# Problems associated with measuring in cloud temperatures

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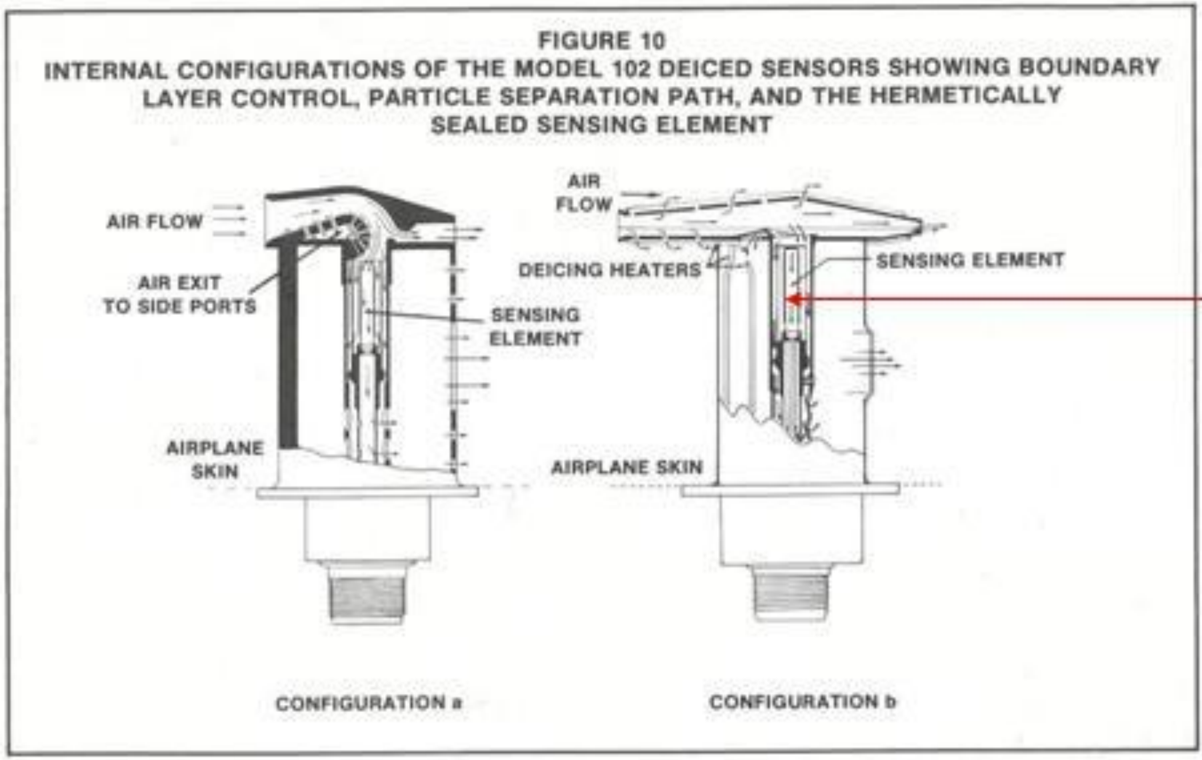
# RICO: Cloud dynamical and thermodynamical measurements

- One key aim of RICO is to validate relationships between mean properties of updraughts and the environment in trade wind cumulus (e.g. updraught velocity and air parcel buoyancy).
- These provide the basis of the parameterization of convective transport in so-called "mass-flux" schemes.
- Up to now the parameterizations have been derived principally from LES model simulations.
- Direct measurements of vertical air velocity and temperature in the cloud updraught and environment are required.

# Rosemount sensors on the 146

- Air is decelerated on entering the instrument.
- Not all kinetic energy is converted into internal energy of air (some is lost)
- Recovery factor to account for this, and measure true air temperature

