

# Ikarus: Large-scale Participatory Sensing at High Altitudes

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*Distributed  
Computing*



# Mobile Phones

- Over 5 billion mobile phones worldwide (72.6% of world population)
- Smartphones account for 19% of sales in 2010



# Phones as a Platform for Mobile Sensing

- Smartphones have already many integrated sensors:

Camera

Microphone

GPS

Compass

Accelerometers

Gyroscope

Proximity sensor

Near-field communication



# People-centric Sensing Applications

- Sense your environment:
  - Air quality/pollution
  - Traffic congestion
- Identify patterns in your behavior:
  - Heart rate/stress level
  - Personal fitness

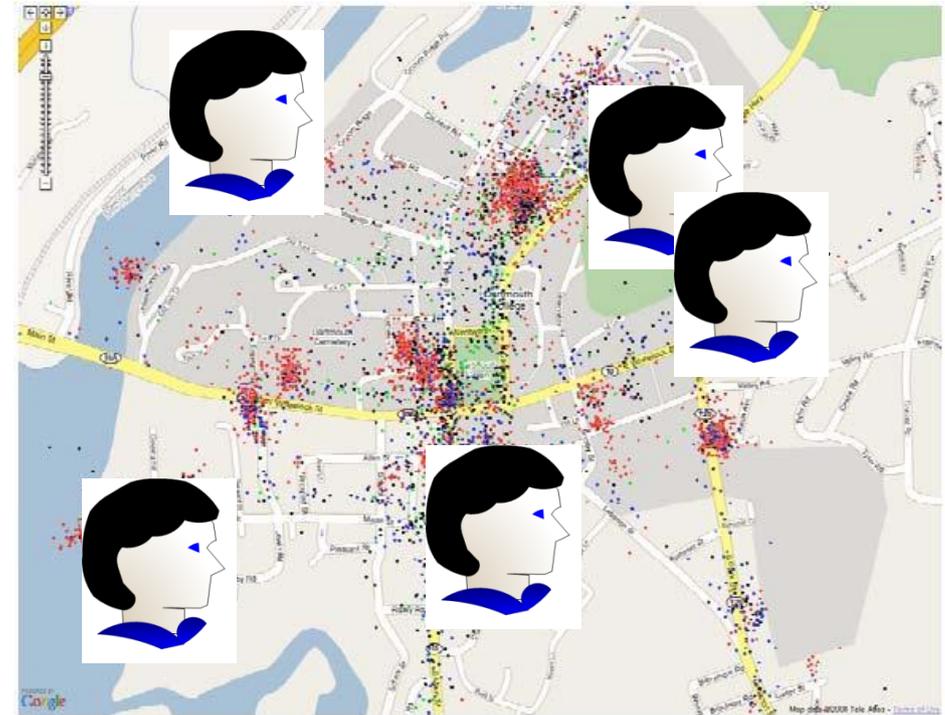


# From Sensor Networks to Participatory Sensing

- Collection and analysis of sensor measurements



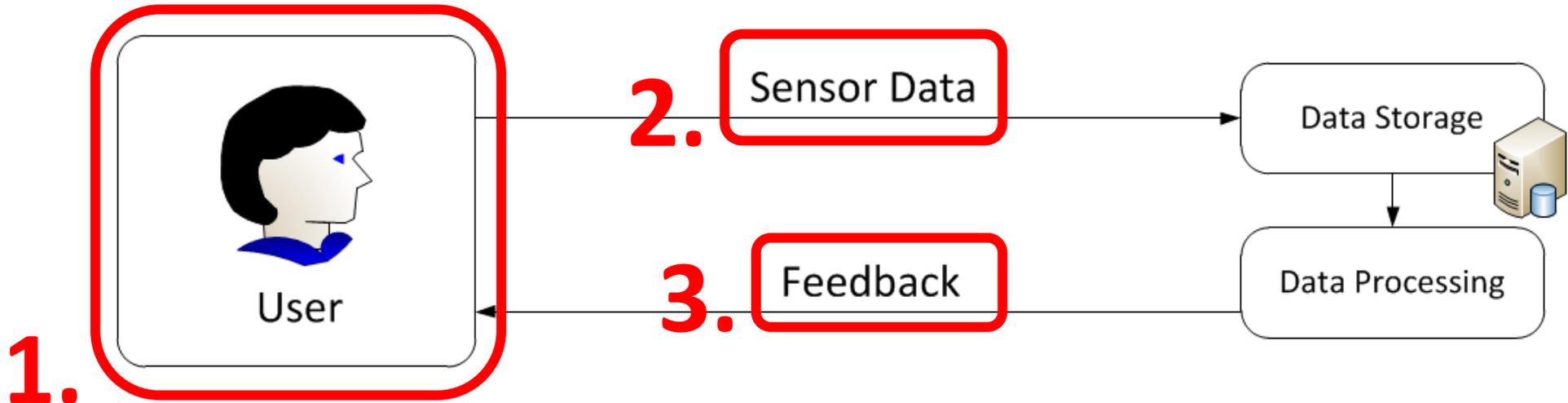
Wireless Sensor Network



Participatory Sensing

# The Participatory Sensing Loop

- How can participatory sensing be successful?



