The Global Observing System for Climate

Towards a global land surface climate fiducial reference measurements network

CIMO-TECO-2018

Amsterdam, The Netherlands

GCOS Secretariat, WMO

Tim Oakley, GCOS Network Manager

GLOBAL CLIMATE OBSERVING SYSTEM

GCOS established April 1992

The vision of GCOS is that all users have access to the climate observations, data records and information which they require to address pressing climate-related concerns. GCOS users include individuals, national and international organizations, institutions and agencies.

The role of GCOS is to work with partners to ensure the sustained provision of reliable physical, chemical and biological observations and data records for the total climate system – across the atmospheric, oceanic and terrestrial domains, including hydrological and carbon cycles and the cryosphere.

UNEP

ICSU International Council for Science

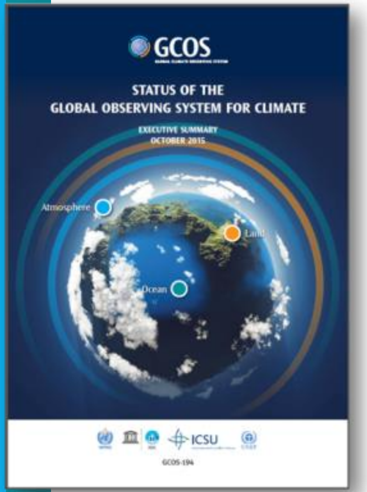
IOC

UNESCO

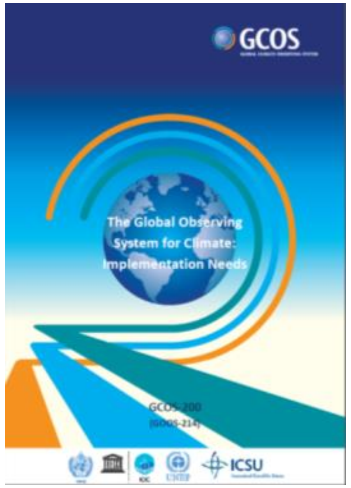
WMO

GCOS Progress: Improving global climate observations

United nations conference on climate change
COP21/CMP11



2015



2016

- Support Adaptation & Mitigation
- Water, Energy and Carbon cycles
- Additional Essential Climate Variables
- More help for networks in developing countries
- Climate Indicators

2017

- First Regional workshop held in Fiji for Pacific Island States
- Working group in Lightning starts work
- Working group on GCOS Reference Surface Network meets for first time
- Weather radar data for climate
- Review of ocean observing systems

WGClimate CEOS CGMS

ECV Inventory: The Architecture for Climate Monitoring from Space in Action

A GCOS Surface Reference Network

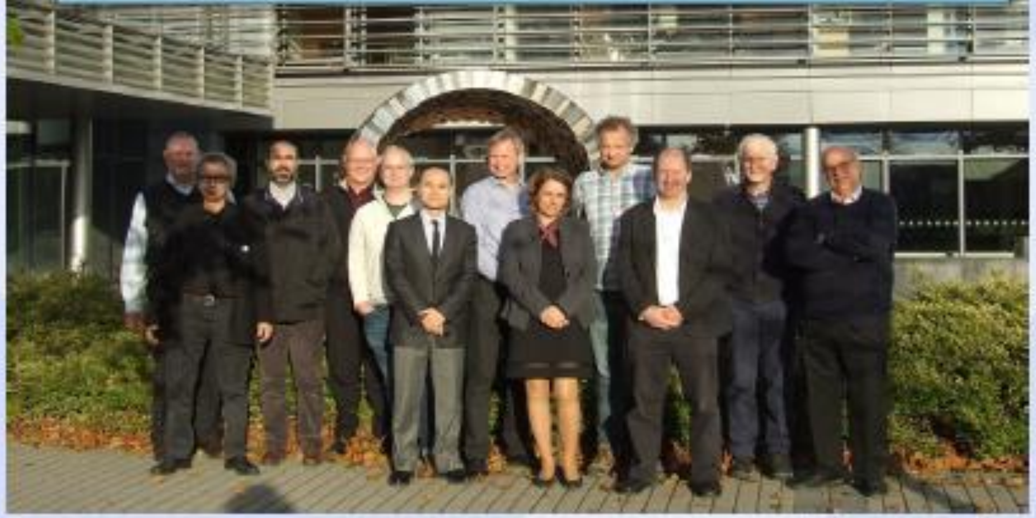
Improved long-term accuracy, stability and comparability of observations.

