Session VI. Heavy Rain Aerodynamics

N91-24181

Heavy Rain Field Measurements
Ed Melson, NASA Wallops

HEAVY RAIN FIELD MEASUREMENTS

W. EDWARD MELSON, JR.

NASA/GODDARD SPACE FLIGHT CENTER/WALLOPS FLIGHT FACILITY

THIRD COMBINED MANUFACTURERS' AND TECHNOLOGISTS'
AIRBORNE WIND SHEAR REVIEW MEETING
OCTOBER 16-18, 1990
HAMPTON, VIRGINIA

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ABSTRACT

Tests have shown that the effects of heavy rain on the aerodynamic performance of a wing produces a degrading influence. These tests have also shown that the transition from steady-state dry condition of the wing to a steady-state wet condition takes place in a matter of seconds. This short transitional period led to a need for understanding short-duration high-intensity natural rainfall. The current data base of the National Weather Service for rainfall is averaged over relative long time constants. This averaging tends to mask the short-duration, high-intensity rainfall characteristics.

A weight-measuring rain gauge was developed to collect rain data and configured to operate at a high sample rate (one sample per second). Instead of averaging the rain rate in minutes, hours, and sometimes days as normally performed, the rain data collected are examined in seconds. The results of six field sites are compiled. Rain rate levels, duration of downpours, and frequency of heavy rainfall events are presented.

OUTLINE

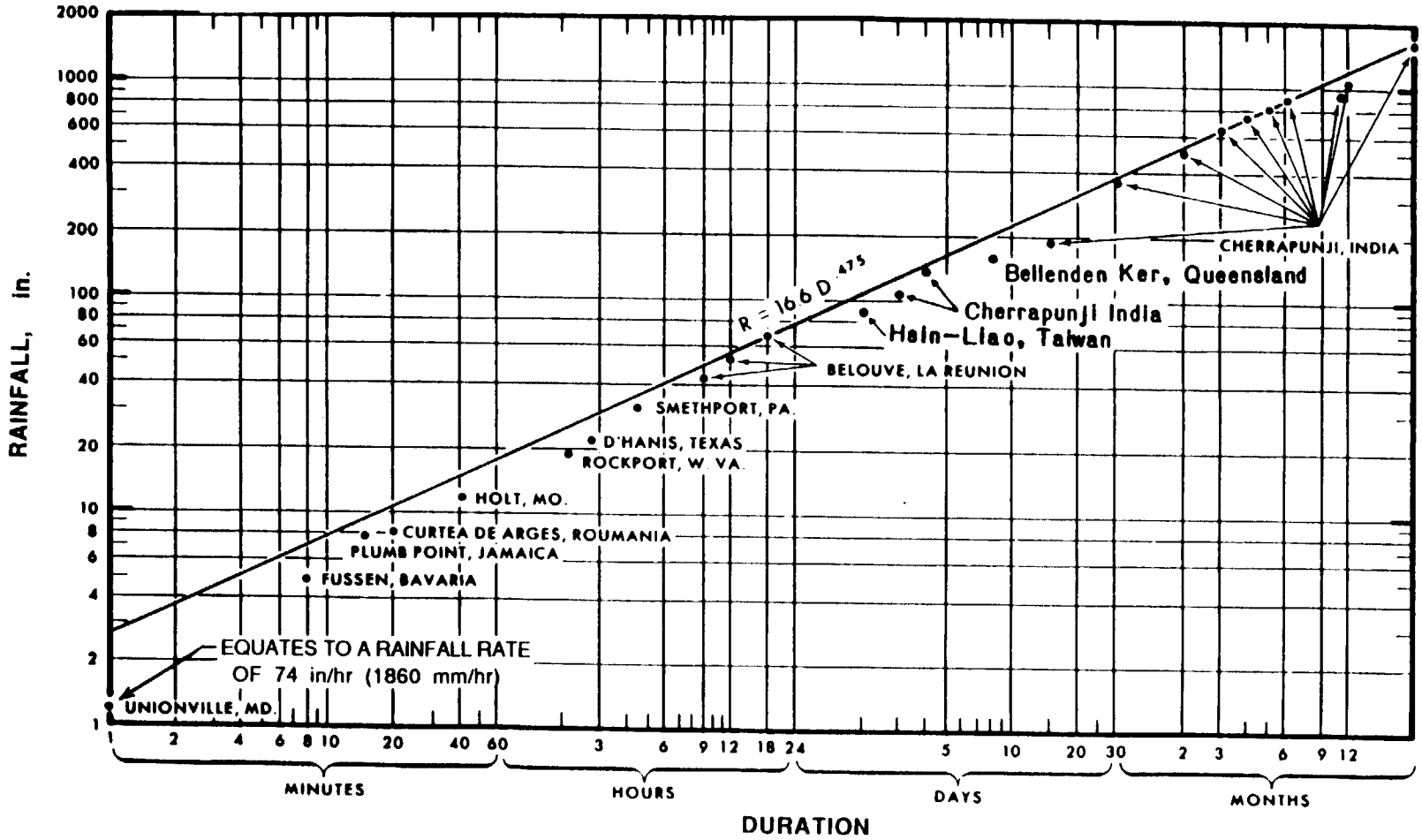
- HEAVY RAIN
- TRANSITION TIME
- RAINFALL MEASUREMENTS
- DATA REDUCTION
- HEAVY RAINFALL CHARACTERISTICS

HEAVY RAIN HAS A DEGRADING INFLUENCE ON THE AERODYNAMIC PERFORMANCE OF A WING

- *WHAT IS HEAVY RAIN ?*

- *WHAT IS THE FREQUENCY OF HEAVY RAIN ?*

WORLD'S GREATEST OBSERVED POINT RAINFALLS



WMO, Probable Maximum Precipitation, 1986

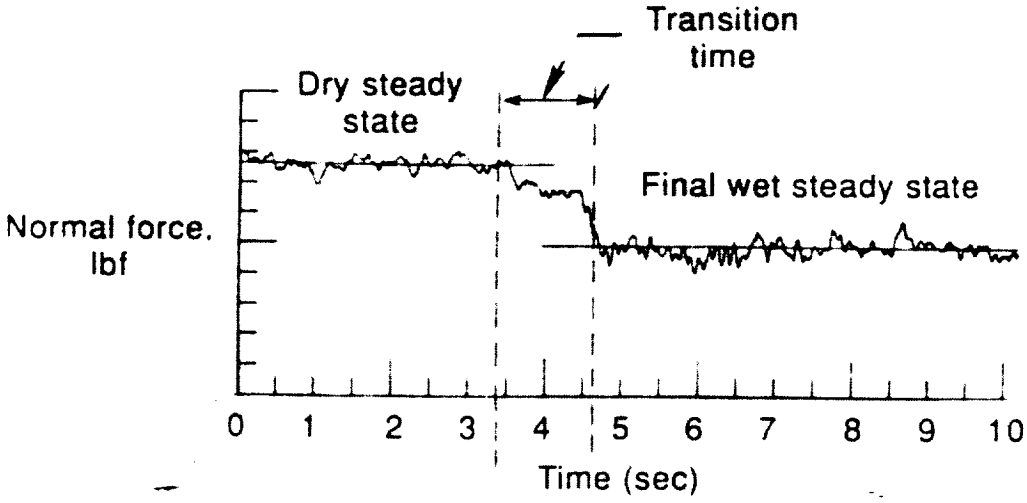
TRANSITION OF THE WING'S PERFORMANCE FROM A DRY TO A WET CONDITION TAKES PLACE IN SECONDS