- We identify three key challenges:
  1. Incentives for participation
  2. Ability to deal with faulty data
  3. Concise data representation

# Related Work: Mobile Sensing Projects

- Most former projects are only small scale

## CenceMe



### 6. USER STUDY

Because CenceMe is designed to be a social network we need to go beyond simple measures of system performance to best understand the utility of people-centric sensing applications such as CenceMe. Our goal is to bring CenceMe to the attention of potential users, ask them to use CenceMe, and provide targeted feedback about their user experience by means of a survey. The experiment we conducted "operational" experiment involved 22 people. Participants were each given a Nokia N95 with the CenceMe software (including ClickStatus) and a free voice/data plan. Users had server-side accounts and access to the CenceMe portal. While some of the users were friends we placed all users in the same

22 users

## Biketastic



### EVALUATION

We conducted a pilot evaluation with 12 users recruited via local bike advocacy organizations. The individuals ran Biketastic for two weeks, and submitted a total of 208 routes. The minimum number of routes submitted by a user was 7 and the maximum was 36. The majority of users submitted routes on at least half of the days the pilot ran. Also, 8 users submitted a total of 14 images. Every user logged onto the website. Overall, 14 people participated in evaluation focus groups, which consisted of 3 sessions made up of 3-4 riders. Focus group discussions centered on motivations for using Biketastic, system usability, and the effectiveness of information dissemination through the system. Interview notes were coded for discussions of usability, including system critiques and suggestions; comments about system use and cycling practices; and analysis of information learned from and conclusions drawn from, the system.

12 users

BikeNet

### 3 System Evaluation

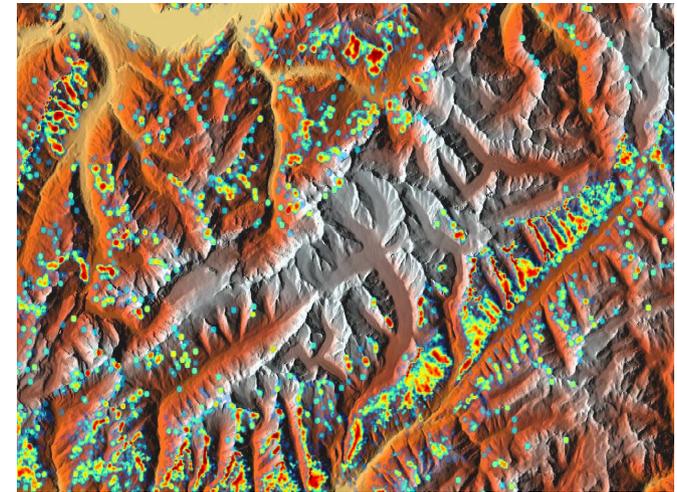
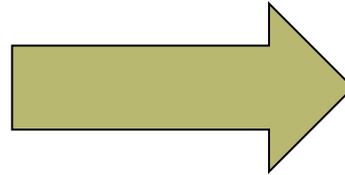
We build five fully equipped BikeNet bicycles, implement all of the aforementioned sensing roles using Tmote Invent nodes and Nokia N80 mobile phones, build a number of static and mobile SAPs, and implement a functional back end web portal offering query submission and data retrieval services. In this section, we present selected results from several groups of cyclists who have respectively targeted at: quantifying the cyclist experience from sensed data collected about a single cyclist and his environment; looking at performance aspects of key BikeNet subsystems; and measuring the real-time performance of a deployed system across the Dartmouth campus and in adjacent areas of the town of Hanover, NH, USA. We use a common path that we call the ground truth route. This route includes a variety of urban cyclone terrain, including built up busy roads in the town center

5 users

# The Ikarus System

- Goal:

Use GPS flight records from paraglider pilots to generate maps of thermal active areas (hotspots)



- Data provided by 2,331 unique users in Switzerland (2003-2009)
- 30,000 flight tracks analyzed, several GByte of data processed

# A Short Introduction to Paragliding

- Recreational flying sport

Flying...



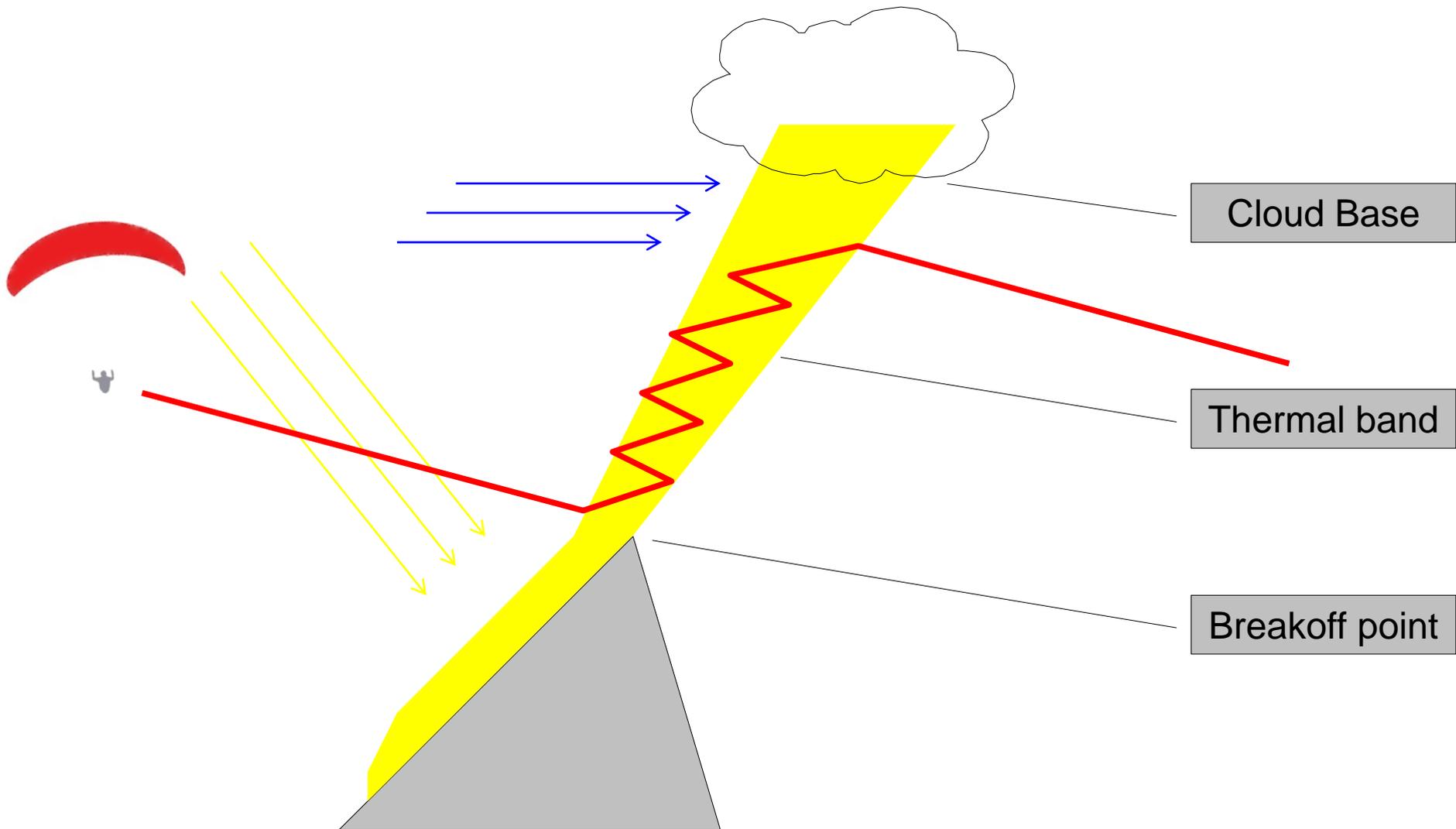
Launching...



