Flying for Free

Exploiting the weather with unpowered aircraft

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What this talk is about

- Hacking the atmosphere.
- Birds, glider pilots and now UAVs can all fly for free by exploiting moving air in the atmosphere (soaring).
- Flights to over 50,000ft and distances of over 3,000km have been achieved in recent years.
- Soaring is an information problem involving lots of data analysis, modelling, prediction and optimisation.
- Increasing amounts of electronics and software involved.
- It's also a lot of fun, and a very cheap way to fly.
  - Learn to fly at a fraction of the cost of powered aircraft.
  - Own your own aircraft for less than 1500€!

Soaring aircraft

Launching

Aerotowing

- Behind a light aircraft, or a microlight for hang gliders.

Winch launching

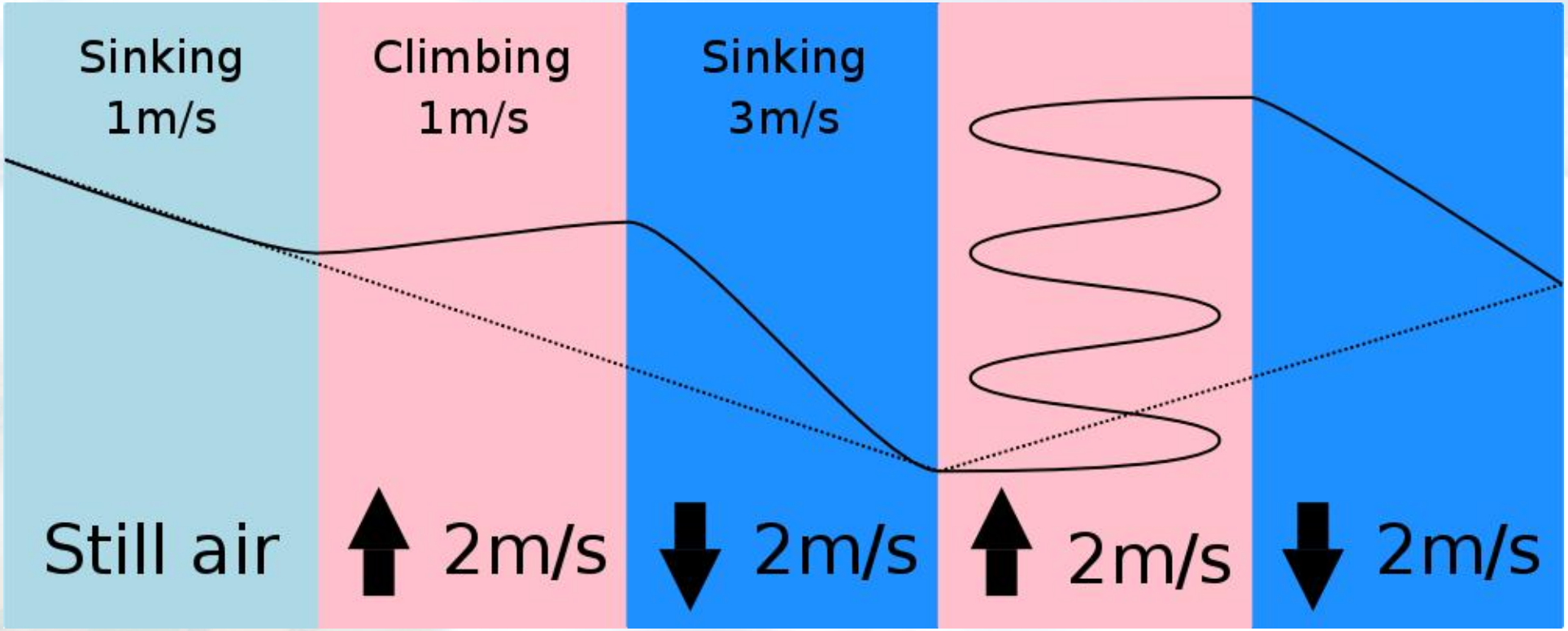
- Glider accelerated by a cable attached to a ground based winch.

Hilltop launching

- Foot launching for hang gliders and paragliders
- Bungee launching for gliders.

Exploiting rising air

- Air that is rising faster than the aircraft descends can be used to climb. We call this lift.

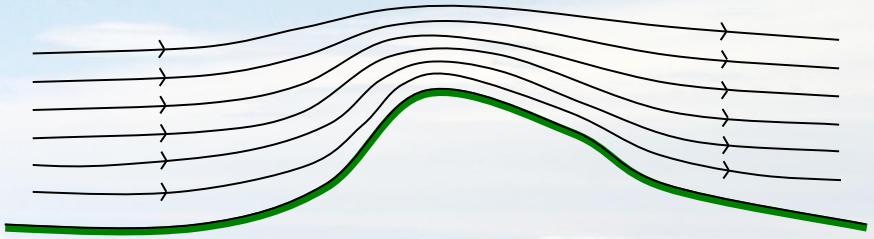


- All the vertical movement in the atmosphere averages to zero. To make an overall gain, we must fly to stay in lift.

Sources of lift

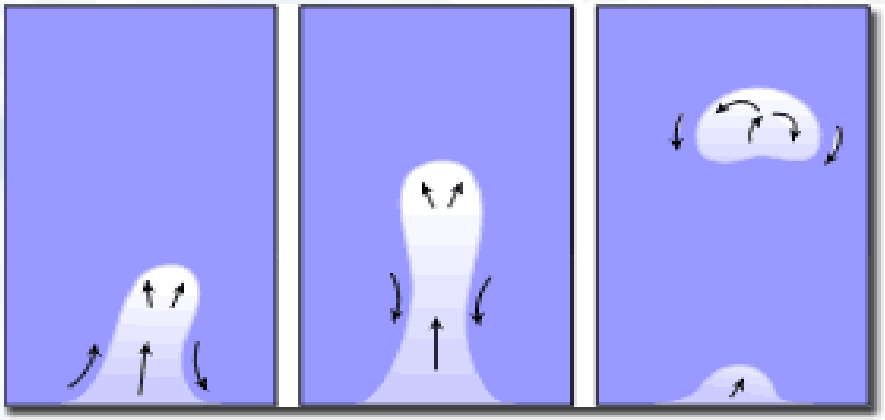
Hill lift

- From wind blowing up slopes.



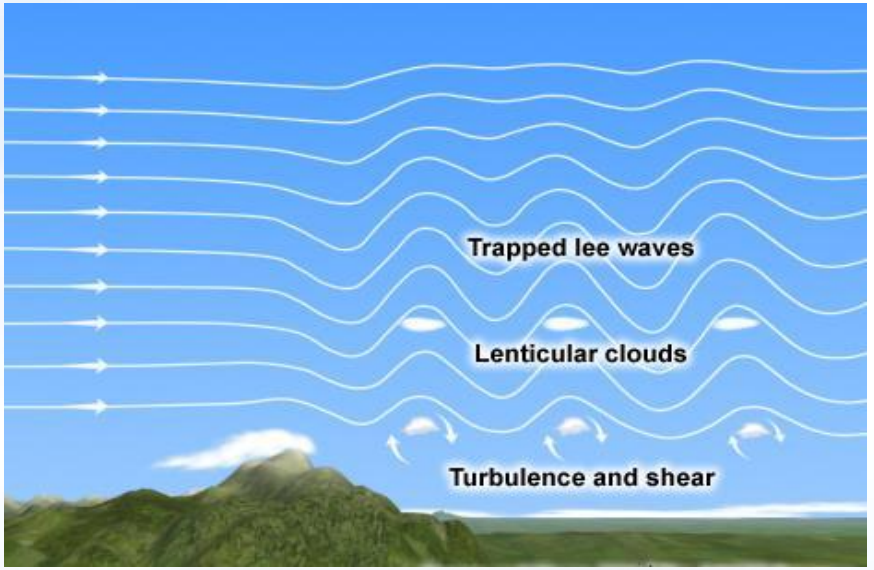
Thermals

- Bubbles of heated air rising through the atmosphere.



