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**Session IX. Airborne Passive Infrared**

**N91-24145**

Status of NASA's IR Wind Shear Detection Research  
Dr. Burnell McKissick, NASA Langley

# **NASA'S EXPERIENCE WITH INFRARED WIND SHEAR DETECTION**

by

**Burnell T. McKissick  
NASA, Langley Research Center  
Hampton, VA 23665**

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Airborne Windshear Review Meeting  
Radisson Hotel, Hampton  
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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 program

# **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 AWASI**

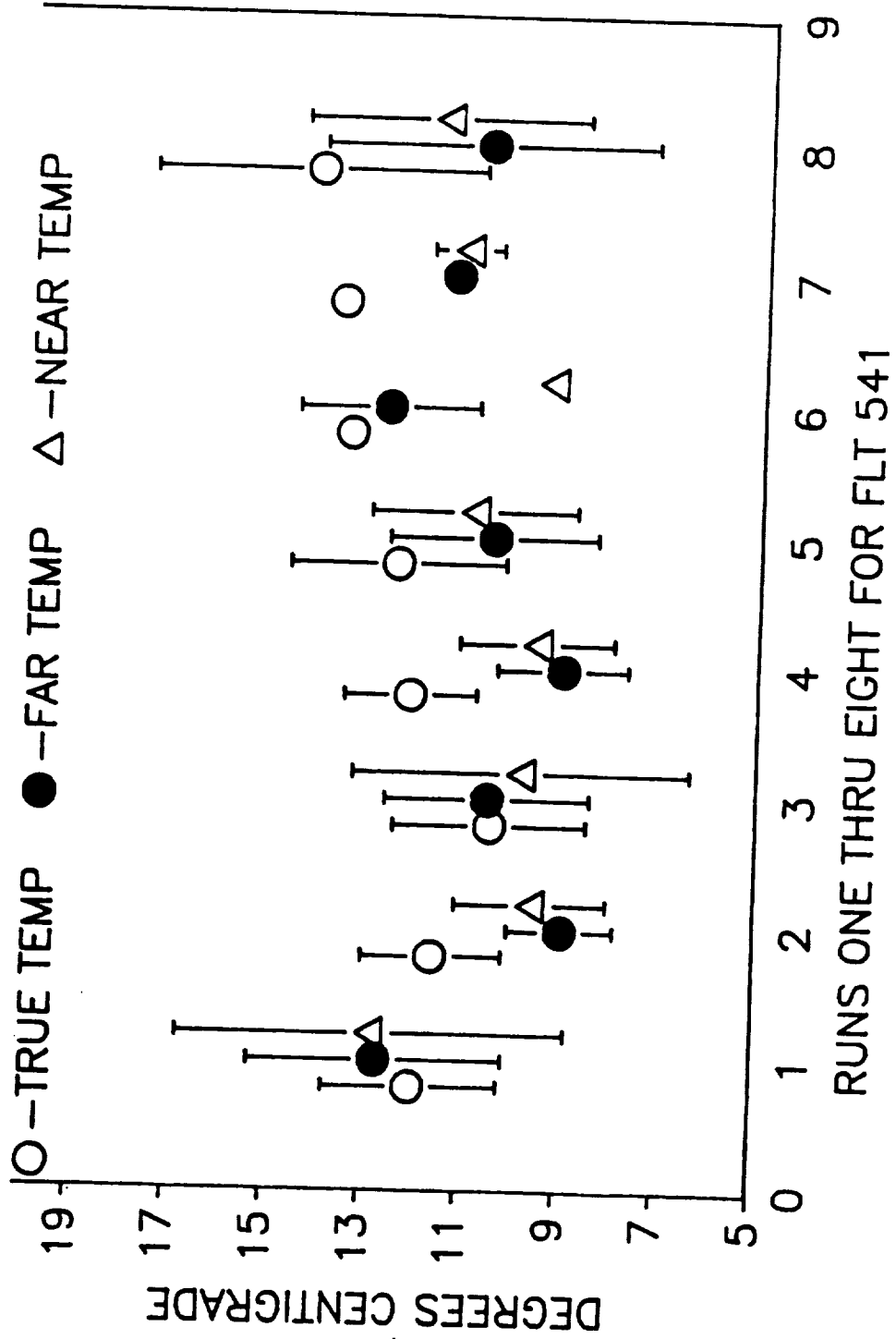
**NEAR FIELD TEMPERATURE - Approx. 100 meters ahead of the aircraft**

