Infrastructure Commission (INFCOM)
Standing Committee on Measurements, Instrumentation and Traceability (SC-MINT)
Expert Team on Quality, Traceability and Calibration (ET-QTC)

Metrology in Meteorology

Part-1: Introduction to Metrology

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Content

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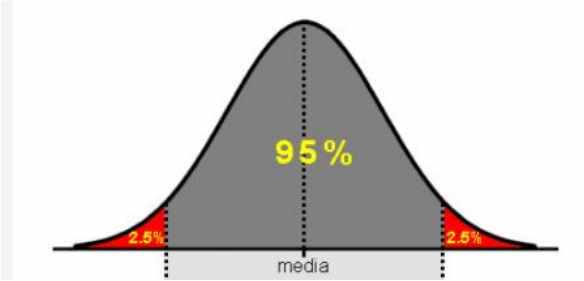
To understand a phenomenon or quantify something, we turn an observation into a quantitative description.

Then we compare the observed value against a commonly accepted reference.

Results need validation, quality check in order to understand the value of the results, through evaluating its uncertainty.

This is the role of metrology.



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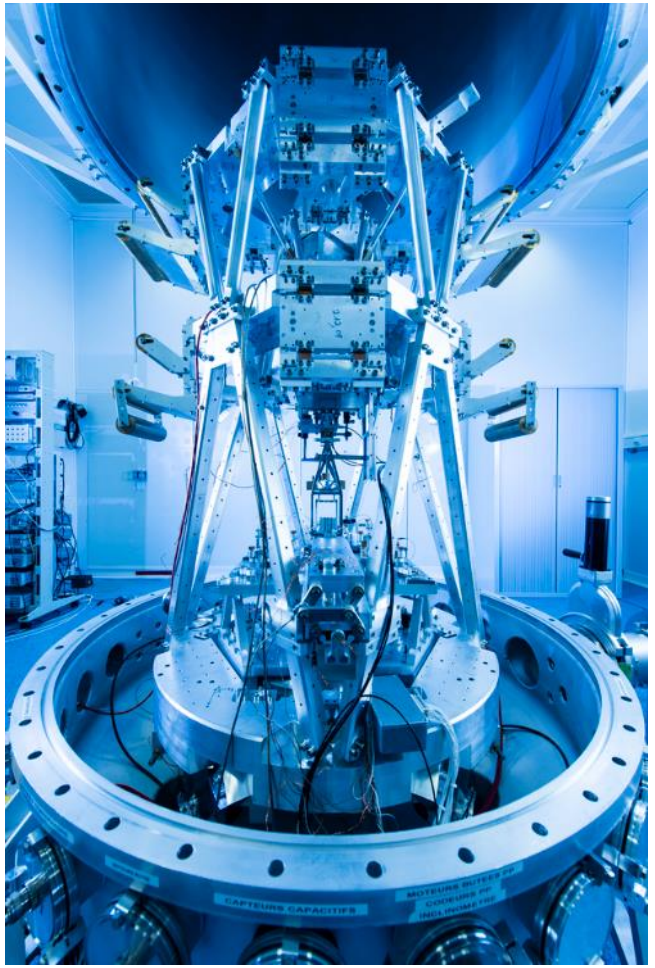
The measurement result is therefore a numerical comparison expressed as ratio between the value obtained by means of the measurement process and a reference standard.

The use of commonly accepted and defined standards is the condition to guarantee comparability of different measurements

The definition and evolution of a System of Units is the key task of metrology



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The Importance of Metrology

Metrology is the “science of measurements”.

It deals with:

- Establishing a common understanding of units, through their definitions and the dissemination of a unique System of Units – the “SI”
- Providing realization of the units, through appropriate standards
- The transfer of traceability from these standards to users in a society.
- The development of new measurement methods, the realization of measurement standards

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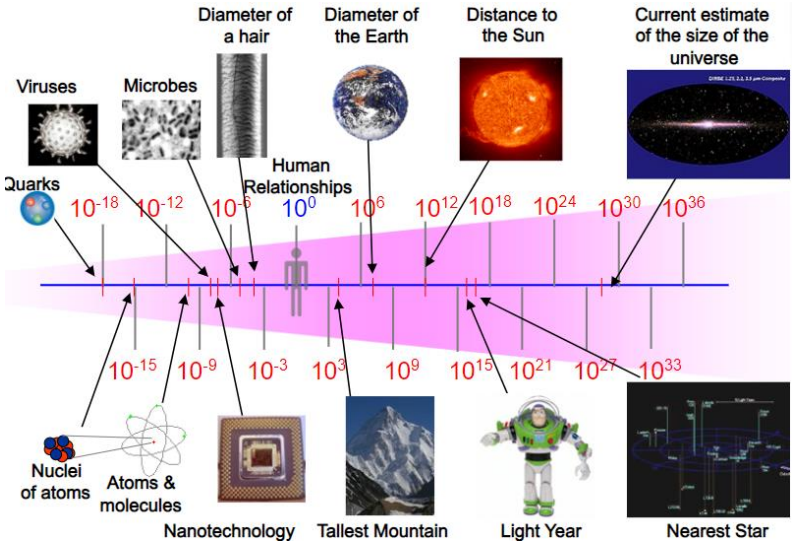
The Importance of Metrology