Wave

- Standing waves downwind of hillls and mountains.
- Can extend to over 50,000ft altitude, and hundreds of km away from the original hills.



Cross-country flying

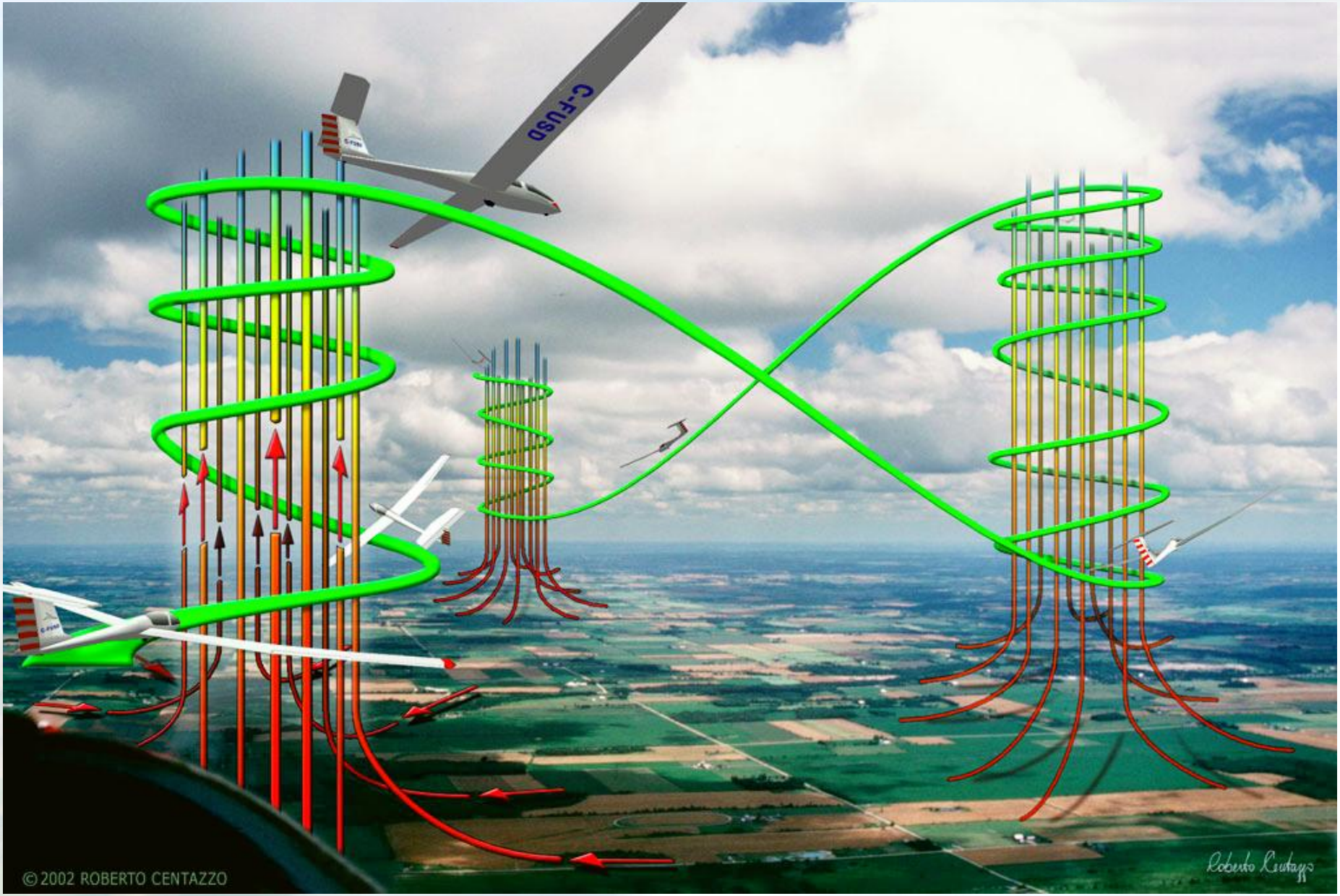
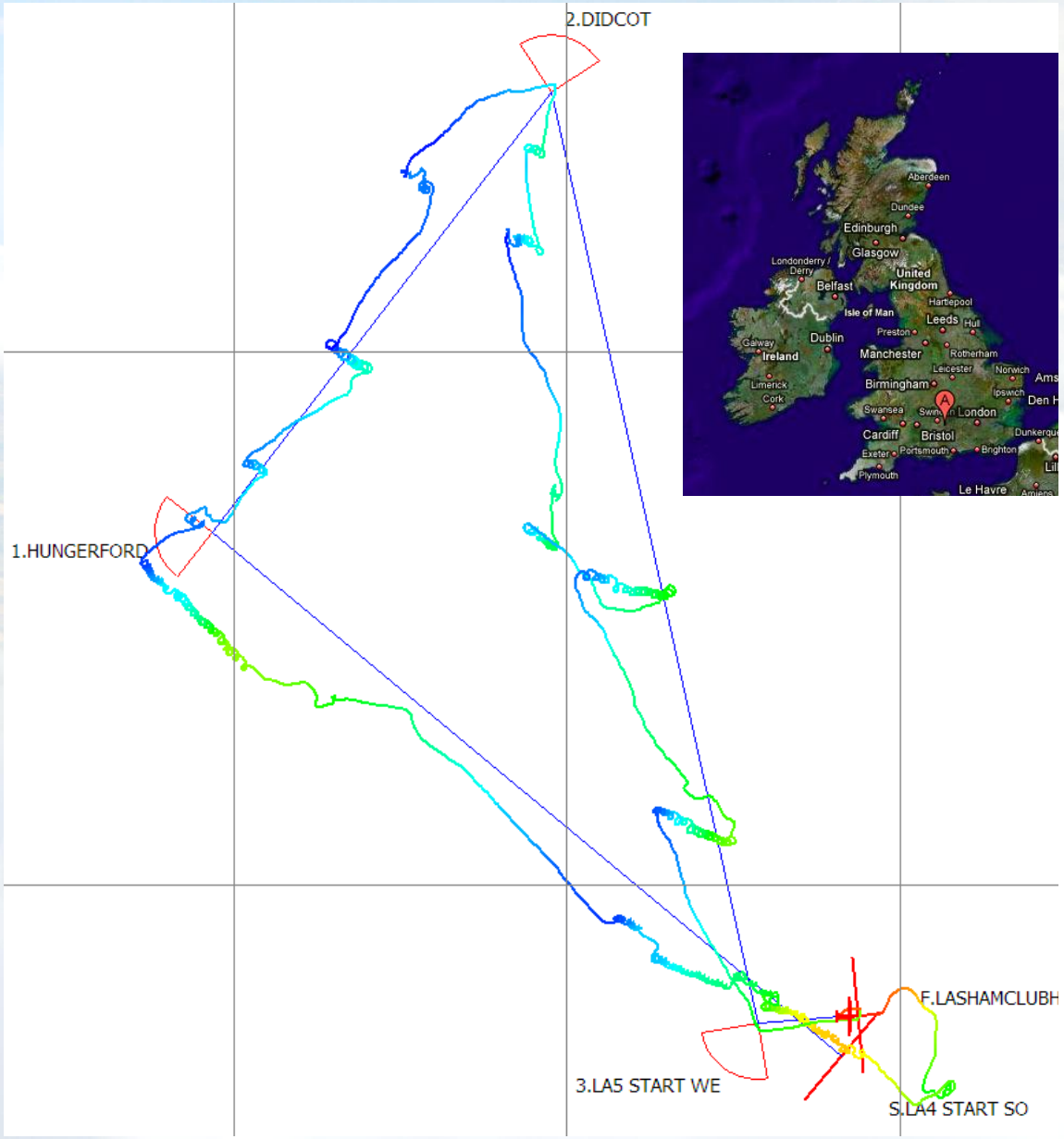


