REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
15-06-2001

2. REPORT TYPE
UU

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
See the abstract below

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
See the abstract below

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Phone.txt   DTICPUB0615.txt

US NAVAL OBSERVATORY COLLECTION

20010705 162

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF: UU			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON See the abstract above
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code) See the phone list above*

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

USNO PUBLICATIONS SENT TO DTIC Friday, June 15, 2001

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Meteorological Survey of Mars

For Opposition Years 1965 - 1995

By: JEFFREY D. BEISH

Association of Lunar and Planetary Observers (A.L.P.O.)

INTRODUCTION

Starting with the 1964-65 Apparition of Mars, the International Mars Patrol (I.M.P.) began a syst observing program designed to record all meteorological activity on Mars using pre-selected colored filt observing techniques developed by the well known Mars authority Charles F. (Chick) Capen, Senior A. Mars Recorder. A continuation of the systematic ground-based support for Mars studies represents apparitions of study. The I.M.P. coordinated the efforts of 1,074 astronomers located the United States foreign countries interested in detailed study of the planet Mars organized for a 24-hour surveillance pr of the planet during each apparition. The I.M.P. is the primary observing program for the Mars Section Association of Lunar and Planetary Observers (A.L.P.O.).

The I.M.P. archives contain 26,161 observations of Mars to date. A catalog of 24,130 observations of M been used for this survey. This paper presents statistical analyses from the wealth of data obtained dur 31-year period from 1964 through 1995 for investigating seasonal and long-term patterns in the meteorology and climate.

Part-I of the Meteorology of Mars report series briefly described methods used in the analysis and pre detailed results of the 1981-82 Martian Environmental and Climatic Survey, [***Beish et al***, 1986]. Infor pertaining to part one was obtained from observations of the Institute for Planetary Research Observ (I.P.R.O.). Further analysis using data from the Association of Lunar and Planetary Observers (A.L.P.O. Section observation records were presented in Meteorology of Mars Parts-II, [***Beish et al,*** 1987], and P [***Beish et al,*** 1987].

A complete systematic survey of I.M.P. observations of Mars resulted in publication of a more detaile analysis of bright aerosols and condensates reported by A.L.P.O./I.M.P. observers during 1968 thro 1985 and was presented to the American Geophysical Union [***Beish*** and ***Parker***, 1990].

MARTIAN CLOUDS, HAZES, AND WHITE AREAS

Clouds, hazes, and white surface areas are observed on Mars during every Martian season. Observ records indicate that these bright features exhibit certain characteristics similar to the familiar ter clouds, fog's and hazes. They are especially bright in blue light and are sometimes observed to brighte colors. From these observations and from the data gathered by the Mariner spacecraft and the Landers/Orbiters, we now know that H2O ice clouds and CO2 hazes do exist on Mars. We shou comfortable with the idea that what we observe as bright patches from Earth are clouds and hazes on Our Earth-based telescopic observations are more significant with this new knowledge [***Capen,*** 1982]

Martian clouds, fogs, frost, and dust clouds come in various shapes and sizes and are sometimes obse move around on the planet blocking out portions of the surface. We were particularly interested i locations and movements, and their seasonal counts. Various methods have been employed to enhanc bright areas, one of which is the use of colored transmission filters. These filters are regularly used by observers for visual and photographic observations of Mars and other planets [*Capen*, 1982].

Table 1 and Figure 1 are general histograms of the observational coverage during each Mars apparition this study. Figure 2 plots the number of visual, photographic, micrometric, and CCD images obser contributed during each opposition year.

Table I. History of ALPO/IMP observations from 1965 through 1993. Given are the dates from the first to last observati opposition date and Planetocentric of the Sun (Ls), Ls range, total span of Ls from first top last observation, actual numb observed, number of observers (OBS), and total observations (Visual, Photographic, Micrometer, and CCD).

Observation Dates	Opposition (Ls)	Ls Range(Span)	Ls Observed	Obs	T
1964 Sep 11-1965 Aug 25	1965 Mar 09 (84)	3-165 (163)	100	3	
1968 Nov 22-1970 Mar 12	1969 May 31 (165)	75-336 (262)	120	31	
1970 Nov 29-1972 Feb 18	1971 Aug 10 (232)	97-347 (251)	138	115	
1973 Feb 24-1974 May 19	1973 Oct 25 (306)	160- 50 (251)	163	78	
1975 Mar 18-1976 Jul 19	1975 Dec 15 (357)	197- 96 (260)	151	54	
1977 Jun 26-1978 Aug 05	1978 Jan 22 (36)	286-124 (199)	136	30	
1979 Jun 06-1980 Oct 22	1980 Feb 25 (70)	300-187 (248)	162	41	
1981 Jul 28-1983 Jan 01	1982 Mar 31 (105)	354-238 (245)	194	56	
1983 Aug 11-1985 Mar 29	1984 May 11 (145)	21-331 (311)	218	59	
1985 Sep 19-1987 Jun 22	1986 Jul 10 (202)	59- 38 (340)	240	90	
1987 Nov 09-1989 Jun 12	1988 Sep 28 (280)	100- 53 (314)	261	306	
1990 Jan 25-1991 Sep 20	1990 Nov 27 (340)	157-117 (321)	199	97	
1992 Apr 24-1993 Nov 14	1993 Jan 07 (22)	236-166 (291)	152	74	
1994 Mar 19-1995 Aug 01	1995 Feb 12 (58)	241-134 (254)	130	66	
			Total	1100	2

