Field Comparison of Methods for Measuring Evapotranspiration and Soil Evaporation, Including a Stable Isotope Method

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CAAS of China was generous enough to host the campaign and provide most of the instruments, at Xiao Tang Shan on the outskirt of Beijing

Field campaign for micrometeorological studies are relative common, but rarely with some focus on the dynamics of soil E vs. crop ET

Each technique has its own limitations and uncertainties, important to compare and evaluate as many different techniques as available.

Crucial to do this simultaneously because the ratio of soil E to Crop transpiration (T) varies dynamically with time and conditions

This means a larger number of researchers must be available to do the work at the same time

Opportunity to have researchers from different member countries, each with his/her expertise, come together at the prepared site to do the intensive joint study

Soil E and crop T cannot be easily measured separately from crop T by eliminating one or the other, because they compete for the same source of energy

For example, covering the soil would increase crop T because more energy is now available to drive crop T, and removing the crop would increase soil E

Original plan was to have stem flow measurements to estimate transpiration and microlysimeters to measure soil evaporation

Unfortunately the person responsible for stem flow measurement by heat pulse method became ill, and a rushed attempt to measure by the heat balance method was not successful

This means we were limited to calculate transpiration from ET and microlysimeter data

$$T = ET - E_{soil}$$

The estimated T is then subject to the errors of both ET and microlysimeter measurement.

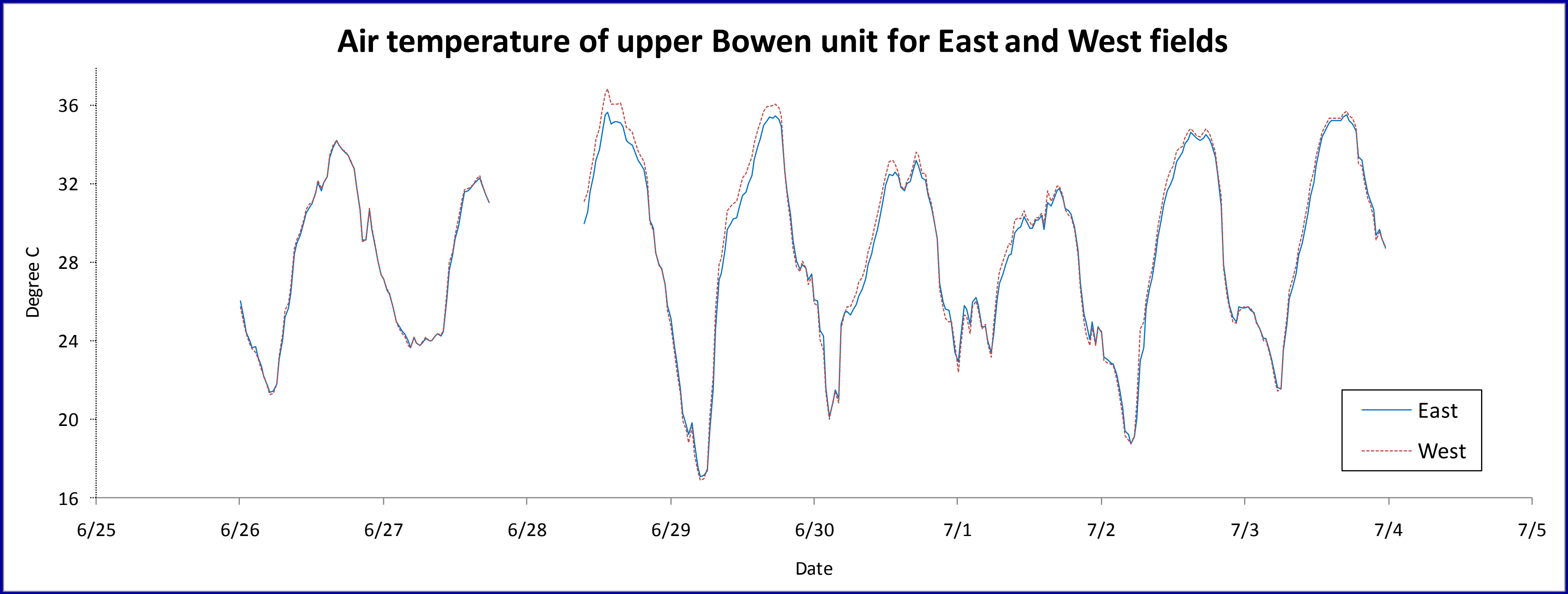
Instruments used:

Large Scale

- Eddy covariance units to measure ET of large area, every 30 min
- Profile sampling apparatus to collect air over large area for subsequent isotope analysis for Keeling plot
- Picarro isotope analyzer for near real time measurement of water isotope profile of air over large area, for Keeling plot
- Bowen ratio/energy balance units to measure ET of large area, hour by hour

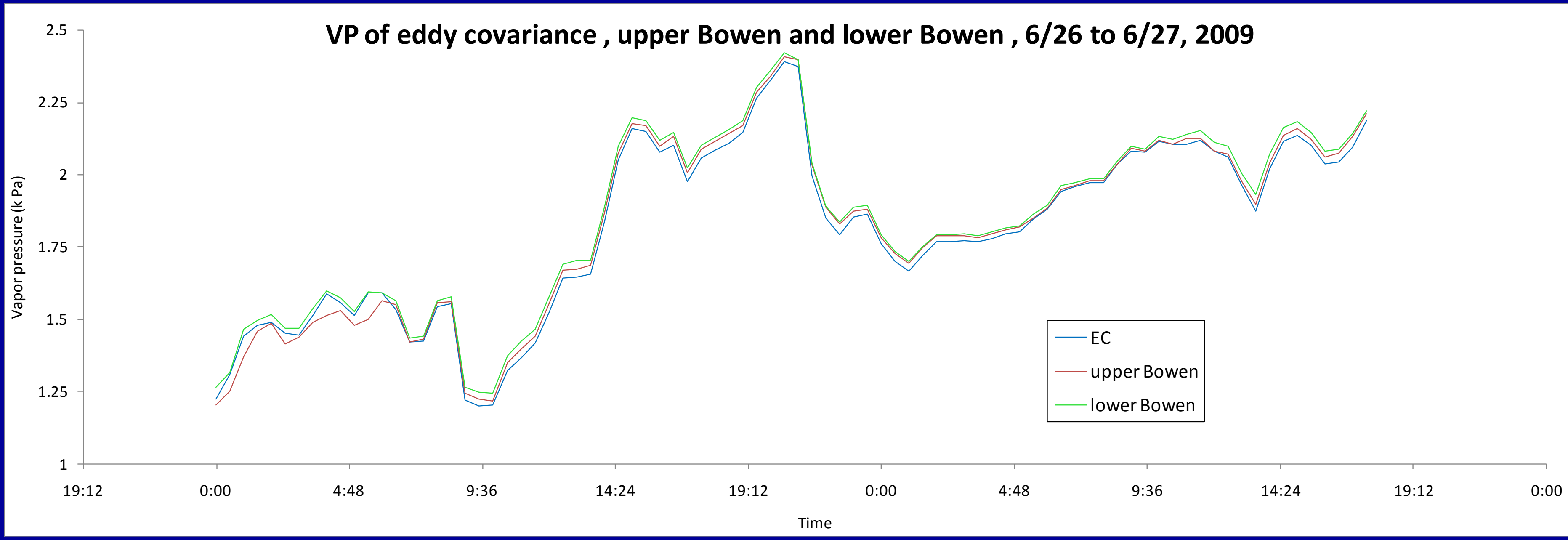
Small Scale

- Microlysimeters to measure soil evaporation, 20 cm diameter, over few hours or overnight. 10 or 20 freshly installed every few days
- Soil surface vapor pressure measurement device, 20 cm diameter, to estimate time of transition from Stage 1 to Stage 2 evaporation
- TDR at two spots to monitor soil water status at different depth every 20 min, to estimate soil E from the time course curves. Sphere of influence = few cm in diameter
- EnvironScan apacitance sensors at two spots to measure every 30 min, same purpose as TDR. Sphere of influence = approx. 15 cm



The temperature measured by the East and West CS Bowen units are in excellent agreement on 6/26 & 6/27. So temperature sensors were good

