Agrometeorology

Lecture Title: Agrometeorology

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INTRODUCTION

1-1 Definition of Agrometeorology

Agrometeorology, abbreviated from agricultural meteorology, science of meteorology to the service of agriculture, in its various forms and facets, to help with the sensible use of land, to accelerate the production food, and to avoid the irreversible abuse of land resources (Smith, Agrometeorology is also defined as the science investigating the logical, climatological, and hydrological conditions that are sign if agriculture owing to their interaction with the objects and processes culture production (Molga, 1962). The definition of biometeorology adopted by the International Society Biometeorology (ISB) states, "Biometeorology is an interdisciplinary science dealing with the application of fields of meteorology and climatology biological systems" (Hoppe, 2000, p. 383). The general scope includes kinds of interactions between atmospheric processes and living isms—plants, animals, and humans. By this definition, it becomes that there are roughly three sub branches of biometeorology: plant, and human biometeorology (Hoppe, 2000). The domain of agrometeorology is the plant and animal sub branches. The third sub branch, biometeorology, is outside the scope of agrometeorology.

1-2 Importance and applications of Agrometeorology

There is hardly a branch of human activities as dependent on the weather as agriculture. Agricultural production is for a large part still dependent on weather and climate despite the impressive advances in agricultural technology over the last half a century. More than ever, agrometeorological services have become essential because of the challenges provided to many forms of agricultural production by increasing climate variability and associated extreme events as well as climate change, all of which affecting the socio-economic conditions, especially of developing countries. 1.2.1 General importance Knowledge in time and space of available environmental resources and on conditions from below the soil surface through the soil-air interface into the boundary layer of the atmosphere, both favorable and unfavorable and all varying a great deal, provide guidance for strategic agrometeorological decisions in long-range planning of agricultural systems. Typical examples are designs of irrigation and drainage schemes, choices related to land-use and farming patterns, and within these choices selections of crops and animals, varieties and breeds, and farm machinery. In modern agriculture, ecology and economy are on equal terms; through environmental issues they are even interdependent. Shortage of resources, destruction of ecological systems and other environmental issues are becoming ever more serious. The large scale and uncontrolled use of chemical fertilizers and plant protection products is not only a burden to the environment but to quite a considerable extent to the farmer's budget, too. Detailed observations/monitoring and real-time dissemination of meteorological information, quantification by remote sensing (radar and satellites) and derived indices and operational services are important for tactical agrometeorological decisions in short term planning of agricultural operations at different growth stages. A well organized, where possible automatic production and a coordinated dissemination of this information and related advisories and services are essential. Tactical decisions include „average cost"-type decisions in low external input sustainable (LEISA) agriculture,regarding timing of cultural practices, such as plowing, sowing/planting, mulching, weeding, thinning, pruning and harvesting. They also include, particularly for high input agriculture, „high cost"-type decisions, such as the application of water, extensive chemicals and the operation of costly crop protection measures. 2 Regardless of the type of decision, an ever improving understanding of the effects of weather and climate on soils, plants, animals, trees and related production in farming systems, is necessary for decision makers (farmers and managers), to make timely and efficient use of meteorological and climatological information and of agrometeorological services for agriculture. To these ends choices have to be made of the right mixture and blending of traditional adaptation strategies, contemporary knowledge in science and technology and appropriate policy environments. Without policy support systems for agrometeorological services, yields with the available production means will remain below optimal.

