

The Abdus Salam
International Centre for Theoretical Physics

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WEATHER TELECOMMUNICATIONS AND DEVELOPING COUNTRIES

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Lecture 1

I. INTRODUCTION

What is the weather forecast for today?
How did you find out?

[Newspaper, TV, Radio, Internet, e-mail, short message services (SMS), etc] How simple!

In most countries, weather forecasts are counted as the most popular of broadcast programmes.

Do you know the effort, expense and technology that are put in to prepare a forecast?

Weather does not recognize any political boundaries. But the world operates through nearly 200 political divisions, called states or countries.

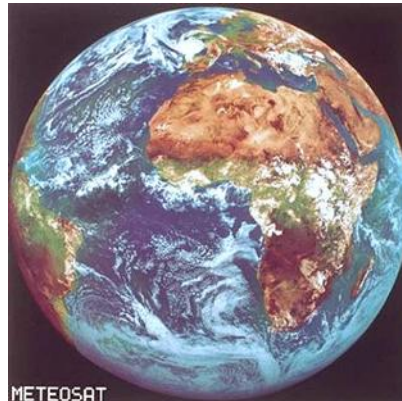
To make today's forecast required the effort and cooperation of all these countries.

Before we started using automatic measuring instruments, advanced telecommunications and satellite measurements and imagery we could not forecast reliably for more than 3 days in advance. [Now over most regions seven-day forecasts have the reliability of the three-day predictions 30 years ago.]

Other than the public, who else uses weather forecasts?

Prompt and accurately weather and forecast services are tailored to aviation, shipping, transport on land and inland waters, air pollution monitoring and research, climate change studies, ozone layer depletion surveillance and above all, to mitigation of damage caused by natural and accidental disasters.

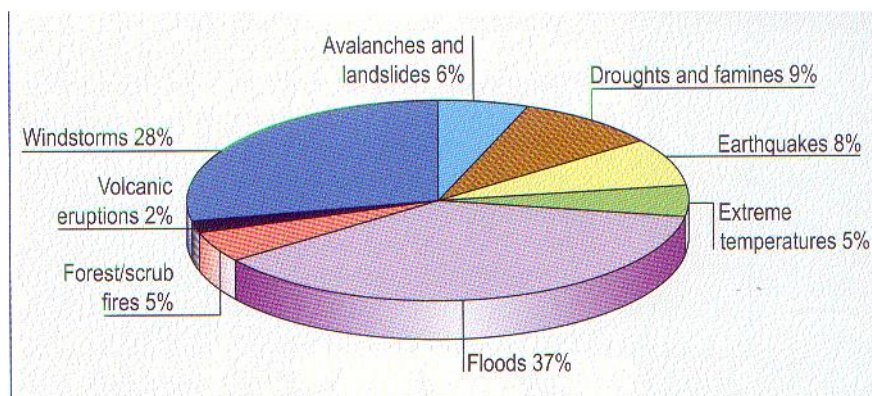
Atmosphere and earth surface form one entity – extremely complex and highly dynamic. An enormous amount of data and information has to be collected continuously, day and night.



The collected information must be processed and disseminated to all users. For this you need a reliable telecommunication system.

Lecture 1 – Weather Telecommunications and developing countries.

Almost 90% of the natural disasters have their origin in weather and climate.



Lecture 2 – Disaster Preparedness and Telecommunications

2. WHAT IS REQUIRED FOR WEATHER FORECASTING?

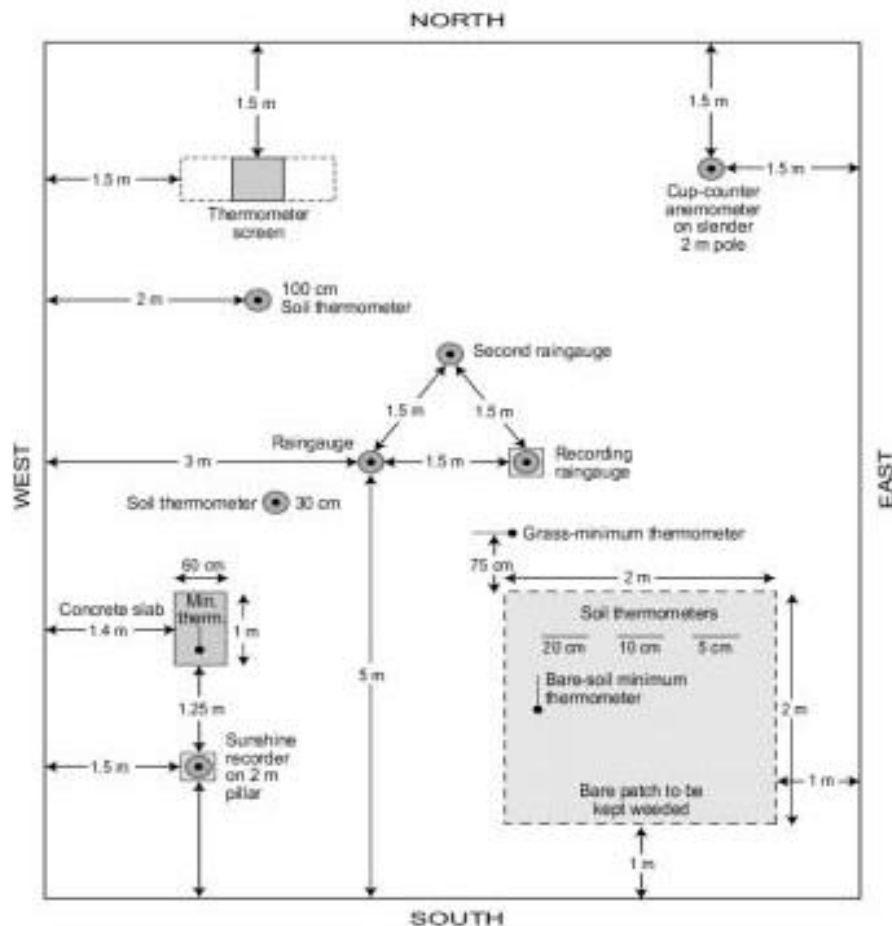
Important note: 75% of the earth surface is oceans and ice caps. Naturally our observation networks are concentrated on land surfaces.

