Household Water Cycle - Psychrometrics and Electronics in a Dunedin Suburb

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Introduction This study looked at detailed time series of home temperatures and humidity. Our objective is to get a sense of home heating and moisture patterns (White 2017). Last winter, we placed sensors in one room of 16 houses in North East Valley, Dunedin, for three months. Also examined were three model "houses", set up by school students. These were subject to sunlight and ventilation. Arduino compatible sensors captured measurements every minute. We taught to school children the science of moist air - psychrometrics - and learned about the moisture cycle of evaporation and condensation, and the storage of water in building materials and furnishings.

Methods

- **Study Houses** We selected 16 North East Valley, Dunedin, houses of a variety of ages, conditions, and living patterns. In 13 of those houses we placed a temperature and humidity sensor in the main occupied room of the house (Typically a lounge, open plan lounge and kitchen, or, in one case, an office). The sensor was placed on a convenient surface roughly 1m above the floor. A questionnaire and house visit collected basic characteristics about the house. Local weather stations provided the external environmental conditions.
- **Model Houses** Three ice cream container house models were constructed and placed in an intermediate school classroom. They were placed side-by-side in the sun - to simulate the environmental influences on a home. One sensor was inside each model, and a fourth monitored the classroom temperature:

  MODELDRY - sensor, sponge, plastic wrap window

  MODELWET - sensor, sponge, 5ml water, plastic wrap window

  MODELWETVENT - sensor, sponge, 5ml water, plastic wrap window, "chimney" vent.

  MODELEXTERNAL - sensor, classroom temperature, "outside" of the three models.
- **Model House Experiments** With students, we compared the temperature and humidity in each of three model houses. On most school days the students printed the last 48 hours of measurements and placed them in a notebook. We weighed the model house weekly to estimate sponge moisture content. Model houses were adjusted after several weeks by adding bubble-wrap insulation. During school visits, we discussed the effects of the damp sponge on humidity, and the effects of sunny or cloudy days on each of the model houses.
- **Sensors** Twenty were constructed with the help of the Dunedin Makerspace and two high school students. They were Arduino compatible WeMos ESP8266 Wifi-connected DHT22 compatible temperature and humidity sensors. Measurements sent via HTTPS to sqllite db on a web server. R was used for analysis and display (ggplot2, dygraphs).