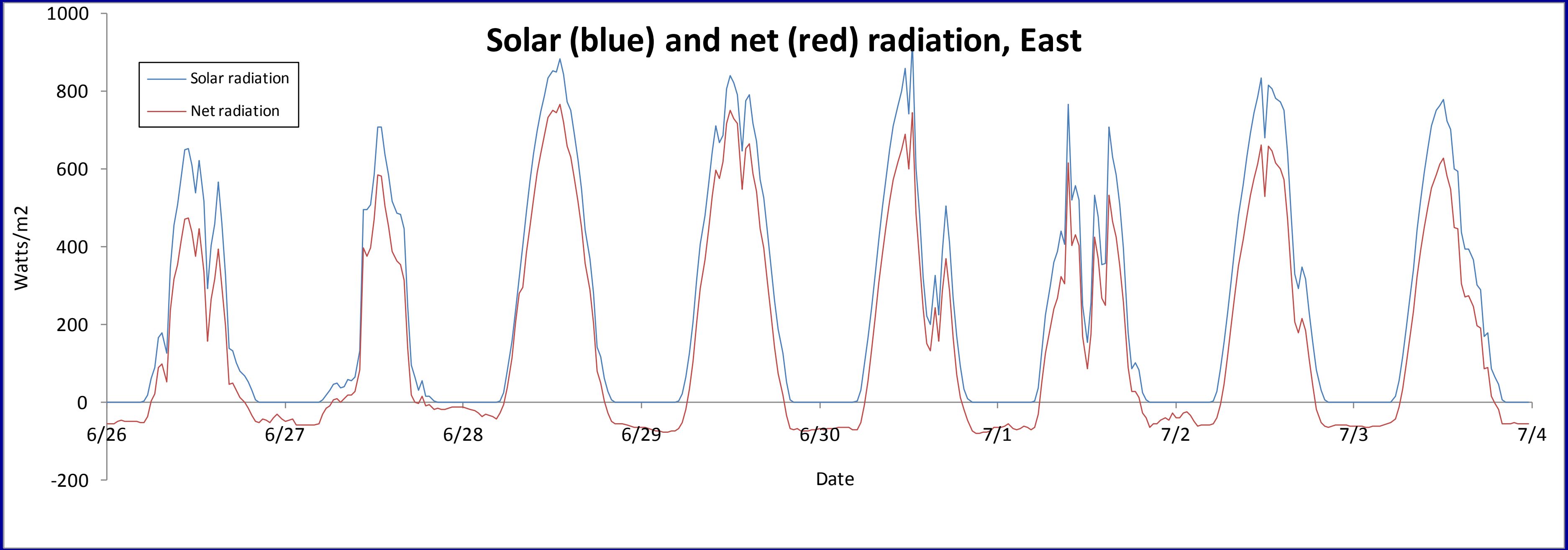
Note that temperature above the east and west fields were the same before the east field was irrigated in the evening of 6/27, but became lower for the east field immediately after due to evaporative cooling. The difference became less each day thereafter as the soil surface dried out



The coincidence of fluctuations in vapor pressure (VP) over the east field indicates the sensors were functioning well

The sensors in EC and Bowen were very different, by infrared absorption and by capacitance change, respectively; yet the data agreed well, although indicating some calibration problem between the EC and Bowen sensors

Note VP measured by the lower Bowen sensor is always higher than that by the upper sensor at day time, consistent with upward VP gradient for ET. But note this small difference is what the Bowen method depends on