**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**

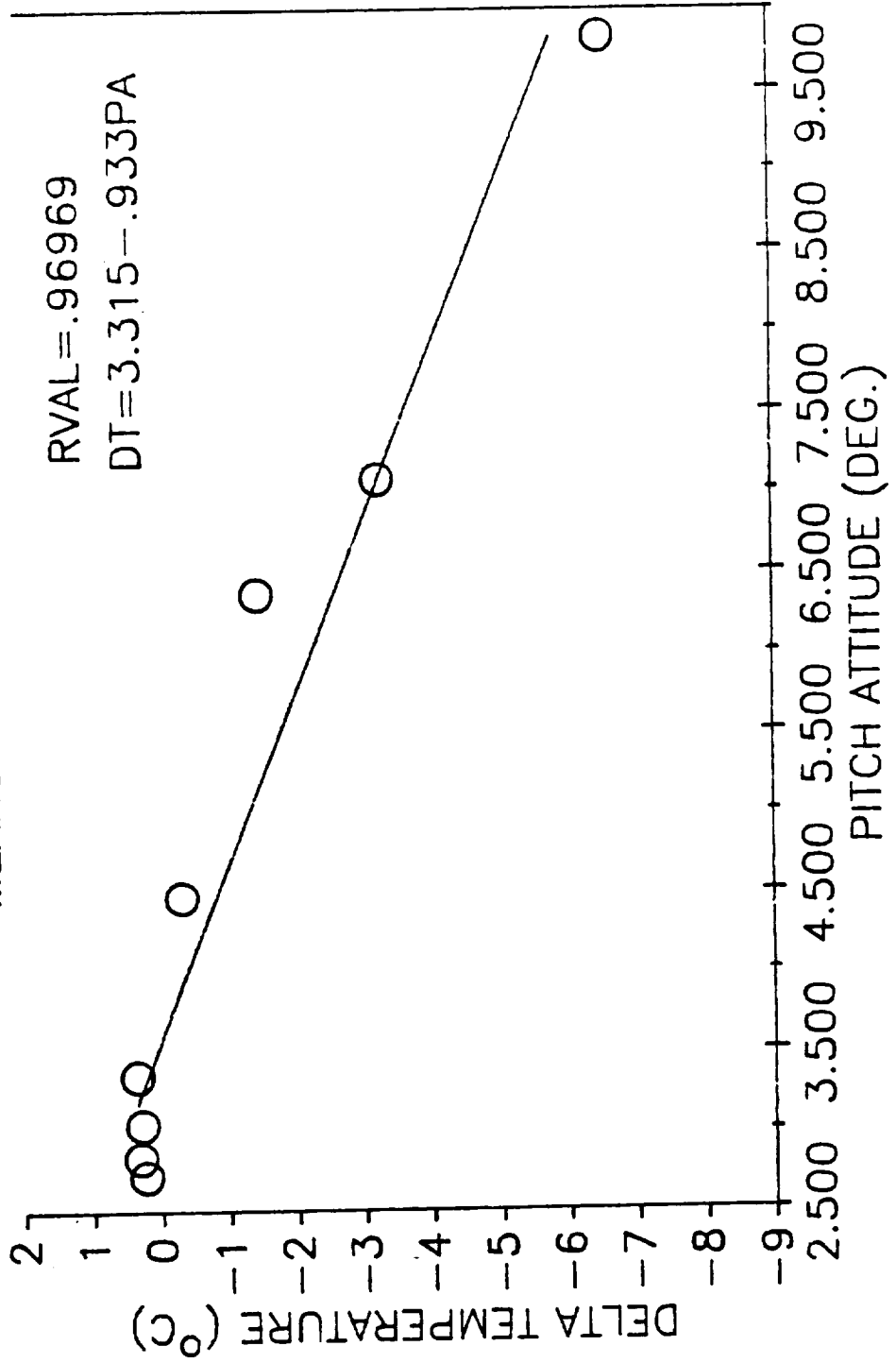
**THERMAL F-factor - A hazard index based on temperature**

