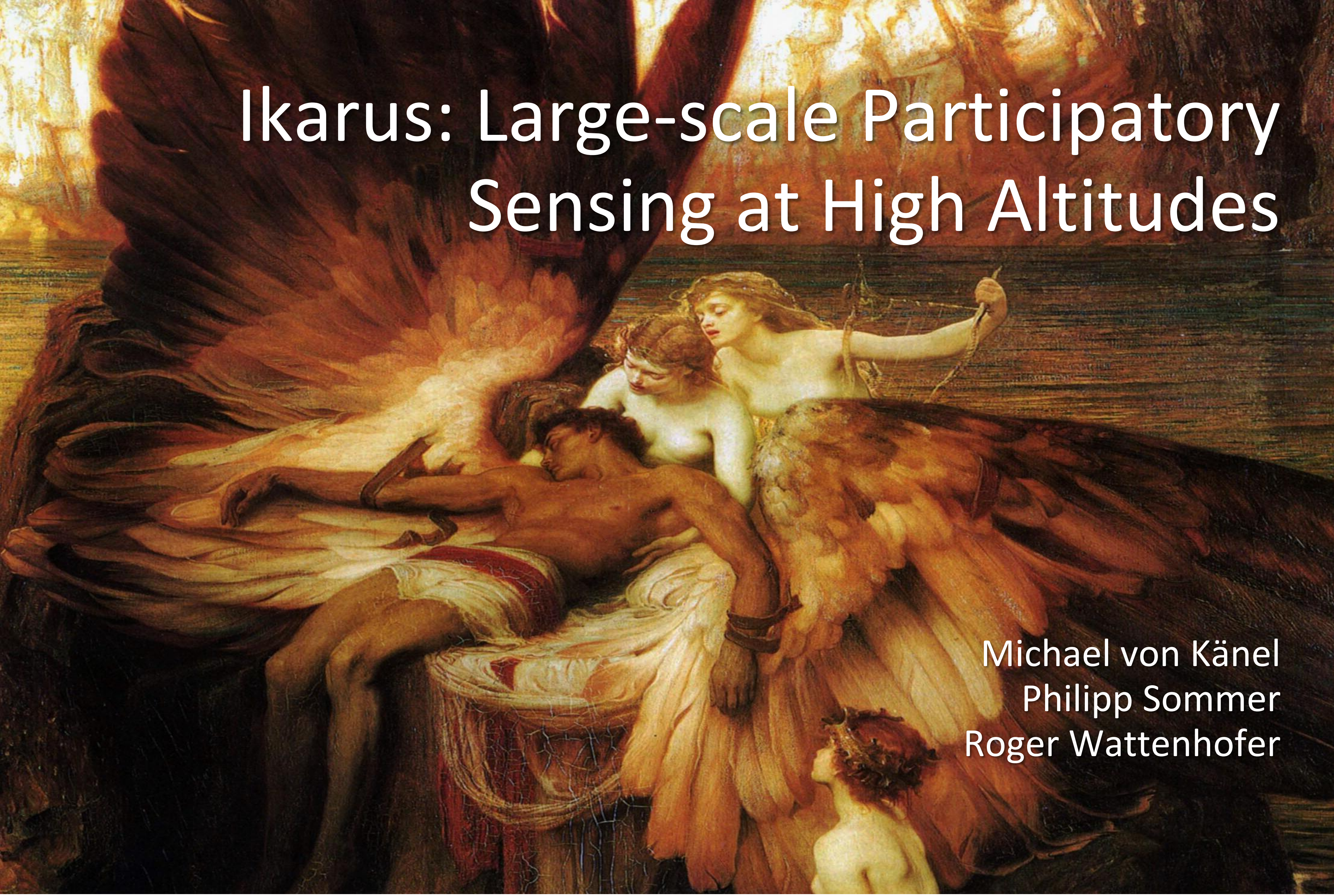

Ikarus: Large-scale Participatory Sensing at High Altitudes

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Distributed Computing

Mobile Phones

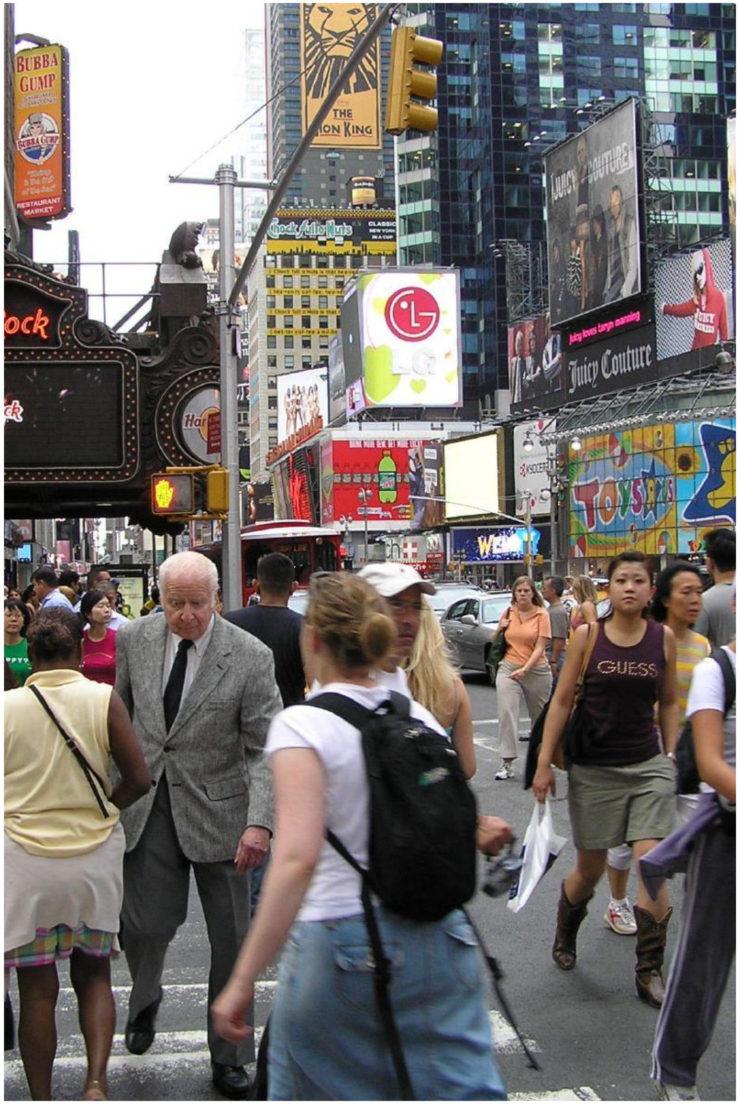
- Over 5 billion mobile phones worldwide (72.6% of world population)
- Smartphones account for 19% of sales in 2010

