land surface climate fiducial reference measurements network"; DOI:10.1002/joc.5458; Thorne et al. (2018)] – Accepted February
- This Task Team is charged with taking this forwards towards practical implementation providing a concrete roadmap as to what would be required and to canvas stakeholders.
- Working models on which to base deliberations include the GCOS Reference Upper Air Network, US Climate Reference Network, and Global Cryospheric Watch.

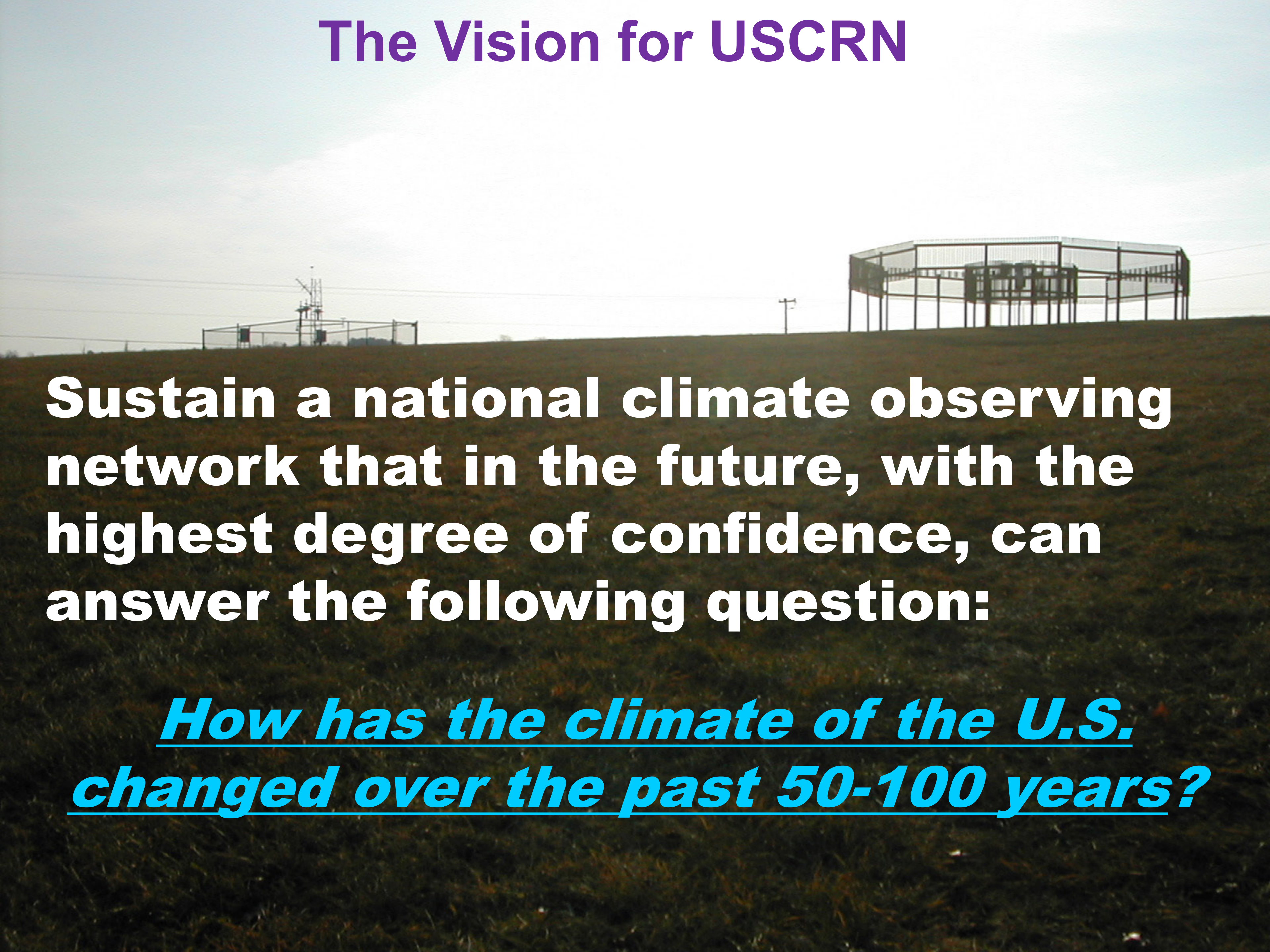
Scientific charge from the AOPC

1. **Create a scientifically robust basis** for a proposed network spatial composition, taking into account fairness in national contributions and the need for globally representative measurements.
2. Accounting for stakeholder needs including inter-alia climate monitoring, process understanding and understanding remaining measurements (including space-borne measurement systems), **define a robust siting rationale**.
3. **Propose a phased implementation** that 'starts small, but starts' and builds over time to a holistic set of measurements of all relevant ECVs at each site to the extent practicable.
4. **Alight on a potential governance structure** in collaboration with key stakeholders.
5. **Propose one or more management options** that undertake day-to-day operational oversight and ensures a globally traceable, comparable network of measurements, recruiting possible host institutions.