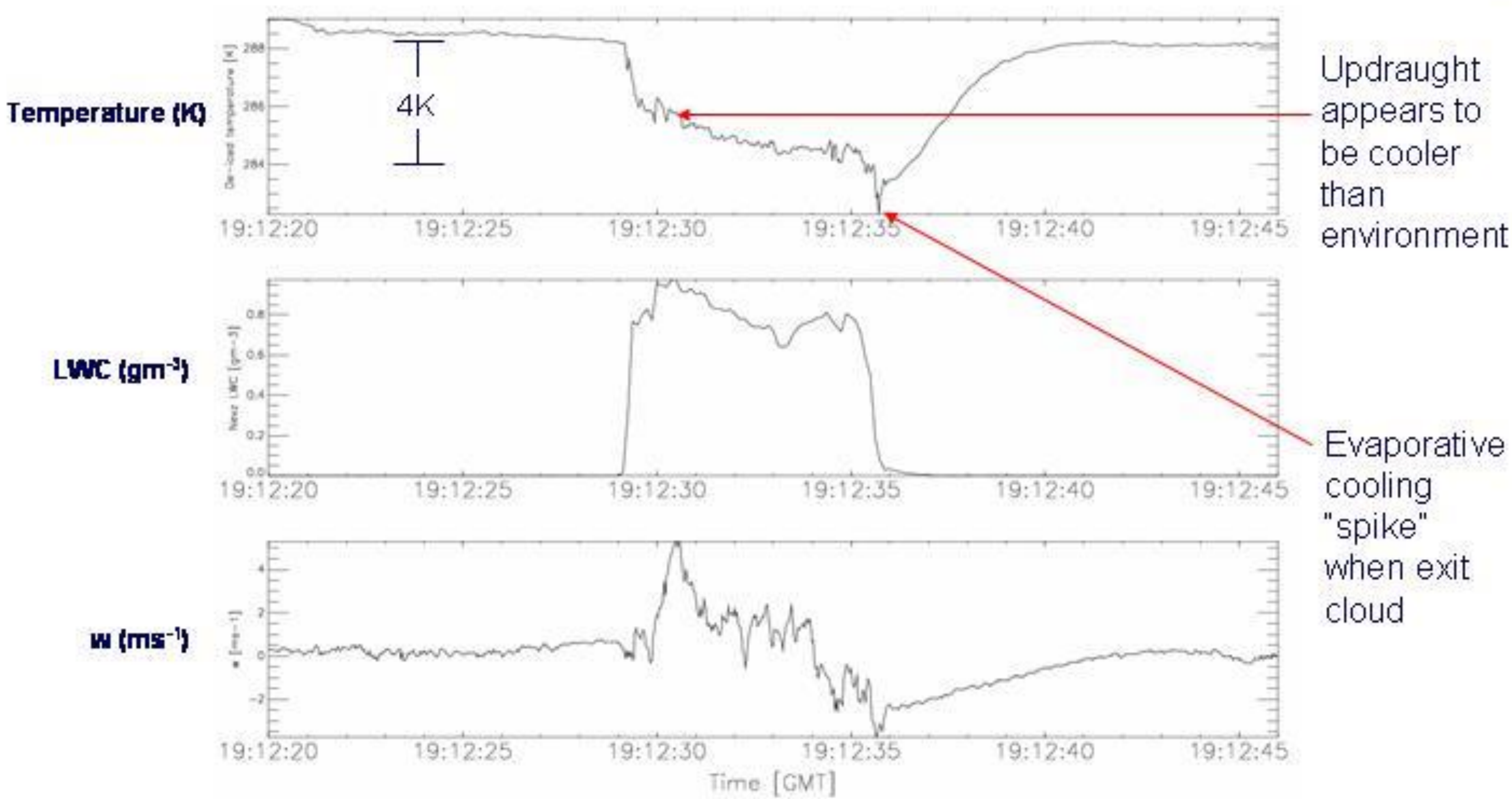



Sensing element is at right angles to the air flow to achieve inertial separation from solid particles and water droplets.

However, sensing element has been shown to become wet in clouds!!

