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Chapter 1 : Meteorology - Wikipedia

Compendium on tropical meteorology for aviation purposes. [T N Krishnamurti; World Meteorological Organization.] -- The objective of this compendium is to provide information on tropical meteorology and the hazards that weather in the tropics might pose for aviation operations.

Parhelion sundog in Savoie The ability to predict rains and floods based on annual cycles was evidently used by humans at least from the time of agricultural settlement if not earlier. Early approaches to predicting weather were based on astrology and were practiced by priests. Cuneiform inscriptions on Babylonian tablets included associations between thunder and rain. In BC, Aristotle wrote Meteorology. At other times, it travels in crooked lines, and is called forked lightning. The Greek scientist Theophrastus compiled a book on weather forecasting, called the Book of Signs. The work of Theophrastus remained a dominant influence in the study of weather and in weather forecasting for nearly 2, years. He describes the meteorological character of the sky, the planets and constellations , the sun and moon , the lunar phases indicating seasons and rain, the anwa heavenly bodies of rain , and atmospheric phenomena such as winds, thunder, lightning, snow, floods, valleys, rivers, lakes. Admiral FitzRoy tried to separate scientific approaches from prophetic ones. Rainbow and Twilight Ptolemy wrote on the atmospheric refraction of light in the context of astronomical observations. Albert the Great was the first to propose that each drop of falling rain had the form of a small sphere, and that this form meant that the rainbow was produced by light interacting with each raindrop. He stated that a rainbow summit can not appear higher than 42 degrees above the horizon. Theoderic went further and also explained the secondary rainbow. Instruments and classification scales[edit] See also: In , Leone Battista Alberti developed a swinging-plate anemometer , and was known as the first anemometer. In , Johannes Kepler wrote the first scientific treatise on snow crystals: In , Gabriel Fahrenheit created a reliable scale for measuring temperature with a mercury-type thermometer. The April launch of the first successful weather satellite , TIROS-1 , marked the beginning of the age where weather information became available globally. Atmospheric composition research[edit] In , Blaise Pascal rediscovered that atmospheric pressure decreases with height, and deduced that there is a vacuum above the atmosphere. In , John Dalton defended caloric theory in A New System of Chemistry and described how it combines with matter, especially gases; he proposed that the heat capacity of gases varies inversely with atomic weight. In , Sadi Carnot analyzed the efficiency of steam engines using caloric theory; he developed the notion of a reversible process and, in postulating that no such thing exists in nature, laid the foundation for the second law of thermodynamics. Coriolis effect and Prevailing winds In , Christopher Columbus experienced a tropical cyclone, which led to the first written European account of a hurricane. Gaspard-Gustave Coriolis published a paper in on the energy yield of machines with rotating parts, such as waterwheels. By , this deflecting force was named the Coriolis effect. Observation networks and weather forecasting[edit] Cloud classification by altitude of occurrence This "Hyetographic or Rain Map of the World " was first published by Alexander Keith Johnston. History of surface weather analysis In the late 16th century and first half of the 17th century a range of meteorological instruments was invented â€" the thermometer , barometer , hydrometer , as well as wind and rain gauges. In the s natural philosophers started using these instruments to systematically record weather observations. Scientific academies established weather diaries and organised observational networks. The collected data were sent to Florence at regular time intervals. Thus early meteorologists attempted to correlate weather patterns with epidemic outbreaks, and the climate with public health. But there were also attempts to establish a theoretical understanding of weather phenomena. Edmond Halley and George Hadley tried to explain trade winds. They reasoned that the rising mass of heated equator air is replaced by an inflow of cooler air from high latitudes. A flow of warm air at high altitude from equator to poles in turn established an early picture of circulation. Frustration with the lack of discipline among weather observers, and the poor quality of the instruments, led the early modern nation states to organise large observation networks. Thus by the end of the