- **To achieve simultaneous high-quality observations of many ECVs**
- **Provide reference data to constrain and calibrate more spatially comprehensive observing systems.**

- **Is traceable to an internationally accepted standard and has a comprehensive uncertainty analysis and is validated;**
- **Is documented in accessible literature and Includes complete metadata description**
- **Will measure temperature and precipitation and a range of other surface ECVs**
- **May be based on existing networks such as the US Climate Reference Network and the Cryonet**

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:
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Co-Chair – Nigel Tapper, PhD
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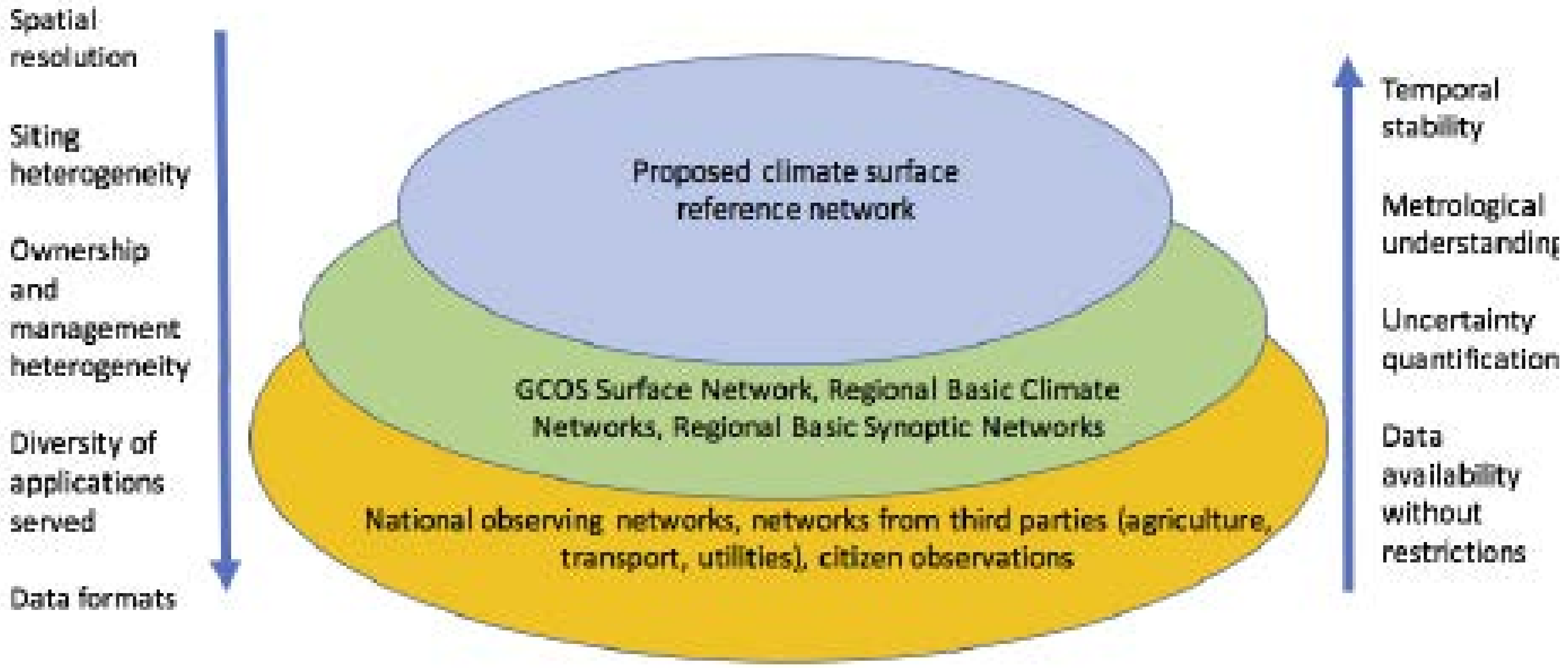
GSRN Task Team Membership

