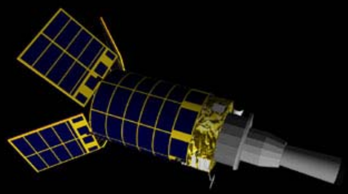
# WEATHER SUPPORT TO THE NASA DEEP SPACE NETWORK

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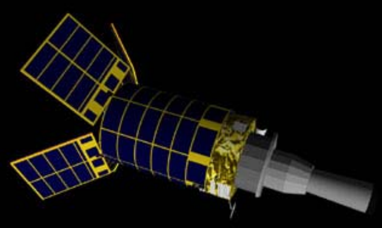
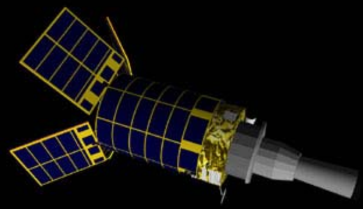


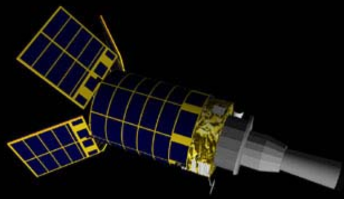
# DSN Major Functions

- Supports Interplanetary Spacecraft Missions
- Radio and Radar Astronomy Observations
- Supports Selected Earth-orbiting Missions



# Weather Support Request

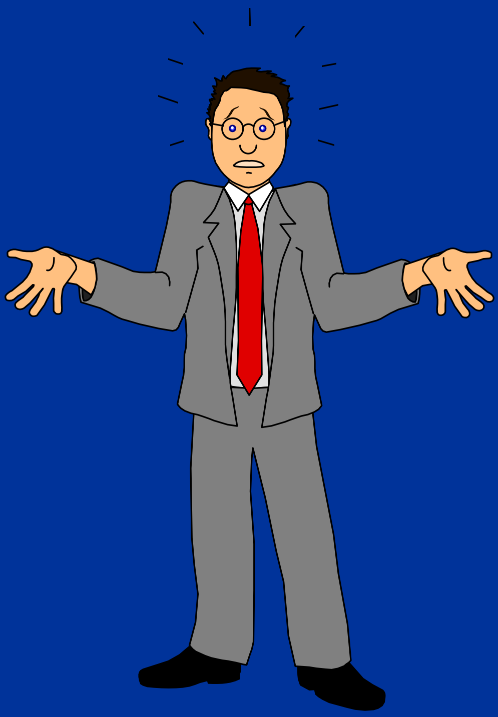
- Initiated by JPL Mid 1998
- Experimental
- Non-interference basis
- Initially for Goldstone only



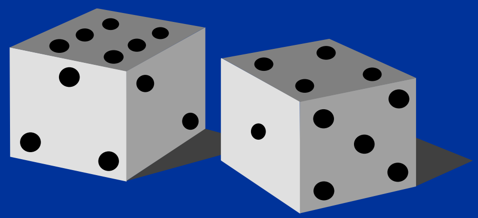
# Why Weather Support?