Metrology guarantees

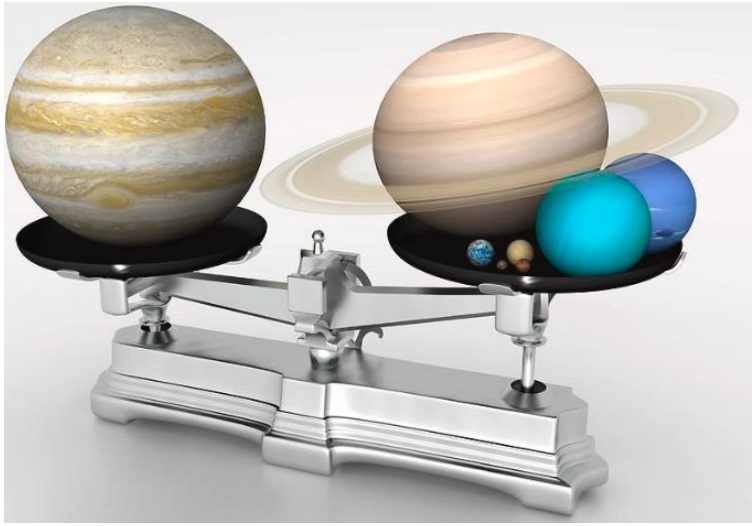
- Universal standards, commonly adopted with unique definitions
- Mutual acceptance and recognition of procedures and certificates
- Links among Regions, Organizations, Laboratories, through continuous comparisons at various level (from key comparisons involving NMIs to comparison for accredited laboratories)
- Unique definition of base units and derived units for every application: all scientific disciplines, medicine, commerce, construction, trade…

The Importance of Metrology

For example, with the single unit meter and a decimal system of multiples and fractions, we can make measurements in nanotechnologies up to astronomy, for physics, geology, infrastructures, GPS or miniaturized techniques, in designing dresses or buildings, etc.



Or with the kilogram we can buy tomatoes at the marketplace, or evaluate the mass of samples in biology, weight the amount of load of a containers cargo, up to the mass of asteroids and planets…



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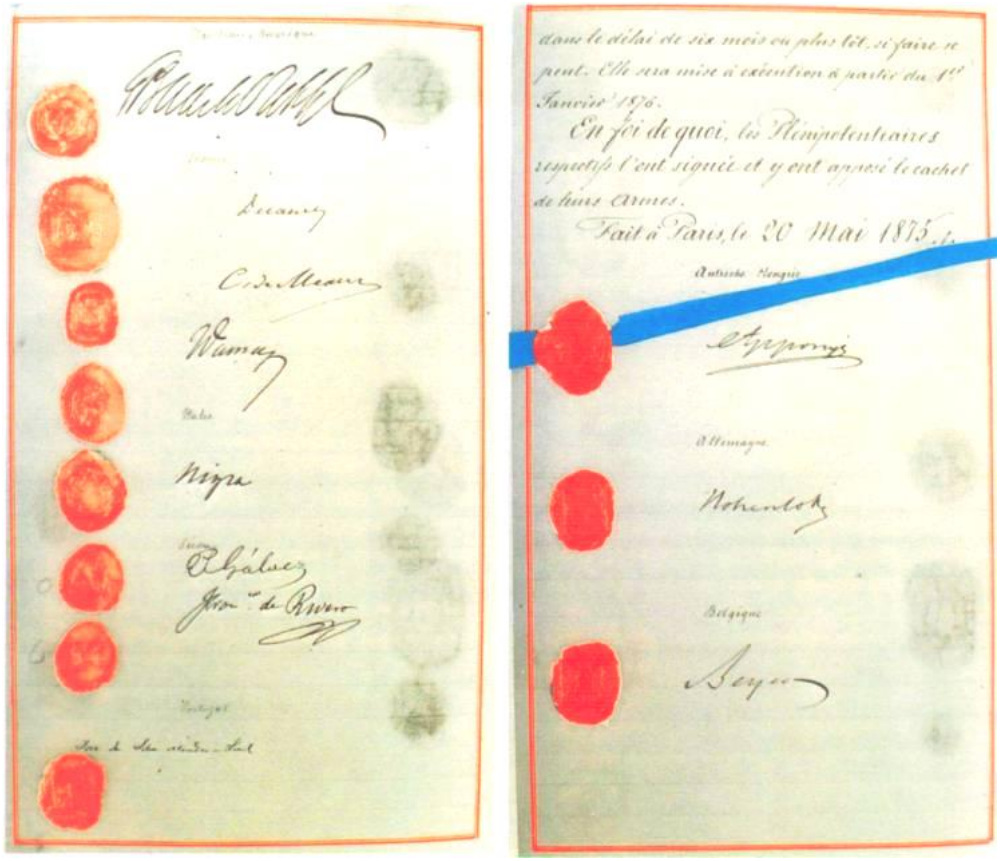
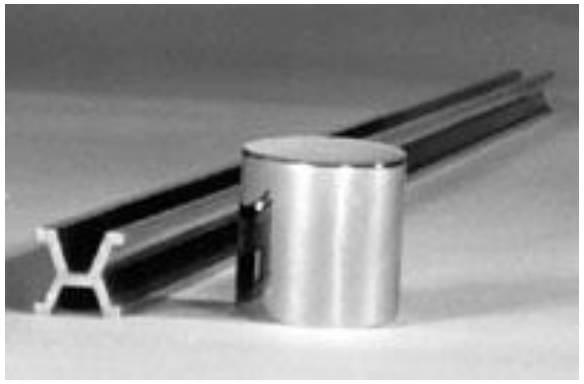
The **Metre Convention** (French: *Convention du Mètre*), also known as the **Treaty of the Metre**, is the international treaty that was signed in Paris on 20 May 1875 by representatives of 17 nations