- *CURRENT RAINFALL DATA BASE IS AVERAGED OVER RELATIVELY LONG TIME PERIODS (MINUTES, HOURS.)*

- *THIS PROCESS TENDS TO MASK THE SHORT-DURATION, HIGH-INTENSITY RAINFALL CHARACTERISTICS*

DYNAMIC RESPONSE OF WING IN SIMULATED RAIN

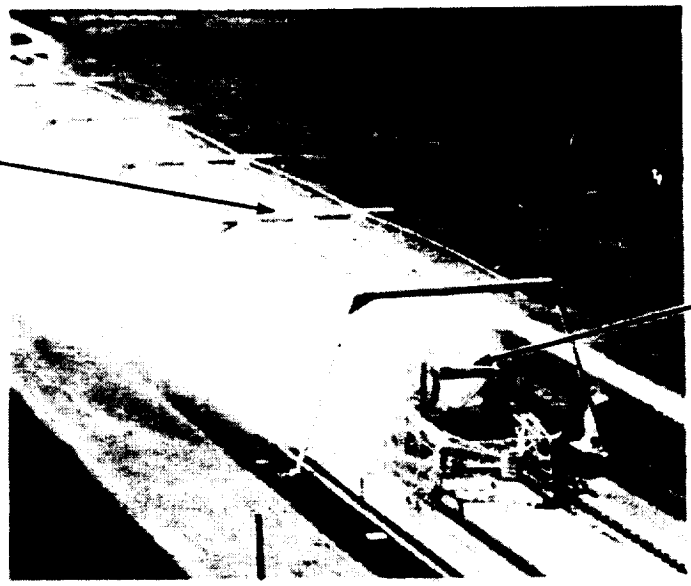
Test set-up in 14-by-22 foot subsonic tunnel

