

小型無人飛行機の開発と南極・デセプション島での 空中磁気観測

船木 實 (元・極地研), Ant-Plane グループ



Ant-Plane Project

Model airplane technology and commercialized parts

Cooperated with amateur model airplane groups

More than 500 km flight in Antarctica

Flight in calm wind and higher than -15°C in temperature

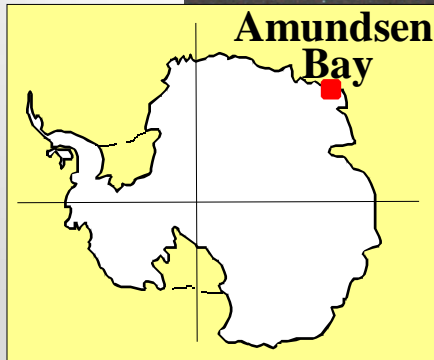
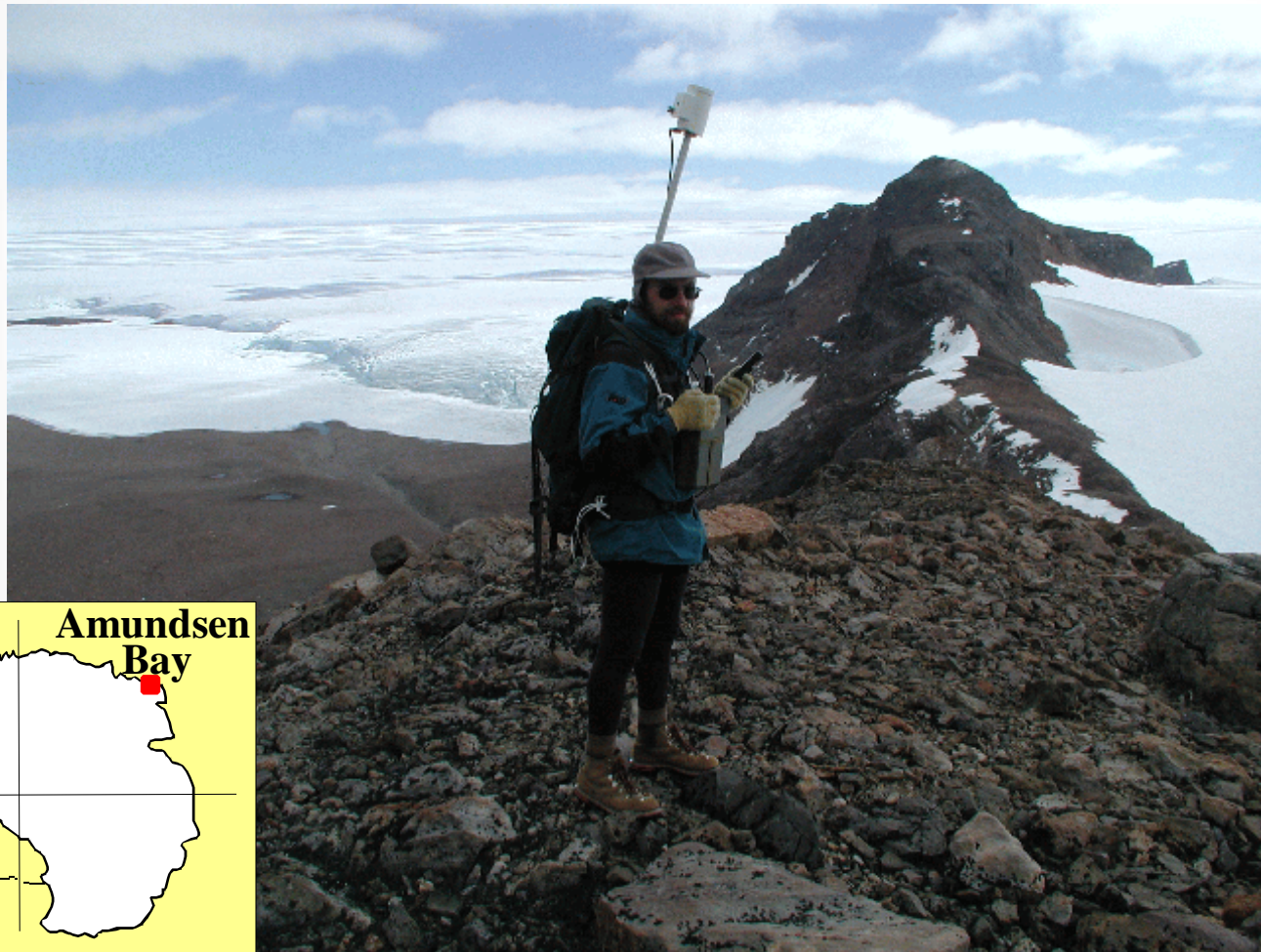
Onboard space of the scientific instruments in the model airplane

Autonomous flight in cruising, while takeoff and landing by manual

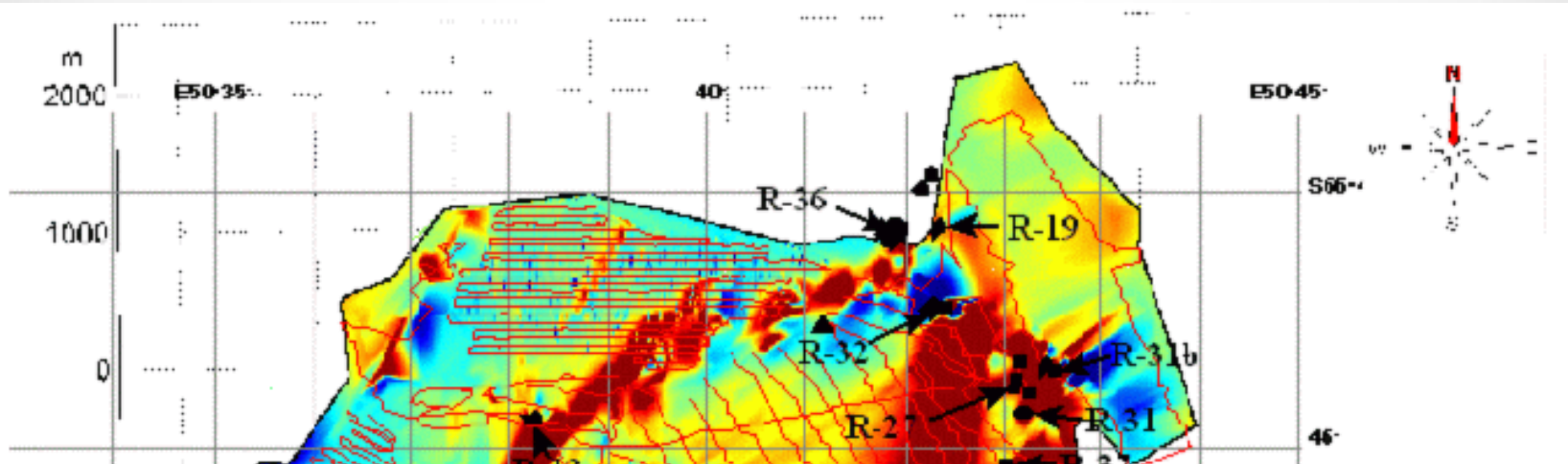
Development of onboard scientific instruments

Why did we start this project?

