LECTURE 2: Meteorological Instruments & Data Collection Techniques

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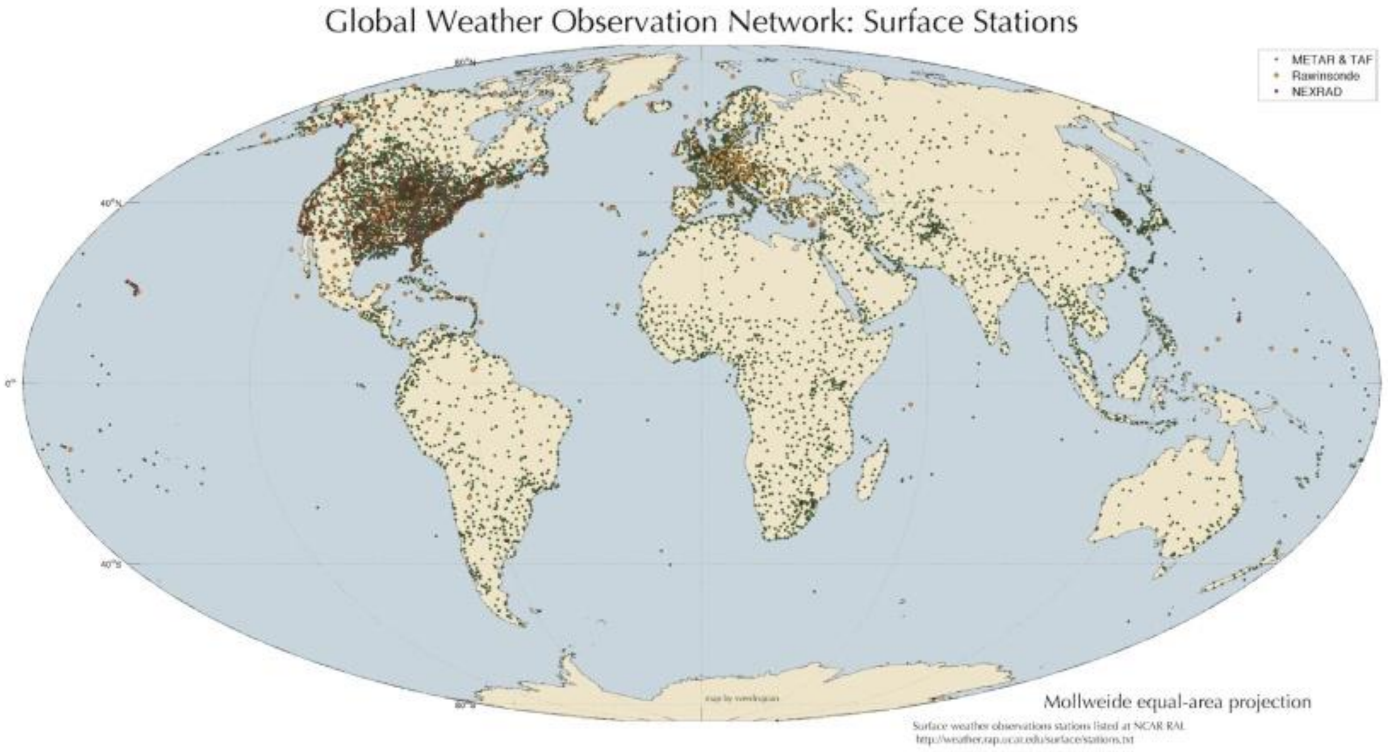
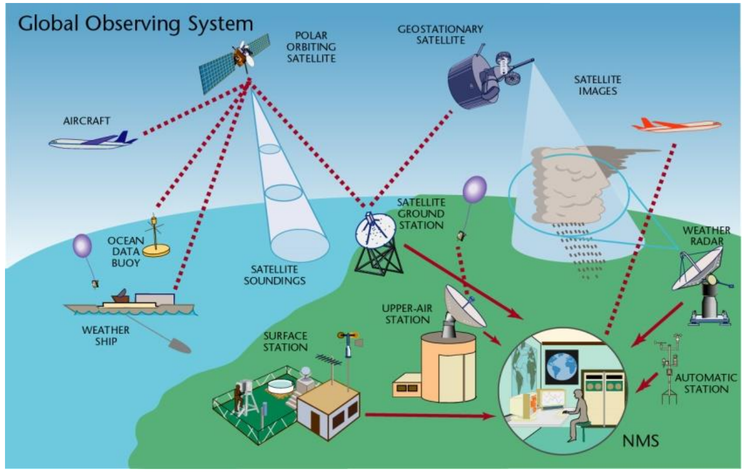
Weather

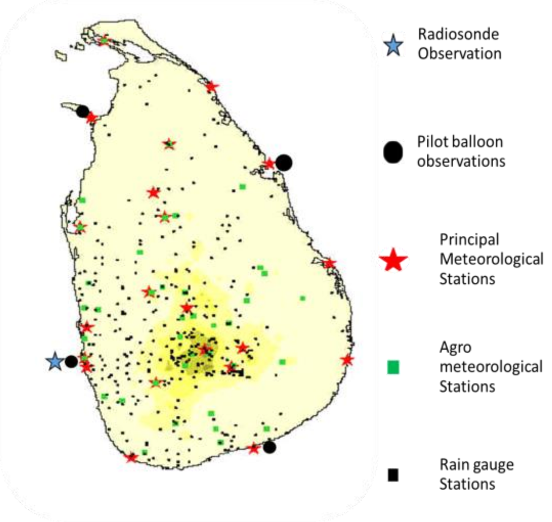
Weather is defined as the state of the atmosphere at a particular place and time, described in terms of the current value of such quantitative variables as temperature, humidity, cloudiness, precipitation, and wind speed and direction.

Weather

- Thousands of weather stations around the world monitor these weather variables at Earth's surface at least hourly every day.
- A place and time must be specified when describing weather because the atmosphere is dynamic and its state changes from one place to another and with time.
- **Meteorology** is the study of the atmosphere, processes that cause weather, and the life cycle of weather systems.

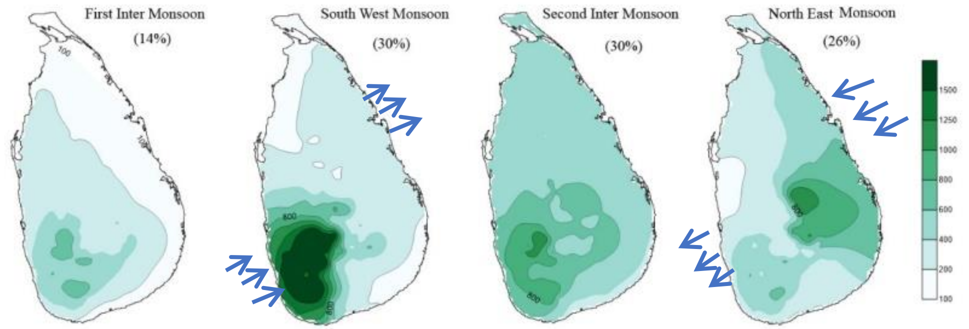


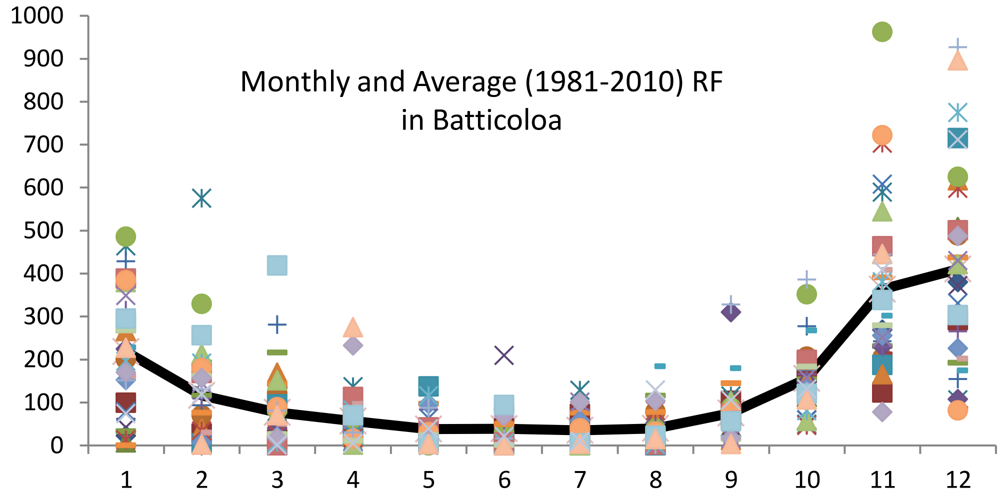


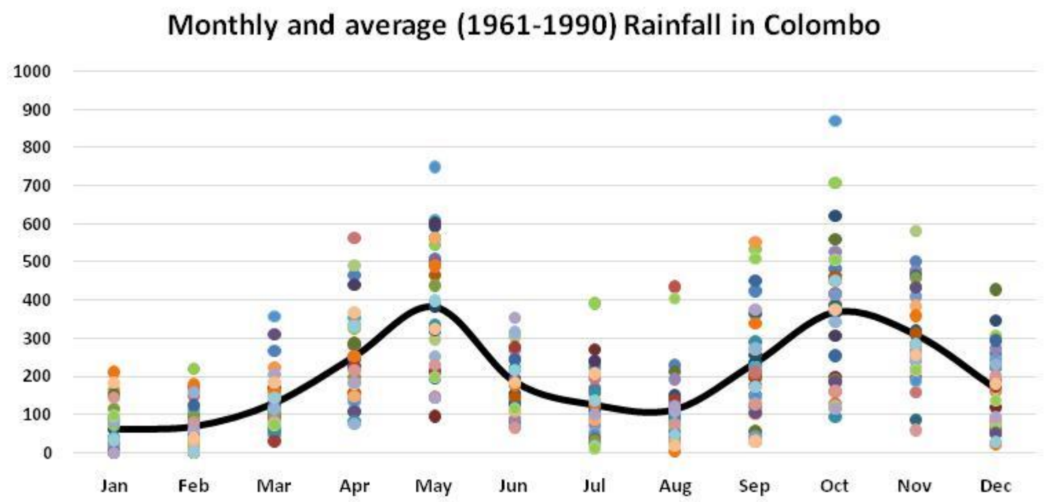


climate

- **climate** is popularly defined as weather conditions at some locality averaged over a specified time interval.
- By international convention, average values of weather elements are computed for a 30-year period beginning with the first year of a decade.
- Current climatic summaries are based on weather records from 1991-2020.
- Thirty-year average monthly and annual temperatures and precipitation totals are commonly used to describe the climate of some locality.
- Climate is the ultimate environmental control in that it governs, for example, what crops can be cultivated, the fresh water supply, and the average heating and cooling requirements for homes.
- Records of weather extremes provide information on the variability of climate at a particular place and give a more complete and useful description of climate.
- **Climatology** is the study of climate, its controls, and spatial and temporal variability.







Weather

- Weather is the short-term variation of the atmosphere and described in terms of the current value of such quantitative variables as temperature, humidity, cloudiness, precipitation, and wind speed and direction.
- It includes changes in
  - air pressure,
  - air temperature,
  - humidity,
  - wind,
  - clouds,
  - precipitation, and
  - visibility.

Surface Observation

Three hourly observation are done at the surface. These observations are called Synoptic Observations. The observations are started globally at 0000UTC and it continue every 3 hrs as 0300UTC, 0600UTC, 0900UTC, 1200UTC, 1500UTC, 1800UTC, 2100UTC. In Sri Lankan context, the observation times are 0530, 0830, 1130, 1430,1730,2030,2330.

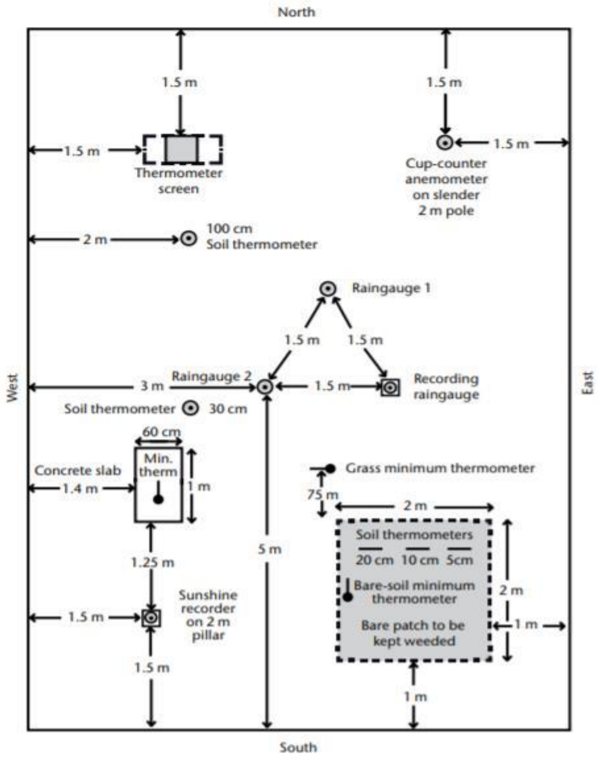


Figure 1 : Schematic Diagram of a Meteorological Enclosure

- Ground should be level and approximately 10 m x 7 m (size of the enclosure), covered with short grass
- • No steeply sloping ground in the vicinity
- • Site should be well away from trees, buildings or other obstructions

The place, where instruments are kept is called "meteorological enclosure" and according to the World Meteorological Organization", there is a standard to install instrument inside the enclosure.

Source : WMO 08 : Guide to Meteorological Instruments and Methods of Observation and Department of Meteorology, Sri Lanka

Critical Role of Surface Observations in Severe Weather

- **No matter the situation—even in extreme conditions like flooding—surface observations are carried out without fail.**
- A flooded observation site—yet the observation was completed.
- That's the level of dedication behind the data.
- **Timely and accurate synoptic observations are essential for initializing and validating numerical weather prediction (NWP) models.**
- These observations provide critical data on surface pressure, temperature, wind, and humidity—parameters necessary to assess and forecast atmospheric behavior.
- **Observations taken during severe weather events are especially valuable.**
- They capture real-time conditions that help forecasters monitor storm development, track system evolution, and issue accurate, location-specific warnings.

  Such data not only improve short-term forecasting but also strengthen long-term model calibration and disaster preparedness.
- Gaps or delays in data collection during these events can severely undermine forecast reliability and public safety.

Video Credit : Mr Sooriyakumar, Retired Meteorological Officer, DoM, Sri Lanka

Temperature -

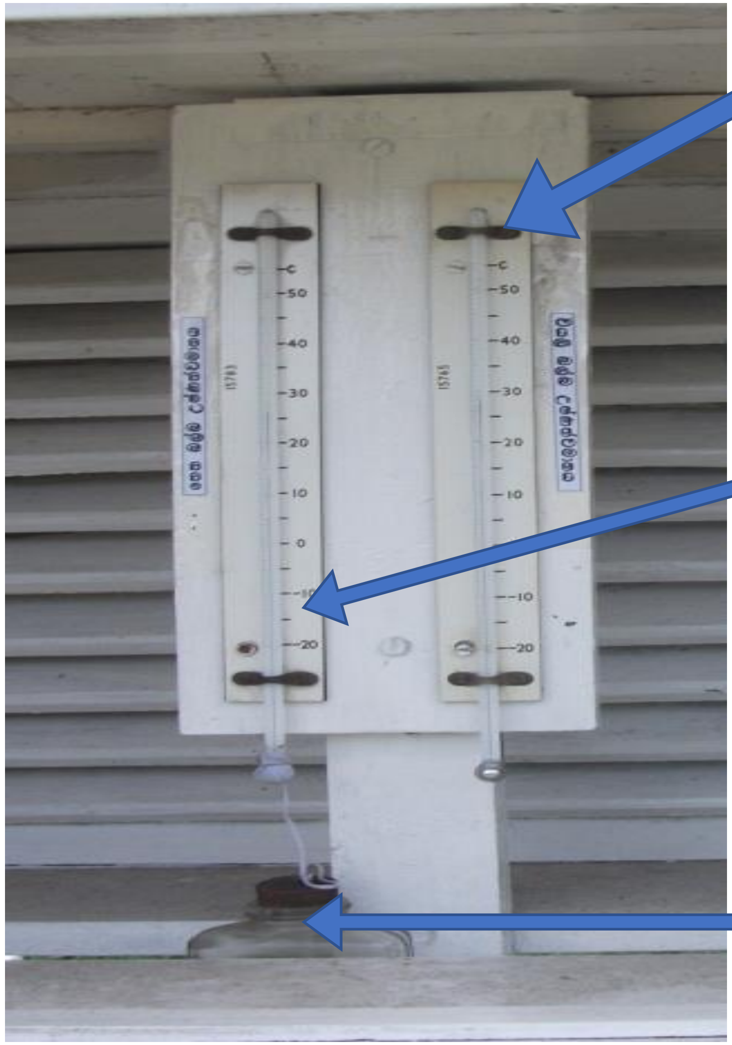
The louvered screen is to shield the thermometers from rain and radiation while allowing free passage of air in to it.

World Meteorological Organization (WMO) (1992) defines temperature as a physical quantity characterizing the mean random motion of molecules in a physical body.

WMO (1992) defines air temperature as "the temperature indicated by a thermometer exposed to the air in a place sheltered from direct solar radiation".