TEMPERATURE +/- ONE STANDARD DEVIATION

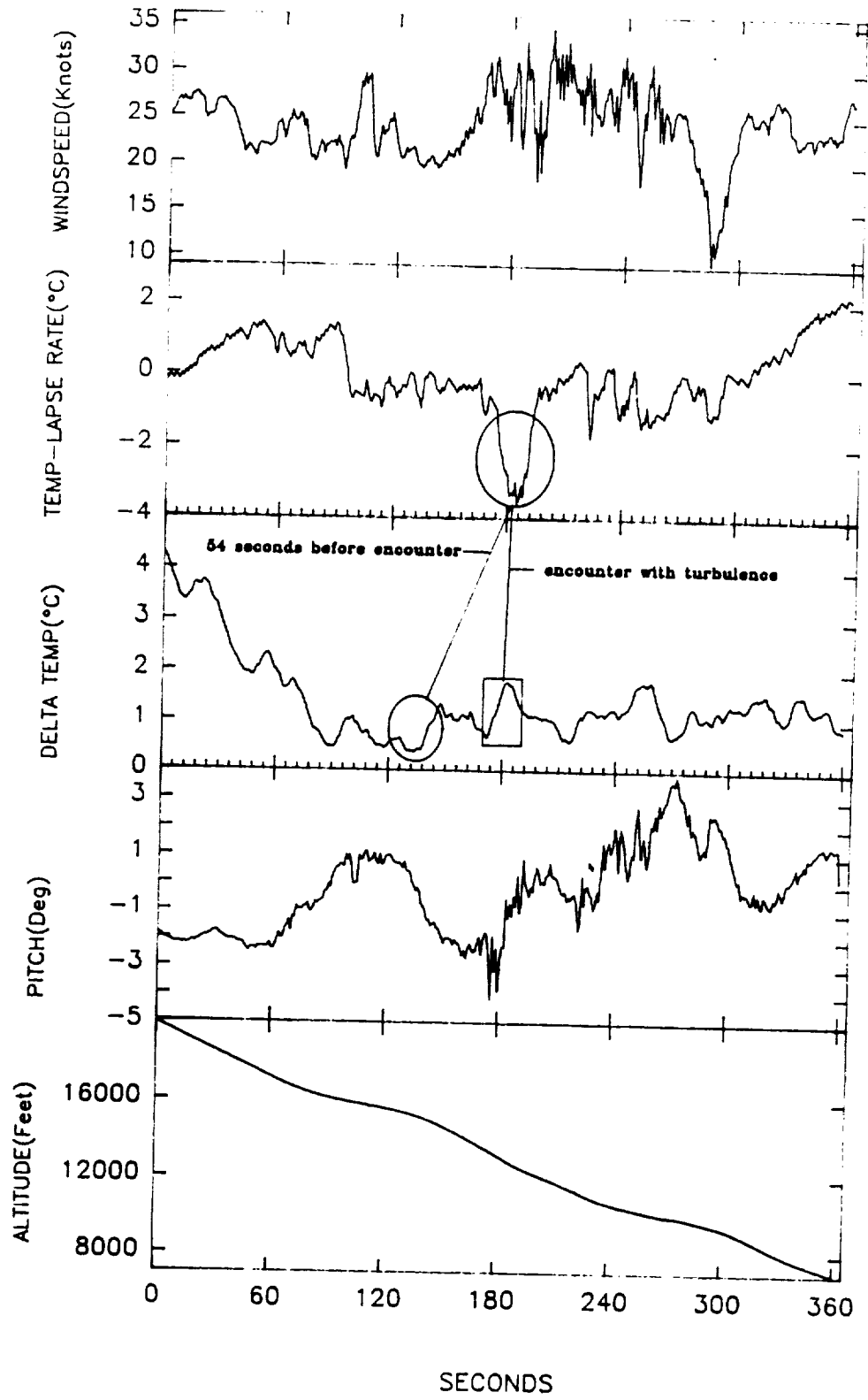


MEANS FROM FLT 541 DATA

RVAL=.96969  
DT=3.315-.933PA



# 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

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