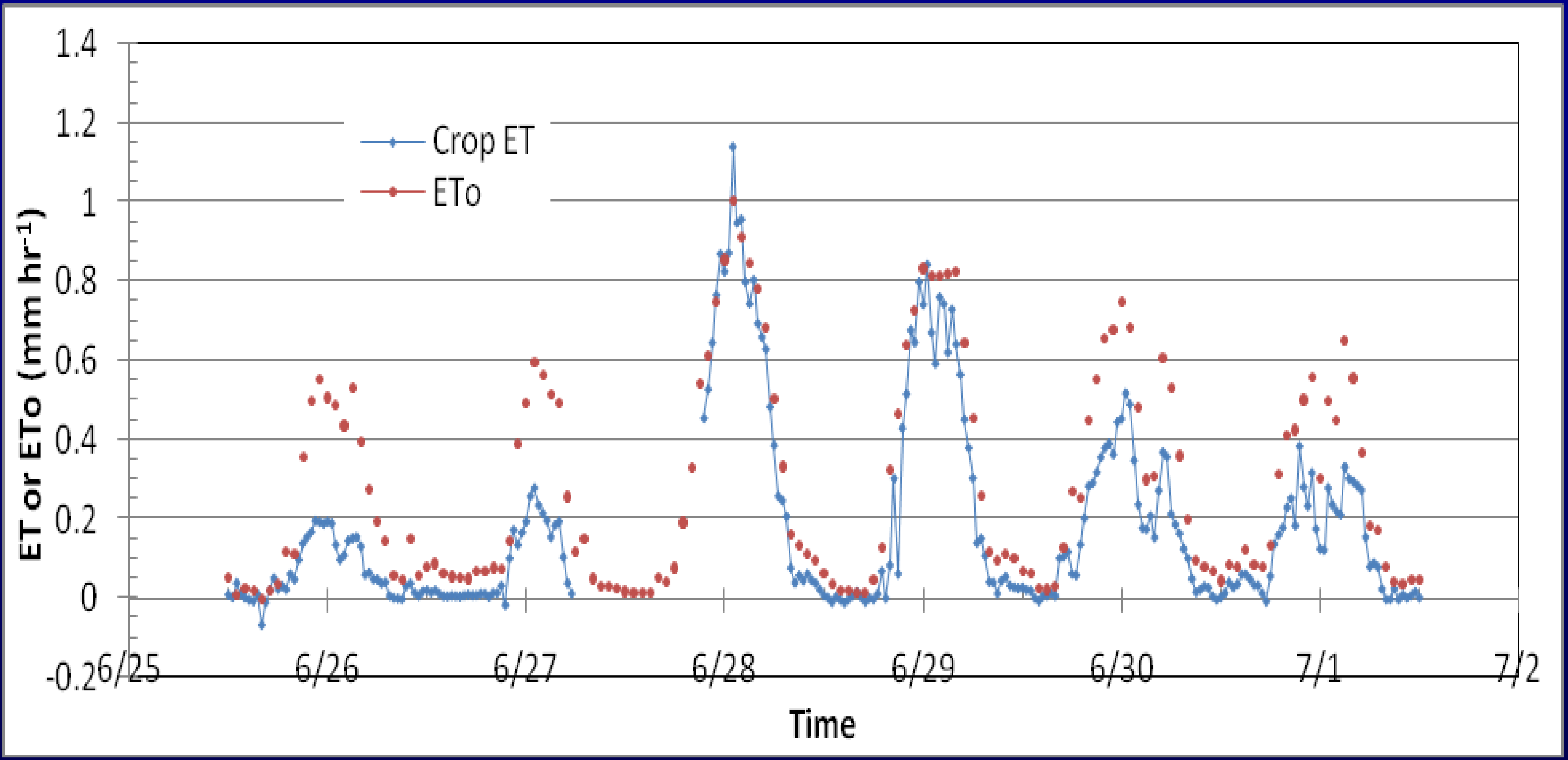
Coincidence of peaks and troughs indicate the solar and net radiometers were working

But the data raise questions about the calibrations, because R_n appears to be too high compared to $R_{s.}$ Either the solar was reading too low or the net was reading too high

Note that the ratio of R_n/R_s increased slightly after night irrigation on 6/27. Due to wetting of the soil, the surface became darker and reflected less solar radiation

