Session IX. Airborne Passive Infrared

N91-24145

Status of NASA's IR Wind Shear Detection Research
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NASA's EXPERIENCE WITH INFRARED WIND SHEAR DETECTION

by

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EARLY EXPERIENCE TO PRESENT

"Can ambient air temperature changes lead to the detection of hazardous wind shear conditions"

- Fawbush and Miller (1954) - Peak Gust = $7 + 3.06\,T - 0.007\,T^2 - 0.00284\,T^3$
- Foster (1958) - $W_o = -(-gz\delta T_o/T_m)^{1/2}$
- Kuhn and others (late 1970's) - infrared radiometer flown on NASA Learjet (1982)
- Proctor (mid-1980's) - microburst modeling: $u_{max} = -2.5\Delta T$
- Adamson (mid 1980's) - development of a FLIR for wind shear detection
- IR is an integral part of the NASA/FAA wind shear detection and warning progam

NASA SBIR NAS1-18637 WITH TURBULENCE PREDICTION SYSTEMS

Phase I (1987)

- Determined that a FLIR is feasible for wind shear detection
- FLIR has considerable commercial potential

Phase II (1989)

- Production of a prototype FLIR, AWAS I
- Installation of AWAS I on NASA 515
- 4.89 hours of flight test in 1989 and early 1990
- Production of an advanced FLIR, AWAS III
- Installation of AWAS III on UND Cessna Citation
- Recording of microburst penetrations in Orlando, FL and Denver, CO
- Installation of AWAS III on NASA 515 in fall of 1990
- Future test flights at LaRC and Denver, CO