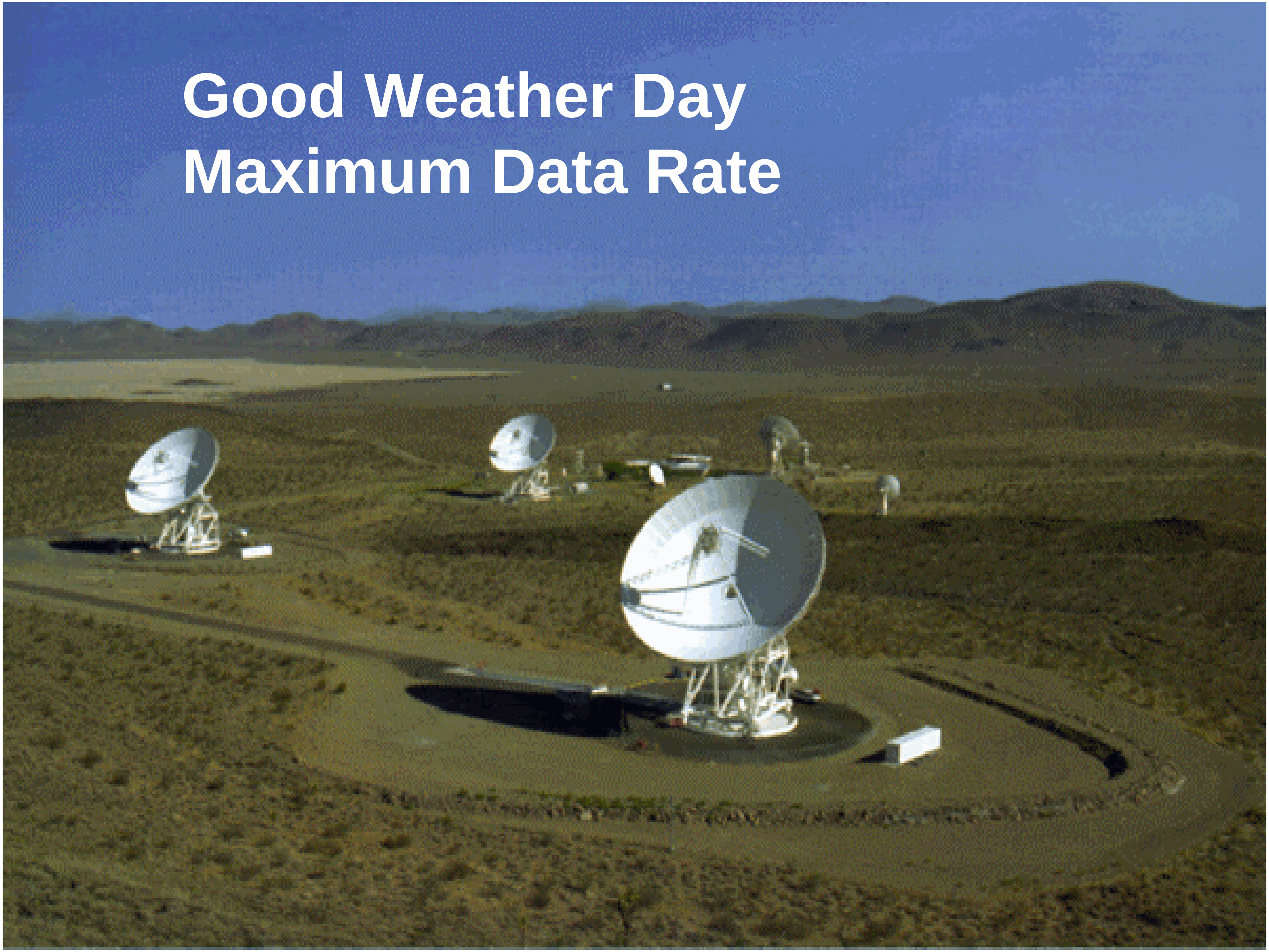
- Clouds, Rain Degrade Ka-band
- Distinct Advantage to Ka-band Operation (Increased Data Rate)
- Need to Work Around Bad Weather

# OLD METHOD



- Use Long Term Statistics for
  - Atmospheric Attenuation
  - Noise Temperature
- Operate at Data Rate Appropriate to 90% Weather (worse 90% of time)
- Excess Link Margin 90% of the time

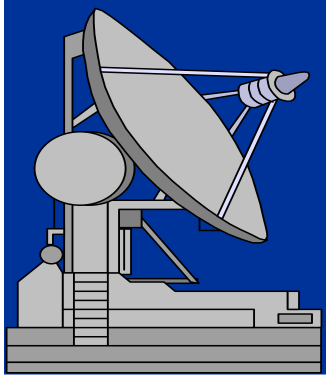


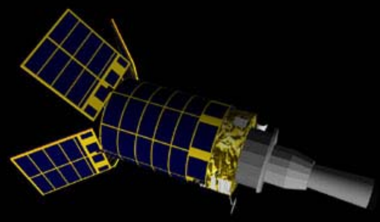

Good Weather Day
Maximum Data Rate

# Bad Weather Day
# What to do?

# Better Idea?

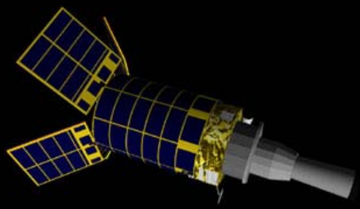
- Obtain Accurate Short Term Forecasts
- Maximum Data During Good Weather
- Reduce Data Rate During Bad Weather, or,
- Switch to X-band During Bad Weather





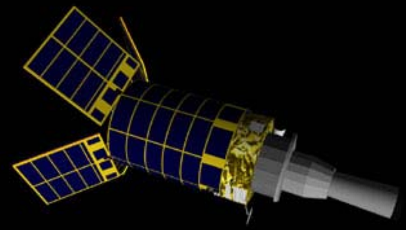
# Premise

Reasonably accurate weather forecasts for Deep Space Communications Complex can improve the efficiency of network operations (Ka-band)



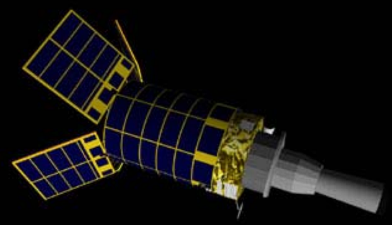
# Data Provided

- Forecasts for Goldstone, Madrid, Canberra
- Forecasts out to 5 days
- Issued in 6 Hour Increments
- 25 MB Pressure levels
- Clouds
- Rainfall
- Absolute Humidity