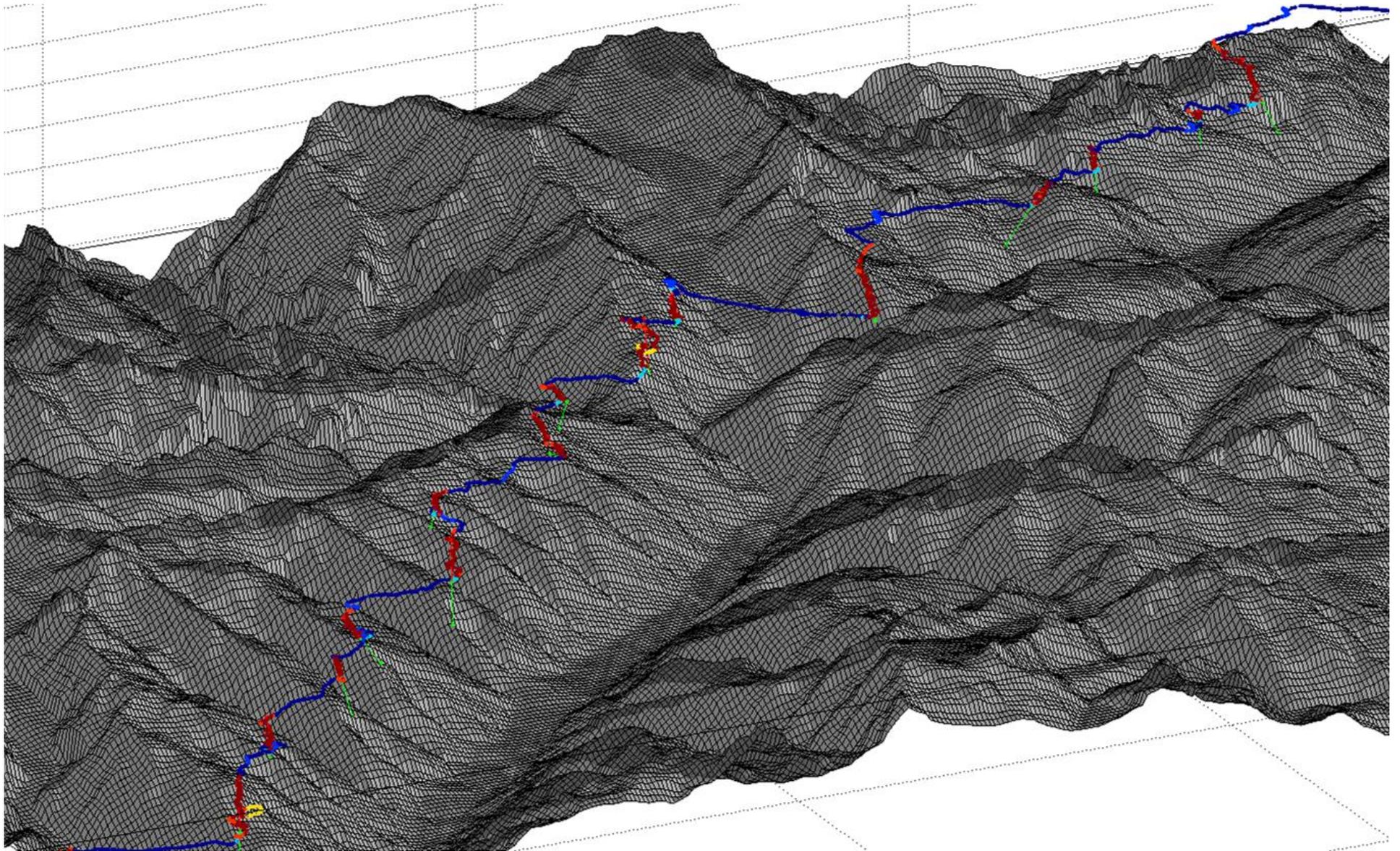
... and Landing



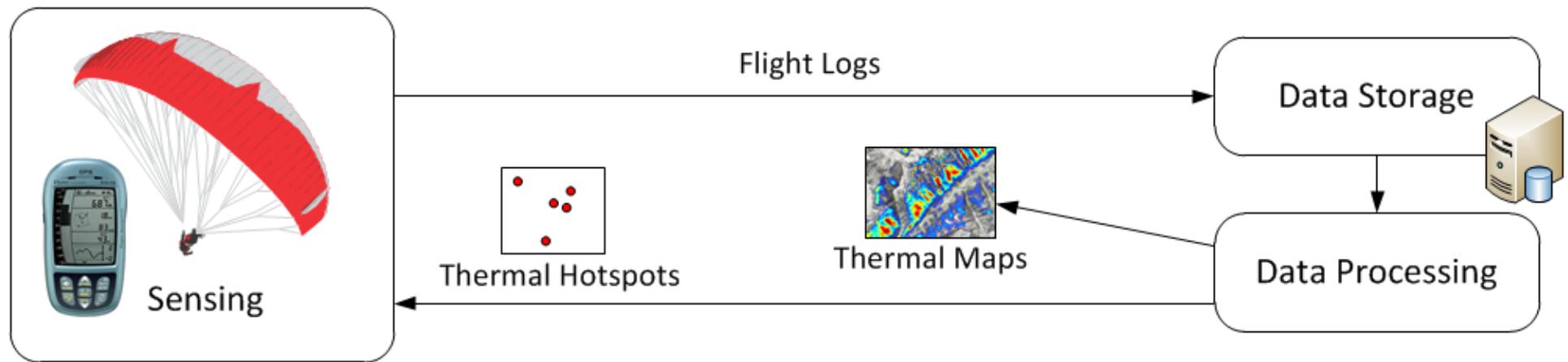
## A Short Introduction to Paragliding (2)



# Example: Paraglider Flight



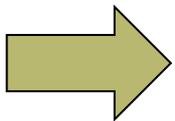
# Ikarus: System Architecture



# Sensing Flights

- Flight navigation devices used by paraglider pilots
  - Records time, GPS position
  - Accurate height measured by barometric pressure
  - Variometer reports climb rate

- Data Integrity
  - Tracks are signed by the device



Cheating is very hard!



# Participation Incentives

- How can we make pilots to share their recorded tracks?
- Pilots share recorded flights on community websites  
Tell friends about their flights (social networks)