Image: Roberto Centazzo, York Soaring, Canada

Tasks

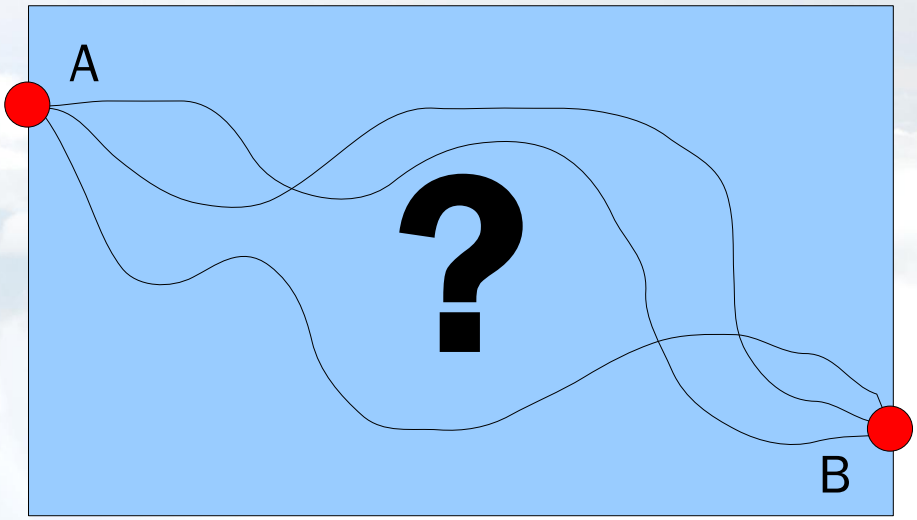
- Staying in the air is fairly easy.
- Going in a particular direction is harder.
- We set “tasks” (sequences of waypoints) as a challenge, and for competitions.
- The winner is the fastest pilot to complete the task.

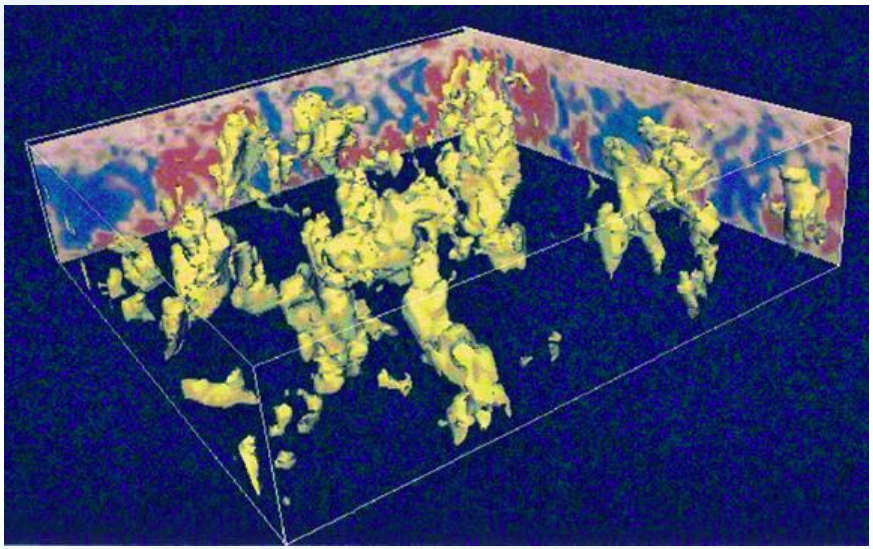


127km task, Lasham-Hungerford-Didcot-Lasham.

Optimisation problem

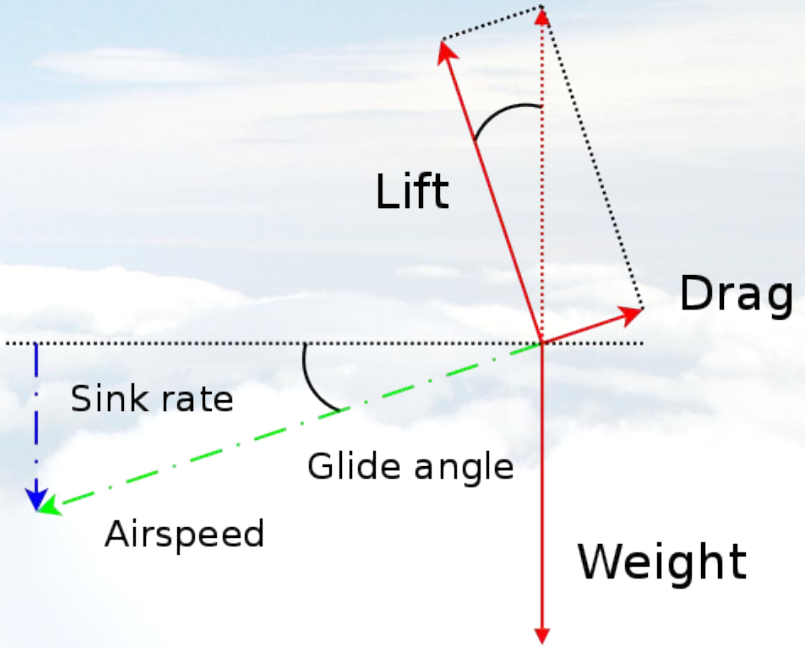
- How to get from A to B as fast as possible without touching the ground, through unknown air?
  - Time-varying 3D vector field.
  - We know the value at our current position, and recently behind us.
  - We can fit our measurements to expected patterns (e.g. thermals).
  - We can guess other values from visual information, e.g. clouds, ground features, birds, aircraft.
  - For this we must understand the weather that gives us lift.





Video

Glider performance



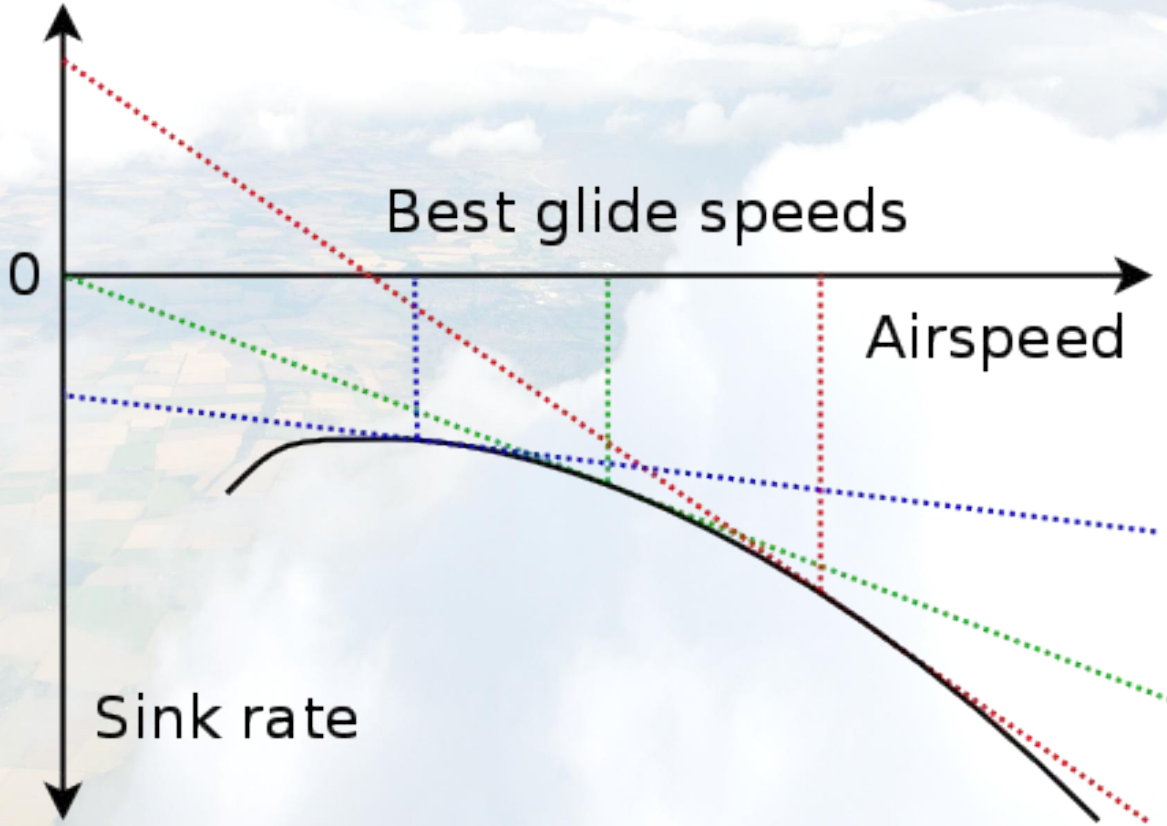
- Glide angle determined by ratio of lift to drag (L/D).
  - Determines glide range as a multiple of start height.
  - Sailplanes typically 30-50, but 72 has been achieved.
  - Hang gliders up to 20, paragliders up to 12.
- Other key factors are minimum sink rate, manouverability, and the relationship of L & D to speed.