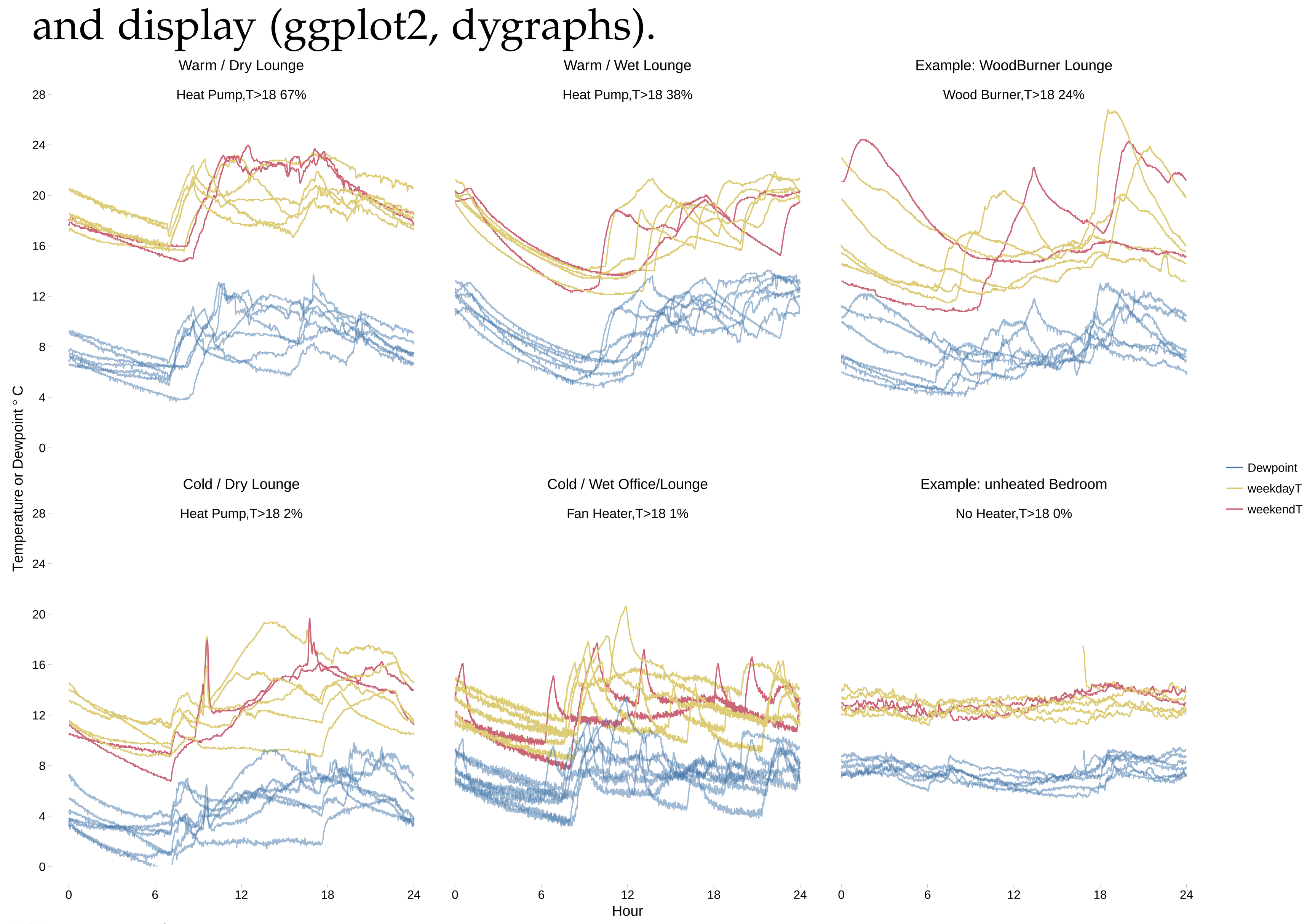
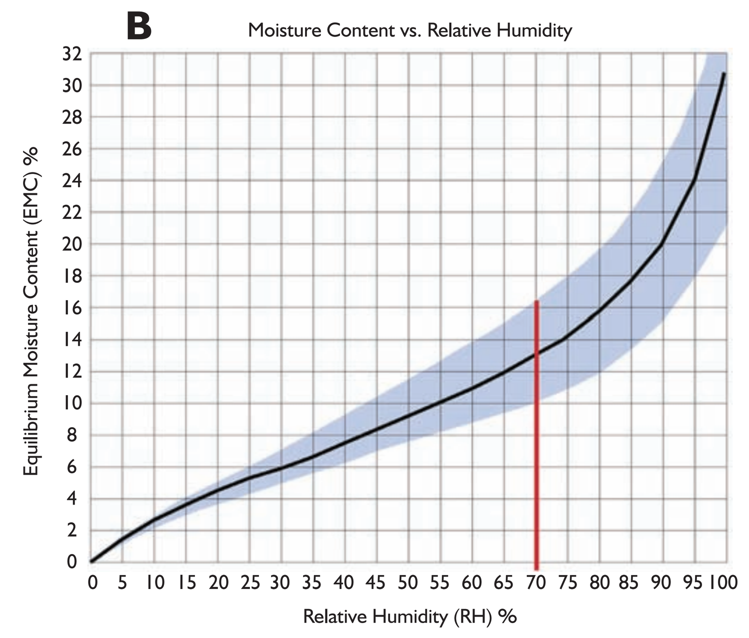
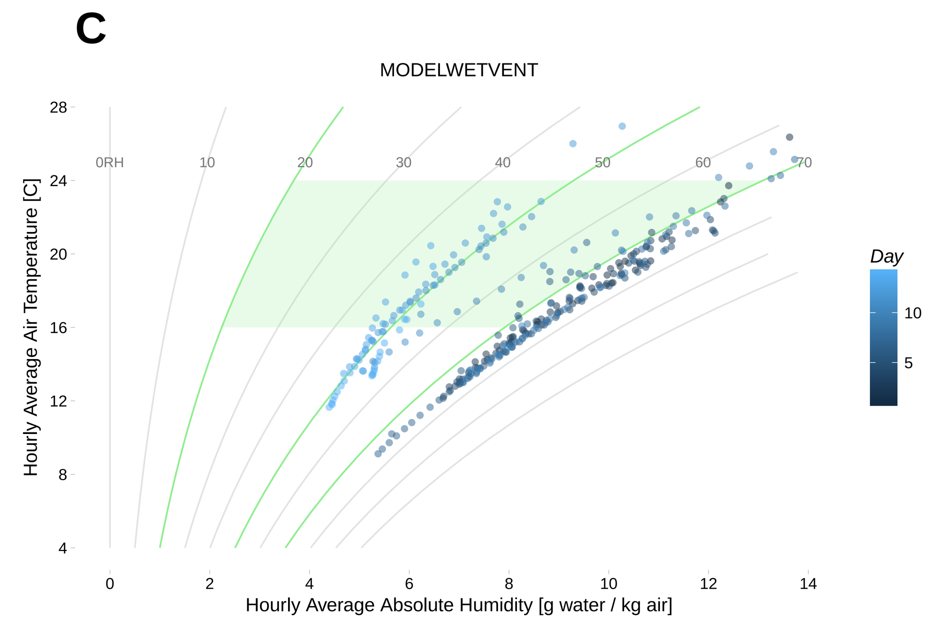