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

# 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

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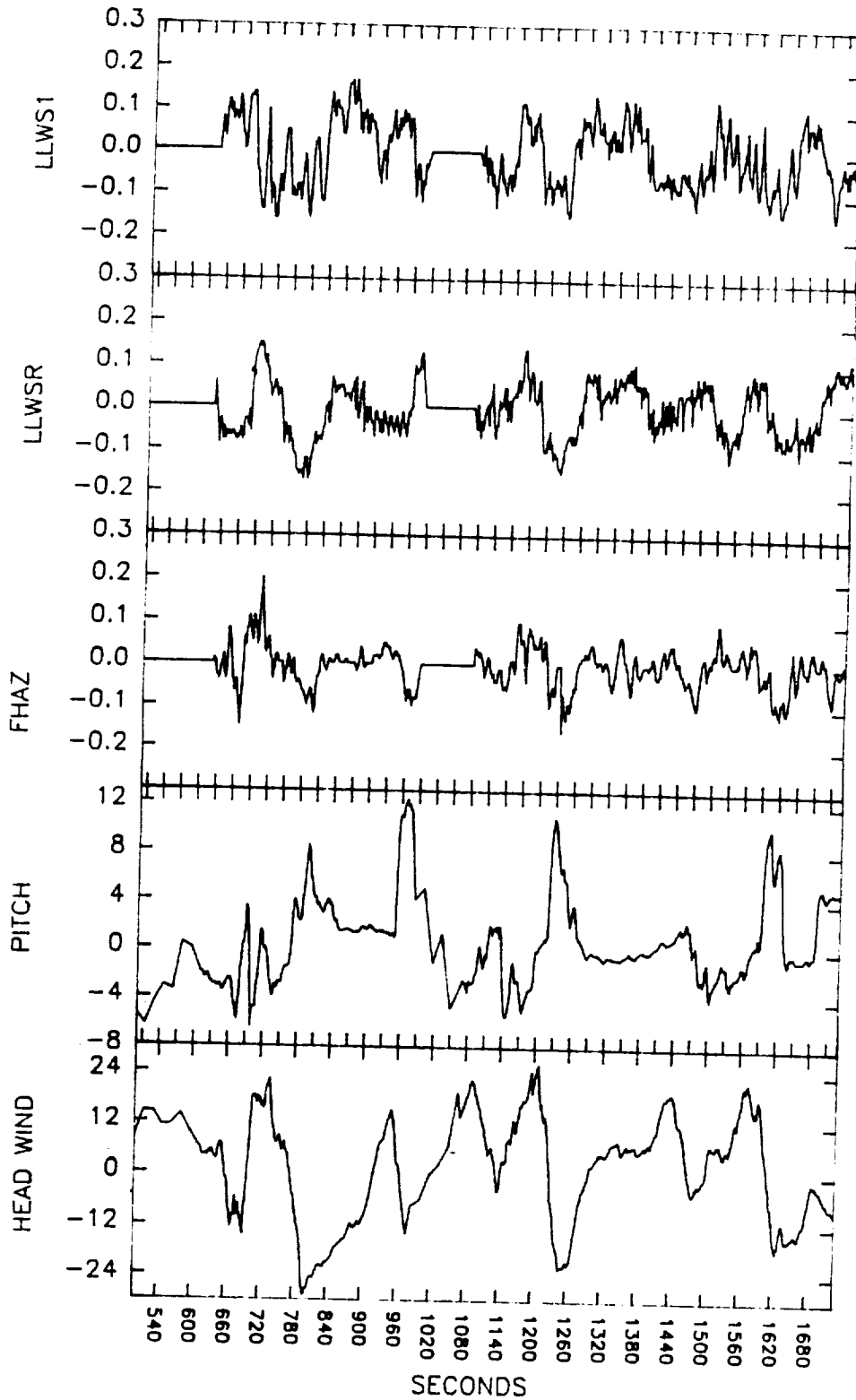
# **AWAS III MNEMONICS**

