Supporting Online Material for

Environmental Monitoring by Wireless Communication Networks

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Materials and Methods
Table S1
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Other Supporting Online Material for this manuscript includes the following:
(available at www.sciencemag.org/cgi/content/full/312/5774/713/DC1)

Movie S1
Materials and methods

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A cellular network control centre routinely registers records of minimum ($RSL_{\text{min}}$) and maximum ($RSL_{\text{max}}$) received signal levels of microwave cellular links through fixed time intervals (here 15 min). The average values $\overline{RSL}_{\text{min}}$, $\overline{RSL}_{\text{max}}$ are estimated during the non-interrupted time frames, and the rain-induced attenuations $A_{\text{max}}$ and $A_{\text{min}}$ are estimated as a difference between the minimum and maximum RSL and their respective non-interrupted average values. The maximal and minimal rainfall intensities $R_{\text{max}}$ and $R_{\text{min}}$ are obtained from $A_{\text{max}}$ and $A_{\text{min}}$ according to the power law model $A(db/km) = aR^b$, parameterized by ITU models (4,7).

We interpreted them according to the long-term statistics of average annual rainfall intensities – probability of rainfall rate $Pr(r)$ given a specific geographic location (3). Then, the unbiased estimate of the average rainfall rate, measured by a link during a time interval, is derived by:

$$r_{av} = E(r \mid R_{\text{min}}, R_{\text{max}}) = \frac{1}{\int_{R_{\text{min}}}^{R_{\text{max}}} \int_{R_{\text{min}}}^{R_{\text{max}}} \Pr(r)dr} \int_{R_{\text{min}}}^{R_{\text{max}}} r \cdot \Pr(r)dr$$

Simultaneous observation of large amount of radio links on any territory covered by a cellular network allows the creation of rainfall maps, reflecting the true rainfall distribution near the surface at the measured time interval.

In order to deduce the spatial patterns of rainfall, tomographic methods were employed. The whole region is divided into small cells, where the rainfall intensity is assumed to be constant. Then, tomographic reconstruction of rainfall maps is done using the Simultaneous Iterative Reconstruction Technique (SIRT) (8), regularized by a smoothness constraint (neighbour correlation) and a feasibility constraint (non-negativeness), imposed at every SIRT iteration. The reconstructed cell size for the cellular DFRS maps is 5.2 $\times$ 5.2 km.

The Movie S1 illustrates the feasibility of the reconstruction of rainfall intensity maps, calculated from the cellular DFRS links. Rainfall intensity distributions are reconstructed from 7 cellular DFRS links, for which measurements were available at that time. The links (denoted as $\Delta$... $\Delta$ in the movie) have lengths of 1-17 km and operate at frequencies 8-23 GHz, both vertically and horizontally polarized (Table 1). $RSL_{\text{min}}$ and $RSL_{\text{max}}$ are measured with the resolution of 1 dB.
<table>
<thead>
<tr>
<th>Link ID</th>
<th>Frequency band, GHz</th>
<th>Length, km</th>
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<tbody>
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<td>5.77</td>
</tr>
<tr>
<td>L4028</td>
<td>18</td>
<td>5.86</td>
</tr>
</tbody>
</table>

Table 1. Characteristics of cellular links used for reconstruction.

**Supporting References and Notes**


Reconstruction of Temporal and Spatial Rainfall Intensity Distributions using cellular DFRS data

Messer et al.

This movie illustrates the feasibility of reconstruction of temporal and spatial rainfall distribution using cellular DFRS data, and demonstrates rainfall intensity maps estimates, produced by 7 cellular links (right) and compared with weather radar (left).

Both radar and cellular rainfall maps are reconstructed over the same region (central Israel) and at the same time slots, for a strong rainfall event on 19-20 January 2005, and are shown in the same scale of rain intensities, with time resolution of 15 minutes.

Note, however, that the radar map does not cover the whole area because of clutter, while the cellular backhaul map is restricted to areas where measurements were available.

The radar shows observed rainfall with spatial resolution (pixel size) of 1 km², whereas the cellular rainfall estimate is average rainfall intensity over the cell of approximately 5.2x5.2 km².