6. **Provide indicative costings on the proposed solutions** sufficient to inform a decision as to whether to move forwards
7. **Address additional needs identified by the Task Team** and agreed with AOPC as they arise.

Rules of the Road

1. The task team shall exist for an initial period of **two years**.
2. The task team **shall work primarily remotely**, facilitated by GCOS secretariat, after the initial Nov 2017 meeting, any possible future meetings will be decided as required and as resources allow.
3. The task **team shall work in conjunction with relevant groups within WMO to ensure broad buy-in including CCl, WIGOS and CBS**.
4. The **task team chair shall be expected to report annually** on progress to AOPC by means of a brief written report and, if support available, verbal reporting in person.
5. The task team shall be expected to lead the **production of a final report** implementation plan) which may form the basis for a decision as to whether, and if so how, to proceed with a GCOS Surface Reference Network.
6. Build on paper accepted "Towards a global land surface climate fiducial reference measurements network"; DOI:10.1002/joc.5458; Thorne et al. (2018)]

The Vision for USCRN



Sustain a national climate observing network that in the future, with the highest degree of confidence, can answer the following question:

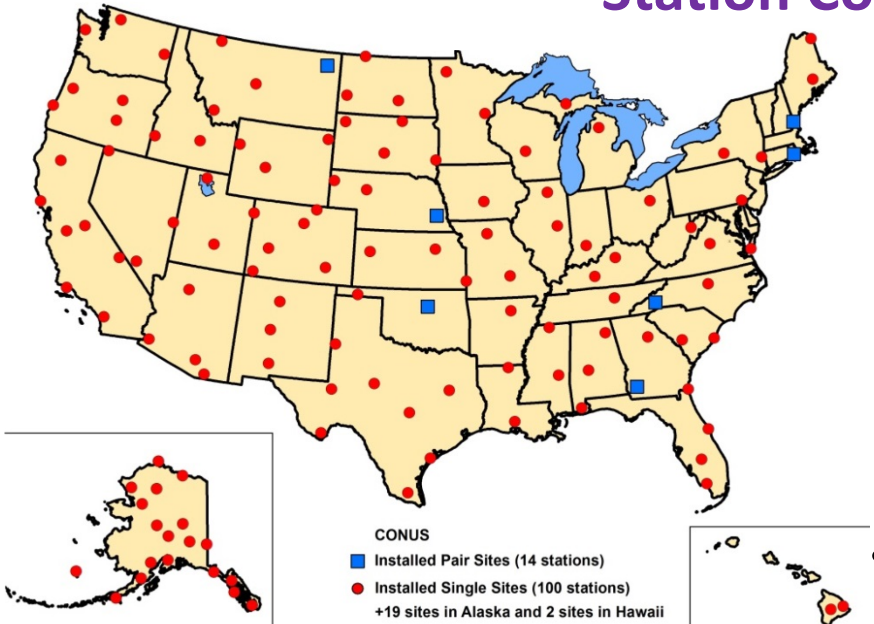
How has the climate of the U.S. changed over the past 50-100 years?