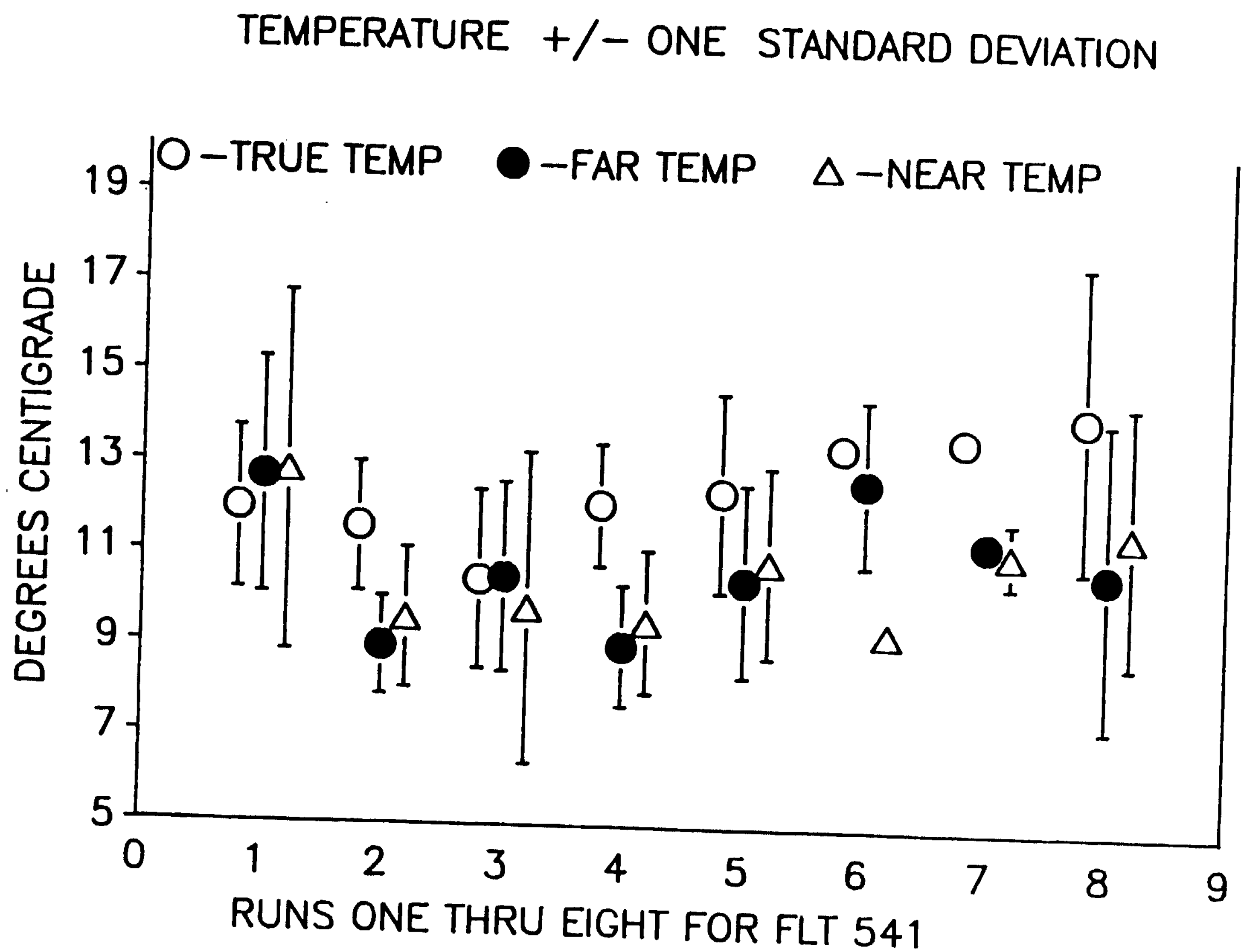
QUANTITIES MEASURED BY AWAS I

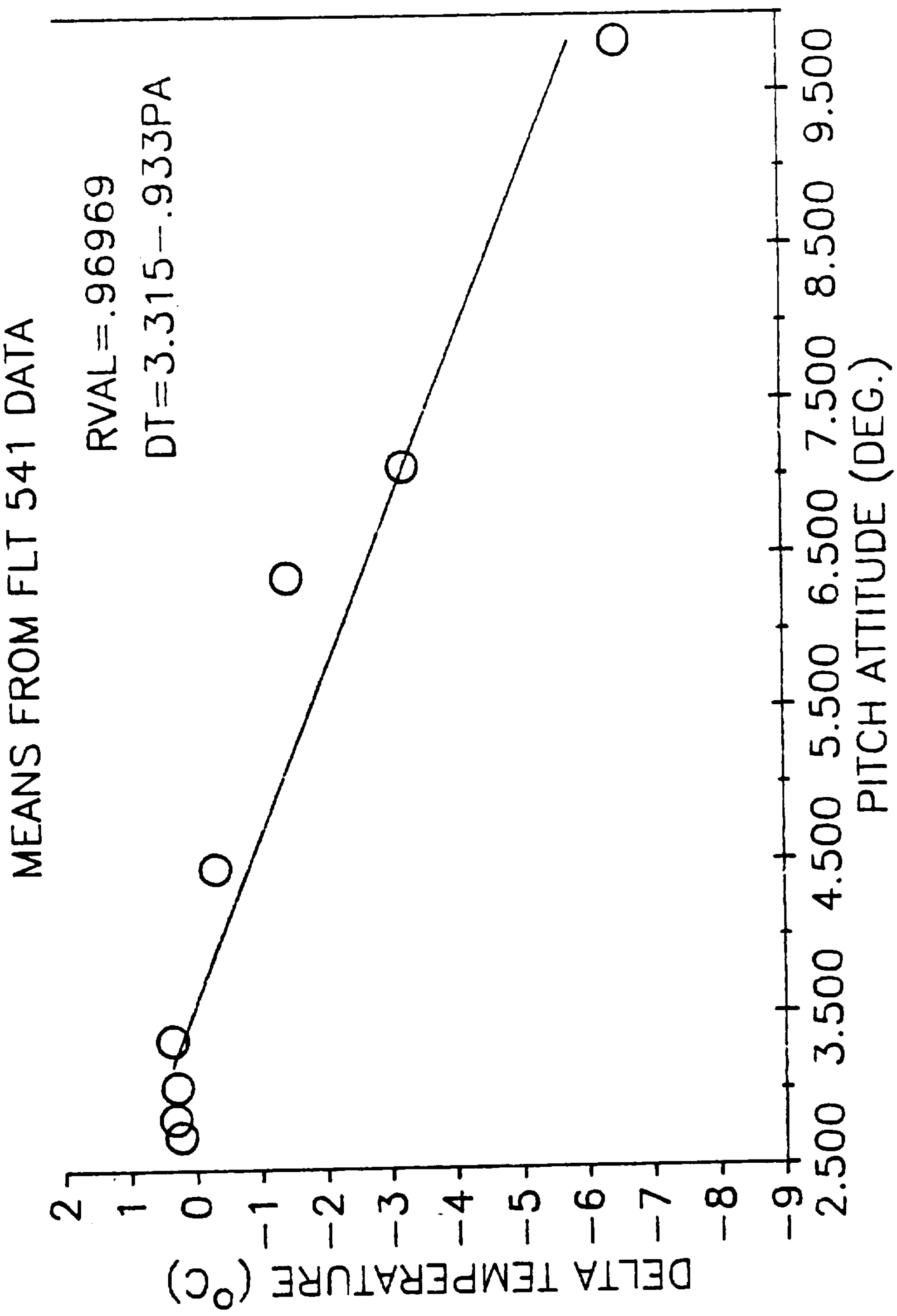
NEAR FIELD TEMPERATURE - Approx. 100 meters ahead of the aircraft

FAR FIELD TEMPERATURE - Up to 6 or more kilometers ahead of the aircraft. Dependent on humidity.