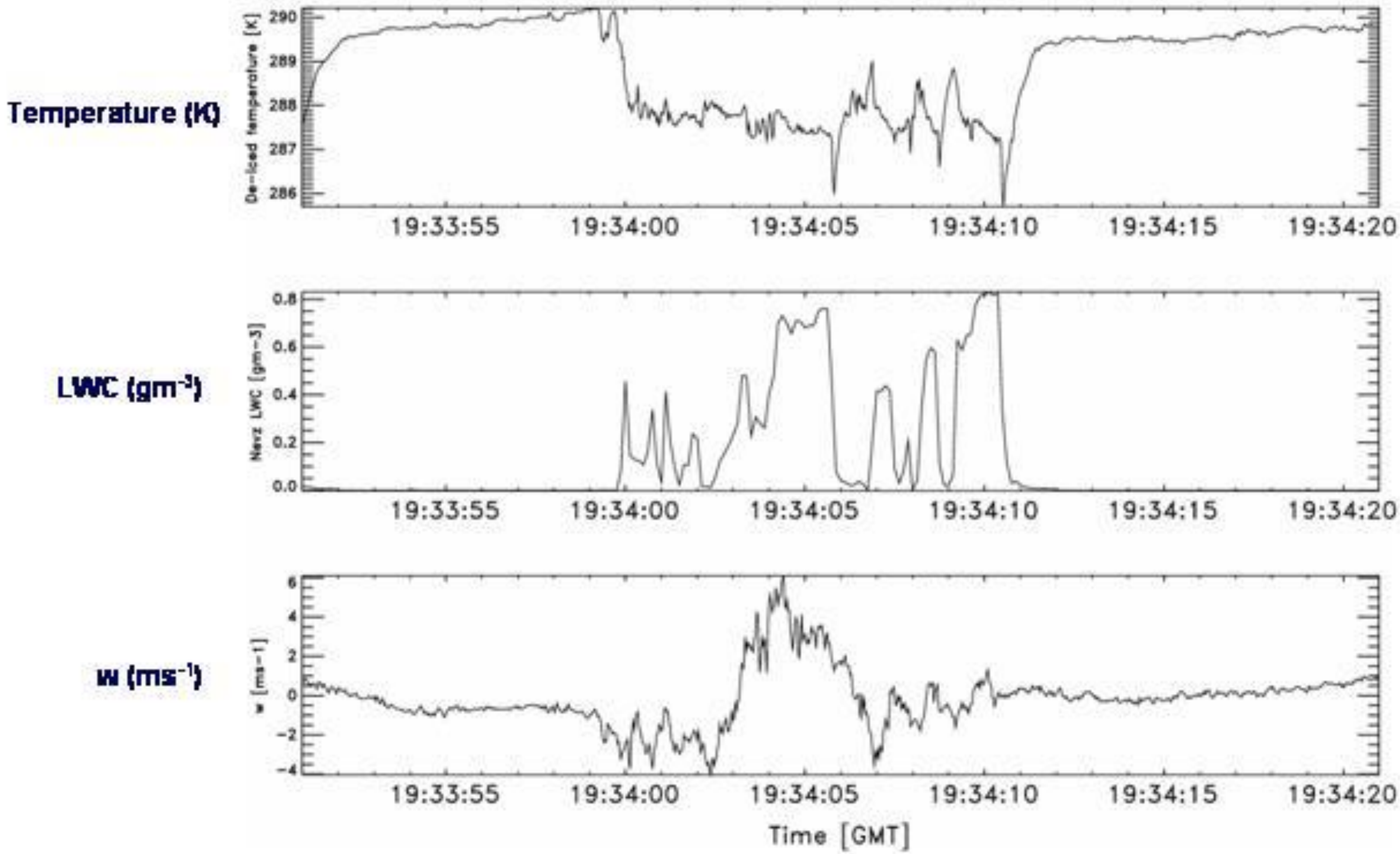
**SENSOR WETTING: Cloudy air reaching sensor is subsaturated and any droplets will evaporate → COOLING effect that is not corrected.**