**JARE 42: 2000-2001, Magnetic survey
at Riiser Larsen Mt., Amundsen Bay**



Magnetic anomaly



300 km on foot / 2 months

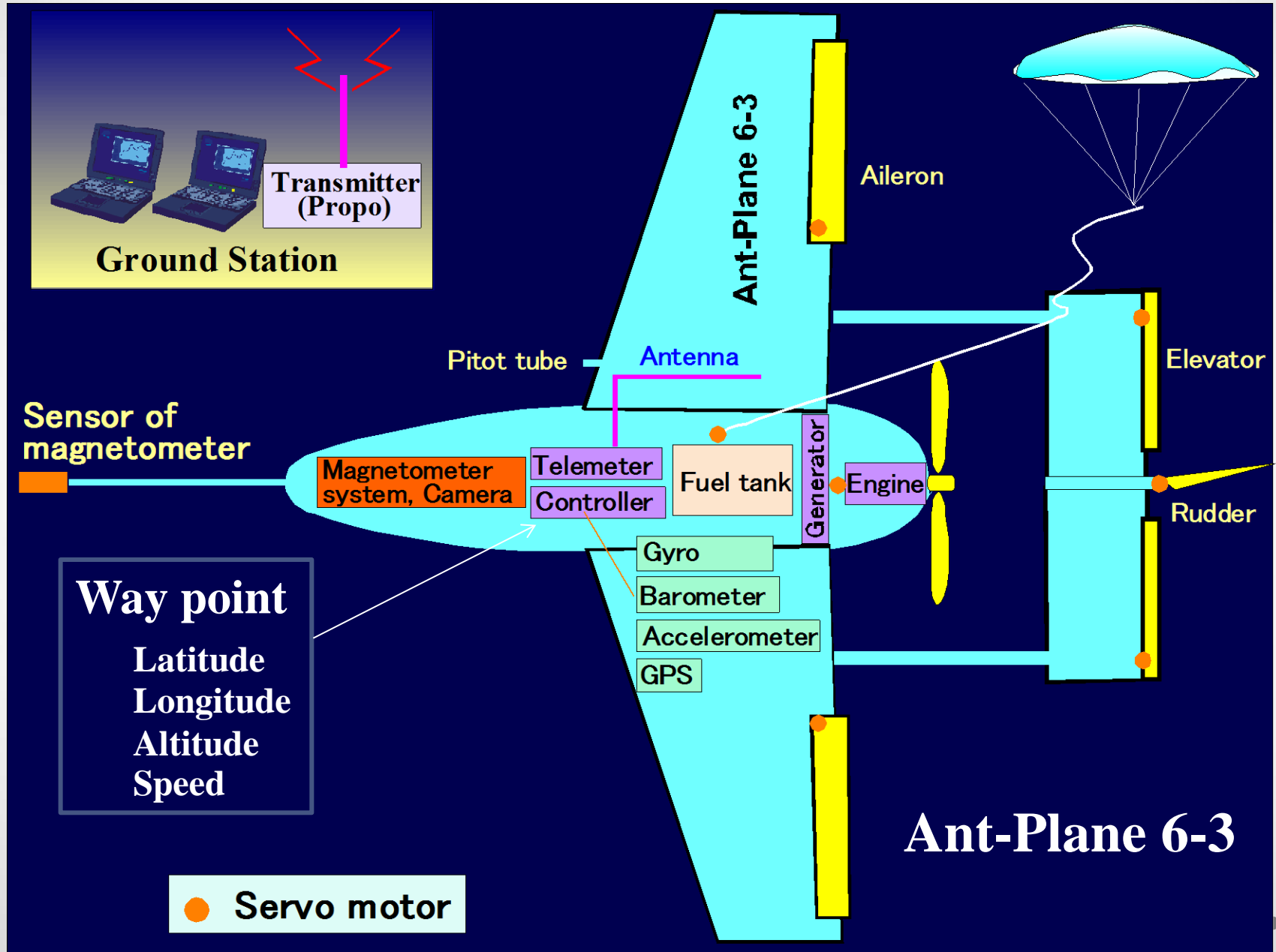
It was too low efficient !!

Magnetic anomaly gives information for mineral resources and volcanic activity

Background for development of UAV

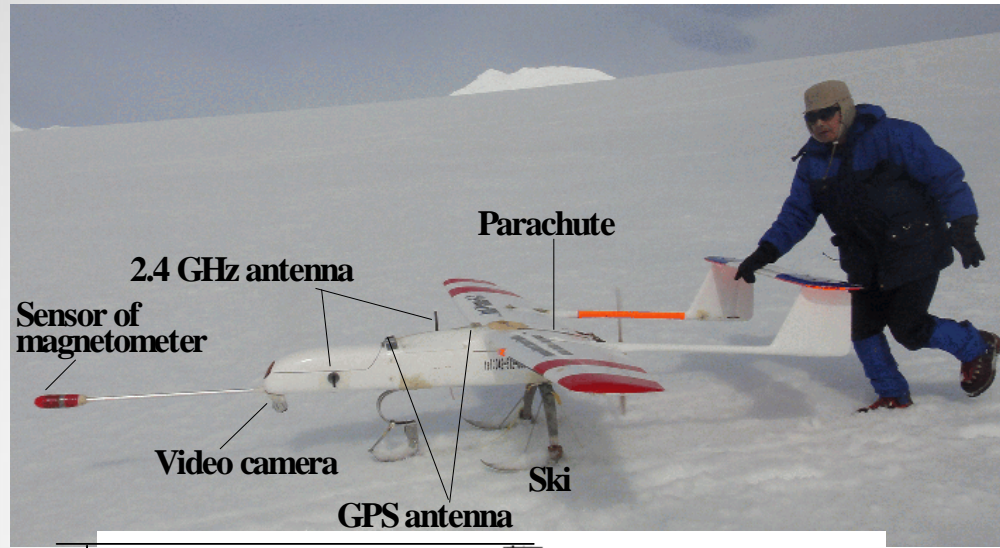
- **May 2000, the accuracy of GPS was improved horizontally from 100 m to 10 m**
- **the reliability of computer and electronic devices increased**
 - **accompanied by a decrease in size, weight, and power consumption**
- **August 2003, TAM 5 flew 3,020 Km from Newfoundland in Canada to Ireland**
 - **3,020 km, 38:23**
- **NIPPI Co. developed UAV in 2002**

Outline of the control system



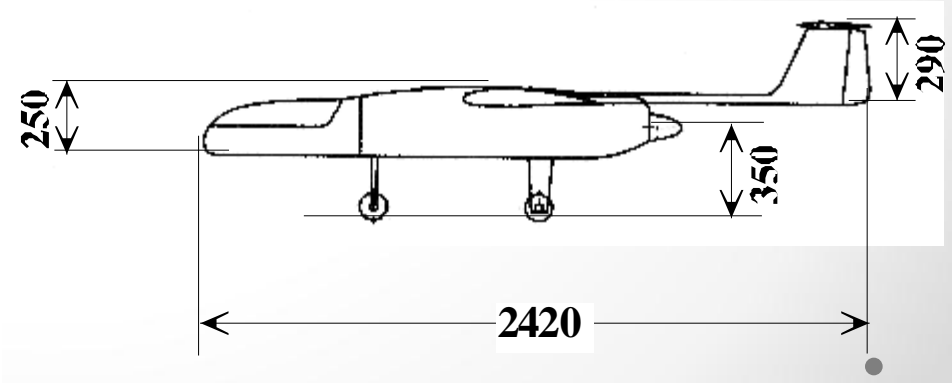
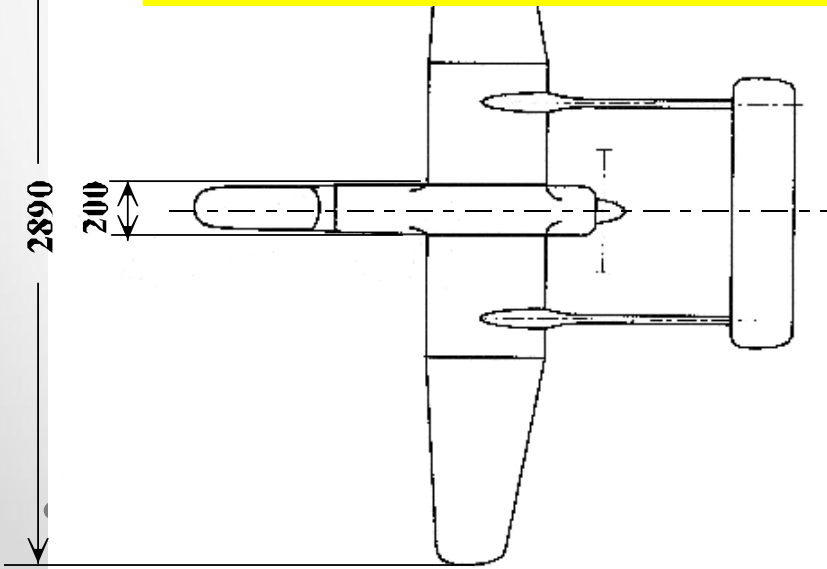
Ant-Plane 6-3 with magnetometer

- pusher type
- dry weight: 20 kg
- length: 2.42 m
- wingspan: of 2.89 m
- distance: 500 km
- engine: 86 cc two-stroke
- fuel: 10 liter gasoline
- cruising time: 5 hours
- cruising speed: 100-120 km/h
- dynamo: 25 W
- payload: 2 kg