(Argentina, Austria-Hungary, Belgium, Brazil, Denmark, France, Germany, Italy, Peru, Portugal, Russia, Spain, Sweden and Norway, Switzerland, Ottoman Empire, United States of America, and Venezuela).





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The Metre Convention established a permanent organizational structure for member governments to act in common accord on all matters relating to units, which includes

• The **International Bureau of Weights and Measures** (*Bureau international des poids et mesures* - **BIPM**), located in Sevres, close to Paris

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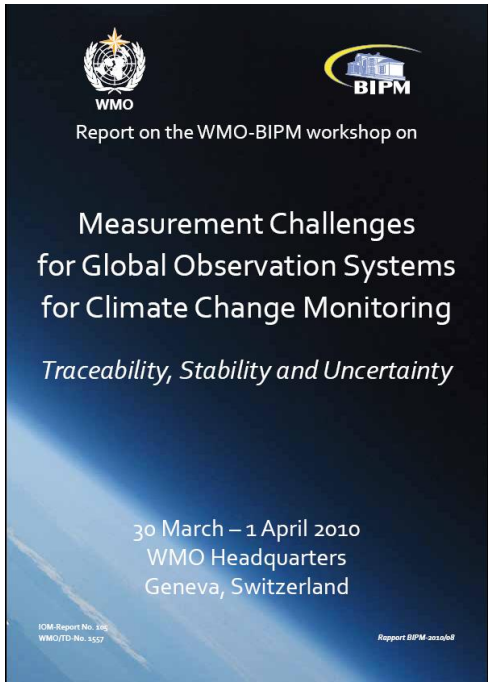
World Meteorological Organization
Working together in weather, climate and water

BIPM

WMO entered the Convention du Metre by signing the Mutual recognition Arrangement. The signing ceremony took place on *1 April 2010*