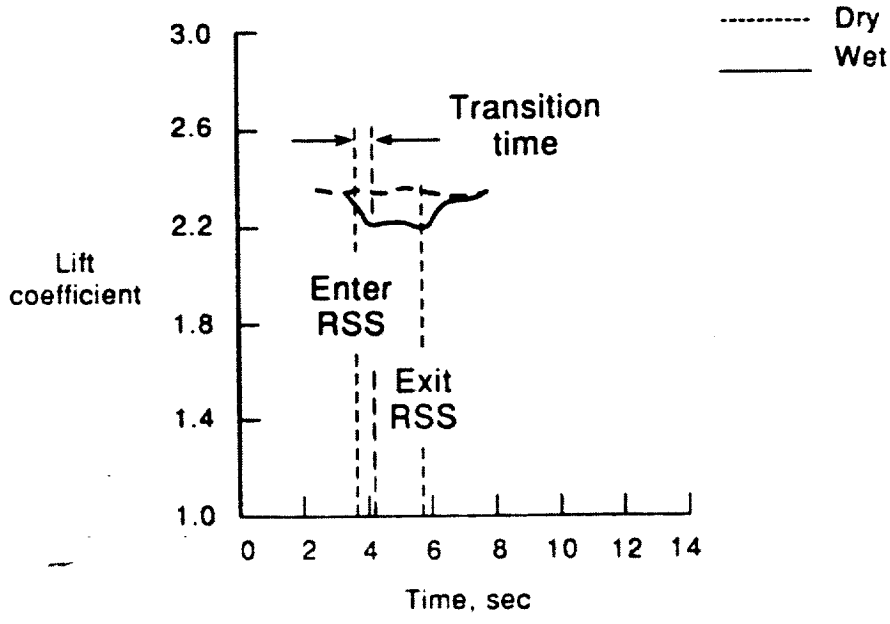


(Campbell & Bezos, 1989

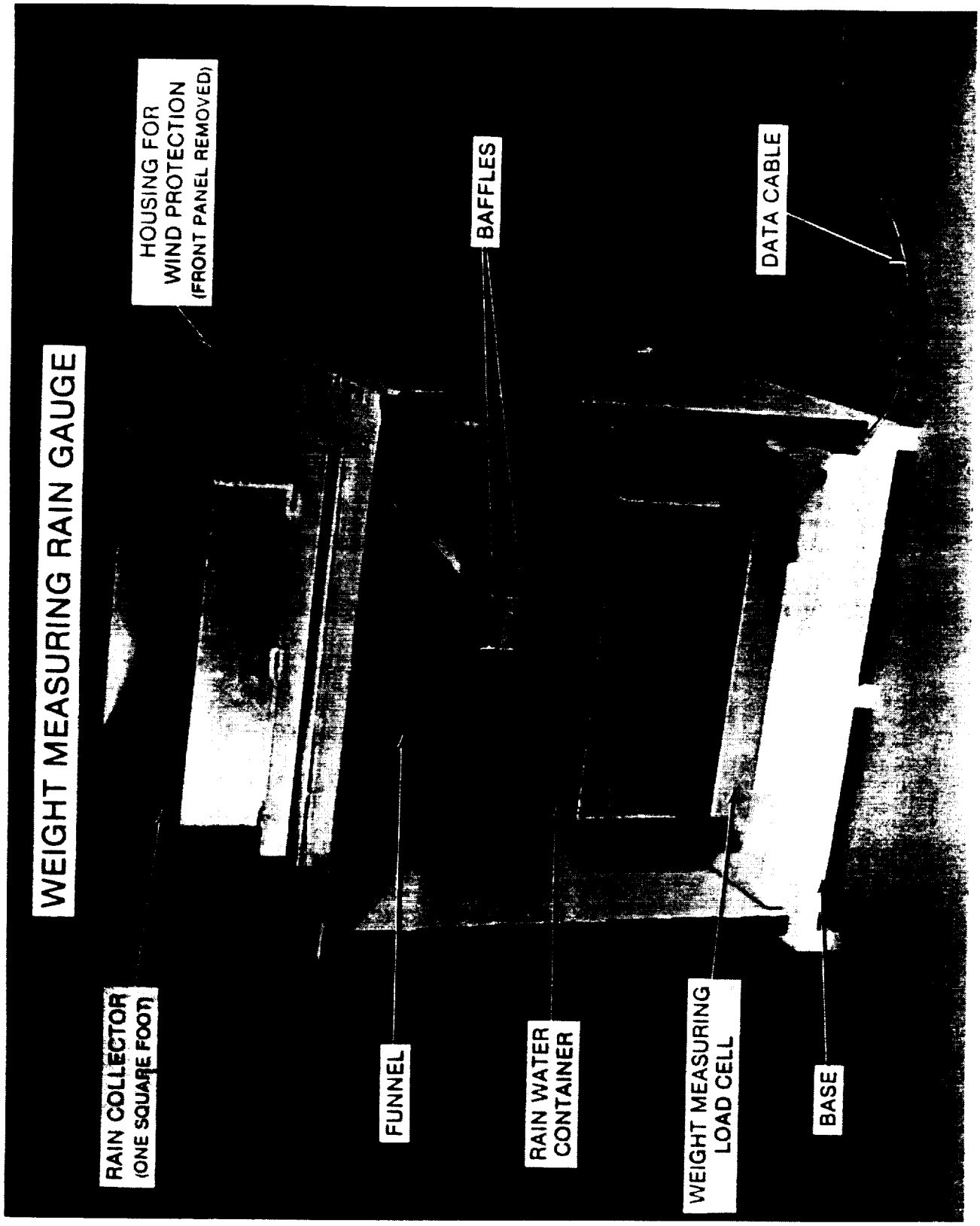
DYNAMIC RESPONSE OF WING IN SIMULATED RAIN

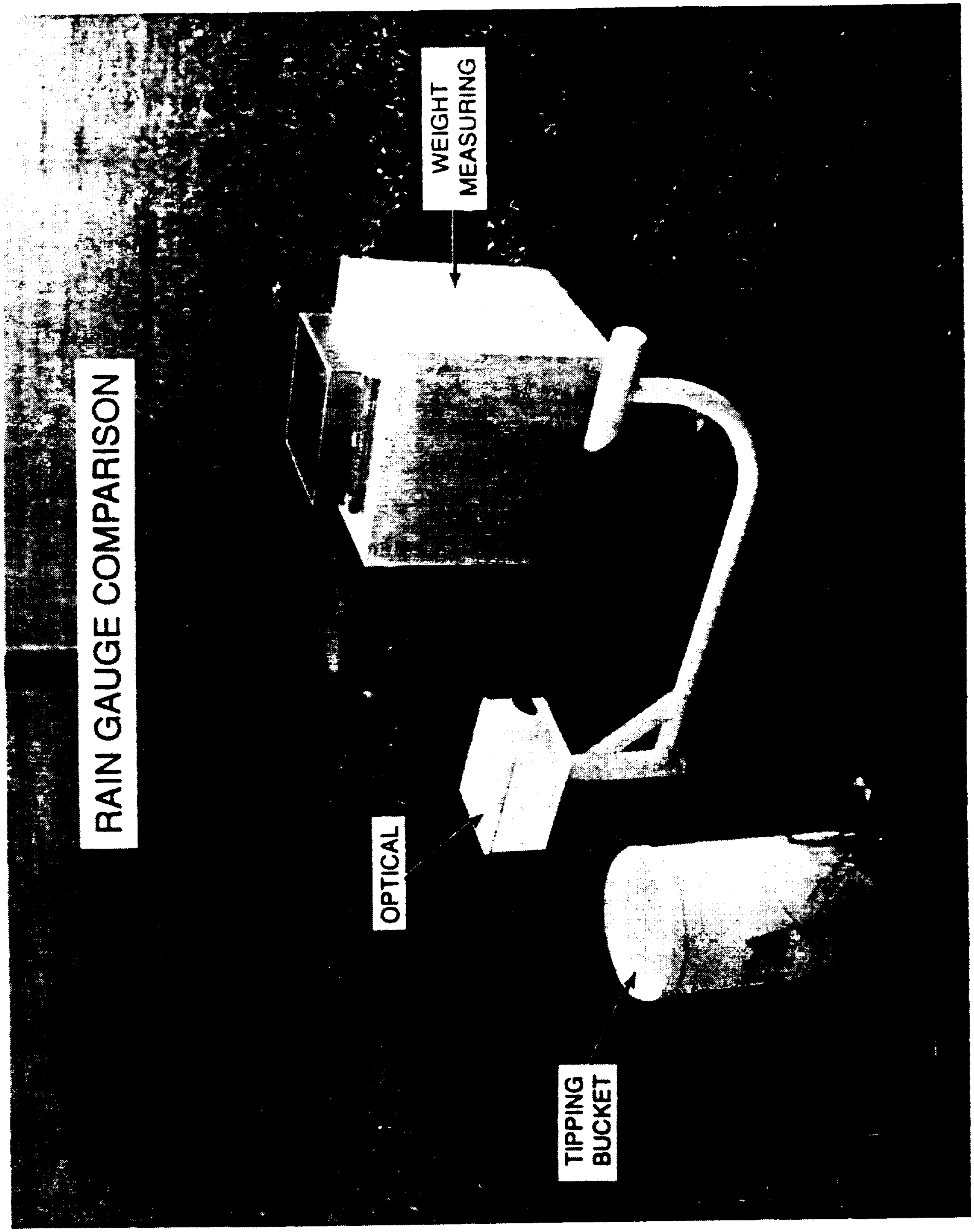
TEST SET-UP AT THE AIRCRAFT LANDING DYNAMICS FACILITY





(Bezos, Dunham, Campbell, Melson; 1990)

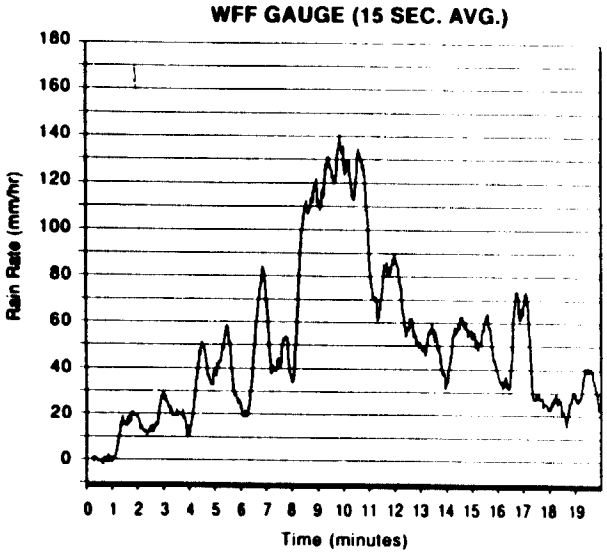


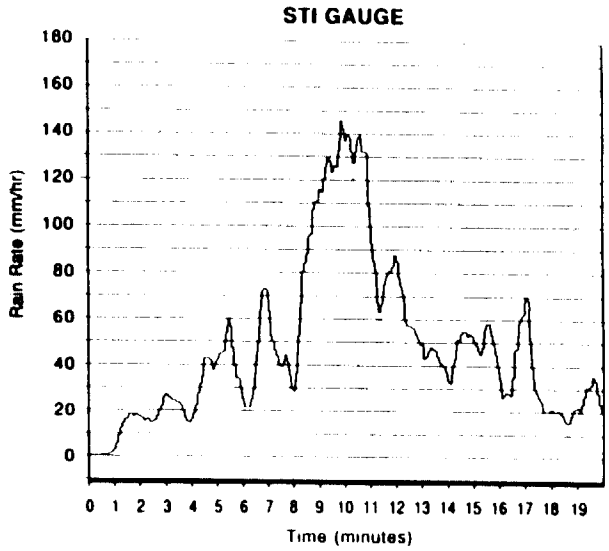


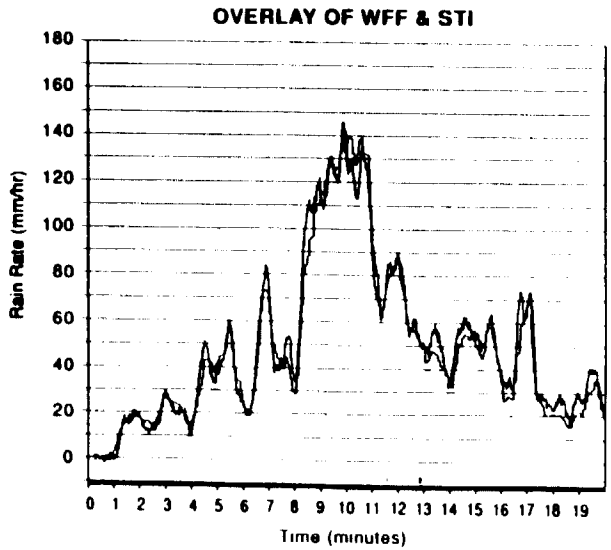
RAINFALL EVENT

12/21/89 (Start 21:38:37)