USCRN Design Principles

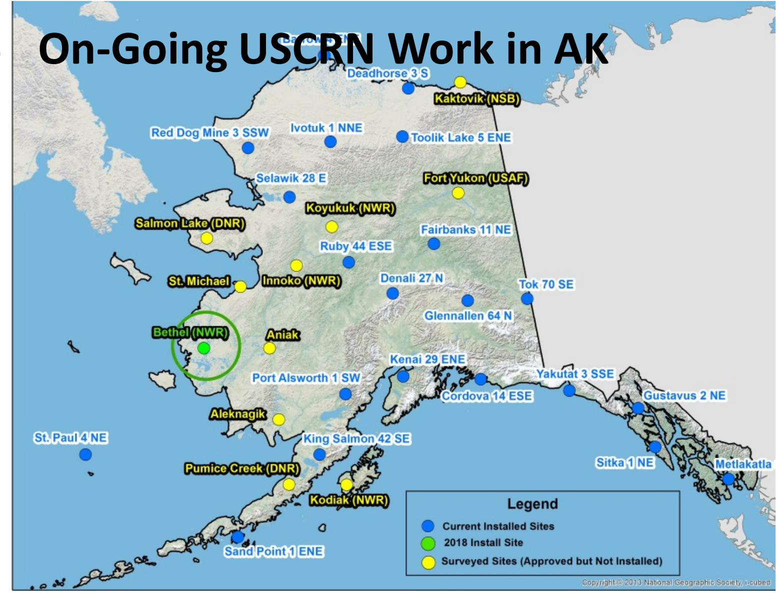
- Adhere to GCOS Monitoring Principles to the greatest extent possible
- Triplicate Sensors
- Excellent and up-to-date documentation
- Consistent and constant monitoring
- Take great care in site selection from a land change perspective (e.g., National Parks, Wildlife Refuges)
- Annual Maintenance for each station; plan for unscheduled maintenance
- Sensor Testing, Engineering, and Sensor Refresh
- Web Site with Good and Easy Data Access
- Keep End-Users in Mind