1-2-1 Applications

The practical application of this knowledge is linked to the availability and accuracy of weather and climate forecasts or expected weather and climate patterns, depending on the time scale. The requirements range from accurate details of short-range weather forecasts (less than two days), medium range forecasts (less than ten days) at certain critical times to seasonal predictions of climate patterns. To ensure that development plans are not rendered meaningless by a significant change in weather and climate behavior, indications of possible climatic variability, and of increasingly frequent and serious extreme events in the context of global climate change, are necessary as agrometeorological services in addition to the application of other agrometeorological information. Although reliable long-term weather forecasts relevant to the agricultural community are not yet available on a routine basis all over the world, significant services may be provided by means of agrometeorological forecasts such as on the dates of phonological events, the quantity and quality of crop yields, and the occurrence of animal and crop epidemics. These forecasts make use of established relationships between weather effects at an early stage of development and the final event expected sometime after the date of issue of the forecast. This approach of „crop prediction without weather forecasting" is particularly promising for the assessment of crop conditions in order that potential production anomalies may be recognized and quantitatively evaluated as early as possible. Surpluses and deficits are organized or occur nationally, regionally and at world scale. Long-term planning of global food production must therefore take into account the effects of year-to-year fluctuations in weather patterns, as well as potential climatic variability's and changes, on crop yields. The global climate is influenced by a lot of factors. Two of the most important components are CO2 and water vapor in the atmosphere. Beside the oceans, forests absorb CO2 and release water vapor. Burning forests produce considerable masses of CO2. So it is necessary to promote reforestation and protect forests against fire and human beings as well as against other destruction, such as by insects, diseases and pollutants. Forest meteorology as a component of agrometeorology provides useful information and services for application to the forest authorities, the foresters and in case of forest fires to the fire-brigades. Agrometeorological services in developing countries have to shoulder greater responsibilities due to greater population pressure and changing modes of agricultural practices. More and more demands pertaining to agrometeorological information and services are expected from the farming communities in the future on technologies, farming systems patterns, water management, weather based pest and disease control etc., preferably with local innovations as starting points. Thus the future challenges include the necessity to emphasize a bottom up approach so that forecasts, specific advisories and contingency planning reach even the small farmers for applications in their planning and day-to-day agricultural operations. Agrometeorological services in developed countries focus on the provision of environmental data and information to national policy and decision makers in support of sustained food production, sustainable development, carbon sequestration in agro-ecosystems and land management practices that affect exchange processes of greenhouse gasses. Because developed countries may have or develop technology to initially adapt more readily to climate change and climate variability, technology transfer may play a certain role but local innovations remain most important for application under the very different conditions in developing countries. Organizations such as WMO/CAgM, FAO and INSAM are playing a role, and will have to play an increasing role, in stimulating development and establishment of agrometeorological services and dissemination of agrometeorological information. Advisories include among others (i) in drier climates information on average sowing date as well as expected sowing dates for the ongoing season, at various temporal and spatial scales, as well as on operational crop protection of all kinds and (ii) in more humid climates information on pest and diseases attacks, all based on weather information and agrometeorological services in location specific and user-friendly format. Other important advisory fields that require attention are:

- Management and modification of microclimate.
- Meteorological information for guiding irrigation and drainage.
- Environmental risks and disaster mitigation.
- Highland andmountain agriculture.
- Prediction of El-Nino and rainfall variability for agricultural planning.
- Information on weather based pesticides/insecticides applications.
- Arial transport of pollutants and knowledge regarding low level winds for operational activities.
- Workday probabilities (e.g. in marine and lake fishing).
- Agro advisory services for farmers on a regional level to strengthen and provide accurate forecasts and advisories for the farming community.

- Communication of information in a format/language understandable to users.

In more advanced agricultural production, with potential for technology transfer where the absorption capacity exists, we may add:

- Crop weather modelling with special emphasis on crop growth simulation models.
- Development of complex data collection systems and speedy processing and interpretation of large spatial data collections.
- Geographical information systems and their use for crop planning at smaller than present scales.
- The use of remote sensing technologies to generate information/ advisories for large areas.
- Quantifying Carbon sequestration.
- Use of audio-visual media and internet for quick dissemination of information to the users.

Forecasts of significant meteorological phenomena that result in issuance of advisories and warnings for sufficiently long lead times are of tremendous value. Early warnings against natural disasters not only help to save the crop, by adopting quick strategic planning, but also to advance or postpone agricultural operations. Dissemination of such warnings to the end users on a real time basis with the help of electronic media may become a key factor for crop production and protection.

