Determination of nonstationarity in the surface layer during the T-REX experiment

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CONTENT

I. INTRODUCTION

- ❖ Statistical theory of turbulence ➔ ensamble averaging of multiple realizations of the same turbulent process (e.g. Lenschow and Stankov 1986)

- ❖ Quite successful in laboratory conditions, but almost never in the atmosphere (e.g. Batchelor 1959; Tennekes and Lumley 1972; Wyngaard 2010)

- ❖ Ergodic assumption for the atmospheric data: average of a single realization represents an ensamble average

- ❖ Ergodicity ⬅ **stationarity**

- ❖ Nonstationary atmospheric data ➔ time average is weak approximation of ensamble average ➔ enhanced scatter in turbulence statistics ➔ enhanced uncertainty in similarity functions (MOST)

❖ **OBJECTIVES**

➜ to investigate Monin-Obukhov similarity theory (MOST) in complex
   terrain using near-surface turbulence time series obtained during
   T-REX on NCAR ISFF towers by sonic anemometers

➜ to determine the nonstationarity of the means and (co-)variances of
   30-min time intervals of these time series ➜ 11 moments:
   - means: Q_U , Q_V , Q_W , Q_T
   - variances: Q_{uu} , Q_{vv} , Q_{ww} , Q_{tt}
   - covariances: Q_{uw} , Q_{vw} , Q_{wt}

➜ to use the stationary portion of data for investigation of MOST

❖ 30-min intervals ➜ based on the assumption that eddies with a time scale
   of 30 min contain most of the turbulence energy

II. DATA

- ❖ T-REX experiment ➔ Owens Valley, California ➔ March and April 2006

- ❖ Three NCAR-ISFF 30-m towers ➔ CSAT3 ultrasonic anemometers at heights of 5, 10, 15, 20, 25 and 30 m ➔ 60 Hz sampling frequency
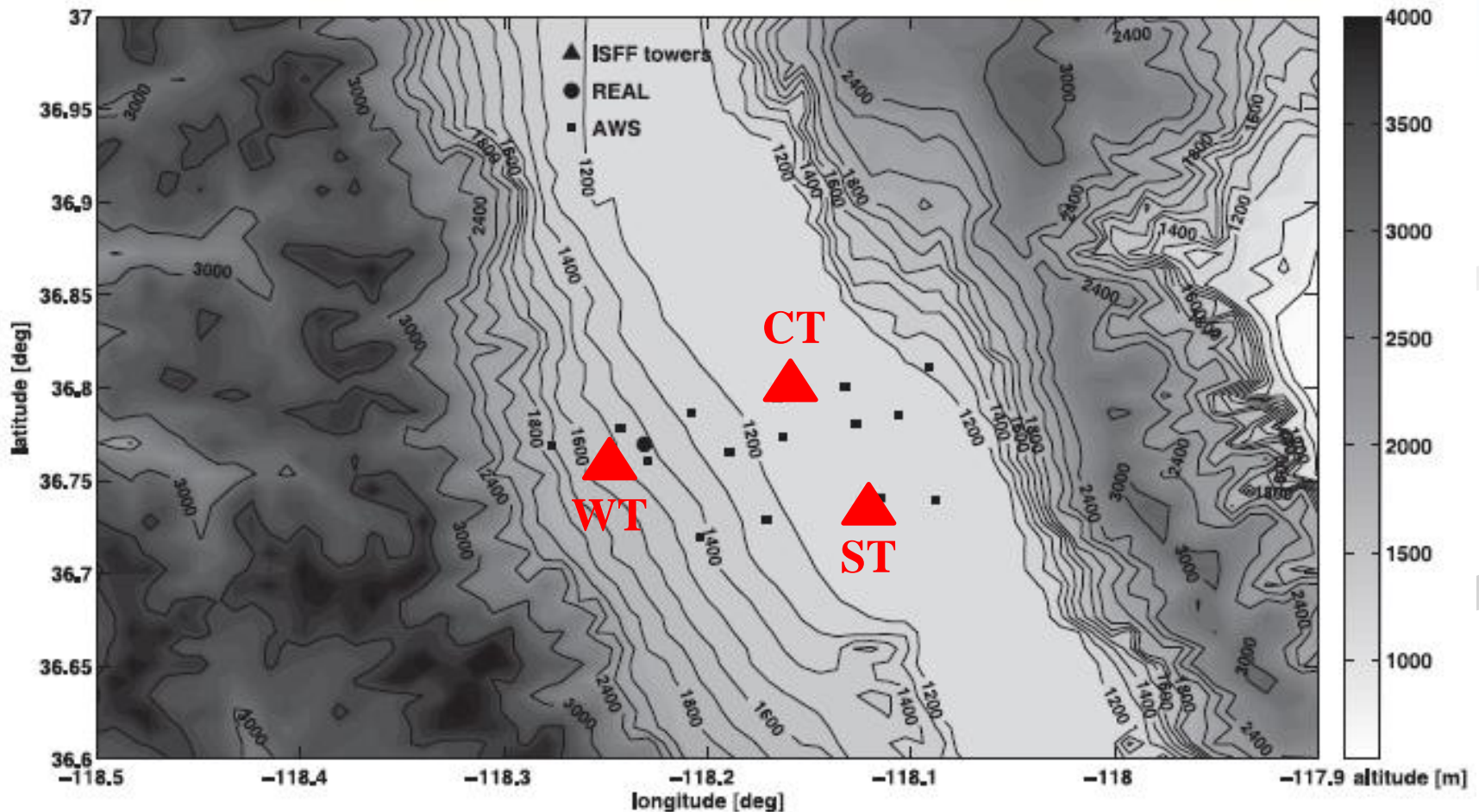
❖ 61-day period (from 0000 UTC 1 March to 2359 UTC 30 April 2006) of u, v, w and t time series