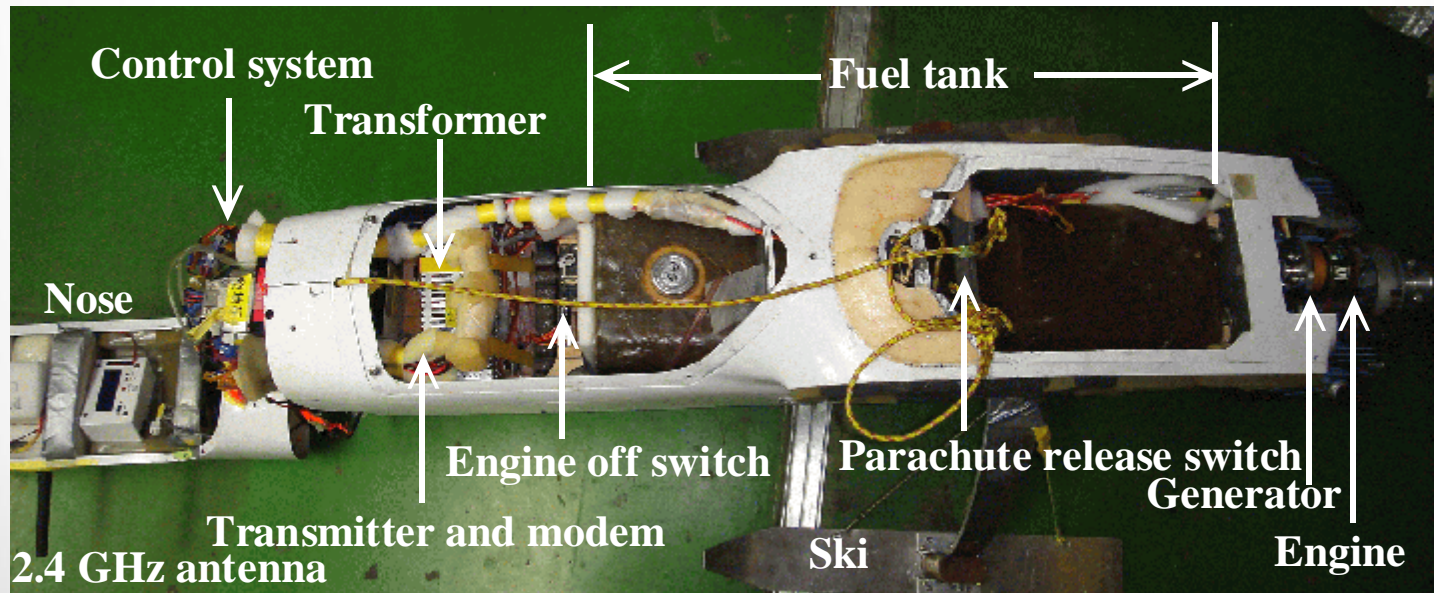
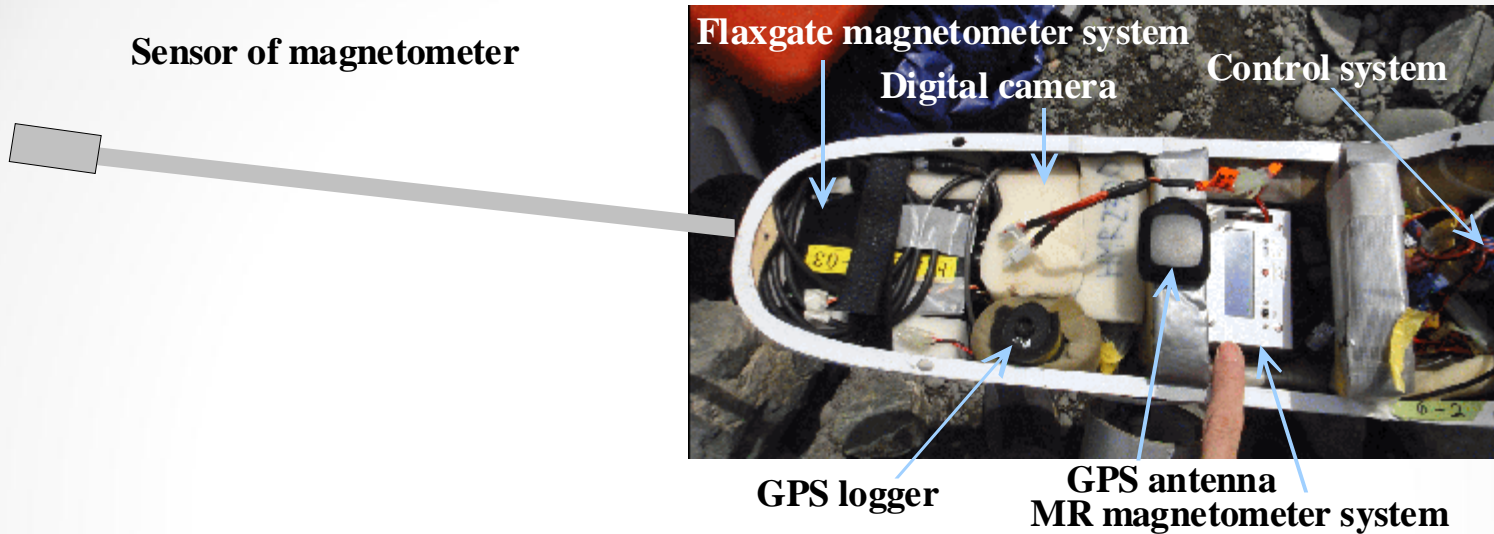


Cost: 20,000 US\$

parachute
on: 5 km



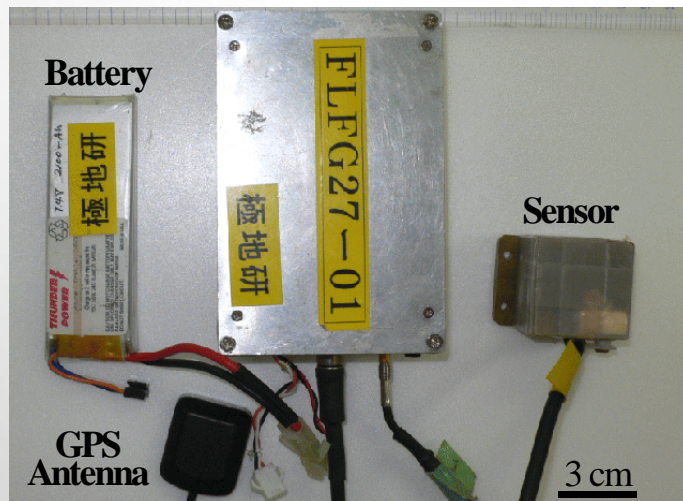
Inside of body, Ant-Plane 6-3



Onboard Magnetometer

Magnetometer	Field	Sensitivity nT	Weight kg	Price US\$	
Station magnetometer					
Cesium	total	0.01	2-4	40,000	
Overhauser	total	0.1	2	20,000	
Proton	total	0.1	4	15,000	
Fluxgate	xyz	0.1	1-3	15,000	
Mobile magnetometer					
Fluxgate	xyz	0.1	0.4	6,000	data logger+GPS
Magneto-resistant	xyz	7	0.4	3,000	data logger+GPS