Source : Department of Meteorology, Sri Lanka

Thermometers in the screen



Thermometers in the screen

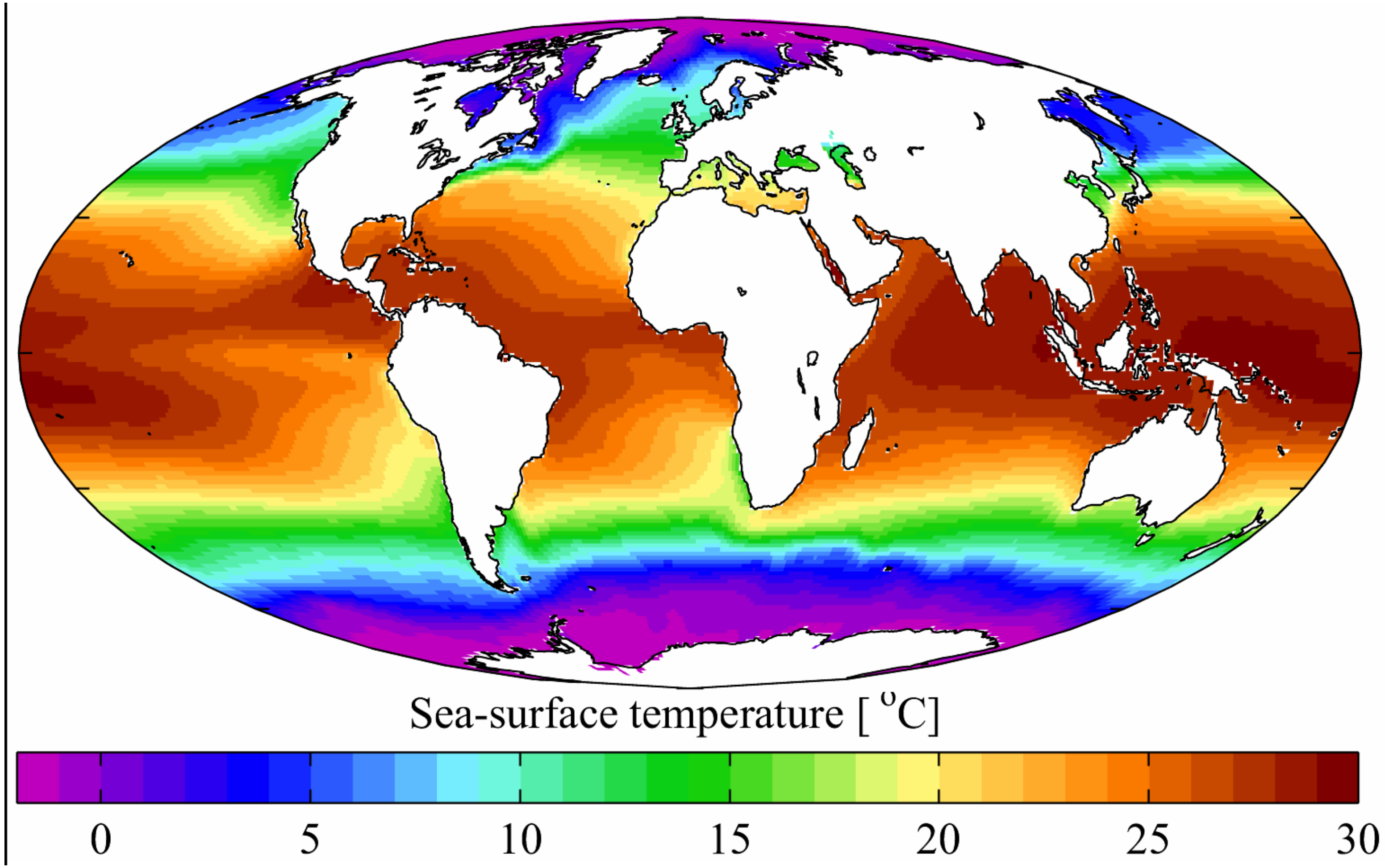
Maximum thermometer

Minimum thermometer

•Soil Temperature
•● Minimum of grass (Temperature)

The standard depths for soil temperature measurements are 5, 10, 20, 50 and 100 cm below the surface

Sea surface temperature (SST)



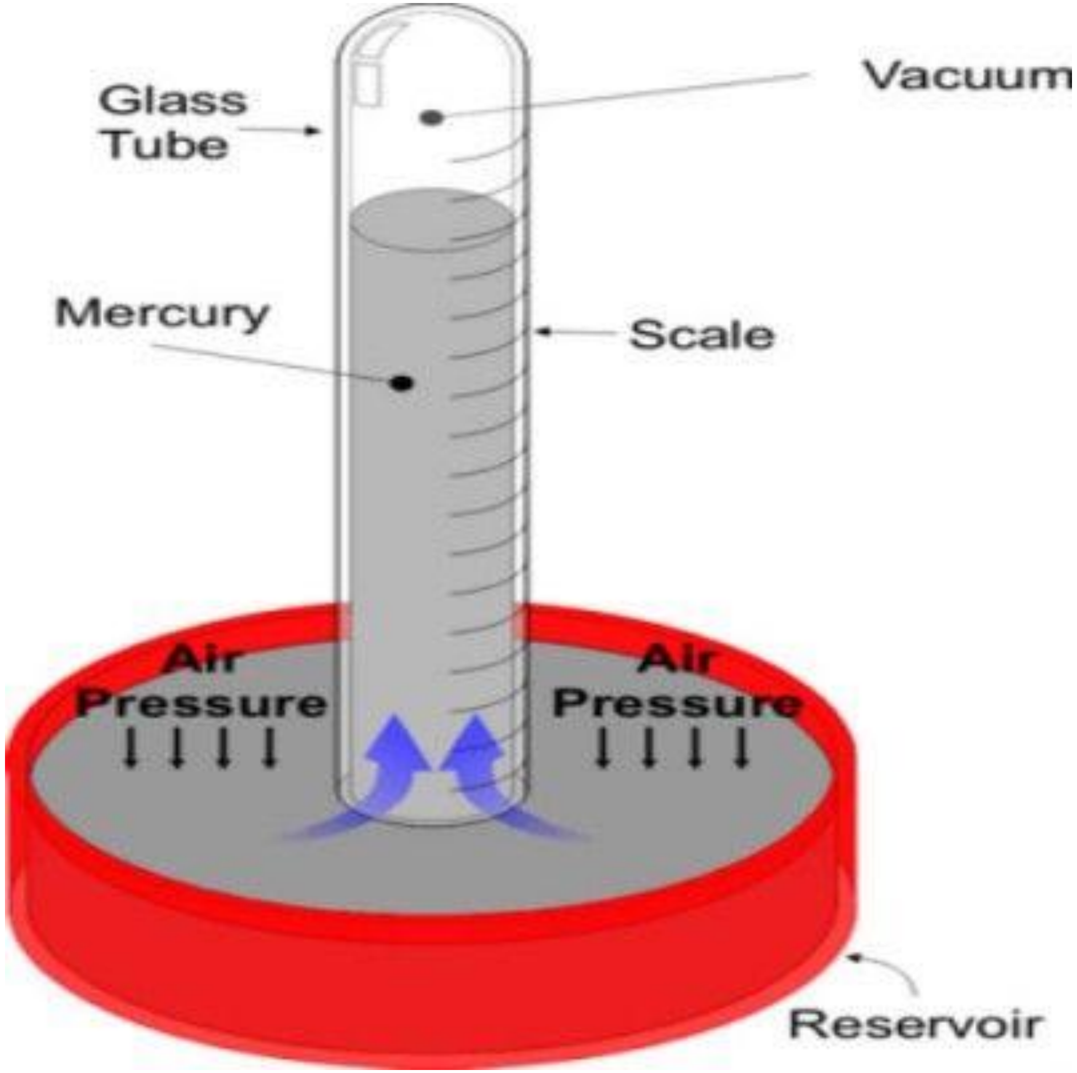
Sea surface temperature (SST) is an "essential climate variable". Applications of SST data include the evaluation of climate and ocean models, observational quantification of climate change and variability, oceanography and geophysics.

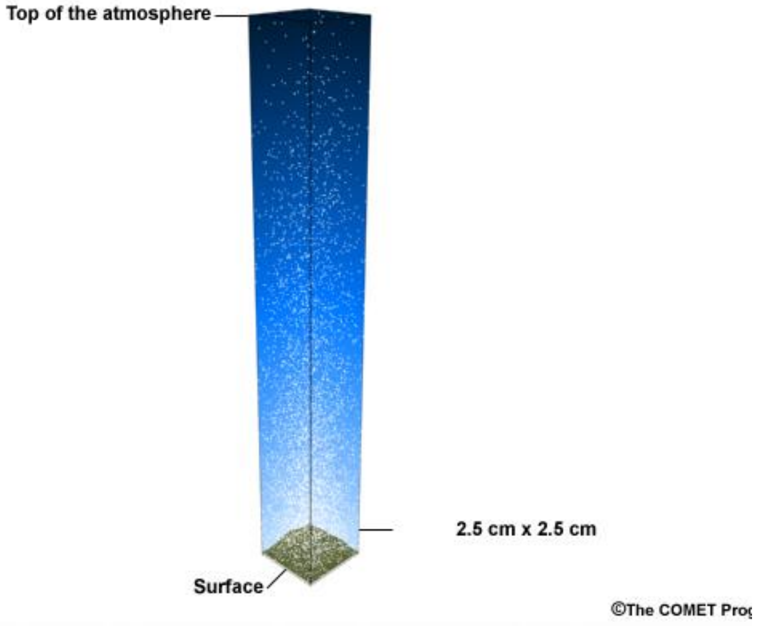
SST has been measured *in situ* for over 150 years, initially from ships and in recent decades from drifting and moored autonomous platforms.

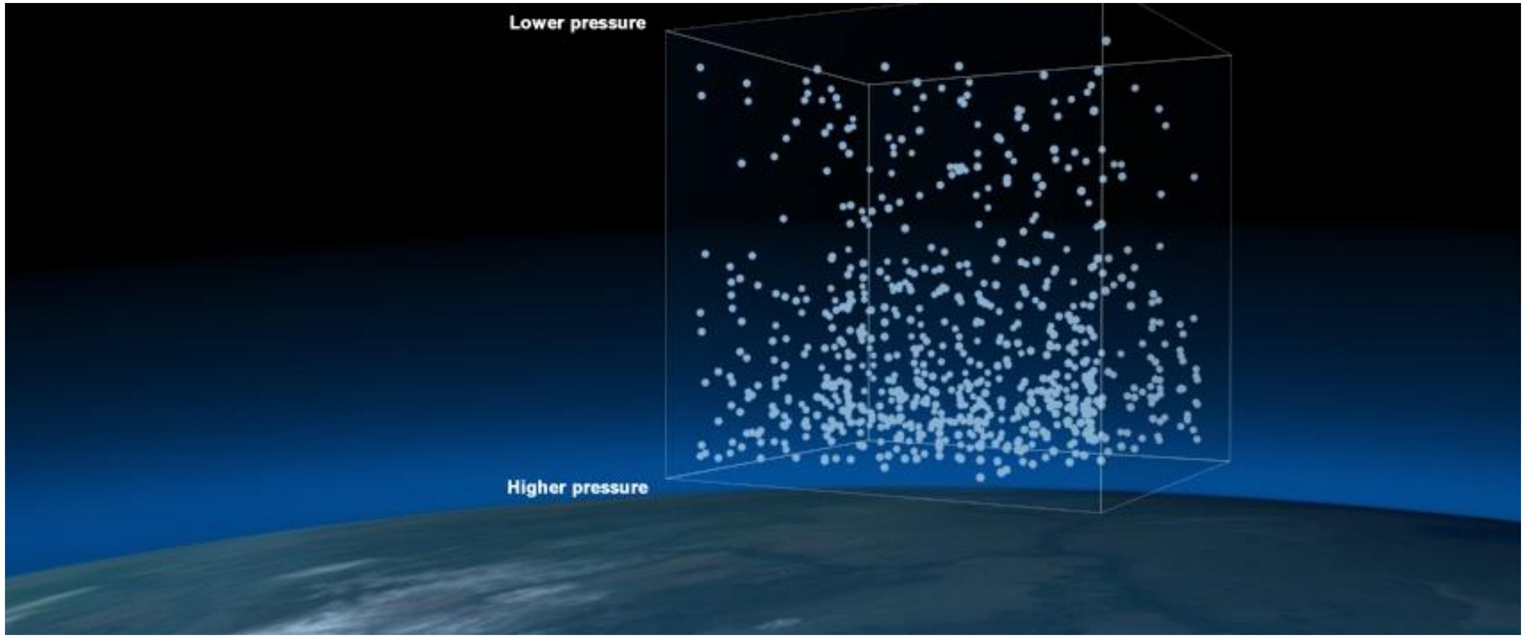
SST products derived from Earth-orbiting satellites are complementary to the *in situ* network, providing finer and more complete spatio-temporal sampling. Satellite SSTs are indirect measurements ("retrievals"), inferred (11 µm, 12 µm) from at-satellite radiances.

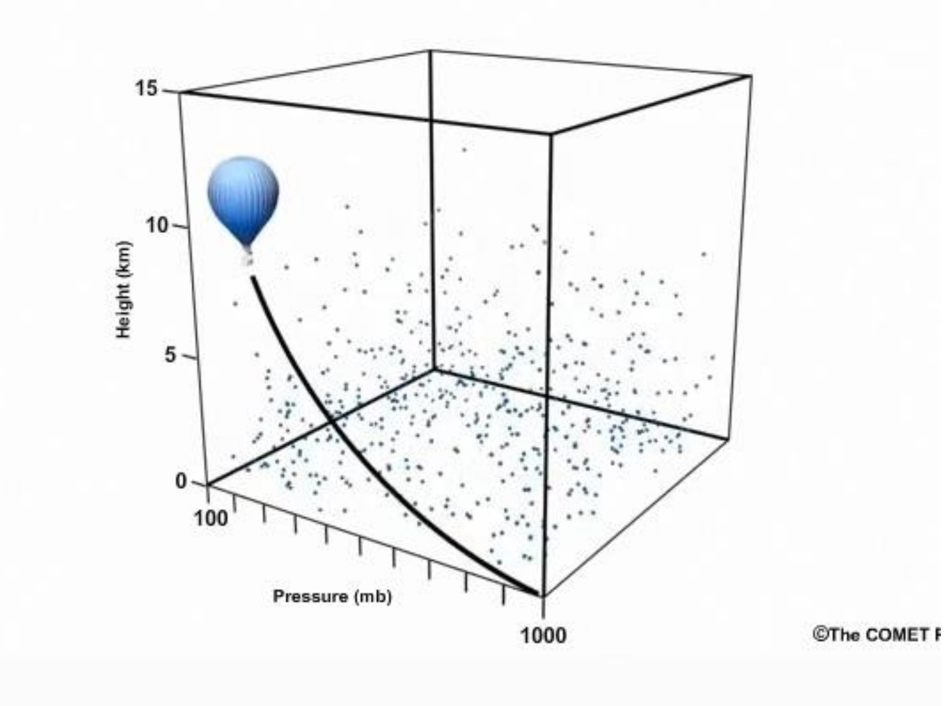
Air Pressure

- The measurement of atmospheric pressure is known as barometry.
- Atmospheric pressure is created by the weight of the atmosphere per unit area above the observation point.
- A mercury-in-glass barometer is a standard instrument for measuring static pressure.
- In this instrument, two columns connected at the base are used, one evacuated and sealed at the top of the column and so subject to no pressure, and the other exposed to the atmosphere at the top.
- The difference in height between the two columns depends on the atmospheric pressure and the known density of mercury and is therefore used to infer the pressure.



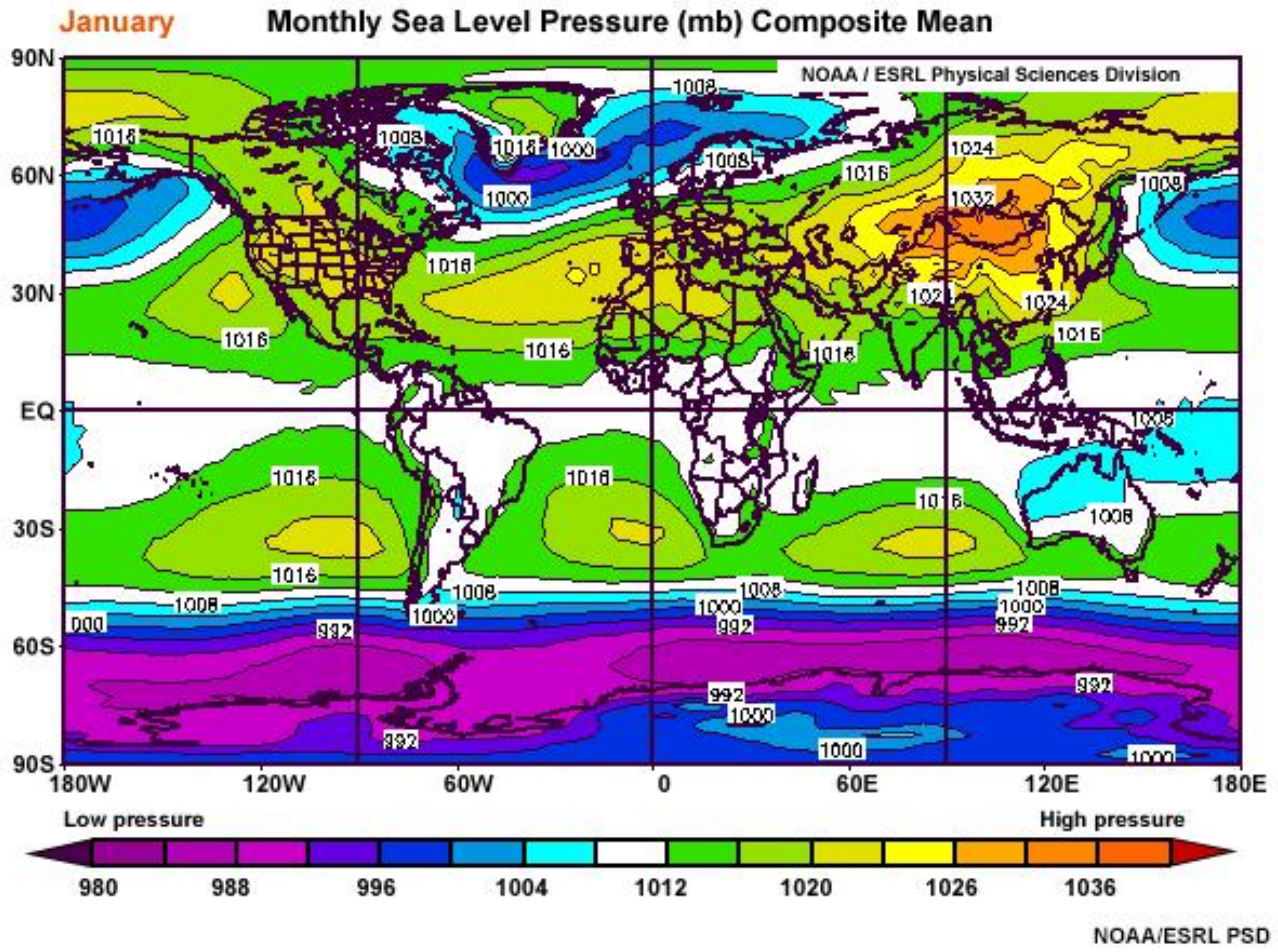






Pressure is a force per area. For the atmosphere, pressure is defined as the force per unit area

Source : COMET



January
Monthly Sea Level Pressure (mb) Composite Mean
NOAA / ESRL Physical Sciences Division
90N
60N
30N
EQ
30S
60S
90S
180W
120W
60W
0
60E
120E
180E
Low pressure
High pressure
980
988
996
1004
1012
1020
1026
1036
NOAA/ESRL PSD

Levar winds
Shamal winds
Tokar winds
L
Monsoon Low level jet
H

WIND

-- motion of the air

ANEMOMETER

Speed – $m\ s^{-1}$

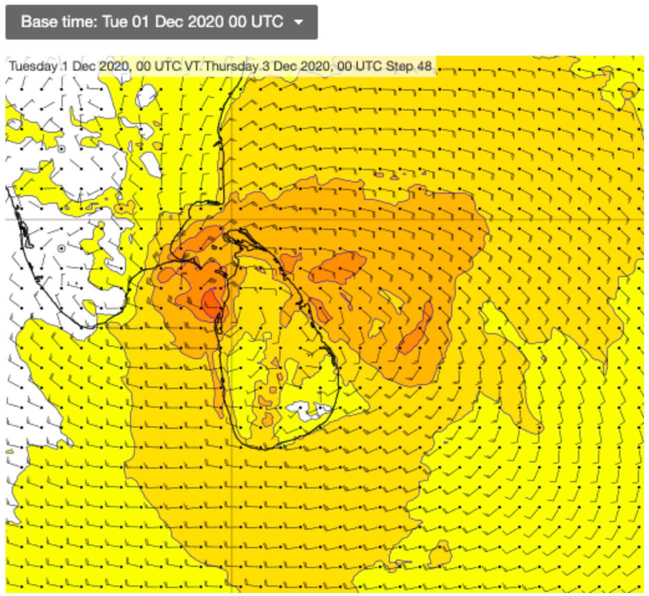
WIND WANE

Direction – using 4 main directions
or
degrees from north

○	0 knots	0-2 mph	0-3.2 kmph		35 knots	38-43 mph	61.5-69.2 kmph
	5 knots	3-8 mph	4.8-12.8 kmph		50 knots	55-60 mph	88.5-96.5 kmph
	10 knots	9-14 mph	14.4-22.5 kmph		55 knots	61-66 mph	98.1-106.2 kmph
	15 knots	15-20 mph	24.1-32.1 kmph		60 knots	67-71 mph	107.8-114.2 kmph
	20 knots	21-25 mph	33.7-40.2 kmph		65 knots	73-77 mph	117.4-123.9 kmph
	25 knots	26-31 mph	41.8-49.8 kmph		100 knots	113-117 mph	181.8-188.2 kmph
	30 knots	32-37 mph	51.4-59.5 kmph		105 knots	119-123 mph	191.5-197.9 kmph