Performance on a budget

- Gliders have lifetimes of decades, and older types can now be very cheap.
- E.g: our PZL SZD-30 Pirat
  - Designed 1966
  - Glide ratio: 33 at 82km/h
  - Minimum sink: 0.7m/s
  - Maximum speed: 250km/h
  - Value: around 2000 €
- Older types even go “free to a good home”, needing some maintenance work.

More about performance

- **Polar curve:** relationship between airspeed and sink rate. Specific to a particular aircraft and configuration.



- Can be used to find optimal speed to fly, for a given combination of lift/sink and expected future lift/sink.

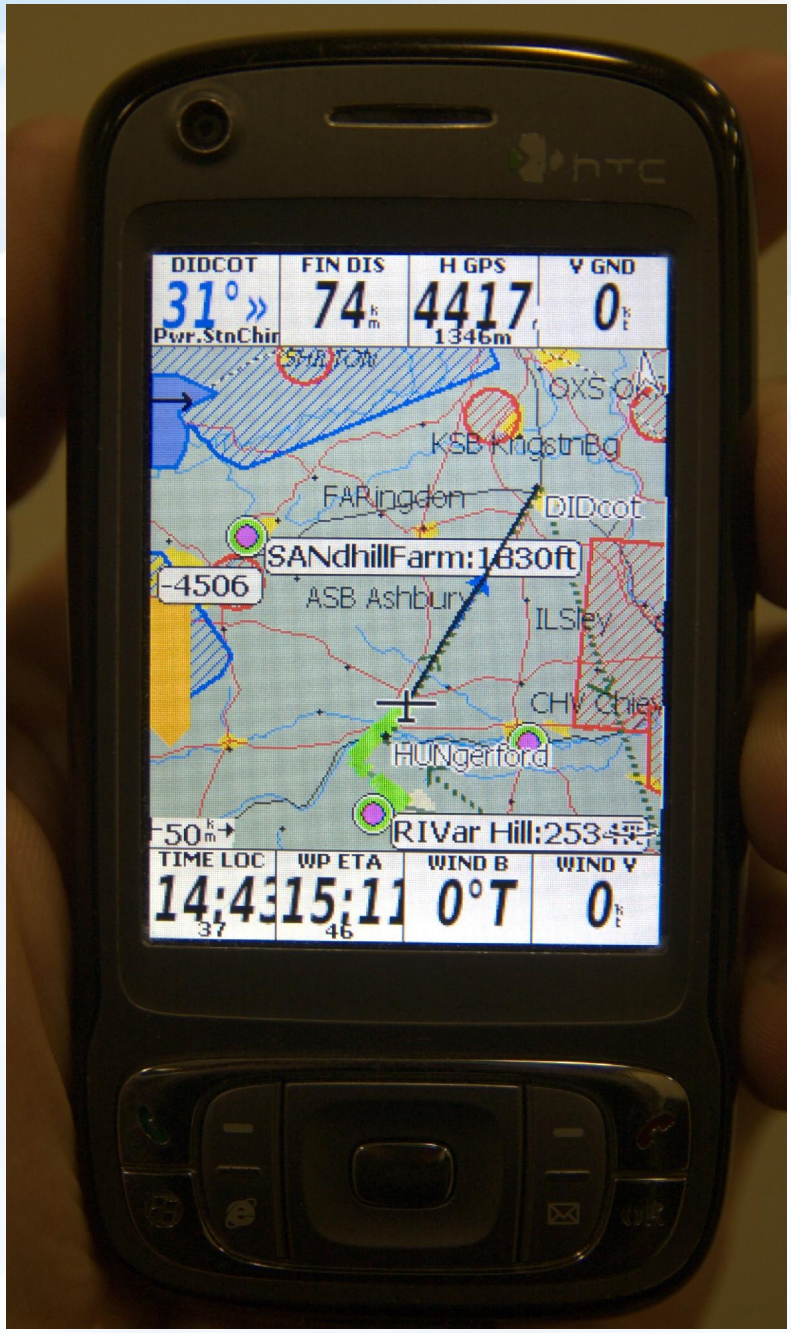
Instruments & Equipment

- Airspeed Indicator, Altimeter, Variometers, Artificial Horizon, Compass, Radio, Parachute, Oxygen, GPS, Flight logger, PDA.

Flight logging

PDA flight software

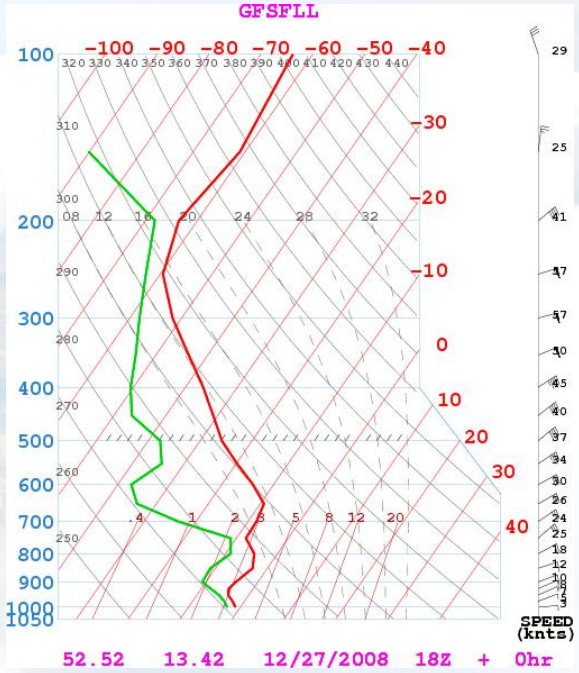
- Many pilots now fly with a PDA running specialised software for:
  - Navigation (moving map).
  - Airspace awareness.
  - Lift plotting and centering.
  - Final glide calculations.
- Several commercial products now being overtaken by an open source project, XCSoar.
  - http://www.xcsoar.org/
- Runs on WinCE devices.