Mainly National Meteorological and Hydrological Services (NMHSs) make weather observations. But with space-based satellite stations international organizations now play a vital role.

2.1 LAND-BASED STATIONS

http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/Draft%207th%20edition/Part2-Ch01FinalEDITED_Corr.pdf

2.1.1 Standard set of elements for measuring



Pressure	Air Temperature
Dew point	Wind speed
Maximum gust speed	Wind direction
Visibility	Cloud type
Cloud amount	Cloud height
Radiation	Rain
Snow	Humidity

The instrument measuring each of these elements is different and the accuracy varies considerably. For example, **Rainfall** and **Snow** are the most difficult to measure. If an accuracy of 5% to 10% could be attained it would be considered excellent.

2.1.2 Types of sensors

Analogue sensors: commonly sensor output is in the form of voltage, current, charge, resistance, or capacitance. Signal conditioning converts these basic signals into voltage signals.

Digital sensors: sensors with digital signal outputs with information contained in a bit or group of bits, and sensors with pulse or frequency output.

'Intelligent' sensors/transducers: sensors including a microprocessor performing basic data acquisition and processing functions and providing an output in serial digital or parallel form.

2.1.3 Automatic Weather Station (AWS)

a. Real-time AWS: A station providing data to users of meteorological observations in real time, typically at internationally agreed/programmed times, but also in emergency conditions (e.g. storm warning, river food) or upon external request.

b. Off-line AWS: A station recording data on site on internal or external data storage devices eventually combined with a display of actual data (e.g. a climatological station). The intervention of an observer is required to send stored data to the remote data user.

The core of an AWS is a **central processing unit (CPU)**. In general, the main functions of the CPU are data acquisition, data processing, data storage, and data transmission.

The rapid technological evolution opens new ways for meteorological applications. The high degree of input/output modulation and flexibility, the drastically increased operating speed of microprocessors and, in particular, the availability of dedicated data acquisition, process control, and transmission software makes an AWS quickly out of date. An AWS to function correctly requires

signal conditioning for preventing unwanted external sources of interference from influencing the raw sensor signals.

- Unwanted noise
- Surge protection
- Pre-amplify low-level signals
- Digital isolation
- Analogue isolation
- Undesirable signals filtering

System software and application software are expensive parts of AWS

[For detailed information on raw electrical signal conversion to meteorological data, calibration, quality control, data reduction, message coding, intra-sensor checks see:

http://www.wmo.int/pages/prog/www/IMOP/publications/CIMO-Guide/Draft%207th%20edition/Part2-Ch01FinalEDITED_Corr.pdf]

2.1.4 Data transmission

The data transmission part of the CPU forms the link with the 'outside world'.

Power supply:

Real-time clock:

Built-in test equipment:

Local display and terminals

3 modes of transmission between an AWS and either local users or the central network processing system:

(a) In response to external commands - the most common basic mode

(b) At periodic time intervals controlled by the AWS time scheduler;

(c) In emergency conditions when certain meteorological thresholds are crossed.

Some telecommunications options for an AWS network:

ONE-WAY COMMUNICATIONS: time cycle or triggered

TWO-WAY COMMUNICATIONS: synoptic time and random access.