			Average	106

RARELY OBSERVED CLOUD BANDS

Rarely observed are the Planetary System Cloud Banding or Equatorial Cloud Band (ECB) ECBs ap broad and diffuse hazy streaks usually observed crossing within ±20 degrees of the Martian equatoria Cloud bands are detected visually using a deep blue (W47B) or violet (W47) filter or photograp ultraviolet or violet light. Cloud bands are probably composed of thin CO2 ice crystals carried aloft b altitude winds.

Until recently, cloud bands were most often observed during the Martian northern summer, ho systematic tricolor CCD imaging has uncovered evidence these wisps of cloud bands may be more fr and may occur in all Martian seasons. Using a special Infrared blocking filter in conjunction with high glass Wratten red, green, and blue filters these ECBs are readily detected and may be unseen by observers.

The I.M.P. has initiated an observing program for intensive investigation into these phenomena and will to all planetary observers using CCD technology to assist us in this important study.

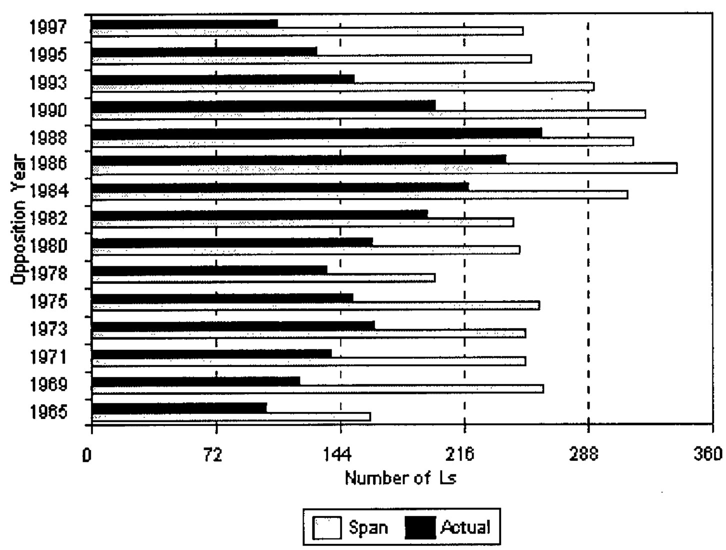

Figure 1. Graph of observational coverage during Mars apparitions as indicated by the corresponding opposition year. Graph includes number of degrees Ls span fo last observation and number of degrees Ls covered by actual observational reports.

ANALYSIS METHODS

Each of the 24,130 Mars drawings, photographs, CCD images in the ALPO Mars Section Observ Report Library was carefully evaluated for quality and accuracy, with special attention given to proper color filters. When multiple observations of a particular phenomena was evident, its precise size, sha location was computed using the least squares method. To reduce systematic errors, the "personal eq for each participating observer was derived from this computation and used to quantify their experience.

Systematic errors are also found in our data as a result of the nature of the reporting of Mars observatio might think of these observations as discrete samples of time or "snap shots" of the conditions on Mars. due to the fact we cannot possibly record every moment of Mars' history, even with the excellent longi coverage provided to us by our world wide network of observers. Large gaps in areographic longitu unseen. To identify