**LLWS1 - Predictive thermal F-factor**

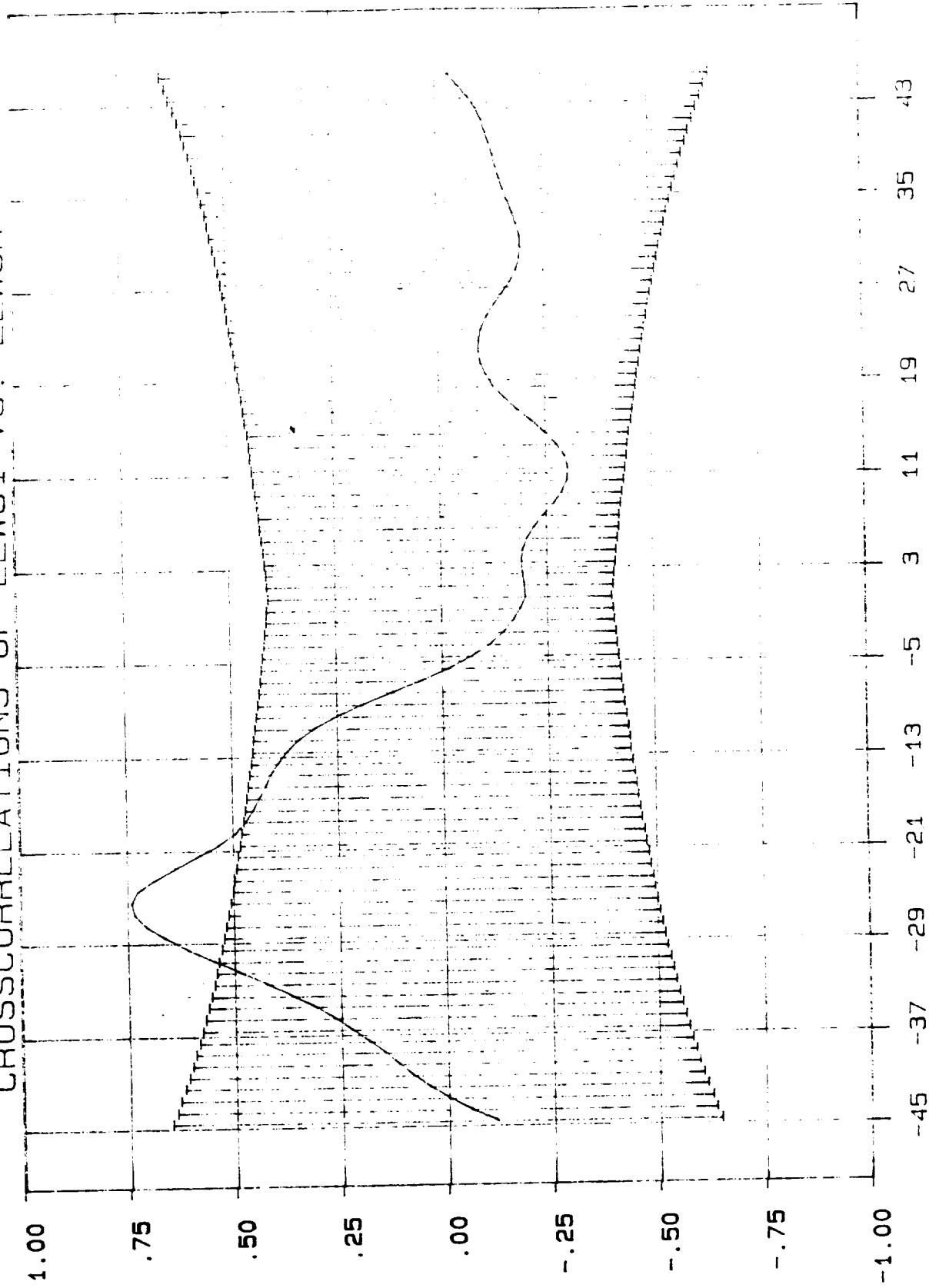
**LLWSR - In situ thermal F-factor**

**FHAZF - In situ winds F-factor**

ORLANDO EXPERIMENT 7/7/90

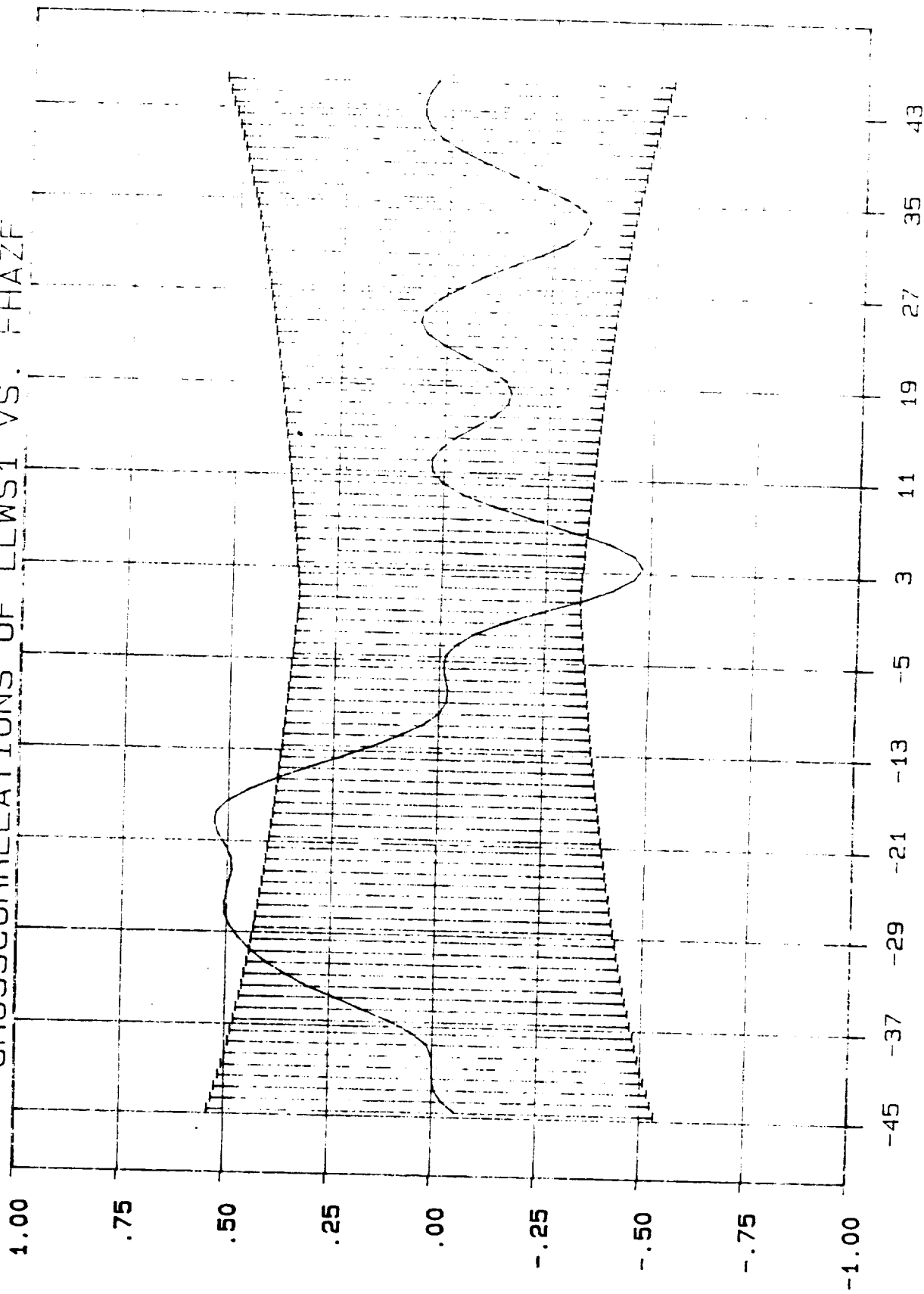


CROSSCORRELATIONS OF LLWS1 VS. LLWSR