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

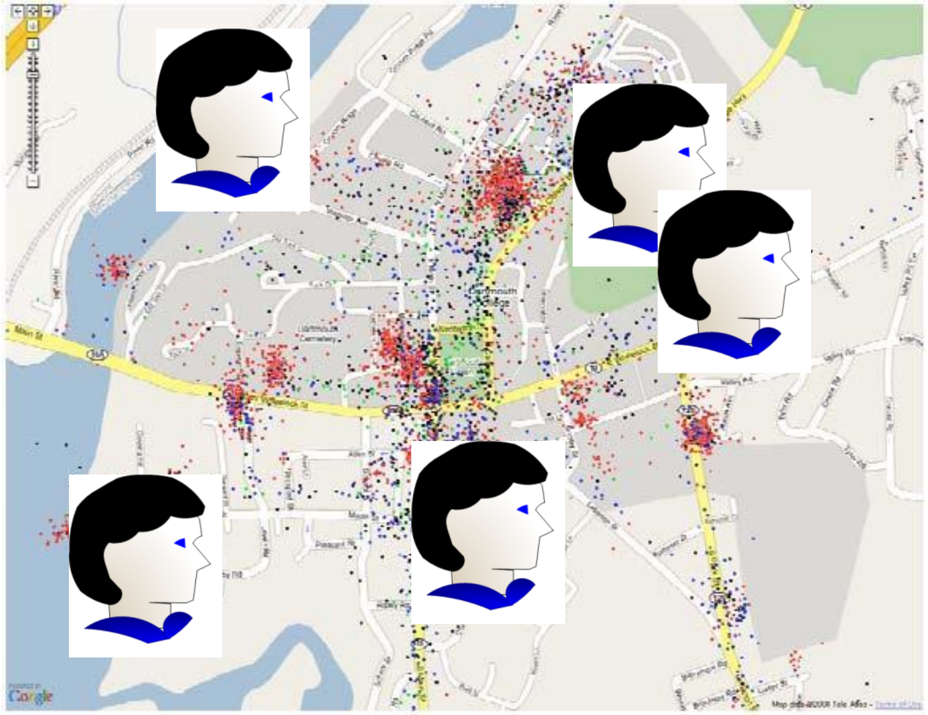
- Sense your environment:
  - Air quality/pollution
  - Traffic congestion
- Identify patterns in your behavior:
  - Heart rate/stress level
  - Personal fitness



From Sensor Networks to Participatory Sensing

- Collection and analysis of sensor measurements

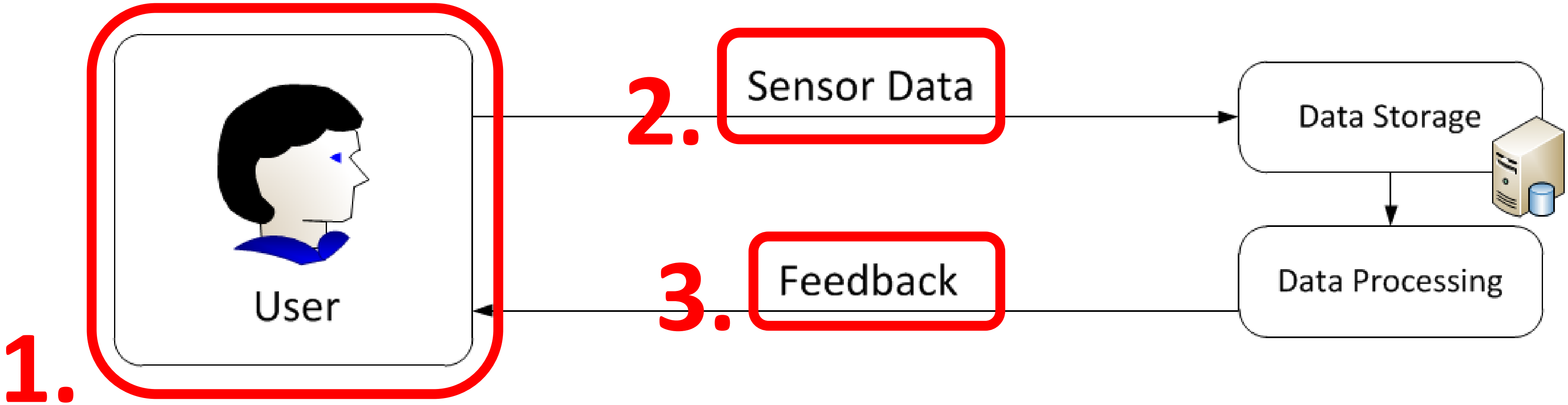
Wireless Sensor Network



Participatory Sensing

The Participatory Sensing Loop

- How can participatory sensing be sucessful?



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

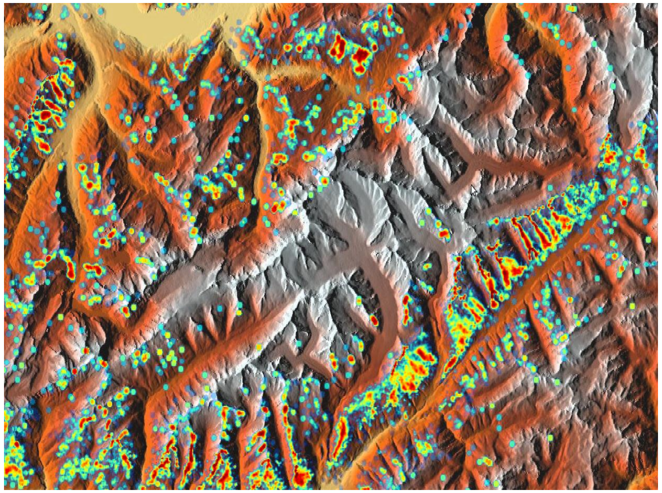
Related Work: Mobile Sensing Projects

- Most former projects are only small scale

The Ikarus System

- Goal:

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

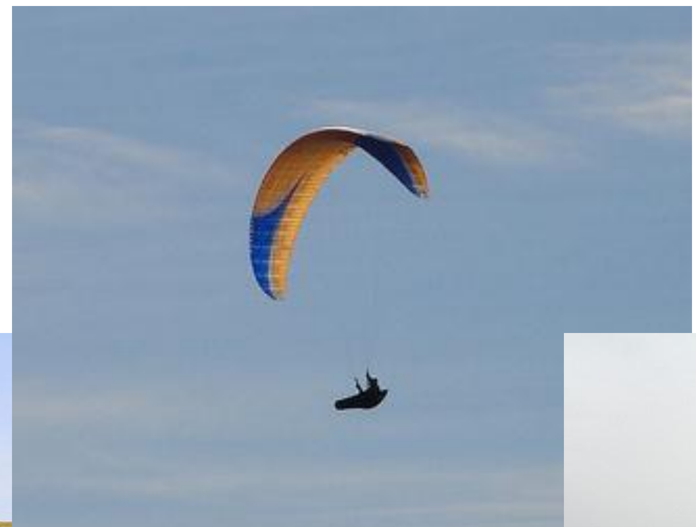


- Data provided by 2,331 unique users in Switzerland (2003-2009)
- 30,000 flight tracks analyzed, several GByte of data processed

A Short Introduction to Paragliding

- Recreational flying sport

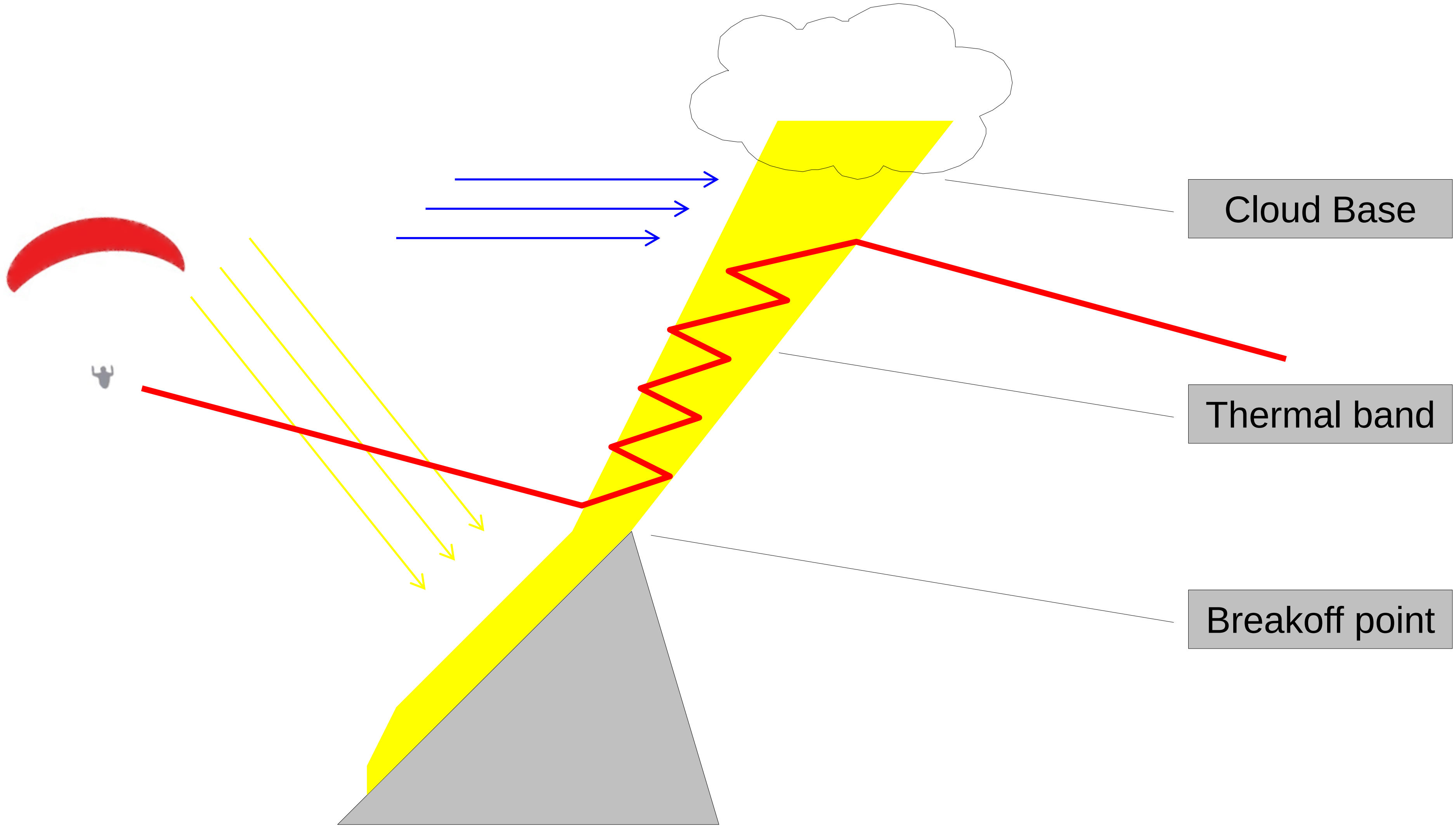
Flying...