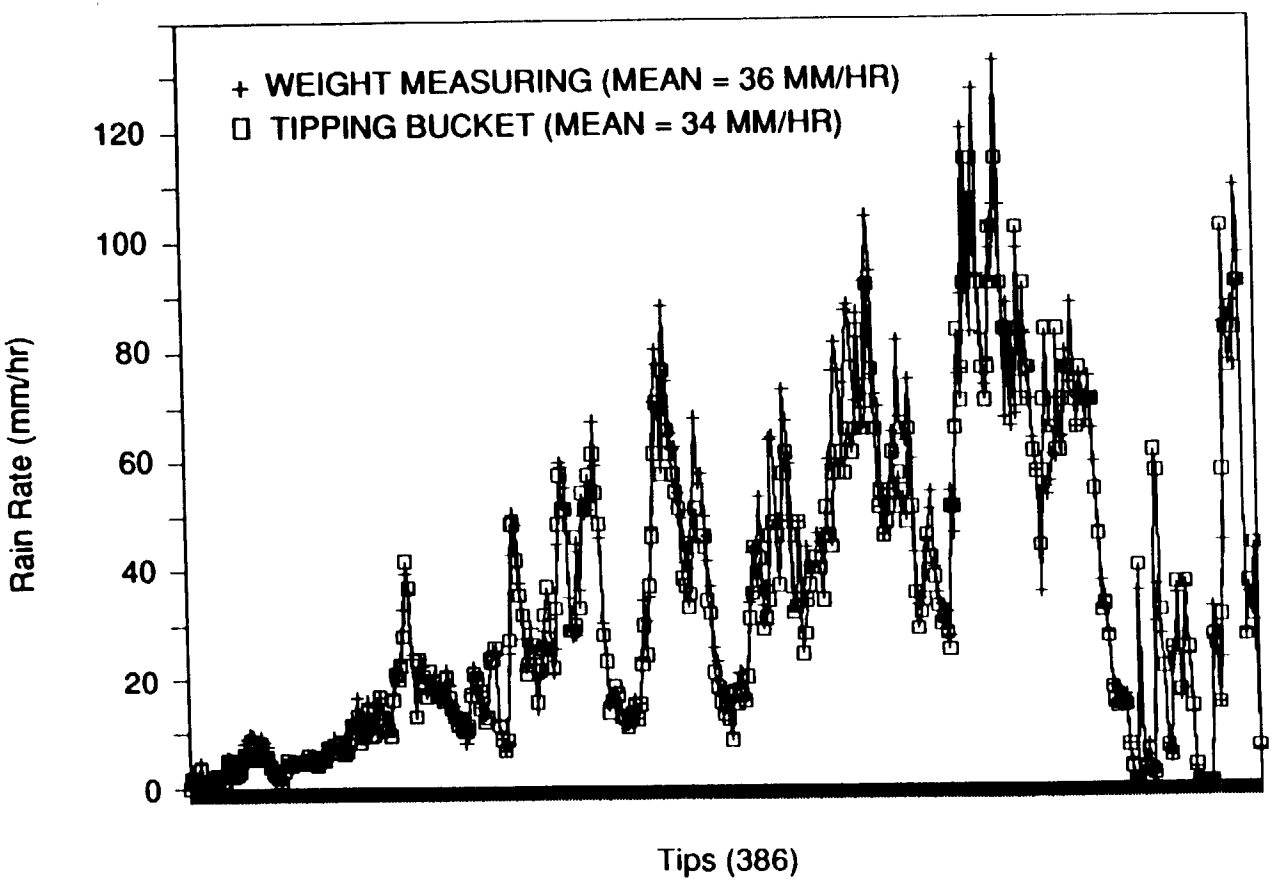
Darwin, Australia File # E6-7







COMPARISON OF THE WEIGHT MEASURING RAIN GAUGE TO A CONVENTIONAL TIPPING BUCKET RAIN GAUGE



LOCATIONS

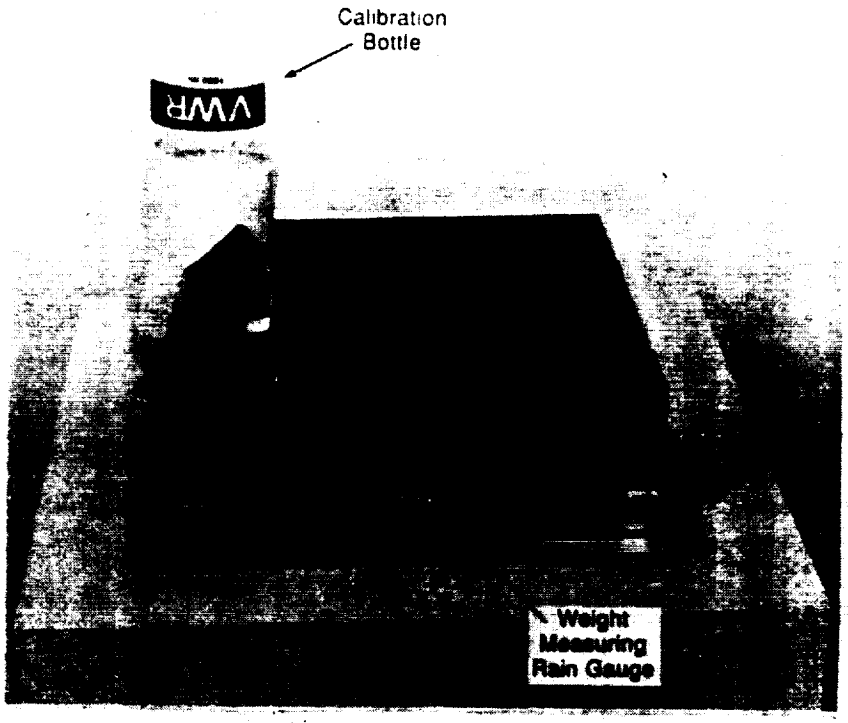
- GSFC/WFF, WALLOPS ISLAND, VA (FEBRUARY 1989)
- LaRC, HAMPTON, VA (JUNE 1989)
- KSC, KENNEDY SPACE CENTER, FL (JUNE 1989)
- NASA/BMRC, DARWIN, AUSTRALIA (NOVEMBER 1989)
- BOEING AIRCRAFT CO., SEATTLE, WA (JANUARY 1990)
- NCAR/NWS, DENVER, CO (FEBRUARY 1990)