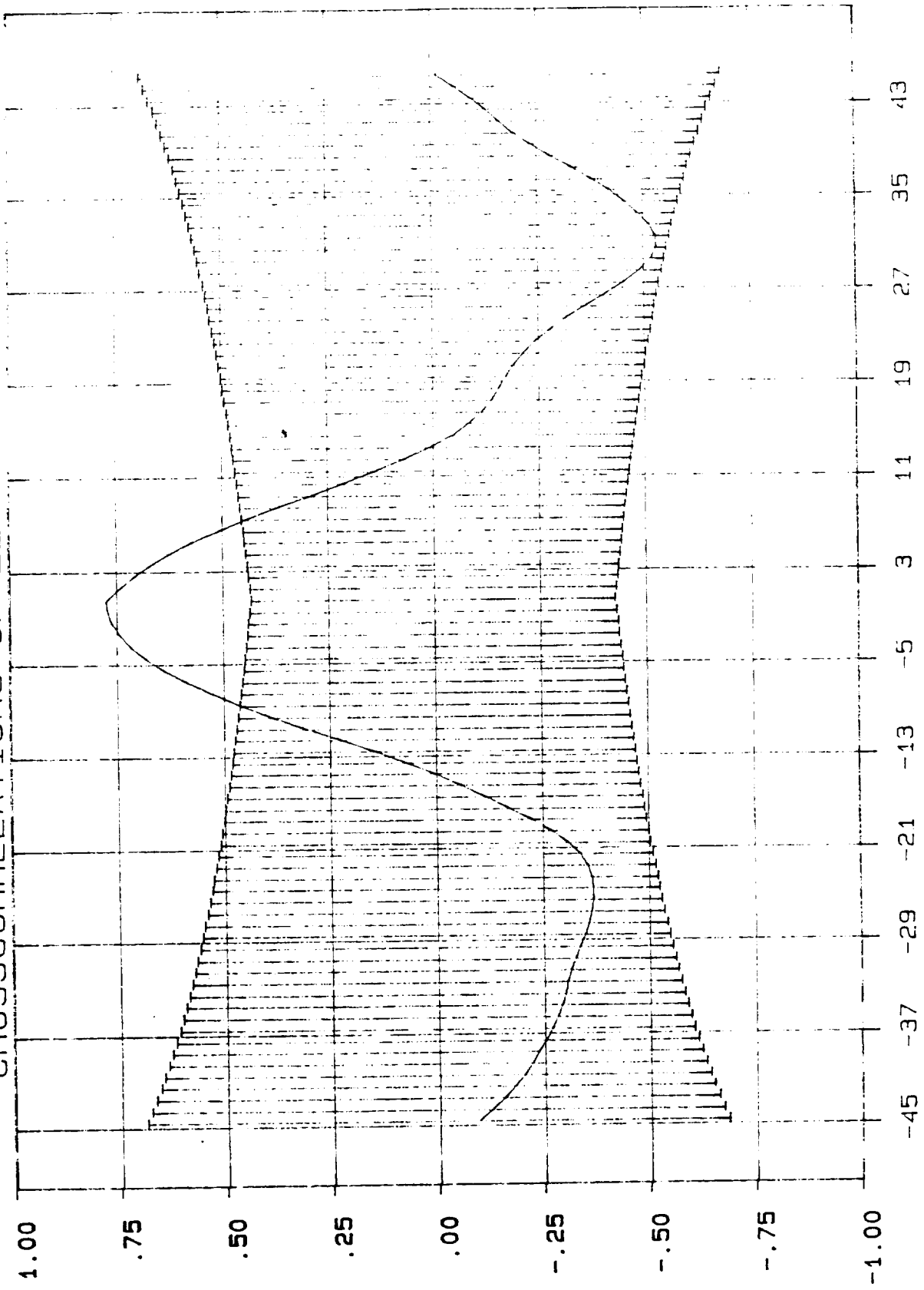
LAGS (1 LAG=2 SEC.)

CROSSCORRELATIONS OF LLWS1 VS. FHAZF



LAGS (1 LAG=2 SEC.)

