Supplementary Material

for

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Synchronisation, coordination and collective sensing during thermalling flight of freely-migrating white storks

Supplementary Figures and Legends

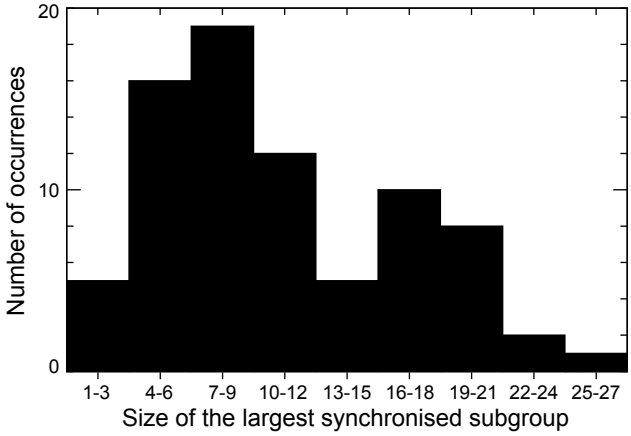


Fig. S1: Histogram of size of the largest synchronised subgroup in circling sections. For each GPS burst that contained at least 20 s of circling within the first 2 minutes, we calculated the largest synchronised subgroup using C_{min}=0.9 as characterization of synchronised circling.

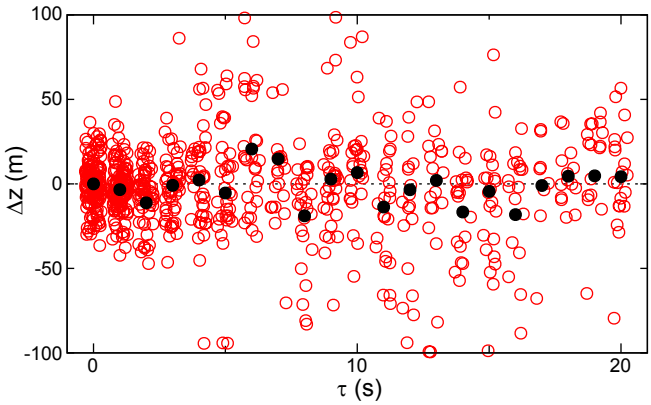


Fig. S2: Height difference (Δz) between individuals who switched circling direction as a function of the time delay between them (τ). a) Open, red circles correspond to synchronised pairs. Δz is measured as the height of the bird that switched first minus the height of the later bird. Circles are scattered using uniformly distributed random numbers between [-0.3; 0.3]. Black dots show the average height difference for each time difference (bin size of 1s).

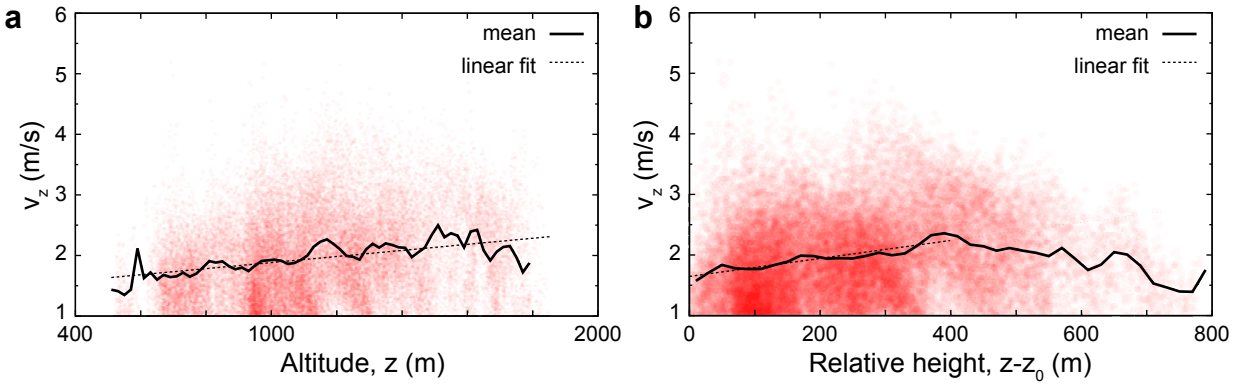


Fig. S3: Distribution of individual's vertical speeds versus altitude and relative height. a) Distribution represents the individual's vertical velocities. The solid black curve shows the average distribution with a 20 m bin size. Dotted black line shows fit of linear model. **b)** Relative height of the individuals was calculated as their altitude minus z_0, the lowest altitude an individual was detected in that thermalling GPS burst. Dotted black line shows model of linear fit between [0m; 400m].