Station Coverage

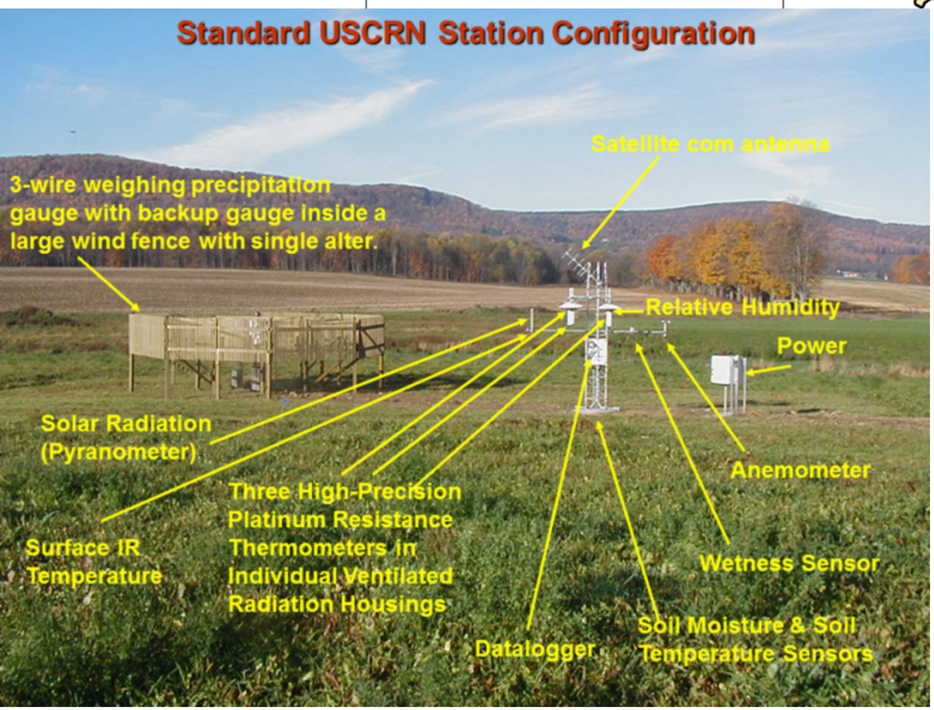
CONUS – Done 2008



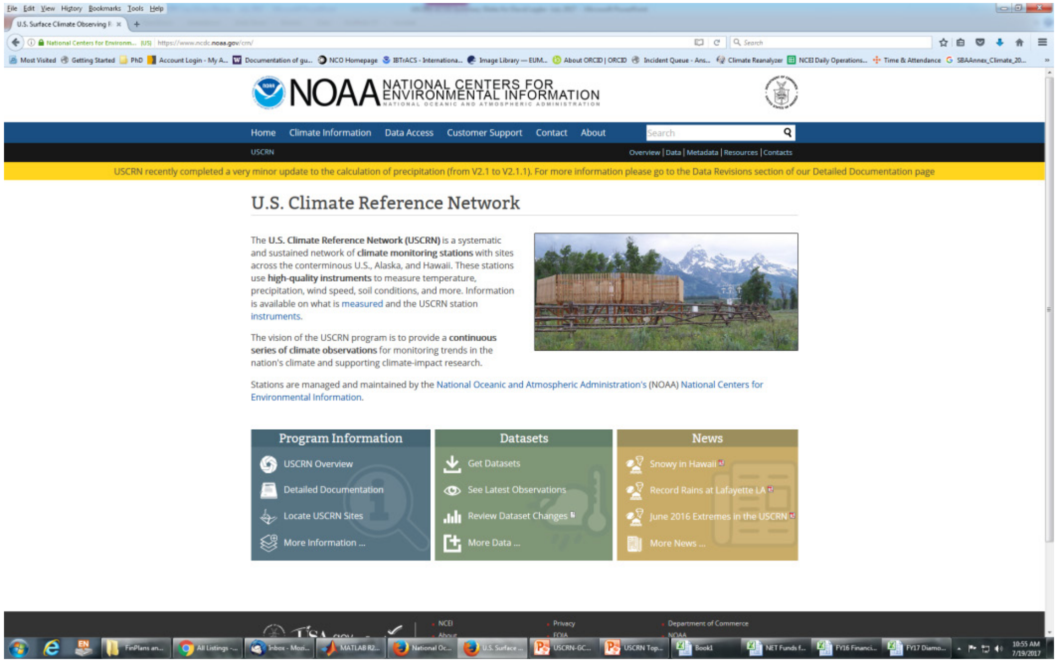
On-Going USCRN Work in AK



- 21 stations installed in AK as of Aug 2017 (blue dots)
- 1 new station for FY18 (green dot)
- 7 more stations to be installed from FY19-22 (yellow dots)