Knots nautical mile per hour	15 kts
m/s (meters per second)	7.7 m/s
km/h (kilometers per hour)	27.8 km/h

WG



To convert between knots (kts) and kilometers per hour $\left(\frac{km}{h}\right)$:

$$Wind_{\frac{km}{h}} = 1.852 \times Wind_{kts}$$

$$Wind_{kts} = 0.5399568 \times Wind_{\frac{km}{h}}$$

To convert between knots (kts) and meters per second $\left(\frac{m}{s}\right)$:

$$Wind_{\frac{m}{s}} = 0.5144444 \times Wind_{kts}$$

$$Wind_{kts} = 1.9438445 \times Wind_{\frac{m}{s}}$$

Beaufort Scale

ESTIMATION OF WIND SPEED

Scale	Conditions at Sea	Wave height	Wind Speed
0 Calm	Sea like a mirror.		1 km/h or less 1 knot or less
1 Light Air	Scaly ripples without foam crests.	Wave height: 0.1 m	1 – 5 km/h 1 – 3 knots
2 Light Breeze	Small wavelets, crests have a glassy appearance, not breaking.	0.2 – 0.3 m	6 – 11 km/h 4 – 6 knots
3 Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps.	0.6 – 1 m	12 – 19 km/h 7 – 10 knots
4 Moderate Breeze	Small waves becoming longer, numerous whitecaps.	1 – 1.5 m	20 – 29 km/h 11 – 16 knots
5 Fresh Breeze	Moderate waves taking longer form, many whitecaps, some spray.	2 – 2.5 m	30 – 39 km/h 17 – 21 knots
6 Strong Breeze	Larger waves begin to form, whitecaps everywhere, more spray..	3 – 4 m	40 – 50 km/h 22 – 27 knots
7 Near Gale	Sea heaps up, white foam from breaking waves begins to be blown in streaks.	4 – 5.5 m	51 – 61 km/h 28 – 33 knots
8 Gale	Moderately high waves of greater length, edges of crests begin to break into spindrift.	5.5 – 7.5 m	62 – 74 km/h 34 – 40 knots
9 Strong Gale	High waves, sea begins to roll, dense streaks of foam.	7 – 10 m	75 – 87 km/h 41 – 47 knots
10 Storm	Very high waves with overhanging crests, heavy rolling, reduced visibility.	9 – 12.5 m	88 – 101 km/h 48 – 55 knots
11 Violent Storm	Exceptionally high waves, sea covered with white foam patches, very poor visibility.	11.5 – 16 m	102 – 117 km/h 56 – 63 knots
12 Hurricane	Huge waves, sea is completely white with driving spray, air filled with foam.	>14 m	118 km/h or more 64 knots or more

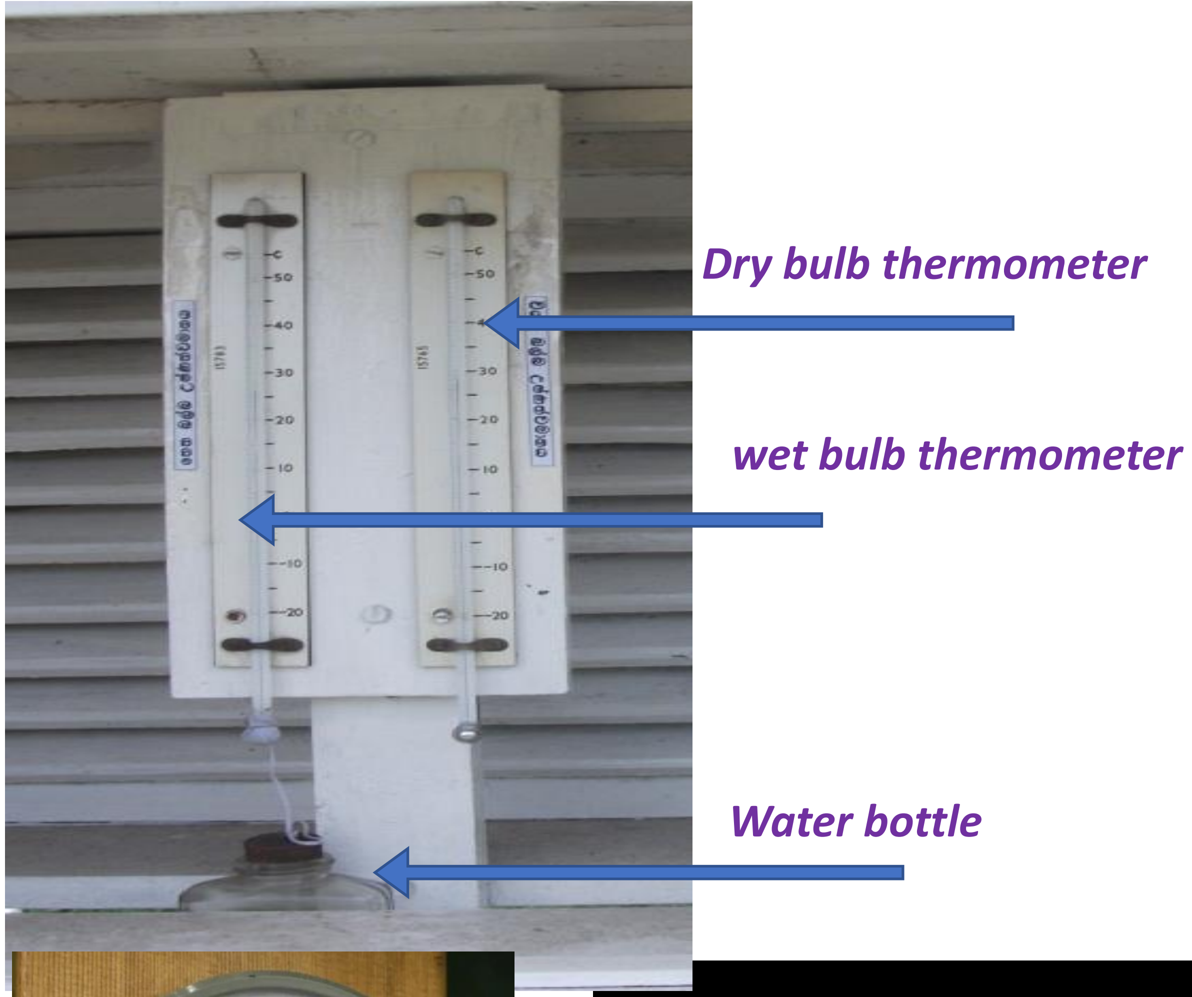
Beaufort Scale

ESTIMATION OF WIND SPEED

Scale	Conditions on Land	Wind Speed
0 Calm	Smoke rises straight up.	1 km/h or less 1 knot or less
1 Light Air	Smoke drift indicates wind direction. Wind vanes do not move.	1 – 5 km/h 1 – 3 knots
2 Light Breeze	Wind felt on face. Leaves rustle. Wind vanes begin to move.	6 – 11 km/h 4 – 6 knots
3 Gentle Breeze	Light flags extended. Leaves and small twigs in constant motion.	12 – 19 km/h 7 – 10 knots
4 Moderate Breeze	Dust, leaves and loose papers raised up. Small branches move.	20 – 29 km/h 11 – 16 knots
5 Fresh Breeze	Crested wavelets form on inland waters. Small trees begin to sway.	30 – 39 km/h 17 – 21 knots
6 Strong Breeze	Umbrellas are difficult to control. Whistling heard in telegraph wires. Large branches move.	40 – 50 km/h 22 – 27 knots
7 Near Gale	Inconvenience felt when walking against the wind. Whole trees in motion.	51 – 61 km/h 28 – 33 knots
8 Gale	Difficult to walk against wind. Twigs and small branches blown off trees.	62 – 74 km/h 34 – 40 knots
9 Strong Gale	Slight structural damage may occur (slates blown off roofs).	75 – 87 km/h 41 – 47 knots
10 Storm	Structural damages likely. Trees uprooted.	88 – 101 km/h 48 – 55 knots
11 Violent Storm	Widespread damage to structures.	102 – 117 km/h 56 – 63 knots
12 Hurricane	Severe structural damage to buildings. Widespread devastation.	118 km/h or more 64 knots or more

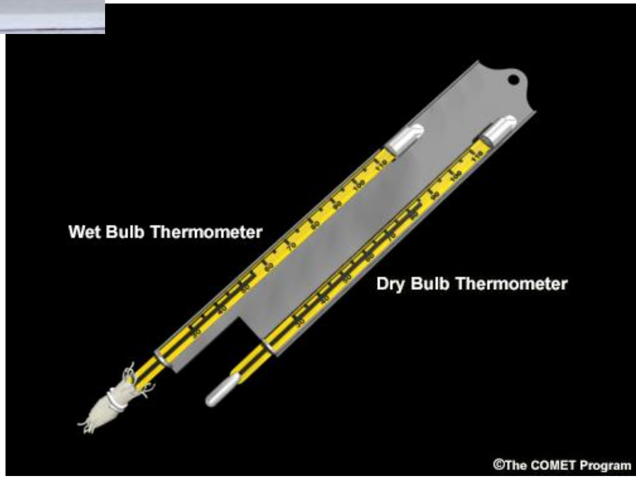
Humidity

- Hygrometry is the measurement of the amount of water vapor in the atmosphere. There are many ways to measure and describe the amount of water vapor in the air.
- Wet bulb temperature is the lowest temperature to which the current air can be cooled. Cooling is achieved by evaporating water into air at a constant pressure. The greater the difference is between wet and dry bulb temperatures, the drier the air is.
- The difference between the ambient air temperature and the dew point temperature or the wet-bulb temperature, known as the dew point depression



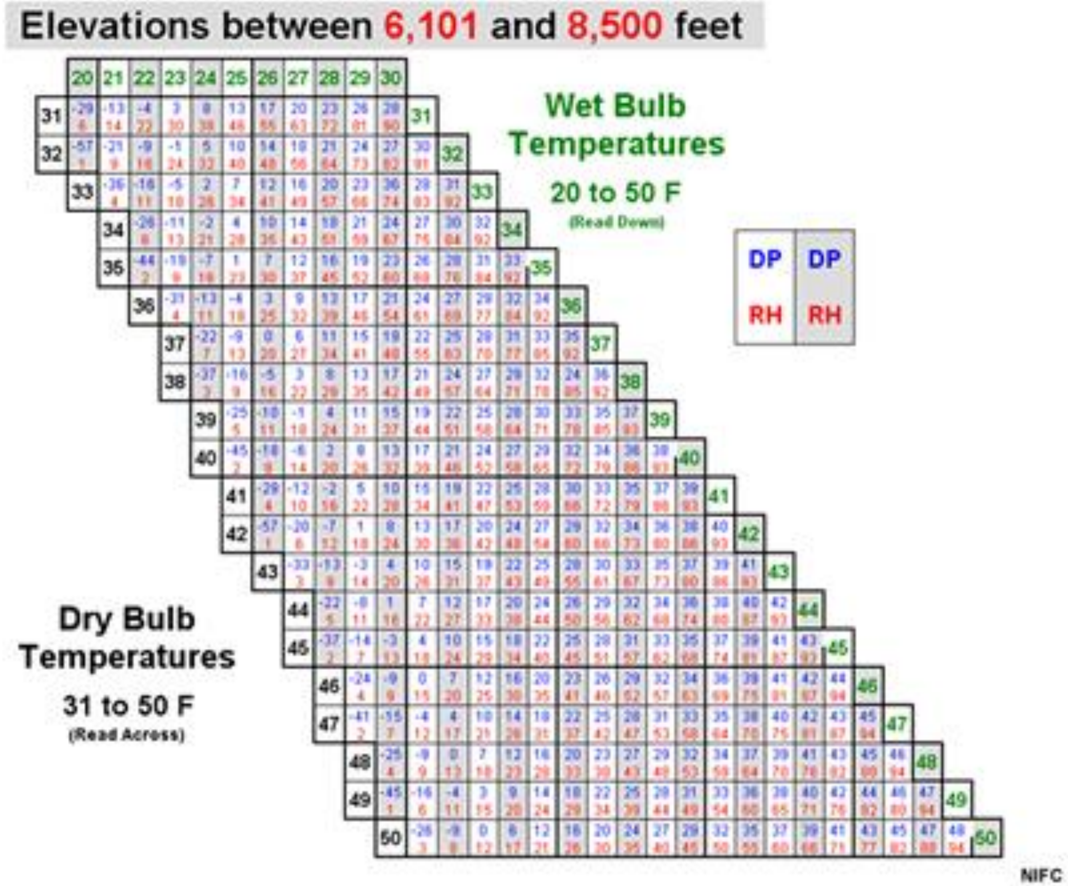
A hygrometer measures atmospheric humidity

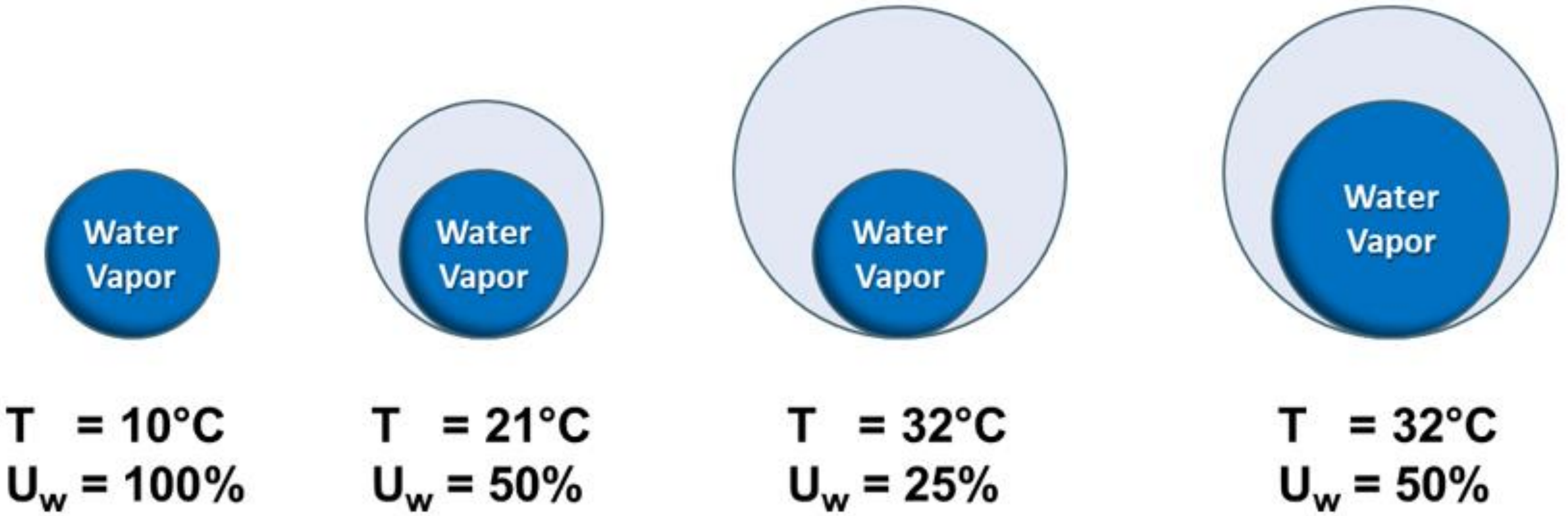
Electrical hygrometers measure the change in electrical resistance of a thin layer of lithium chloride, or of a semiconductor device, as the humidity changes.



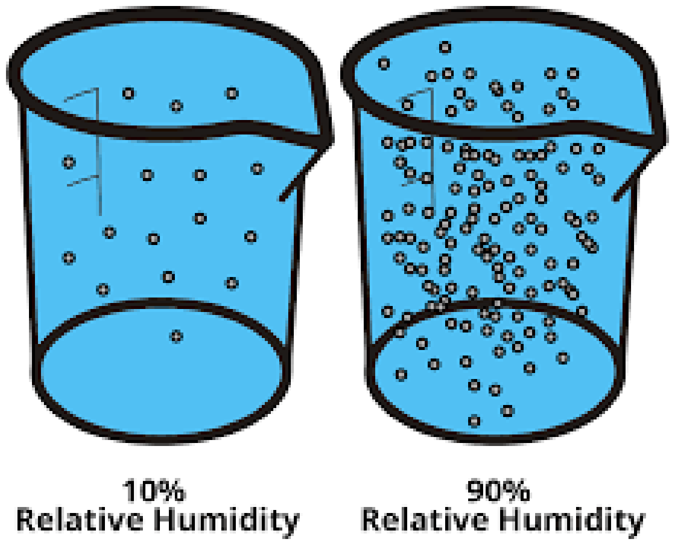
Relative Humidity

- Relative humidity is the percent of water vapor in the air compared to what would be present if the air were saturated.
- Relative humidity can be determined by measuring the dry bulb and wet bulb temperatures in the field.
- Using these measured values, the dew point and relative humidity can be determined with the use of tables.
- These psychrometric tables are valid for specific elevation ranges because relative humidity and dewpoint change with atmospheric pressure, which varies with elevation.



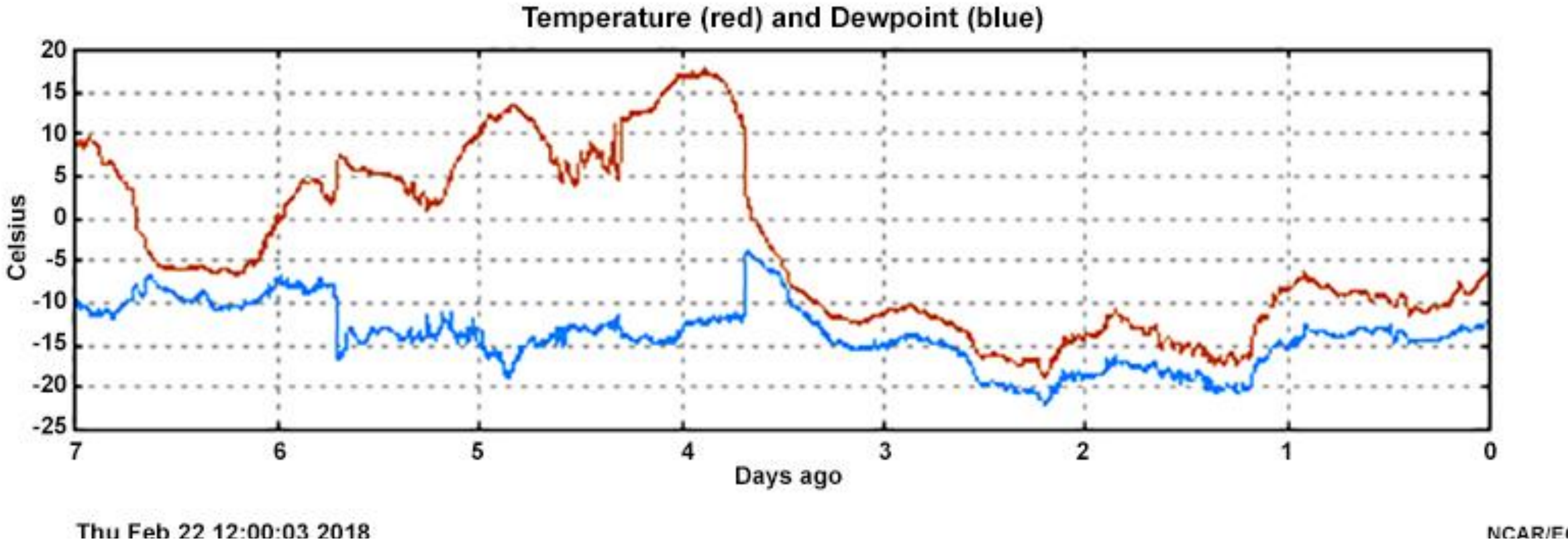


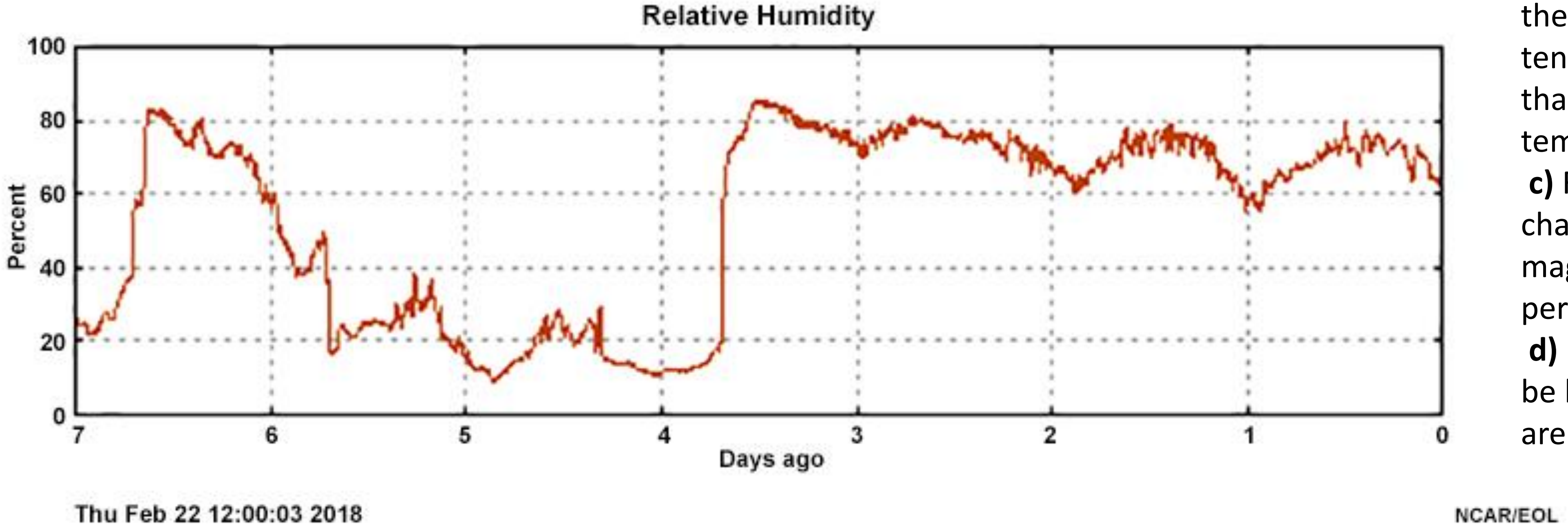
NCAR/EOL



Relative humidity is not a conserved quantity and depends both on the amount of water vapor as well as on temperature. Because it is a relative value, it doesn't have much significance without the accompanying temperature, as illustrated here.