❖ Gaps in observed 61-day time series due to:

➔ The occasional power loss at different towers
➔ the occasional malfunction of anemometers at different towers/levels

➔ not all 30-min intervals (2928 of them) are suitable for our analysis

z [m]	WT [%]	CT [%]	ST [%]
5	96.96	93.72	98.05
10	96.79	96.41	97.40
15	98.19	89.00	97.75
20	98.50	96.76	97.64
25	98.26	96.55	98.26
30	98.60	90.68	98.22

III. DIAGNOSTIC OF THE NONSTATIONARITY

❖ 3 independent approaches ➔ 4 different methods:

(1) Statistical tests to determine trends

    1a) Reverse arrangement test (RAT)

      - if $162 \leq A \leq 272$ ➔ stat. moment is stationary

    1b) Run test (RUT)

      - if $10 \leq R \leq 21$ ➔ stat. moment is stationary

(2) Mahrt's (1998) method (M98)
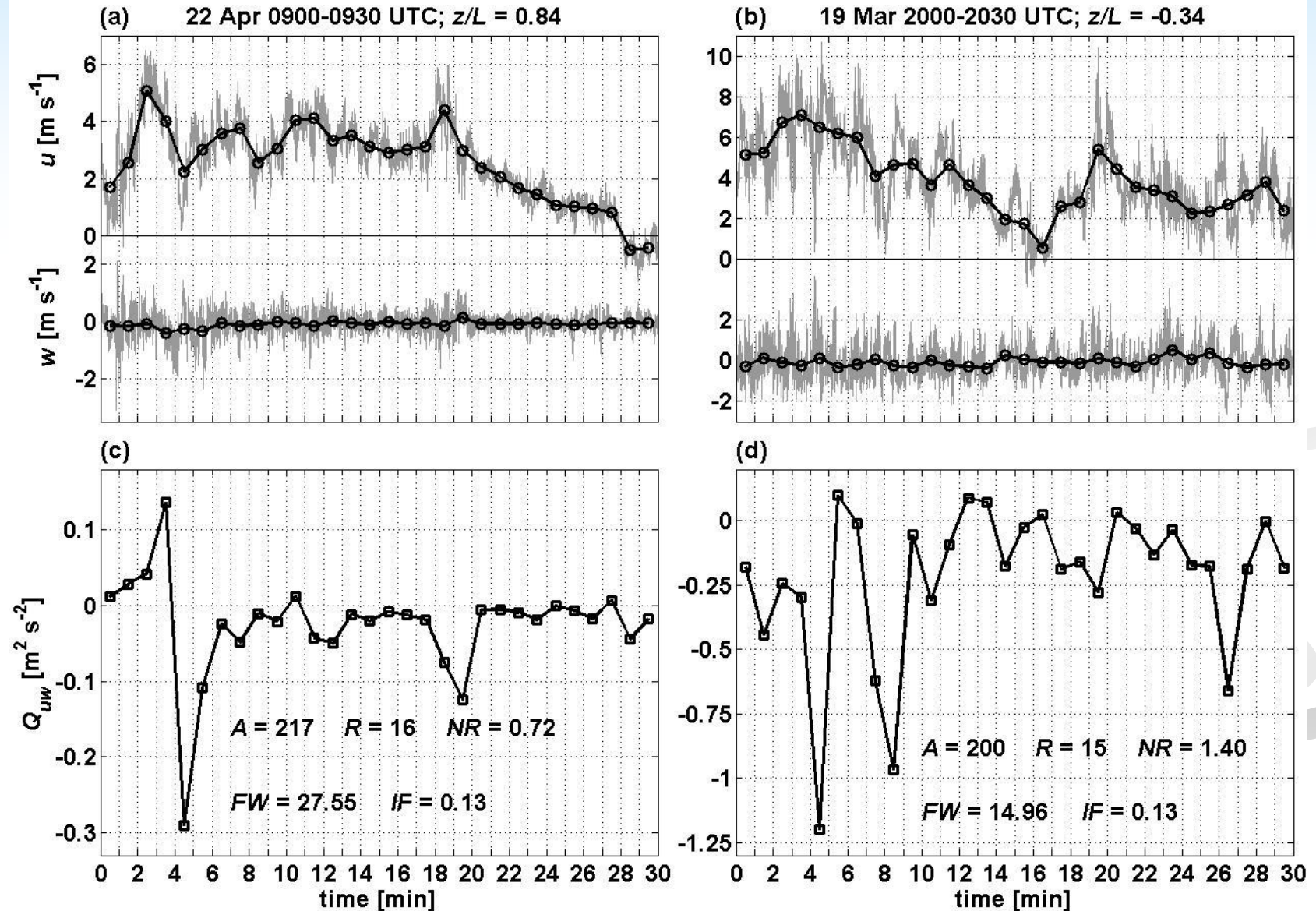
      - if $NR \leq 2$ ➔ stat. moment is stationary

(3) Foken and Whichura (1996) method (FW96)
    ➔ it works only for second order moments