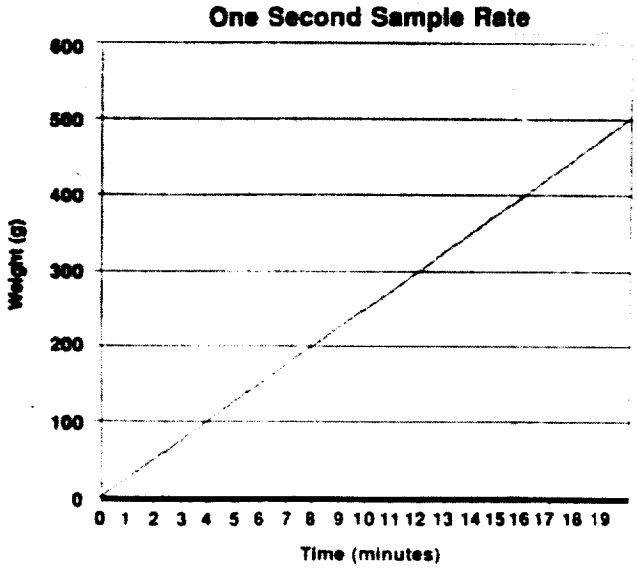
REDUCTION OF THE WEIGHT-MEASURING RAIN GAUGE RAINFALL DATA

- *ACCUMULATOR*
- *RESOLUTION*
- *DIFFERENTIATION*
- *TIME*

SYSTEM CALIBRATION

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH





EXAMINE THE HEAVY RAINFALL CHARACTERISTICS

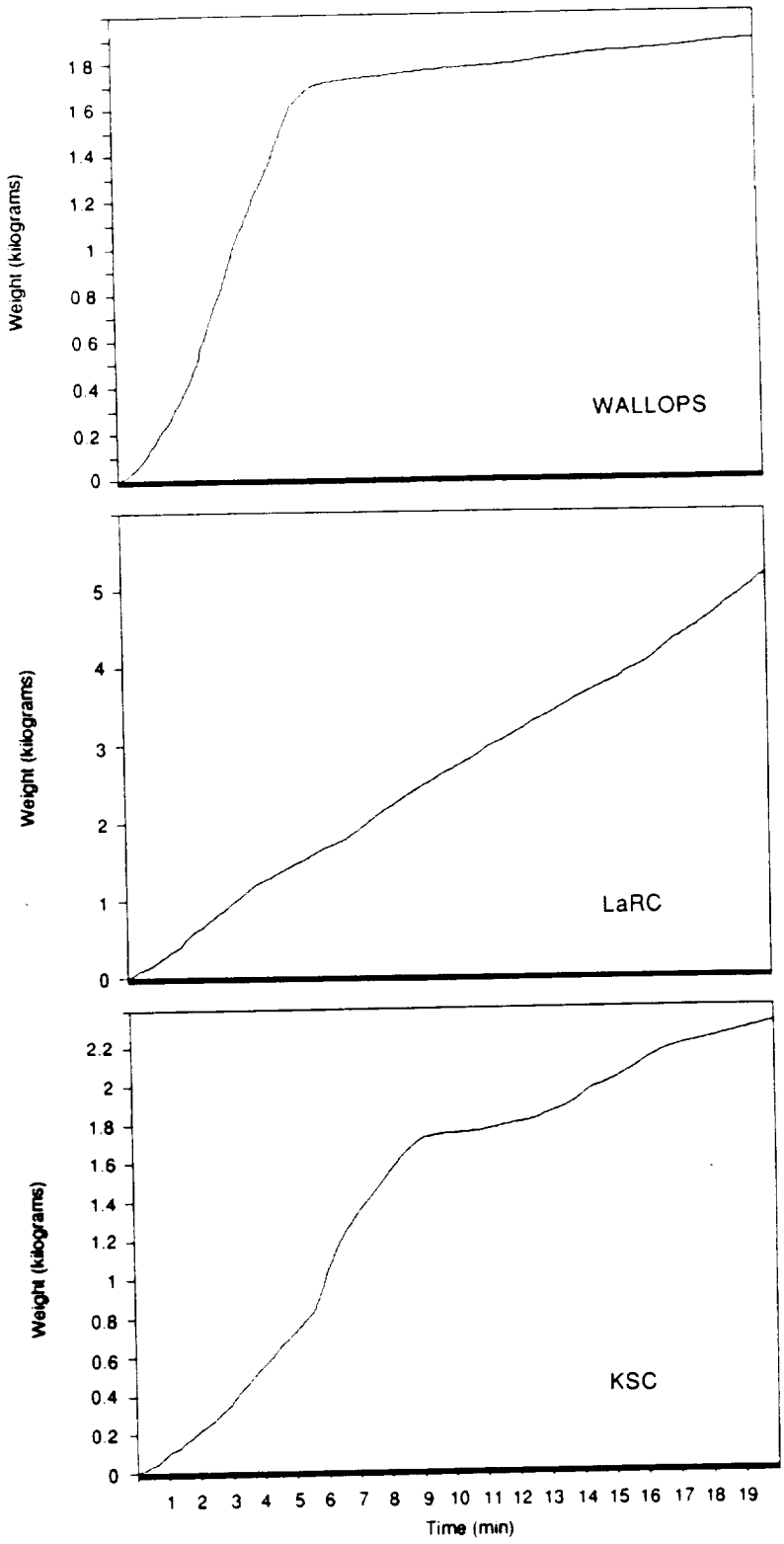
- HEAVY RAIN RATE LEVELS
- DURATION OF DOWNPOURS
- FREQUENCY OF HEAVY RAINFALL

SUMMARY

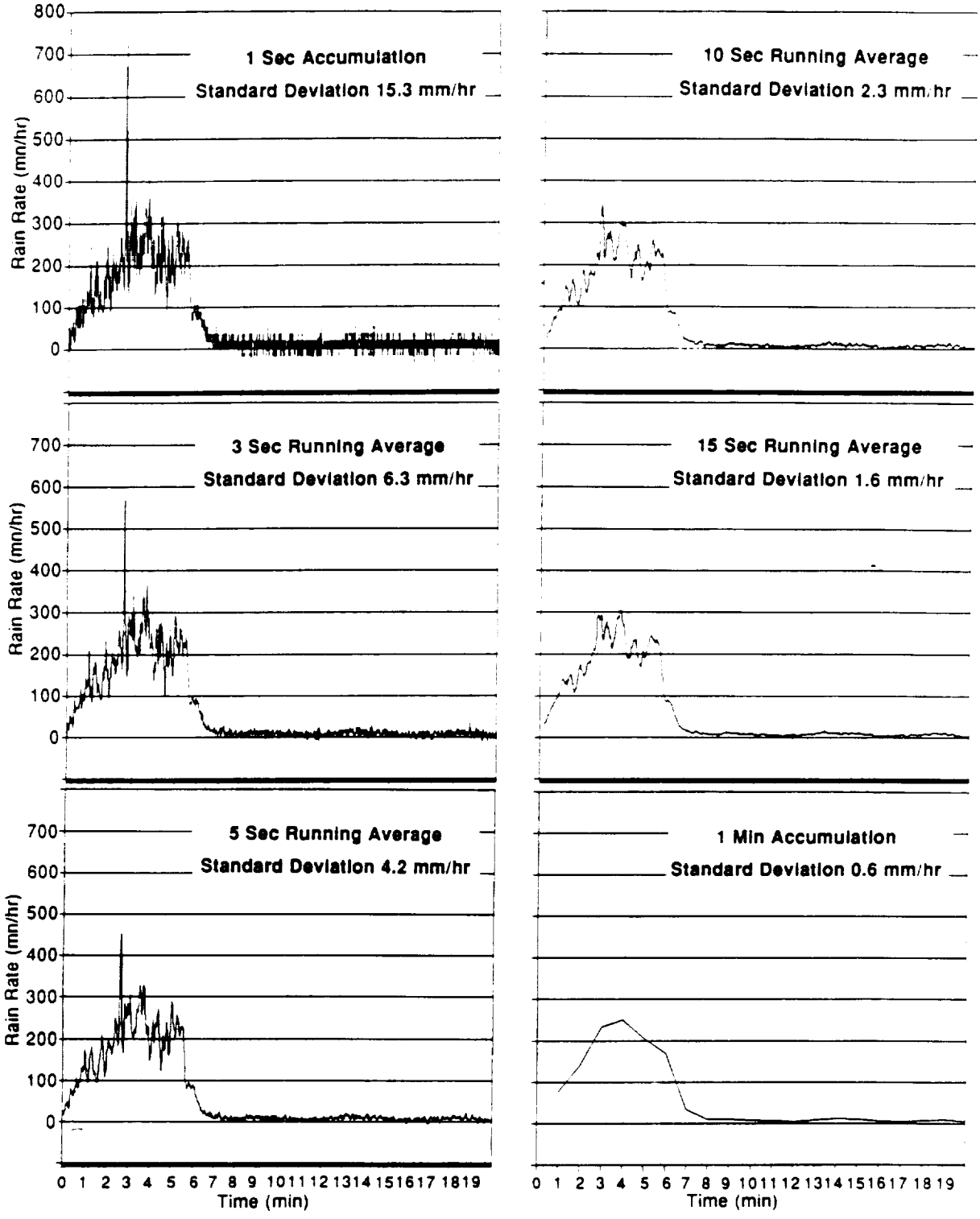
LOCATION	MONTHS	GAUGE* OPEATIONAL TIME (SEC)	DATA POINTS	DATA POINTS GREATER THAN 100 MM/HR	MEAN RAIN RATE (MM/HR)	MAXIMUM RAIN RATE (MM/HR)
DARWIN	5	11,741,760	285,600	3,361	10	299
KSC	9	21,072,960	255,600	4,123	10	492
LaRC	4	9,564,480	122,400	1,158	4	633
WALLOPS	15	35,303,040	910,800	4, 142	5	722
DENVER	5	11,664,000	262,800	30	1	123
SEATTLE	6	14,074,560	366,000	10	1	105
TOTALS	----	103,420,800	2,203,200	13.094	- - - -	- - - -