QUIZ





View the plots of temperature and dewpoint temperature and relative humidity. What do you observe about the relationship between relative humidity and temperature? (Choose all that apply.)

a) When the air temperature and dew point temperature have similar values, relative humidity is high.

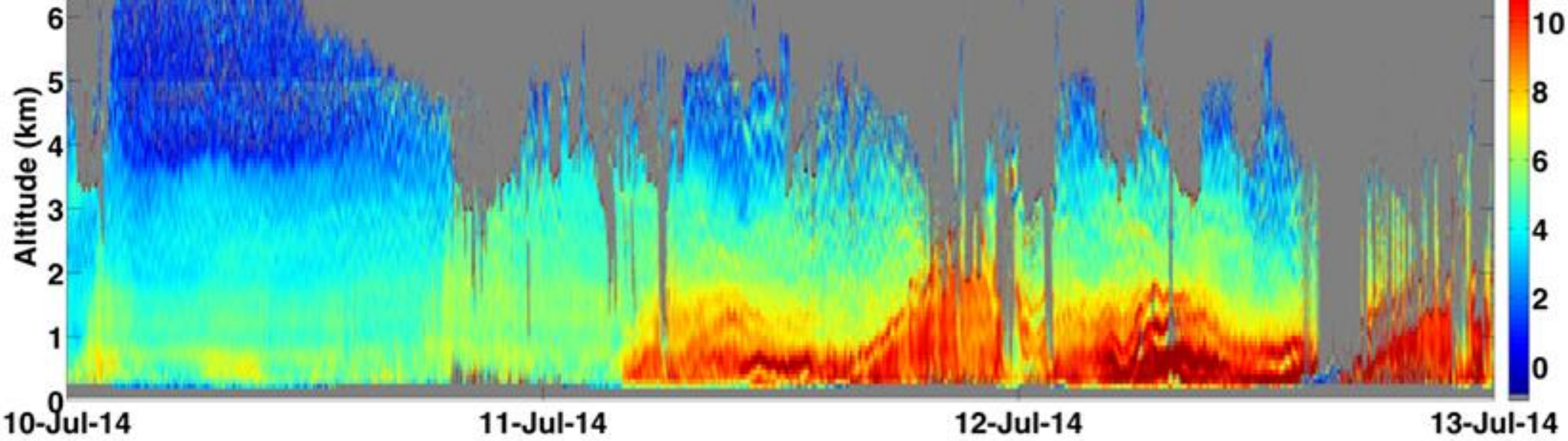
b) The air temperature over the course of multiple days tends to have a smaller range than the dew point temperature.

c) Relative humidity can change by an order of magnitude in a very short period of time.

d) Relative humidity tends to be higher when temperatures are cooler.

Answer

- The correct answers are a, c, d.
- From the temperature and dew point measurements and corresponding relative humidities, we observe that when the dewpoint is close to the temperature, relative humidity is high (option a) and for the days shown in the plots, relative humidity is higher at cooler temperatures (option d). The relative humidity can change dramatically in a very short time (option c), though temperature tends to demonstrate larger day-to-day changes than the dewpoint, making option b incorrect.

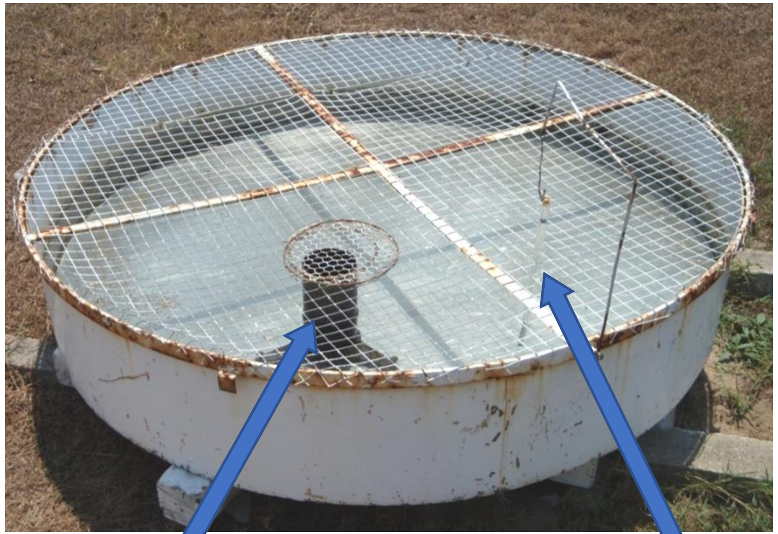


Remote Sensing Instruments » Lidar

- Lidar (Light Detection And Ranging) is an active remote sensing technique, in which a pulsed laser beam at select wavelengths is emitted vertically into the atmosphere, where air and water vapor molecules scatter and absorb the laser light. The scattered laser pulses are measured on the ground and from the time of flight the altitude is determined at which the light was scattered.

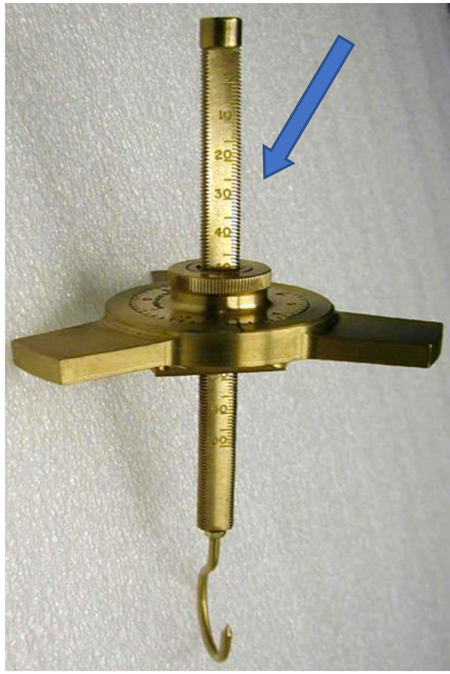
Evaporation -- *Height of the water evaporated from a surface of water (mm)*

Pan evaporation is the process of evaporation influenced by various meteorological parameters. The main factors affecting the rate of evaporation include temperature, wind speed, surface area, and humidity



hook gauge

Stilling well



Evaporation pan

Stilling well

thermometer

[American class- A]
Diameter - 120.7 cm
Height - 25.4 cm

A **hook gauge** is used to measure the water level

A Hook gauge evaporimeter is a precision instrument used to measure changes in water levels due to evaporation. It is used to precisely measure the level of a free water surface as an evaporation pan. adjusting the height of a hook until its point just breaks the surface.

Source : Department of Meteorology, Sri Lanka

Tipping bucket rain gauge

Rainfall

– ***height of the rain water collected on a horizontal surface if it is not absorbed or flowed away***

- **mm**

The bucket tips and empties when 0.5 mm of rainfall accumulates..
Tipping buckets are the most widely used precipitation measurement devices in the world owing to their reliability, relatively low cost, and automated electronic signalling for data transfer from remote sites.

Standard ***Rain gauge*** with 5 inch diameter

Inner bucket

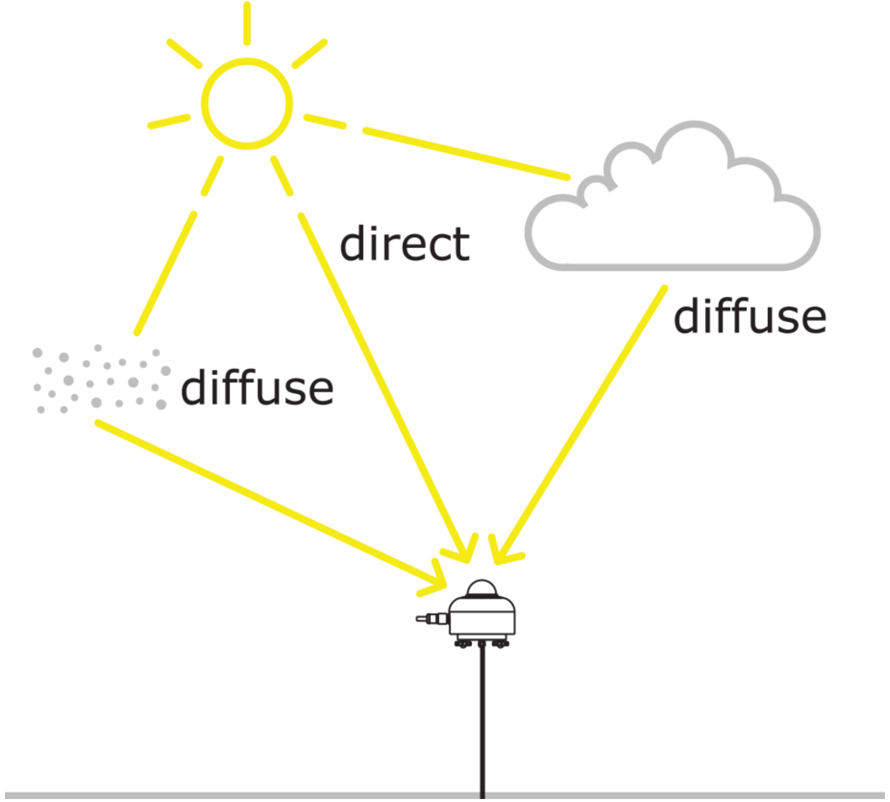
Specially calibrated ***Measuring cylinder***

Source : Department of Meteorology, Sri Lanka

Source : COMET

MEASUREMENT OF RADIATION

A pyranometer is a device used to measure the total solar irradiance on a horizontal surface.



Pyranometer

Source : https://www.hukseflux.com

Sun shine recorder

Source : Department of Meteorology, Sri Lanka

Sun shine chart

-time duration that the sunshine is available without covered by clouds

- Number of sunshine hours

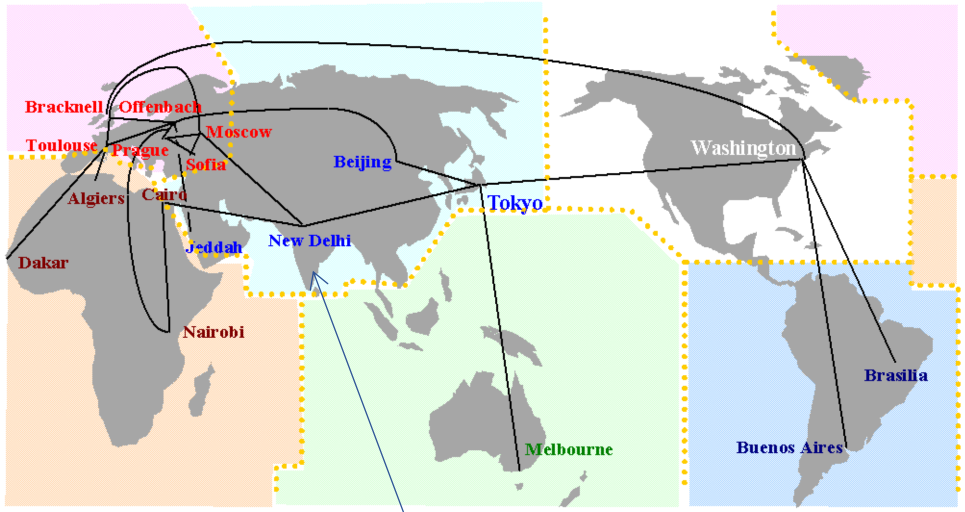
Source : Department of Meteorology, Sri Lanka

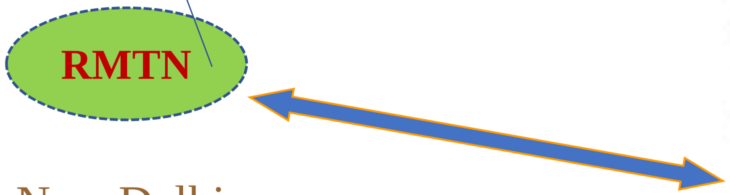
The Global Telecommunication System (GTS) is "The co-ordinated global system of telecommunication facilities and arrangements for the rapid collection, exchange and distribution of observations and processed information within the framework of the World Weather Watch.

The Global Telecommunication System shall be so organized as to accommodate the volume of meteorological information and its transmission within the required time limits as the core network of WIS and to meet the needs of World, Regional Specialized and National Meteorological Centres, resulting from the implementation of the WWW.

Global Telecommunication System (GTS)

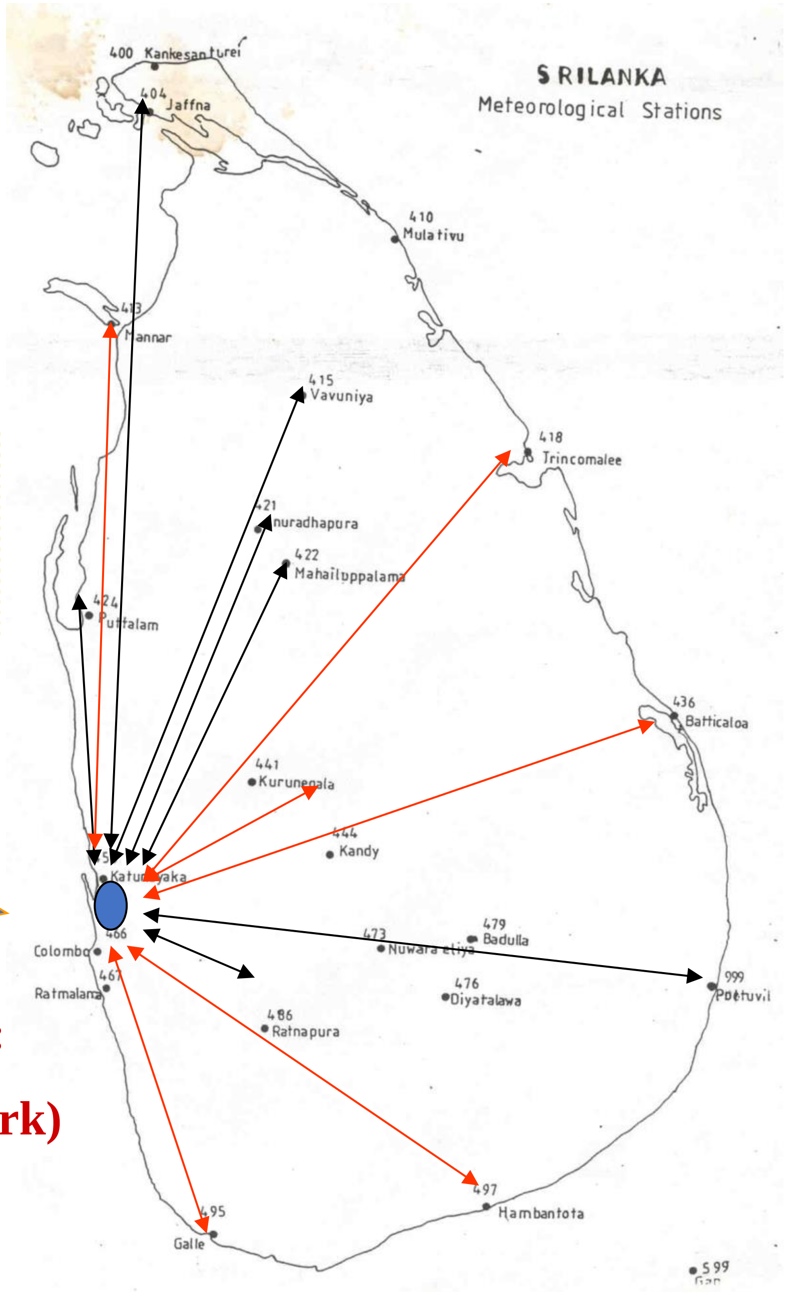
MTN





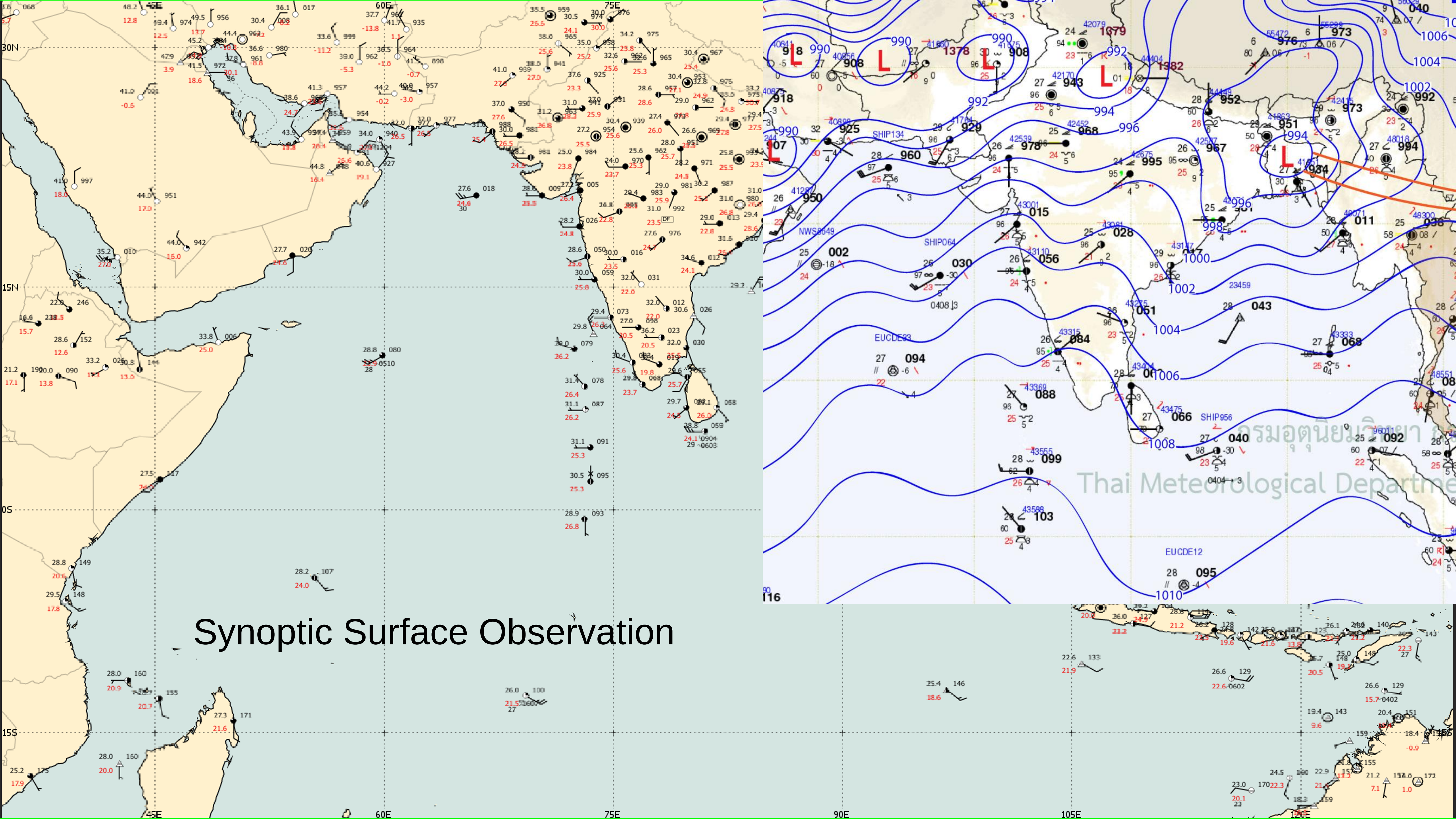
New Delhi

NMTN



GTS consists of three level networks namely:

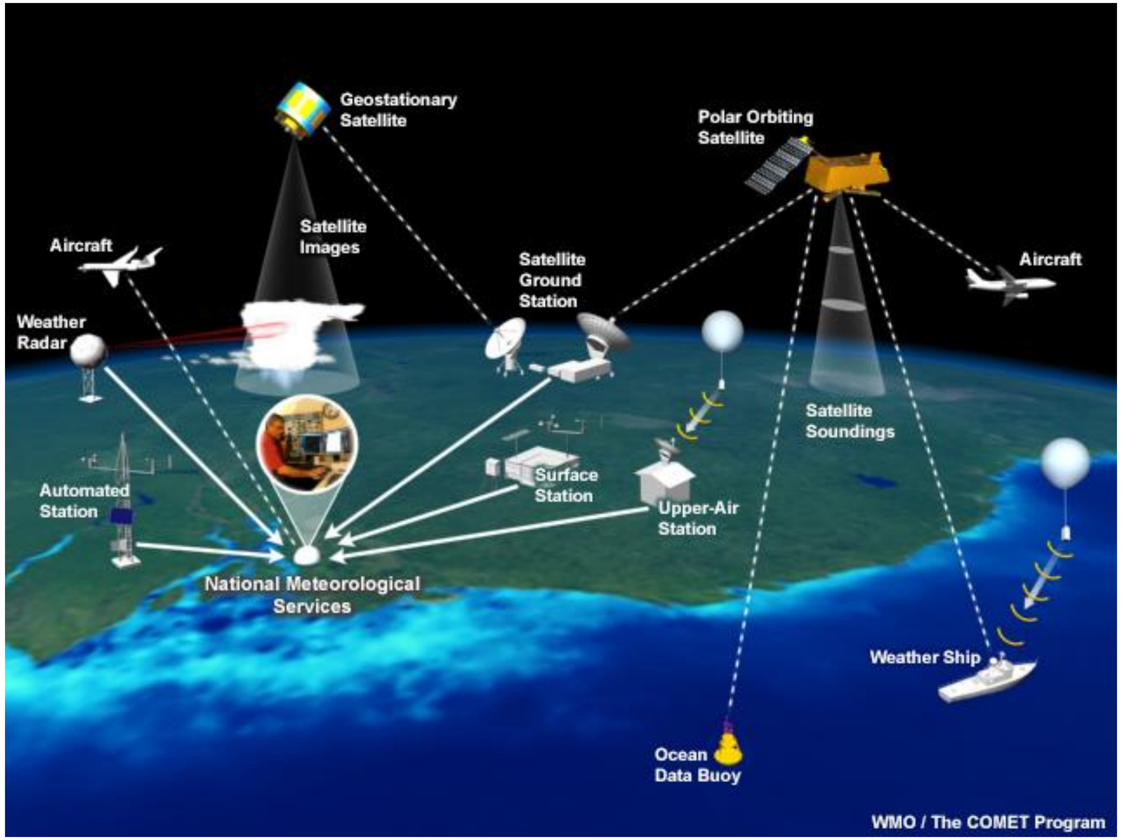
- **MTN (Main Telecommunication Network)**
- **RMTNs (Regional Meteorological Telecommunication Networks)**
- **NMTNs (National Meteorological Telecommunication Networks)**



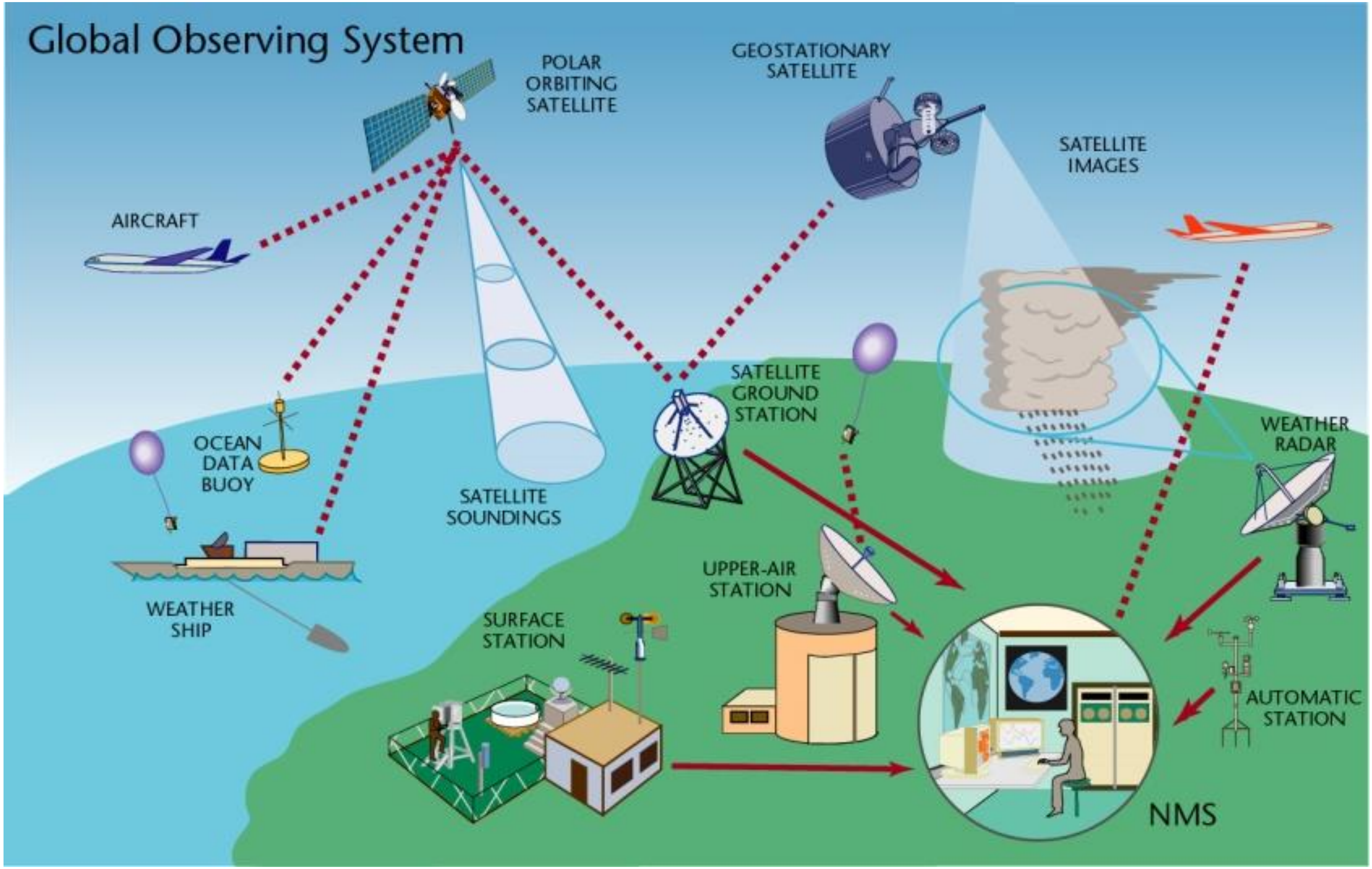
Synoptic Surface Observation

- Observations of temperature, winds, humidity, and other variables are used to determine the atmosphere’s current state, prepare numerical weather prediction models for forecasting, and evaluate the accuracy of models and forecasts.
- Information about our atmosphere can come from automated weather stations, human observers on the ground, aircraft, ships, radiosondes (a miniature radio transmitter that is carried aloft—as by an unmanned balloon—with instruments for sensing and broadcasting atmospheric conditions), or ocean buoys, as well as from more sophisticated systems like radars and satellites.
- These observations are fed to national meteorological services for analysis and forecasting applications.

Atmospheric Observations



Continual heat transfers and circulations within the global atmospheric system make its observable properties highly variable in both space and time.
Various observation techniques have benefits and challenges in terms of the representativeness of the observations, but all are important for understanding atmosphere and its behavior.



Global Observing System
POLAR ORBITING SATELLITE
GEOSTATIONARY SATELLITE
SATELLITE IMAGES
AIRCRAFT
SATELLITE GROUND STATION
OCEAN DATA BUOY
SATELLITE SOUNDINGS
WEATHER RADAR
WEATHER SHIP
UPPER-AIR STATION
SURFACE STATION
AUTOMATIC STATION
NMS

Weather buoys

- Weather buoys are **instruments which collect weather and ocean data within the world's oceans**

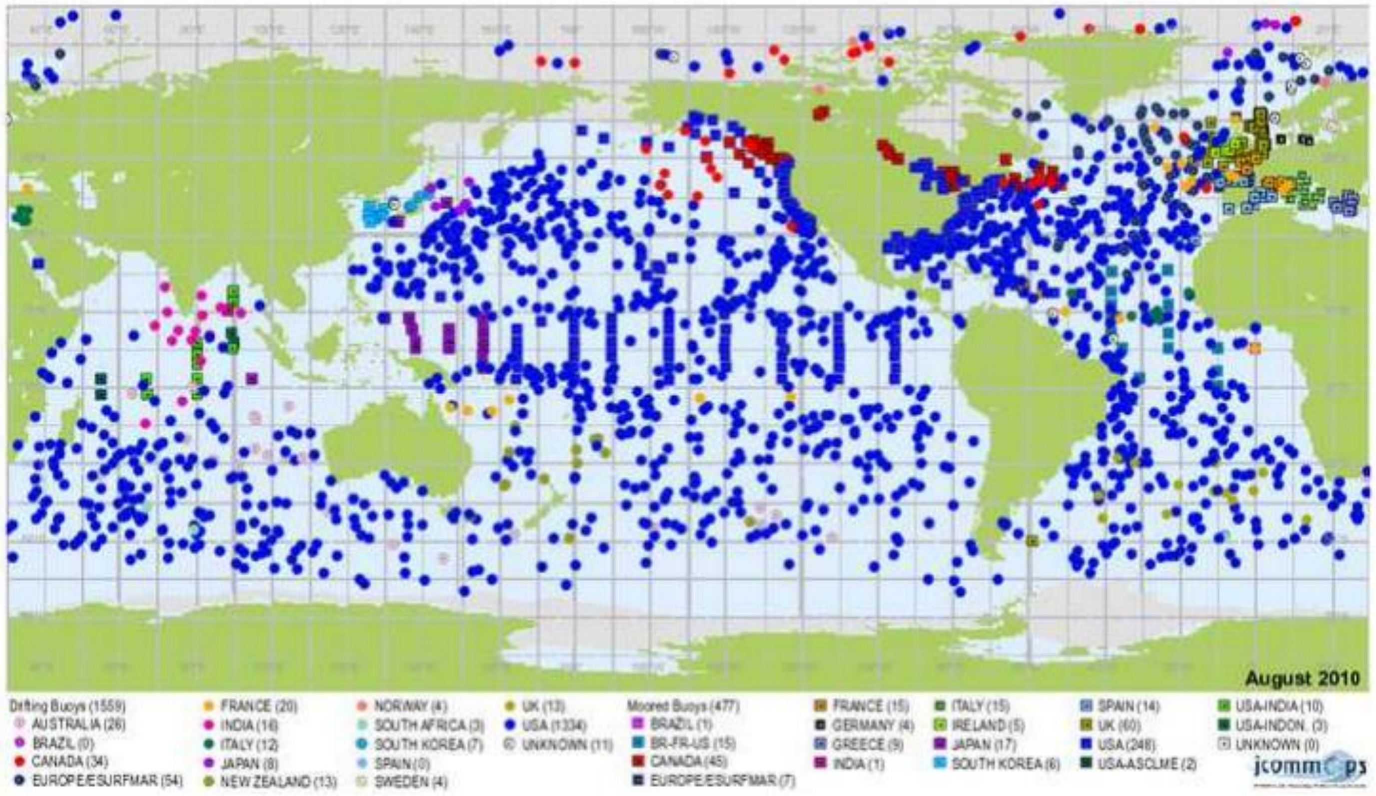
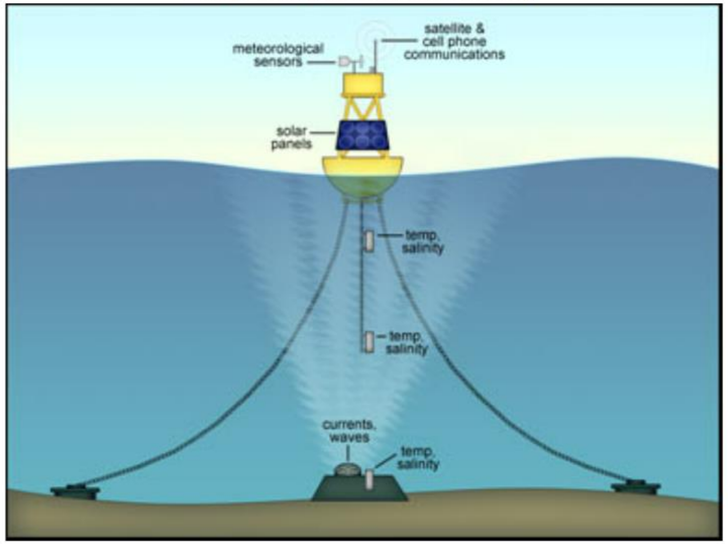
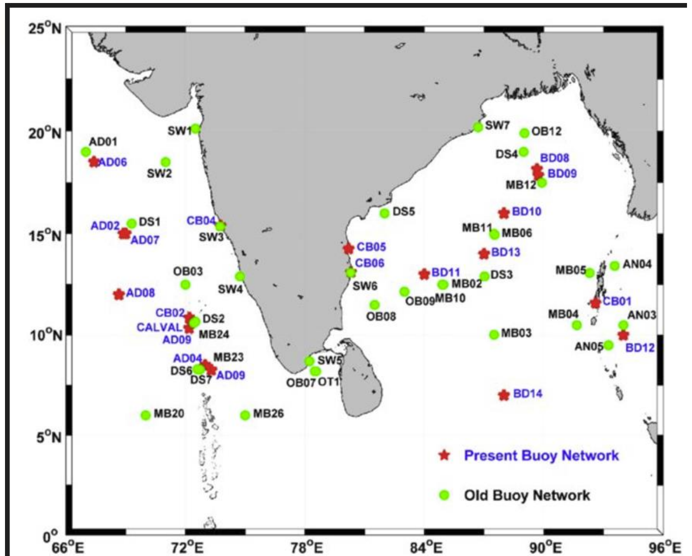
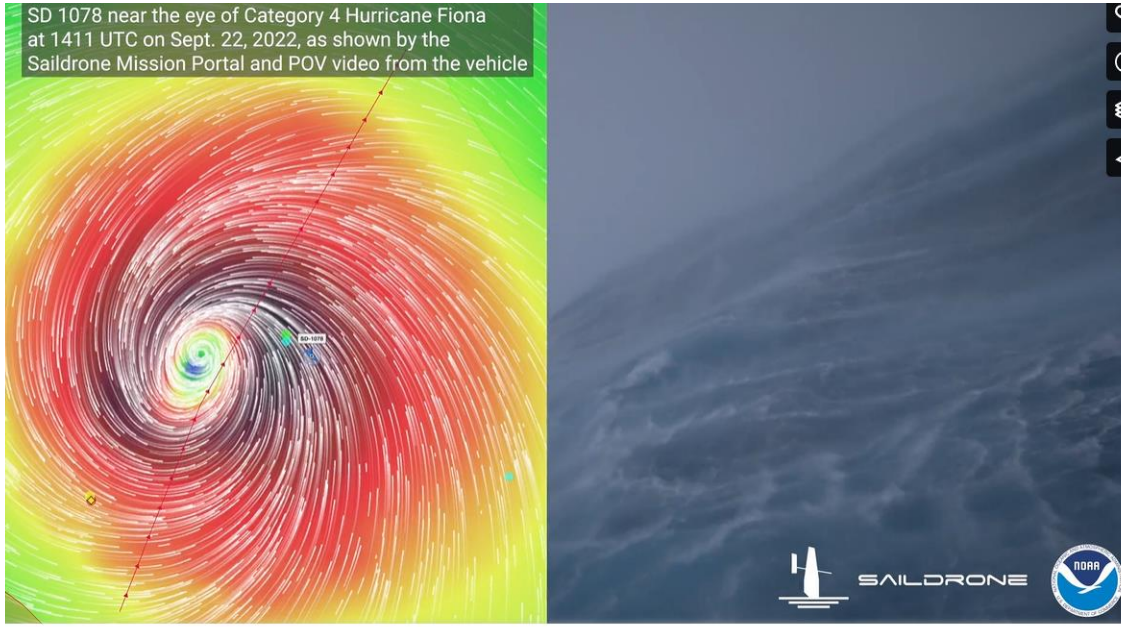


Figure 1. Drifting and Moored Buoys Transmitting on the GTS, Aug. 2010
[Source: DBCP web site [*http://www.jcommops.org/dbcp/*](http://www.jcommops.org/dbcp/) *]*