2.1.5 Meteorological telecommunication network

- a. **Landline and/or radio communications:** public service or dedicated leased 'private network'
- b. Many telecommunications authorities offer an **Integrated Service Digital Network (ISDN)** that provides for voice, data and video transmission with pulse-code modulation (PCM) over upgraded public switched telephone network cables and switches. A basic channel provides for 64 kbps data, which may carry X.25 packet switch or frame relay protocols. The digital circuits provide very high data security.
- c. **Wide area network communications (WAN):** With the worldwide increase in data traffic and the use of modern communications protocols, together with the increased computing and data storage capability at remote terminals, **it is now common to view the remote AWS and the central control and data acquisition computer as nodes of a wide area network (WAN)**. The data or control message is divided into 'packets' according to rules (protocols) like X.25 or the faster *frame relay*. Each data packet is routed through the telecommunications provider's switched data network and may arrive at the destination by different routes. Circuit-switching is ideal when real-time data (like live audio and video) must be transmitted fast and arrive in the same order in which it is sent. Packet switching is more efficient and robust for data that can withstand some short delay in transmission. Message costs are related to connect time and data volume.
- d. **Frame relay and ATM.** Frame relay is a packet-switching, networking protocol for connecting devices on a WAN, operating at data speeds from 64 kbps to 2 Mbps or higher. Unlike a point-to-point private line, there is network switching between the AWS and the central station. In fact there is a private line to a node on the frame relay network, and the remote location gets a private line to a near-by frame relay node. The user gets a 'virtual private network'. Costs are decreasing and are independent of the volume of data or time connected. However, frame relay is being replaced in some areas by newer, faster technologies, such as **asynchronous transfer mode (ATM)**. The ATM protocol attempts to combine the best of both worlds — the guaranteed delivery of circuit-switched networks and the robustness and efficiency of packet-switching networks.
- e. **Transmission protocol:** A de facto standard for transmission between computers over networks is **Transmission Control Protocol/Internet Protocol (TCP/IP)**. The **Internet Protocol (IP)** specifies the format of packets (datagrams).

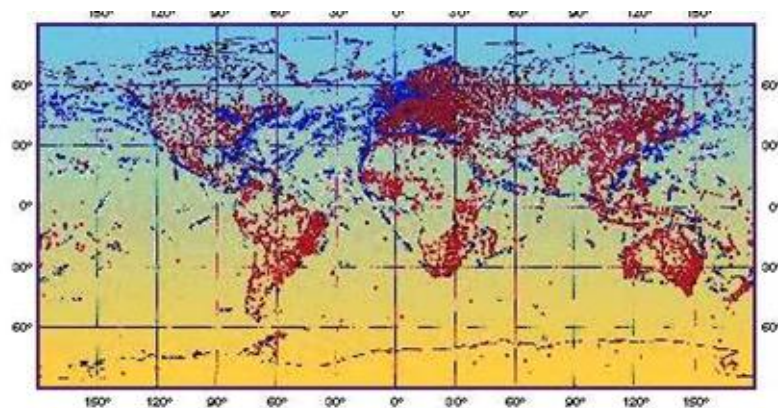
The higher level protocol TCP establishes a virtual connection between source and destination so that two-way data streams may be passed for a period of time and that datagrams are delivered in correct sequence with error correction by retransmission. TCP also handles the movement of data between software applications. The functioning of the Internet is based on TCP/IP protocols, and IP is also used in WANs where the nodes have processing capability and high volumes of data are exchanged over the network.

- f. *Switched or dedicated circuits:* A decision will have to be made whether to use cheaper switched data circuits where telecommunications network access has to be shared with other users, or whether to lease much more expensive dedicated circuits that provide reliable, high speed, real-time communications. Local telecommunications companies readily offer guidance in the choice of their services.

2.2 How many land-based stations?

About 11,000 stations send out at least every 3 hours and often hourly observed weather data.

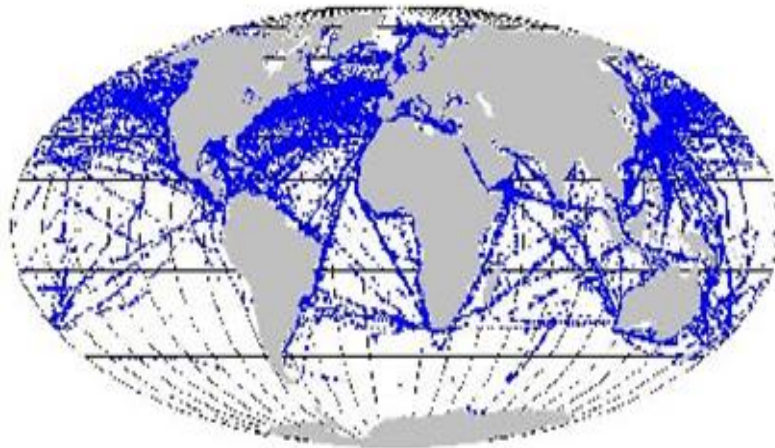
Some 4000 of these stations comprise the Regional Basic Synoptic Networks. Data from these stations are exchanged globally and in real time.