# In cloud temperature measurement problems: Example 1

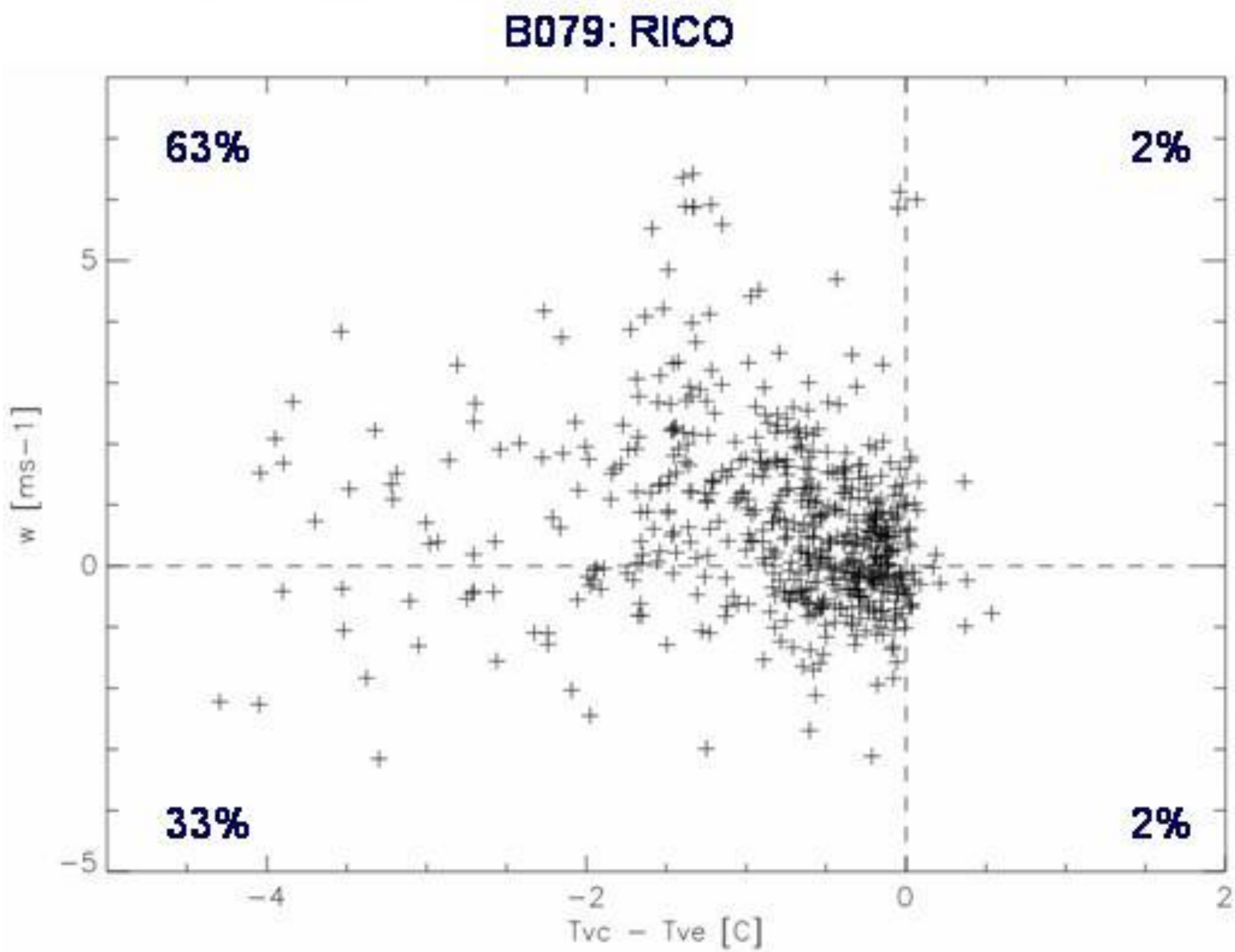



Gradual cooling in cloud may arise as sensing element becomes more wetted

# In cloud temperature measurement problems: Example 2



# Vertical velocity (w) vs buoyancy (Tvc-Tve)




Accurate in cloud temperature measurements are required to determine buoyancy (x axis).

# Radiometric temperature measurements

- ICTP (SNOOPY) and OPHIR (NCAR C-130) radiometers use the 4.3 µm $CO_2$ absorption band.
- Temperature of the emitting volume can be determined from the spectral radiance through Plank's law.

$$Tair = \frac{hc}{\lambda k \ln\left(\frac{(2hc^2)}{P(\lambda, Tair)\lambda^5} + 1\right)}$$

- At 500 mbar in clear air 90% of the signal comes from within 10m of the aircraft.
- Not susceptible to sensor wetting effects.