Buoy Configuration and Mooring





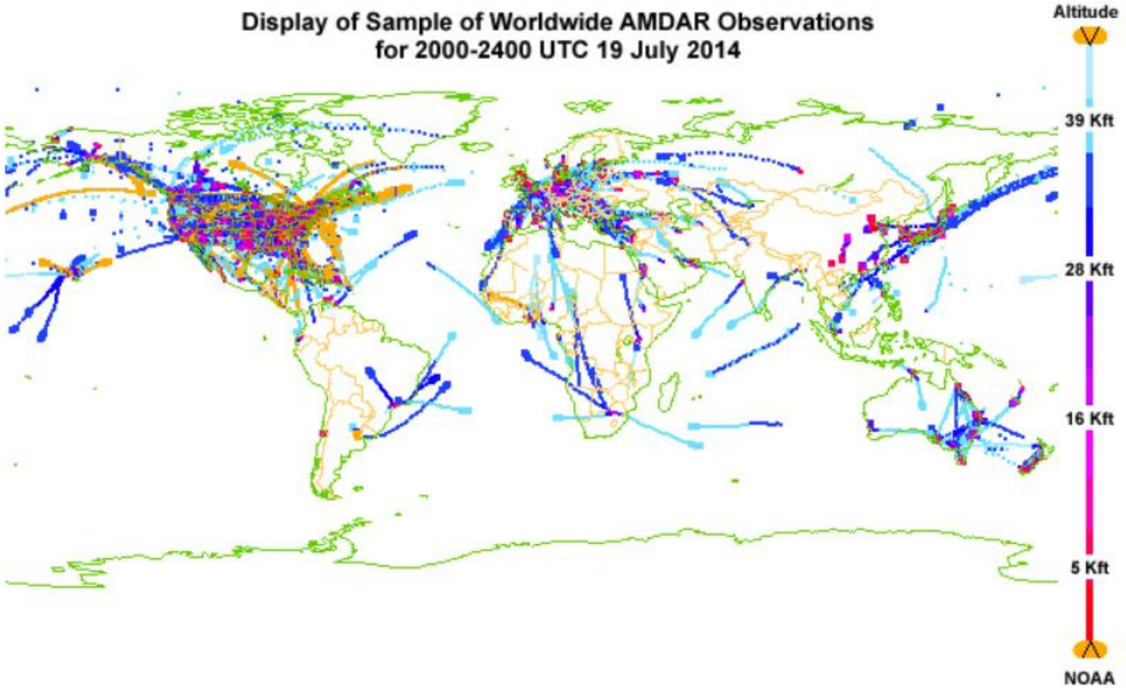


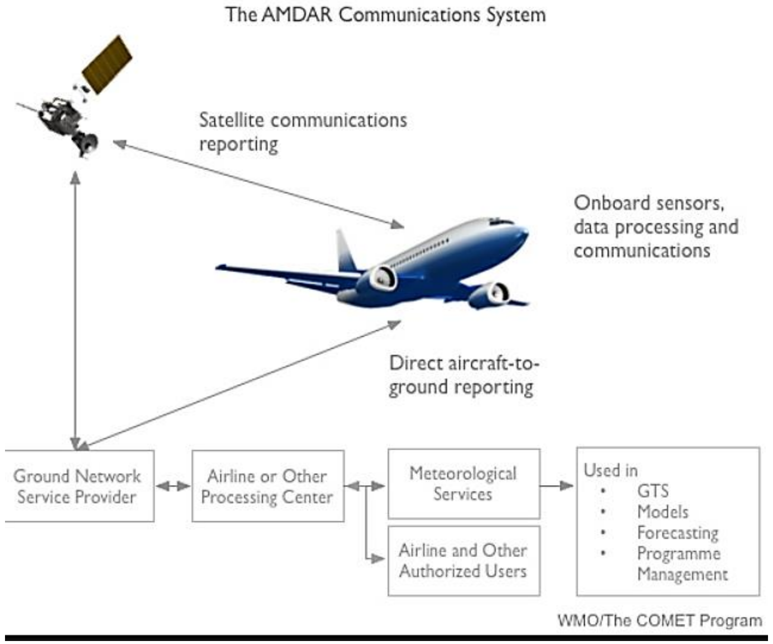
Hurricane Fiona is a Category 4 storm in Atlantic ocean . SD 1078 is battling 50-foot waves and winds measured over 100 mph to collect critical scientific data and, in the process, is providing a completely new view of one of Earth's most destructive forces.

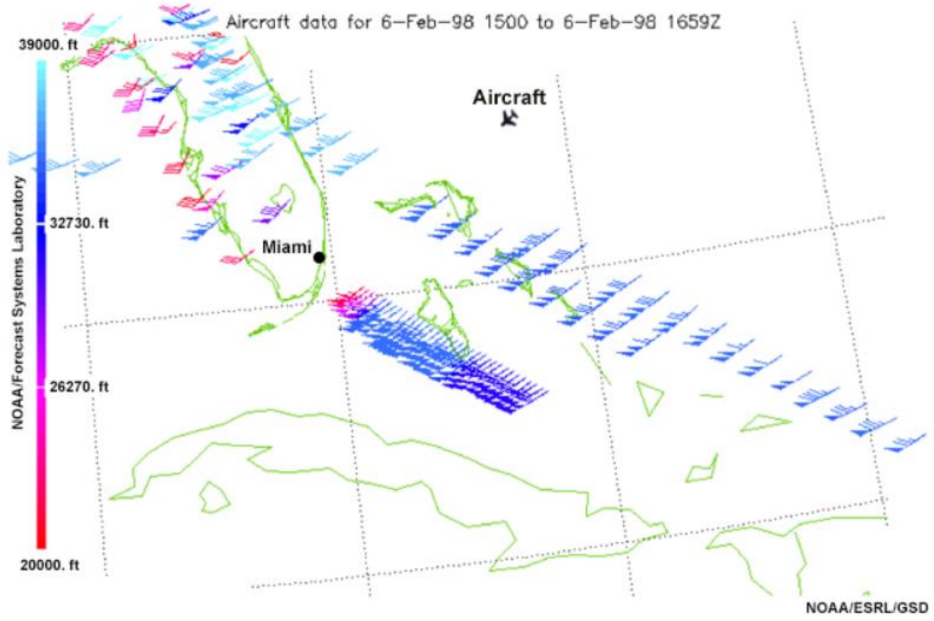
https://vimeo.com/752704936

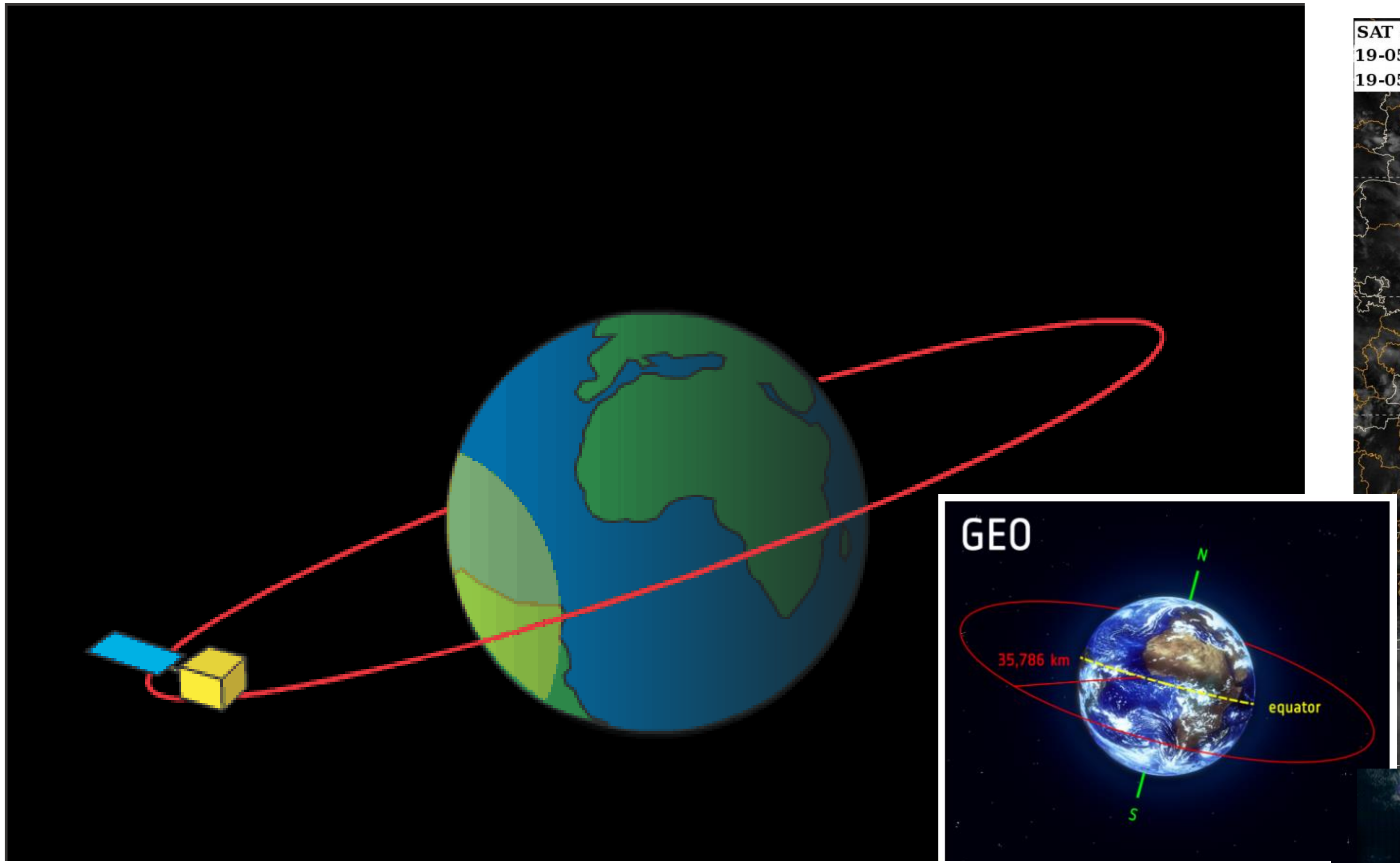
Aircraft Meteorological Data Relay (AMDAR)

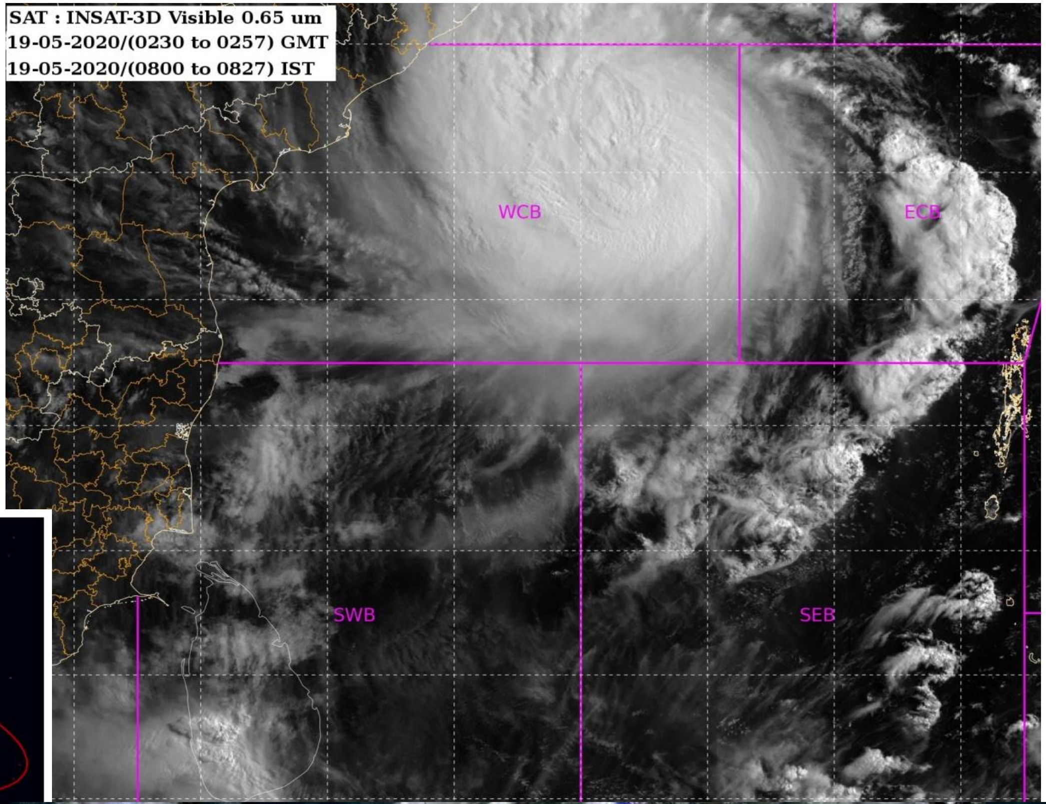
- The World Meteorological Organization (WMO), in cooperation with over 40 airlines globally, has established the Aircraft Meteorological DAta Relay (AMDAR) programme.
- AMDAR is an aircraft based meteorological observation system that uses data gathered, and transmitted, by aircraft in flight to help improve the accuracy of forecasts.
- AMDAR collects and distributes the following meteorological data with very accurate time, pressure altitude, and latitude and longitude coordinates:
  1. Air temperature (static air temperature)
  2. Wind speed and direction
  3. Pressure altitude (barometric pressure)
  4. Turbulence (Eddy Dissipation Rate or Derived Equivalent Vertical Gust, if the algorithm is installed)
  5. Water vapour (if sensor is installed)

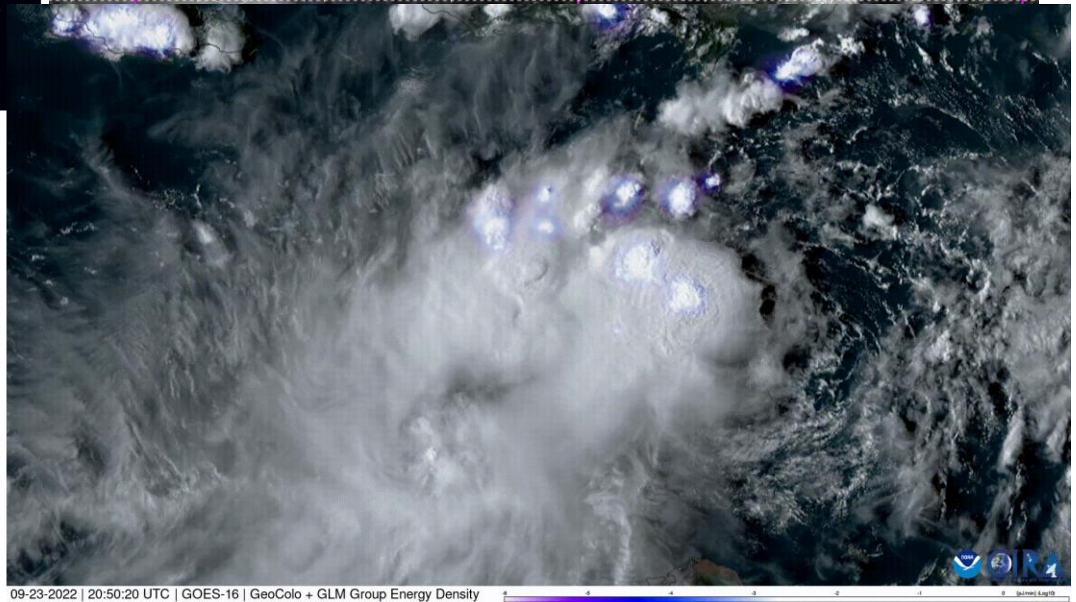






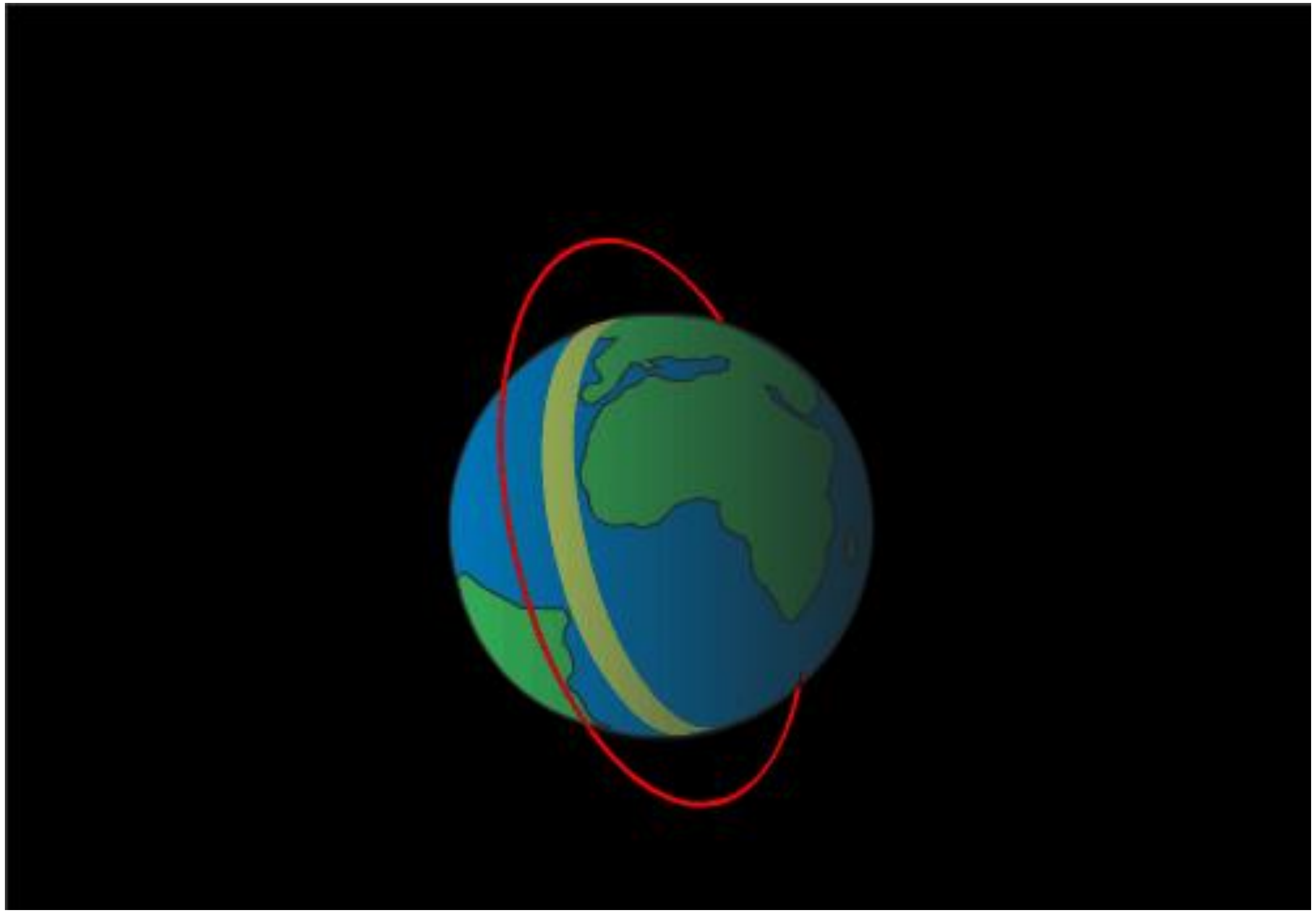


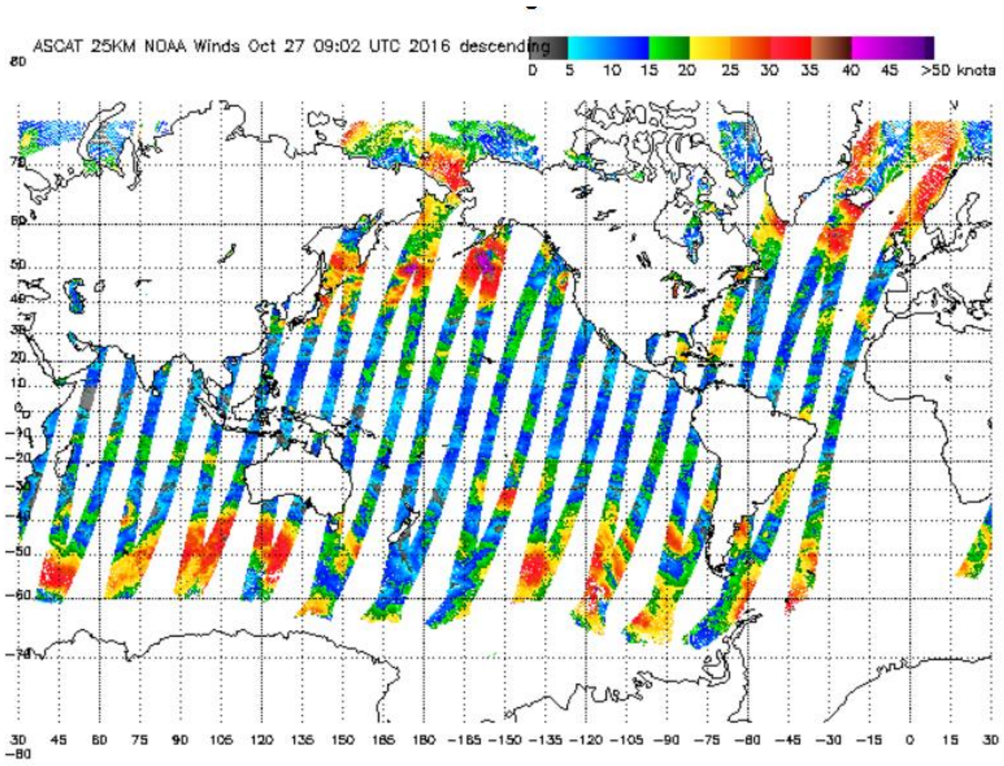


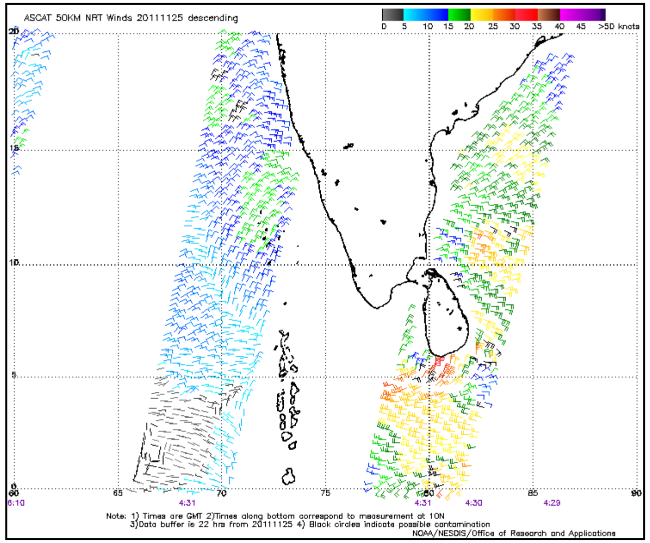


Geostationary orbit (GEO)

