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Department of Earth and
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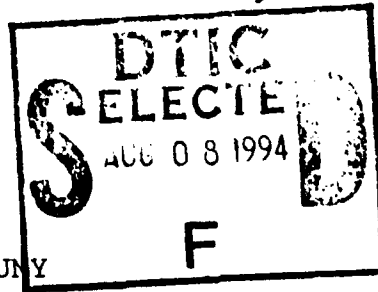
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To: Nellie Cerpa, RF/CUNY

From: Prof. Ward Hindman, PI

Subject: Performance Technical Report, 1 March 1993 to 28 February
1994, RF/CUNY Project 447312, **Modern Methods in Meteorological
and Oceanographic Data Acquisition and Analyses** (ONR Contract
N00014-93-1-0486)

Technical objectives:

The <u>first objective</u> is to educate and train students to collect
and analyze meteorological and oceanographic data using the new
weather station computer system.

The <u>second objective</u> is to keep the systems networking and
computation capabilities up-to-date by procuring system upgrades.

The <u>third objective</u> is to teach students scientific programming.

Technical accomplishments:

First objective:

The computer system was used to collect and analyze satellite
images of the eastern Pacific to identify ship-produced clouds. The
images were used by Najita (1994, abstract attached) to study the
occurrence of the clouds and the meteorological conditions. She
found an apparent relationship between the location of the clouds and
the location of the Pacific high pressure region which may be useful
in forecasting cloud events. Student meteorologist K. Kong collected
and analyzed the satellite images used by Hindman, et al. (1994,
abstract attached); the report cloud lined appear to be due to
ship-produced particles and updrafts.

Second objective:

The systems engineer (David Ahn, Ph. D. candidate in Electrical
Engineering) completed the local-area network which attached four
work stations to the IBM RISC 6000. He also connected the RISC to
the outside world through Internet. As a result, our weather station

is used for teaching, research and data reception and transmission on Internet.

Third objective:

Undergraduate research assistant Robert Bodowski, a meteorology major, assisted with computations reported by Hindman and Bodowski (1994, abstract attached). The investigated the role of ship-produced particles and updrafts on the modification of a marine stratus cloud; the particles played the dominant role.

Graduate research assistant Robert Arnold (M.A., CCNY, 1993) helped the PI's colleague develop a cloud microphysical model which was used to explain the form of cyclonic precipitation (Gedzelman and Arnold, 1993, abstract attached). Also Robert helped develop a model that explains the isotopic composition of precipitation (Gedzelman and Arnold, 1994, abstract attached).

References:

Gedzelman, S. D. and R. Arnold, 1993: The form of cyclonic precipitation and its thermal impact. *Mo. Wea. Rev.*, **121**, 1957-1978.

Gedzelman, S. D. and R. Arnold, 1994: Modeling the isotopic composition of precipitation. *J. Geophys. Rsch.*, 99, 10,455-10,471.

Hindman, E. E., W. M. Porch, J. G. Hudson and P. A Durkee, 1994: Ship-produced cloud lines of 13 July 1991. *Atmos. Environ.*, in press.

Hindman, E. E. and R. Bodowski, 1994: A marine stratus layer modified by ship-produced CCN and updrafts. *Proc. 6th Sci. Conf. Wea. Modif.*, WMO/TD No. 596, pp 417-420.

Najita, T., 1994: Anomalous cloud lines: Occurrences and predictions. EAS310.2 Paper, 15 pp. (on file CCNY EAS Dept).

The Form of Cyclonic Precipitation and Its Thermal Impact

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(Manuscript received 20 April 1992, in final form 10 November 1992)

ABSTRACT

A two-dimensional, parameterized kinematic cloud microphysics model is described and used to simulate
the form of cyclonic precipitation and its thermal impact in three idealized situations. The first situation represents
a strong, warm, or stationary front with a zone of freezing rain and ice pellets separating regions of rain and
snow. The second represents a storm with initial surface temperatures slightly above 0°C, and in which precip-
itation at the ground changes from rain to snow as a result of cooling by melting and evaporation of hydrometeors.
The third represents a shallow cloud in a sounding with all temperatures below 0°C that initially produces
freezing drizzle before a change to snow or ice pellets.

1. Introduction

The form of precipitation becomes difficult to predict whenever the temperature at or near the surface approaches 0°C. Snow, rain, or ice pellets may fall when the surface wet-bulb temperature T_w is somewhat above 0°C, while snow, ice pellets, or freezing rain can all fall when surface temperatures are below 0°C.