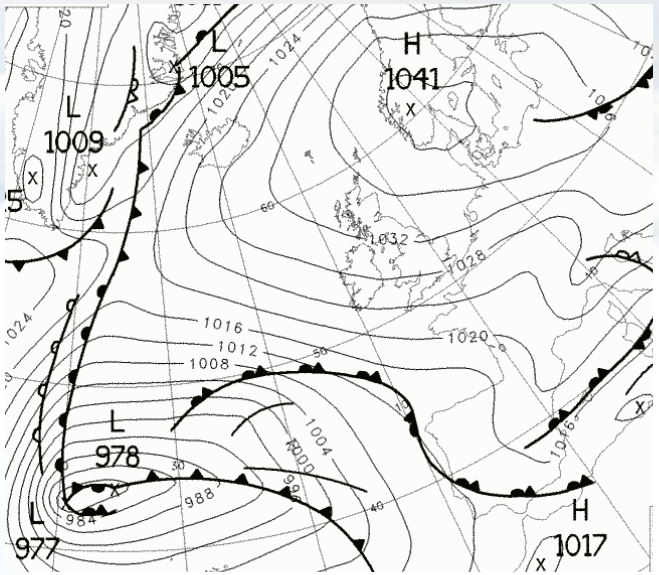


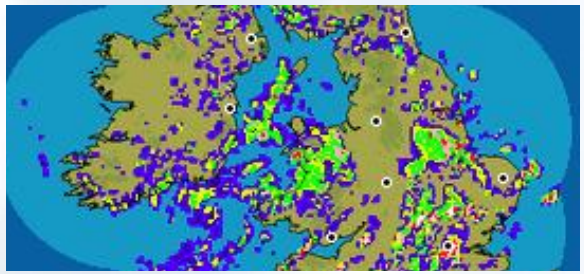
Weather forecasting tools

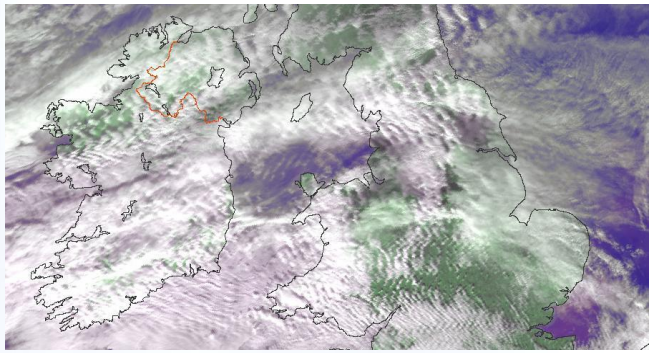
- Predicting soaring conditions helps decide when to fly, where to go, and what to expect. Traditional resources:
  - Synoptic charts
  - Local forecasts
  - Soundings
  - Satellite images
  - Rainfall radar

0300		3°C	ESE	6 mph	Moderate
0600		3°C	ESE	5 mph	Moderate
0900		3°C	E	7 mph	Very Good
1200		4°C	E	6 mph	Very Good
1500		4°C	ENE	6 mph	Good
1800		4°C	E	7 mph	Good
Night		4°C	E	9 mph	Good





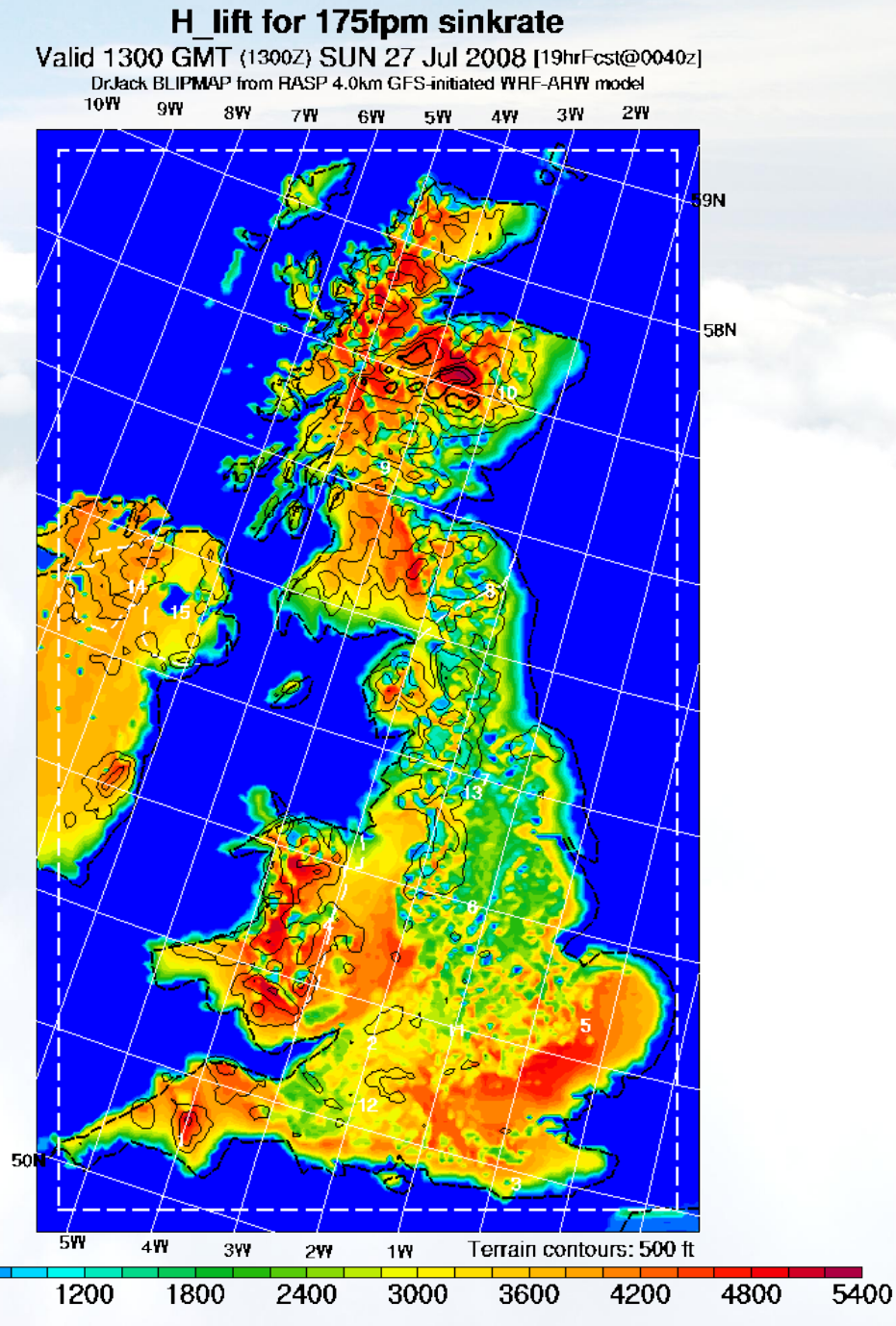




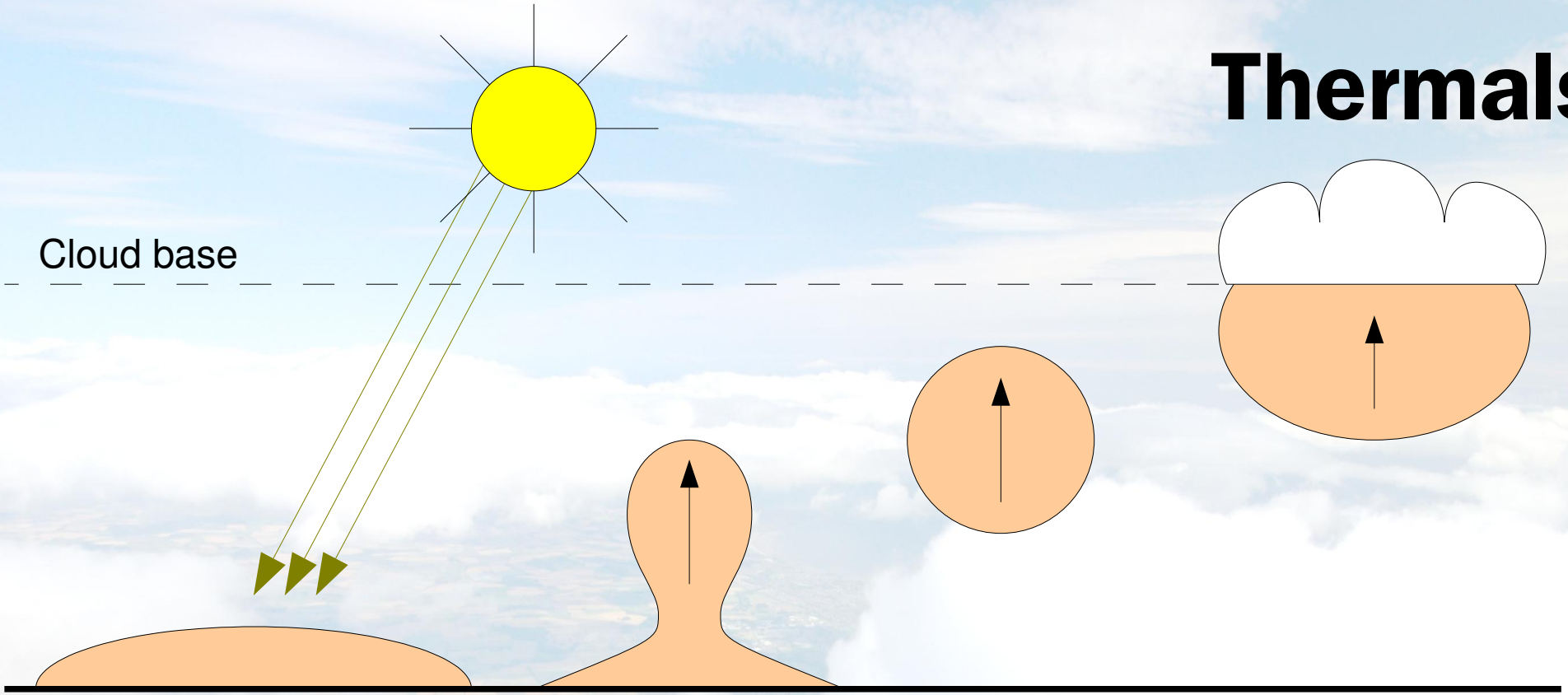
- It take skill and local experience to forecast soaring conditions accurately. Often there is insufficient detail.