PHYSICAL CLIMATOLOGY AND AGROMETEOROLOGY

2-1 *The relation between physical climatology and Agrometeorology and their effects*

A branch of meteorology that examines the effects and impacts of weather and climate on crops, rangeland, livestock, and various agricultural operations. The branch of agricultural meteorology dealing with atmospheric-biosphere processes occurring at small spatial scales and over relatively short time periods is known as micrometeorology, sometimes called crop micrometeorology for managed vegetative ecosystems and animal biometeorology for livestock operations. The branch that studies the processes and impacts of climatic factors over larger time and spatial scales is often referred to as agricultural climatology. Agricultural meteorology, or agrometeorology, addresses topics that often require an understanding of biological, physical, and social sciences. It studies processes that occur from the soil depths where the deepest plant roots grow to the atmospheric levels where seeds, spores, pollen, and insects may be found.
Agricultural meteorologists characteristically interact with scientists from many disciplines. Agricultural meteorologists collect and interpret weather and climate data needed to understand the interactions between vegetation and animals and their atmospheric environments. The climatic information developed by agricultural meteorologists is valuable in making proper decisions for managing resources consumed by agriculture, for optimizing agricultural production, and for adopting farming practices to minimize any adverse effects of agriculture on the environment. Such information is vital to ensure the economic and environmental sustainability of agriculture now and in the future. Agricultural meteorologists also quantify, evaluate, and provide information on the impact and consequences of climate variability and change on agriculture. Increasingly, agricultural meteorologists assist policy makers in developing strategies to deal with climatic events such as floods, hail, or droughts and climatic changes such as global warming and climate variability. Agricultural meteorologists are involved in many aspects of agriculture, ranging from the production of agronomic and horticultural crops, trees, and livestock to the final delivery of agricultural products to market. They study the energy and mass exchange processes of heat, carbon dioxide, water vapor, and trace gases such as methane, nitrous oxide, and ammonia, within the biosphere on spatial scales ranging from a leaf to a watershed and even to a continent. They study, for example, the photosynthesis, productivity, and water use of individual leaves, whole plants, and fields. They also examine climatic processes at time scales ranging from less than a second to more than a decade.

- **Agricultural Climatology**

In general, the study of climate as to its effect on crops; it includes, for example, the relation of growth rate and crop yields to the various climatic factors and hence the optimum and limiting climates for any given crop. Also known as agroclimatology.

- **Biometeorology**

A branch of meteorology and ecology that deals with the effects of weather and climate on plants, animals, and humans. The principal problem for living organisms is maintaining an acceptable thermal equilibrium with their environment. Organisms have natural techniques for adapting to adverse conditions. These techniques include acclimatization, dormancy, and hibernation, or in some cases an organism can move to a more favorable environment or microenvironment. Humans often establish a favorable environment through the use of technology.

- **Climatology**

The scientific study of climate. Climate is the expected mean and variability of the weather conditions for a particular location, season, and time of day. The climate is often described in terms of the mean values of meteorological variables such as temperature, precipitation, wind, humidity, and cloud cover. A complete description also includes the variability of these quantities, and their extreme values. The climate of a region often has regular seasonal and diurnal variations, with the climate for January being very different from that for July at most locations. Climate also exhibits significant year-to-year variability and longer-term changes on both a regional and global basis. The goals of climatology are to provide a comprehensive description of the Earth's climate over the range of geographic scales, to understand its features in terms of fundamental physical principles, and to develop models of the Earth's climate for sensitivity studies and for the prediction of future changes that may result from natural and human causes.

- **Crop Micrometeorology**

The branch of meteorology that deals with the interaction of crops and their immediate physical environment.

- **Micrometeorology**

The study of small-scale meteorological processes associated with the interaction of the atmosphere and the Earth's surface. The lower boundary condition for the atmosphere and the upper boundary condition for the underlying soil or water are determined by interactions occurring in the lowest atmospheric layers. Momentum, heat, water vapor, various gases, and particulate matter are transported vertically by turbulence in the atmospheric boundary layer and thus establish the environment of plants and animals at the surface. These exchanges are important in supplying energy and water vapor to the atmosphere, which ultimately determine large-scale weather and climate patterns. Micrometeorology also includes the study of how air pollutants are diffused and transported within the boundary layer and the deposition of pollutants at the surface. In many situations, atmospheric motions having time scales between 15 min and 1 h are quite weak. This represents a spectral gap that provides justification for distinguishing micrometeorology from other areas of meteorology. Micrometeorology studies phenomena with time scales shorter than the spectral gap (time scales less than 15 min to 1 h and horizontal length scales less than 2–10 km). Some phenomena studied by micrometeorology are dust devils, mirages, dew and frost formation, evaporation, and cloud streets.