A three-component fluxgate magnetometer system



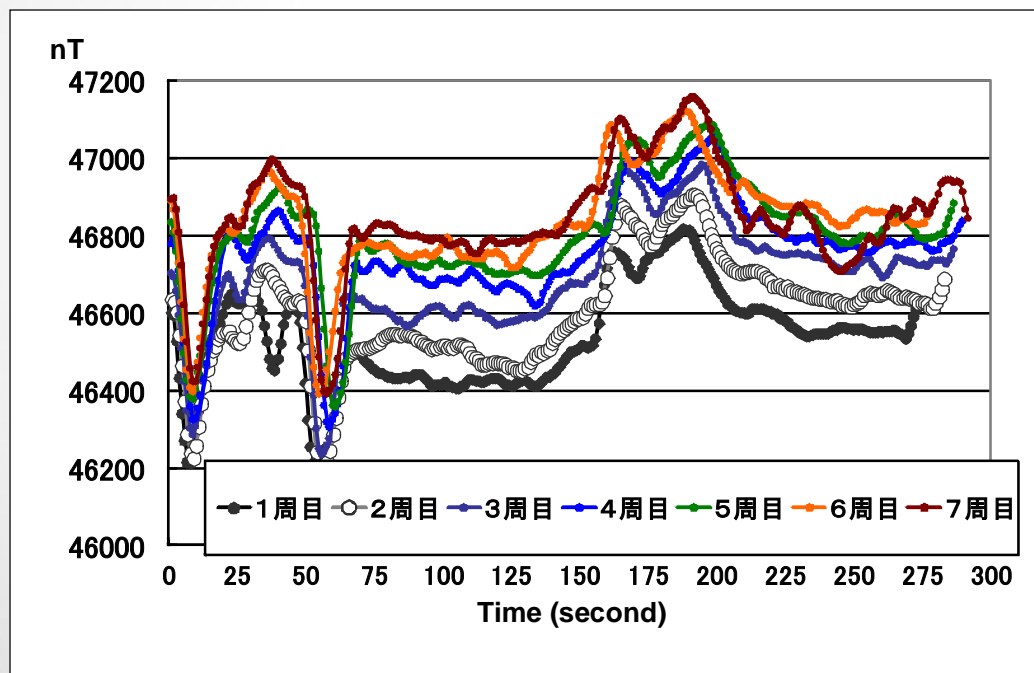
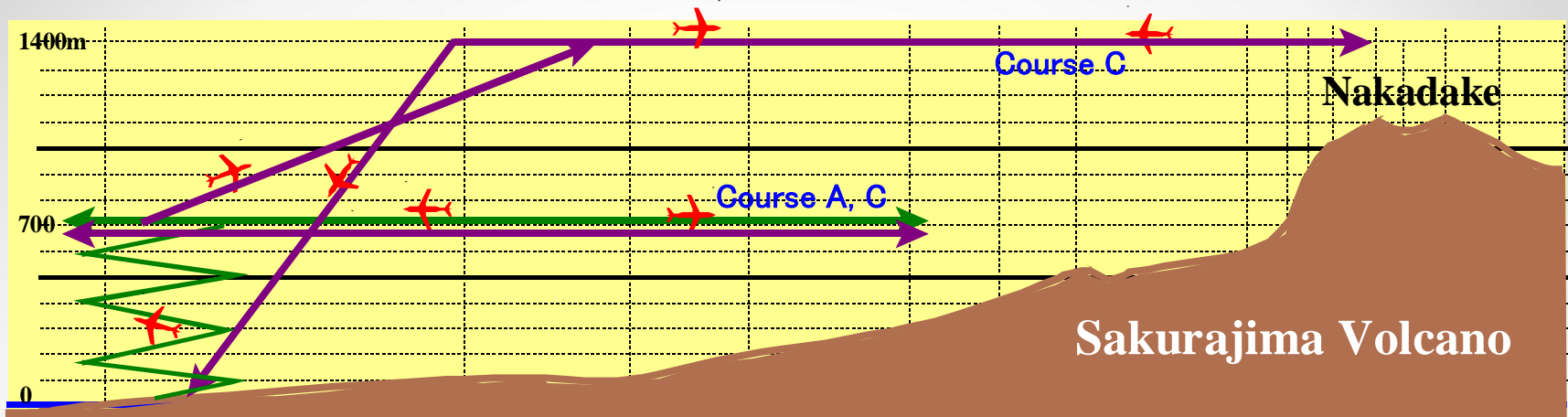
Sensitivity 0.1 nT, 523g, 0.5W,
 Battery: 7.4V, 2100mA
 SD-card

Achievements of UAV flights 2003-12

1. Sakurajima Volcano, 2003 Nov. 17-18

Aeromagnetic survey, aerial photograph





2. Mt. Vettors Station, Kalgoorlie, Western Australia

Mar. 22, 2006



GPS altitude: 427 m
Ground distance: 505.7km
Temp.: 30–36 °C
Wind: 7.5 m W

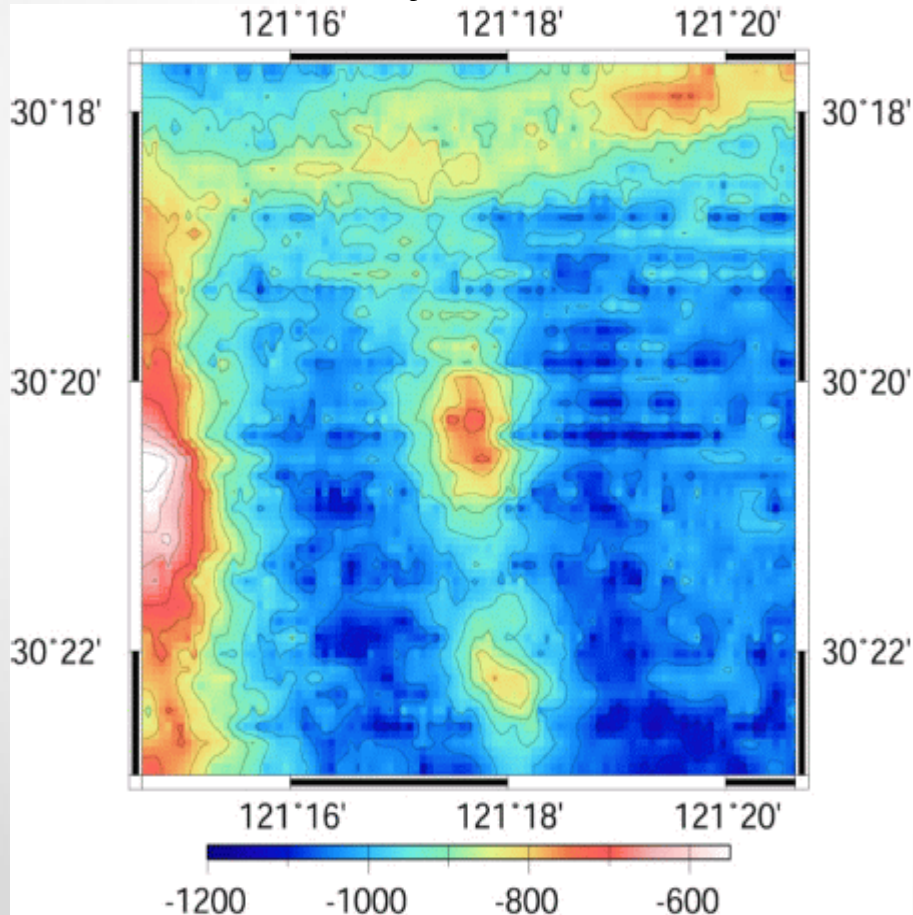


span: 2.6m, length: 2m,
cruising to 600 km (max.
1108km, elevation 5800m),
86cc 2 cycle gasoline engine