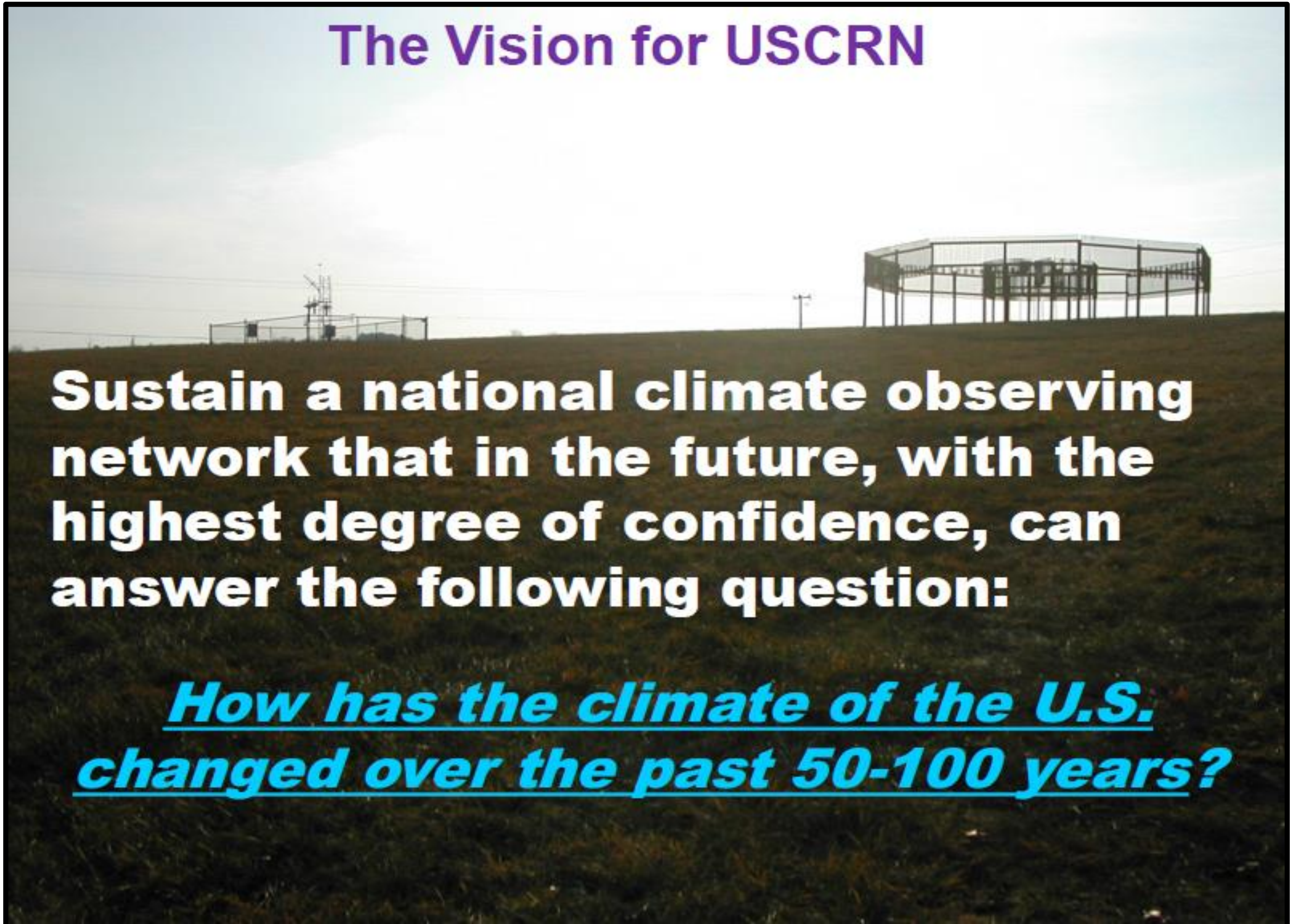
- Co- Chair – Howard Diamond – USA
- Co-Chair and TOPC Rep – Nigel Tapper - Australia
- AOPC Representative – Phil Jones – UK
- GRUAN Representative – Peter Thorne – Ireland
- GSN Representative – Tim Oakley – UK
- CBS/WIGOS/CIMO Representative – Andrew Harper – New Zealand
- NMHS Representative – Jiankai 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