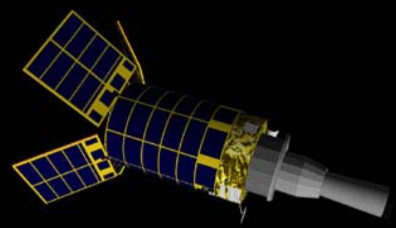
# Cloud Data

- METAR Descriptors (CLR, FEW, SCT, BKN, OVC
- Bases and tops (Ft. AGL)
- Liquid water content (gm/m$^3$)



# Rainfall Data

- Beginning & end time
- Rate at ground (mm/hr)



# MODEL DATA (GFS)

- Uses NCEP BUFR Data
- LAPS & AFPS Algorithms
- Cloud Amount & Type
- Cloud Base Height
- Cloud Top Height
- T, Z, AH, Liquid Water Content
- Surface Rainfall Rate

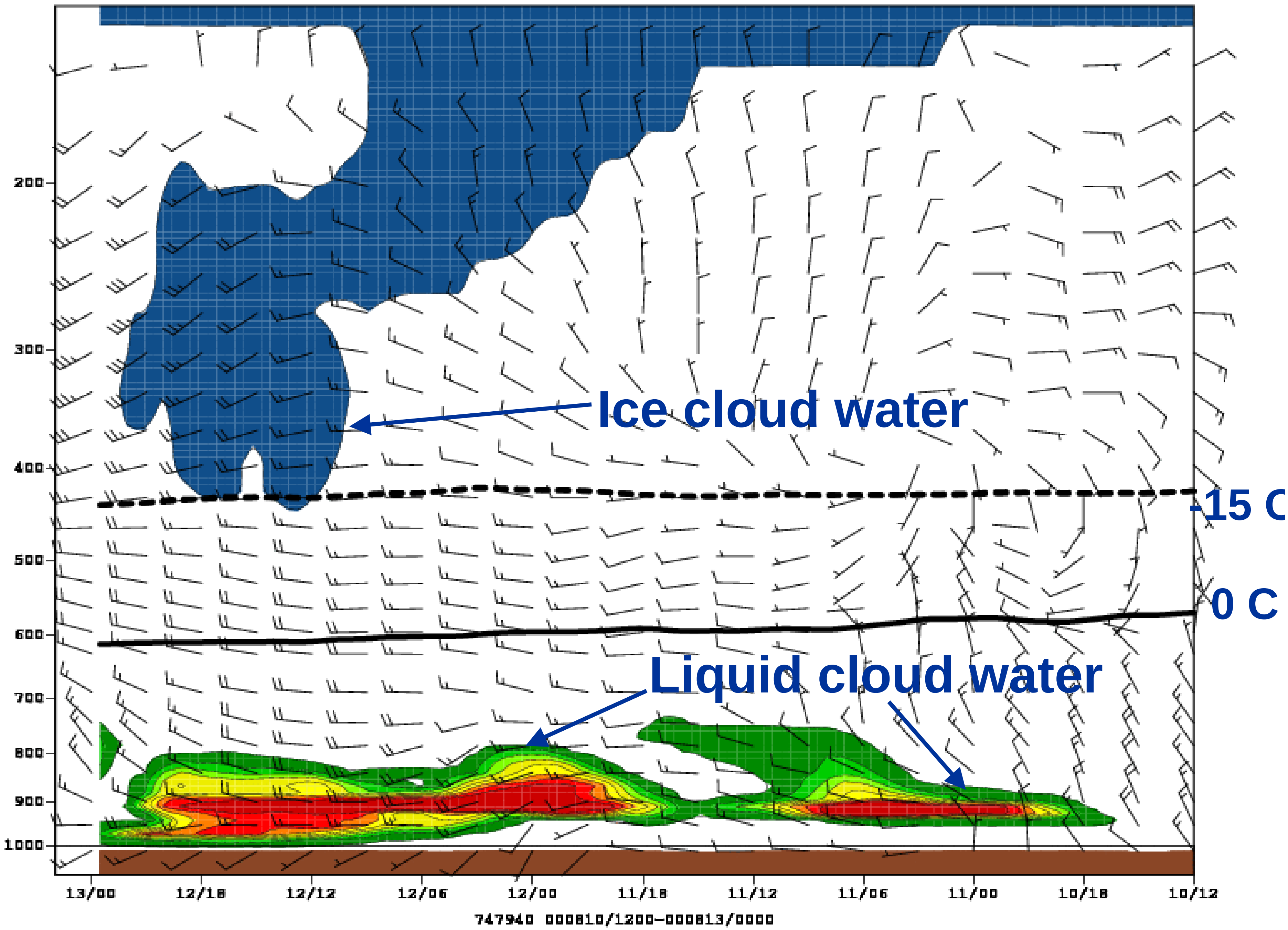
# The GFS Atmospheric Model

- Spectral Model
- Horizontal Resolution
  - Gaussian Grid
  - Spacing - 0.5 degrees (~56 km)
- Vertical Domain
  - Sigma Coordinate
  - 64 unequally spaced sigma (pressure) levels.