China campaign data, ET by eddy covariance, coordinate rotated

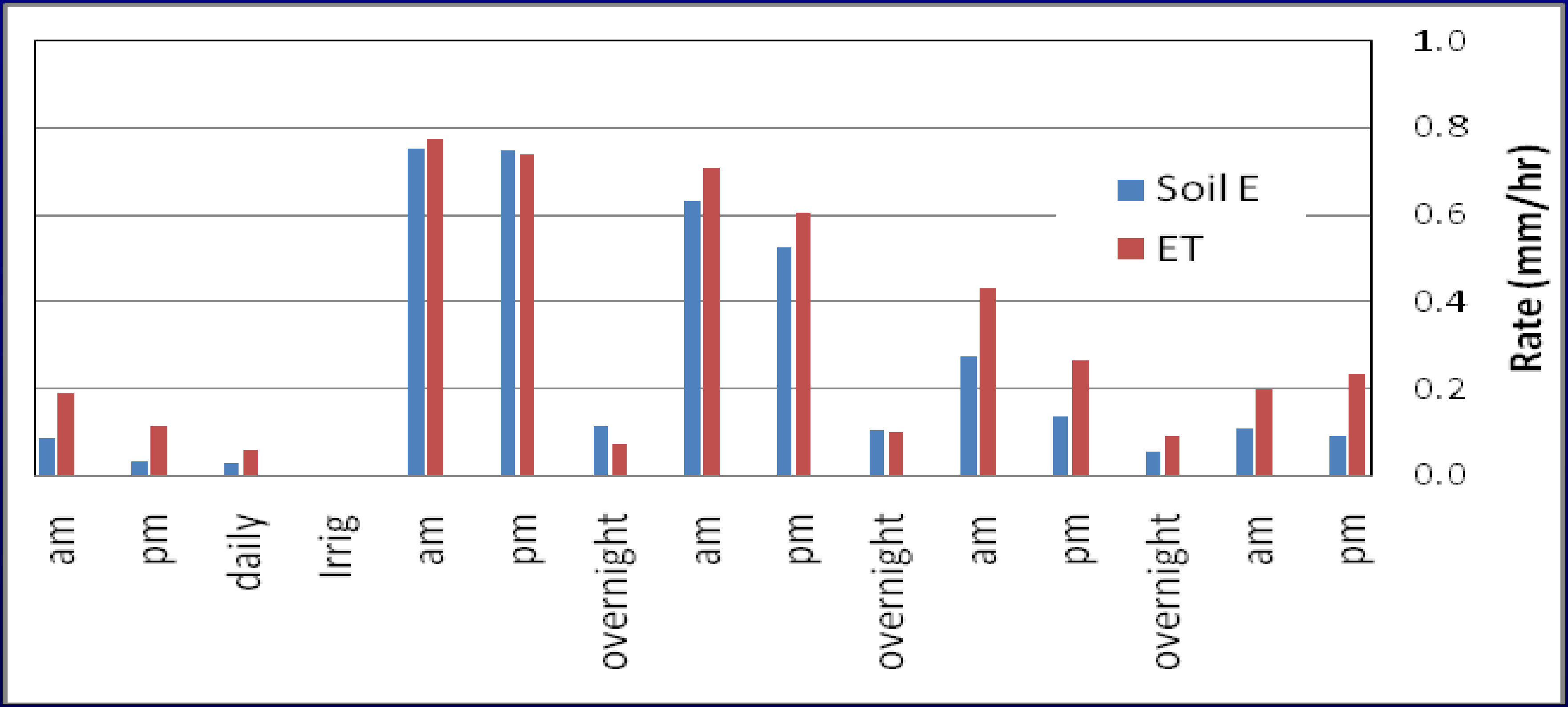
irrigation was in the night of 6/27



Note ET was slightly lower than ETo even right after the irrigation when soil surface was fully wet

Kc calculated was between 0.85 and 0.9 hour by hour on 6/28, suggesting measured ET was too low because Kc for wet soil or full crop canopy should be >1.0

Soil E measured by micro-lysimeters and crop ET summed over the same time intervals, from June 26 to July 1, 2009.



Without corrections, ET was lower than or equal to soil E the day after irrigation, an impossibility

Where are the uncertainties?

Eddy Covariance (EC)

- Well known for a lack of complete energy closure , i.e., underestimate ET by a small fraction (e.g., 8-15%)
- Complex technique, involving a number of assumptions and simplifications, which might not be justified under some conditions
- Must make several corrections (coordinate rotation and filtering out data spikes) with uncertainly in the corrections