The sounding serves as the primary data source for determining the form of precipitation (Bocchieri 1980). Precipitation will reach the ground as rain when the melting level is far above the ground and T_w is well above 0°C. Snow is recorded when the entire sounding is below 0°C, and the cloud is deep enough to contain ice. Snow can reach the ground even when the temperature is above freezing so long as T_w is below about 2°C through a thin layer (Lumb 1961, 1963). When surface temperatures are below 0°C, but there is a melting layer aloft, freezing rain or ice pellets, rather than snow, will reach the ground.

The sounding can even be used to distinguish ice pellets from freezing rain (Stewart 1985; Stewart and King 1987a,b; Ivens 1987; Huffman and Norman 1988). Ice pellets arise principally when a thin melting layer with wet-bulb temperatures barely above 0°C overlies a layer of subfreezing air near the surface. The most important criterion for distinguishing ice pellets from freezing rain is the degree of melting that takes

place in the warm layer aloft. If a falling snowflake melts entirely, it is not likely to freeze again, even when the freezing layer near the surface is both thick and quite cold (Stewart 1985; Stewart and King 1987a; Raga et al. 1991). Ivens (1987) employed this criterion successfully in his technique for forecasting precipitation type. Furthermore, the similarity of the size distributions of ice pellets and of snowflakes observed in one storm by Kimura and Kajikawa (1984) provides microphysical evidence for the conclusion that ice pellets result from the refreezing of largely but not entirely melted snowflakes.

Several cloud microphysical processes affect precipitation form. The size and density of the hydrometeors determine how far they fall before melting. A snowflake or an ice pellet that has grown to a large size as a result of processes such as aggregation or riming will fall farther before completely melting than a smaller hydrometeor (Matsuo and Sayso 1981) and, depending on the lapse rate, can penetrate several hundred meters below the $T_w = 0°C$ level.

Supercooling also affects precipitation form. Bocchieri (1980) found that about 30% of the cases of freezing precipitation occur in soundings for which the temperature remains below 0°C at all heights. The clouds in these cases are shallow and have tops warmer than −10°C and, hence, quite often do not have ice crystals (Rogers and Yau 1989). Huffman and Norman (1988) showed that such supercooled clouds reduced the accuracy of statistical techniques for predicting freezing precipitation from the sounding data.

The form of precipitation can also have an important

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Modeling the isotopic composition of precipitation

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Abstract. The physics of the stable isotopes of water is incorporated into a two-dimensional, kinematic, bulk cloud microphysical model. The model is run for several idealized, classical stratiform and convective storm situations, and the resulting isotope ratios of precipitation and water vapor are diagnosed and compared to observations. For stratiform snow, the model produces low isotope ratios that decrease rapidly poleward of the warm front. The lowest isotope ratios occur when the atmosphere is cold and when the vertical velocity attains its maximum value high in the troposphere. For stratiform rains, the model produces much higher isotope ratios without a significant poleward gradient as a result of isotope exchange between the falling rain and the surrounding vapor. Isotope ratios of rain are lowest when the melting level is near the ground and isotope exchange is minimized. For air mass thunderstorms, isotope ratios are uniformly high in warm air, no matter what the cloud height, unless hail approaches or reaches the ground. The model also produces a significant amount effect for rain, in which isotope ratios decrease with increasing rainfall totals. Isotope ratios are particularly low when the rain derives from a recirculation process in which air previously charged by vapor from falling rain subsequently rises. Under such conditions, the model sometimes produces isotope ratios that decrease from the periphery to the core of the precipitation shield. It is suggested that this recirculation process is responsible for extraordinarily low isotope ratios observed in some hurricanes and organized thunderstorms. The dominant cloud microphysical processes can sometimes be inferred from isotope ratios of precipitation. The model produces ice pellets with isotope ratios close to those of rain when the pellets are produced by homogeneous freezing of rain and close to those of snow when the pellets are produced by refreezing of partially melted snow. A climatology of isotope values that matches the main features of the observed global data set and of a seven-year record of storms at Mohonk Lake, New York is generated by running the model for a wide range of conditions. This includes the deuterium excess ($d \equiv \delta D - 8 \times \delta^{18}O$) for Antarctic snows that increases markedly as δD falls below -300‰ and the deuterium deficit observed for rain in warm, dry regions.

1. Introduction

The proven value of the stable isotopic ratios of meteoric waters (HDO/H_2O and $H_2^{18}O/H_2^{16}O$, often expressed in standard δ notation as,

$$\delta = \left[\frac{R_{sample} - R_{SMOW}}{R_{SMOW}} \right] \times 1000 \qquad (1)$$

where R represents the isotope ratio and SMOW is Standard Mean Ocean Water) as indicators of past climate [Friedman et al., 1964; Dansgaard, 1964; Dansgaard et al., 1982; Jouzel et al., 1987a] derives from a few dominant physical processes and meteorological situations.