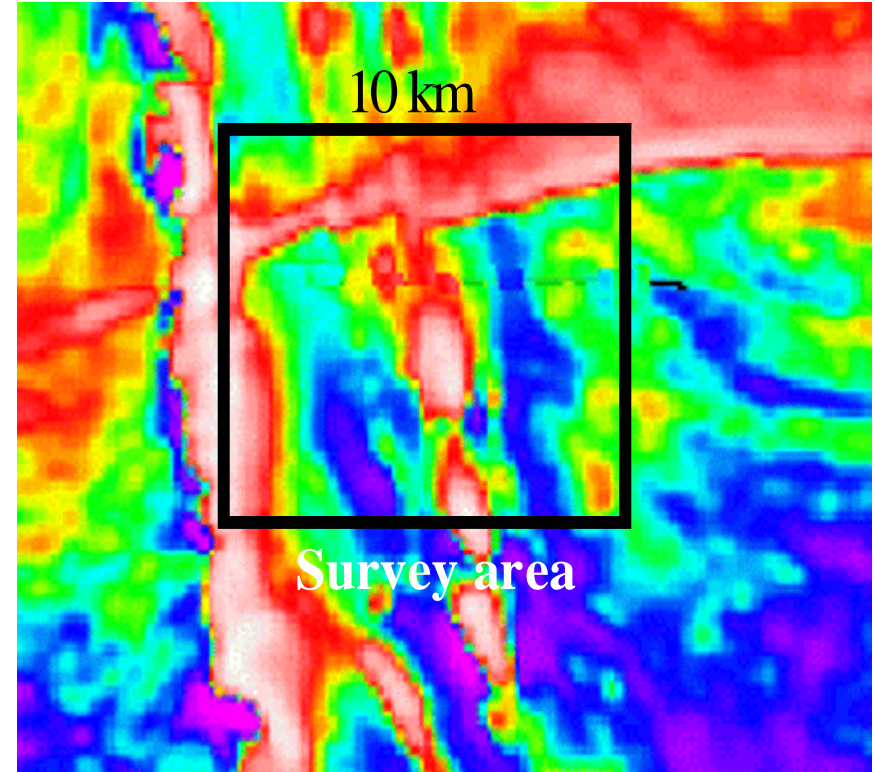
Magnetic anomaly

10x10 km, 200 m span, 51 lines

Magnetic anomaly pattern
obtained by Ant-Plane 4



Magnetic anomaly by
Geoscience, Australia

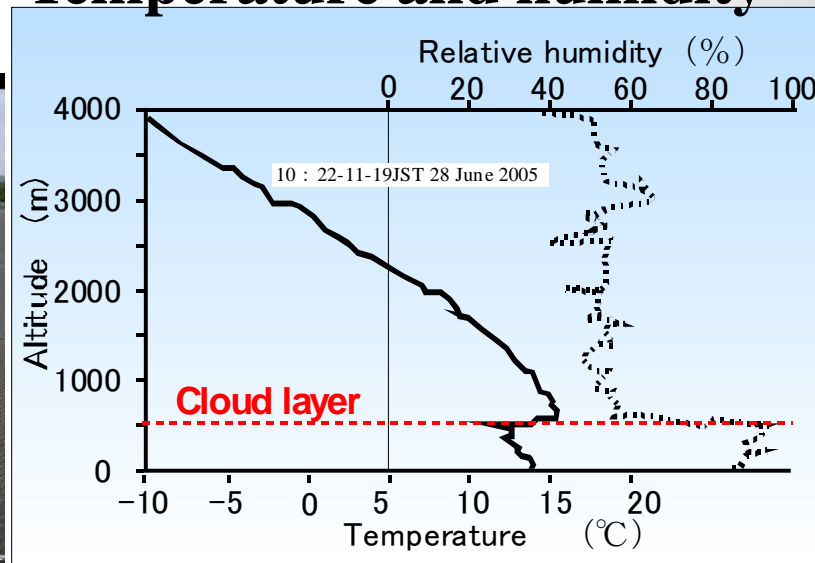


3. Flight to 5700 m in altitude at Monbetsu

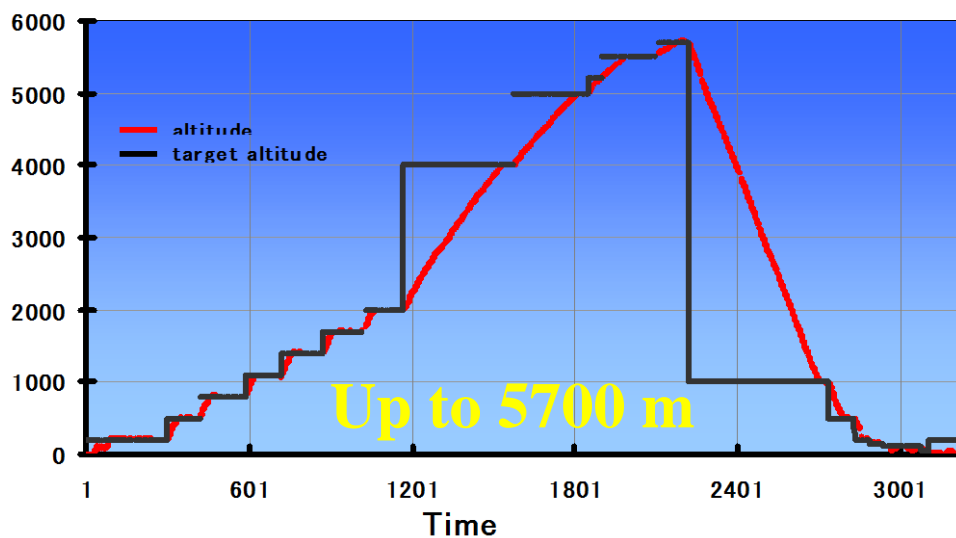
June 28, 2005



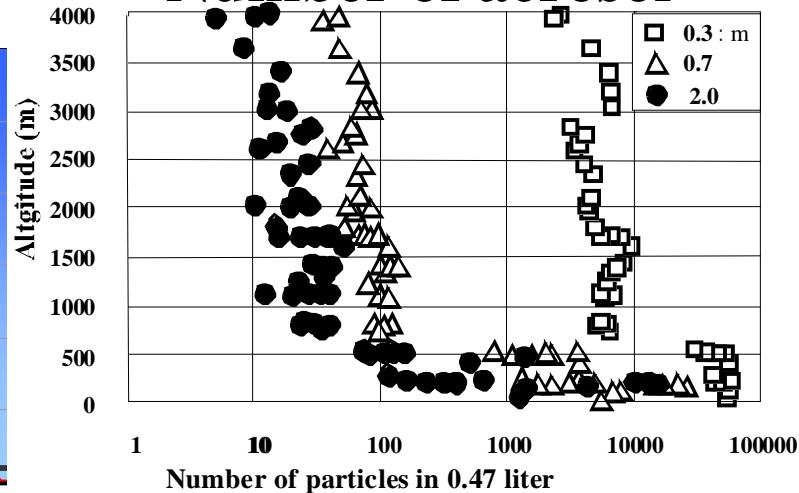
Temperature and humidity



Altitude (m)