MARINE OBSERVATIONS

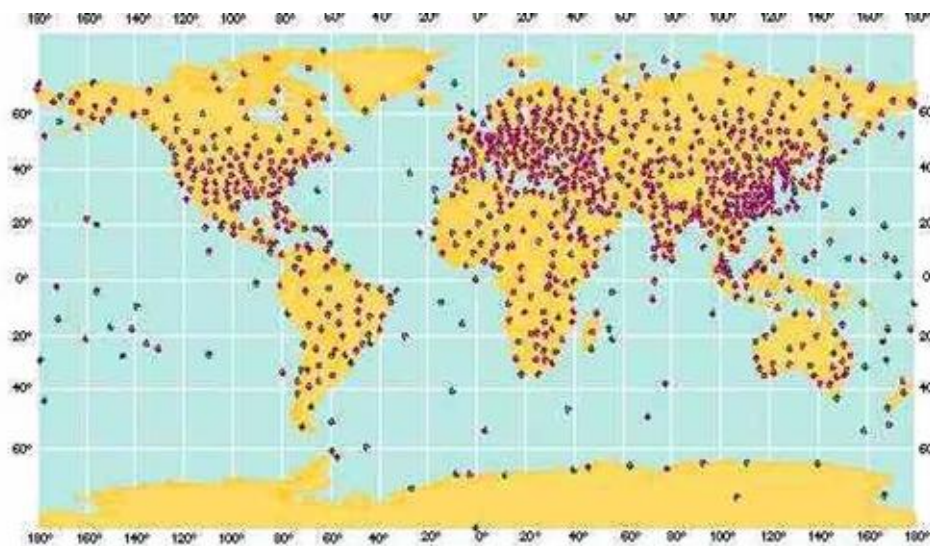
The number of observing ships is about 7,000. About 40% are at sea at any given time.

900 drifting buoys provide 12,000 reports per day



UPPER AIR MEASUREMENTS (BALLOON TECHNIQUES)

Roughly 900 upper-air stations, radiosondes attached to free rising balloons make measurements to heights of up to 30km.

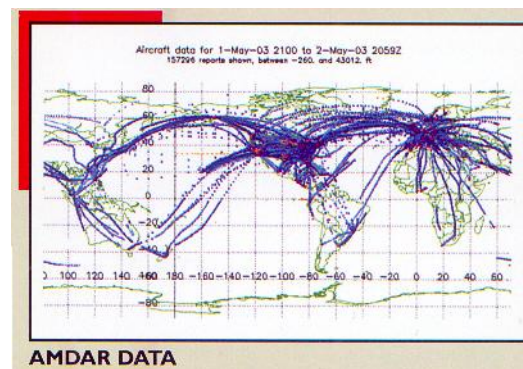


MEASUREMENTS AND OBSERVATIONS AT AERONAUTICAL STATIONS

Every airport has one or more meteorological station tailored for aviation. Most of them are also equipped to measure other weather and pollution related elements.

AIRCRAFT OBSERVATIONS

Over 3000 aircraft provide high quality reports of pressure, winds and temperature at cruising level as well as at selected levels in ascent and descent. Reports have increased dramatically - from 78,000 in 2000 to 300,000 reports in 2005



SATELLITE OBSERVATIONS:

The global requirements could be met by an adequate network of about 5 000 conventional stations, preferably regularly distributed all over the globe, [each measuring the pressure at the surface as well as the wind, temperature, and humidity at many levels, from the surface to 50 hPa, two to four times each day]. However, ocean areas cannot sustain such a network, and the cost of such a network would be of the order of **US\$ 10 billion**. In this respect, the role of satellites has become important.

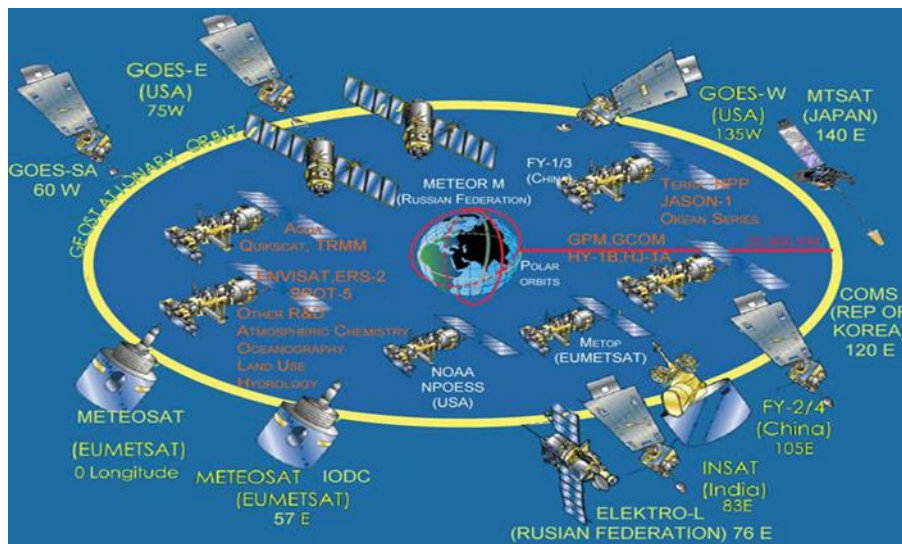
16 satellites -Typical meteorological satellites orbit the Earth at elevations of about 36 000 km or about 850 km, and they are used to obtain both images and quantitative information about surface features and about the lowest 20 km of the atmosphere. This, of course, requires very sensitive instrumentation and data processing

and very expensive systems, but the cost is justified by the quantity and quality of the data obtained

Meteorological quantities which are measured operationally with satellites at present, with varying resolution and accuracy, include:

- (a) The temperature profile, and the temperature at the cloud top and at the surface of the sea and land;
- (b) The humidity profile;
- (c) The wind at cloud level and at the ocean surface;
- (d) Liquid and total water and precipitation rate;
- (e) Net radiation and albedo;
- (f) Cloud type and height of top (visible and infrared images);
- (g) Atmospheric chemistry and total ozone;
- (h) Stratospheric temperature
- (i) The coverage and the edge of ice and snow
- (j) Earth's radiation budget.