DIY high resolution forecasts: RASP

- High resolution (down to 1km) atmospheric models, seeded from sounding data and global forecast models.
- Run on Linux, 3-4 hours to execute on a good PC, results from regular runs for various areas are posted online.
- Perl script using WRF model, NCR plotting tools, and data available over the net.
- Full 3D atmospheric state available for plotting.
- http://www.drjack.info/RASP/



Thermals



- The sun heats the ground, which in turn heats the air.
- A bubble of warm air builds up close to the ground.
- Various triggers can cause the bubble to begin to rise.
- With a suitable temperature profile in the atmosphere, the bubble will continue to rise upwards.
- Cumulus clouds form when the rising air cools enough.

Thermals in action

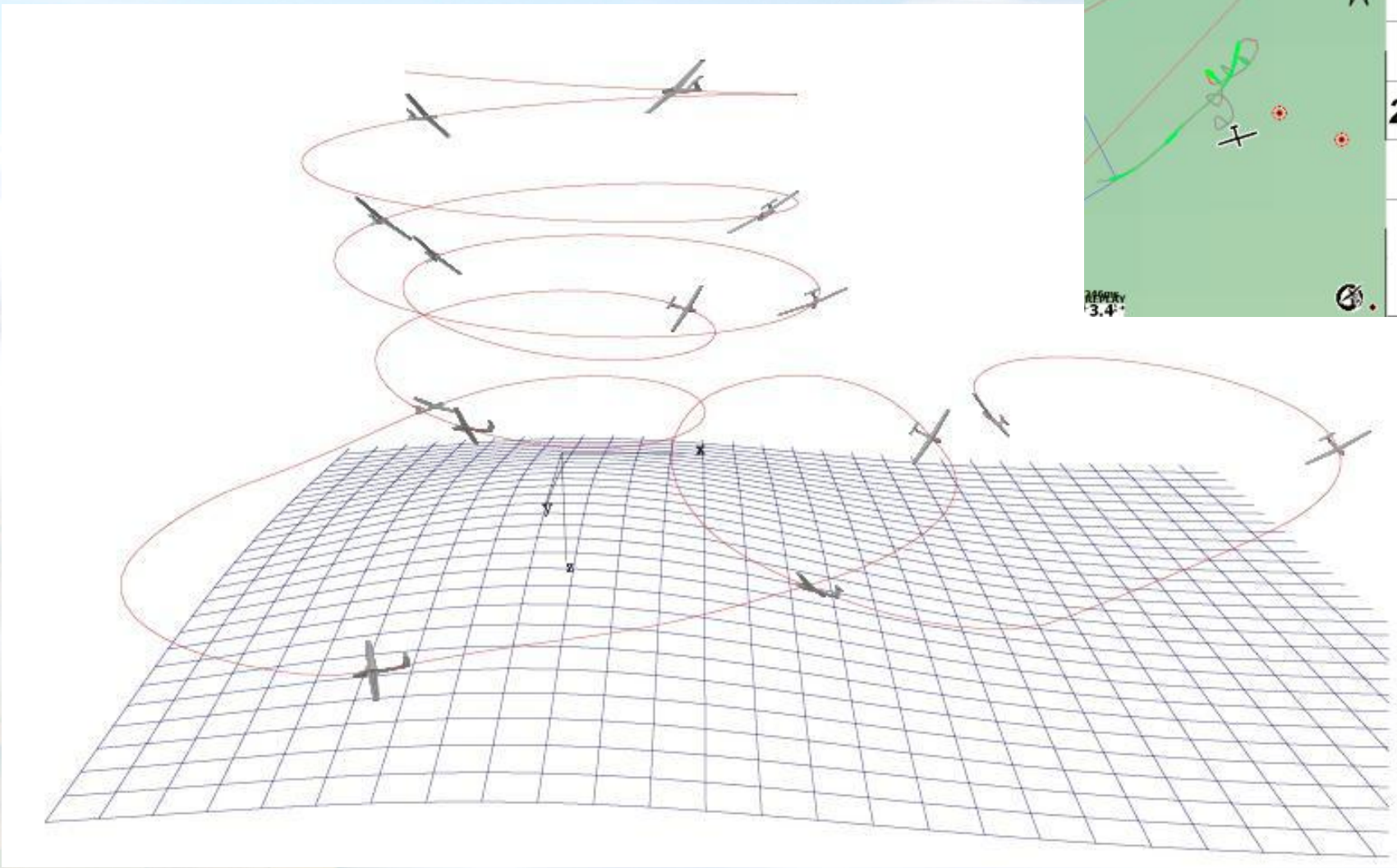
Clip from “Sky and clouds" by Bitlas: http://www.vimeo.com/1310438


winter
km
ON
OFF
MUT
TEMP

Finding thermals

- Visual cues
  - Clouds
  - Terrain shape
  - Different surfaces
  - Other gliders
  - Birds
  - Sun on ground
- Blind search
  - Fly in a straight line or search pattern, wait for lift.

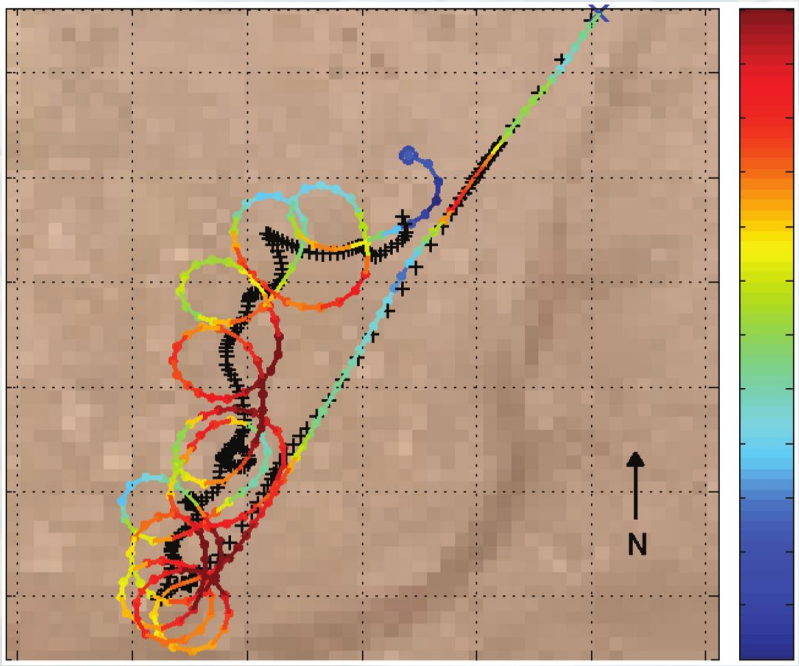
Centering in a thermal



- This is a classic hill climbing problem!
  - Requires a good mental or software model of thermals.

