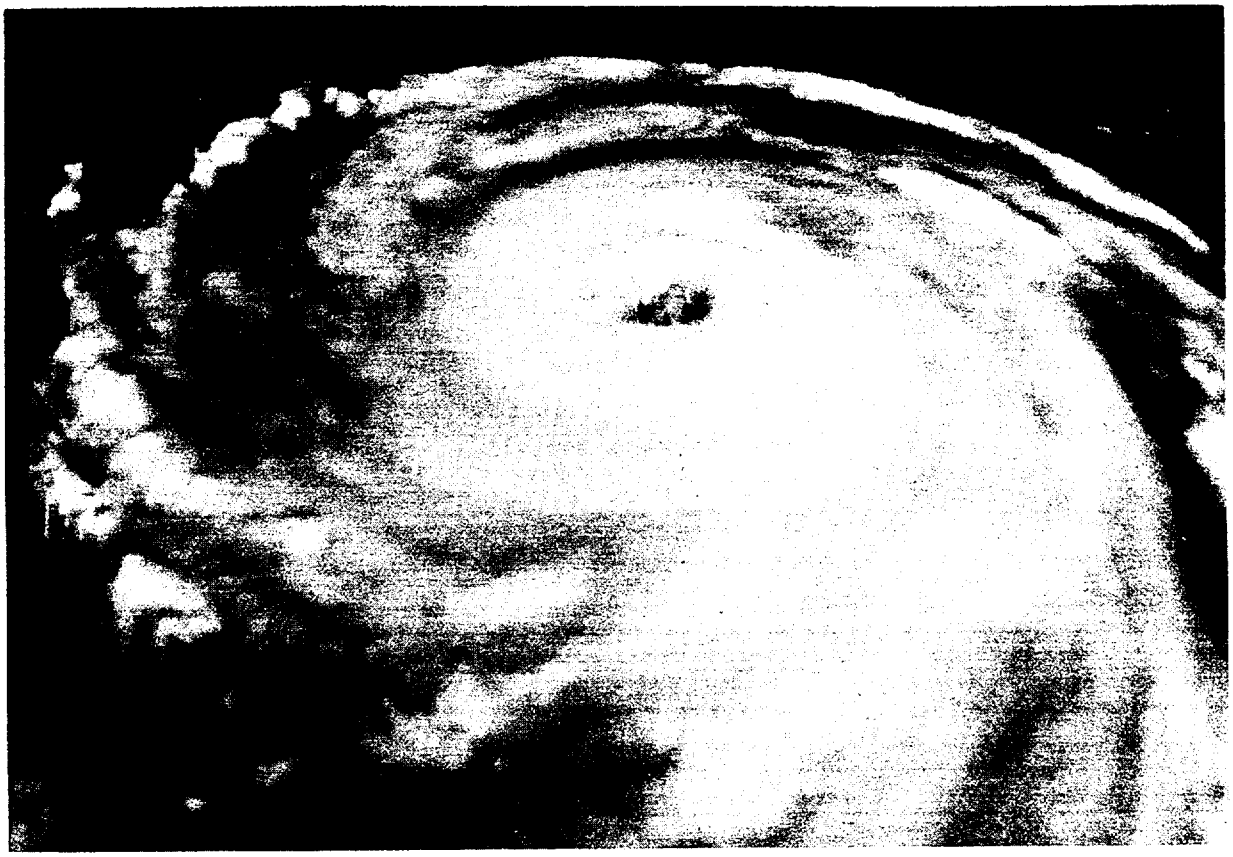
# 1991 ANNUAL TROPICAL CYCLONE REPORT



## JOINT TYPHOON WARNING CENTER
## GUAM, MARIANA ISLANDS

**FRONT COVER CAPTION**: This visual NOAA satellite image of Typhoon Pat (24W) at 070511Z October 1991 is transformed by the Meteorological Imagery, Data Display, and Analysis System (MIDDAS) software into a three-dimensional cloud map by vertically shifting each pixel according to its infrared brightness temperature-derived height. The map is then rotated to produce this dramatic psuedo-perspective.