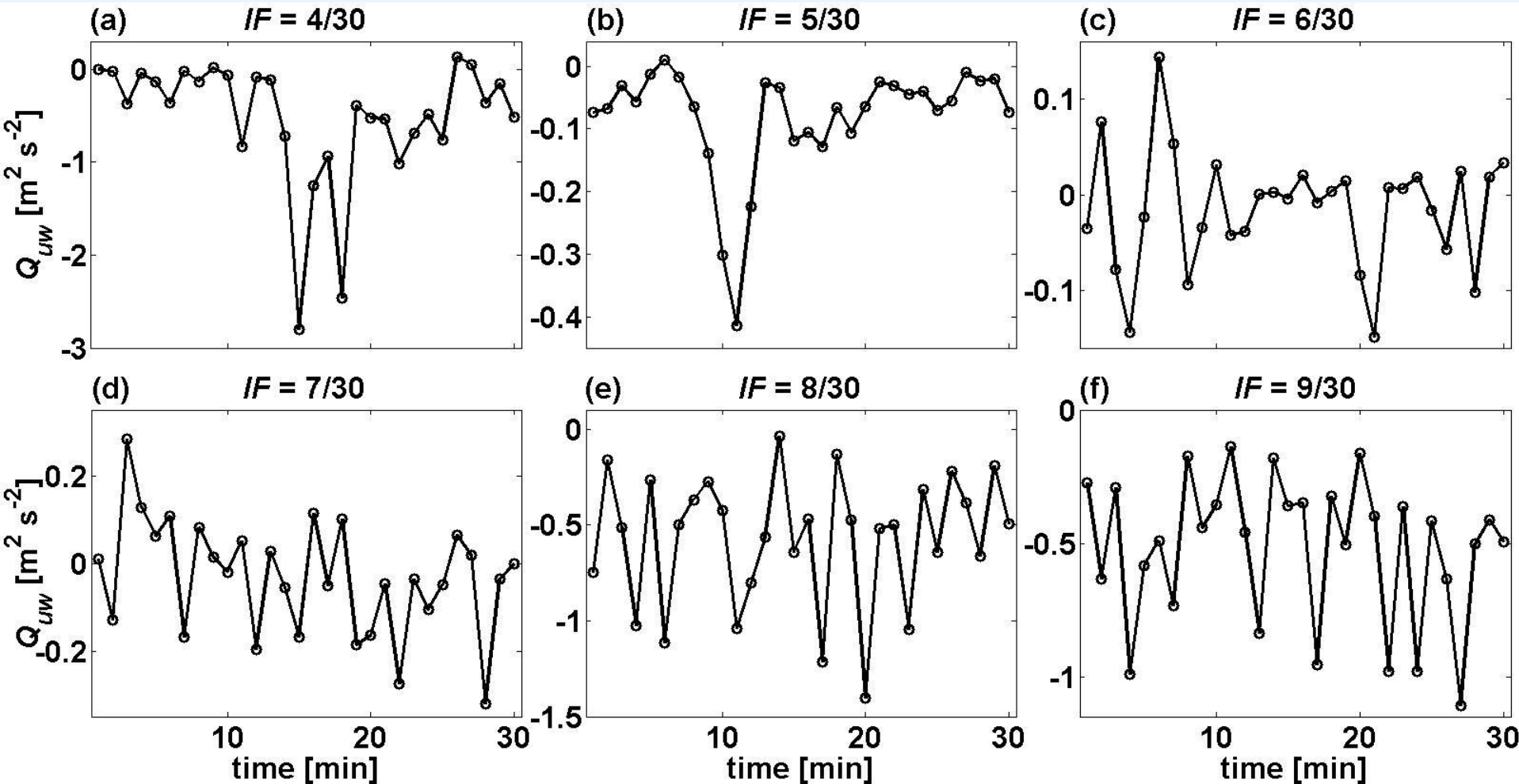   - if $FW < 30 \%$ ➔ stat. moment is stationary