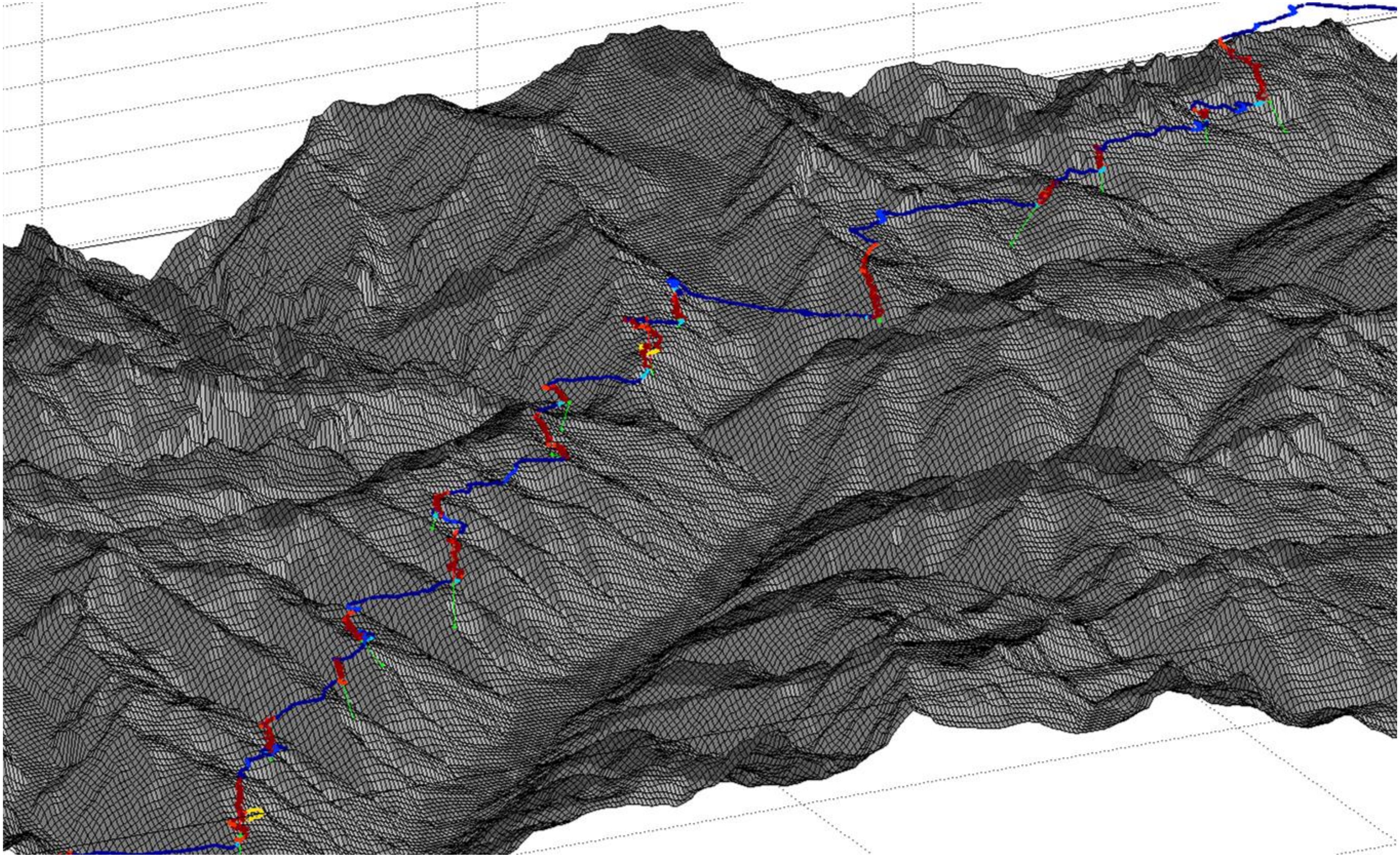
Launching...

... and Landing

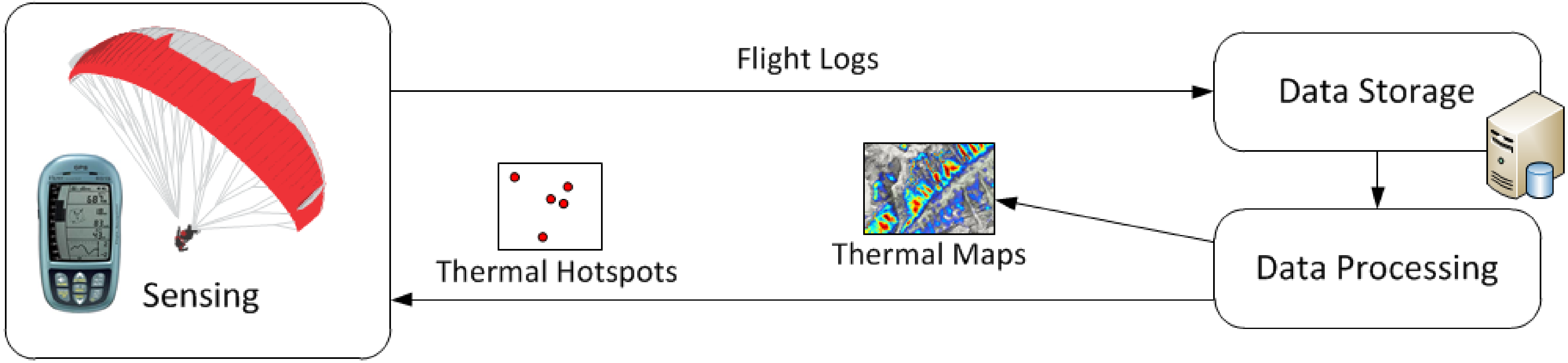
A Short Introduction to Paragliding (2)



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!

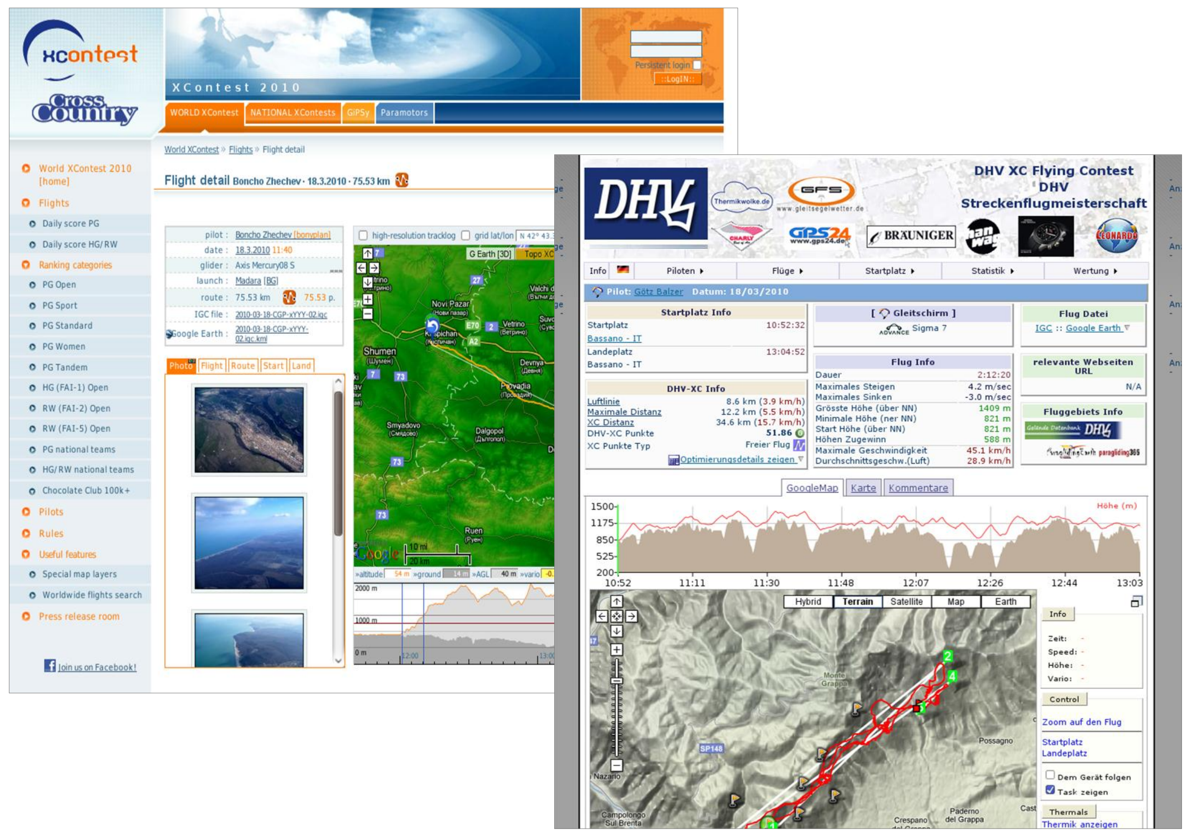
Participation Incentives

- How can we make pilots to share their recorded tracks?
- Pilots share recorded flights on community websites