Satellites in geostationary orbit (GEO) circle Earth above the equator from west to east following Earth’s rotation –by travelling at exactly the same rate as Earth. This makes satellites in GEO appear to be ‘stationary’ over a fixed position. In order to perfectly match Earth’s rotation, the speed of GEO satellites should be about 3 km per second at an altitude of 35 786 km.

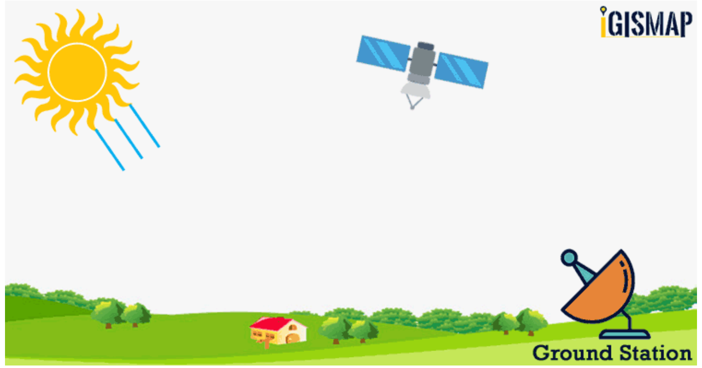


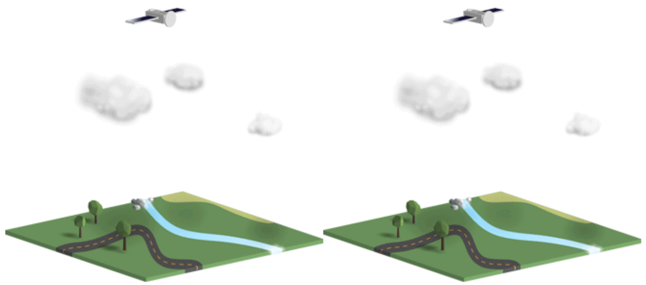




The Polar Orbiting satellite system offers the advantage of daily global coverage, by making nearly polar orbits 14 times per day approximately 850km above the surface of the Earth.

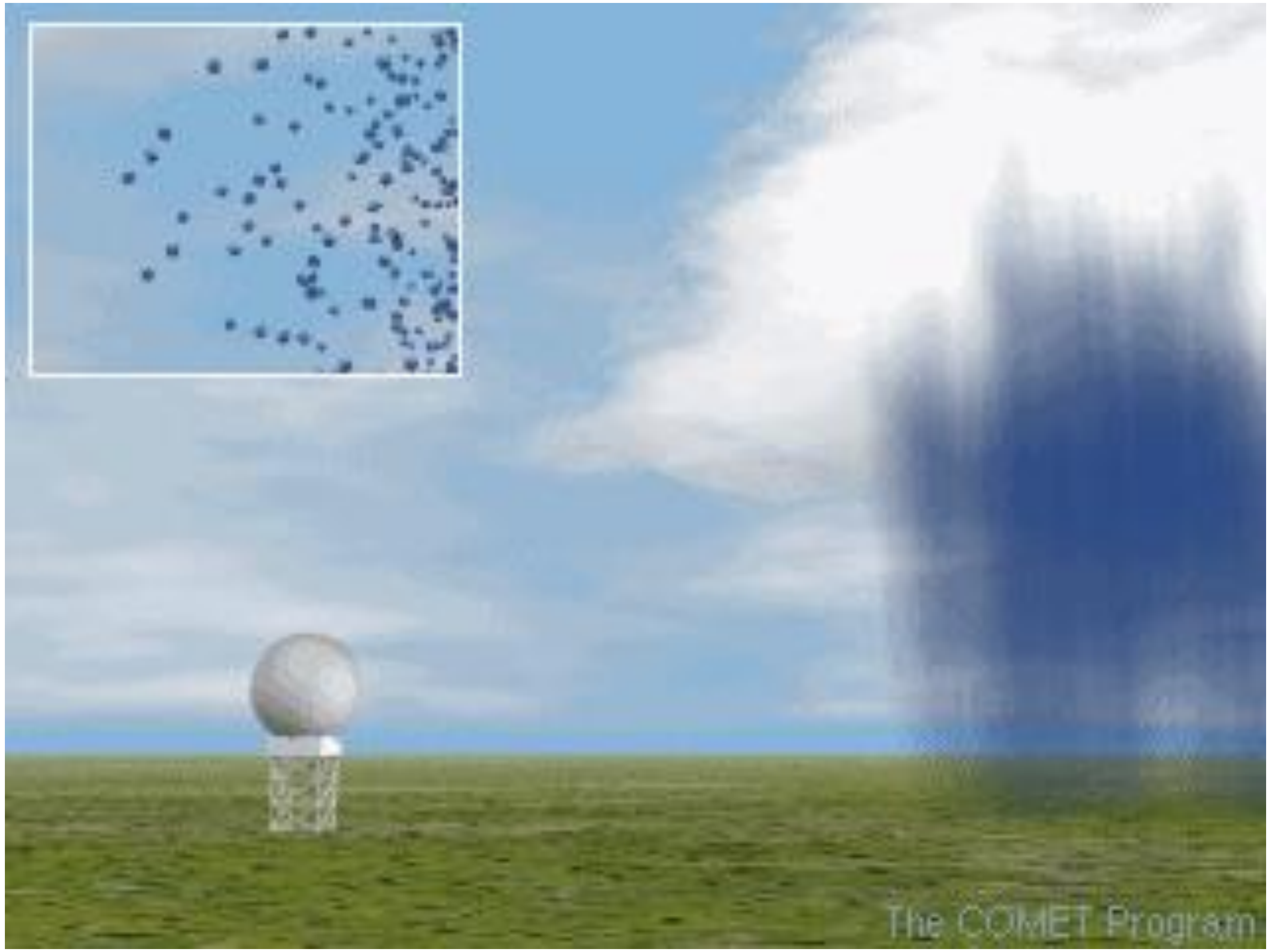
The Earth's rotation allows the satellite to see a different view with each orbit, and each satellite provides two complete views of weather around the world each day.



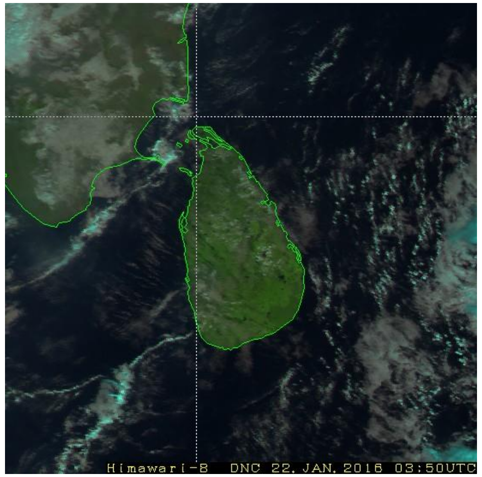


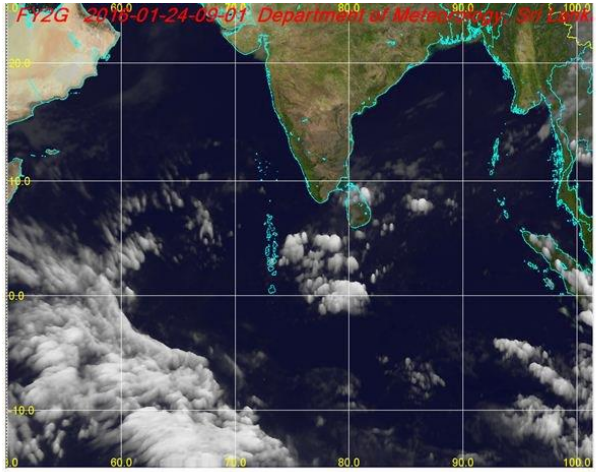
Passive | Sensors detect only what is emitted from the landscape, or reflected from another source (e.g., light reflected from the sun).

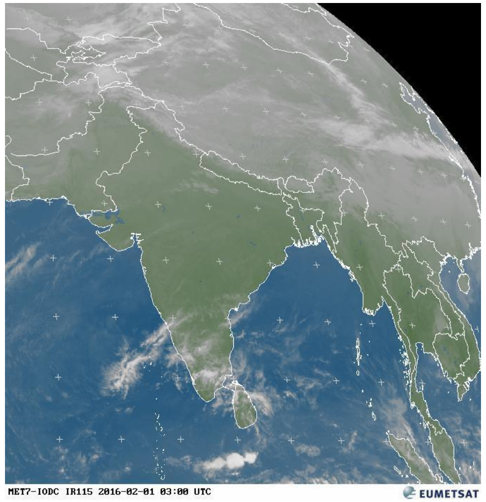
Active | Instruments emit their own signal and the sensor measures what is reflected back. Sonar and radar are examples of active sensors.

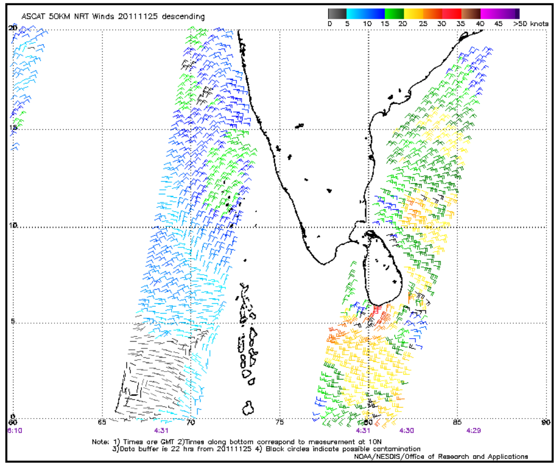


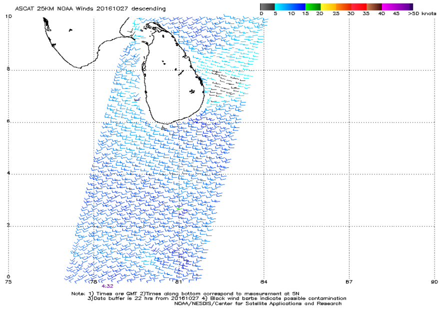
Satellite images (eg: Himawari 8,FY2G, ASCAT, ect.)