*ASSUME GAGE IS 90% OPERATIONAL DURING MONTHS IN SERVICE

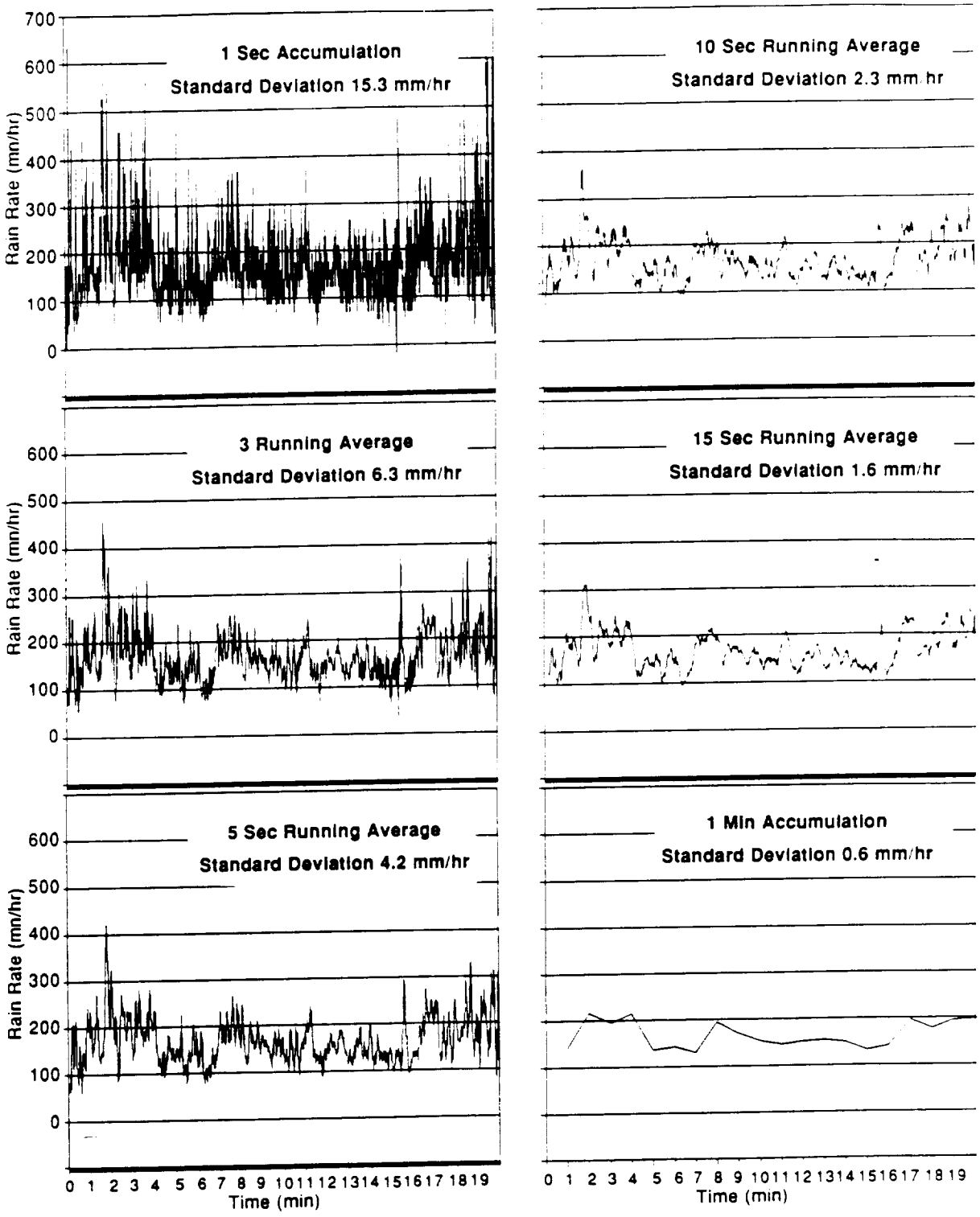
COLLECTED RAIN WATER WEIGHT FOR 20 MINUTES AT A ONE SECOND SAMPLE RATE



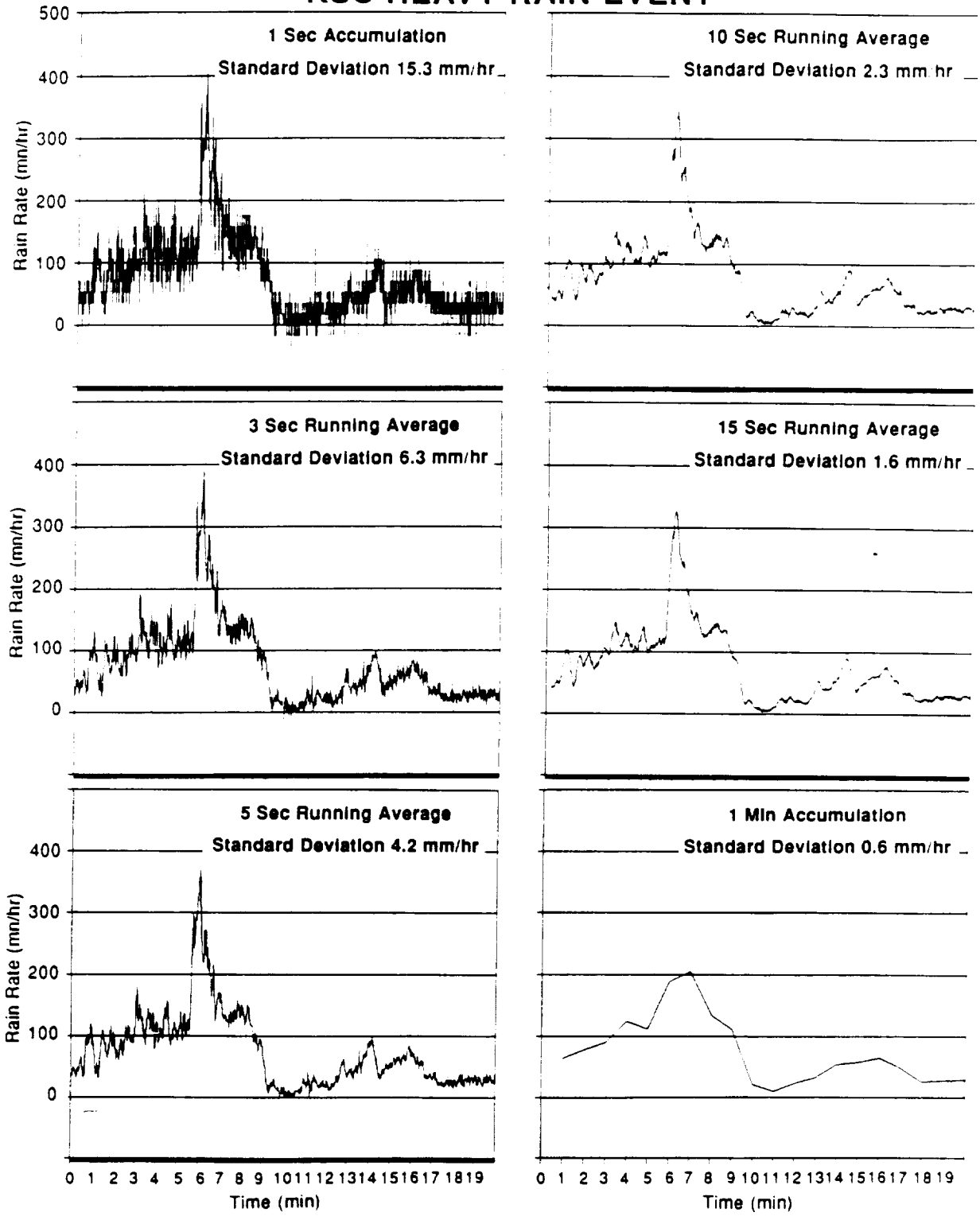
WALLOPS HEAVY RAIN EVENT