Number of aerosol

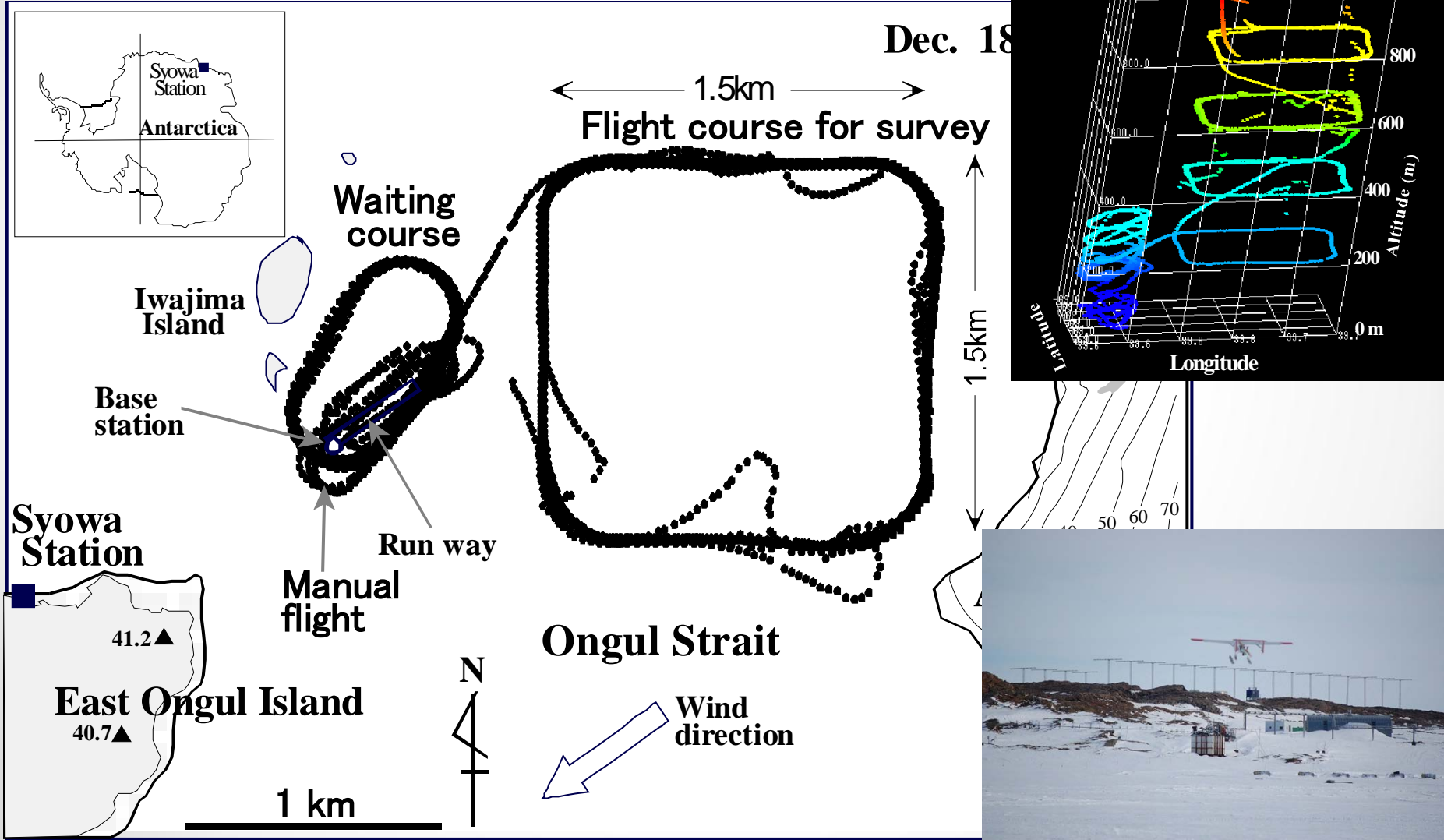


Max. distance: 1108km by 20 l of gasoline

4. JARE49, Ant-Plane 4-3

Dec. 18, 2008, 12:52-13:51

Meteorological devices, wind: 5.3m/s NE



5. Bransfield Strait: Ant-Plane 6 2011-12

Aeromagnetic survey, aerial photograph **in the storm zone**

Following institutions cooperated with this study

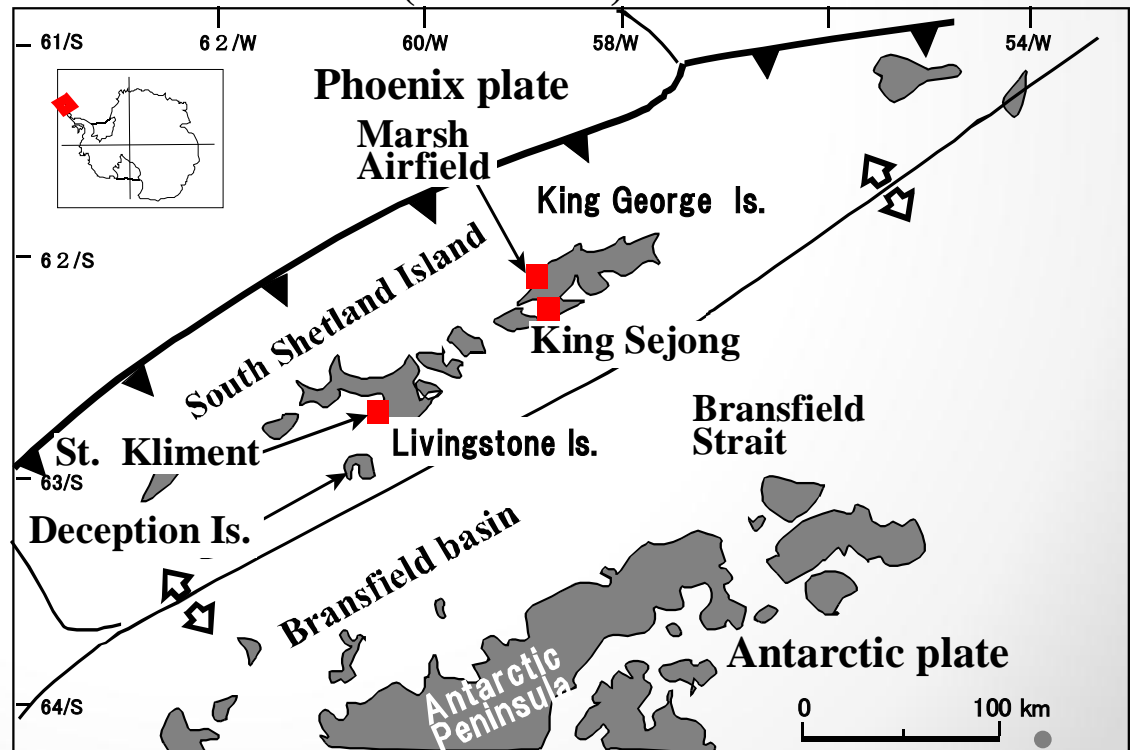
Korea Polar Research Institute

Chile Antarctic Institute

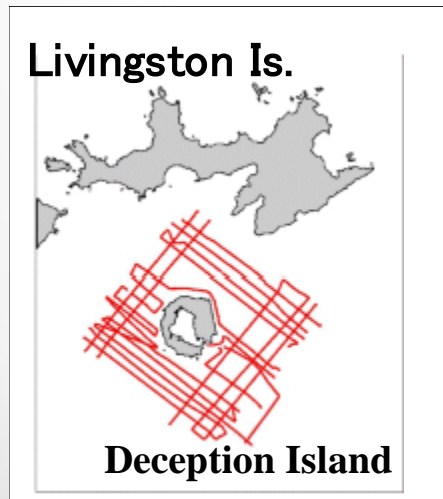
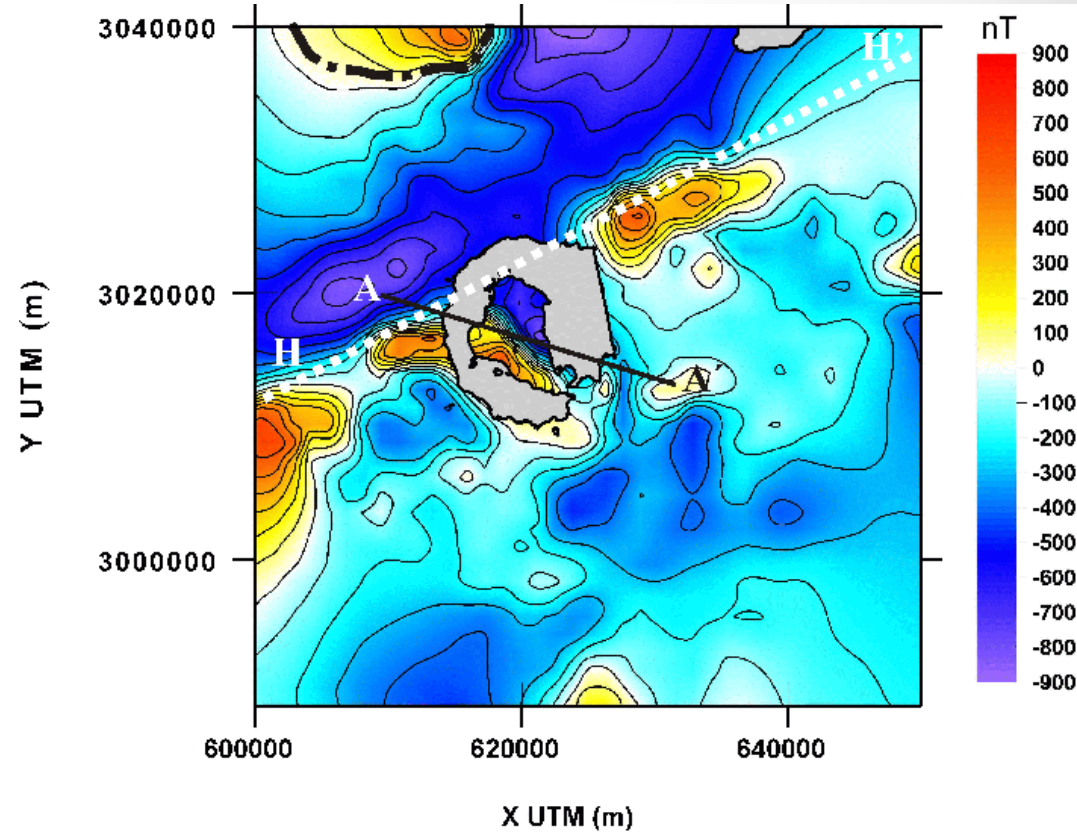
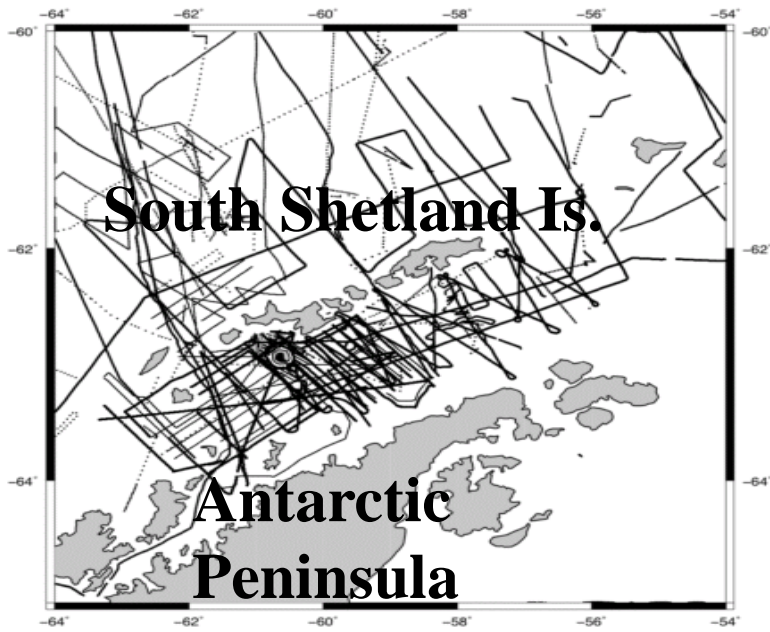
Bulgarian Antarctic Institute

Spanish Antarctic team

Russian Antarctic Research (unofficial)