The space-based subsystem of the Global Observing System



Data, information and imagery provided by satellite stations have proved invaluable for generating modern reliable weather forecasts that one sees on TV or Internet.

RADAR MEASUREMENTS (ground)

Mainly land-based radars are used to observe frontal activities and estimate quantitative precipitation forecast (QPF) that a storm might produce. They are essential for the operation of water reservoirs and flash flood forecasting in certain river basins.

URBAN OBSERVATIONS: Radiation, Wind flux, sunshine duration, evaporation, soil moisture, soil temperature, atmospheric composition,

3. *ROLE OF NATIONAL METEOROLOGICAL AND HYDROLOGICAL SERVICES (NMHSS)*

http://www.wmo.int/pages/governance/policy/ec_statement_nmhs_en.html

NMHSSs are continuously monitoring the environment through observations of the Earth system and predicting changes in this system. They provide governments with timely and precise warnings of most potential natural hazards and contribute essential environmental information and services for urban planning, sustainable energy development, access to freshwater, and food production.

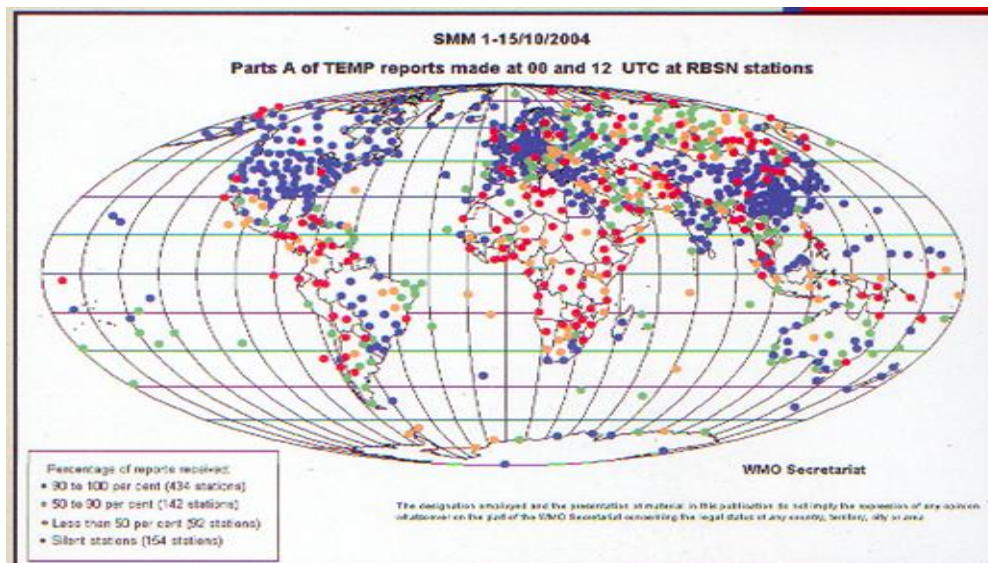
- From the beginning, NMHSSs are obliged to equip themselves with the latest technologies for measuring instruments, data collection and processing, telecommunications, information dissemination, atmospheric modelling and research.
- The first non-military use of the most powerful computers was by NMHSSs (CRAY).
- The first major non-military use of satellites was for telecommunications and meteorology.

While the NMHSSs of developing countries have kept up pace with the use of the latest technologies, the developing countries especially in Africa have not been able to do so. WHY?

STATUS OF WEATHER DATA COLLECTION AND EXCHANGE (1997)			
(Source: WMO)			
REGION	No. of reports required	% expected	% received
Africa	2484	84	45
Asia	4752	96	81
South America	1744	78	48
N & Central America	2328	90	71
SW Pacific	1624	63	51
Europe	2728	98	90
TOTAL	15660	88	69

NMHSs are usually financed by Governments from taxes. Until recently these services did not produce revenues. Therefore they do not get priority in government budgeting. It is the international commitment that allows them to survive. Moreover other government departments are quite jealous of the relative technological advance of NMHSs. "They already have enough"!

Red dots show lack of upper-air temperature data. Note Africa



4. WORLD WEATHER WATCH (WWW)

To predict the weather, modern meteorology depends upon near instantaneous exchange of weather information across the entire globe.