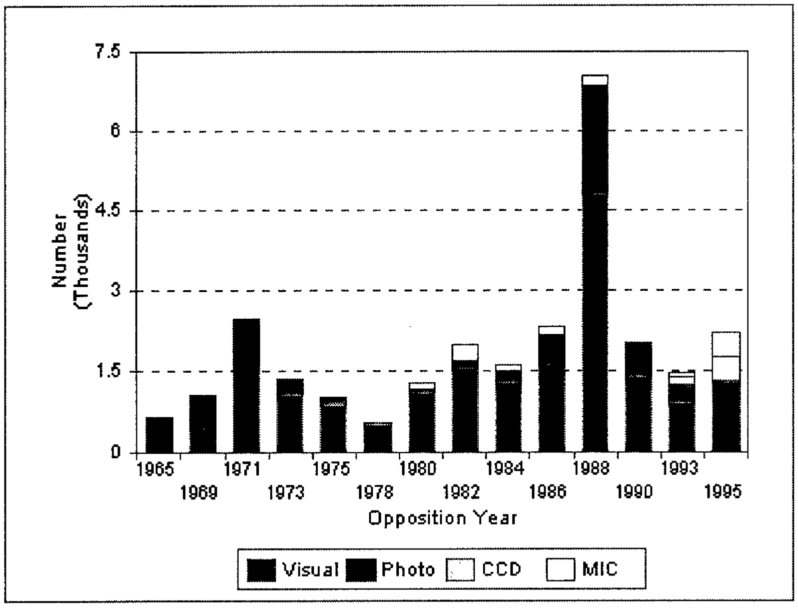

Figure 2. Bar graph showing number of observations by type, i.e., visual drawing reports, photographs, micrometer measurements, and CCD images.

simultaneous observations of clouds or white areas seen by several astronomers is much less difficult separate limb phenomena. This is because limb hazes and clouds appear to stick close to the limbs an phenomena rotate with the planet, as if these clouds are continuously being created and destroyed.

In performing this study we have made every effort to reduce systematic errors. The least square meth employed to construct each individual observer's personal error equation. Each observer's experien reliability, type and size telescope used, reported atmospheric "seeing" conditions, and general locati considered carefully when selecting observations for the survey.

Whenever available, photographs were utilized to cross check and confirm phenomena reported vi Nevertheless, owing to the orbital geometry of Earth and Mars and Mars' axial tilt, considerable unavoidable. For example, the sub-earth point (De) can be situated more than 25° from Mars' equator fo of an apparition. This prohibits observations of those regions near the hidden pole. Areas from latitudes and more are sometimes hidden as are the back side Mars and terminator areas. All these lost observati into the "bucket of the unknown." Other sources of bias include the greatly varying distance of Mars fr Earth (changing Mars' apparent size by some 4-5 times), the period near conjunction with the Sun, whe cannot be observed at all or only briefly each night, and the changing value and position of the phase an complicates observations of hazes and clouds near Mars' poles, limbs, and terminator. These problems a but uncontrollable, since we cannot yet change our vantage point and must remain earthbound.

STATISTICAL ANALYSIS

Statistical analysis was carried out using a 486DX2-50 Express Business Computer and Gateway-2000 66 Business Computer. Graphics plots presented here has been the product of Borland's Quattro Pro 5.0.

The tables in this report are simple percentages of the frequency with which we observe the various t meteorological phenomena on Mars. Owing to a small difference in axial tilt, Mars' seasonal peri similar to those of Earth. When observing Mars from Earth, we see both the planet's northern and so hemispheres, so we must specify that hemisphere's season and is indicated on each graph and table.

Due to the longer year and higher eccentricity of the Martian orbit, the seasons on Mars are not as sym as Earth's. The Martian northern spring and summer are longer than autumn and winter, (reversed Southern Hemisphere).

For statistical analyses, percentages are generally based on the number of activities of weather phen observed during seasonal periods versus the actual time spent observing Mars during that particular The Martian year of four seasons start with its vernal equinox at 0° planetocentric longitude (Ls) and eastward in its orbit through the seasons. Martian seasons are defined as: spring (0° - 89° Ls), summer 179° Ls), autumn (180° - 269° Ls), and winter (270° - 359° Ls). For this study, the Martian year is sub into 90° periods, measured in degrees of Areocentric or planetocentric longitude of the Sun (Ls); and th "Nsp/Sau," "Nsu/Wwi," "Nau/Wsp," and "Nwi/Ssp" corresponds respectively to "spring," "su "autumn," and "winter" that identifies with the Martian seasons in each of the planet's hemispheres.

To provide a valid and systematic distribution of the observational data, I chose to (1) discard observations made when Mars was less than 6 arcsec apparent diameter, (2) exclude seasonal periods w than 12% observational coverage, and (3) eliminate observations by very inexperienced or novice pl astronomers. These three criteria confine analysis to at least much of each Martian season oc immediately before and after opposition and to observations made by experienced planetary astronomers

Table II and III summarize the results of our statistical analysis for each phenomenon by season. Althou knowledge of "white areas" is limited, their characteristics suggest they are surface deposits of frosts. included white areas in this survey because these phenomena may prove to be both surface and atmosp nature. Also, bright areas have been observed immediately after dust storm activity further suggesting deposits of fresh dust.

Figure 3 represent a more detailed breakdown for each type of meteorology by season and include the south hemisphere occurrences as well. In each case, the percentages reflect the number of activities ver number of degrees Ls observed for each period.