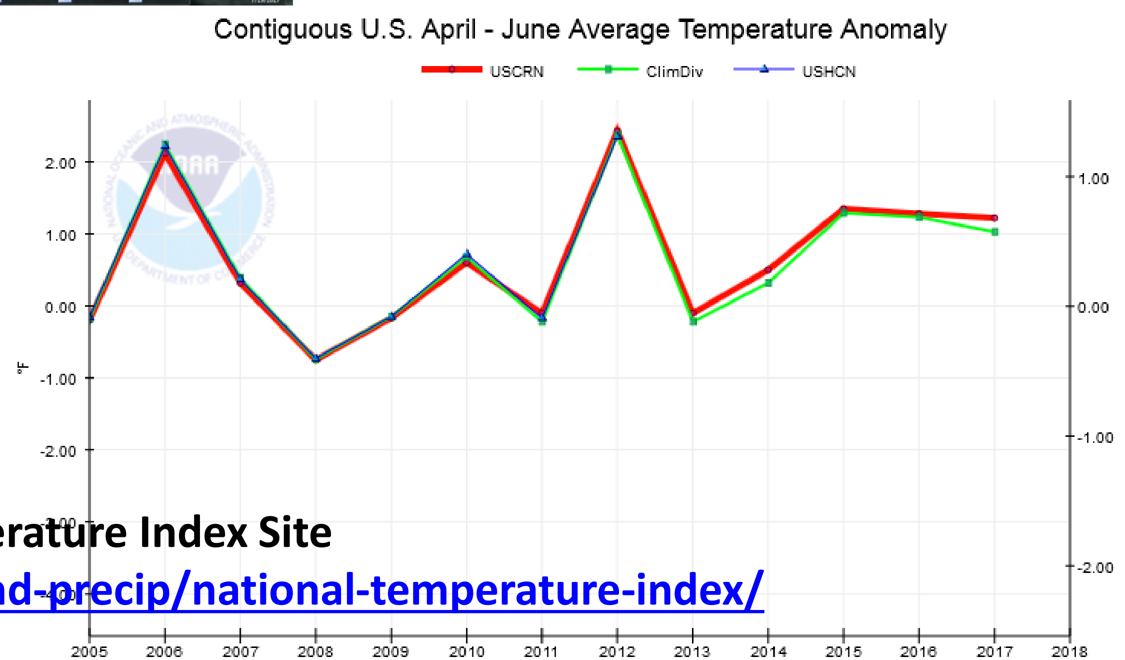


USCRN Data Access and Reference Standard Comparison



USCRN Web Site:
http://www.ncdc.noaa.gov/crn

Data Available as follows:
- **Current Hourly**
- **Monthly**
- **Daily**
- **Hourly**
- **Sub-Hourly**



Temperature Index Site
https://www.ncdc.noaa.gov/temp-and-precip/national-temperature-index/

USCRN Data and Users

- The following groups of users are using the data from the standpoint of planning how climate change impacts in watersheds, farms, national parks that can feed into climate adaptation strategies related to climate change; USCRN has also become a model for what the international Global Climate Observing System is looking to develop. The user community is diverse and large including:
  - NIDIS Program; and drought monitoring community in general
  - NWS Forecast Offices using the data in their warning & forecast program; and the NOAA Water Center
  - Re-Insurance, Legal, and Agriculture Communities, as well as the General Public
  - Agriculture community (small farmers to agri-business); land-use and soil scientists
  - Climate Scientists, State Climatologists, and Students
  - Resource Managers (e.g., Watersheds, National Parks and Wildlife Refuges, and Horticulturists)

- Provides a reference standard for verifying the accuracy of older networks (e.g., USHCN) – National Temperature Index – see https://www.ncdc.noaa.gov/temp-and-precip/national-temperature-index/ [validates consistent rates of anomalous warming] – this is a critical application for the on-going study of climate change.

- USCRN Web Site at http://www.ncdc.noaa.gov/crn provides access to real-time observations (a one-hour delay) as well as quality controlled sub-hourly, hourly, daily, and monthly datasets.

The GCOS Reference Upper-Air Network

GRUAN Leadcentre[1] **and the GRUAN Working Group**
(1) GRUAN Lead center, Richard-Assmann-Observatorium, Deutscher Wetterdienst, Lindenberg, Germany

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Website :
https://www.gruan-online.org

The Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) is an international reference observing network, designed to meet climate requirements and to fill a major void in the current global observing system. GRUAN observations will provide long-term, high-quality climate records from the surface, through the troposphere, and into the stratosphere. These will be used to determine trends, constrain and validate data from space-based remote sensors and to provide accurate data for the study of atmospheric processes. GRUAN is envisaged as a global network of 30-40 stations, where possible building on existing observational networks and capabilities.

Figure 1: The GRUAN network, 2017

GRUAN goals

- Provide long-term high-quality upper-air climate records
- Constrain and calibrate data from more spatially-comprehensive global observing systems
- Fully characterize the properties of the atmospheric column and their changes (fig.2)
- Measure co-related climate variables with deliberate measurement redundancy
- Focus efforts on characterizing observational biases, including complete estimates of measurement uncertainty (fig. 3)
- Ensure traceability of measurements by extended metadata collection and comprehensive documentation of observational methods (fig.4);
- Tie measurements to SI units or internationally accepted standards
- Ensure long-term stability by managing instrumental changes
- Further the understanding of climate variability and change

Reference quality

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

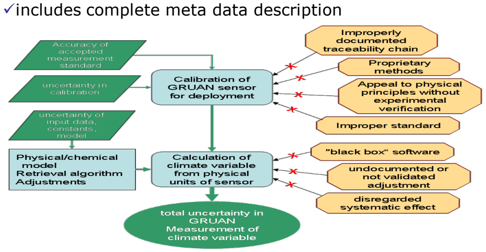
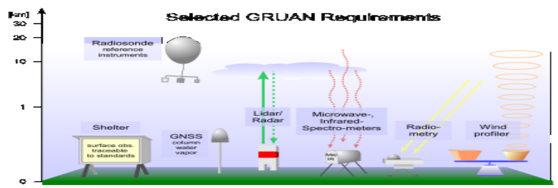


Figure 4: Schematic for establishing reference quality by calibrating to a standard, describing all sources of uncertainty (green) and recording all important meta data. The red boxes contain components jeopardizing traceability (Immler et al., AMT, 2010).