WORLD WEATHER WATCH

- [Global Observing System \(GOS\)](#)
- [Global Telecommunication System \(GTS\)](#) and
- [Radio Frequency Coordination \(RFC\)](#)
- [Global Data-processing and Forecasting System \(GDPFS\)](#)

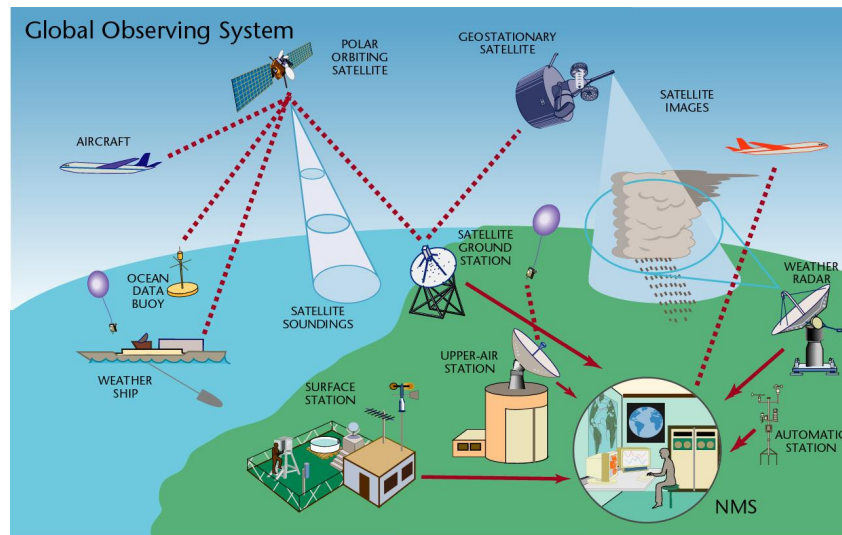
The World Weather Watch (WWW), the core of the World Meteorological Organization (WMO) Programmes, combines observing systems, telecommunication facilities, and data-processing and forecasting centres - operated by Members (countries) - to make available meteorological and related geophysical information needed to provide efficient services in all countries.

The WWW is a unique achievement in international cooperation: in few other fields of human endeavour, and particularly in science and technology, is there - or has there ever been - such a truly world-wide operational system to which virtually every country in the world contributes, every day of every year, for the common benefit of mankind.

4.1 The Global Observing System (GOS)

GOS provides from the Earth and from outer space observations of the state of the atmosphere and ocean surface for the preparation of weather analyses, forecasts, advisories and warnings, for climate monitoring and environmental activities carried out under programmes of WMO and of other relevant international organizations. It is operated by National Meteorological Services, national or international satellite agencies, and involves several

consortia dealing with specific observing systems or specific geographic regions



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FORECASTS - ADVISORIES - WEATHER ANALYSES - WARNINGS

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4.2. Global Telecommunication System (GTS)

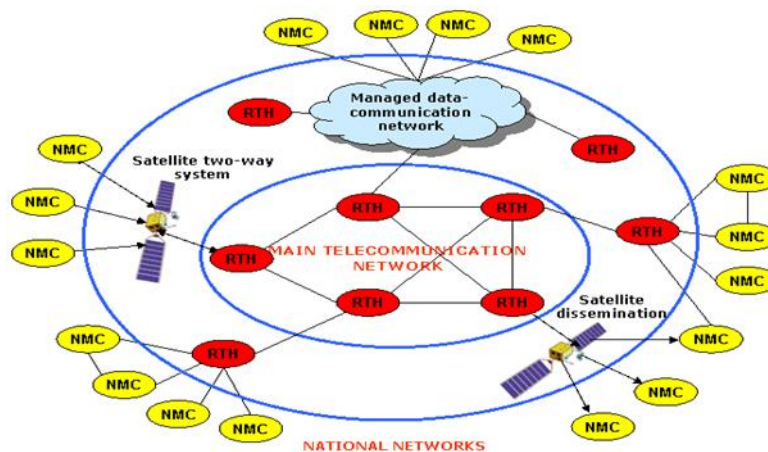
GTS is a co-coordinated global system that consists of an integrated network of

- point-to-point circuits,
- point-to-multi-point circuits for data distribution,
- multi-point-to-point circuits for data collection,
- as well as data-communication network services.

These circuits are composed of a combination of terrestrial and satellite telecommunication links.

GTS is implemented and operated by National Meteorological Services and also a few International Organizations (ECMWF, EUMETSAT).

THE GLOBAL TELECOMMUNICATION SYSTEM (GTS): An integrated network of point-to-point circuits, and multi-point circuits which interconnect meteorological telecommunication centres and some International Organizations (ECMWF, EUMETSAT).



The GTS is organized at three levels:

The GTS is organized on a three level basis, namely:

1. The Main Telecommunication Network ;
2. The Regional Meteorological Telecommunication Networks;
3. The National Meteorological Telecommunication Networks ;

THE MAIN TELECOMMUNICATION NETWORK (MTN):The MTN is the core network linking together three World Meteorological Centres (WMCs) and 15 Regional Telecommunication Hubs (RTHs):

WMCs: Melbourne, Moscow and Washington;

RTHs: Algiers, Beijing, Bracknell, Brasilia, Buenos Aires, Cairo, Dakar, Jeddah, Nairobi, New Delhi, Offenbach, Toulouse, Prague, Sofia and Tokyo.