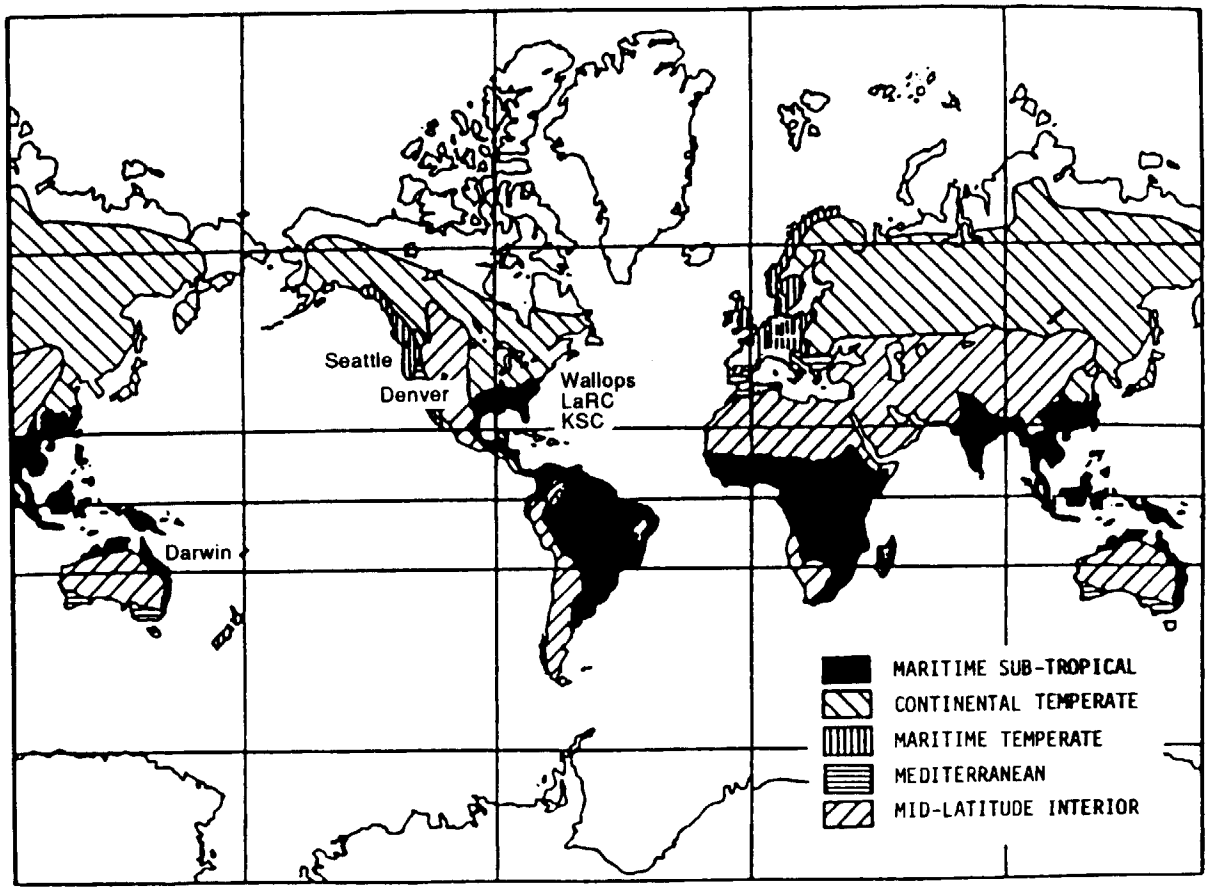
LaRC HEAVY RAIN EVENT



KSC HEAVY RAIN EVENT

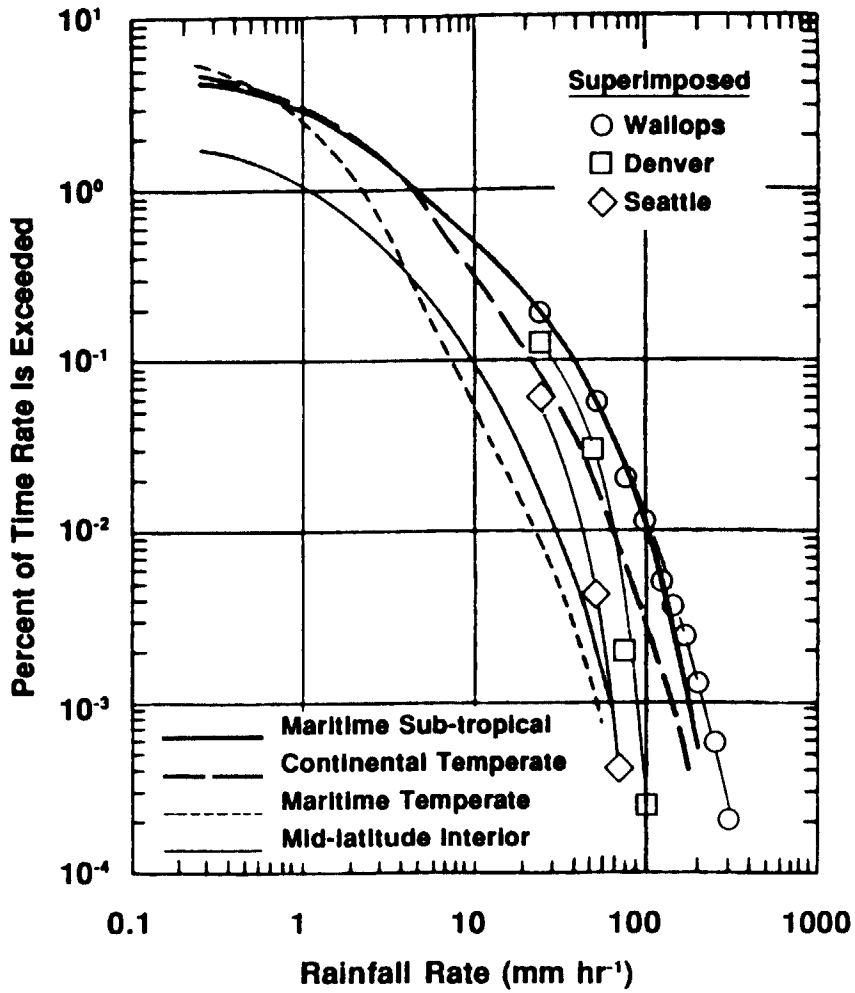


RAIN CLIMATES OF THE WORLD



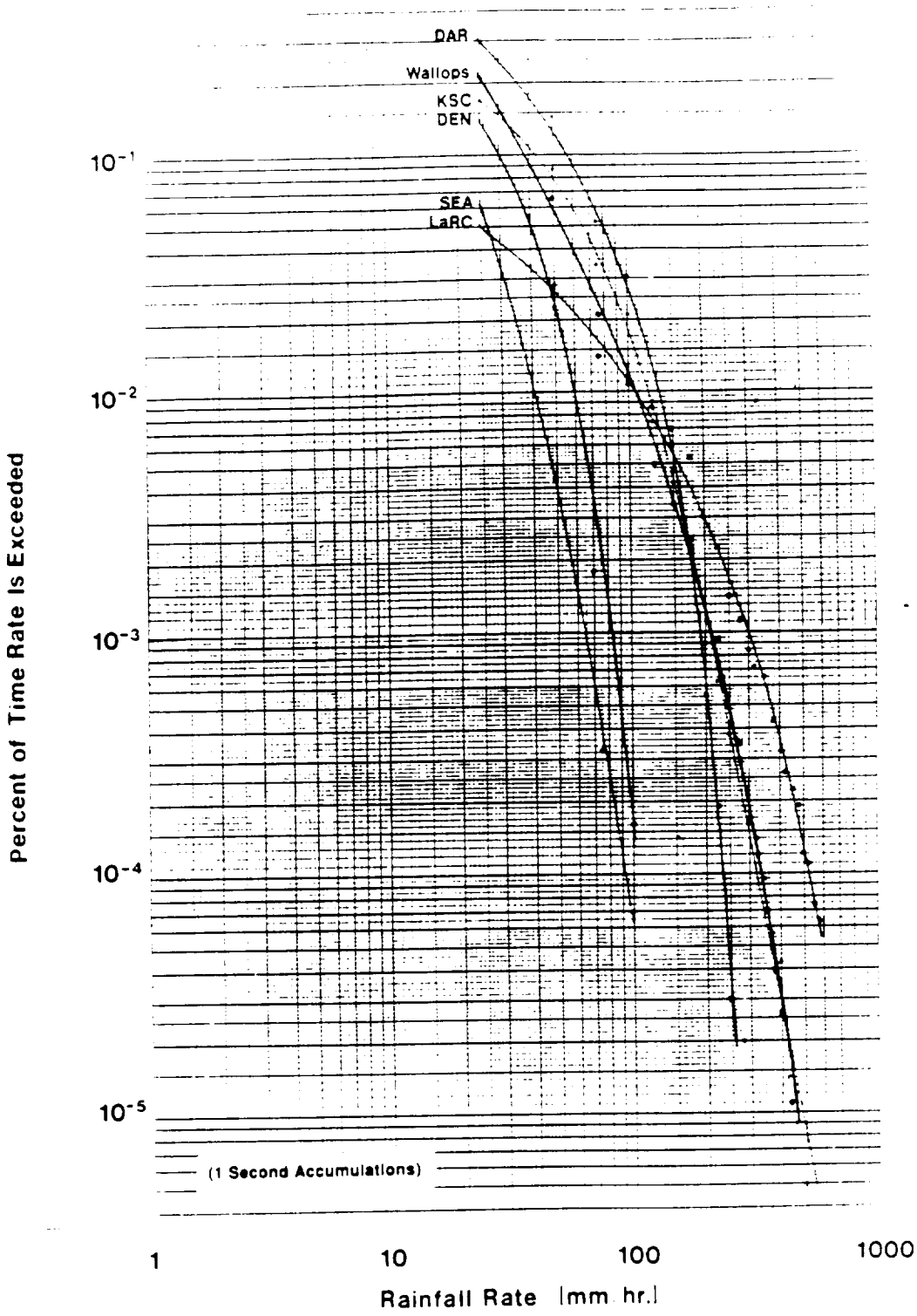
(Herbstritt, 1973)