Figure A Six of the study houses. Air and dewpoint temperature for each day of the week of 2016-08-22. Higher dewpoint is more damp. Also shown is the heating appliance and the percent of the time that room temperature was above 18°C.





Results

Study Houses In a chart of daily temperature and dewpoint vs hours of the day (Figure A), houses seem to remain at different average levels of dampness while exhibiting different heating patterns. Shown are four selected rooms from our study, cold and wet, cold and dry, warm and wet, warm and dry.

We think room humidity might be stabilised by being in equilibrium with the water content of building materials and furnishings, or by condensing/evaporating from cold/warm surfaces. This finding was first suggested by the vented model house created for the school classroom. A typical sorption curve (Pine) shows the relationship between moisture in materials and air moisture (isothermic) (Figure B) (Lstiburek 2008).

Model Houses In the vented model house hourly humidity vs temperature chart (Figure C), humidity remained high for the first 9 days while sponge slowly dried (right, darker cluster). On day 10, when the sponge was nearly dry, humidity abruptly decreased over 15 hours (one hour per dot), until sponge was dry and humidity remained low (left, light-blue cluster, RH≈50).

Classroom Working with school students inspired us to create three simple model houses that clarified our understanding of the physical processes while helping to teach the students.

Sensors required calibration to meet claimed manufactured accuracy. With temperature, we observed sensor self-heating (average 1.2°C, 250mW). Relative humidity was very inaccurate (±20%) until calibrated (±5%).

Conclusions

- **Ventilation**: If you take a cold and damp house, and add insulation and/or block draughts, you get a warm and damp house. You need to also add ventilation to get a dry house. (windows/dehumidifier/ventilation system)
- **Moisture Content**: There is a lot of moisture stored in building materials and furnishings. That moisture content stabilises the air moisture to a certain level, that varies house by house.
- **Open Windows** frequently when it is sunny out to dry your house.

References

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2. Lstiburek, J. W. (2008) "Psychrometric Chart & Wood Sorption Curve", ASHRAE Journal, Vol. 50, p. 70, May 2008

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About the Author Tim Bishop is an engineer and project manager. He trained in energy and building physics at the University of Otago, and electrical and computer engineering at Brown University. Tim's research and practical interests are in how the design of the New Zealand built environment can be progressed to reduce the total energy resources and greenhouse gas emissions that are required to support a good quality of life, as perceived by New Zealanders.