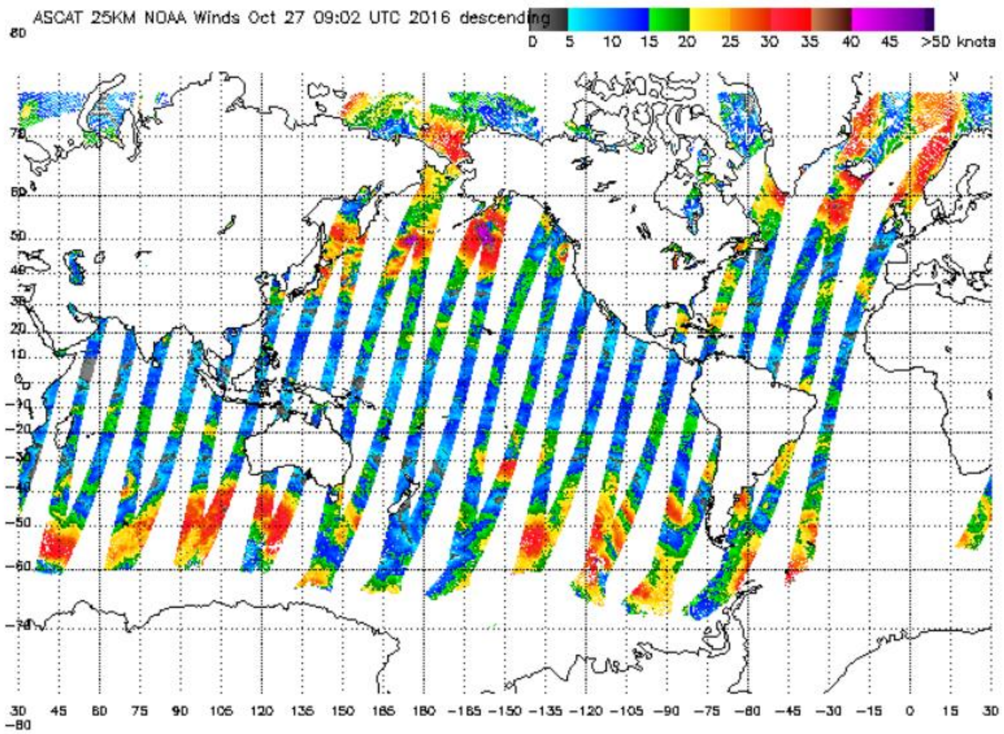




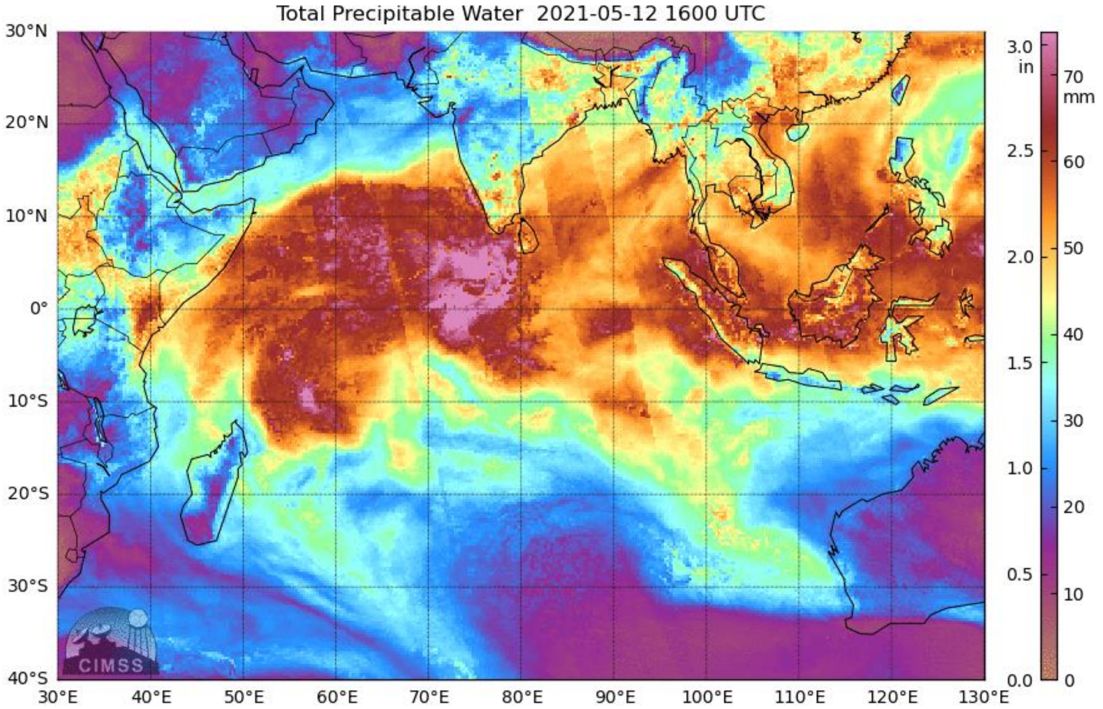


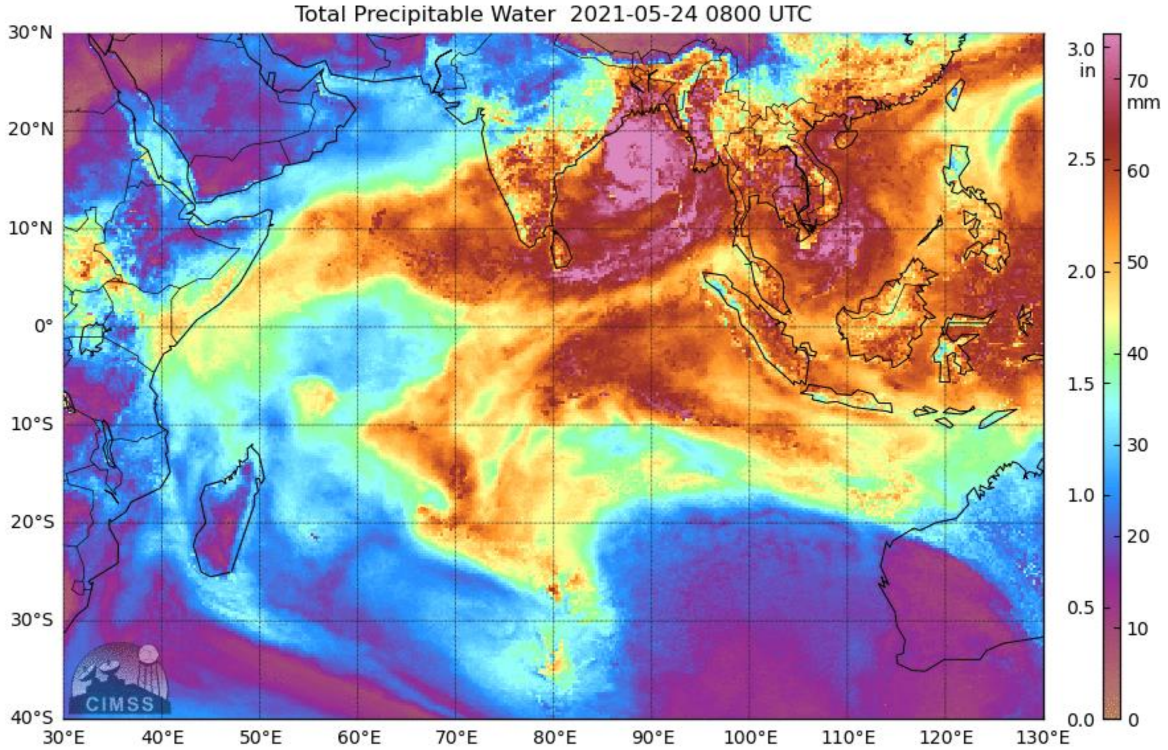


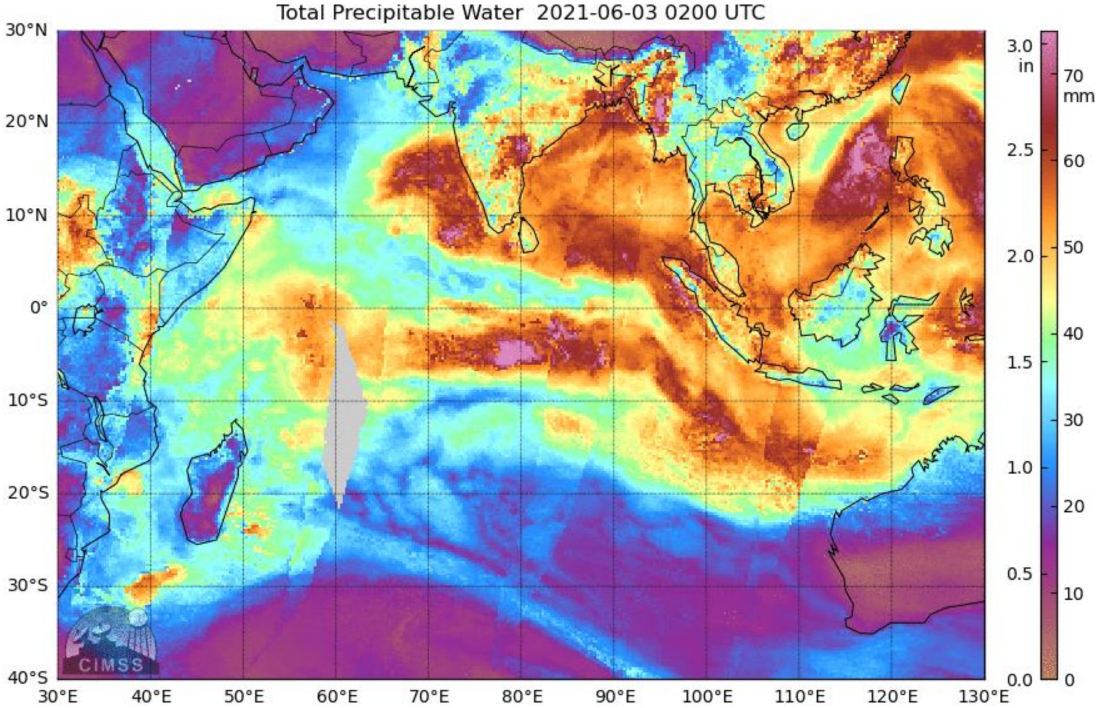




- Total precipitable water







Quality Control Strategies in Data Collection and Monitoring

Key WMO Standards for Surface Observation

Instrument Siting and Placement

General Guidelines:

- **Open Area:** Instruments should be placed in an open area, away from obstructions such as buildings, trees, and other structures to ensure free air flow and representative measurements.
- **Elevation:** Instruments should be mounted at standard heights above the ground (e.g., thermometers at 1.25 to 2 meters) to avoid ground heat and moisture interference.
- **Uniform Surface:** The ground surface around the instruments should be uniform and preferably covered with natural vegetation or grass to minimize heat reflection and absorption.

•No steeply sloping ground in the vicinity

Specific Instruments:

Thermometers: Placed in a ventilated shelter (e.g., Stevenson screen) at a height of 1.25 to 2 meters above the ground.

Anemometers: Positioned on masts or poles at a height of 10 meters above ground level in open terrain.

Rain Gauges: Positioned away from obstructions and mounted on a level platform to ensure accurate rainfall measurements.

Source : WMO 08 : Guide to Meteorological Instruments and Methods of Observation

VOLUME I	MEASUREMENT OF METEOROLOGICAL VARIABLES
Chapter 1	General
Chapter 2	Measurement of temperature
Chapter 3	Measurement of atmospheric pressure
Chapter 4	Measurement of humidity
Chapter 5	Measurement of surface wind
Chapter 6	Measurement of precipitation
Chapter 7	Measurement of radiation
Chapter 8	Measurement of sunshine duration
Chapter 9	Measurement of visibility
Chapter 10	Measurement of evaporation
Chapter 11	Measurement of soil moisture
Chapter 12	Measurement of upper-air pressure, temperature and humidity
Chapter 13	Measurement of upper wind
Chapter 14	Observation of present and past weather; state of the ground
Chapter 15	Observation and measurement of clouds
Chapter 16	Measurement of atmospheric composition
VOLUME II	MEASUREMENT OF CRYOSPHERIC VARIABLES
Chapter 1	General
Chapter 2	Measurement of snow
Chapter 3	Measurement of glaciers

VOLUME V	QUALITY ASSURANCE AND MANAGEMENT OF OBSERVING SYSTEMS
Chapter 1	Quality Management
Chapter 2	Sampling meteorological variables
Chapter 3	Data reduction
Chapter 4	Testing, calibration and intercomparison
Chapter 5	Training of instrument specialists

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Guide to Instruments and Methods of Observation (WMO-No. 8)

ACTIVITY AREAS (1)

Instruments and Methods of

PROCESS FOR UPDATING THE WMO-No. 8

Procedure for updating the Guide to Instruments and Methods of Observation (WMO-No. 8)

VOLUME III	OBSERVING SYSTEMS
Chapter 1	Measurements at automatic weather stations
Chapter 2	Measurements and observations at aeronautical meteorological stations
Chapter 3	Aircraft based observations
Chapter 4	Marine observation
Chapter 5	Special profiling techniques for the boundary layer and the troposphere
Chapter 6	Electromagnetic methods of lightning detection
Chapter 7	Radar measurements
Chapter 8	Balloon techniques
Chapter 9	Urban observations
Chapter 10	Road meteorological measurement
VOLUME IV	SPACE-BASED OBSERVATIONS
Chapter 1	Introduction
Chapter 2	Principles of Earth observation from space
Chapter 3	Remote-sensing instruments
Chapter 4	Satellite programmes
Chapter 5	Space-based observation of geophysical variables
Chapter 6	Calibration and validation
Chapter 7	Cross-cutting issues

Instrument Calibration and Maintenance

Calibration:

Regular Calibration: Instruments should be regularly calibrated against standard reference instruments to ensure their accuracy.

Traceability: Calibration procedures should be traceable to international standards, such as those maintained by the International Bureau of Weights and Measures (BIPM).

Maintenance:

Routine Inspection: Regular inspection and maintenance of instruments to ensure they are functioning correctly and free from damage.

Cleaning: Periodic cleaning of instruments to prevent dirt, dust, and other contaminants from affecting measurements.

Replacement: Timely replacement of worn-out or malfunctioning parts to maintain data quality.

QC Tests

For observations that are either fully or partially manually read, the following checks should be performed (a checklist might help ensure that these are carried out in a systematic manner):

- Consistency checks against other manual observations;
- Range and constraint checks against reasonable climatological norms;
- Consistency checks against the station record (the historical record for that station, including past extremes);
- Calculations on observations (such as the relative humidity computation);
- For manned sites, independent checks, which may be performed by the officer in charge or another observer

Table 1. Selected quality assurance and quality control tests and suggested importance

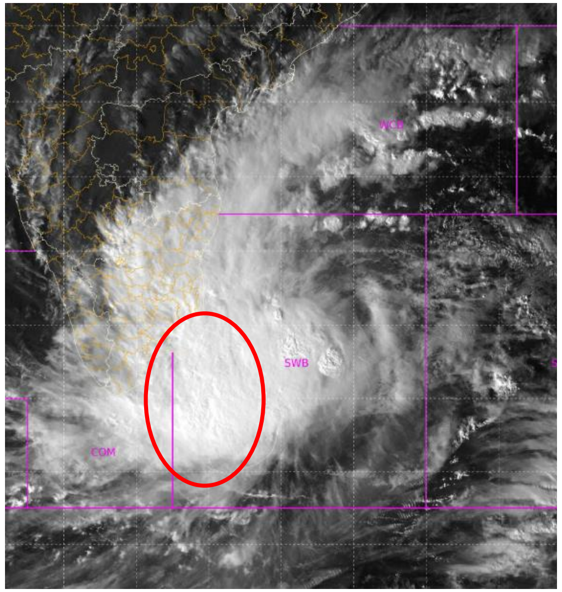
Legend: M = Mandatory, R = Recommended, O = Optional

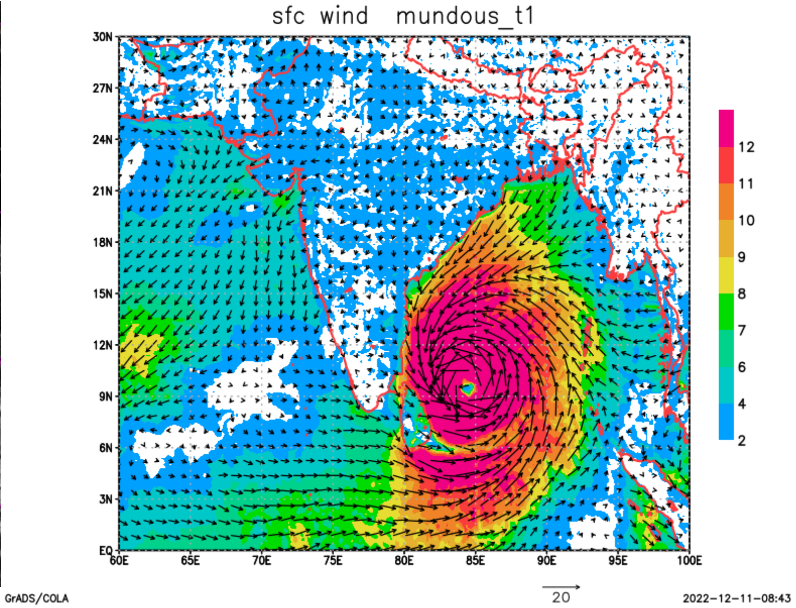
Constraint tests: Tests to ensure that observations are technically and scientifically plausible based upon theoretical and climatological limits, sensor hardware specifications or database limits on data ingestion.

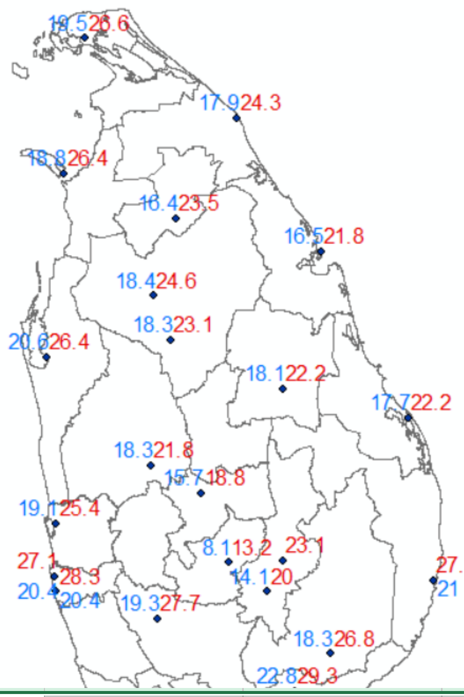
Name of test	*Short description*	*Notes*	*Suggested importance*
Sensor-based range test	Detects observations that are outside the range of theoretical limits or sensor hardware specifications		M
Database range test	Detects values that are outside the range of the ingestion criteria for the storage system	This test is carried out while the data are being ingested into the storage system.	M
Domain test	Determines whether the meteorological value is within the realm of scientific possibility, for example, T > 70 °C		M

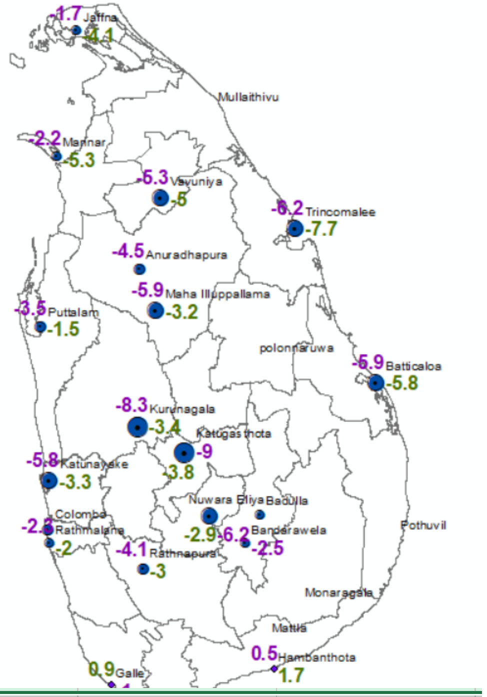
Consistency tests: Tests utilizing comparisons with other parameters to ensure that inconsistent, unlikely or impossible combinations are either rejected or flagged as suspect. A manual investigation may then assess the validity of the suspect values.

Name of test	*Short description*	*Notes*	*Suggested importance*
Sub-daily test	This test is conducted to determine whether there are consistencies between values recorded at sub-daily observations, for example, three-hourly observations, and daily values.		M
Daily minimum versus daily ground minimum test	Compares the daily minimum and daily ground minimum temperatures		O
Hourly MSLP and SLP difference test	Tests to determine whether there is a significant change in the difference between mean sea-level pressure (MSLP) and station-level pressure (SLP) over two consecutive recordings	This test can be performed using hourly, three-hourly, etc. observations.	O
Precipitation multi-source comparison test	Checks whether data from one source is consistent with data from another source	The data sources may be different instruments or the same instrument from different communication paths.	R
Zero precipitation spatial test	Checks for instances when significant precipitation is recorded at one site but not at neighbouring sites, and vice versa. Note that the experience of QC operators may be required here to ensure that neighbouring comparison stations are sufficiently representative of the climate in the area.	Typically, this indicates precipitation being recorded on the wrong day or that the value is an accumulated total.	M
Insufficient neighbours test	Checks whether there is a sufficient number of stations within a reasonable distance of the candidate station to perform spatial tests	This test is generally performed on the first day of the month and for precipitation data.	R
Precipitation period test	Tests for overlap and underlap of rainfall accumulations (to check whether the period value of the record is inconsistent with the actual null precipitation reported dates)	Designed for rainfall precipitation records	R
Tracking test	Compares whether two or more elements, or instances of the same element at two neighbouring stations, rise and fall together	The two elements are expected to rise and fall together. This test is a very effective means of determining whether values should be rejected or flagged as suspect.	R
Maximum (minimum) air temperature consistency test	Checks for consistency between daily maximum (minimum) air temperature and sub-daily observations	This is an extension of the sub-daily tests referred to above.	R









Sheared intense thick cloud to the west and southwest of the center of Mandous shielded Sri Lanka from 07th onwards blocking incoming solar radiation for 3 days from 07th experiencing significantly below normal day/night temperatures from 07th to 09th.

Trincomalee station experienced minimum temperature of 16.5^{0}C on 09th , which is the lowest ever recorded night temperature at Trincomalee

	8Max	8Min		8Max	8Min
Nuwara Eliya	13.2	8.1	Katugastota	-9.0	-3.8
Katugasthota	18.8	15.7	Kurunegala	-8.3	-3.4
Bandarawela	20.0	14.1	Nuwara Eliya	-6.2	-2.9
Trincomalee	21.8	16.5	Trincomalee	-6.2	-7.7
Kurunagala	21.8	18.3	Batticaloa	-5.9	-5.8
Batticaloa	22.2	17.7	Maha Iluppalla	-5.9	-3.2
polonnaruwa	22.2	18.1	Katunayake	-5.8	-3.3
Badulla	23.1	15.1	Vavuniya	-5.3	-5.0
Maha Illuppallama	23.1	18.3	Anuradhapura	-4.5	-3.5
Vavuniya	23.5	16.4	Rathnapura	-4.1	-3.0
Mullaithivu	24.3	17.9	Puttlam	-3.5	-1.5
Anuradhapura	24.6	18.4	Colombo	-3.2	-2.4
Katunayake	25.4	19.1	Bandarawela	-2.5	-1.2
Mannar	26.4	18.8	Rathmalana	-2.3	-2.0
Puttalam	26.4	20.6	Badulla	-2.3	-3.4
Jaffna	26.6	19.5	Mannar	-2.2	-5.3
Monaragala	26.8	18.3	Jaffna	-1.7	-4.1
Colombo	27.1	20.4	Galle	-1.0	0.9
Pothuvil	27.1	21.0	Hambantota	0.5	1.7

Tracking test	Compares whether two or more elements, or instances of the same element at two neighbouring stations, rise and fall together	The two elements are expected to rise and fall together. This test is a very effective means of determining whether values should be rejected or flagged as suspect.	R

The file mystation_duplicates.csv includes all dates which appear more than once in a datafile. In the listing below, one can see that 1958/08/26 occurs twice, and thus will be reported in mystation_duplicates.csv.

1951 8 24
1951 8 25
1951 8 26
1951 8 26
1951 8 28
1951 8 29
1951 8 30
1951 8 31

mystation_toolarge.csv

The file mystation_toolarge.csv reports precipitation values exceeding 200 mm (this and any other threshold can be easily reconfigured before execution) and temperature values exceeding 50 ºC.

mystation_tx_jumps.csv

mystation_tn_jumps.csv

The files mystation_tx_jumps.csv and mystation_tn_jumps.csv will list those records where the temperature difference with the previous day is greater or equal than 20 ºC.

mystation_tmaxmin.csv

The mystation_tmaxmin.csv file, records all those dates where maximum temperature is lower than minimum temperature.

mystation_temp_nastatistics.csv

Common Errors

- Inadequate Data Validation,
- Inconsistency In Data Collection Methods,
- Lack Of Standardized Metrics For Comparison,
- Insufficient Stakeholder Engagement, And
- Failure To Incorporate Feedback Loops.

errors are related to the design and implementation of the monitoring and evaluation (M&E) system,

These errors can be avoided or minimized by following good practices and principles for M&E, such as relevance, effectiveness, efficiency, equity, and learning.

- Biased Sampling,
- Inaccurate Data Entry,
- Insufficient Sample Size,
- Typo And Human Errors,
- Misinterpretation Of Data,
- Loss Of Data Due To Technical Issues, And
- Confirmation Bias.

Other errors are related to the data collection and analysis process

These errors can be reduced or eliminated by using appropriate methods and tools for data collection and analysis, such as surveys, interviews, focus groups, observations, experiments, statistical tests, and software applications5.

Quality control for adaptation monitoring is important because it can help to ensure the validity and credibility of the data and information generated, which can then be used to inform decision making, improve adaptation planning and implementation, and demonstrate results and impacts. Therefore, it is essential to avoid or correct the common errors that can compromise the quality of the M&E system and the data and information it produces.

Improving Data Accuracy and Reliability

- These errors can significantly impact the reliability and validity of the collected data, leading to incorrect conclusions and decisions.

- Addressing these errors is crucial for improving the accuracy and reliability of monitoring efforts.

  - Effective training and standard operating procedures play a crucial role in minimizing errors.

  - Rigorous quality control checks, including data validation and verification processes, further enhance accuracy.

  - Utilizing technology for data backup ensures data integrity and prevents loss.

  - Implementing unbiased data collection and analysis methods helps maintain reliability.

Thank you