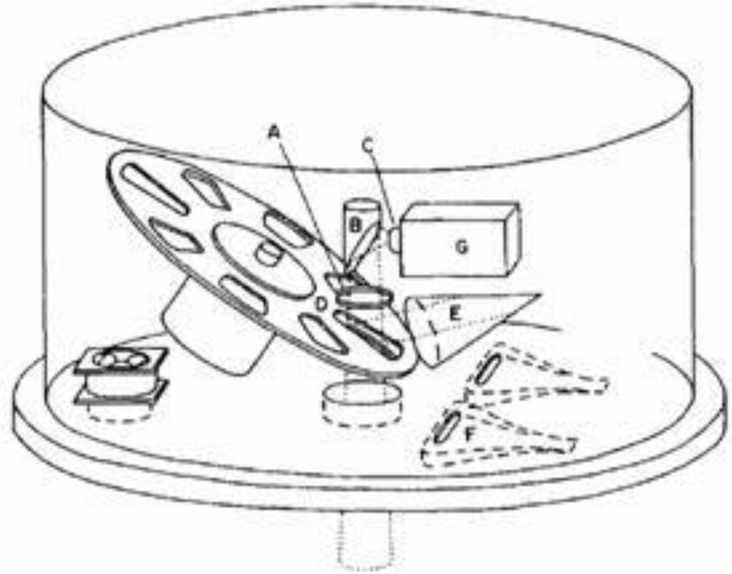


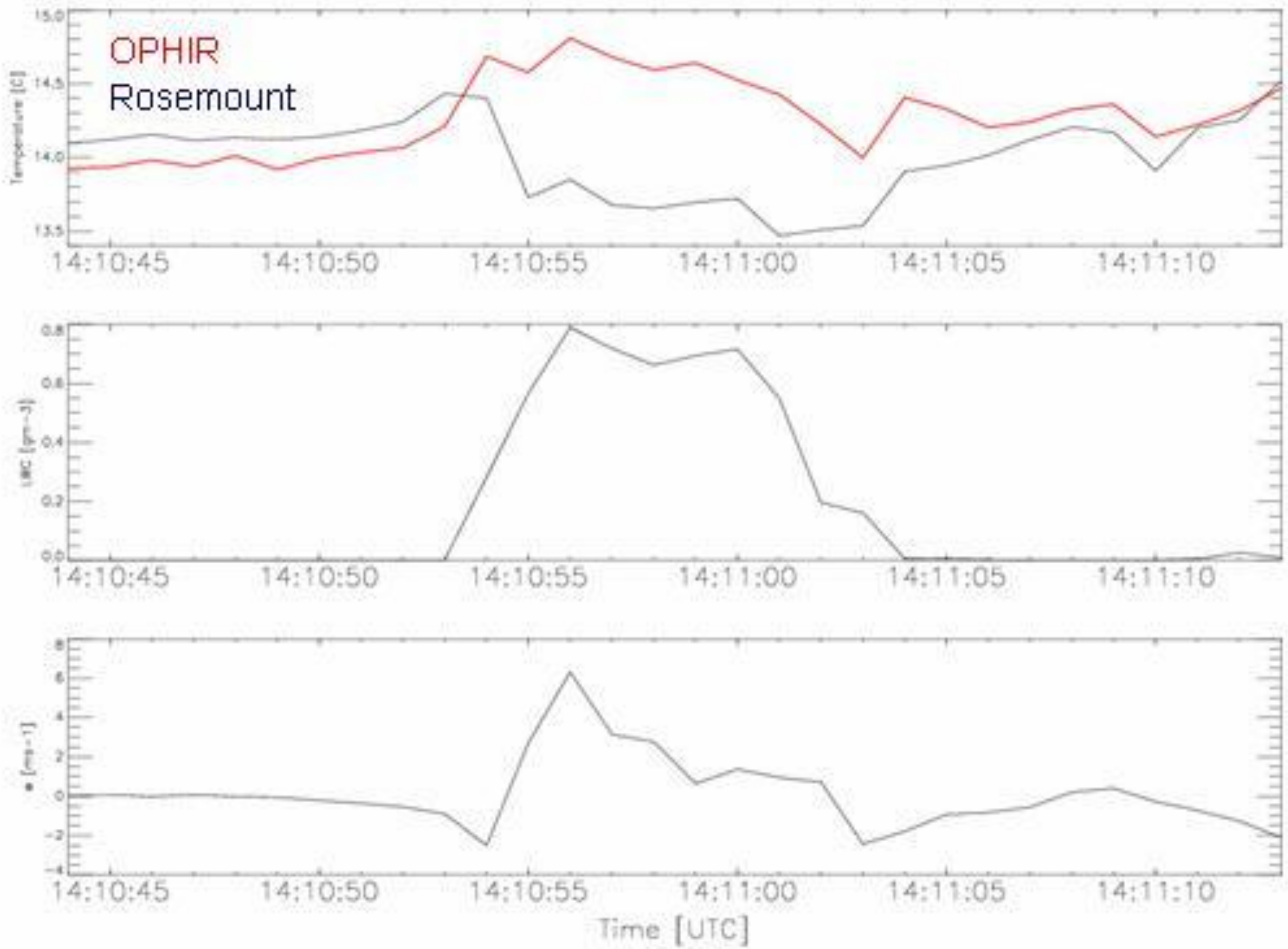

FIG. 2. Principal components of the Ophir radiometric thermometer: (A) interference filter; (B) parabolic mirror; (C) lead selenide detector; (D) mirrored chopper wheel; (E) black-body reference cone; (F) ventilation ports; (G) heat sink and thermoelectric cooler.