- **Ecosystem**

An ecosystem is a complete community of living organisms and the nonliving materials of their surroundings. Thus, its components include plants, animals, and microorganisms; soil, rocks, and minerals; as well as surrounding water sources and the local atmosphere. The size of ecosystems varies tremendously. An ecosystem could be an entire rain forest, covering a geographical area larger than many nations, or it could be a puddle or a backyard garden. Even the body of an animal could be considered an ecosystem, since it is home to numerous microorganisms. On a much larger scale, the history of various human societies provides an instructive illustration as to the ways that ecosystems have influenced civilizations.

- **Weather Observations**

The measuring, recording, and transmitting of data of the variable elements of weather. In the India the National Data Centre (NDC), a division of the India Meteorological Department (IMD), has as one of its primary responsibilities the acquisition of meteorological information. The data are sent by various communication methods to the NDC of IMD. At the Center, the raw data are fed into large computers that are programmed to plot, analyze, and process the data and also to make prognostic weather charts. The processed data and the forecast guidance are then distributed by special National Weather Service systems and conventional telecommunications to field offices, other government agencies, and other stake holders. They in turn prepare forecasts and warnings based on both processed and raw data. A wide variety of meteorological data are required to satisfy the needs of meteorologists, climatologists, and users in marine activities, forestry, agriculture, aviation, and other fields.

- **Weather forecasting and prediction**

Processes for formulating and disseminating information about future weather conditions based upon the collection and analysis of meteorological observations. Weather forecasts may be classified according to the space and time scale of the predicted phenomena. Atmospheric fluctuations with a length of less than 100 m (330 ft) and a period of less than 100 s are considered to be turbulent. The study of atmospheric turbulence is called micrometeorology; it is of importance for understanding the diffusion of air pollutants and other aspects of the climate near the ground. Standard meteorological observations are made with sampling techniques that filter out the influence of turbulence. Common terminology distinguishes among three classes of phenomena with a scale that is larger than the turbulent microscale: the mesoscale, synoptic scale, and planetary scale. The mesoscale includes all moist convection phenomena, ranging from individual cloud cells up to the convective cloud complexes associated with prefrontal squall lines, tropical storms, and the inter tropical convergence zone. Also included among mesoscale phenomena are the sea breeze, mountain valley circulations, and the detailed structure of frontal inversions. Most mesoscale phenomena have time periods less than 12 h. The prediction of mesoscale phenomena is an area of active research. Most forecasting methods depend upon empirical rules or the short-range extrapolation of current observations, particularly those provided by radar and geostationary satellites. Forecasts are usually couched in probabilistic terms to reflect the sporadic character of the phenomena. Since many mesoscale phenomena pose serious threats to life and property, it is the practice to issue advisories of potential occurrence significantly in advance. These "watch" advisories encourage the public to attain a degree of readiness appropriate to the potential hazard. Once the phenomenon is considered to be imminent, the advisory is changed to a "warning," with the expectation that the public will take immediate action to prevent the loss of life. The next-largest scale of weather events is called the synoptic scale, because the network of meteorological stations making simultaneous, or synoptic, observations serves to define the phenomena. The migratory storm systems of the extra tropics are synoptic-scale events, as are the undulating wind currents of the upper-air circulation which accompany the storms. The storms are associated with barometric minima, variously called lows, depressions, or cyclones. The synoptic method of forecasting consists of the simultaneous collection of weather observations, and the plotting and analysis of these data on geographical maps. An experienced analyst, having studied several of these maps in chronological succession, can follow the movement and intensification of weather systems and forecast their positions. This forecasting technique requires the regular and frequent use of large networks of data. Planetary-scale phenomena are persistent, quasi stationary perturbations of the global circulation of the air with horizontal dimensions comparable to the radius of the Earth. These dominant features of the general circulation appear to be correlated with the major orographic features of the globe and with the latent and sensible heat sources provided by the oceans. They tend to control the paths followed by the synoptic-scale storms, and to draw upon the synoptic transients for an additional source of heat and momentum.