- Paragliding contests

Credits awarded for distance or shape of the track (triangle)

The image displays two screenshots of paragliding contest websites. The left screenshot shows the 'hcontest' website with a flight detail page for 'Boncho Zhechev' on 18.3.2010, showing a distance of 75.53 km. The right screenshot shows the 'DHV XC Flying Contest' website with a flight detail page for 'Götz Balzer' on 18/03/2010, showing a distance of 34.6 km and a maximum speed of 45.1 km/h.

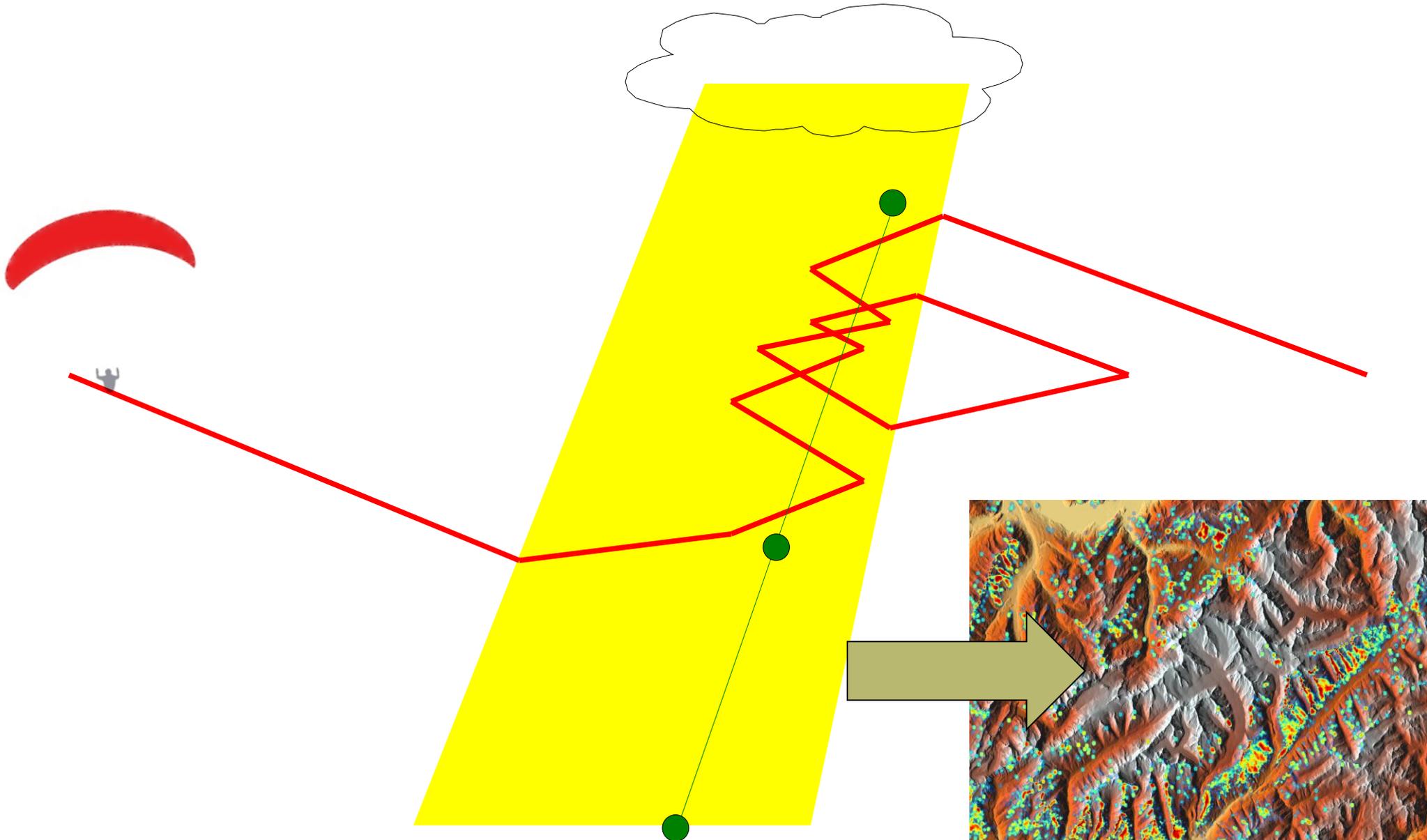
**hcontest Flight Detail:**

- Pilot: Boncho Zhechev (bonchot)
- Date: 18.3.2010 11:40
- Glider: Axis Mercury08 S
- Launch: Madara (BG)
- Route: 75.53 km
- IGC file: 2010-03-18-CGP-XXXX-02.icg