# OPHIR vs Rosemount temperature example from RICO

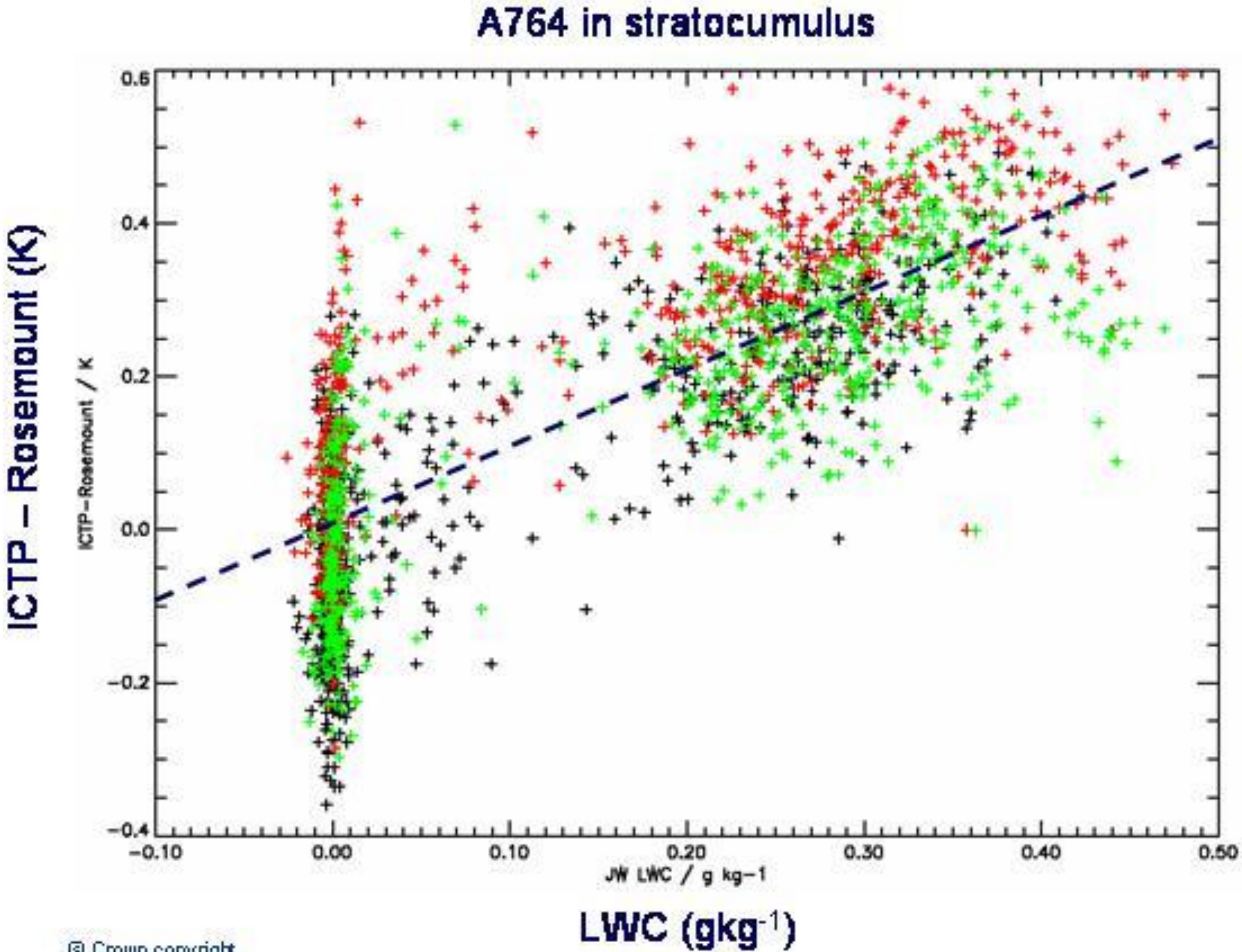
Temperature (K)

LWC (gm$^{-3}$)

w (ms$^{-1}$)



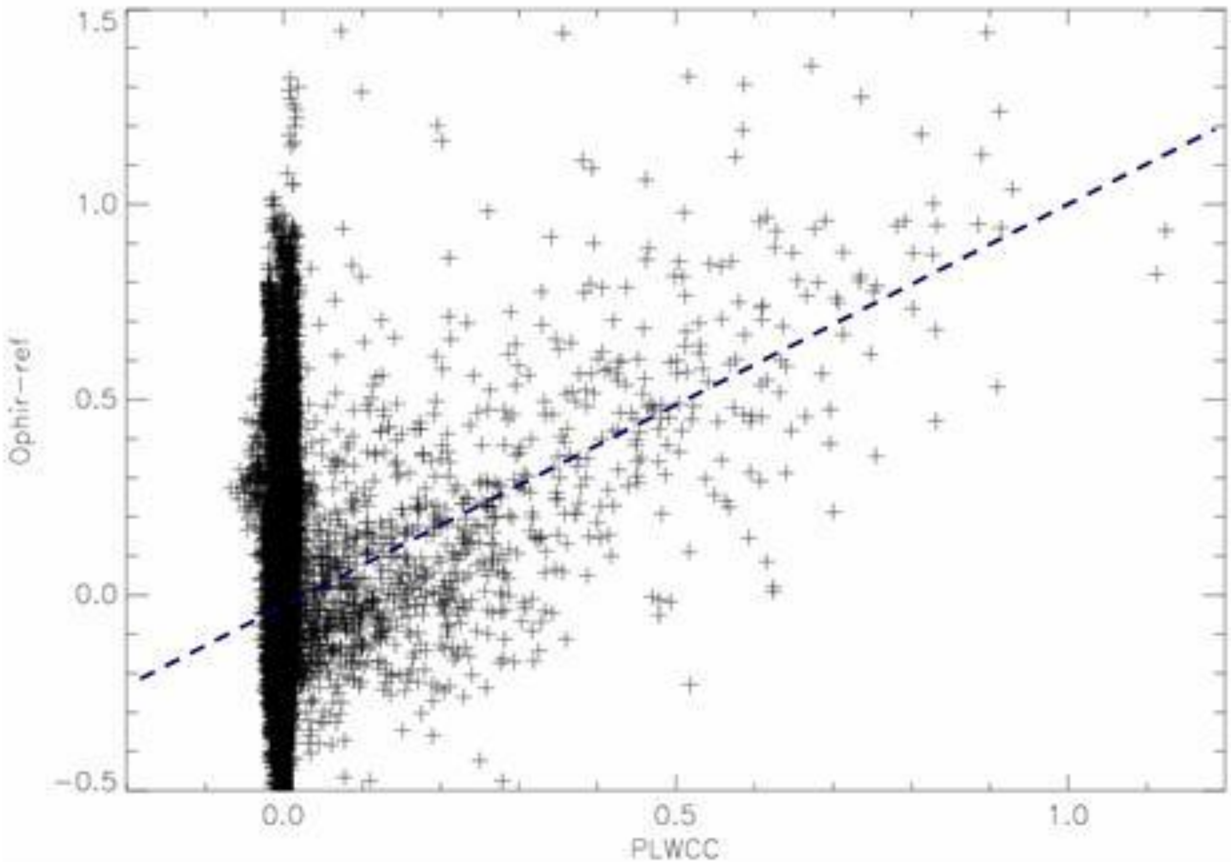
# Comparison of Rosemount and ICTP temperature measurements