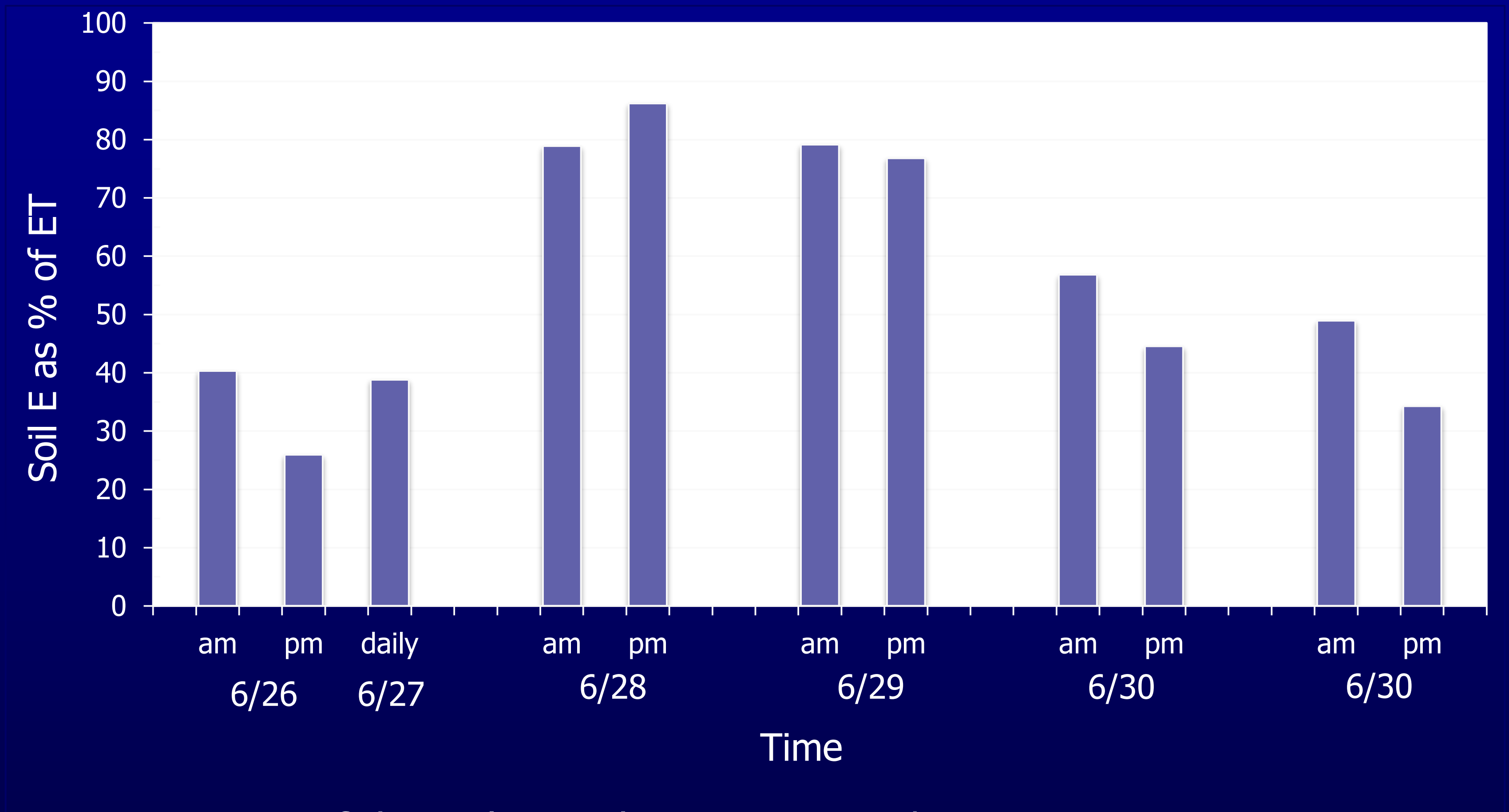
Where are the uncertainties?

Microlysimeters

- Depends **completely** on the moisture condition of the soil surface and adjacent layer below being representative of the soil outside the lysimeter
- Foot traffic around the lysimeter creates a condition different from that representing the field
- Cannot be used for long periods because soil in the lysimeter is hydraulically isolated from the field and roots are cut off. Must install new lysimeters every few days
- Problem of drainage loss after a heavy irrigation, leading to overestimate of soil E

Likely some drainage loss after the irrigation, because the microlysimeters were weighed only 3 hours afterward

After correction for microlysimeter drainage and ET underestimation by eddy covariance