Autonomous thermal soaring

- NASA 2005 (M. Allen)
  - First working attempt.
- NCSU 2008 (D. Edwards)
  - 97km flight in October.



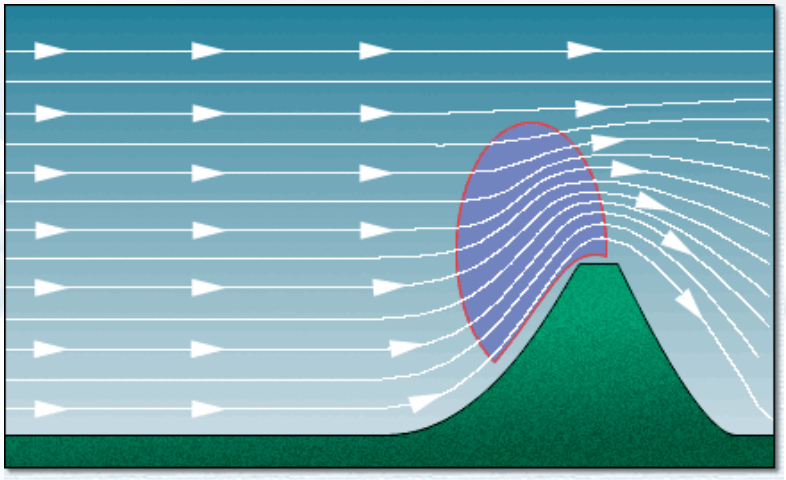
NASA paper:
http://dtrs.dfrc.nasa.gov/archive/00001620/

Dan Edwards' site:
http://soaring.goosetechnologies.com/

- Both fly until they encounter lift, then try to center in it.

Hill lift

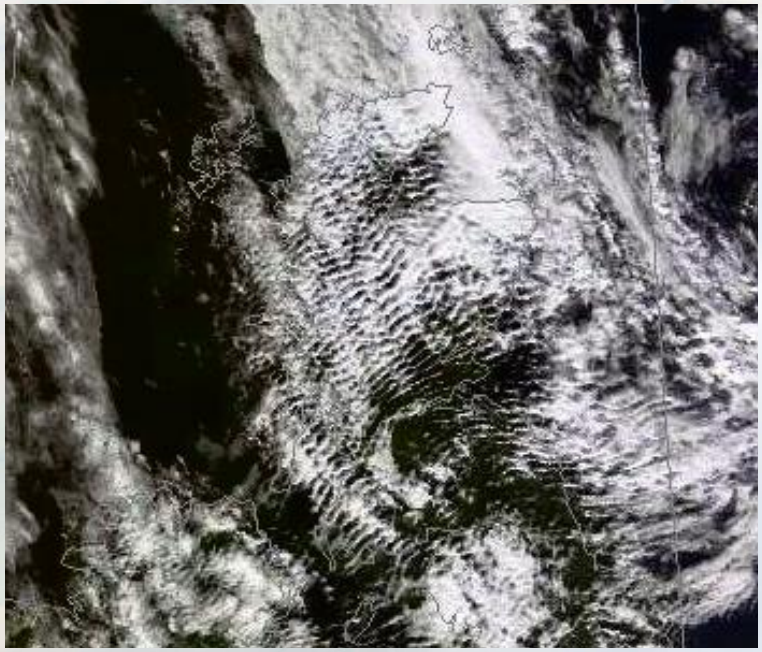
- Where wind meets a hill, the air is forced to rise.
- This has a knock-on effect to the air above. Lift often works to 500m above hilltop height.
- Very predictable: determined by wind speed and terrain.
- Smooth slopes are better than sharp cliffs (less turbulence).
- Prolonged cross-country flight between ridges is possible.

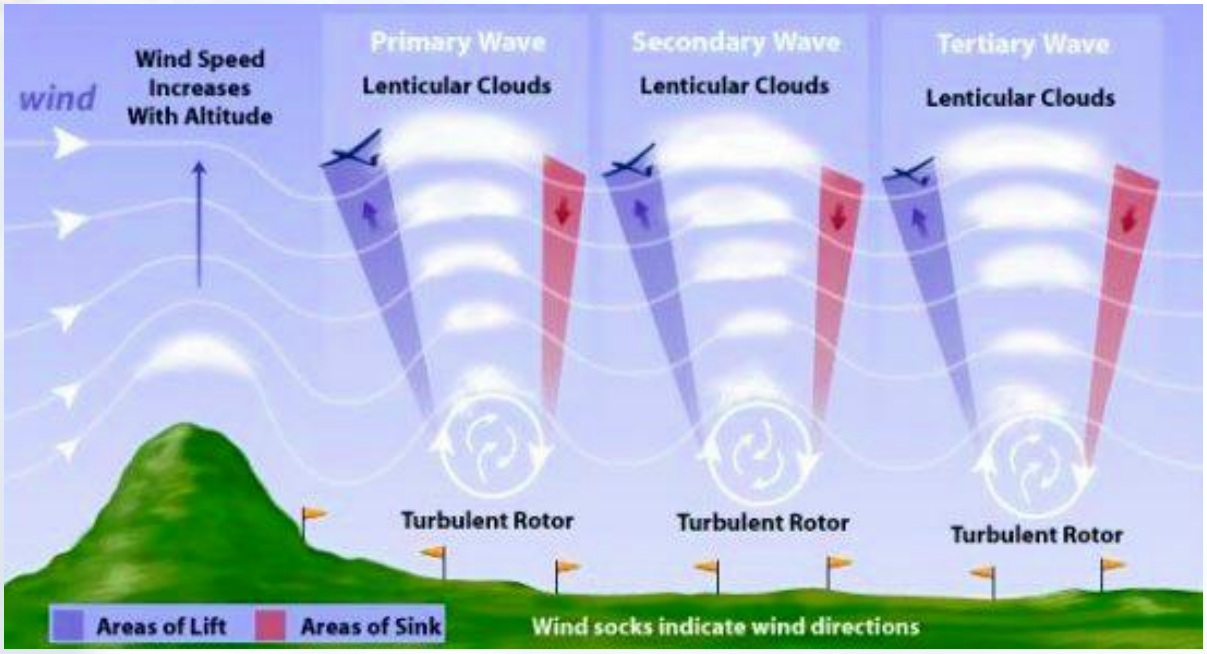


Mountains not required

Wave

- Standing waves downwind of hills.
- Extend to high altitude: 3-6km is common, 15km possible.
- Can extend hundreds of km downwind of the original hills.
- Marked by static bars of cloud.