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18th century meteorologists had access to large quantities of reliable weather date. To make frequent weather forecasts based on these data required a reliable network of observations, but it was not until that the Smithsonian Institution began to establish an observation network across the United States under the leadership of Joseph Henry. The following year a system was introduced of hoisting storm warning cones at principal ports when a gale was expected. Over the next 50 years many countries established national meteorological services. The India Meteorological Department was established to follow tropical cyclone and monsoon. The Australian Bureau of Meteorology was established by a Meteorology Act to unify existing state meteorological services. He described how small terms in the prognostic fluid dynamics equations that govern atmospheric flow could be neglected, and a numerical calculation scheme that could be devised to allow predictions. Richardson envisioned a large auditorium of thousands of people performing the calculations. However, the sheer number of calculations required was too large to complete without electronic computers, and the size of the grid and time steps used in the calculations led to unrealistic results. Though numerical analysis later found that this was due to numerical instability. Starting in the s, numerical forecasts with computers became feasible. These climate models are used to investigate long-term climate shifts, such as what effects might be caused by human emission of greenhouse gases. Weather forecasting Meteorologists are scientists who study meteorology. In the United States, meteorologists held about 9, jobs in Some radio and television weather forecasters are professional meteorologists, while others are reporters weather specialist, weatherman, etc.

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Chapter 2 : National Weather Service Climate

DOWNLOAD COMPENDIUM ON TROPICAL METEOROLOGY FOR AVIATION PURPOSES compendium on tropical meteorology pdf Both Jennifer Marohasy and Graham Lloyd are both doing great work here: The Australian.

 In general, the 48 h forecast in the vicinity of the Tropical Upper Tropospheric Trough TUTT underpredicts the magnitude of the westerly mb winds on the order of 5 to 10 ms This unrealistic weakening of the TUTT and associated cold lows by the Aviation model results in erroneous values of the vertical to mb wind shear. These systematic errors are in the same order of magnitude as the minimum shear threshold for tropical cyclone genesis and development. Thus, 48 h tropical cyclone formation and intensity forecasts based upon the Aviation model are often incorrect in the vicinity of the TUTT. Knowing the correct future upper wind regime is also crucial for track forecasting of more intense tropical cyclones, especially in cases of recurvature. If the TUTT is weak such that mb easterly winds occur, climatology tends to be the best predictor as it nudges the forecast back to a normal westerly wind regime. TUTTs often can inhibit the formation of TCs by allowing large amounts of vertical wind shear VWS to be positioned directly over the prestorm disturbance. VWS can be quantified in the following manner: According to equation 1 , westerly flow at mb superimposed over easterly tradewind flow at mb will give high VWS values. Likewise, a tropical disturbance in a deep tropospheric easterly flow has a better chance of development if u and u are similar in magnitude, since this will yield low VWS values. Values of VWS 10 ms-1 are generally considered to be great enough to inhibit TC genesis by advecting upper level moisture and temperature anomalies away from the low-level disturbance center Zehr Sadler a also found that directly below the divergence sector of the TUTT a surface disturbance may be induced in a trade wind regime which could then develop into a TC. Sadler b proposed a comparable genesis mechanism for the monsoon trough region. Similarly, the competing effects of VWS and angular momentum eddy fluxes by TUTTs and mid-latitude troughs are also hypothesized to affect TC intensification Molinari and Vollaro once genesis has occurred. In a quantitative treatment of the problem, DeMaria et al. Additionally, Chen and Gray have extensively discussed the different upper tropospheric outflow characteristics associated with TC intensification. Finally, it is generally accepted that the motion of the TC is primarily the result of the deep layer flow in which it resides, usually taken to be from to mb Elsberry While TUTTs are primarily maximum in strength at mb, many times they can extend into the mid-troposphere. Thus, they can often influence the current and future motion of a nearby TC of any intensity. It has also been shown recently that the infringement of a deep baroclinic layer of westerly winds upon a TC can be a precursor to recurvature, since this usually precedes encroachment of deeper westerly flow close to the poleward side of the storm center Hodanish and Gray Therefore, poor forecasting of any upper-level wind characteristic can result in degraded motion predictions. From this discussion, it is clear that the upper tropospheric flow is very important in many forecasting aspects of TCs. The next section will discuss the structure, climatology, and hypothesized causes of the TUTT, and it describes the AVN model and the systematic biases that have been identified in the tropical predictions of this model. Section 3 details a mb AVN easterly wind bias in the Caribbean basin during the peak hurricane season and shows that currently persistence and climatology are better mb wind forecast tools. The final section relates these findings to the context of TC forecasting and provides hypotheses which may explain the biases found. It is a shallow, cold core trough that is oriented across the subtropical and

