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Novel method for water vapour monitoring using wireless communication networks measurements

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1 Background

We propose a new technique for monitoring near-surface water vapour, by estimating humidity from data collected through existing wireless communication networks.

Weather conditions and atmospheric phenomena affect the electromagnetic channel, causing attenuations to the radio signal (Figure 1).

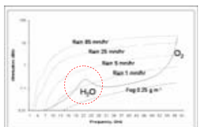


Figure 1: Transmission losses due to atmospheric conditions.
Dashed lines represent attenuation for different rain intensities and fog, while the full line represents attenuation due to the primary gases of water vapour and oxygen. The water vapour absorption line is marked in red.

Of the various wireless communication systems, we focus on the microwave point-to-point links (Figure 2) which are used for backhaul communication in cellular networks, as they seem to have the most suitable properties for our purposes:

- Fixed, Line-Of-Sight
- Built close to the ground
- Operate at frequencies of tens GHz
- Operate 24 hours a day with no supervision and additional cost
- Commercial microwave communication networks are widespread over the world

Figure 2: microwave point-to-point static links

2 The idea: high resolution, low cost water vapour monitoring

- In wireless communication, the Received Signal Level (RSL) depends on the water vapour density found along the propagation path.
- In many wireless communication systems power control is used, so RSL is measured and recorded.
- Wireless communication is everywhere, and huge amount of data is available.

⇒ **Measurements from wireless networks can be used for water vapour monitoring**

3 The method

Backhaul links in cellular networks often operate around frequencies of 22 to 23 GHz, we focus on the 22.235 GHz absorbing line to monitor the water vapour.

The specific attenuation γ [dB/km] due to dry air and water vapour, at centimeter wavelengths, is well studied and can be evaluated (Recommendation ITU-R P.676-6, 2005) using the following procedure:

(1) $$\gamma = A_W + A_0 \quad [dB/km]$$

(2) $$\gamma = 0.1820 f N'' \quad [dB/km]$$

A_w: The specific attenuation due to water vapour [dB/km].

A_o: The specific attenuation due to dry air [dB/km] (Assuming the air is moist, A_o is one order of magnitude lower than A_w since at frequencies of ~22 GHz, the attenuation is caused predominantly by the water vapour).

f: The link's frequency [GHz].

$N''= N''(p,T,\rho,f)$: The imaginary part of the complex refractivity measured in N units, a function of the pressure p [hPa], temperature T [°C] and the water vapour density ρ [g/m³].

- Given measurements of the Received Signal Level (RSL), γ can be derived based on the microwave link's measurements.
- Consequently, given the atmospheric temperature, pressure and the link's frequency, the water vapour density ρ [g/m3] is estimated numerically through Eq. (2), using the known relation between N'' and ρ.

4 Results

Moisture observations using microwave links were made in several different locations in Israel, and at several different times.

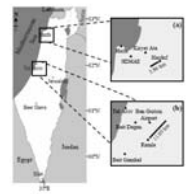
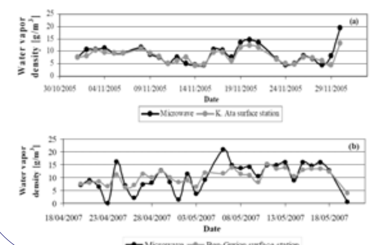


Figure 3: The examined regions.
(a) The microwave link (3.86 km long, marked as a line) in front of Kiryat Ata (where the humidity gauge is located), Haifa bay. The distance from the surface station to a point located in the middle of the wireless link is 7.5 km. The surface station is situated 45 m ASL, while the microwave transmitter and receiver are located on two hills: 265 and 233 m ASL.
(b) The microwave link (11.05 km) in front of Ben-Gurion airport (humidity gauge's location), central Israel. The distance from the surface station to a point located in the middle of the link is 5 km. The airport surface station is situated at 41 m ASL, while the link's transmitter and receiver are located at heights of 116 and 98 m ASL.

Figure 4 presents results for inter-daily variations in the absolute moisture which were calculated using data obtained from the wireless communication network, as compared to in-situ measurements, over a month. The system from which the data were collected captures a single signal every 24 hours at 03:00 a.m. The surface station observations used were taken from the vicinity of the link's area at the same hour.

Figure 4: The water vapour density ρ [g/m³] as estimated using RSL measurements from the microwave link data (dark) vs. conventional humidity gauge data (bright). The measurements were taken once a day at 03:00 a.m.



(a) Northern Israel - The observations were made during the month of November 2005, where 2 rainy days were excluded (7 and 22 November). The rainfall data were taken from two different surface stations situated in the Haifa District Municipal Association for the Environment (HDMAE) and in Kiryat Ata, about 12.5 km and 7 km, respectively, from Harduf (see Fig. 3a). The link's frequency is 22.725 GHz. The calculated correlation between the two curves is 0.9.

(b) Central Israel - The measurements were taken between 20 April and 20 May 2007, excluding 2 days when showers occurred (5 and 19 May). The precipitation data were taken from Beit Gamliel surface station which is located about 13 km from Ramla (see Fig. 3b). The link's frequency is 21.325 GHz and the calculated correlation between the time series is 0.82.

5 Summary

- As we aim to prove visibility, at this stage, the technique is restricted to weather conditions which exclude rain, fog or clouds along the propagation path. Strong winds that may cause movement of the link transmitter or receiver (or both) may also interfere with the ability to conduct accurate measurements.
- Since measurements from the microwave link are line integrated data, where in-situ measurements are point measurements in a humidity gauge, some disparities are expected. The difference in location between the measurement sites introduces additional disparities between the microwave measurements and those made by the conventional humidity gauges.
- Current atmospheric observation systems include predominantly: humidity gauges, radiosondes and satellites. Humidity gauges supply only point measurements, balloons – being launched only 2-4 times a day - also provide only limited information. Satellites are frequently not accurate enough at surface levels. The proposed novel method overcomes these obstacles.
- Our method enables measurements in places that have been hard to measure in the past, or have never been measured before since many of these links are installed in areas where access is difficult such as orographic terrain and complex topography.
- The wireless measurement technique can thus either replace existing techniques or preferably be used in conjunction with them in order to obtain more accurate moisture fields.
- Given the newly available data provided by the wireless communication facilities, improved initialization of atmospheric models can be achieved, thus enhancing prediction and hazards warning skills as well as providing a better understanding of the global climate system.

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