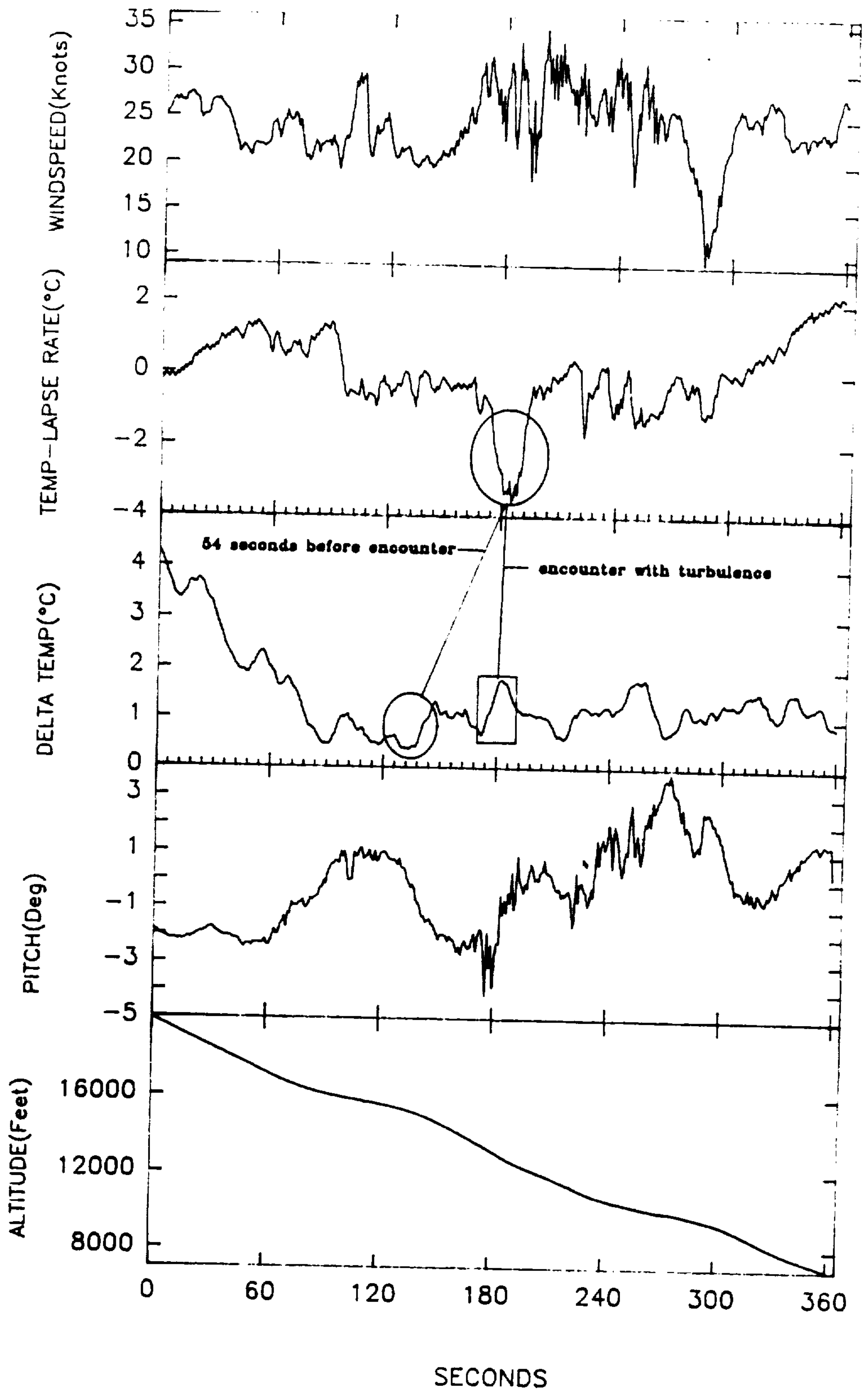
DELTA TEMPERATURE - Spectral measurement of near field minus far field temperatures

THERMAL F-factor - A hazard index based on temperature


TEMPERATURE +/- ONE STANDARD DEVIATION
O -TRUE TEMP
● -FAR TEMP
Δ -NEAR TEMP
DEGREES CENTIGRADE
19
17
15
13
11
9
7
5
0
1
2
3
4
5
6
7
8
9
RUNS ONE THRU EIGHT FOR FLT 541


MEANS FROM FLT 541 DATA
RVAL=.96969
DT=3.315-.933PA
DELTA TEMPERATURE (°C)
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
2.500
3.500
4.500
5.500
6.500
7.500
8.500
9.500
PITCH ATTITUDE (DEG.)