tropical portions of these oceans Whitfield and Lyons The maximum intensity of the cold core of the TUTT exists at roughly mb while the vorticity maximum is located approximately at mb below strong upper tropospheric and lower stratospheric subsidence-forced warming, as shown in Fig. TUTTs and associated cold lows are thought to be maintained by radiational cooling which causes this upper tropospheric subsidence, as is required to maintain atmospheric thermal balance in the mid-ocean regions during the summer. Little research has been conducted to explain the seasonal cycle of the TUTT, but one possible scenario for the North Atlantic is as follows. During the summer, continental convection increases due to higher sensible heat flux Jaeger ; Peixoto and Oort , transporting heat and moisture upwards in the form of latent heat which more than balances radiational cooling. However, precipitation decreases on average over the subtropical ocean in the warmer months. Therefore, the upper tropical atmosphere experiences net cooling due to radiational losses in the summer, and subsidence occurs to maintain thermal balance. In turn, this upper-tropospheric subsidence dries the atmosphere, creating large long-wave radiation flux divergence which further enhances cooling. More research on the summer genesis and maintenance of the TUTT needs to be conducted to determine the specific role of these and other processes. In its climatological position, the trough axis tilts from the central North Atlantic into the Gulf of Mexico as shown for mean August conditions in Fig. It is these strong cold lows that are most important in regards to tropical cyclone forecasting because they are associated with maxima in VWS and horizontal eddy momentum fluxes. It is a global spectral model run on a 12 h cycle after assimilating all available data 2 h 45 min after the synoptic time Peterson and Stackpole Forecasts are generated out to 72 h from the initialization time. According to Kanamitsu et al. In addition, on 11 August , the number of levels in the vertical was increased to 28 and an Arakawa-Schubert convective parameterization scheme with moist downdrafts was implemented in the model. This new scheme is a slight modification of that described in Grell et al. In a study on the systematic errors of the MRF model, Rosen et al. They also found that this bias was observable even in a two day forecast. Apparently, this type of systematic error is a common one for operational global spectral models as the same unrealistic overproduction of tropical upper level easterlies was identified in the European Centre for Medium Range Weather Forecasts ECMWF model Bengtsson According to Rosen et al. However, beyond this general identification of an easterly bias in the tropical troposphere, specifics about the longitudes, times of year, and synoptic conditions including periods when the TUTT is present when this problem was most severe are, to our knowledge, lacking. The next section details our findings for the tropical North Atlantic during the hurricane-prone months of August and September for the year The data were provided to us with a grid spacing of 2. Starting in early August , AVN analyses and forecast fields for the 48 h forecast for and mb were saved when data were received. The 48 h forecast fields were selected, since this lead time provides key information for crucial tropical cyclone forecast decision making, such as the placement of watches and warnings Sheets From early August through late September , a total of 63 cases that contained the analyses, forecast fields, and their verification were available. On the whole, data availability for the initial time analyses were very good. Within the region of the climatological TUTT axis, there exists several reliable rawindsonde stations, numerous jet aircraft reports, and many cloud track wind vectors from cirrus at mb every synoptic time. Thus the ability of the Aviation analysis was more than adequate to pick out synoptic-scale features, such as the TUTT. It was found that the upper tropospheric forecast flow fields in the vicinity of the climatological position of the TUTT were biased toward stronger easterlies than what verified. The low-level forecast flow fields were, in general, observed to have very little systematic bias. Figure 3b shows the mb forecast field valid on 00 UTC 3 September. However, in the verification of the mb forecast field Fig. The TUTT axis is in nearly the same location with the same magnitude of westerlies south of the axis. One new feature is the anticyclone over northern South America. This feature also was not forecast by the AVN. Since the mb was observed to have very little bias not shown , errors in the vertical wind shear VWS - the critical measure for TC genesis and intensity forecasting - are dominated by the errors at mb. Shear values were calculated from the AVN for the initial time period and the 48 h prediction fields by using equation 1. Note that the locations of large positive errors correspond