Fractionation during phase change and slower diffusion rates for the heavy isotopes are the two physical processes that produce the isotope signals in precipitation and atmospheric water vapor. In most situations, fractionation is the primary process. The heavy isotopes have lower vapor pressures than the normal form of water and, as a result, are enriched in the liquid or solid phase and correspondingly depleted in the vapor phase. Condensation of vapor as an air parcel cools progressively lowers the heavy isotope ratios of the remaining vapor and the condensate that forms from it. Because most condensation results from moist adiabatic ascent, isotope ratios of vapor and precipitation both decrease with altitude [Dansgaard, 1954].

Much of the world's precipitation forms either during gently sloped ascent in extratropical cyclones or during nearly vertical ascent in convective clouds (Figure 1). Sloped ascent over a frontal surface mimics many of the features of a fractionation chamber. Tropical air begins its ascent with a high isotope ratio near the surface front. As

Ship-produced cloud lines of 13 July 1991

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Abstract – On 13 July 1991, a well-defined cloud line produced by an unidentified steaming ship was detected in satellite imagery and was simultaneously photographed from the *R/V EGABRAG III*. The *EGABRAG* produced a much less well-defined cloud line. Measurements made from the *EGABRAG* revealed that the cloud lines formed in a shallow boundary layer which was nearly saturated, unstable, drizzling and nearly free of cloud condensation nuclei (CCN). The *EGABRAG* passed through the plume of the ship as indicated by elevated CCN concentrations coincident with the cloud line. Thereafter, both ships passed under a shallow stratus layer where background CCN concentrations increased significantly. Only the cloud line produced by the ship extended into the stratus layer; the *EGABRAG* did not affect the layer. The CCN and updraft from the ship were involved in the formation of the cloud line. In contrast, the CCN and updraft from the *EGABRAG* were insufficient to produce a well defined cloud line. Production of the cloud lines appeared dependent on a combination of environmental conditions and ship-produced CCN and updrafts.

Key word index: Ship trails, ship-produced clouds, ship effluents

A marine stratus layer modified
by ship-produced CCN and updrafts[*]

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Abstract

This study was conducted to determine if ship-produced cloud condensation nuclei (CCN) and updrafts could explain a linear feature detected in 3.4 μm satellite images of a stratus layer offshore Baja California. Near-simultaneous satellite and marine boundary layer measurements were obtained in the ambient stratus layer and in the feature affected by effluents from an unidentified steaming ship. Using a 1-D cloud formation model, the average droplet size calculated from the ambient CCN correspond to the satellite-detected effective droplet size in the ambient stratus. Likewise, the ship-produced CCN could explain the reduced effective droplet size detected in the linear feature. The calculated droplet sizes, however, did not vary significantly for reasonable ambient and ship-produced updraft values. Nevertheless, it is argued that ship-enhanced updrafts may have been required to trigger the linear feature because ambient updrafts, alone, are expected to have produced a more diffuse feature. These results may be useful to studies of techniques to prevent ship modifications of marine stratus layers.

ANOMALOUS CLOUD LINES
Occurrences and Predictions

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EAS 310.2
Spring Semester 1994

ABSTRACT

Bowley (1967, J.Atmos.Sci) reports that ship-produced anomalous cloud lines (ACL's) detected in satellite images occurred when the marine boundary layer (MBL) was shallow and foggy. Shallow MBL tend to occur on the east side of the Eastern Pacific High in the summertime as maximum subsidence occurs at that location. Thus, occurrences of ACL's may be related to position and strength of the Pacific High. This hypothesis was tested by comparing the average position of ACL events (using Geosynchronous Orbiting Environmental Satellite (GOES) images) and the corresponding average position and strength of the Eastern Pacific High (using surface weather analysis maps provided by Difax) for the summers of 1991 and 1993. It was found that the ACL positions corresponded to the position of the High; the ACL regions occurred approximately 10-15° east of the High at nearly the same latitude. It was also found that the position and strength of the High on non-ACL days was similar to that on ACL days. Consequently, knowledge of the position and strength of the High is not sufficient to predict the occurence of ACL. However, if broken stratus regions occur 10-15° east of the High, ACL's would most likely occur in those regions since conditions favorable to broken stratus regions would also be favorable for ACL development. ACL would be undetectable if the stratus layer were too thick since GOES images cannot distinguish between the two types of clouds and ACL have not yet been observed during "clear" periods (no stratus clouds).