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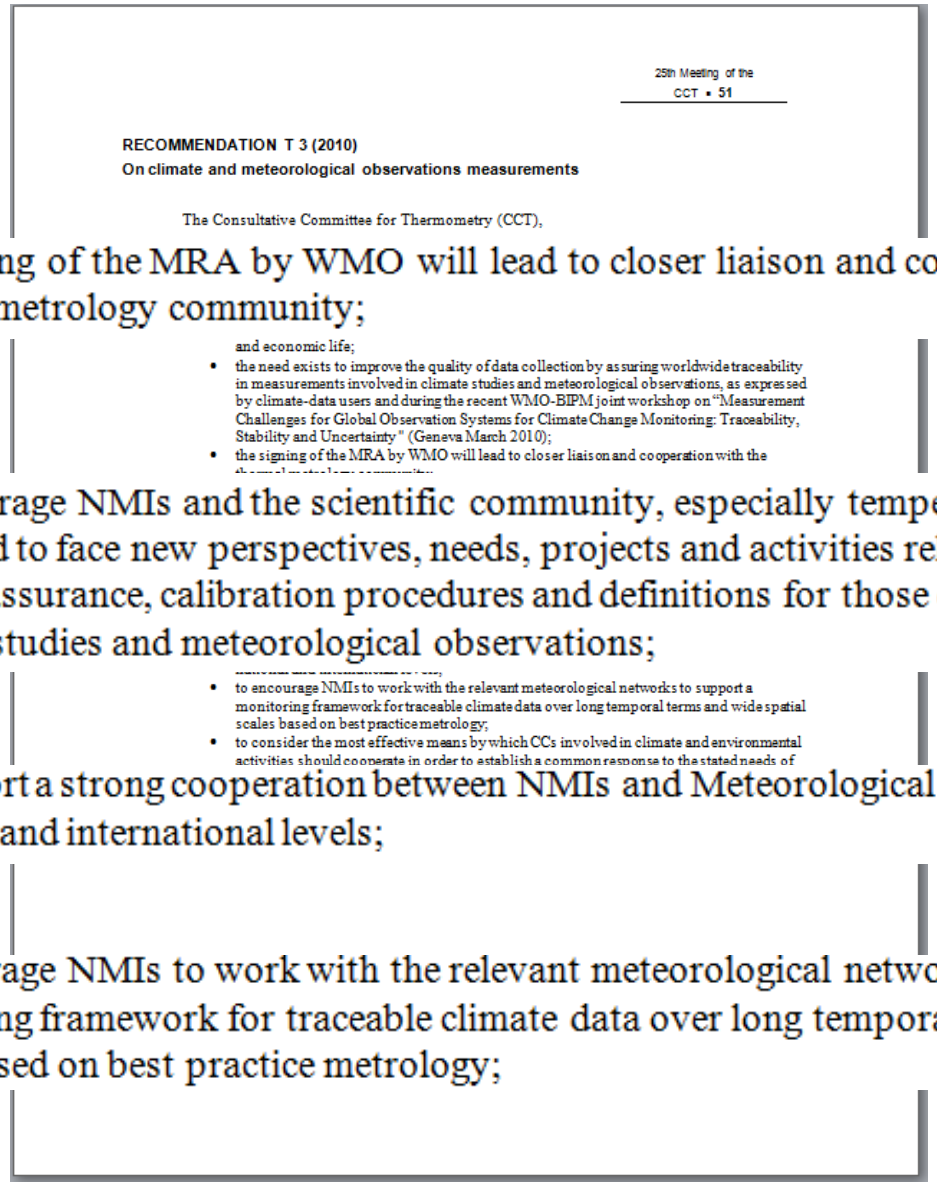
Left to right: Len Barrie (WMO), Andrew Wallard (Director BIPM), Michel Jarraud (Secretary General WMO), Ernst Göbel (President CIPM), Wenjian Zhang (WMO)

May 2010

CCT Recommendation to CIPM



25th Meeting of the
CCT • 51

RECOMMENDATION T 3 (2010)
On climate and meteorological observations measurements

The Consultative Committee for Thermometry (CCT),

and economic life;
- the need exists to improve the quality of data collection by assuring worldwide traceability in measurements involved in climate studies and meteorological observations, as expressed by climate-data users and during the recent WMO-BIPM joint workshop on "Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty" (Geneva March 2010);
- the signing of the MRA by WMO will lead to closer liaison and cooperation with the

- to encourage NMIs to work with the relevant meteorological networks to support a monitoring framework for traceable climate data over long temporal terms and wide spatial scales based on best practice metrology;
- to consider the most effective means by which CCs involved in climate and environmental activities should cooperate in order to establish a common response to the stated needs of

- the signing of the MRA by WMO will lead to closer liaison and cooperation with the thermal metrology community;
- to encourage NMIs and the scientific community, especially temperature metrologists, to be prepared to face new perspectives, needs, projects and activities related to the traceability, quality assurance, calibration procedures and definitions for those quantities involved in the climate studies and meteorological observations;
- to support a strong cooperation between NMIs and Meteorological Institutions at local, national and international levels;
- to encourage NMIs to work with the relevant meteorological networks to support a monitoring framework for traceable climate data over long temporal terms and wide spatial scales based on best practice metrology;

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7 Base Units

kg | m | s | A | K | mol | cd

Derived Units

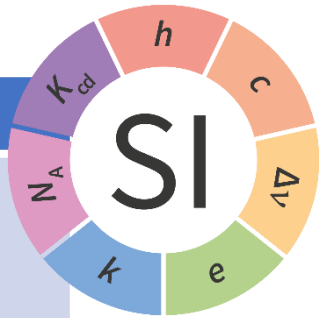
$kg\ m^{-3}$ | $m\ s^{-1}$ | $m\ s^{-2}$