National Meteorological Telecommunication Networks (NMTNs)

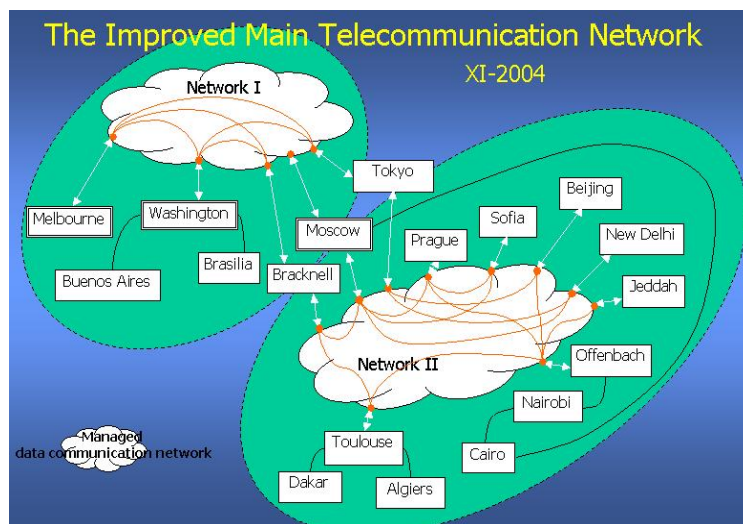
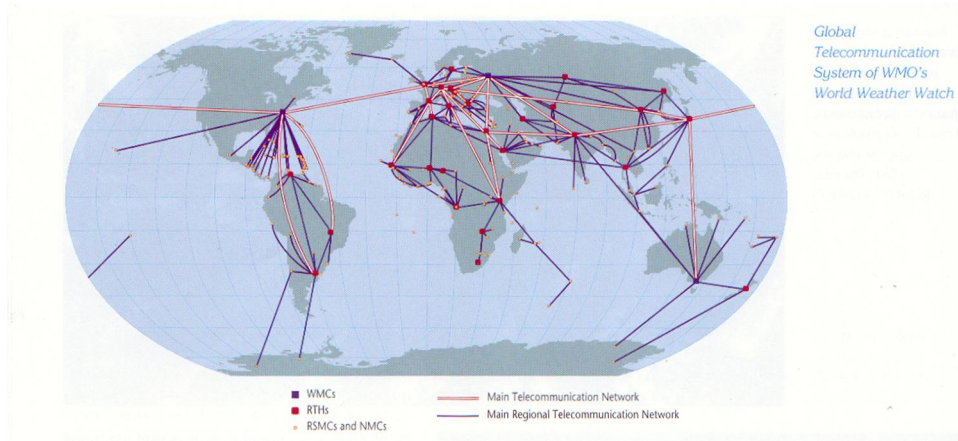
The NMTN enables the National Meteorological Centres to collect observational data and to receive and distribute meteorological information on a national level.

Satellite-based data collection and/or data distribution systems are integrated in the GTS. Data collection systems operated via geostationary or near-polar orbiting meteorological/environmental satellites, including ARGOS, are widely used for the collection of observational data from Data Collection Platforms. Marine data are also collected through the International Maritime Mobile Service and through INMARSAT. International data distribution systems operated either via meteorological satellites or via telecommunication satellites are efficiently complementing the point-to-point GTS circuits. Several countries use satellite-based telecommunication systems for their national Meteorological Telecommunication Networks.

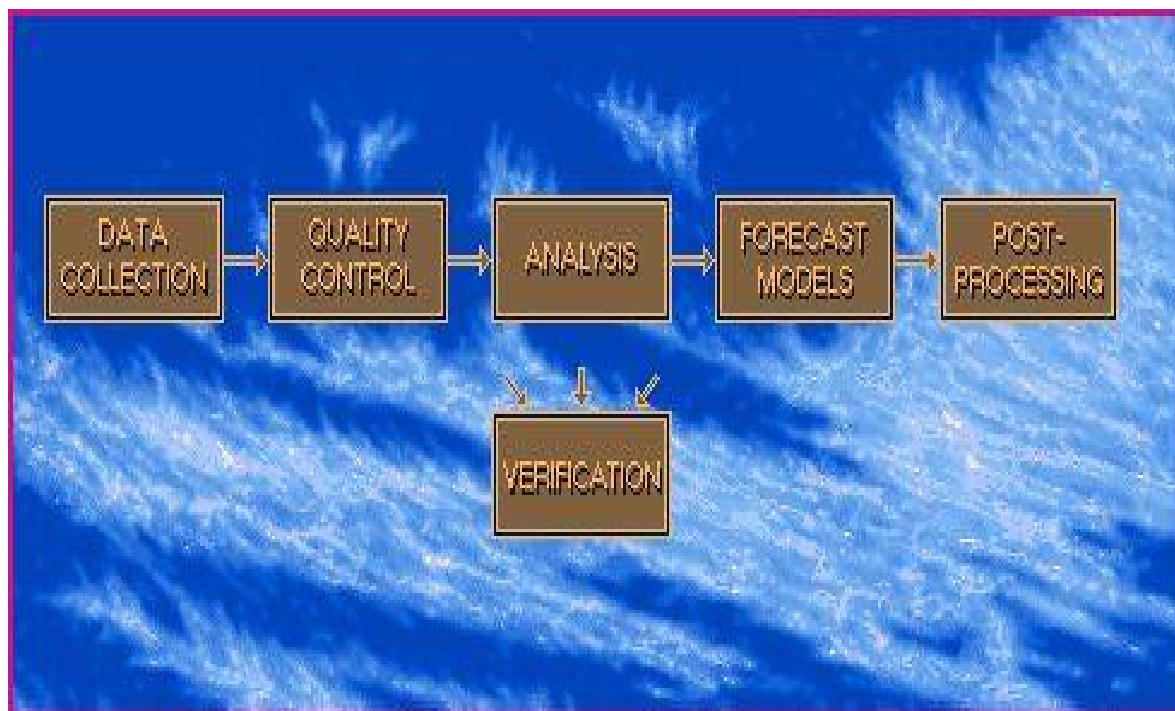
Regional Meteorological Telecommunication Networks (RMTNs)