FLT 551 TURBULENCE ENCOUNTER



TIME SERIES MODEL FOR FLIGHT 551

$DT(t)$: Infrared measurement of temperature difference at time t

$\Delta T(t)$: $T(t) - T(t+54)$; difference of air temp. 54 seconds apart

$\theta(t)$: pitch attitude at time t

B : shift operator; $B^K X(t) = x(t-k)$

$E(t)$: Residual error from modelling

$$(1 - \Sigma a_k B^k) DT = \Sigma b_k B^k \theta + \Sigma c_k B^k \Delta T + E$$

Model $R^2 = .98$

estimated look distance 9.6 km

Advance detection time is 54 seconds

Average ground speed of 346.09 knots

Altitude ranged from 19,921 feet to 7,079 feet

C-2

CONCLUSION FROM NASA 737 FLIGHTS

- Prototype Infrared sensor measures temperature

- Temperature measurement is affected by pitch

- Look ahead distance of approximately 9.6 km or look ahead time of 54 seconds at high altitude for Flight 551

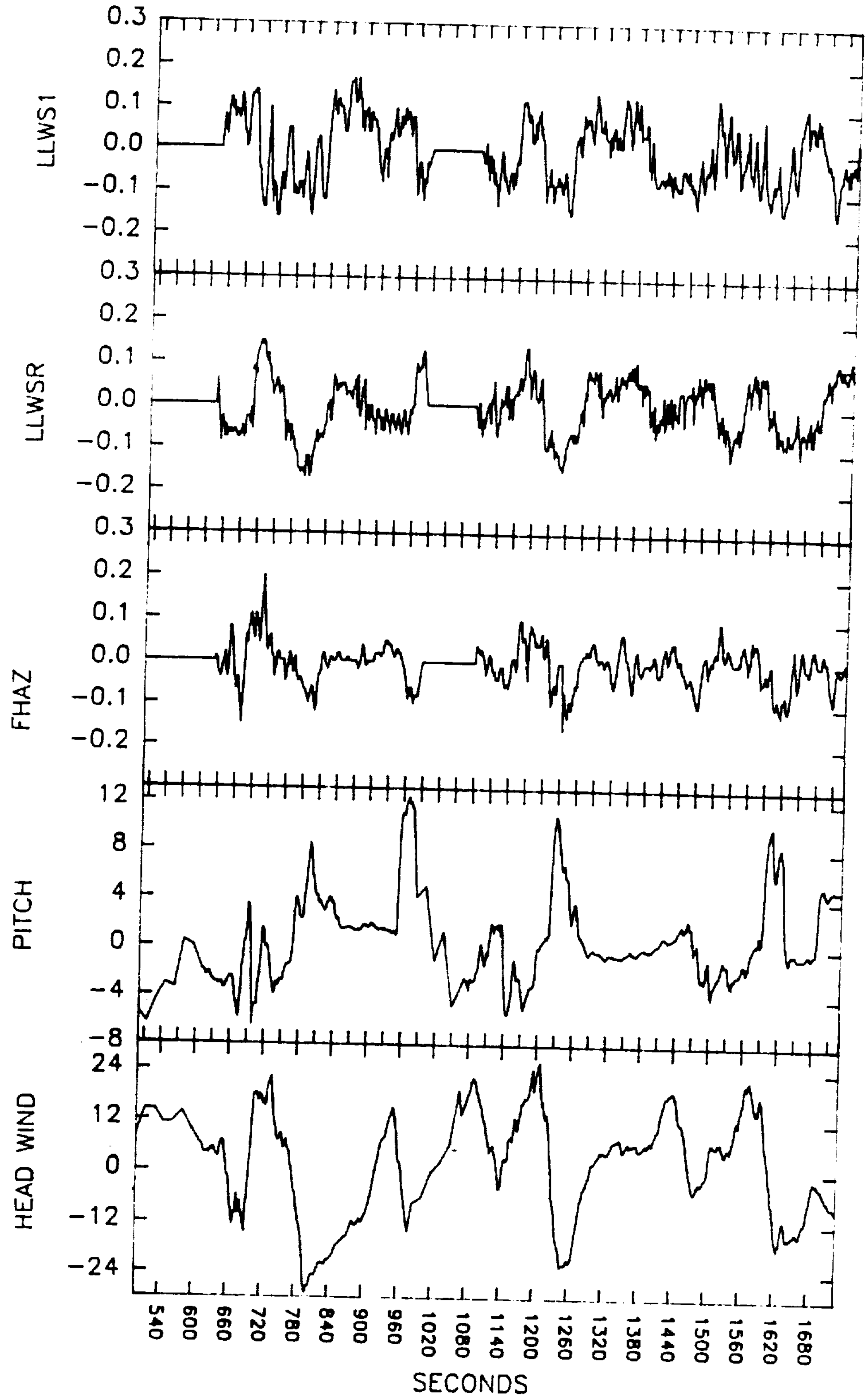
AWAS III MNEMONICS

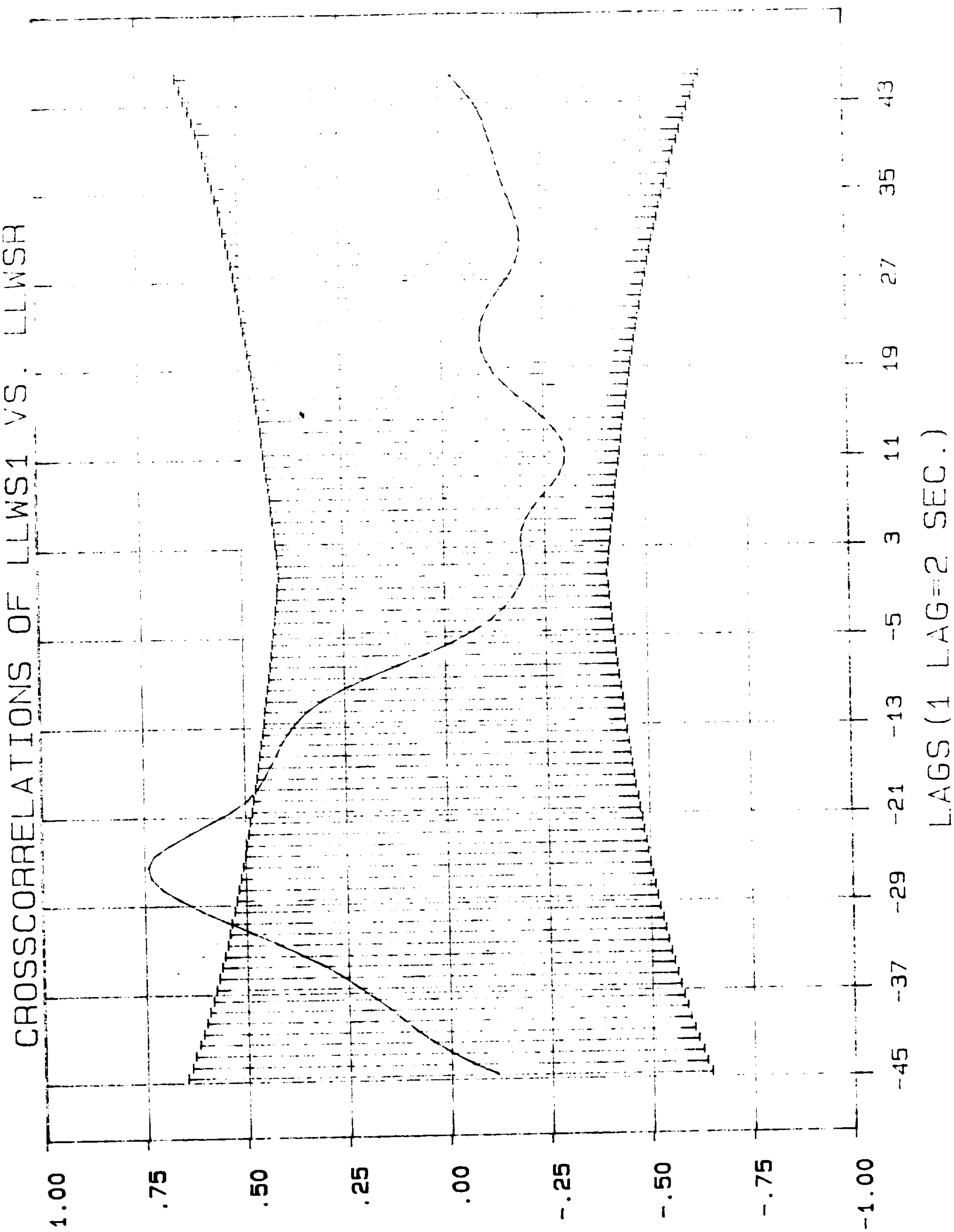
LLWS1 - Predictive thermal F-factor

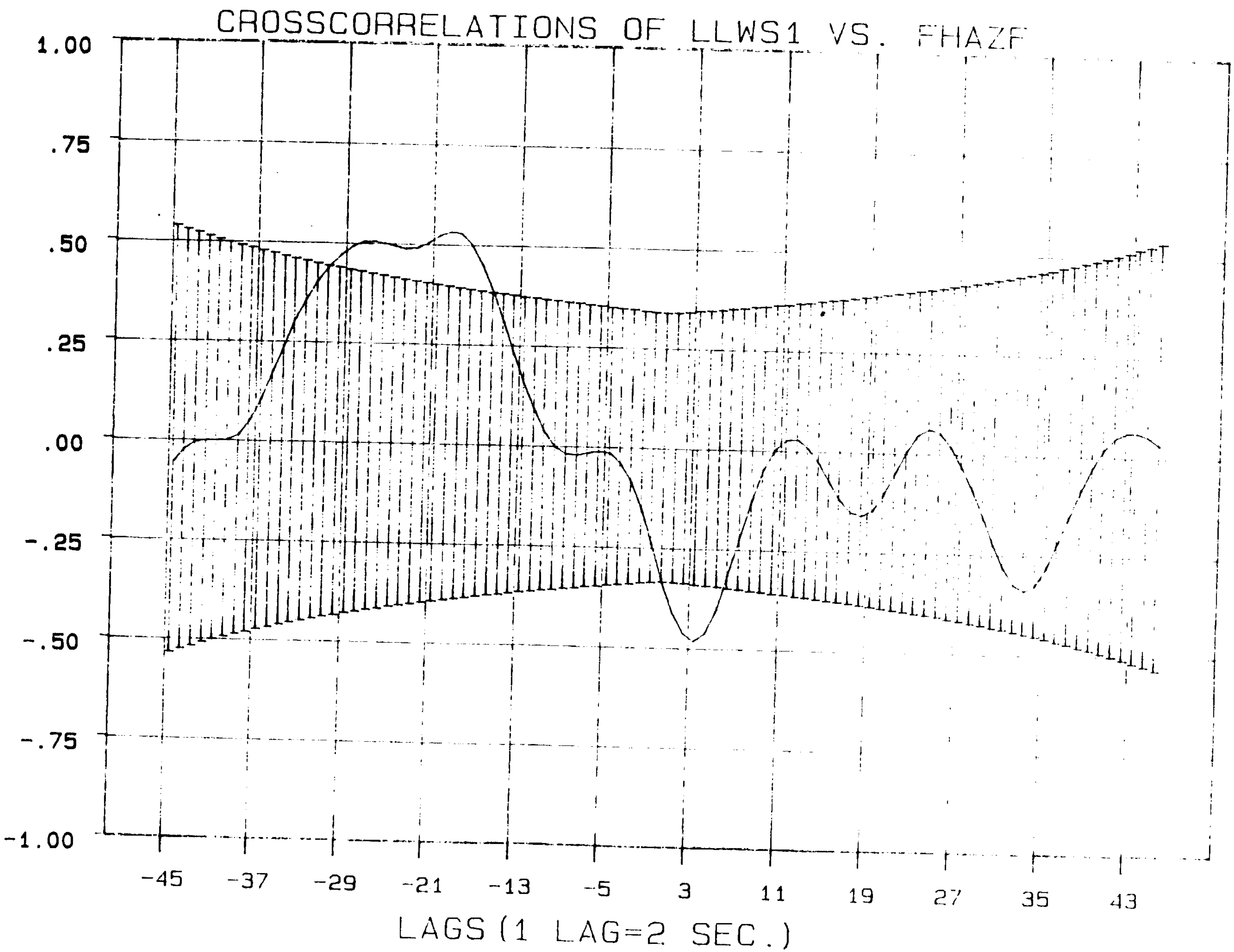
LLWSR - In situ thermal F-factor

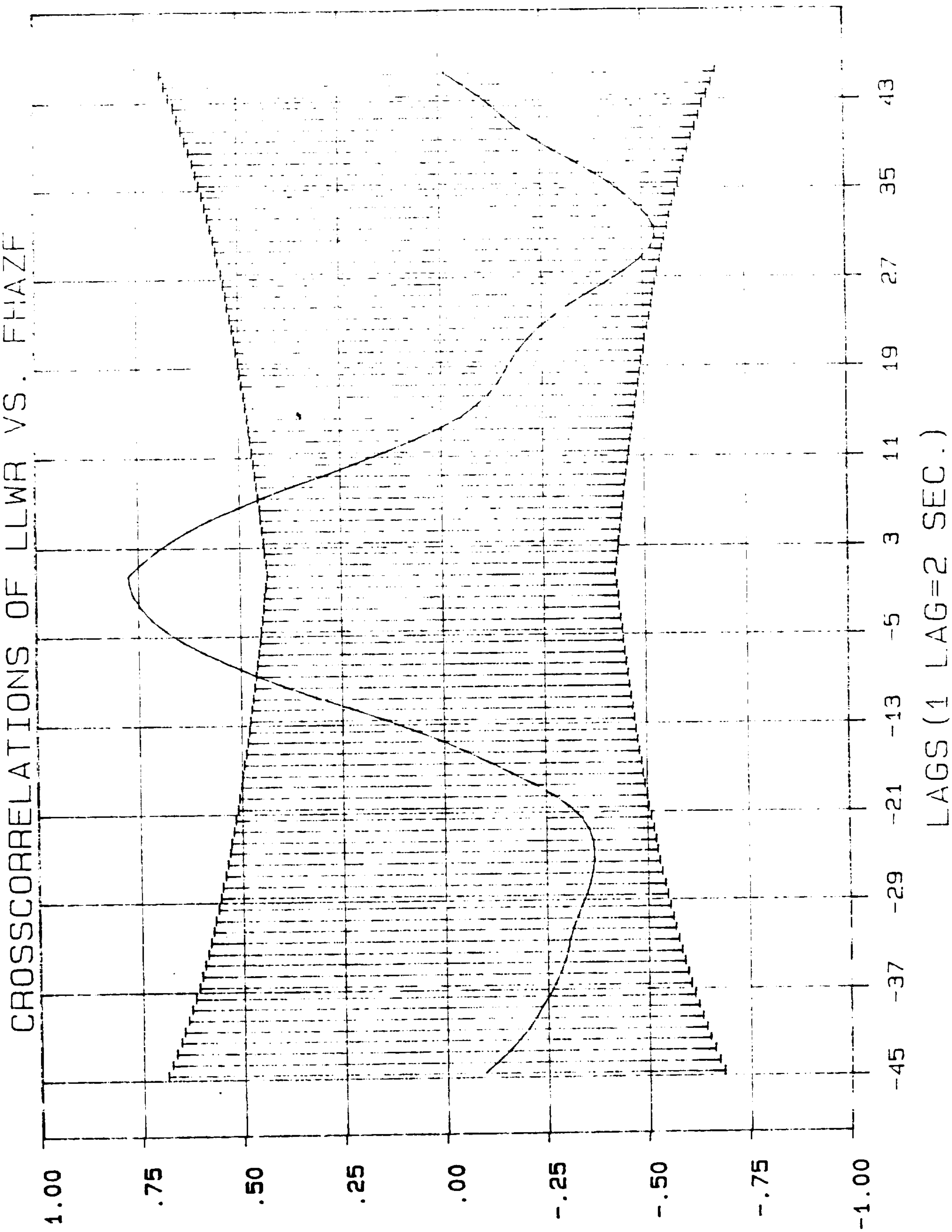
FHAZF - In situ winds F-factor

ORLANDO EXPERIMENT 7/7/90

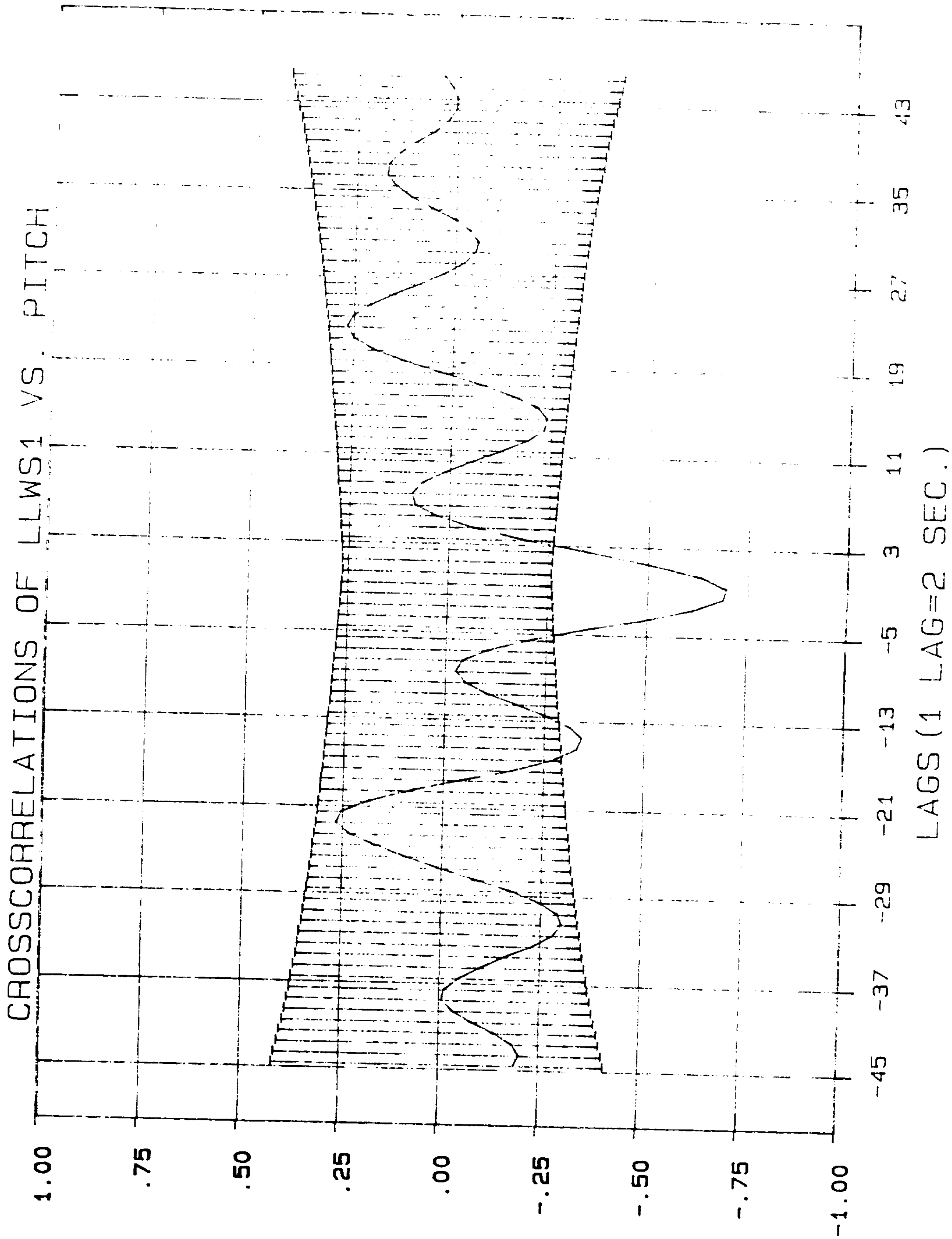



CROSSCORRELATIONS OF LLWS1 VS. LLWSR
LAGS (1 LAG=2 SEC.)
-45
-37
-29
-21
-13
-5
3
11
19
27
35
43
1.00
.75
.50
.25
.00
-.25
-.50
-.75
-1.00


CROSSCORRELATIONS OF LLWS1 VS. FHAZF