**DHV XC Flying Contest Flight Detail:**

| Startplatz Info |          | Flug Info                   |            |
|-----------------|----------|-----------------------------|------------|
| Startplatz      | 10:52:32 | Dauer                       | 2:12:20    |
| Baszano - IT    |          | Maximales Steigen           | 4.2 m/sec  |
| Landeplatz      | 13:04:52 | Maximales Sinken            | -3.0 m/sec |
| Baszano - IT    |          | Grösste Höhe (über NN)      | 1409 m     |
|                 |          | Minimale Höhe (über NN)     | 821 m      |
|                 |          | Start Höhe (über NN)        | 821 m      |
|                 |          | Höhen Zuegewinn             | 588 m      |
|                 |          | Maximale Geschwindigkeit    | 45.1 km/h  |
|                 |          | Durchschnittsgeschw. (Luft) | 28.8 km/h  |

# Data Processing: Finding Thermal Columns



## Data Quality

- Hardware challenges of participatory sensing:

  - Sensor device is owned by the user

  - Different hardware

  - Bad calibration (time, altitude)

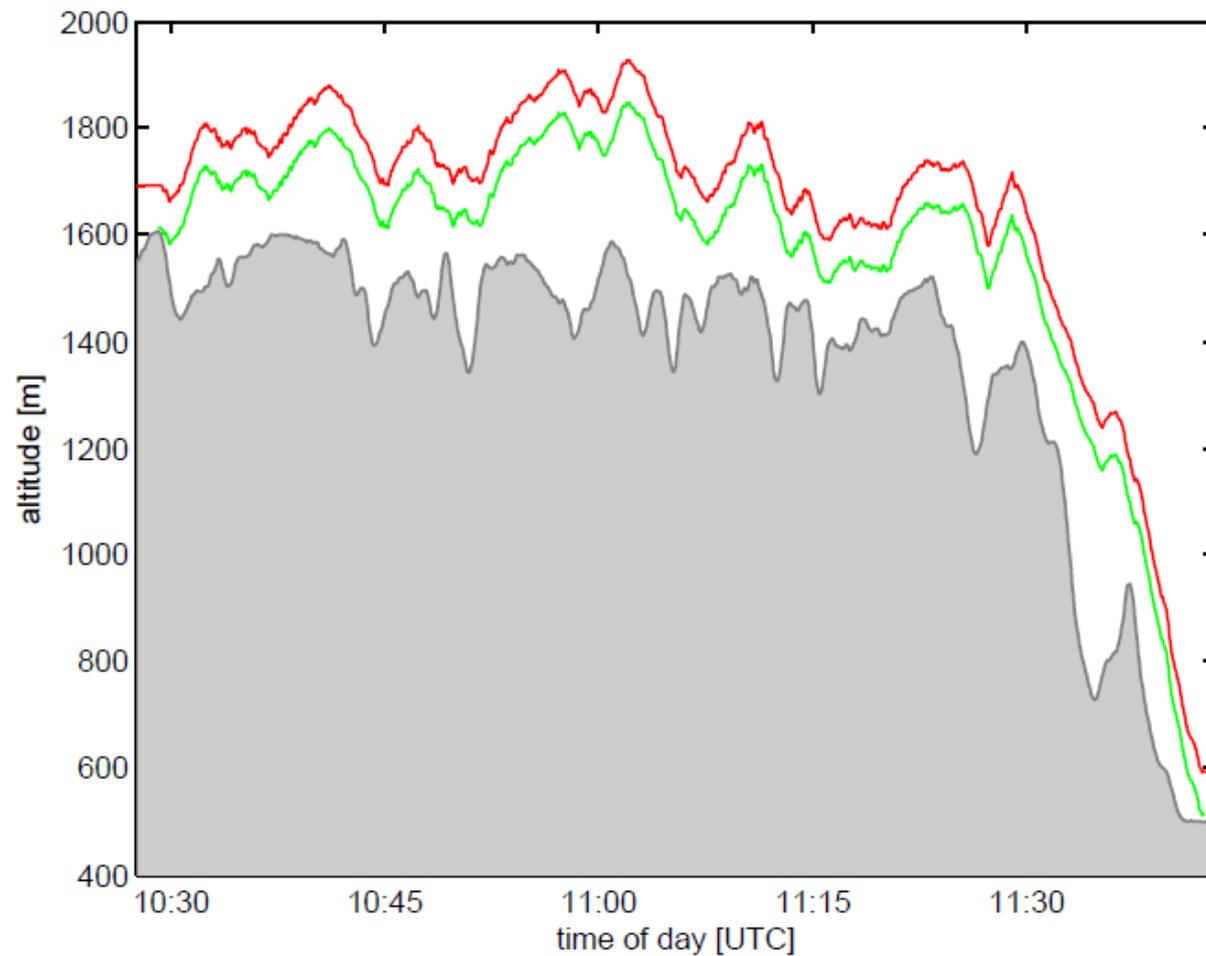
|  |        |
|--|--------|
| None or invalid altitude information           | 7.0 %  |
| Flight outside area of interest                | 4.0 %  |
| Too many successive GPS spikes                 | 2.5 %  |
| Tracks far below terrain after correction      | 5.0 %  |
| Other errors (night flight, altitude outliers) | 0.4 %  |
| Total removed tracks                           | 18.9 % |