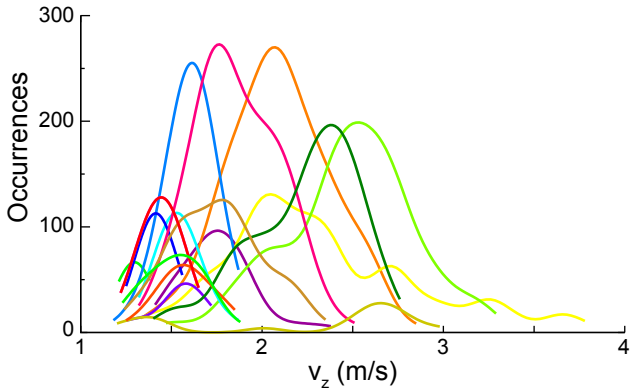


Fig. S4: Distribution of vertical speeds of individuals in thermals. Each curve represents the distribution of vertical speeds of all individuals within one thermal.

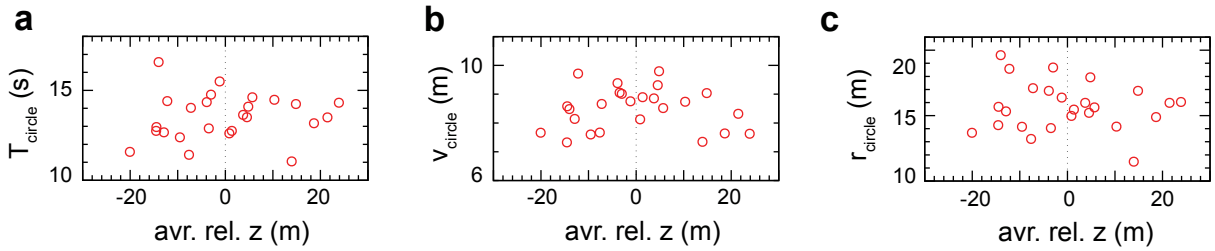
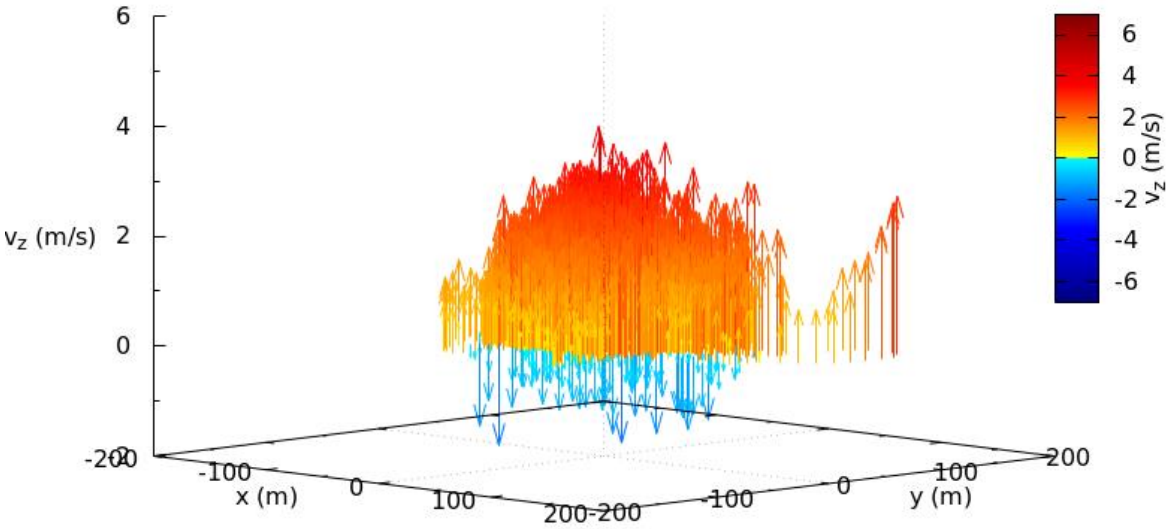
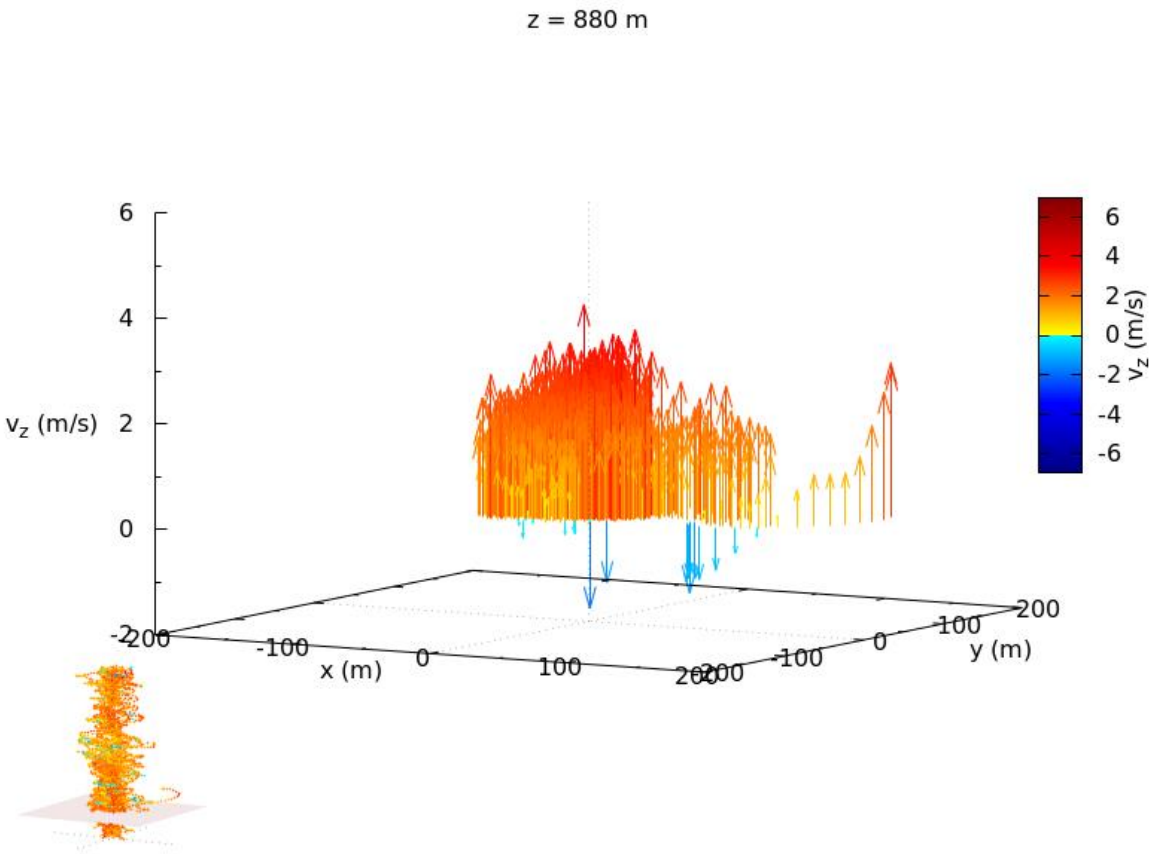


Fig. S5: Individuals' performances in mapped thermal structure. a-c) Each circle represents the mean value of one individual. Plots show period of circling, T_{circle} (a), horizontal speed of circling, v_{circle} (b), and circling radius, r_{circle} (c; calculated using T_{circle} and v_{circle}; see Methods for details) against height relative to the center of mass of the flock.