Magnetic survey operated by Spanish team



Flights from Marsh Airfield, King George Island, and St. Kliment Ohridski Base, *Livingston* Island

Marsh Airfield, Jan. 2012

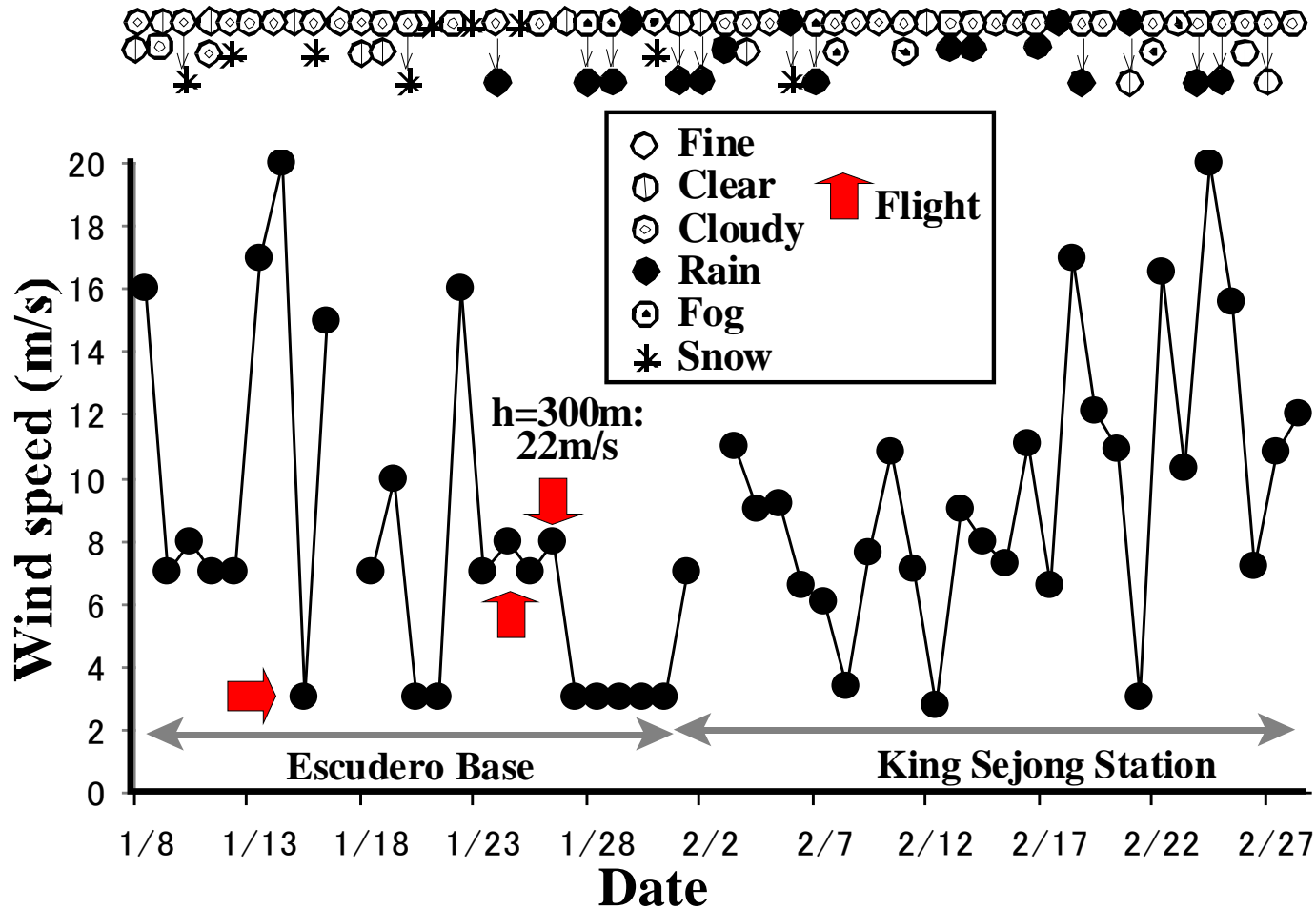
- Strong wind in the clear day
- Dominant weather of cloudiness and rain at King George Island
- Civil and military flights in clear day
- Restriction to use the runway and airspace by control tower

St. Kliment Ohridski Base, Dec. 2012

- 100 km apart from Marsh Airfield
- Flat glacier behind the base
- Relatively good weather compared with King George Island

Weather at King George

King George Island Jan. 8 - Feb. 28, 2011



Flight from St. Kliment Ohridski Base to Deception Island by Ant-Plane 6-3

St. Kliment Ohridski Base: Bulgarian Antarctic station



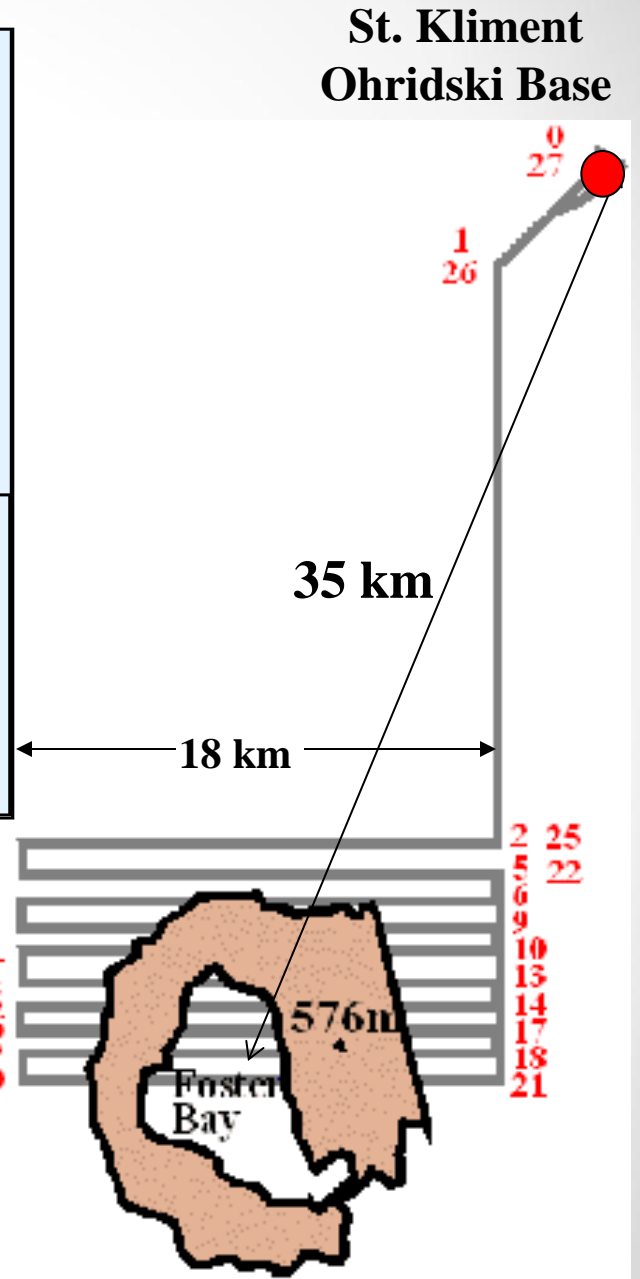
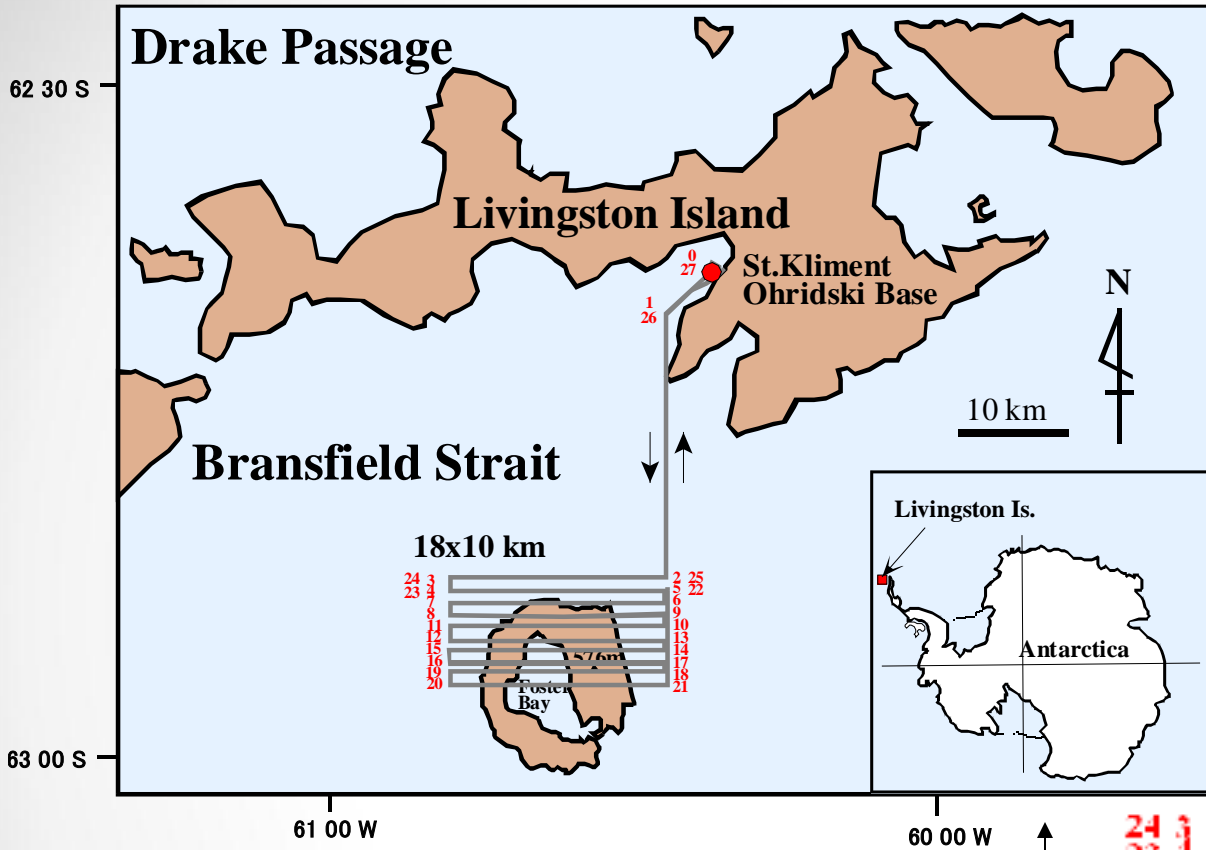
Glacier behind the base