$kg\ m\ s^{-2}$ = newton, N

N m = $kg\ m^2\ s^{-2}$ = joule, J

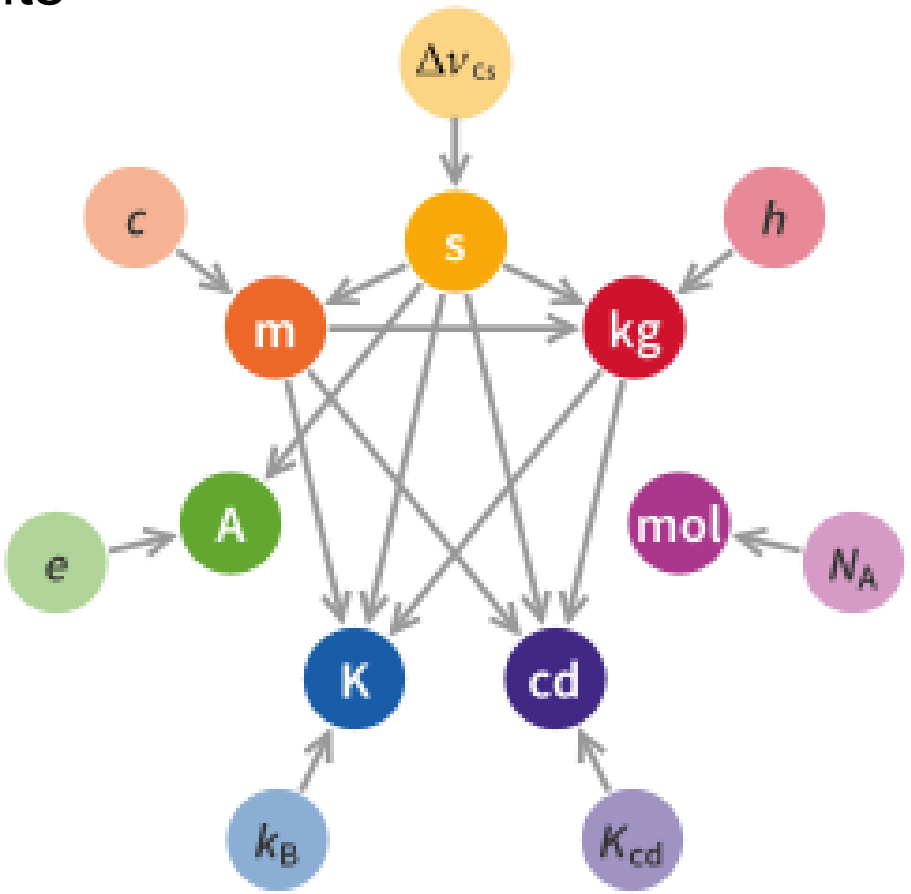
N / m^{-2} = $kg\ m^{-1}\ s^{-2}$ = Pascal, Pa

In 2019 the new SI is adopted, with the seven base units defined by fixing exact values of the fundamental constants.



Symbol	Constant	Numerical Value	Unit
$\Delta\nu_{Cs}$	the unperturbed ground state hyperfine transition frequency of the caesium 133 atom	9 192 631 770	Hz
c	the speed of light in vacuum	299 792 458	m s^{-1}
h	the Planck constant	$6.626\,070\,15 \times 10^{-34}$	J s
e	the elementary charge	$1.602\,176\,634 \times 10^{-19}$	C
k	the Boltzmann constant	$1.380\,649 \times 10^{-23}$	J/K
N_A	the Avogadro constant	$6.022\,140\,76 \times 10^{23}$	mol^{-1}
K_{cd}	the luminous efficacy of monochromatic radiation of frequency 540×10^{12} hertz	683	lm/W.

The SI is now based on fundamental constants



But no worries… nothing will change for instrument and measurement results.

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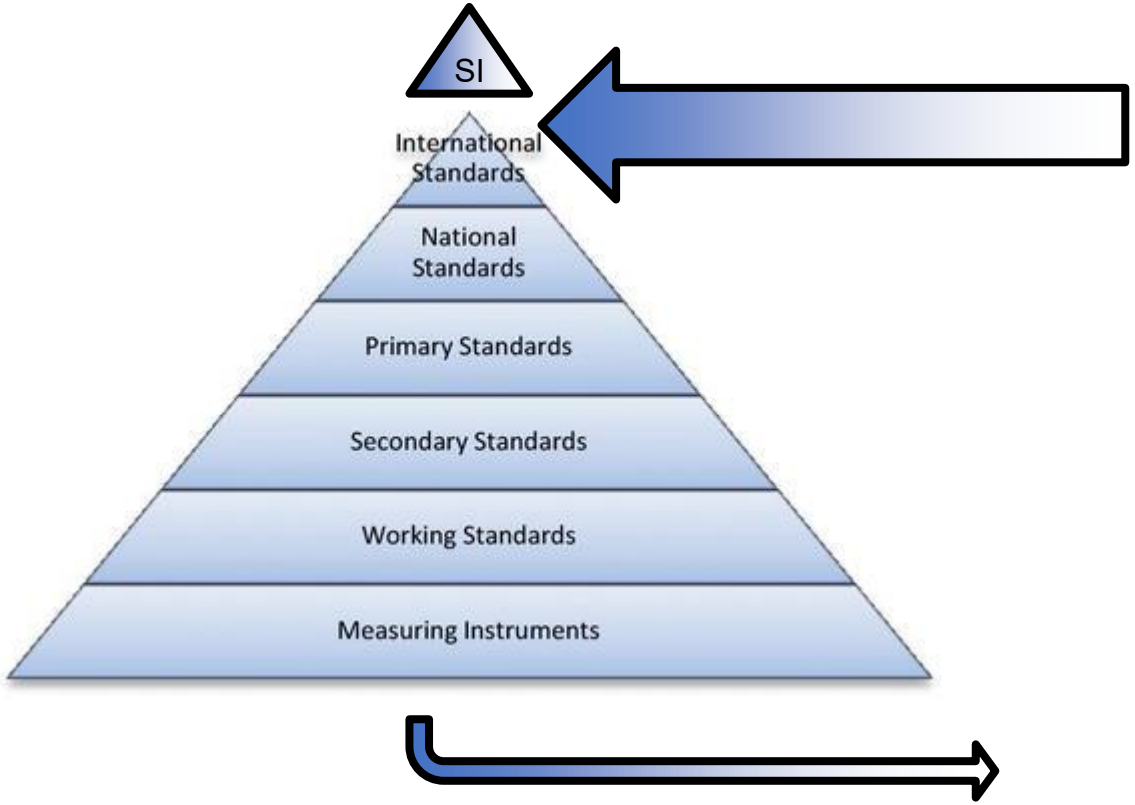
Metrological Traceability