Six Regional Meteorological Telecommunication Networks (RMTNs)

	Point-to-Point	Point-to-Multipoint
Africa	[GIF] [PPT]	[GIF]
Asia	[GIF] [PPT]	[GIF]
South America	[GIF] [PPT]	
North America, Central America & the Caribbean	[GIF] [PPT]	
South-West Pacific	[GIF] [PPT]	[GIF]
Europe	[GIF] [PPT]	[PPT]



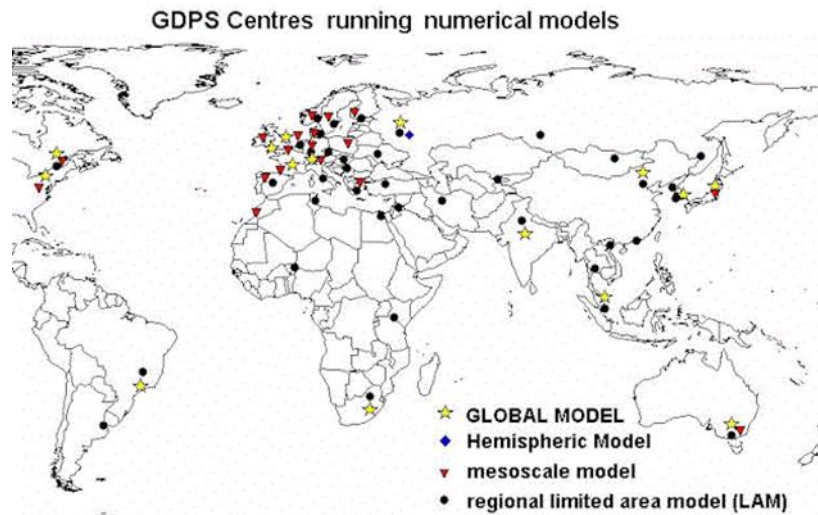
4.3 THE GLOBAL DATA-PROCESSING AND FORECASTING SYSTEM Numerical Weather Prediction (NWP)



Telecommunications have permitted us collect information, process it, analyze it, and use it in global, regional, national and local scales models to generate weather and climate forecasts of many ranges from NOWCASTING to A FEW HOURS, to ONE DAY, to 3 DAYS to WEEKS and MONTHS. They can be for specific purposes such as typhoons, storms, agriculture, tourism, disaster preparedness. Global-scale models for NWP have been developed mainly by advanced countries, some through regional institutions such as the European Centre for Medium-Range Weather Forecasts located in the UK. Many other countries are actively using region-scale models.

Models are interconnected and the products are available online to every person who can access Internet. The amount of information – data and imagery that is transmitted is mind boggling. The human

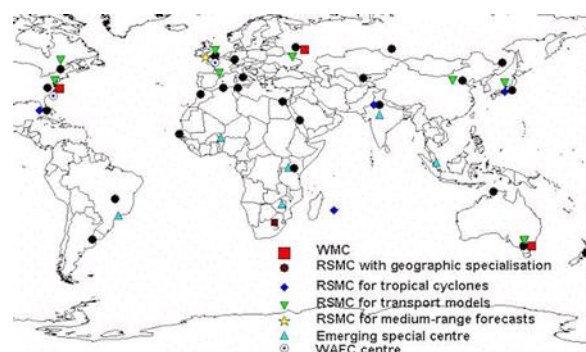
effort that goes to make it accurate is enormous. All developing countries could benefit more from these products if they had the means to apply them to various economic sectors.



What is the weather in Melbourne, Australia? You may wish try it out the system at:

<http://www.wmo.int/pages/prog/www/DPS/gdps-2.html#centres>.

World and Regional Meteorological Centers



5. OPPORTUNITIES

Hardly 15 years ago a meteorological technician or observer walked kilometres or rode a bicycle to go to a weather station in some not so remote part of a developing country. On a piece of paper, he noted the readings from meteorological instruments at fixed times. He coded the data in a standard format. He went to a post office or some wireless station (police) and telegraphed or voice-fed the coded information to his head office.

Discussion:

- (a) What developments have taken place in developing countries in recent years?
 - (b) How have the new transmission systems impacted the accuracy and timeliness of information?
 - (c) Do you see opportunities, investment and/or employment, for you in this sector?
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