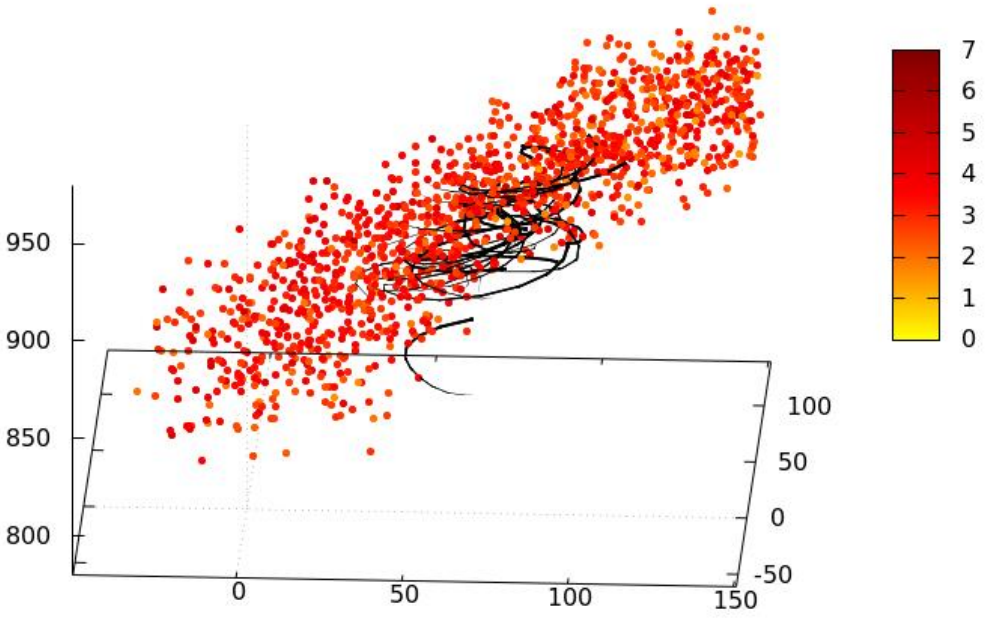
Supplementary Movie Legends



SI Movie 1: The vertical speed profile of the thermal resulting from the collective movements of the entire flock. The plot shows the vertical speed of all individuals in the flock (on the z axis) represented in relative coordinate system Δx, Δy with an origin at the estimated centre of the thermal at every altitude (see also Fig. 7b). The video shows that the combination of all individuals add up to a full representation of the vertical speed distribution of the thermal. The viewing angle is rotated along the z axis. Lift is maximal in the central region and decreases with the distance to the centre.



SI Movie 2: The vertical speed profile of the thermal at different altitudes. The plot is similar to Fig. 7b and SI Movie 1, but it additionally shows the vertical speed distributions at different altitudes ranging from [*z*-50m; *z*+50m]. Altitude (z) is shown on the top, and can also be seen in the inset (at the bottom left). The inset shows the full trajectories of all birds (same data as on Fig. 7a) in the relative coordinate system (Δx, Δy, z) centred around the centre of the thermal.



SI Movie 3: Visualisation of the storks' GPS tracks together with the estimated movement of the air. Black curves show 10 s trajectories of each bird; the width of the path is smaller for earlier points. The moving dots indicate the velocity of the air in the thermal; they colour coding represents the vertical speed. The vertical component of the air velocity was estimated for a 5 x 5 x 4 m (*x*, *y*, *z*) sized grid using the average vertical speed of the individuals. While rising in thermals, storks sink in the air that rises around them at a faster speed. Sink rate during gliding has a peak value of 1.2 m/s, and defines a minimum sinking speed. We estimated the air's vertical speed to be 1.2 m/s larger than the vertical speed of the storks. The horizontal speed of the air is estimated from the path of the centre of the thermal. The tracks of the storks were not modified, they show the original GPS locations, and the viewpoint of the visualisation is moving with the centre of mass of the flock. The video plays 10x the normal speed. Note the dynamics of the synchronised subgroups.