Only 81.1% of all tracks could be used

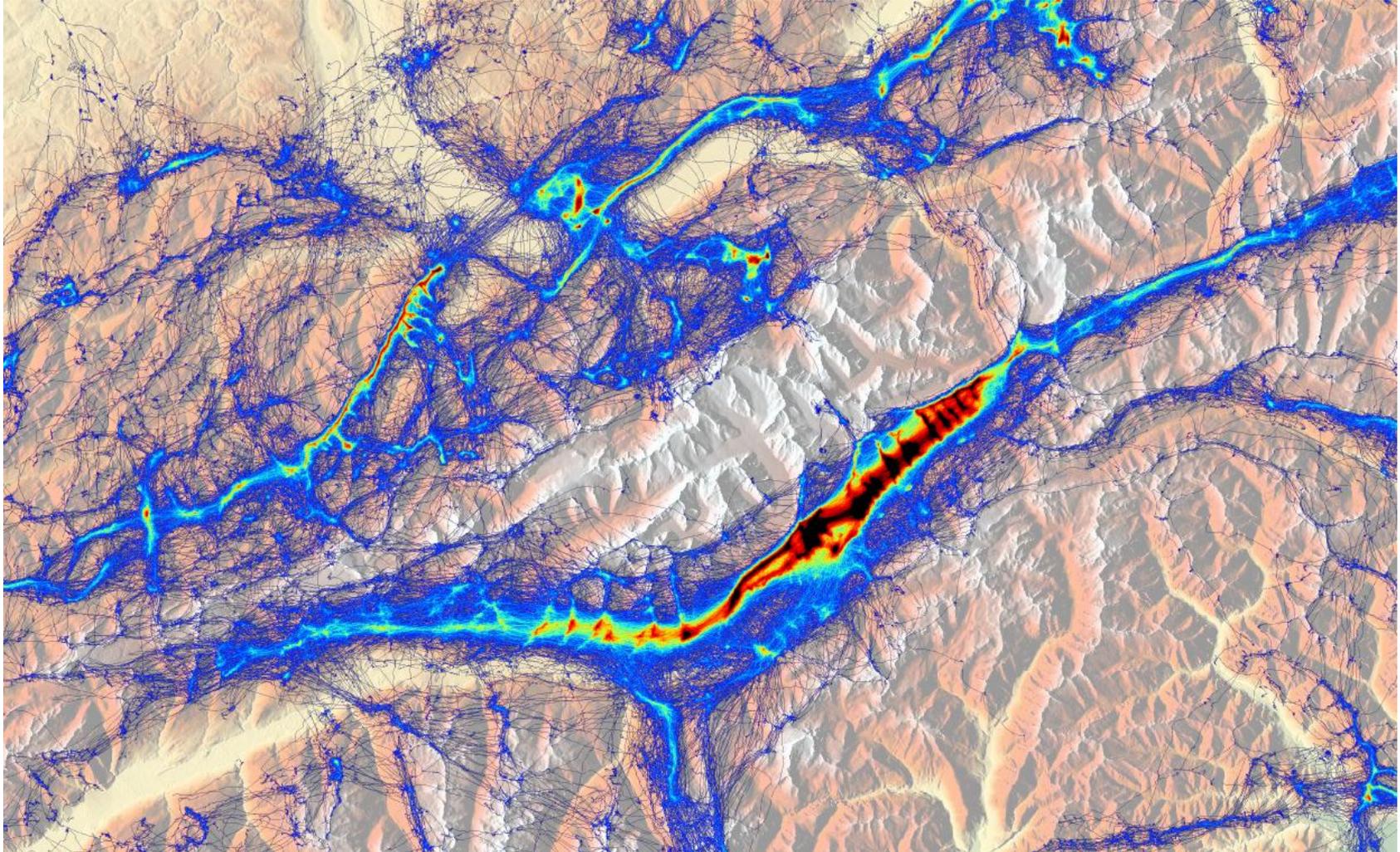
## Data Quality: Example

- Pilot forgot to calibrate altitude before launch



## Problem: Flight Distribution

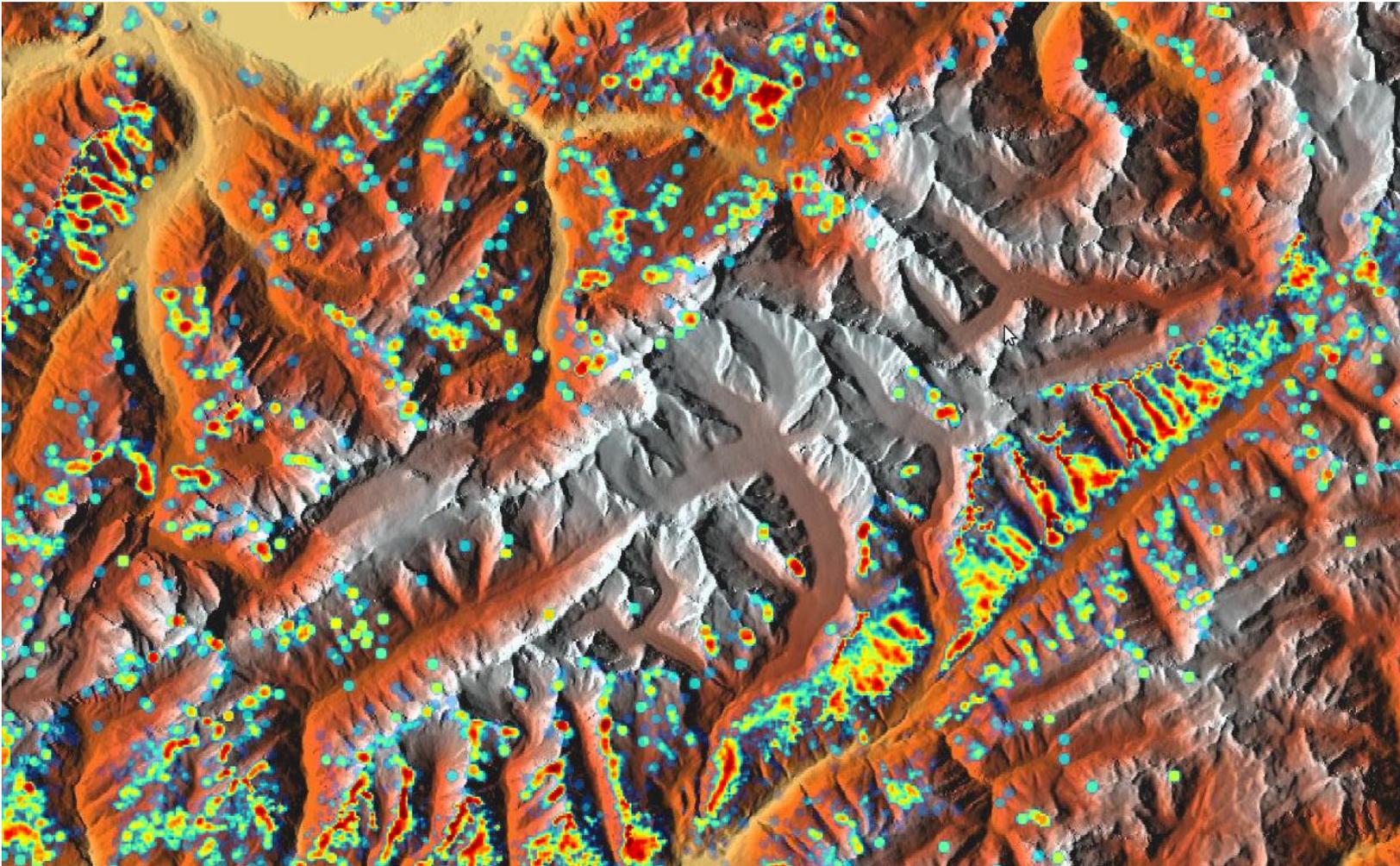
- Flight tracks are distributed very unequally