RESULTS

One striking finding of this study is the marked proclivity for limb clouds and discrete clouds to appear northern hemisphere spring and summer. This seasonal preference may result from different composi the polar caps. Viking data has shown that many of the white limb and discrete clouds are composed of ice crystals. The Viking spacecraft have demonstrated that the primary composition of the South Pol (SPC) is carbon dioxide ice (CO_2) with perhaps a tiny core of water ice clathrate [***James et al.***, 1979] the North Cap consists of a layer of carbon dioxide covering a fairly large water-ice remnant [***Kieffer*** 1976]. The frequency distribution of these clouds appears to follow the regression of the north cap, incr as the remnant cap is exposed during Martian northern summer.

The much lower incidence of white clouds during southern spring and summer agrees well with Mars' asymmetry in water vapor abundance [***Farmer*** and ***Doms***, 1979; ***Jakosky*** and ***Farmer,*** 1982]. It should

pointed out, however, that the apparitions most favorable for studying these Martian seasons were 19 1973, years of global dust storm activity. During these two apparitions, dust clouds obscured large areas planet throughout much of the southern spring and summer, reducing the chances of observing white While this has no doubt introduced some bias, our preliminary reduction of the considerable data fr 1986 and 1988 apparitions [***Parker et al.***, 1989] suggests that there is indeed much less discrete and lim activity in southern spring and summer than there is during these seasons in the north. Even the orograp clouds" in 1986 around 200°-220° Ls were neither so numerous nor so long-lived that they would be alter the dominance of the "more usual" northern spring/summer meteorology in this survey. Th apparition displayed even fewer clouds, despite a record number of experienced observers participating meteorological survey. As the data from 1986, 1988, 1990, and 1993 is added to this study, any bias global storms have been reduced considerably.

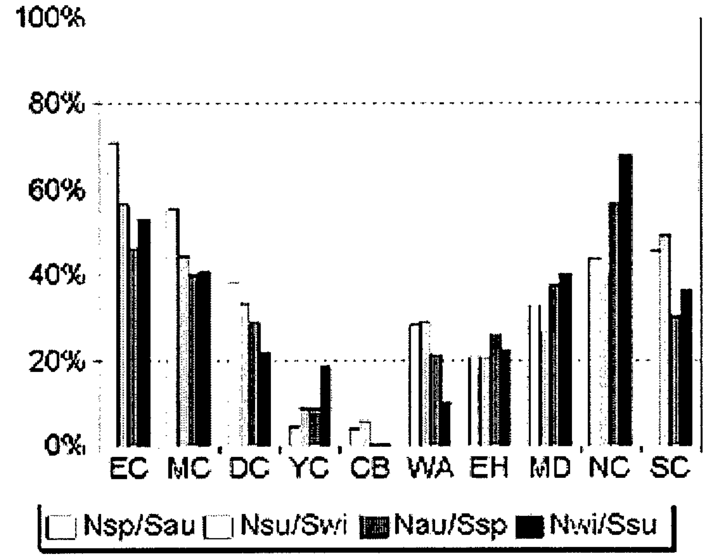

Figure 3. Graph indicating the overall simple average meteorological active degrees Ls during all apparitions from 1964 through 1993. Each type of meteorology in li vertical scale and percentage of the observed Martian year is indicated in the horizontal axis. The terms Nsp/Sau = Northern spring/Southern autumn, Nsu/Swi = N winter, Nau/Ssp = N. autumn/S. sprint, and Nwi/Ssu = N. winter/S. summer.

A short-term climatic phase of this survey is being completed. Although the seasonal coverage is inco for 1971 and 1973 (due to global dust storms) enough data was available to qualify the survey under the 12% criterion. I have also included data from C.F. Capen's observational records and photographic libr the 1964-65 and 1966-67 apparitions and further reducing the data from the 1962-63 apparition obser and photographs by C.F. Capen.

Despite the resultant gaps in the coverage, meteorological observations of the 1960s are considered cr since C.F. Capen, who organized this survey, performed most of the work at Table Mountain Observator

As a result of this survey this author will not rule out the possibility of short-term and highly variable c changes on Mars as predicted by past I.M.P. studies and has published these suggestions before [***Parke*** 1983]. On the surface this meteorology study can be used in conjunction with past studies of the Martia cap behavior indicates the planet Mars was either cooler during the 1960's and warmer in the early 19 the observing techniques and equipment have so biased our results that we need to completely revolu the art of observing the Solar System with more objective methods.

The spacecraft missions to Mars during the 1960's and 1970's have resulted in a new impetuous for g based telescopic observing of the Red Planet. Astronomers are now armed with new knowledge abou made available by close-up surveillance by the Viking Orbiters and Landers. Of course, the loss o Observer has ended prospects of continuing the close-up watch on Mars and all those machines are jus junk now.

The benefits of the study of Mars' climate will help in the understanding of our own planet's climat methods arrived from the meteorological survey of Mars using A.L.P.O. observations and modern tech will increase our knowledge of the planet Mars. The amateur astronomer has earned a place in modern s

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Tables

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