Canopy cover of the soil was about 22% on 6/28

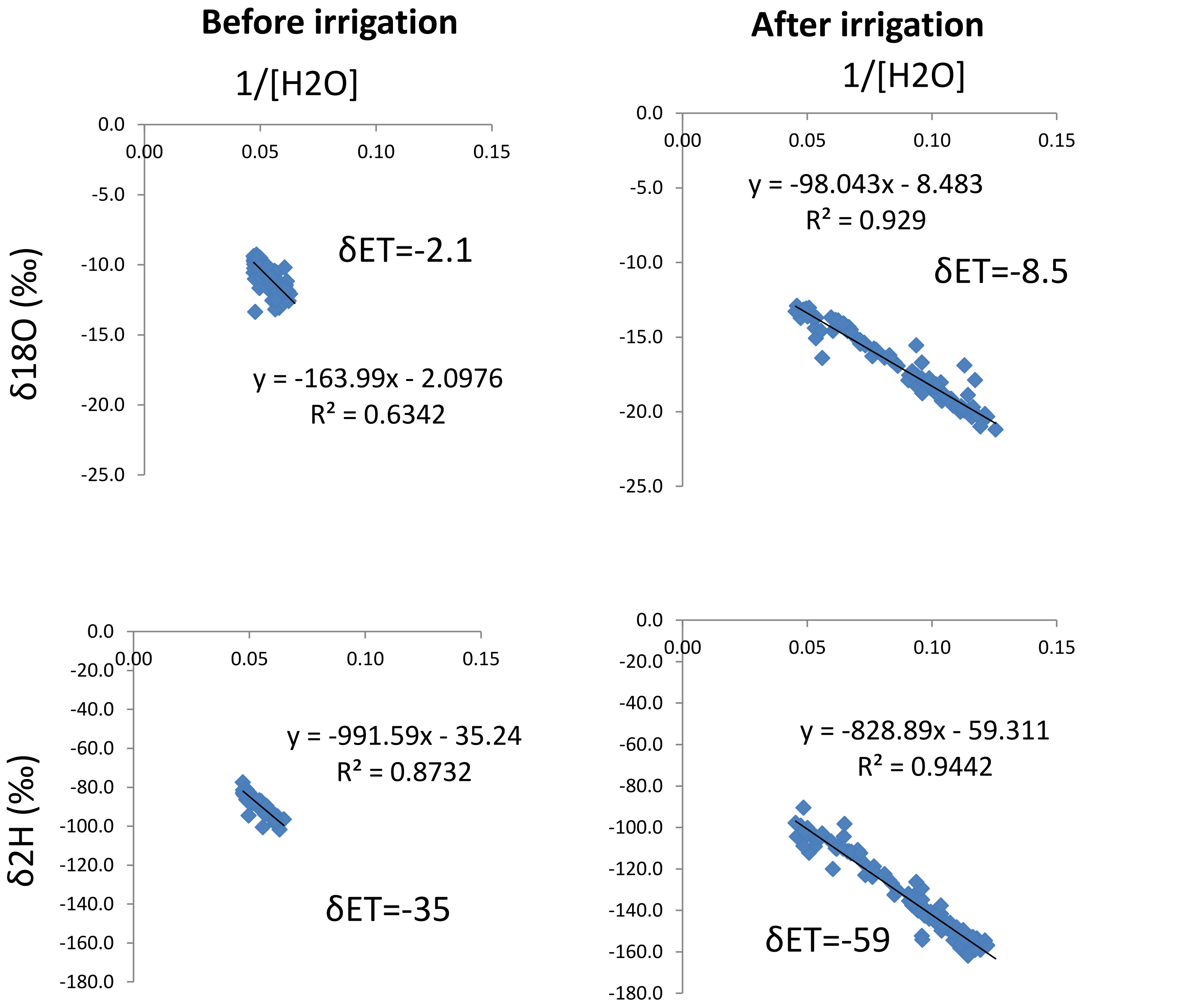
Expect soil E to be less in the afternoon than in the morning due to replenishment of surface moisture at night

Main challenge and experimental problem:

Combining or comparing methods at very different scales requires a very uniform field or the sampling of many points in the field to make the micro measurements representative

More micro measurements means more traffic will be in the field or many automated measurement units, parts of the field could be overly disturbed and the results not representative

Unfortunately, our field (2^{nd} planting, east) was less than uniform, particularly in plant distribution, introducing errors in all the micro measurements



Before irrigation
After irrigation
1/[H2O]
1/[H2O]
δ18O (‰)
δ2H (‰)
0.00
0.05
0.10
0.15
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
δET=-2.1
y = -163.99x - 2.0976
R² = 0.6342
y = -98.043x - 8.483
R² = 0.929
δET=-8.5
-20.0
-40.0
-60.0
-80.0
-100.0
-120.0
-140.0
-160.0
-180.0
y = -991.59x - 35.24
R² = 0.8732
δET=-35
y = -828.89x - 59.311
R² = 0.9442
δET=-59

Thank you!

Bowen ratio – combination of large, medium and small scales

- Temperature and humidity gradients in air – large scale
- Net radiation – medium small scale
- Soil heat flux – small scale

Campbell Scientific unit – single area of 0.3 x 1 m, with sensors at 2 spots

Hsiao's home made unit – 6 spots of 3 cm diameter each, distributed over tens of square meters