U. S. NAVAL OCEANOGRAPHY COMMAND CENTER
JOINT TYPHOON WARNING CENTER
COMNAVMARIANAS
PSC 489, BOX 12
FPO AP 96540-0051

# DIETER K. RUDOLPH

CAPTAIN, UNITED STATES NAVY
COMMANDING OFFICER

# CHARLES P. GUARD

LIEUTENANT COLONEL, UNITED STATES AIR FORCE
DIRECTOR, JOINT TYPHOON WARNING CENTER
COMMANDER, DETACHMENT 1, 633 OPERATIONS SUPPORT SQUADRON

# STAFF

## JOINT TYPHOON WARNING CENTER

| | | | | |
|---|---|---|---|---|
| * | LCDR | NICHOLAS D. GURAL | USN | DEPUTY DIRECTOR |
| | LCDR | LESTER E. CARR, III | USN | DEPUTY DIRECTOR |
| | LCDR | ROBERT L. BEARD | USN | TDO |
| * | CAPT | ANN R.GOETZ | USAF | TDO, BEST TRACK OFFICER |
| * | CAPT | BRUCE W. THOMPSON | USAF | TDO |
| | CAPT | ELIZABETH B. BORELLI | USAF | TDO |
| | CAPT | STEPHEN C. HALLIN | USAF | TDO |
| | LT | DAVID J. STREMLER | USN | TDO |
| | LT | STACY R. STEWART | USNR | TDO** |
| * | LT | RICHARD A. JEFFRIES | USN | TDO |
| | LT | THOMAS H. CECERE | USN | TDO |
| | AGCS | PATRICK J. HENDRICKS, JR. | USN | LCPO |
| | AG2 | RONALD H. BRYAN | USN | TDA, LPO |
| | AG3 | HOLLY L. HOULIHAN | USN | TDA, STATISTICS |
| * | AG3 | TRACEY R. DUNCAN | USN | TDA, STATISTICS |
| | SRA | CORNELIUS MASSEY | USAF | TDA |
| | A1C | TIMOTHY J. GALLAGHER | USAF | TDA, STATISTICS |
| | A1C | JANET E. KEMBLE | USAF | TDA |
| * | A1C | JEREMY A. ENTWISTLE | USAF | TDA |
| | AGAN | BONNIE J. CAMPBELL | USN | TDA |
| | AGAA | DAVID L. HAZEL | USN | TDA |

## DET 1, PACAF

| | | | | |
|---|---|---|---|---|
| | CAPT | DANIEL N. SHOEMAKER | USAF | TDO, TECHNIQUE DEVELOPMENT |
| | CAPT | ROBERT G. HUDSON | USAF | MSC |
| * | CAPT | JOSEPH A. HANSER | USAF | DATA DEVELOPMENT |
| | 1LT | SCOTT C. JACOBS | USAF | DATA DEVELOPMENT |
| * | MSGT | CHARLES P. BONINI | USAF | TECHNIQUE DEVELOPMENT, NCOIC |
| | MSGT | JOY L. HARDING | USAF | ANALYST, NCOIC |
| | TSGT | DANILO O. MONTILLANO | USAF | INFORMATION MANAGEMENT |
| * | TSGT | BRIAN P. BURKE | USAF | ANALYST, NCOIC |
| | TSGT | WILLIAM GATES, JR. | USAF | ANALYST |
| | TSGT | PHILLIP A. ROSEBERRY | USAF | ANALYST |
| | TSGT | JEFFERY E. OAKES | USAF | ANALYST |
| * | SSGT | MICHELLE R. TIMPERIO | USAF | ANALYST |
| * | SSGT | PAUL F. HARPER | USAF | ANALYST |
| | SSGT | RAYMOND L. SOUZA, JR. | USAF | ANALYST |
| * | SSGT | WAYNE I. GENTRY | USAF | ANALYST |
| | SSGT | DANIEL T. EBBERT | USAF | ANALYST |
| | SSGT | JAMES G. BROCK | USAF | ANALYST |

## ATCR STAFF

| | | | | |
|---|---|---|---|---|
| | CAPT | DAN B. MUNDELL | USAF | TDO, STATISTICS OFFICER, EDITOR |
| | MR | FRANK H. WELLS | CIV | TECHNICAL EDITOR |
| | SGT | BRIAN L. McDONALD | USAF | SENIOR TDA, GRAPHICS |
| | SGT | CARLOS A. DELANUEZ | USAF | TDA, GRAPHICS |
| * | SGT | RAY O. BELEW | USAF | TDA, GRAPHICS |

## ONR POST - DOCTORATE FELLOW

| | | | | |
|---|---|---|---|---|
| | DR | MARK A. LANDER | CIV | UNIVERSITY OF GUAM |

* TRANSFERRED DURING 1991
** ACTIVE DUTY TRAINING

# FOREWORD

The Annual Tropical Cyclone Report is prepared by the staff of the Joint Typhoon Warning Center (JTWC), a combined Air Force/Navy organization operating under the command of the Commanding Officer, U.S. Naval Oceanography Command Center/Joint Typhoon Warning Center, Guam. The JTWC was founded 1 May 1959 when USCINCPAC directed that a single tropical cyclone warning center be established for the western North Pacific region. The operations of JTWC are guided by CINCPACINST 3140.1U.