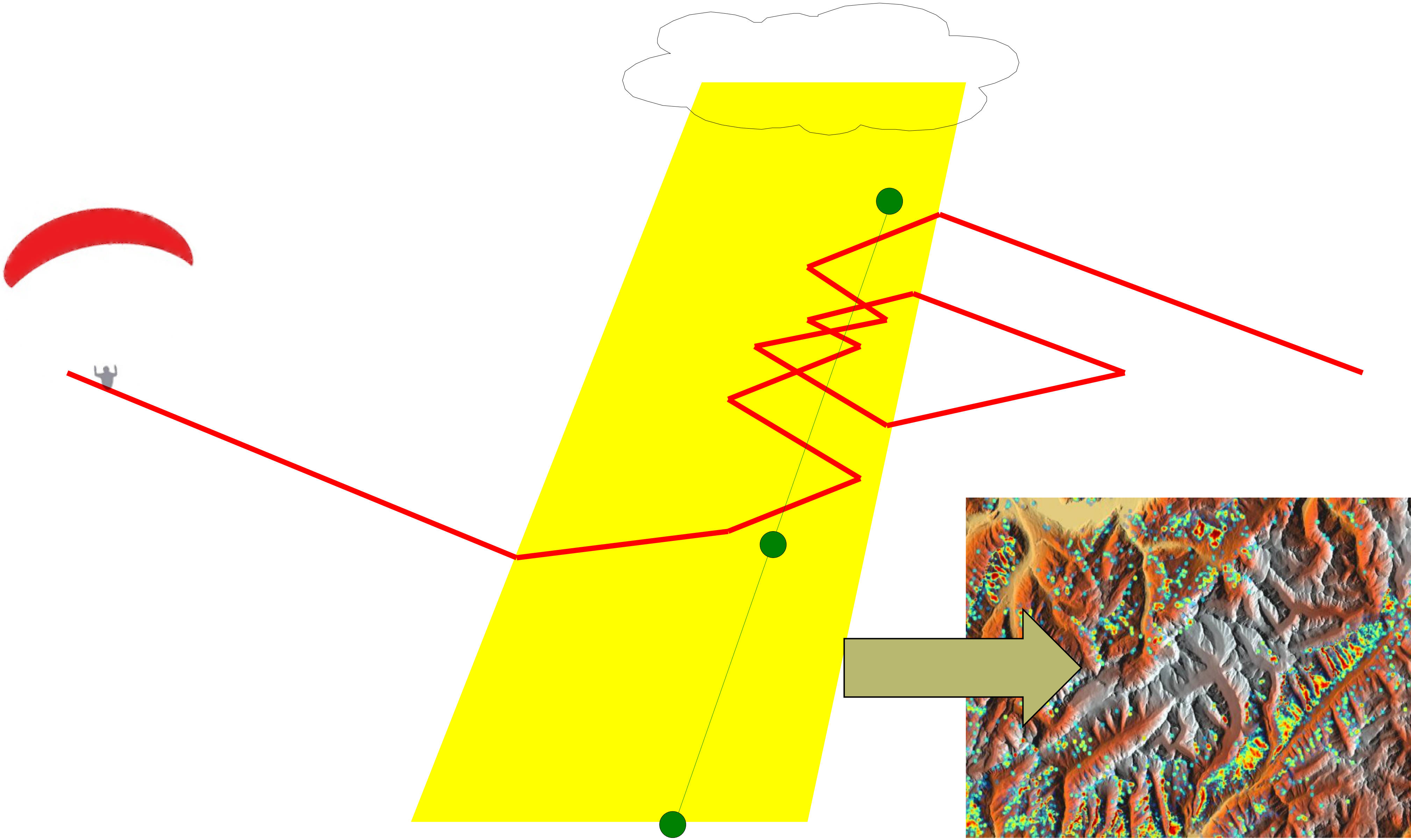
  Tell friends about their flights (social networks)

- Paragliding contests

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



Data Processing: Finding Thermal Columns



Data Quality

- Hardware challenges of participatory sensing:

  Sensor device is owned by the user

  Different hardware

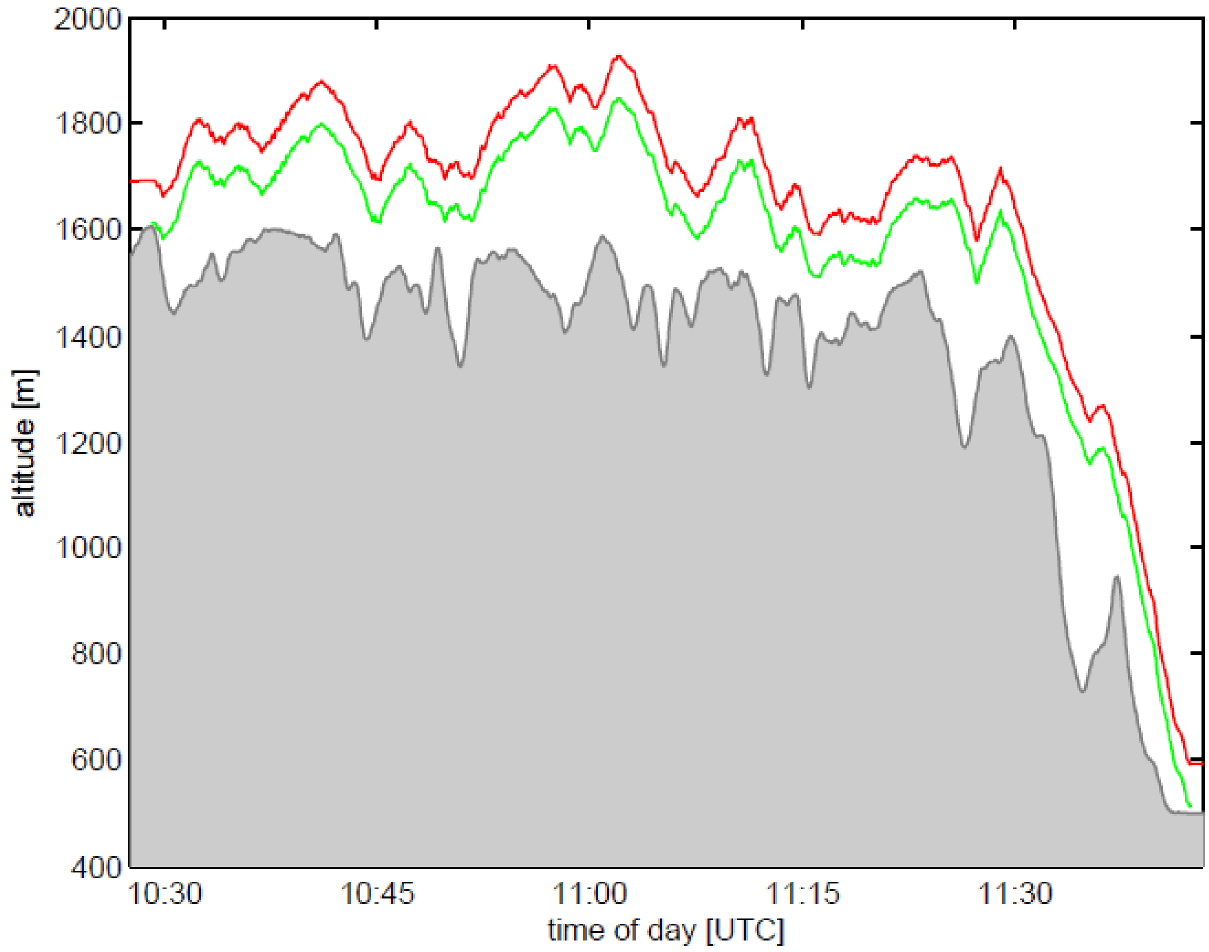
  Bad calibration (time, altitude)