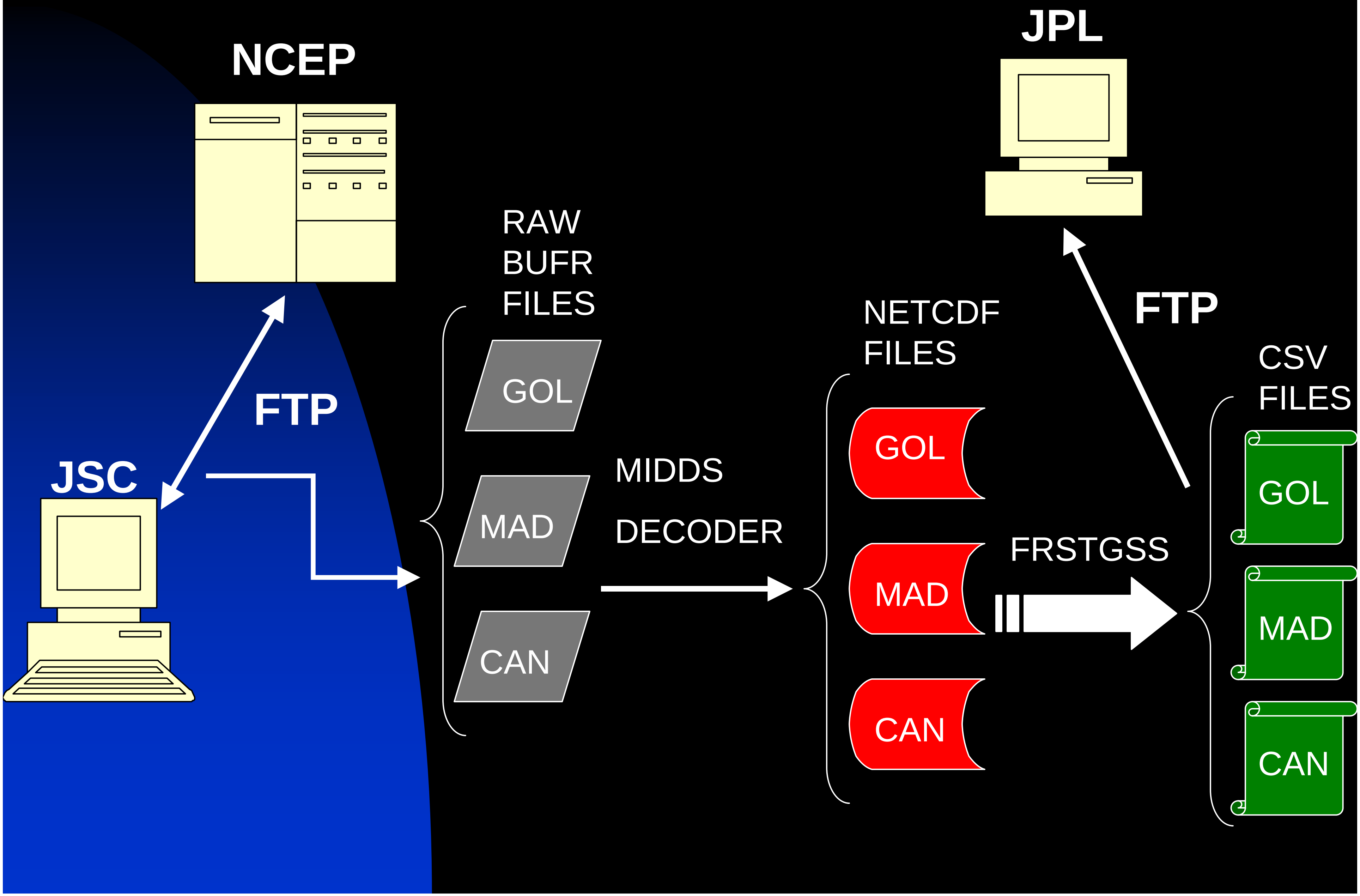
  Time Integration Scheme – 3 hour increments (only sending 6 currently)

# Atmospheric Dynamics

- Primitive Equations
- Dependent variables
  - Vorticity
  - Divergence
  - Log of surface pressure
  - Specific humidity virtual temp
  - Cloud condensate
- http://wwwt.emc.ncep.noaa.gov/gmb/moorthi/gam.html


Ice cloud water
-15 C
0 C
Liquid cloud water
200
300
400
500
600
700
800
900
1000
13/00
12/18
12/12
12/06
12/00
11/18
11/12
11/06
11/00
10/18
10/12
747940 000810/1200-000813/0000