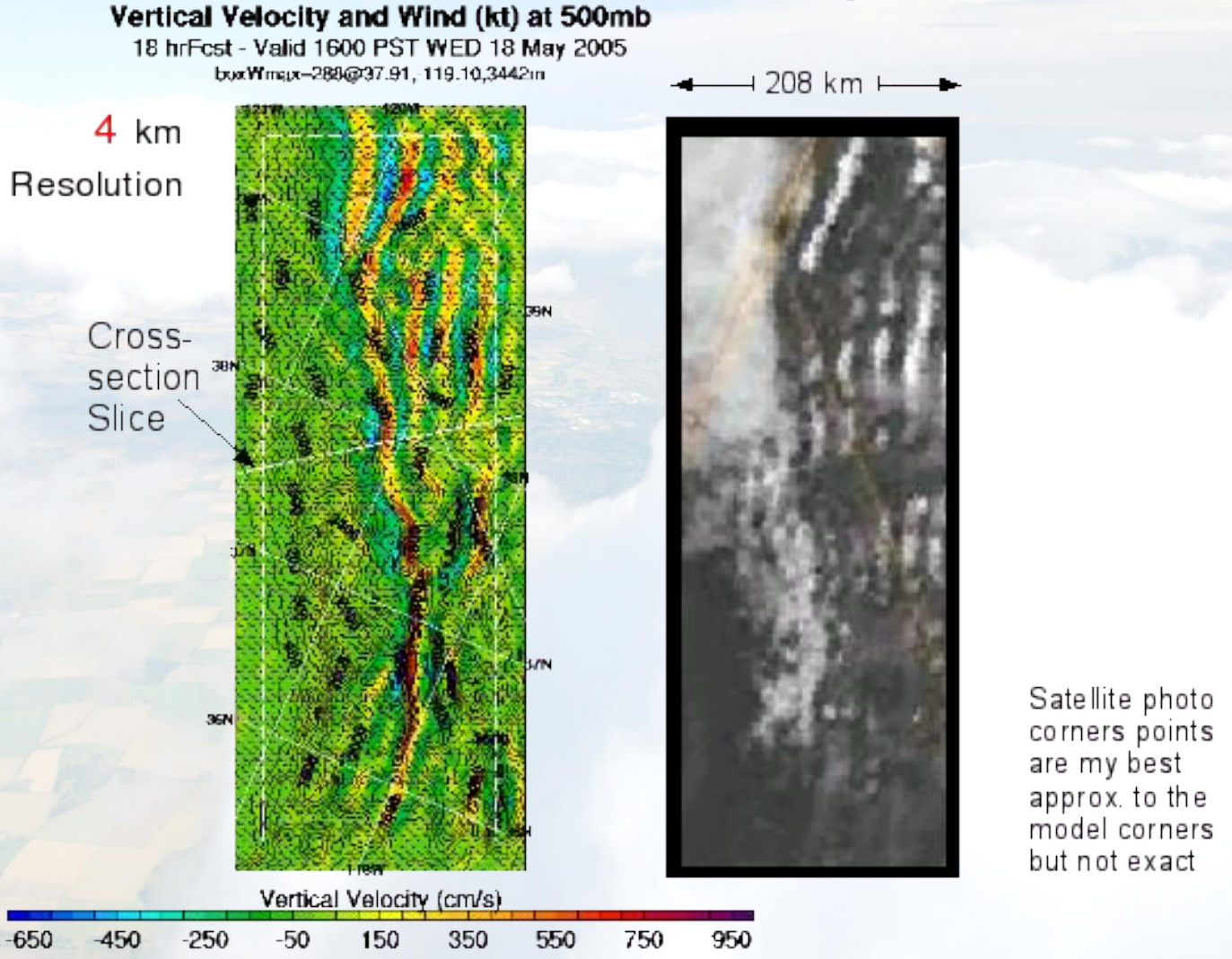




Wave bars

Forecasting individual waves

Sierra Wave – Vertical Velocity vs Obs.



Satellite photo corners points are my best approx. to the model corners but not exact

Image: Dr John Glendining ("DrJack")

From http://www.drjack.info/twiki/bin/view/BLIPinfo/MtWavePrediction

The future

- Soaring is an information sport, and greater acheivements will come from better information.
  - More weather data from ubiquitous distributed sensing.
  - High resolution weather modelling in near real time.
  - Human and robot pilots will have a lot to learn from each other.
- Our biggest challenge is political: excessive regulation and the continued growth of restricted airspace.
- Try it while you still can.

Getting involved

- Flying is usually done in clubs, most will offer training.
  - Look up your local clubs via your national organisations:
    - http://start.fai.org/gliding-federations.asp
    - http://start.fai.org/hg-federations.asp
- Basic training up to going solo.
  - On gliders – maybe £500-1000 cost to solo (40-50 flights). Easily done in a few months, if you fly regularly.
  - Plenty of opportunity for interesting flying in two-seaters before going solo. After the first few flights you'll be doing almost all the flying.
- Some further training needed for cross-country flying.
  - Mostly related to navigation, and field landings.

It's an adventure!

- You never quite know where you'll end up...

Extra slides beyond here

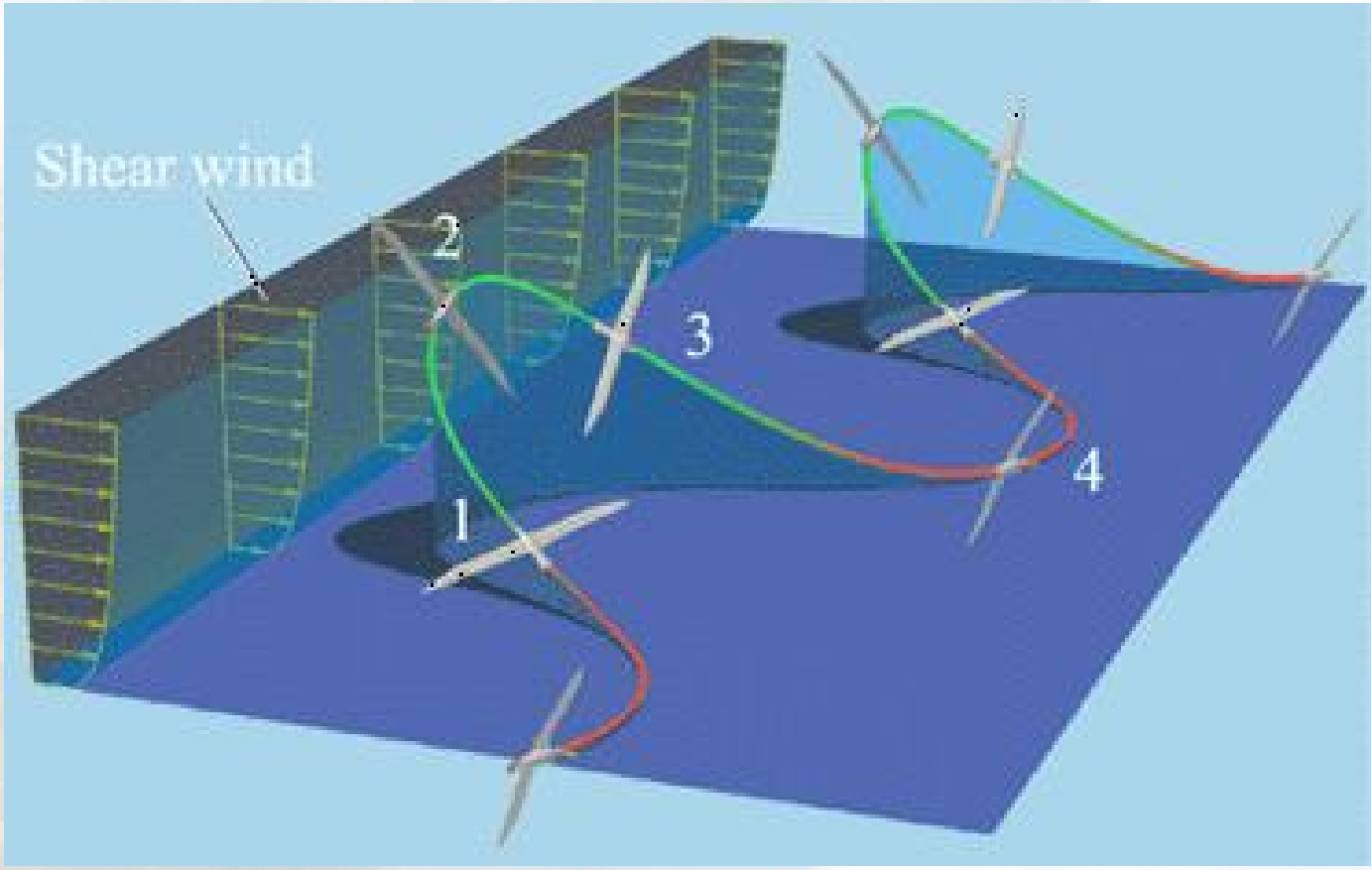
Realtime tracking

Telemetry, TV cameras, chase helicopter and long range microwave links.

Clip from “Gladiators of the Sky” DVD, showing 2006 Gliding Grand Prix, NZ

Dynamic soaring

- A different way to soar, using differences in wind speed.
  - Gain airspeed by climbing through a wind gradient.
  - Dive back into slower air and repeat.



Dynamic soaring with RC gliders