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

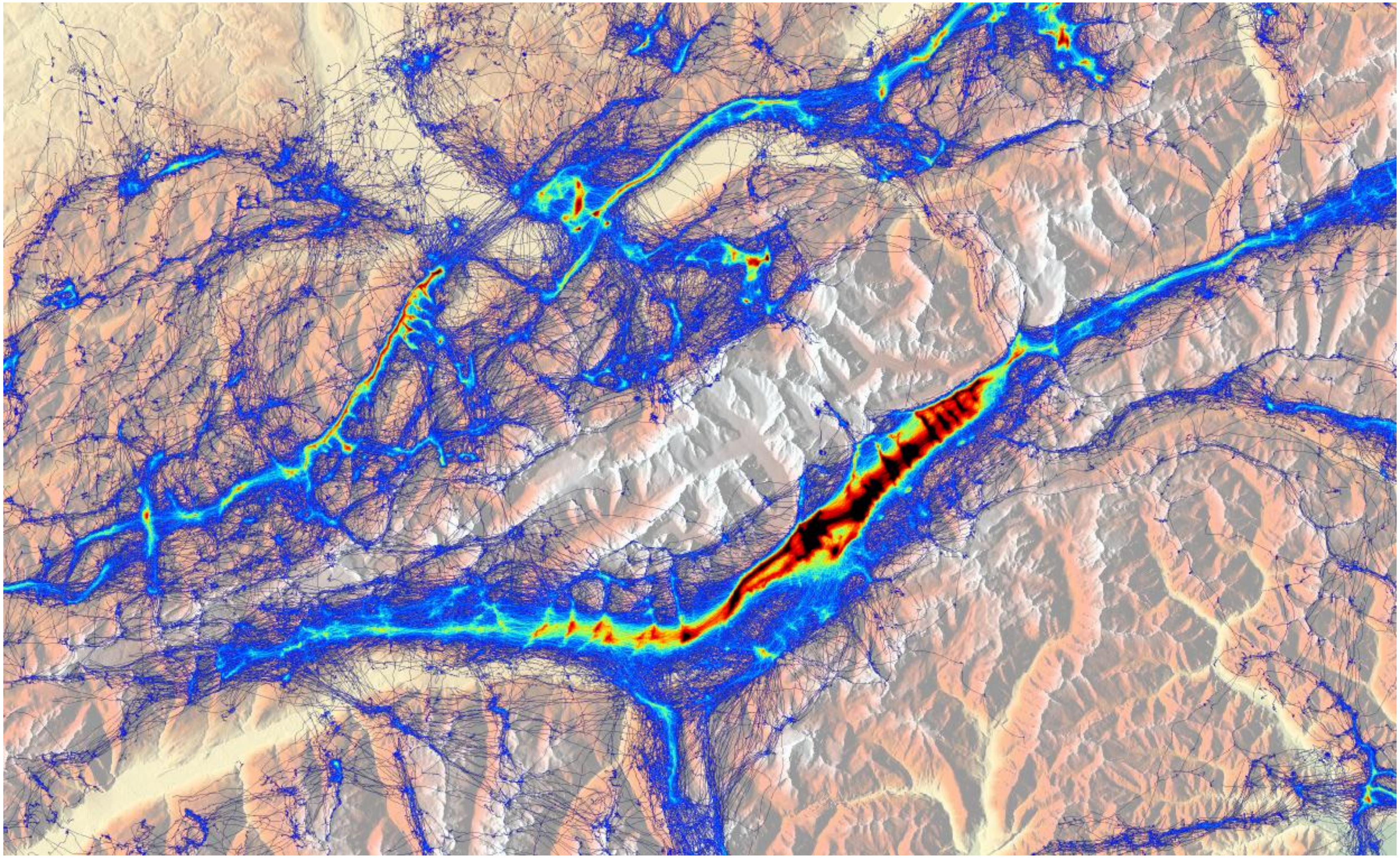
Data Quality: Example

- Pilot forgot to calibrate alititude before launch



Problem: Flight Distribution

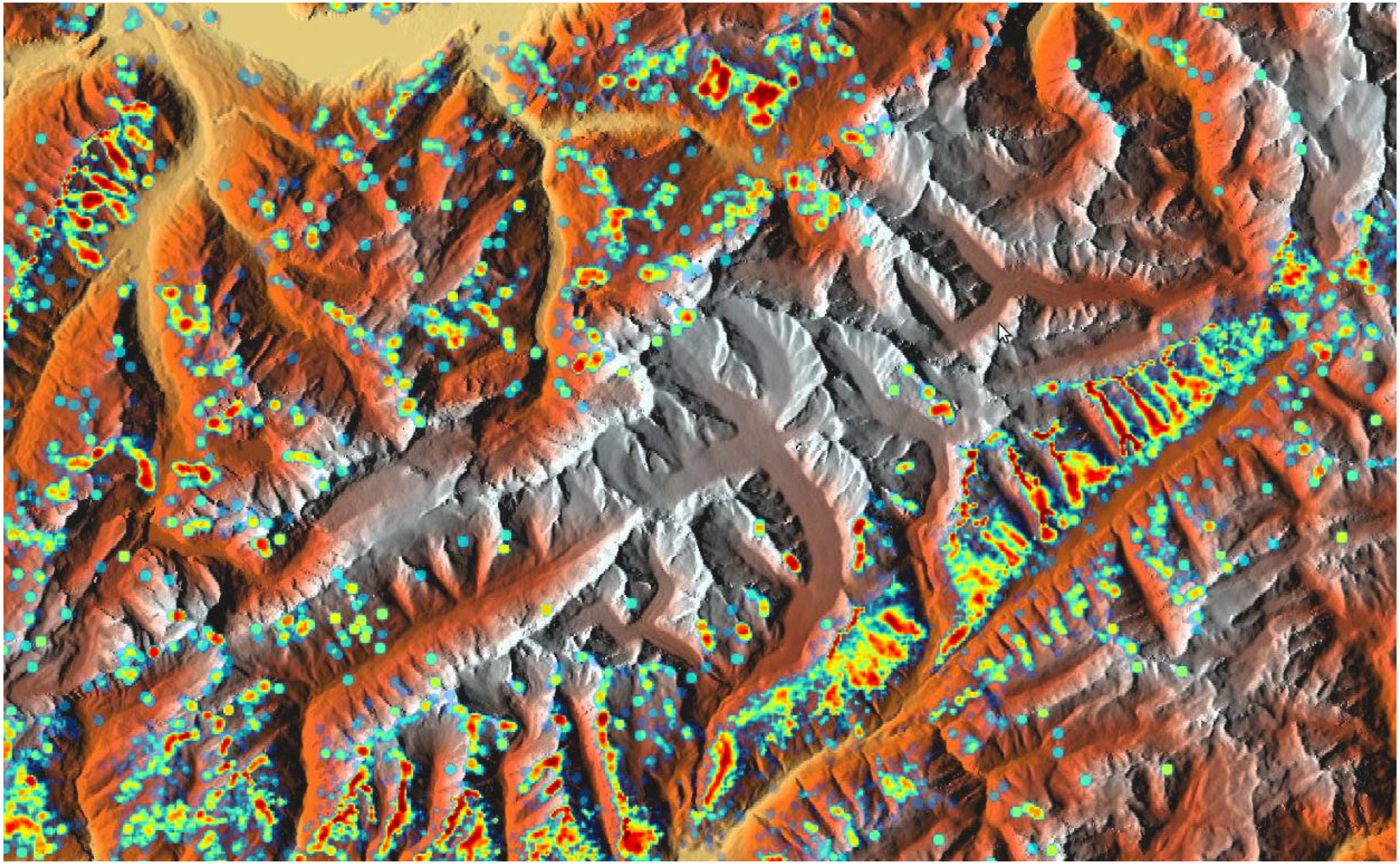
- Flight tracks are distributed very unequally



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

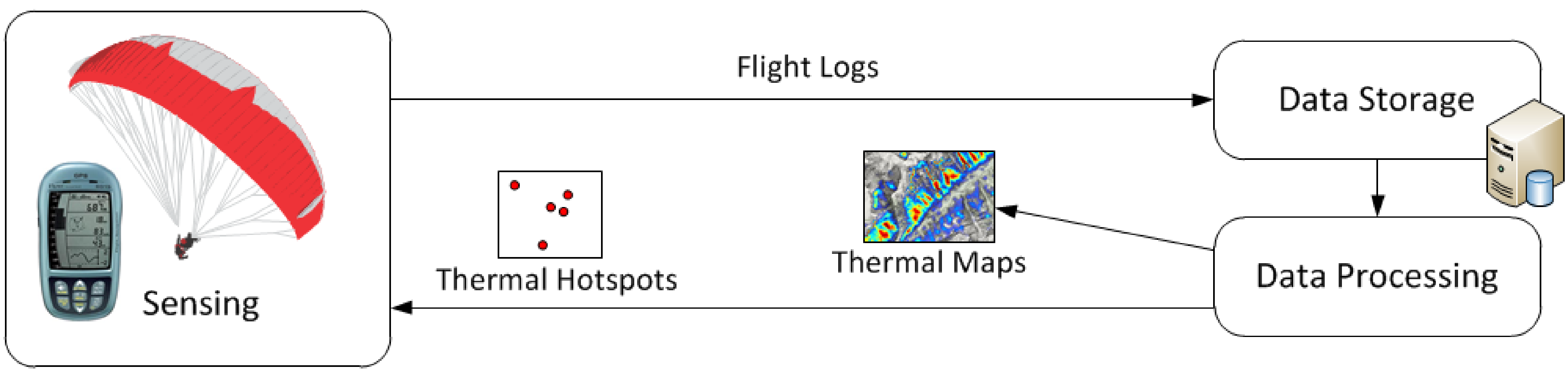
Solution: Probability based Thermal Maps