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.

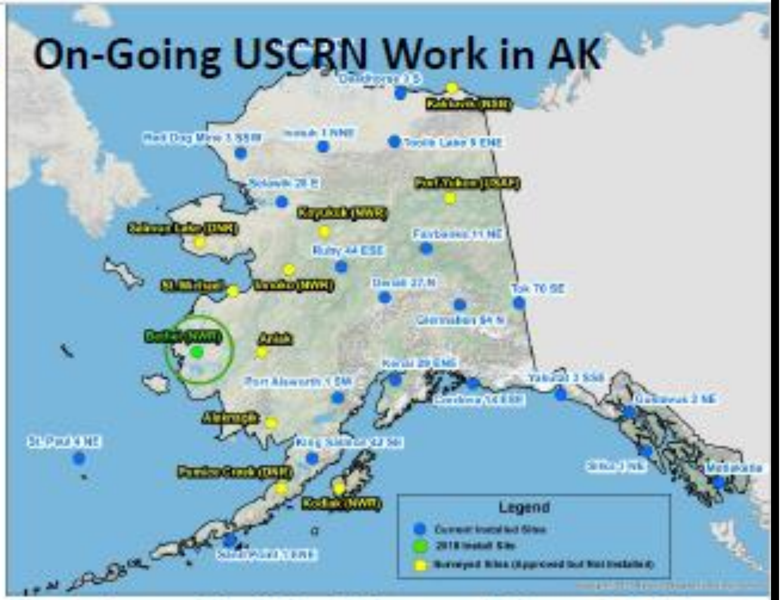


Spatial resolution
Siting heterogeneity
Ownership and management heterogeneity
Diversity of applications served
Data formats
Proposed climate surface reference network
GCOS Surface Network, Regional Basic Climate Networks, Regional Basic Synoptic Networks
National observing networks, networks from third parties (agriculture, transport, utilities), citizen observations
Temporal stability
Metrological understanding
Uncertainty quantification
Data availability without restrictions