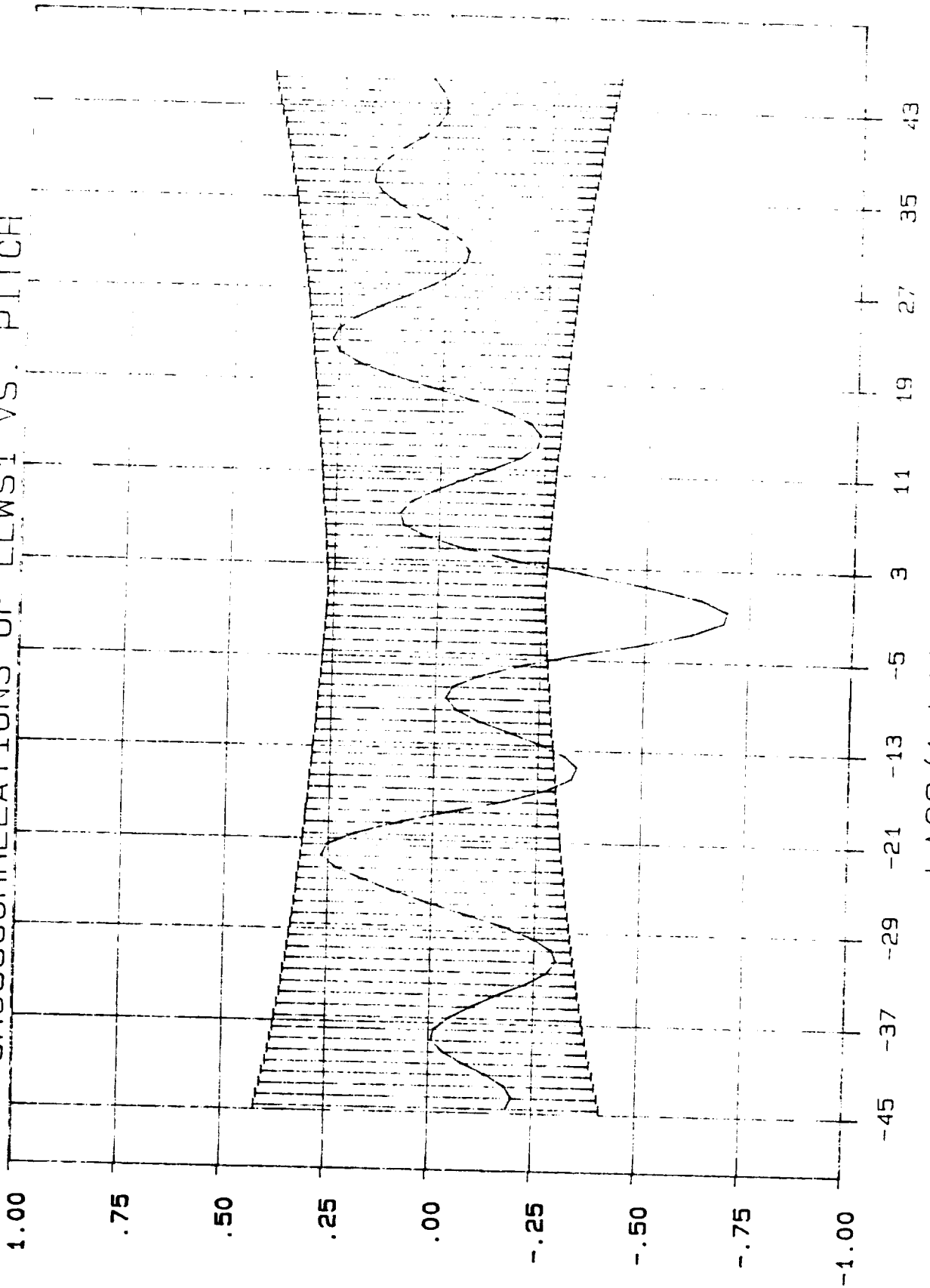
CROSSCORRELATIONS OF LLWR VS. FHAZF



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CROSSCORRELATIONS OF LLWS1 VS. PITCH



LAGS (1 LAG=2 SEC.)



# TIME SERIES ANALYSIS OF ORLANDO 7-7-90 EVENT

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

where  $F_T$  = thermal look-ahead F-factor

$F_{TI}$  = thermal in situ F-factor

$\theta$  = 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  $\theta$

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.**