# Forecast Process



# Raw Data vs. Output Data – "Surface"

| | Raw Data (in BUFR file) | Output Data (sent to JPL) |
|---|---|---|
| "Surface T" | T2MS | 2-meter T (NOT calc.) |
| "Surface TD" | PSFC, Q2MS | **2-meter TD (calculated)** |
| "Surface P" | PSFC | Surface P (NOT calc.) |
| "Surface AH" | T2MS, PSFC, Q2MS | **Surface AH (calculated)** |

# Cloud Type Algorithm

- Algorithm used to determine cloud layers described by Weir (1996). http://www-md.fsl.noaa.gov/eft/publications/papers/IIPS/model/
- WeatherGenerationandTests.Paper1.html
- Cloud fraction is a function of RH w/ thresholds defined for CLR, SCT, BKN, OVC
- RH thresholds a function of height AGL
- RH at each level compared to RH thresholds to determine cloud type

| | | | | | | |
|---|---|---|---|---|---|---|
| Location | Goldstone CA | | | | | |
| Elevation | 3153 | | | | | |
| Issue Date | 2005/01/11 | | | | | |
| Issue Time | 12 Z | | | | | |
| FCST HR | | 12 | 18 | 24 | 30 | 36 |
| Valid Date | | 1/12/2005 | 1/12/2005 | 1/12/2005 | 1/12/2005 | 1/13/2005 |
| Valid Time | (GMT) | 0 | 600 | 1200 | 1800 | 0 |
| Total Cloud | (CLR/CLDY | BKN | CLR | CLR | CLR | CLR |
| Cloud1 | Base | 6566 | | | | |
| Cloud1 | Top | 18798 | | | | |
| Cloud2 | Base | | | | | |
| Cloud2 | Top | | | | | |
| Cloud3 | Base | | | | | |
| Cloud3 | Top | | | | | |
| Pcpn | Begin(GMT) | | | | | |
| Pcpn | End(GMT) | | | | | |
| Pcpn | Rate(mm/hr) | | | | | |
| Surface | T(C) | 4.6 | 1.1 | | 2.3 | 5.6 |
| | Td(C) | 2 | 0.6 | -1.4 | -3.6 | -0.6 |
| | P(mb) | 898.1 | 901.9 | 906 | 911.6 | 911.2 |
| | AH(gm/m* | 5.5 | 5 | 4.4 | 3.7 | 4.5 |

# Raw Data vs. Output Data – “Upper Levels”

| | Raw Data (in BUFR file) | Output Data (sent to JPL) |
|---|---|---|
| Hgt | P, T, TD | **Hgt (calc.&interp.)** |
| T | T | T (intrp. only) |
| AH | P, T, TD | **AH (calc.&interp.)** |
| LWC | P, T, TD | **LWC (calc.&interp.)** |

# “Upper Levels” Example: 12 hr Fcst 2005 Jan. 27

- Raw Data – “Upper Levels”

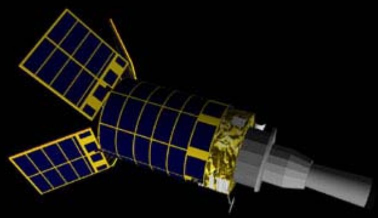
| SIGL | P [mb] | T [K] | TD [C] |
|---|---|---|---|
| 7 | 858.80 | 274.70 | -2.38 |
| 8 | 848.30 | 273.90 | -2.91 |

- Output Data – “Upper Levels”

| P [mb] | Hgt [m] | T [C] | AH [gm/m**3] | LWC [gm/m**3] |
|---|---|---|---|---|
| 850 | 487 | 0.9 | 3.9 | |