Goms Valley, Switzerland, all flights from 2003-2010, 80 x 50 km

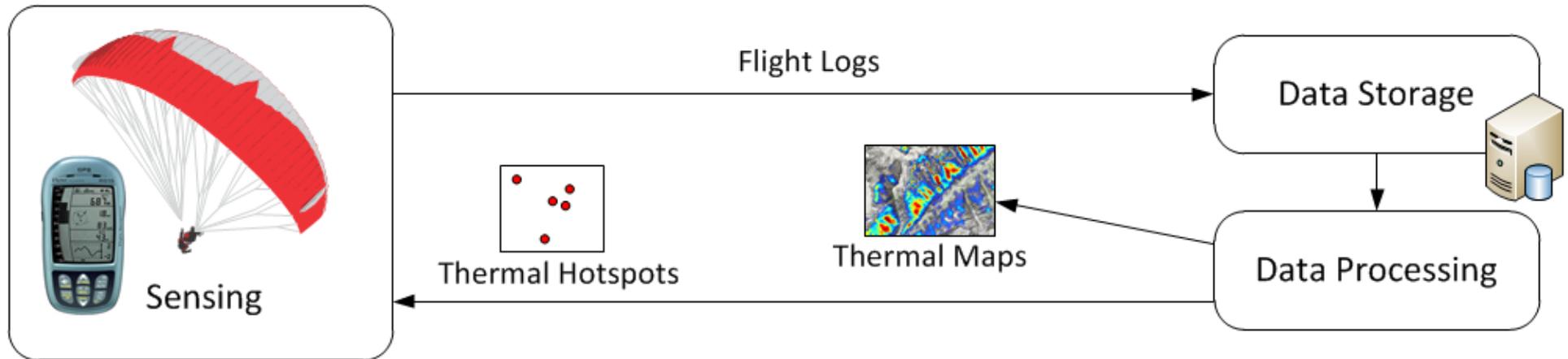
## Solution: Probability based Thermal Maps

- Assign an uncertainty value to each thermal trigger point



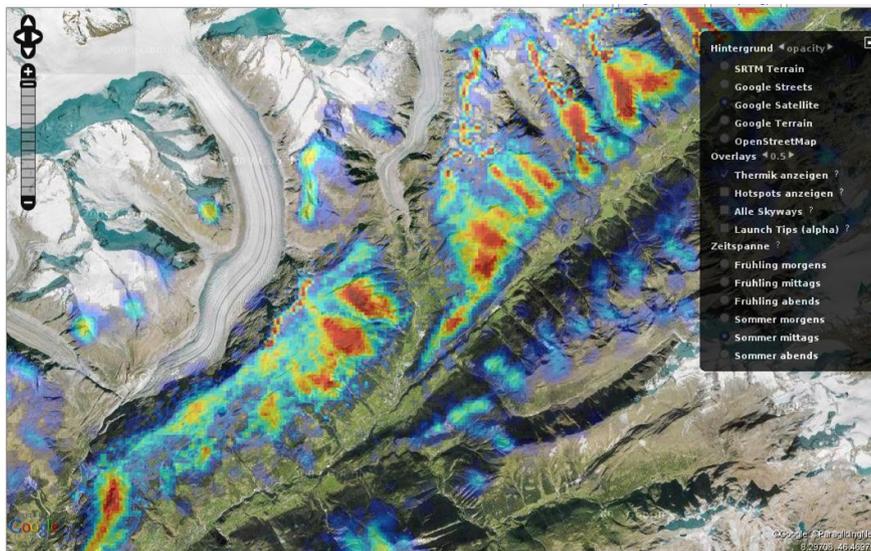
# Closing the Loop

- Feedback to users is crucial in participatory sensing
  - Increase awareness for data quality (calibration)
  - Encourage pilots to upload their flights