- Assign an uncertainty value to each thermal trigger point



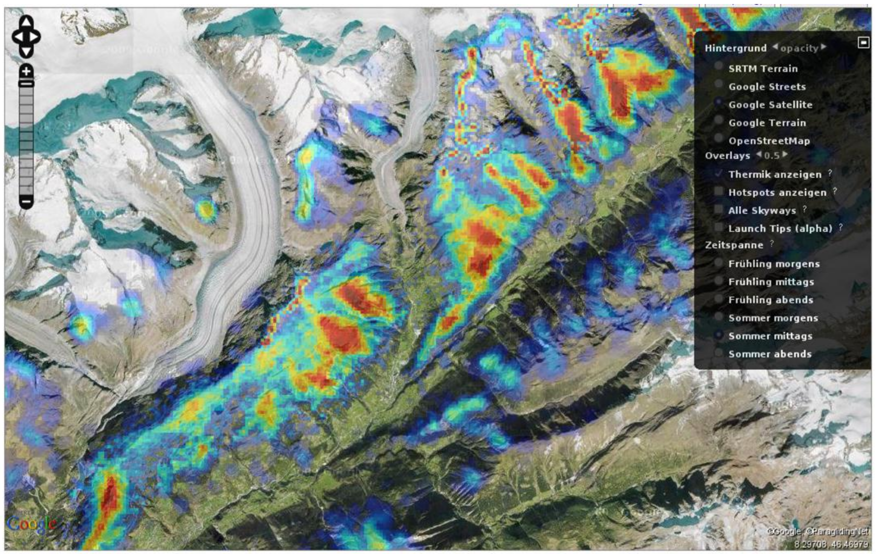
Closing the Loop

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

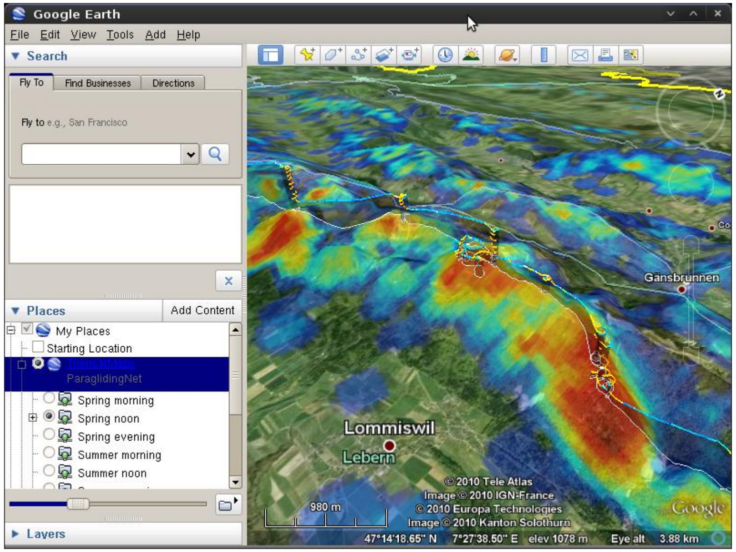


Feedback to pilots: Thermal maps

- Thermal maps for flight preparation



Google Maps

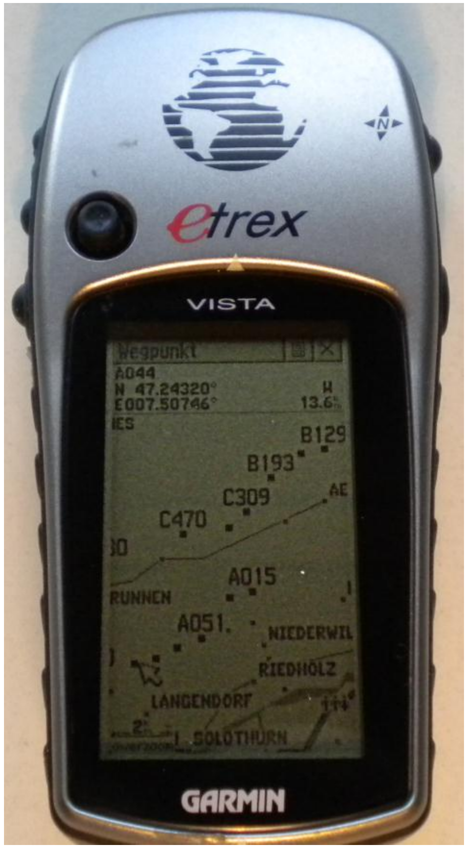


Google Earth

Website: http://thermik.kk7.ch

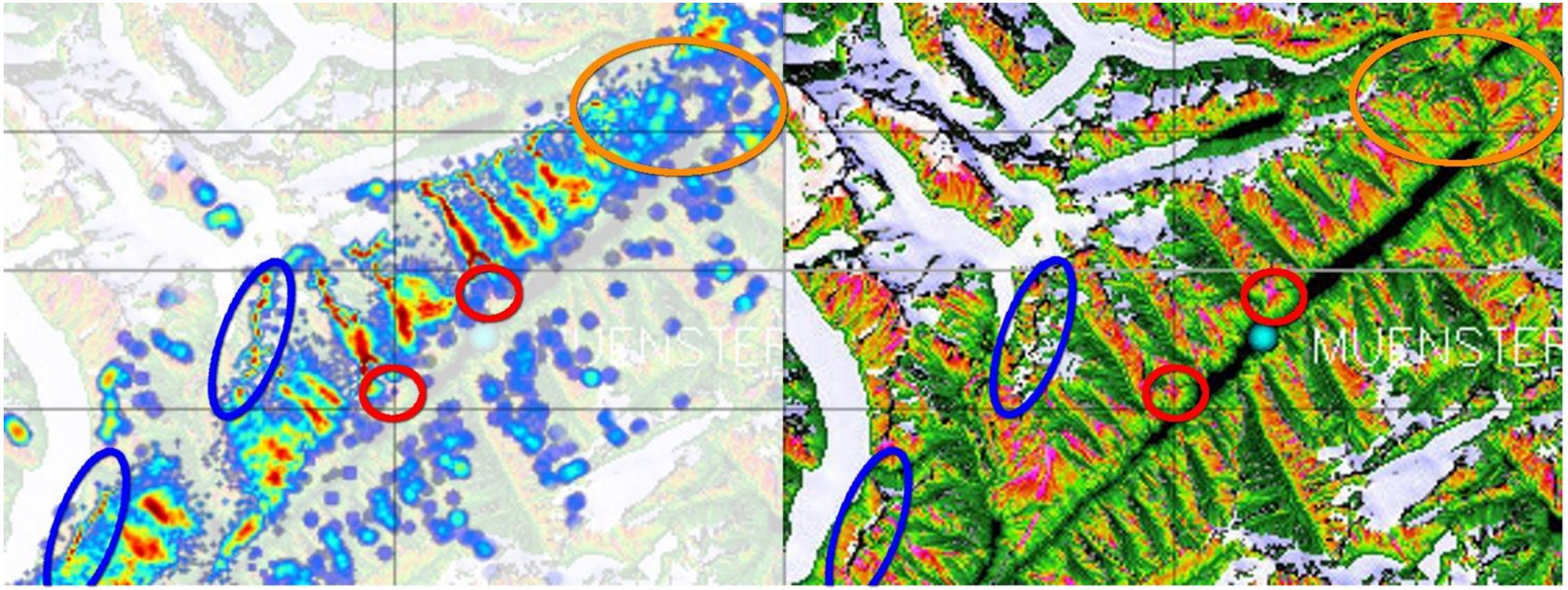
Feedback to pilots: Hotspots

- 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