1.00
.75
.50
.25
.00
-.25
-.50
-.75
-1.00
-45
-37
-29
-21
-13
-5
3
11
19
27
35
43
LAGS (1 LAG=2 SEC.)



CROSSCORRELATIONS OF LLWR VS. FHAZF
LAGS (1 LAG=2 SEC.)
-45
-37
-29
-21
-13
-5
3
11
19
27
35
43
1.00
.75
.50
.25
.00
-.25
-.50
-.75
-1.00


CROSSCORRELATIONS OF LLWS1 VS. PITCH
LAGS (1 LAG=2 SEC.)
-45
-37
-29
-21
-13
-5
3
11
19
27
35
43
1.00
.75
.50
.25
.00
-.25
-.50
-.75
-1.00

TIME SERIES ANALYSIS OF ORLANDO 7-7-90 EVENT

$$(1 - \Sigma a_k B^k) F_T(t) = \Sigma b_k B^k F_{TI}(t + 23) + \Sigma c_k B^k \theta(t) + E_T(t)$$

where F_T = thermal look-ahead F-factor

F_{TI} = thermal in situ F-factor

θ = pitch attitude

E_T = residual error from modeling

Model R^2 =.996

Estimated look distance 4.659 km

Advance detection time of 46 seconds

Average ground speed of 196.838 knots

Altitude ranged from 1843 to 393 ft.

CONCLUSIONS ON ORLANDO 7-7-90

F_T correlates with F_{TI}

F_T correlates with F

F_{TI} correlates with F

F_T correlates with θ

AWAS III showed an advance warning time of 46 sec for the first pass through the 7-7-90 event at Orlando, FL

SUMMARY

Atmospheric temperature changes and microbursts can be detected with forward looking infrared devices

NASA and Industry are continuing research (Orlando, LaRC and Denver) that will lead to the validation of windshear detection via infrared technology

Status of NASA's IR Wind Shear Detection Research
Questions and Answers

Q: MIKE TAYLOR (Boeing) - Will a lightning flash or a series of flashes in the infrared sensors field of view cause a temperature anomaly similar to a microburst event?

A: BURNELL McKISSICK (NASA Langley) - Lightning flashes tend to be too local. They are very small events. The temperature anomaly that is sensed by infrared, the one that is really detectable from the standpoint of wind shear hazards, is a reduction in temperature drop. Lightning wouldn't be that. If you could sense one, it would be like a spike, I would think, a rise in temperature. Also being very local, I don't think it would be something you could sense from infrared.