The mission of the Joint Typhoon Warning Center is multi-faceted and includes:

1. Continuous monitoring of all tropical weather activity in the Northern and Southern Hemispheres, from 180 degrees east longitude westward to the east coast of Africa, and the prompt issuance of appropriate advisories and alerts when tropical cyclone development is anticipated.

2. Issuance of warnings on all significant tropical cyclones in the above area of responsibility.

3. Determination of requirements for tropical cyclone reconnaissance and assignment of appropriate priorities.

4. Post-storm analysis of significant tropical cyclones occurring within the western North Pacific and North Indian Oceans, which includes an in-depth analysis of tropical cyclones of note and all typhoons.

5. Cooperation with the Naval Research Laboratory (NRL), Monterey, California on the operational evaluation of tropical cyclone models and forecast aids, and the development of new techniques to support operational forecast scenarios.

Changes in this year's publication include: 1) In Chapter 3, extended captions have been used for most western North Pacific tropical depressions and tropical storms to reduce the amount of text; 2) a summary of individual warning statistics (formerly Annex A) has been added as Chapter 6 to provide a printout of 6-hourly positions and verification statistics; 3) the tables in Chapter 6 were expanded to include cross- and along-track errors; 4) the mean errors for each tropical cyclone appear in Chapter 6 instead of Chapter 5 to improve the presentation of error statistics; 5) the cross- and along-track errors prior to 1986 were calculated for the Indian Ocean and western South Pacific to establish a longer term of record; and, 6) western South Pacific verification statistics only include JTWC performance, and do not include NAVWESTOCEANCEN forecasts.

Special thanks to: the men and women at the Fleet Numerical Oceanography Center for their unfaltering operational and software support; the Naval Research Laboratory at Monterey for their dedicated research and forecast improvement initiatives; the Air Force Global Weather Central for continued satellite support and microwave imagery enhancements; the 633 Communications Squadron, Operating Location Charlie and the Operations and Equipment Support departments of the Naval Oceanography Command Center, Guam for their high quality support; personnel of the Pacific Fleet Audio-Visual Center, Guam for their assistance in the reproduction of satellite data for this report; the Navy Publications and Printing Service Branch Office, Guam; Dr. Bob Abbey and the Office of Naval Research for their support to the University of Guam for the Post Doctorate Fellow at JTWC; Dr. Mark Lander for his training efforts, suggestions and valuable insights; and to Sgt. Brian L. McDonald for his continuing excellent support in the JTWC graphics department.

# EXECUTIVE SUMMARY

The Joint Typhoon Warning Center, Guam (JTWC) experienced an extremely busy year during 1991, both in terms of the number of tropical cyclone warnings issued and in terms of collateral contingency support. JTWC warnings were critical to the safe deployment of ships and aircraft involved in operations DESERT STORM and DESERT SHIELD, and to the safe and successful employment of ships and aircraft supporting operations SEA ANGEL (Bangladesh relief) and FIERY VIGIL (Philippine evacuation due to the Mount Pinatubo eruption).

In 1990, JTWC set a record for workload by issuing 1139 warnings during the year. That record was short-lived as the Center prepared 1155 warnings in 1991. During the year, the western North Pacific experienced 32 tropical cyclones — 5 super typhoons, 15 less intense typhoons, 10 tropical storms and 2 tropical depressions — which resulted in 835 warnings, not including amendments. North Indian Ocean totals were 56 warnings on 4 tropical cyclones including a rare super cyclone (02B), that killed over 138,000 people in Bangladesh. In the Southern Hemisphere, the Center issued 265 warnings on 22 cyclones. JTWC was in warning status a total of 254 days. One-hundred-ten of those days had at least two storms, 20 days at least 3 storms at the same time, and 4 days had 4 storms occurring simultaneously.

JTWC's track forecast performance for the western North Pacific during 1991 was the best in its 32-year history. Errors were 96 nm at 24 hours, 185 nm at 48 hours, and 287 nm at 72 hours. This represents an improvement of 20, 23, and 20 percent over the long term average errors of 120 nm, 240 nm, and 360 nm. When compared to the climatology-persistence model, CLIPER, JTWC forecasts were 20 percent better across the board. Over 55 percent of the tropical cyclones recurved, making 1991 a relatively difficult forecast year. While JTWC's cross track (directional accuracy) was outstanding, improvement is still needed in forecasting along-track (speed) errors. In the Southern Hemisphere, forecast errors were the lowest in its 11-year history, 115 nm at 24 hours and 220 nm at 48 hours. This is 17 percent below normal.

As in the previous two years, JTWC forecasters out-performed every forecast aid at every forecast period. Routine boguses of tropical cyclone location, intensity, and wind distribution (size) provided to the the Fleet Oceanography Center at 6-hour intervals have significantly improved the performance of the Navy Operational Global Atmospheric Prediction System (NOGAPS), especially in the tropics. As a result, the One-Way (interactive) Tropical Cyclone Model (OTCM) performed well.