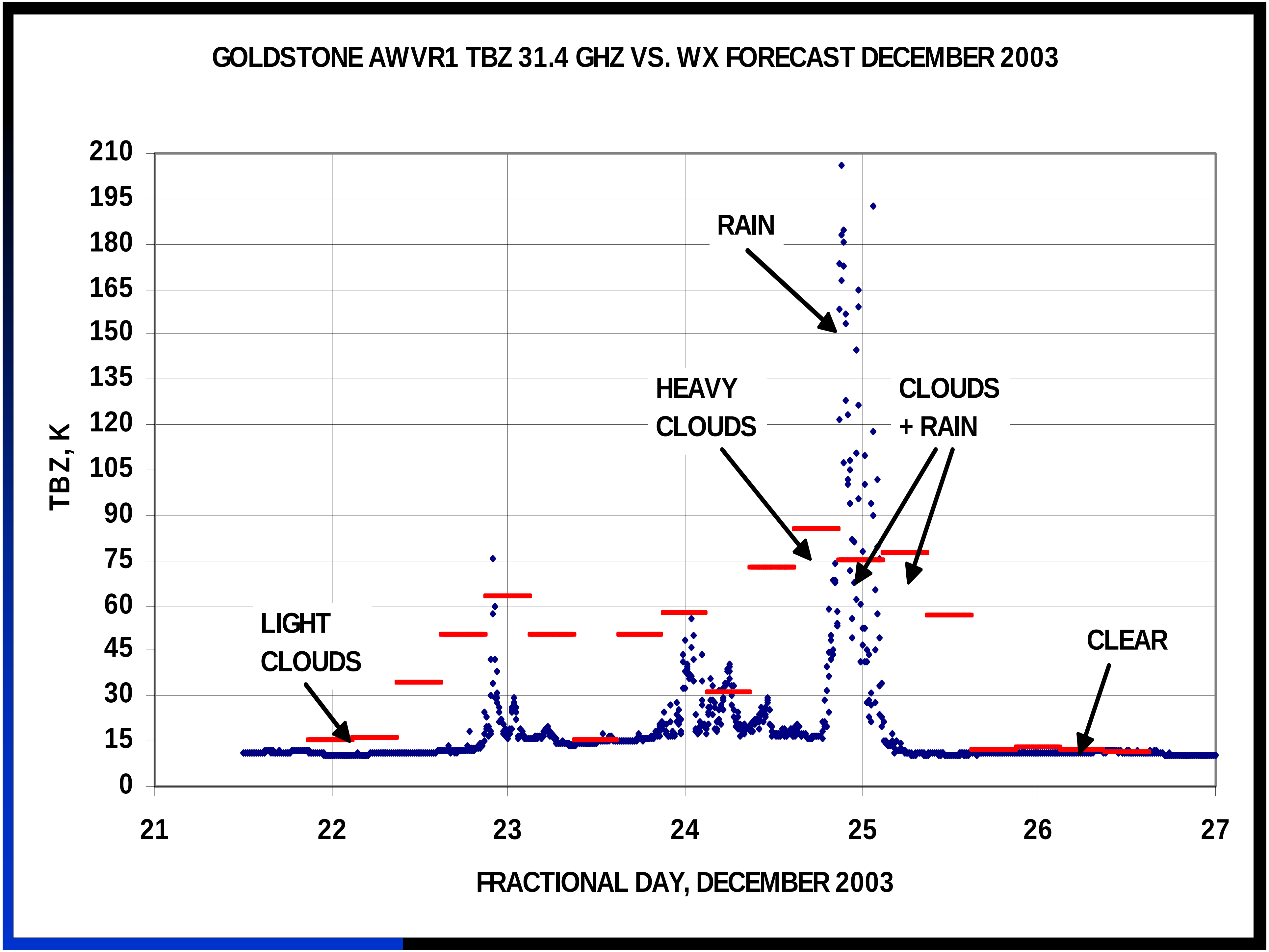
Data values are computed at 2 sigma levels closest to 25mb increment level and then **INTERPOLATED!!**