RAINFALL RATE – FREQUENCY RELATIONSHIPS

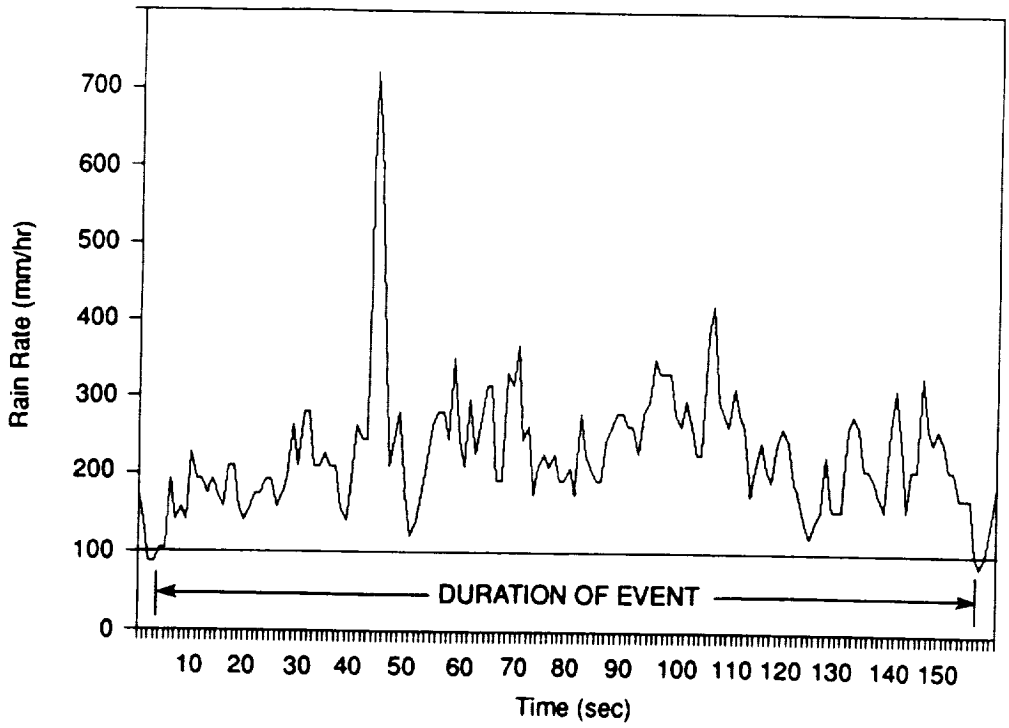


Jones & Sims, 1978: Climatology of Instantaneous Rainfall Rates (as defined by 1 and 4 minute accumulations)

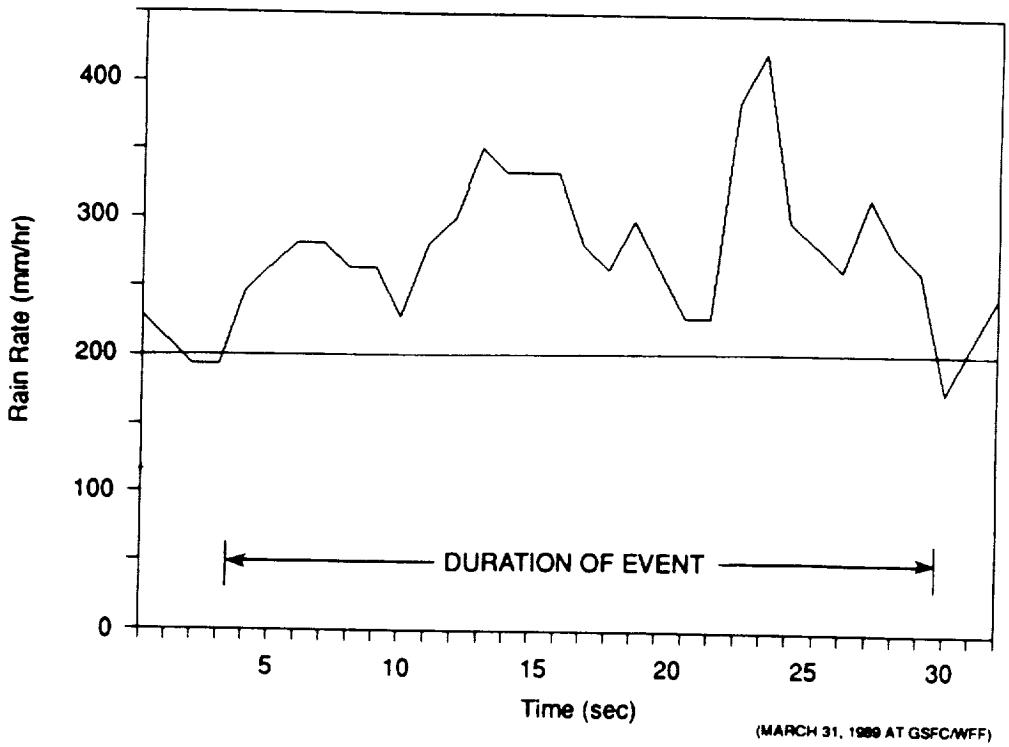
Rainfall Rate – Frequency Relationships



RAINFALL EVENT EXCEEDING 100 MM/HR



RAINFALL EVENT EXCEEDING 200 MM/HR



(MARCH 31, 1989 AT GSFC/WFF)

NUMBER AND DURATION OF HEAVY RAINFALL EVENTS

	NUMBER OF EVENTS EXCEEDING						
in/hr	3.9	7.9	11.8	15.7	19.7	23.6	27.6
mm/hr	100	200	300	400	500	600	700
DURATION (SEC)							
01-10	4705	630	129	48	18	4	1
11-20	131	8					
21-30	41	5					
31-40	22						
41-50	16						
51-60	8						
>61	14						

SUMMARY

500 MM/HR (19.7 IN/HR) RAIN RATE EVENTS OCCUR IN NATURE AT A FREQUENCY THAT SUPPORTS THE NEED TO CONDUCT ALDF TESTS AT 500 MM/HR SIMULATED RAIN RATES

Heavy Rain Field Measurements - Questions and Answers

Q: ANDY PECZALSKI (Honeywell) - What are typical velocity values of rain droplets? Is there any correlation between droplet velocity and rain rate? Where can I find this information?

A: ED MELSON (NASA Wallops) - I'm going to have to quote that from memory, so it will be an order of magnitude. A small droplet, say in the order of 1/2 millimeter, would fall around 2 millimeters per second and a large droplet, in the order of 4 millimeters diameter, would fall somewhere in the order of 8 millimeters per second. This data was from Gunn and he related the fall velocity of droplets. The larger droplets he said follow Newtonian physics, whereas the small droplets with Stokes. The relationship is indirect in that we are looking at the velocity of droplets. If you want to relate that to rainfall rate, the Marshall-Palmer Report, relates drop size to rain fall rate, so indirectly you could relate fall velocity to rain rate. But from the reports I've seen it's mostly drop size distribution related to rain fall rate.

Q: NORMAN CRABILL (Aero Space Consultants) - Have you correlated any of the rain rate measurements with radar measurements?

A: ED MELSON (NASA Wallops) - No, I haven't at this time. We do have three of our gauges in locations within the range of radars. The one at Denver is under radar coverage, and the one in Florida is also under radar coverage. The one in Darwin is being moved so it will be in a better position to be under radar coverage. I know that the data at Kennedy is being evaluated. The data at Darwin is going to be evaluated by the Tropical Rain Measurement Mission people. The are using a satellite based radar and they are concerned about the Z versus R curve, so they are using ground point measurement devices to validate these radars.

Q: CHET EKSTRAND (Boeing) - Field measurements apparently only involve sampling at a single geographical position at each site. What do we know about the distribution of rain rates over a large geographical area at a single site? In other words, in an environment where significant wind shear might occur, how long might an airplane moving at typical approach speeds be continuously exposed to rain rates which have significant effects on aircraft climb performance or stall margin? Do you have any plans to do simultaneous sampling at several geographic positions at a single site?

A: ED MELSON (NASA Wallops) - We're right now purchasing 3 gauges to put in one single site so we can get an idea of what is the graphical positioning area of some of these storms. I think some of this work has been done. I know the WMO, which is the World Meteorological Organization, in their report on the probability of maximum participation have looked at how large some of these cells are, and I'm sure this group has looked at how large some of the microburst cells are also. I don't particularly know how large some of them are, nor do I know exactly how long it would take an aircraft to fly through these cells. But I think that's something that we are going to have to address as soon as we get most of our information together from some of the tests that we are doing at these sites and also in the wind tunnel. The question on are we looking at rain data in a microburst, the site at Darwin, Australia, is particularly being set up to look for some of that type of data right now. We had a report from Tom Keenan of Australia who indicated that they were seeing from the Toga radar on the average of five microbursts a week during the transition from the monsoon season to the convective storm. At this time there is going to be a weight measure rain gauge, a tipping bucket, and optical gauge and a distrometer to

measure drop size, located at a site in which the Toga radar will be able to overlook it. This is planned to be conducted this winter here, they're summer there.