Numerical weather prediction is the prediction of weather phenomena by the numerical solution of the equations governing the motion and changes of condition of the atmosphere. Numerical weather prediction techniques, in addition to being applied to short-range weather prediction, are used in such research studies as air-pollutant transport and the effects of greenhouse gases on global climate change. The first operational numerical weather prediction model consisted of only one layer, and therefore it could model only the temporal variation of the mean vertical structure of the atmosphere. Computers now permit the development of multilevel (usually about 10–20) models that could resolve the vertical variation of the wind, temperature, and moisture. These multilevel models predict the fundamental meteorological variables for large scales of motion. Global models with horizontal resolutions as fine as 125 mi (200 km) are being used by weather services in several countries. Global numerical weather prediction models require the most powerful computers to complete a 10-day forecast in a reasonable amount of time. Research models similar to global models could be applied for climate studies by running for much longer time periods. The extension of numerical predictions to long time intervals (many years) requires a more accurate numerical representation of the energy transfer and turbulent dissipative processes within the atmosphere and at the air-earth boundary, as well as greatly augmented computing-machine speeds and capacities. Long-term simulations of climate models have yielded simulations of mean circulations that strongly resemble those of the atmosphere. These simulations have been useful in explaining the principal features of the Earth's climate, even though it is impossible to predict the daily fluctuations of weather for extended periods. Climate models have also been used successfully to explain paleoclimatic variations, and are being applied to predict future changes in the climate induced by changes in the atmospheric composition or characteristics of the Earth's surface due to human activities. Surface meteorological observations are routinely collected from a vast continental data network, with the majority of these observations obtained from the middle latitudes of both hemispheres. Commercial ships of opportunity, military vessels, and moored and drifting buoys provide similar in-place measurements from oceanic regions. Information on winds, pressure, temperature, and moisture throughout the troposphere and into the stratosphere is routinely collected from (1) balloon-borne instrumentation packages (radiosonde observations) and commercial and military aircraft which sample the free atmosphere directly; (2) ground-based remote-sensing instrumentation such as wind profilers (vertically pointing Doppler radars), the National Weather Service Doppler radar network, and lidars; and (3) special sensors deployed on board polar orbiting or geostationary satellites. The remotely sensed observations obtained from meteorological satellites have been especially helpful in providing crucial measurements of areally and vertically averaged temperature, moisture, and winds in data-sparse (mostly oceanic) regions of the world. Such measurements are necessary to accommodate modern numerical weather prediction practices and to enable forecasters to continuously monitor global storm (such as hurricane) activity. Forecast products and forecast skill are classified as longer term (greater than 2 weeks) and shorter term. These varying skill levels reflect the fact that existing numerical prediction models such as the medium-range forecast have become very good at making large-scale circulation and temperature forecasts, but are less successful in making weather forecasts. An example is the prediction of precipitation amount and type given the occurrence of precipitation and convection. Each of these forecasts is progressively more difficult because of the increasing importance of mesoscale processes to the overall skill of the forecast. Now casting is a form of very short range weather forecasting. The term now casting is sometimes used loosely to refer to any area-specific forecast for the period up to 12 h ahead that is based on very detailed observational data. However, nowcasting should probably be defined more restrictively as the detailed description of the current weather along with forecasts obtained by extrapolation up to about 2 h ahead. Useful extrapolation forecasts can be obtained for longer periods in many situations, but in some weather situations the accuracy of extrapolation forecasts diminishes quickly with time as a result of the development or decay of the weather systems. Forecasts of time averages of atmospheric variables, for example, sea surface temperature, where the lead time for the prediction is more than 2 weeks, are termed long-range or extended-range climate predictions. Extended-range predictions of monthly and seasonal average temperature and precipitation are known as climate outlooks. The accuracy of long-range outlooks has always been modest because the predictions must encompass a large number of possible outcomes, while the observed single event against which the outlook is verified includes the noise created by the specific synoptic disturbances that actually occur and that are unpredictable on monthly and seasonal time scales. According to some estimates of potential predictability, the noise is generally larger than the signal in middle latitudes.