Applied Metrology

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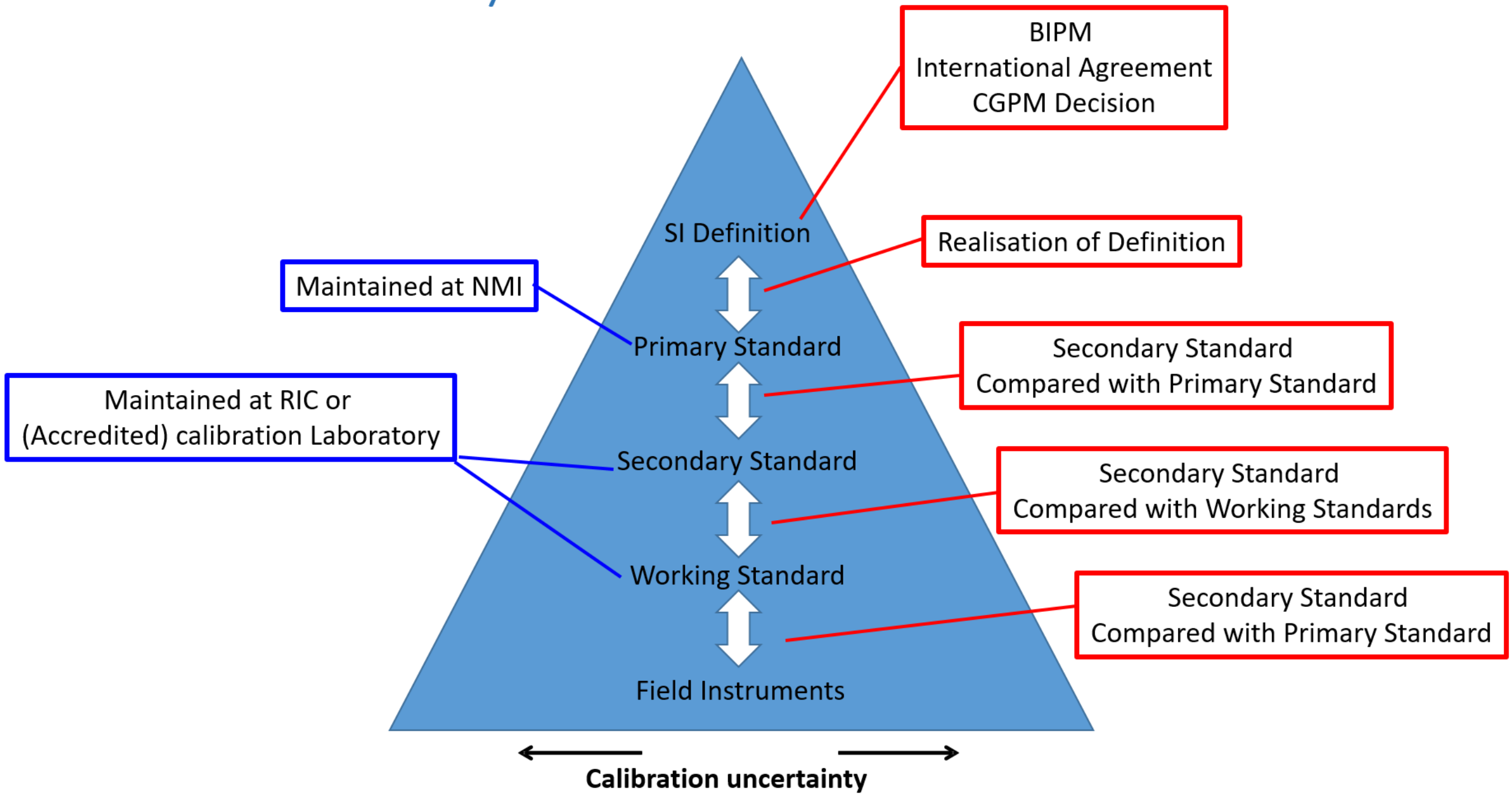
Traceable measurements

- *Traceability* ensures that different measurement methods, using different instruments in different countries produce reliable, repeatable, reproducible, compatible and comparable measurement results. This allows meaningful comparison of results obtained at different places and at different times.