Intensity forecast errors for western North Pacific tropical cyclones were 10 percent better than average at 24 and 48 hours, and average at 72 hours. These values were below the 1990 improvements of 22, 19 and 15 percent for the respective periods. In-house techniques developed during 1989 and 1990 to improve intensity forecasts worked well, however the large turnover of experienced personnel and an above average number of midget typhoons proved to be a challenge.

Once again, JTWC has seen many changes over the past year. Perhaps one of the most significant was the operational acceptance by Detachment 1, 633 OSS on 1 April of the Meteorological Imagery, Data Display, and Analysis System (MIDDAS) which continues to improve satellite reconnaissance support to JTWC.

# TABLE OF CONTENTS


PAGE

FOREWORD ..... iii
EXECUTIVE SUMMARY ..... iv

1. OPERATIONAL PROCEDURES ..... 1
   - 1.1 General ..... 1
   - 1.2 Data Sources ..... 1
   - 1.3 Communications ..... 2
   - 1.4 Data Displays ..... 4
   - 1.5 Analyses ..... 5
   - 1.6 Forecast Procedures ..... 5
   - 1.7 Warnings ..... 8
   - 1.8 Prognostic Reasoning Messages ..... 9
   - 1.9 Tropical Cyclone Formation Alerts ..... 9
   - 1.10 Significant Tropical Weather Advisories ..... 9

2. RECONNAISSANCE AND FIXES ..... 11
   - 2.1 General ..... 11
   - 2.2 Reconnaissance Availability ..... 11
   - 2.3 Satellite Reconnaissance Summary ..... 11
   - 2.4 Radar Reconnaissance Summary ..... 16
   - 2.5 Tropical Cyclone Fix Data ..... 16

3. SUMMARY OF NORTHWEST PACIFIC AND NORTH INDIAN OCEAN TROPICAL CYCLONES ..... 19
   - 3.1 General ..... 19
   - 3.2 Western North Pacific Tropical Cyclones ..... 24

INDIVIDUAL TROPICAL CYCLONES

| TROPICAL CYCLONE | PAGE | TROPICAL CYCLONE | PAGE |
|---|---|---|---|
| (01W) TS SHARON | 36 | (16W) TS HARRY | 90 |
| (02W) TY TIM | 38 | (17W) TY IVY | 92 |
| (03W) TS VANESSA | 42 | (18W) TS JOEL | 96 |
| (04W) STY WALT | 44 | (19W) TY KINNA | 98 |
| (05W) TY YUNYA | 48 | (20W) TS LUKE | 102 |
| (06W) TY ZEKE | 54 | (21W) STY MIREILLE | 108 |
| (07W) TY AMY | 58 | (22W) TY NAT | 112 |
| (08W) TY BRENDAN | 62 | (23W) TY ORCHID | 116 |
| (09W) TY CAITLIN | 66 | (24W) TY PAT | 120 |
| (06E) TS ENRIQUE | 70 | (25W) STY RUTH | 124 |
| (10W) TS DOUG | 72 | (26W) STY SETH | 128 |
| (11W) TY ELLIE | 74 | (27W) TS THELMA | 132 |
| (12W) TY FRED | 78 | (28W) TS VERNE | 136 |
| (13W) TD 13W | 82 | (29W) TS WILDA | 138 |
| (14W) TY GLADYS | 84 | (30W) STY YURI | 140 |
| (15W) TD 15W | 88 | (31W) TY ZELDA | 146 |

PAGE

3.3 North Indian Ocean Tropical Cyclones . . . . . .150

INDIVIDUAL TROPICAL CYCLONES

TROPICAL CYCLONE PAGE

TC 01A. . . . . .152

TC 02B. . . . . .154

TC 03B. . . . . .158

TC 04B. . . . . .160

4. SUMMARY OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES. . . . . 163

4.1 General . . . . . 163

4.2 South Pacific and South Indian Ocean Tropical Cyclones . . . . 163

5. SUMMARY OF FORECAST VERIFICATION. . . . . 169

5.1 Annual Forecast Verification . . . . . 169

5.2 Comparison of Objective Techniques . . . . . 184

5.3 Testing and Results . . . . . 186

6. TROPICAL CYCLONE WARNING VERIFICATION STATISTICS. . . . . 191

7. TROPICAL CYCLONE SUPPORT SUMMARY . . . . . .221

BIBLIOGRAPHY . . . . . .228

APPENDIX A - Definitions. . . . . 230

APPENDIX B - Names for Tropical Cyclones . . . . . .232

APPENDIX C - Contractions. . . . . 233

APPENDIX D - Past Annual Tropical Cyclone Reports. . . . . .236

APPENDIX E - Distribution List. . . . . 237