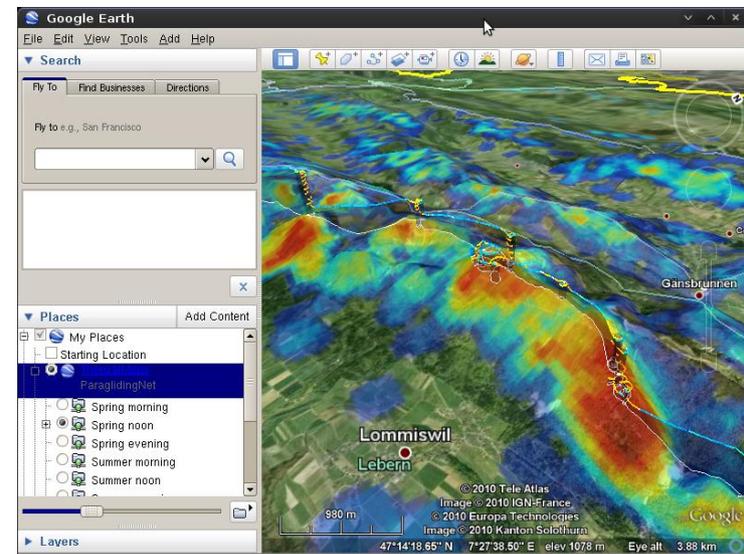


# Feedback to pilots: Thermal maps

- Thermal maps for flight preparation



Google Maps

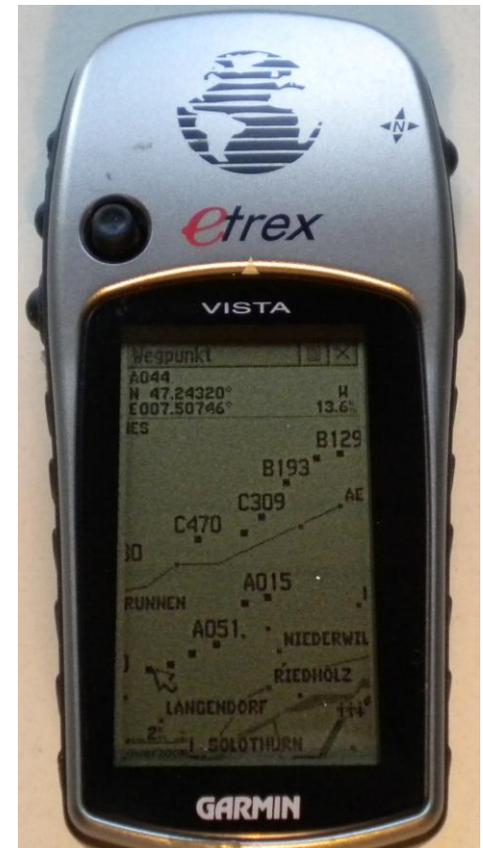


Google Earth

Website: <http://thermik.kk7.ch>

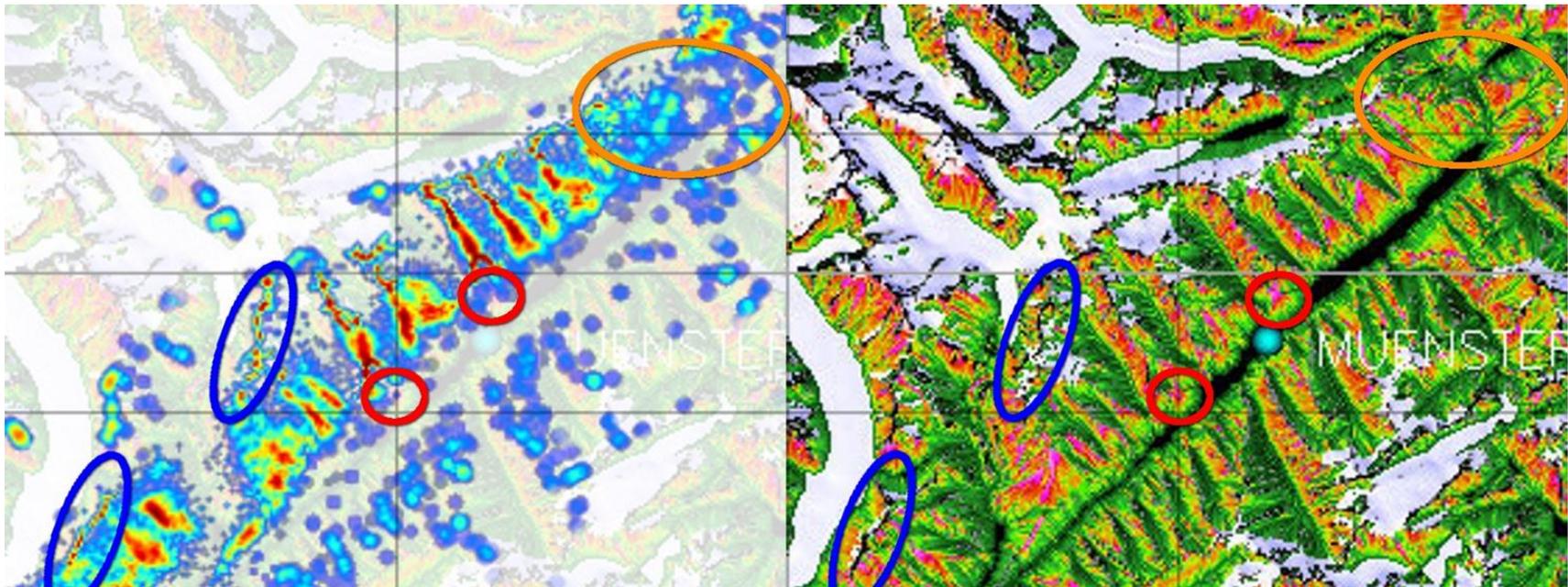
## Feedback to pilots: Hotspots

- Import thermal hotspots on the flight navigation device  
XML file with coordinates of strong thermal uplift
- Recommendation system during flights  
Find good thermals in your area  
Explore new areas
- Future devices will likely include 3G connectivity  
Get live feedback from other pilots?



## Evaluation: Ikarus vs. TherMap

- Comparison with a physical simulation of thermal uplift



# Conclusions

- Ikarus: Large scale participatory sensing with 2331 users
- First thermal maps based on GPS flight logs