Approximate 1:1 correlation although there is a lot of scatter!!!

# Comparison of Rosemount and OPHIR temperature measurements

**Flight RF18 (RICO)**



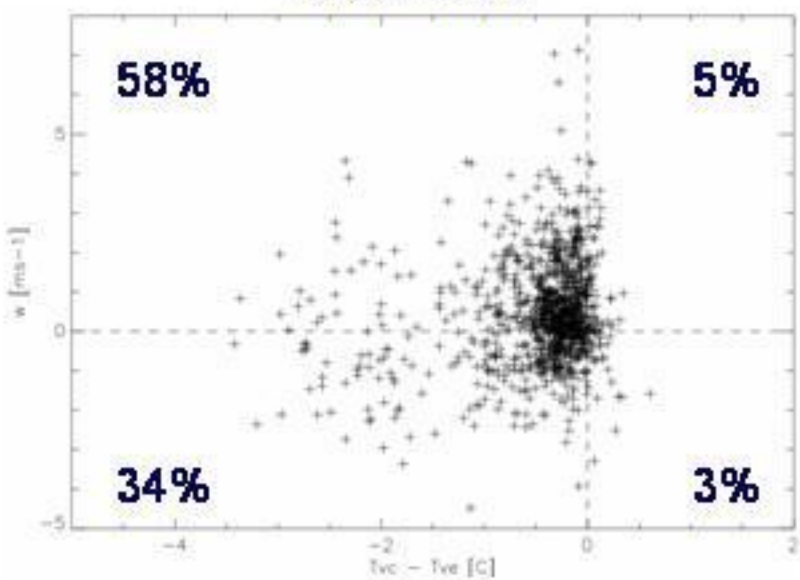

Again an approximate 1:1 correlation although there is a lot of scatter!!!

**Some of the scatter may be when aircraft is banked or because instruments not co-located e.t.c.**

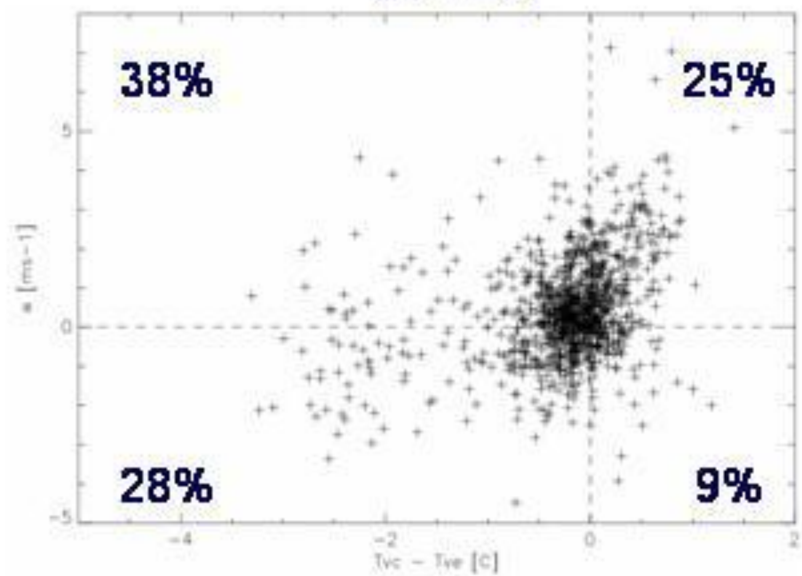
# Vertical velocity vs buoyancy from the NCAR C-130