extremely well with the regions of observed westerly winds south of the TUTT axis. However, when the TUTT was either very weak or not present in the analysis, it was found that the errors were substantially reduced. To contrast results shown in Figs. The eastern half of the United States is under the influence of a strong subtropical ridge. When compared with the analysis at the verification time Fig. It does, however, dissipate the mb trough that extends from the eastern Pacific basin and washes out the closed anticyclone over Honduras. The errors are smallest where easterly winds persisted throughout the analysis period, and are small where westerly winds became northeasterly in the eastern Caribbean. There is only one region that has errors in excess of 12 ms-1 which is located in a region of westerly winds just south of a weak east-west trough in the Gulf of Mexico. This feature is curiously eliminated in the forecast field see Fig. Note that with the exception of two small regions to the south of Honduras and the other over South Carolina all positive forecast errors shown are associated with observed upper-level westerly winds at verification time. Table 1 documents the 48 h AVN model errors found at specific locations throughout the entire two month time period under analysis. The locations of these four points are shown in Fig. All four locations show an underestimation of the VWS during the two month period for all cases with the largest errors occurring at the two westernmost points. When stratified by mb westerly and easterly wind cases at the verification time 48 h , it becomes apparent that the easterly bias is strongest when westerly winds were observed. Typically, these westerlies only occurred when the TUTT axis was to the north of the location in question. This implies that there is a consistent tendency for the AVN to unrealistically diminish all westerly momentum, even for westerly winds with substantial strength, in the tropics. However, when mb easterly winds occurred at 48 h, the errors are small. This contrast is even more evident when the four locations on Fig. For an additional perspective, the 48 h forecast VWS errors are plotted in terms of 5 ms-1 classes for easterly, westerly, and strong westerly wind regimes at the 48 h verification time Fig. As expected, when easterly winds were observed, the AVN errors are semi-Gaussian. However, west winds experience a positive error bias and, in fact, very few errors are negative. For strong westerlies the bias is strongly skewed to toward positive, and the errors are almost never negative. To examine these errors in more detail, the AVN shear values were stratified by winds observed at model initialization and by winds observed at the 48 h verification time Table 2. For example, the VWS errors are highest when: In contrast, for the cases when: While identifying such a bias provides useful information, the forecaster is left with a dilemma - how does one predict the mb flow in the future for a tropical westerly wind regime? One approach is to assume that the TUTT is approximately a steady-state system, and use persistence. Another approach is to utilize climatology to predict the future and mb wind flow. Both procedures are further investigated. The persistence scheme simply extrapolates the observed VWS into the future. The climatology scheme uses average 15 day climatological values for the verification time.

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Chapter 3 : Aviation Weather (eBook PDF)

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A cloud which is dependent on a larger cloud system for development and continuance. Roll clouds , shelf clouds , and wall clouds are examples of accessory clouds. Accuracy Degree of conformity of a measure to a standard or true value. Acid rain Cloud or rain droplets containing pollutants, such as oxides of sulfur and nitrogen, to make them acidic. Acre-foot The amount of water required to cover one acre to a depth of one foot. An acre-foot equals , gallons, or 43, cubic feet. Active Conservation Storage The portion of water stored in a reservoir that can be released for all useful purposes such as municipal water supply, power, irrigation, recreation, fish, wildlife, etc. Conservation storage is the volume of water stored between the inactive pool elevation and flood control stage. Active Usable Storage Capacity The total amount of reservoir capacity normally available for release from a reservoir below the maximum storage level. It is total or reservoir capacity minus inactive storage capacity. More specifically, it is the volume of water between the outlet works and the spillway crest. The change of temperature of air without transferring heat. In an adiabatic process compression results in warming, and expansion results in cooling. Adirondack Type Snow Sampling Set A snow sampler consisting of a 5-foot fiberglass tube, 3" in diameter, with a serrated-edge steel cutter at one end and a twisting handle at the other. This sampler has a inch snow depth capacity. Advection The horizontal movement of an air mass that causes changes in the physical properties of the air such as temperature and moisture. Commonly used with temperatures, i. Advection Fog Fog that forms as warmer, moist air moves over a cold ground. The air is cooled to saturation by the loss of heat to the cold ground. Unlike radiation fog , advection fog may form under cloudy skies and with moderate to strong winds. Initial stability is relatively unimportant since low level cooling makes the air unstable near the ground. Highlights special weather conditions that are less serious than a warning. Official information issued by tropical cyclone warning centers describing all tropical cyclone watches and warnings in effect along with details concerning tropical cyclone locations, intensity and movement, and precautions that should be taken. Advisories are also issued to describe tropical cyclones prior to issuance of watches and warnings, and subtropical cyclones. Aeration Zone A portion of the lithosphere in which the functional interstices of permeable rock or earth are not filled with water under hydrostatic pressure. The interstices either are not filled with water or are filled with water that is no held by capillarity. Afterbay The tail race of a hydroelectric power plant at the outlet of the turbines. The term may be applied to a short stretch of stream or conduit, or to a pond or reservoir. Agglomerate An ice cover of floe formed by the freezing together of various forms of ice. AGL Above ground level. Airborne Snow Survey Program Center NOHRSC program that makes airborne snow water equivalent and soil moisture measurements over large areas of the country that are subject to severe and chronic snowmelt flooding. Airborne Snow Water Equivalent Measurement Theory A theory based on the fact that natural terrestrial gamma radiation is emitted from the potassium, uranium, and thorium radioisotopes in the upper eight inches of the soil. The radiation is sensed from low flying aircraft feet above the ground. Water mass in the snow cover attenuates the terrestrial radiation signal. The difference between airborne radiation measurements made over bare ground and snow-covered ground can be used to calculate a mean areal snow water equivalent value with a root mean square error of less than a half inch. Air Mass Air Mass Thunderstorm Generally, a thunderstorm not associated with a front or other type of synoptic-scale forcing mechanism. Air mass thunderstorms typically are associated with warm, humid air in the summer months; they develop during the afternoon in response to insolation , and dissipate rather quickly after sunset. However, operators of large aircraft may also be concerned with these phenomena. Air Parcel An imaginary small body of air that is used to explain the behavior of air. A parcel is large enough to contain a very great