GRUAN Structure

- Working Group (WG-GRUAN)
- GRUAN Lead Centre at the Lindenberg Meteorological Observatory (DWD)
- Current GRUAN task teams:
  - Radiosondes
  - GNSS-Precipitable Water
  - Measurement schedules and associated site requirements
  - Ancillary measurements
  - Sites



Priority 1: Temperature, Water Vapor, Pressure
Priority 2: Ozone, Wind, Radiation, Clouds, Aerosols, …

Figure 2: Schematic set-up of a GRUAN station

Key scientific questions

- Characterization of changes in temperature, humidity, and wind
- Understanding the climatology and variability of water vapour, particularly in the Upper Tropo-sphere/Lower Stratosphere region as it is of crucial importance for ascertaining climate sensitivity
- Understanding changes in the hydrological cycle
- Understanding and monitoring tropopause characteristics
- Understanding the vertical profile of temperature trends
- Bringing closure to the Earth's radiation budget and balance
- Understanding climate processes and improving climate models.

Example: Water Vapour

Water vapour is the most important greenhouse gas, as it is responsible for about 60% of the natural greenhouse effect. There are vigorous discussions within the research community whether stratospheric humidity has changed and whether any further change is expected to influence the effect of global warming. At the same time, water vapour measurements, particular in the upper troposphere/lower stratosphere (UTLS) region, are afflicted with high measurement uncertainties. Even key mechanisms are not fully understood, leading to significant deficiencies in the predictive skill of global climate models. Currently, satellites and special research-quality instruments on aircraft and balloon platforms are the main sources of information about UTLS water vapour, and differences among these measurement systems have been difficult to reconcile.

GRUAN Data Products

GRUAN data based on RS92 Temperature, Humidity and wind measurements available on:

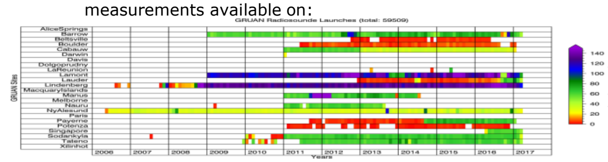


Figure X. A comprehensive volume of measurement data has been collected by GRUAN since about 9 years. The archive includes raw data and related meta-data. For the Vaisala RS92 radiosonde, the first GRUAN data product (GDP) is fully implemented and available since 2012. Further data products (GDP) are under development.

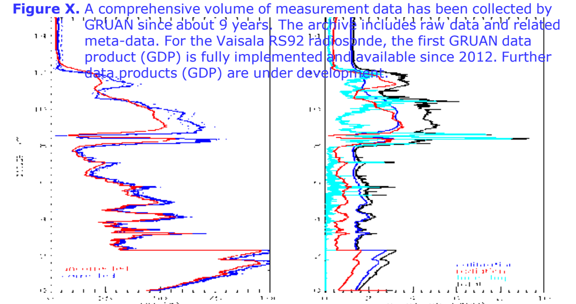


Figure 3 a: Humidity profiles from Vaisala RS92 radiosonde uncorrected (red) and corrected with uncertainties (blue), b: contribution of different sources to total uncertainty (black): calibration uncertainty (blue), uncertainty of the radiation correction, uncertainty of time-lag correction (light blue)