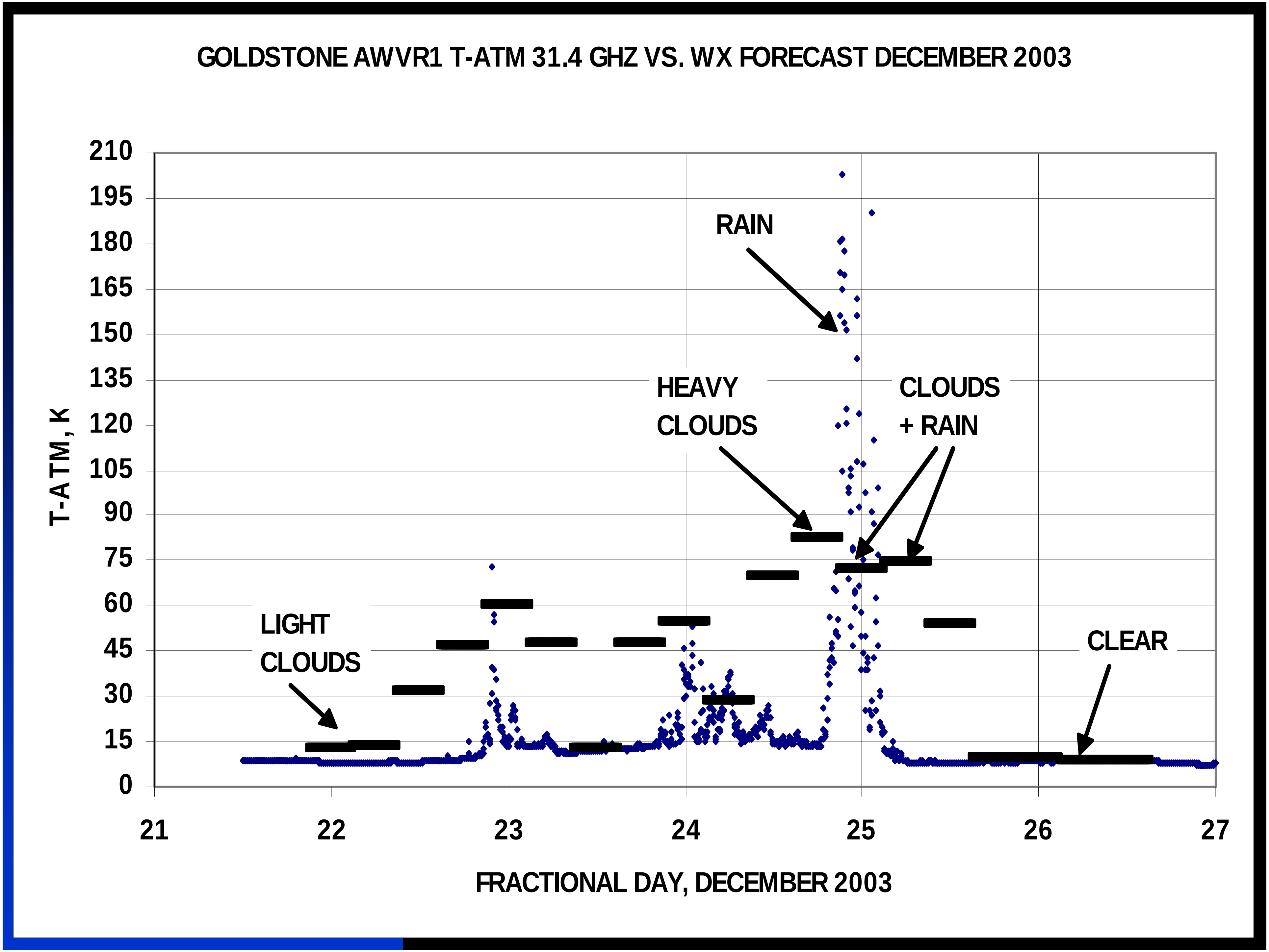
| | | | | | | |
|---|---|---|---|---|---|---|
| 850 | Hgt(m) | 436 | 468 | 503 | 551 | 553 |
| | T(C) | 1.4 | 1.1 | 0.4 | -0.9 | 1.4 |
| | AH(gm/m* | 3.6 | 3.1 | 2.3 | 1.6 | 2.1 |
| | LWC(gm/n | | | | | |
| 825 | Hgt(m) | 675 | 708 | 741 | 789 | 793 |
| | T(C) | -0.8 | -0.3 | -1.6 | -2.2 | 0.3 |
| | AH(gm/m* | 3.4 | 2.6 | 2.1 | 1.4 | 1.8 |
| | LWC(gm/n | | | | | |
| 800 | Hgt(m) | 920 | 953 | 986 | 1033 | 1040 |
| | T(C) | -2.9 | -2.1 | -3.3 | -2.5 | -0.1 |
| | AH(gm/m* | 3.2 | 2.4 | 1.8 | 1 | 1.3 |
| | LWC(gm/n | 0.049 | | | | |
| 775 | Hgt(m) | 1171 | 1205 | 1236 | 1285 | 1294 |
| | T(C) | -5 | -4 | -4.2 | -3 | -0.3 |
| | AH(gm/m* | 3 | 2 | 1.4 | 0.8 | 0.8 |
| | LWC(gm/n | 0.2 | | | | |
| 750 | Hgt(m) | 1429 | 1463 | 1494 | 1544 | 1556 |
| | T(C) | -7 | -5.5 | -5.1 | -3.8 | -1.2 |
| | AH(gm/m* | 2.7 | 1.7 | 1 | 0.6 | 0.6 |
| | LWC(gm/n | 0.2 | | | | |
| 725 | Hgt(m) | 1692 | 1728 | 1760 | 1811 | 1825 |
| | T(C) | -8.6 | -7 | -6.2 | -5 | -2.4 |
| | AH(gm/m* | 2.3 | 1.3 | 0.8 | 0.5 | 0.5 |
| | LWC(gm/n | 0.2 | | | | |