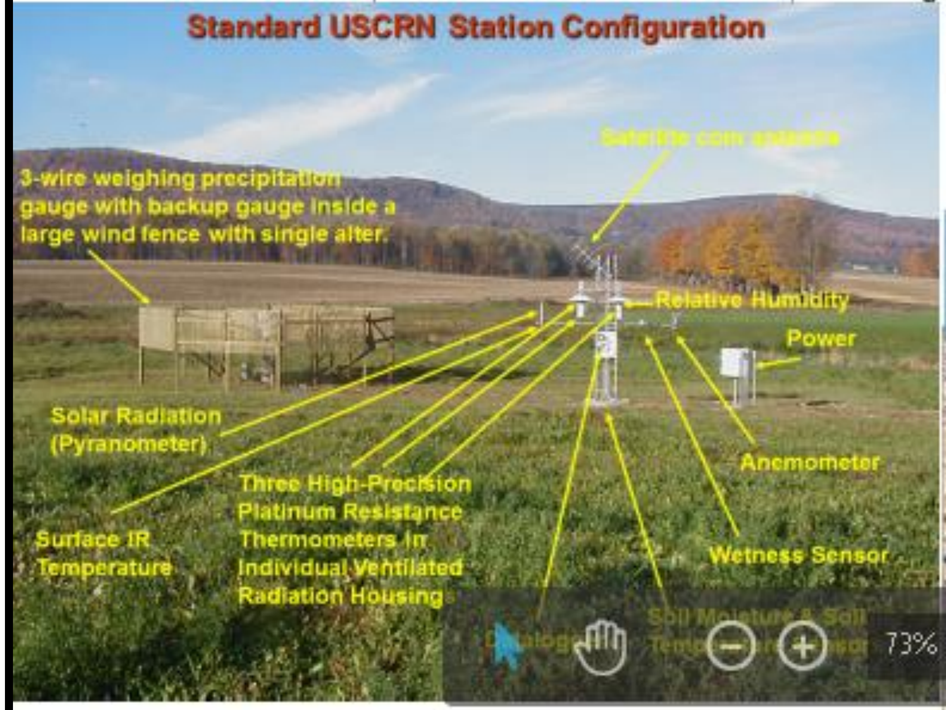

The Vision for USCRN
Sustain a national climate observing network that in the future, with the highest degree of confidence, can answer the following question:
How has the climate of the U.S. changed over the past 50-100 years?

Station Coverage

CONUS – Done 2008



- 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)



Typical soil sensor installation

The GCOS Reference Upper-Air Network

GRUAN Leadcentre[1] and the GRUAN Working Group
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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.

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

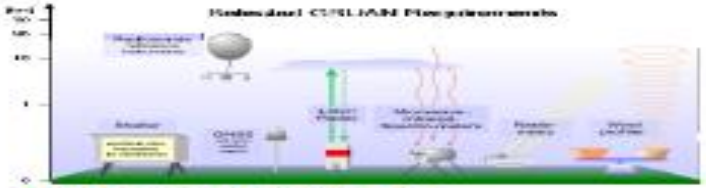
✓traceable to an SI unit or an accepted standard
✓provides a comprehensive uncertainty analysis
✓documented in accessible literature
✓validated (e.g. by intercomparison or redundant observations)
✓includes complete meta data description

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

Figure 1: The GRUAN network, 2017



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.

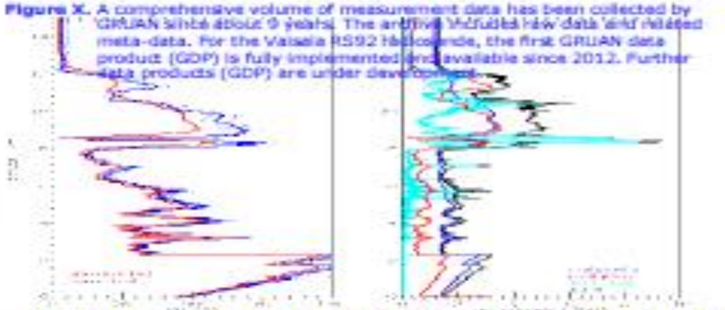


Figure 3 a: Humidity profiles from Vaisala RS92 radiosonde uncorrected (red) and corrected with uncertainties (blue), b: contribution of different sources to total uncertainty (black): calibration uncertainty (blue), uncertainty of the radiation correction, uncertainty of time-lag correction (light blue)

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

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.

But then...... Day 2!

GSRN Design Principles

Define the measurement requirements of the station, including uncertainty and traceability
Define the calibration and maintenance requirements
Define the infrastructure requirements of the station
Define the data requirements of the station
Define the local management requirements and skill requirements

No predefined set of stations but a vision of global coverage, maximum number of stations, representation of different climatic zones. Need to articulate the stakeholder needs and the priority questions that need to be addressed

Need to identify a Lead Centre (s)

Define the centralised management, infrastructure, data processing, data policy, station/data monitoring, outreach

Funded and managed cooperation mechanism to support 'least developed countries' in the implementation of stations (new or upgrade) and ongoing operations. Trust fund, twining.

Invite Member countries to nominate candidate stations to the GSRN and have a robust selection criteria

ABOVE can be based on the GRUAN document GCOS-112 but will need extensive revision

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

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.

The Global Observing System for Climate

Thank you

gcos.wmo.int