- Traceability is established through an unbroken chain of calibrations.

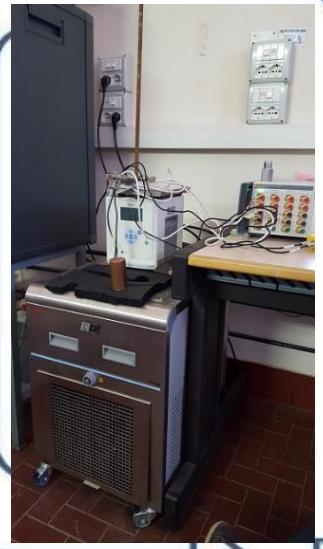
- This underpins all meteorological and climate science.

How to ensure traceability?



ITS 90

-39 °C t
± 0.001 °C



-39 °C to 30 °C
± 0.005 °C

-39 °C to 30 °C
± 0.05 °C

±

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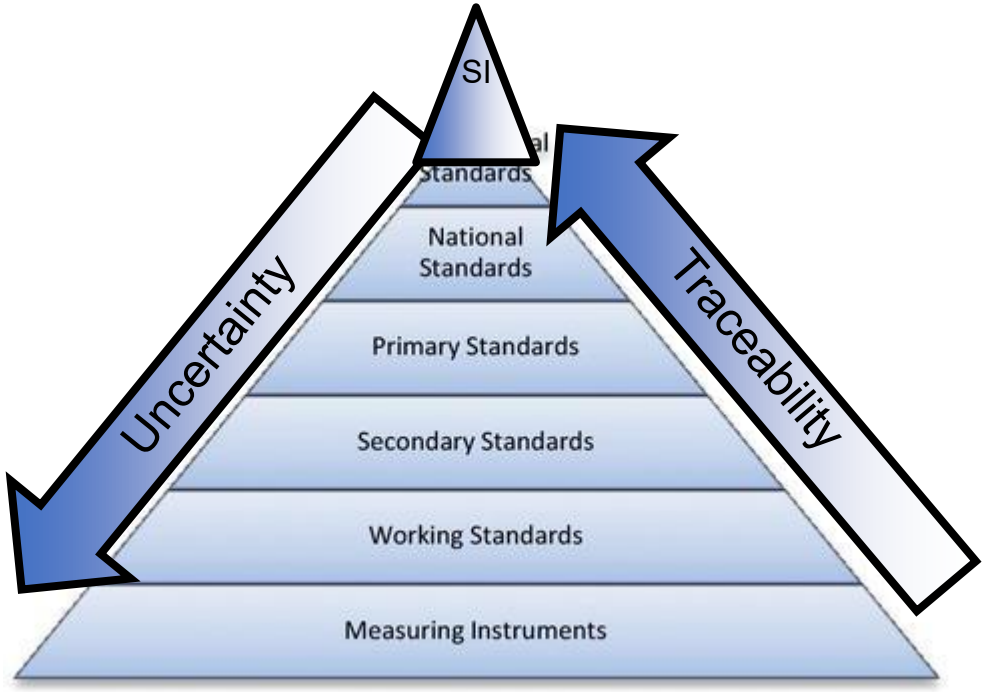
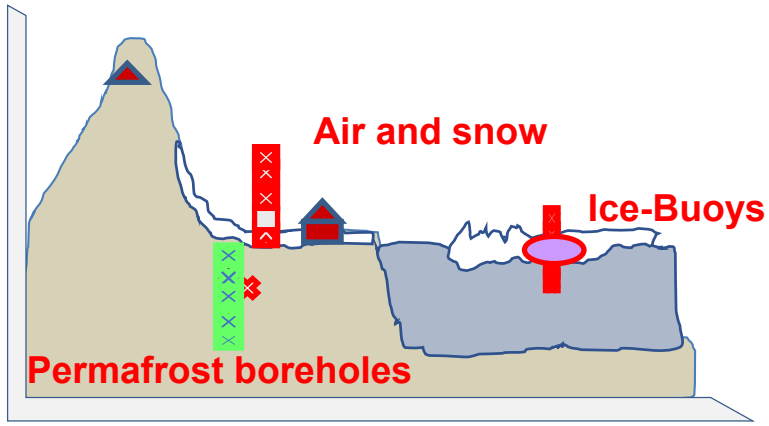
Traceability is required to reach full comparability