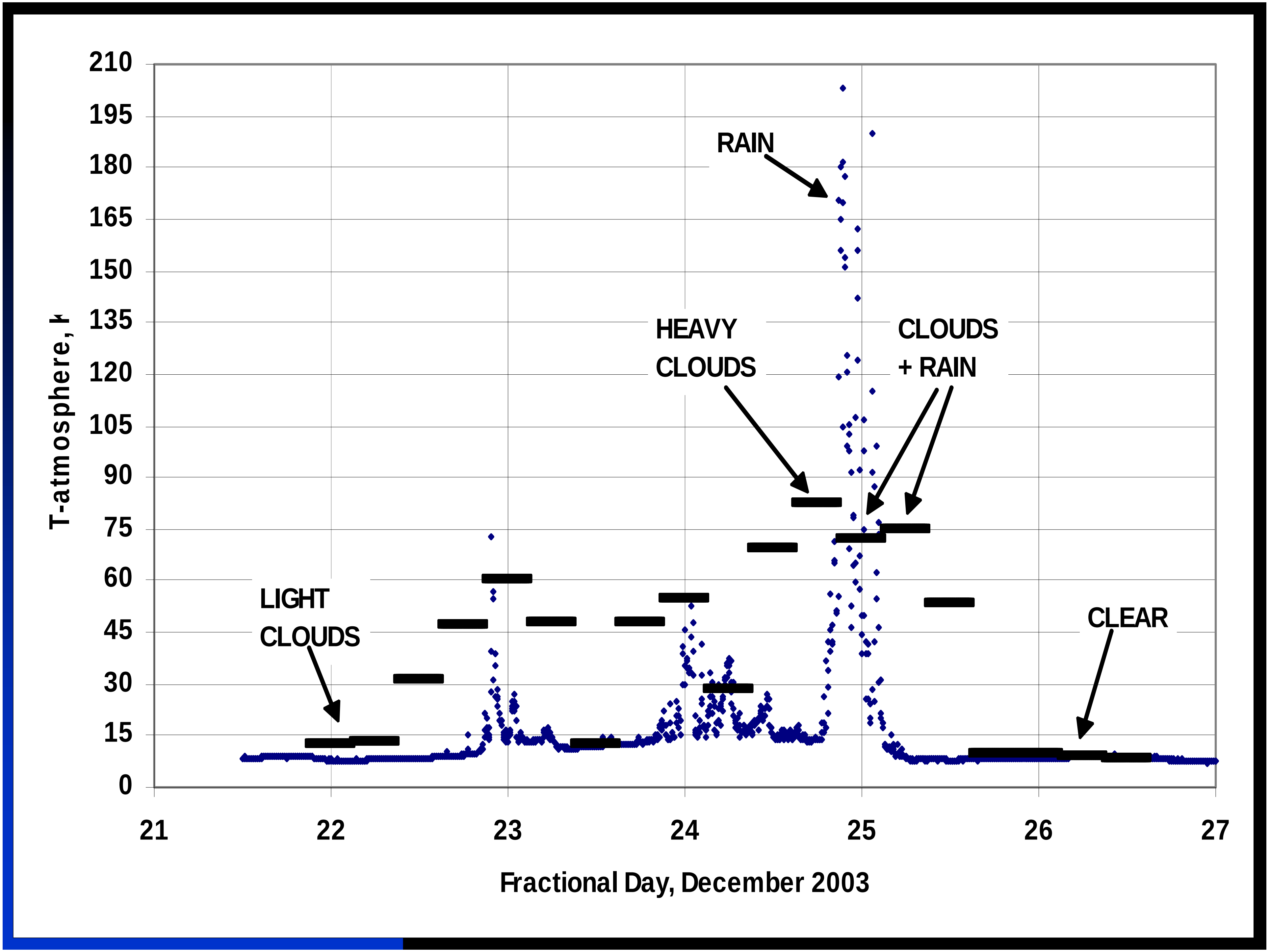


# JPL Applications

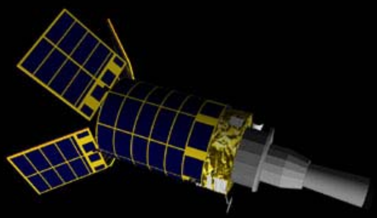
- Import CSV Spreadsheet Into JPL Calculation Spreadsheet
- Calculate Noise Temperature
- Compare to Actual WVR Measurements


GOLDSTONE AWVR1 TBZ 31.4 GHZ VS. WX FORECAST DECEMBER 2003
TBZ, K
210
195
180
165
150
135
120
105
90
75
60
45
30
15
0
21
22
23
24
25
26
27
FRACTIONAL DAY, DECEMBER 2003
RAIN
HEAVY CLOUDS
CLOUDS + RAIN
LIGHT CLOUDS
CLEAR


GOLDSTONE AWVR1 T-ATM 31.4 GHZ VS. WX FORECAST DECEMBER 2003
T-ATM, K
210
195
180
165
150
135
120
105
90
75
60
45
30
15
0
RAIN
HEAVY CLOUDS
CLOUDS + RAIN
LIGHT CLOUDS
CLEAR
21
22
23
24
25
26
27
FRACTIONAL DAY, DECEMBER 2003



T-atmosphere, K
210
195
180
165
150
135
120
105
90
75
60
45
30
15
0
21
22
23
24
25
26
27
Fractional Day, December 2003
RAIN
HEAVY CLOUDS
CLOUDS + RAIN
LIGHT CLOUDS
CLEAR



# Next Steps

- Convert from CSV to XML
- Consider including all levels
- Verification at all 3 sites
- Evaluate Results
- Determine Value
- Program Decision