## Flight RF18 (RICO)

### Rosemount



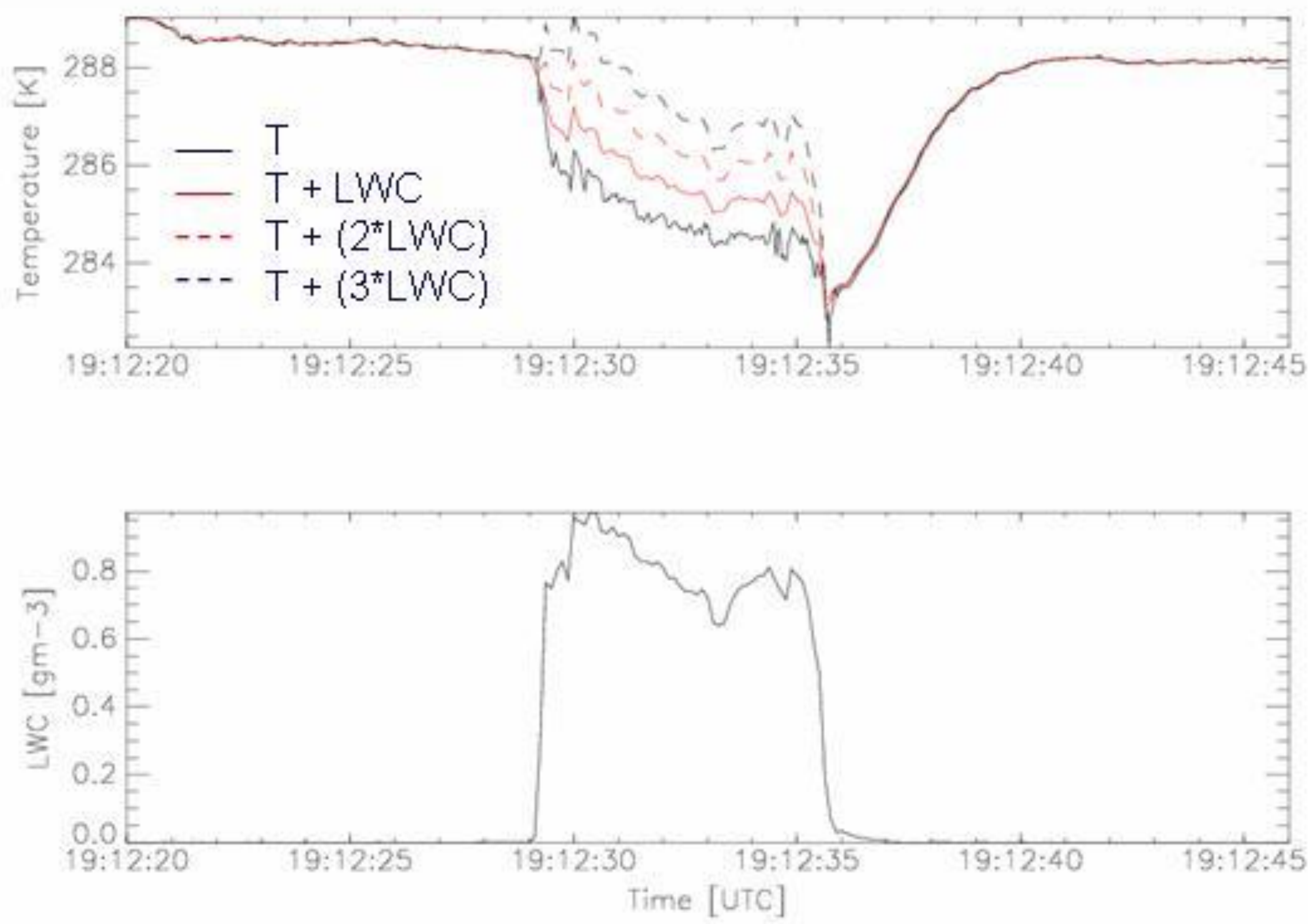

### OPHIR




**Similar to the 146 data**

**More positively buoyant parcels in updraughts**

# Can we adjust the 146 in cloud Rosemount temperature measurements from RICO?



# Conclusions

- Rosemount temperatures on the 146 are subject to sensor wetting effects in cloud.
- Radiometric temperatures provide a solution to this problem. Resurrect the ICTP probe for the 146?
- No simple correction to the Rosemount data.
- Not possible to calculate buoyancy strength in updraughts using the 146 data from RICO, although the OPHIR data from the NCAR C-130 is available.

# Questions & Answers