- Comparability on climate-change scales
- Comparability to fundamental physical models
- Comparability across generations
- Comparability across borders & organizations
- Comparability across methodologies
- Comparability within and among networks
- Comparability across domains



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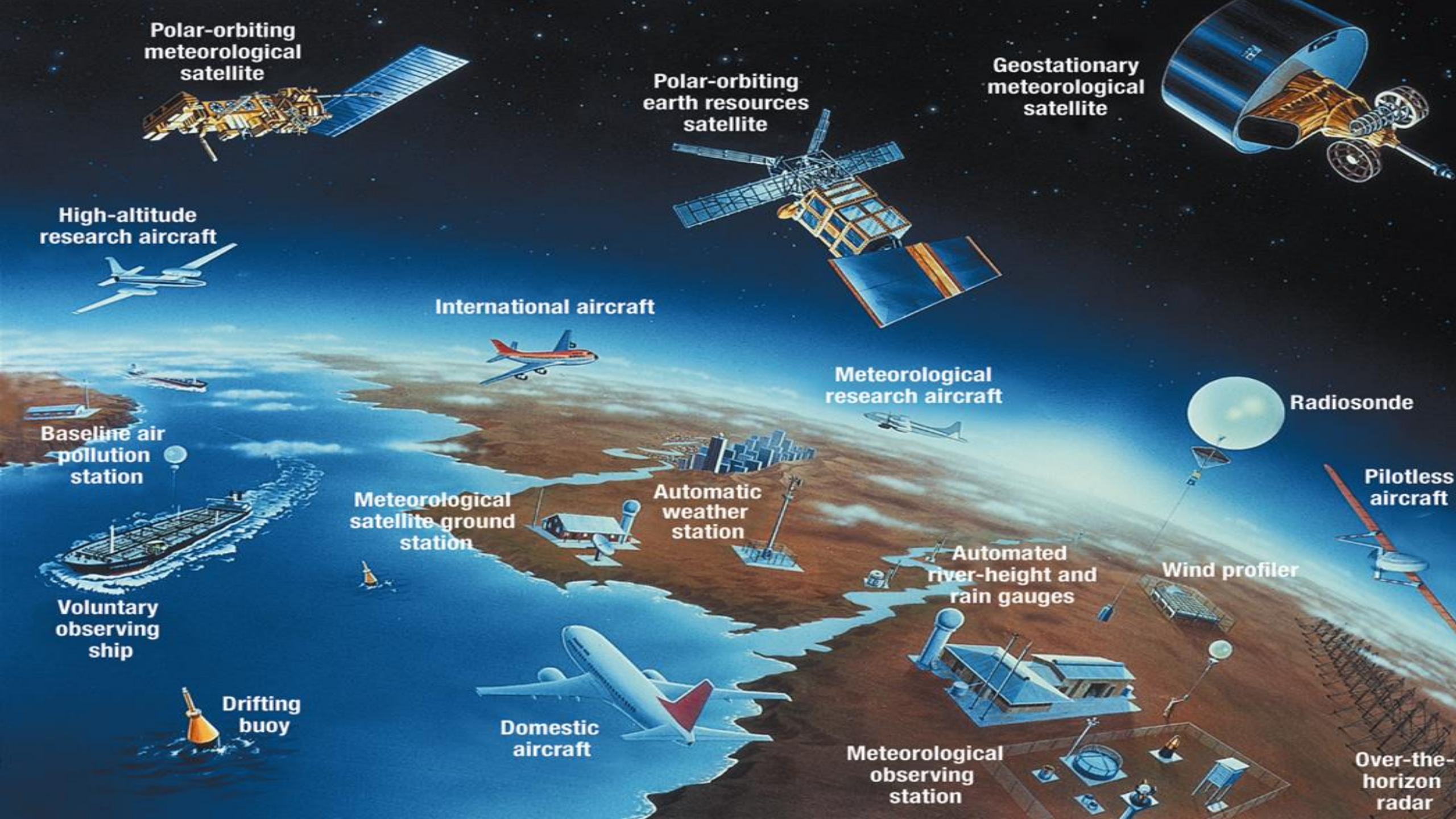
Polar-orbiting meteorological satellite
Polar-orbiting earth resources satellite
Geostationary meteorological satellite
High-altitude research aircraft
International aircraft
Meteorological research aircraft
Radiosonde
Baseline air pollution station
Meteorological satellite ground station
Automatic weather station
Pilotless aircraft
Automated river-height and rain gauges
Wind profiler
Voluntary observing ship
Drifting buoy
Domestic aircraft
Meteorological observing station
Over-the-horizon radar

Thank you.

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