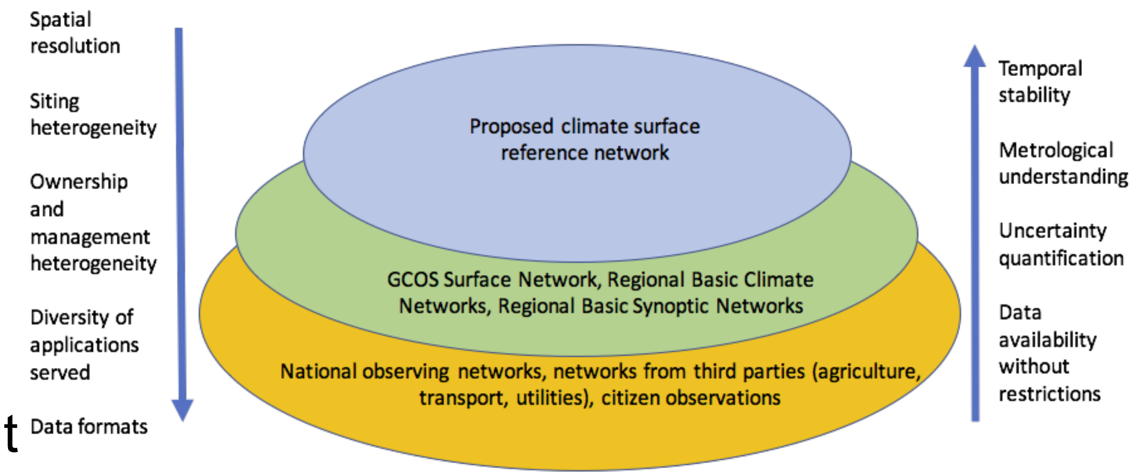
References:

- GCOS-134, **2009**, GRUAN Implementation Plan 2009-2013, WMO Tech. Doc No. 1506
- GCOS-121, **2008,** Report of the GRUAN Implementation Meeting WMO Tech. Doc. No. 1435, WMO
- GCOS-112, **2007**, GCOS Reference Upper-Air Network (GRUAN): Justification, requirements, siting and instrumentation options WMO Tech. Doc. No. 1379, WMO
- Immler, F. J. et al. , **2010**, Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products, Atmospheric Measurement Techniques, 3, 1217-1231
- Seidel, et al., **2009,** Reference Upper-Air Observations for Climate: Rationale, Progress, and Plans *Bulletin of the American Meteorological Society*

GCOS
GLOBAL CLIMATE OBSERVING SYSTEM

Report from the November 2017 TT Meeting

- Benefits of a Global Climate Observing System
- Specific Benefits of a GSRN
- GSRN Requirements
- Design Principles for a GSRN
- Governance and Management
- Preliminary List of ECVs to be Monitored
- Tiered Network Approach
  - The climate is observed by many networks, and the GSRN would be the stable backbone of this network of networks
- CCL Perspective for a GSRN



Benefits of a GSRN

1. Relevance of “reference”-type measurements
    a. Having each single measurement traceable to an absolute standard allows moving from relative to absolute accuracy in measurements
    b. Defined and agreed measurement standards
2. Underpinning existing networks
    a. Validation of the GSN and broader surface networks and CDRs derived therefrom
    b. Long term homogeneous record will ensure better use of the data and serve to improve the quality of data from other networks
3. Capacity Building
    a. Exchange of knowledge and skills between institutes globally
4. Scientific value of answering questions about long-term nature of climate change
    a. Increased accuracy and confidence in observed changes will allow us to answer new questions and open still unknown new fields of research
    b. Better understanding of the Global Cycles (e.g. Water, Carbon and Energy)
5. Societal Benefits
    a. An initial focus on temperature and precipitation would support plans to adapt to climate change to heat waves, flooding and drought
6. Looking to the Future
    a. Supersites can contribute in research on the evaluation of emerging technologies, improved measurement procedures and measurement principles.

Preliminary List of ECVs to be Monitored (not every GSRN site would need to necessarily observe each ECV)

- Atmospheric
  - Air temperature
  - Precipitation
  - Pressure
  - Wind speed and direction (10 m)
  - Relative humidity
  - Surface radiation (down and up)

- Terrestrial
  - Land Surface Temperature
  - Soil moisture (standard WMO depths)*
  - Soil temperature (standard WMO depths)*
  - Snow/Ice*
  - Albedo*
  - River discharge
  - Ground water

* In conjunction with satellite derived data to a certain degree

Work Plan and Path Forward

General Activities:

- Rework of GCOS 112 into a GSRN document
- Measurements requirements: what, how; frequency
- Terminology documented
- Identify climate zones – the most critical, sensitive ones (e.g., Galapagos Islands); perhaps a better approach than using WMO RAs; Dual Approach of existing stations and climate regions
- Satellite requirements (e.g., Cal/Val) – Work with CEOS WG on Climate

Specific Near-Term Activities:

- Briefings to GCOS/TOPC in 19-22 March 2018; WMO/CCl 11-12 April 2018
- Possible benefits document to be included in a document for EC (June 2018)
- Initial Version of a reworked GCOS-112 by the end of June 2018
- Resourcing investigation – Linkages to adaptation and mitigation activities - bring in people to the TT experienced with such applications for funding (e.g., Green Fund, Foundations/NGOs, EU)
- Draft of rework of GCOS 112 for GSRN: Interim version targeted for AOPC-24 in 2019
- Final deliverable of Task Team – Rework of GCOS 112 for GSRN for AOPC-25 in 2020
- Potential Implementation Plan Outline (depends on the existence of a Lead Centre): AOPC 2020
- Canvassing of potential Lead Centre candidates and site candidates (ongoing)
- Considerations of building into WMO technical regulatory documentation and framework (TBD)
- Outreach activities (e.g., EOS article; next CIMO Commission Meeting; EURAMET Conference, side events at meetings of opportunity)

Table on Terminology

Term	Definition	Note
Measurement	Process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity The measurement, including the measuring system and the conditions under which the measurement is carried out, might change the phenomenon, body, or substance such that the quantity being measured may differ from the measurand as defined. In this case, adequate correction is necessary. [*Note to the term Measurand in the VIM – 2.3*] A measurement result is generally expressed as a single measured quantity value and a measurement uncertainty. If the measurement uncertainty is considered to be negligible for some purpose, the measurement result may be expressed as a single measured quantity value. In many fields, this is the common way of expressing a measurement result. [*Note to the term Measurand in the VIM – 2.9*] Quantity: property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference	From VIM
Accuracy of measurement	Closeness of the agreement between the result of a measurement and a true value of the measurand	VIM:1993, definition 3.5

Personal Thoughts of the Presenting Co-Chair

1. Focus should be on what is practical, reasonable, and doable.

2. We should focus outside the box, particularly with respect to funding and support – I have found that Governments over the years have not been the place to fund these activities. Could we go to the World Economic Forum in Davos, Switzerland for example? Just a thought.

3. So, in line with that, can we bring in private foundations (e.g., Gates, Buffett) and sell them on the benefits of such surface reference observing?

4. Can we sketch out a nascent network configuration based on existing surface reference observing efforts in Australia, Canada, China, the U.S.; others?

5. Establishing, operating, and sustaining an environmental observing system, let alone a reference observing system is frankly a daunting task even USCRN is under constant budget pressures); we have frankly had issues maintaining what we have today (e.g., GSN and GUAN); so are the prospects, resources, and will of members there to do this? I do not know.

6. As has worked well for the GRUAN, regular in-person meetings for the GSRN may be quite worthwhile, particularly once we have a firm 112-like plan in hand.

Summary

- First Task Team Meeting was a successful meeting of the minds with some basic agreements to requirements, design principles, diversity of areas observed, and ECVs.

- Builds on an initial whitepaper, now Thorne et al. (2018) accepted for publication that gives us a firm underlying scientific foundation.

- Use existing reference observing systems (GRUAN and USCRN) as a model to begin from.

- Draft a "GCOS-112-like" document to give the GSRN a firm technical foundation – this was successful for the GRUAN and we believe will serve a possible GSRN very well. May also help to consider regular in-person meetings on an annual basis once we have that in hand.

- A number of related near-term activities over the next year, to be reported out at APOC-24, will be undertaken.

- This is not a small effort, nor is there any thought that this will be easy to do. There are many obstacles in the way.

- The job of this Task Team is to provide the documentation and work necessary to WMO members to decide if this is indeed something that the global climate community wants to take on.

- The Task Team will do its best to deliver on the charter for the Task Team as laid out by the AOPC with a final deliverable by AOPC-25 in 2020.

Thank you. Any Questions?