number of molecules, but small enough so that the properties assigned to it are approximately uniform throughout. The force exerted on a surface by the weight of the air above it. The internationally recognized unit for measuring this pressure is the kilopascal. Air Stagnation A meteorological situation in which there is a major buildup of air pollution in the atmosphere. This usually occurs when the same air mass is parked over the same area for several days. During this time, the light winds cannot "cleanse" the buildup of smoke, dust, gases, and other industrial air pollution. Air Transportable Mobile Unit A modularized transportable unit containing communications and observational equipment necessary to support a meteorologist preparing on-site forecasts at a wildfire or other incident. Albedo The portion of incoming radiation which is reflected by a surface. Alberta Clipper A fast moving low pressure system that moves southeast out of Canadian Province of Alberta southwest Canada through the Plains, Midwest, and Great Lakes region usually during the winter. This low pressure area is usually accompanied by light snow, strong winds, and colder temperatures. Another variation of the same system is called a "Saskatchewan Screamer". It is a generating area for storms and migratory lows often reach maximum intensity in this area. It is most active during the late fall to late spring. During the summer, it is weaker, retreating towards the North Pole and becoming almost nonexistent. During this time, the North Pacific High pressure system dominates. Algorithm A computer program or set of programs which is designed to systematically solve a certain kind of problem. The process by which frequencies too high to be analyzed with the given sampling interval appear at a frequency less than the Nyquist frequency. Altimeter An instrument that indicates the altitude of an object above a fixed level. Pressure altimeters use an aneroid barometer with a scale graduated in altitude instead of pressure. Altimeter Setting That pressure value to which an aircraft altimeter scale is set so that it will indicate the altitude above mean sea-level of an aircraft on the ground at the location for which the value was determined. Altitude Height expressed as the distance above a reference point, which is normally sea level or ground level.

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Chapter 6 : NWS JetStream - Weather Glossary: A's

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Chapter 7 : DOCUMENTATION OF A SYSTEMATIC BIAS IN

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Chapter 8 : | Tropical numerical weather prediction in Hawaii, - | National Weather Service (NWS)

Books by T. N. Krishnamurti, Compendium on Tropical Meteorology for Aviation Purposes, An introduction to global spectral modeling, An introduction to numerical weather prediction techniques, Workbook on numerical weather

prediction for the tropics for the training of class I and class II meteorological personnel, Remote sensing and modeling of the atmosphere, oceans, and interactions III.

Chapter 9 : Compendium on Tropical Meteorology for Aviation Purposes : T N Krishnamurti :

The international standards, recommended practices and procedures relating to aeronautical meteorology are provided in the Annex 3 to the Convention on International Civil Aviation "Meteorological Service for International Air Navigation".