❖ Examples: stationary by RAT, RUT, M98 and FW96 methods but still
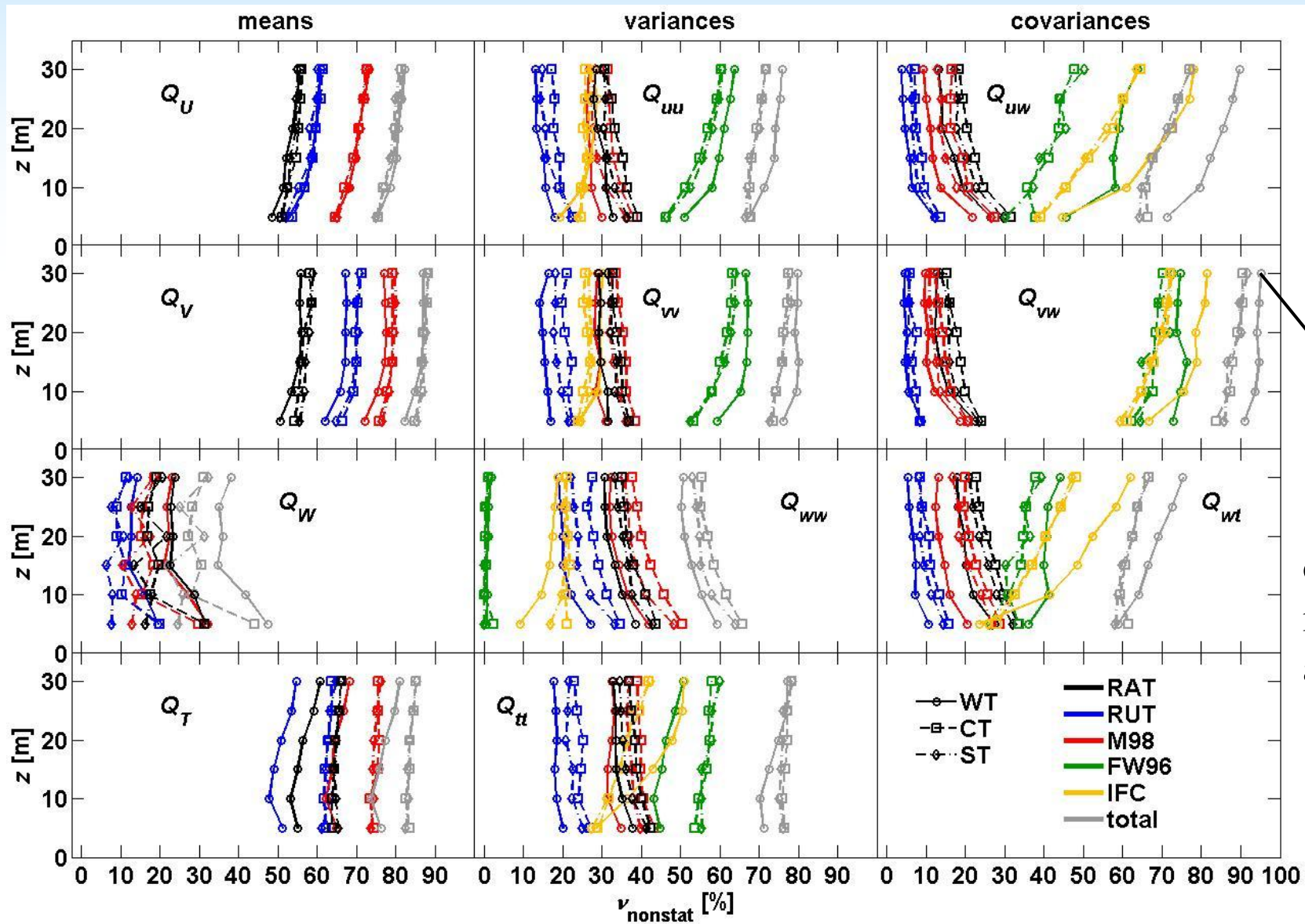   nonstationary ➔ INTERMITTENCY

(a) 22 Apr 0900-0930 UTC; $z/L = 0.84$

(b) 19 Mar 2000-2030 UTC; $z/L = -0.34$

(c) $A = 217$ $R = 16$ $NR = 0.72$ $FW = 27.55$ $IF = 0.13$

(d) $A = 200$ $R = 15$ $NR = 1.40$ $FW = 14.96$ $IF = 0.13$

❖ Additional criterion for stationarity of second orderr moments ➜
   - if *IF* > 6/30 ➜ stat. moment is stationary

IV. COMPARISON OF DIFFERENT APPROACHES

95.08 % ➔ 142 out of 2887 intervals are stat.

V. SUMMARY

❖ Degrees of nonstationarity vary considerably with the used approach ➜ extremely ambiguous results

❖ Not clear which method(s) would be most suitable for detecting nonstationarity in T-REX near-surface time series of statistical moments

❖ Simultaneous implementation of criterions imposed by RAT, RUT and M98 methods to means and criterions imposed by RAT, RUT, M98, FW96 and IFC methods to (co-)variances ➜ extremely rigorous approach

❖ For the statistical moments that are declared as stationary by this approach, we have no further doubts in their stationarity