$62^{\circ}38'29''S$

$60^{\circ}21'53''W$

Flight plan for Deception Island



Flight distance: 300 km

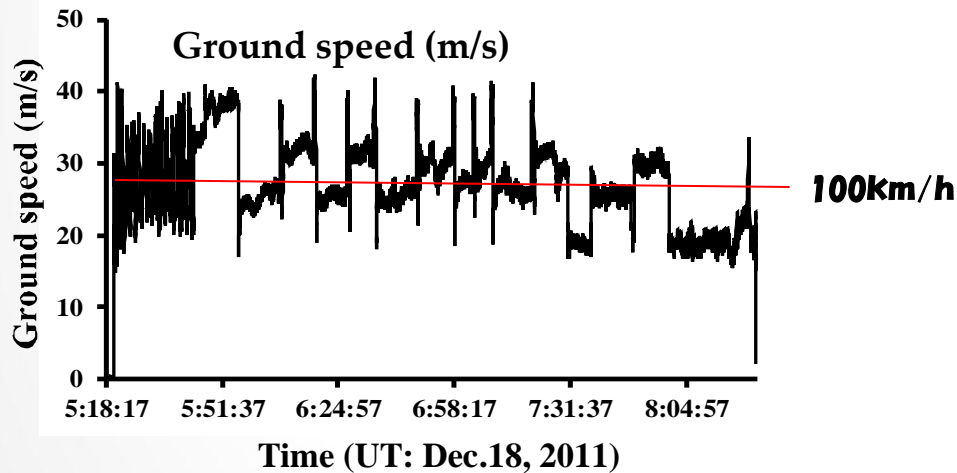
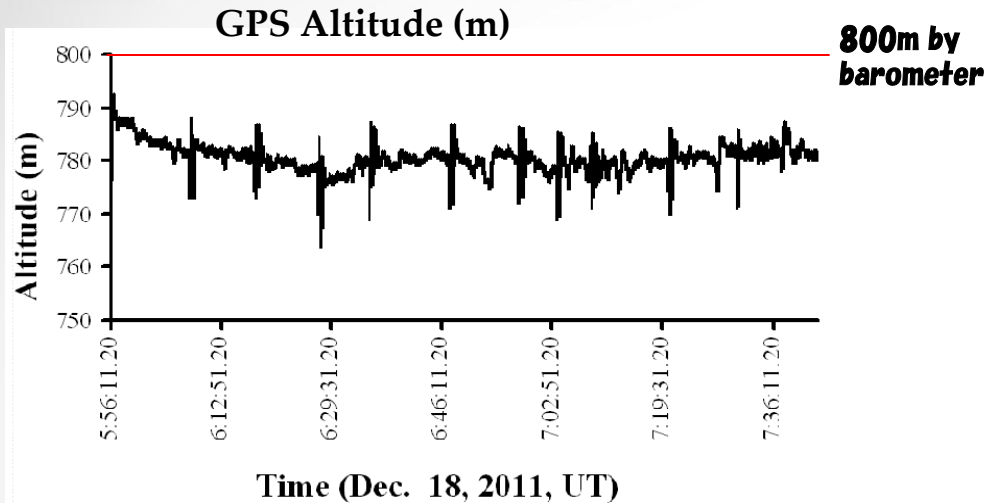
Speed: 120 km/h

Altitude: 800 m

1km interval

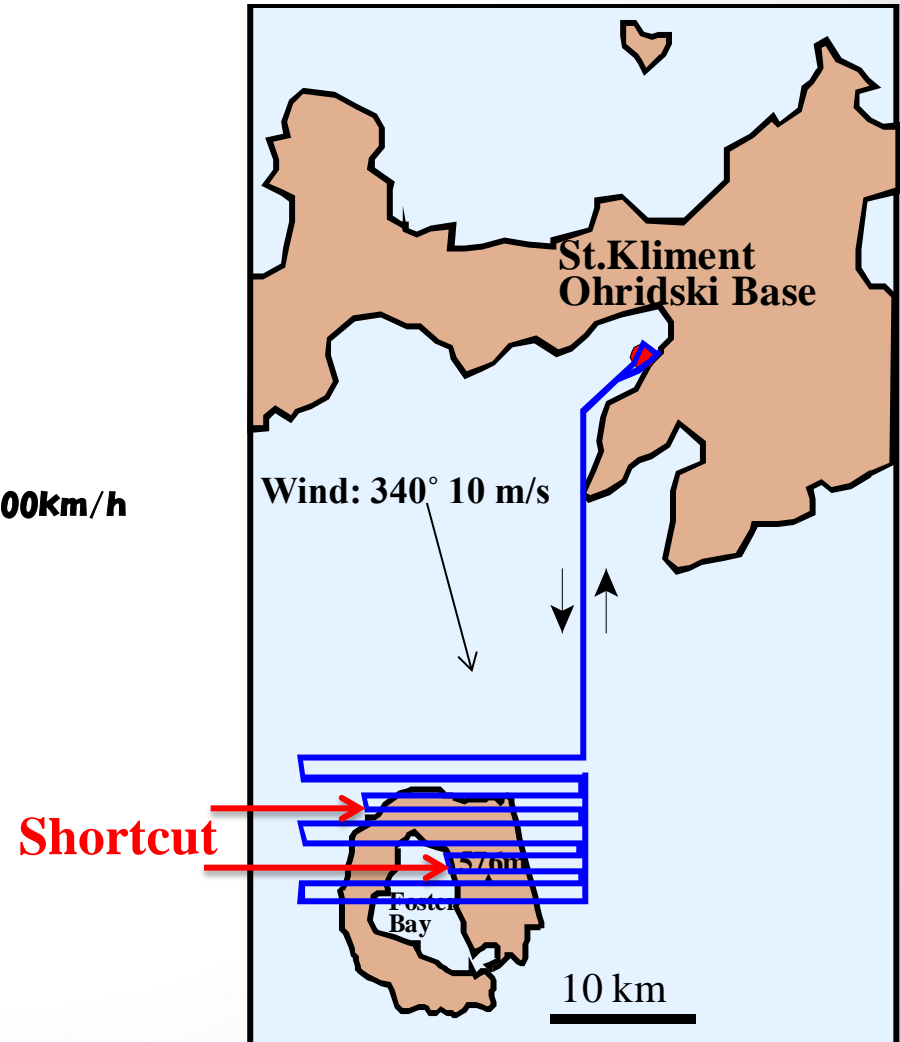
12 lines

Flight result

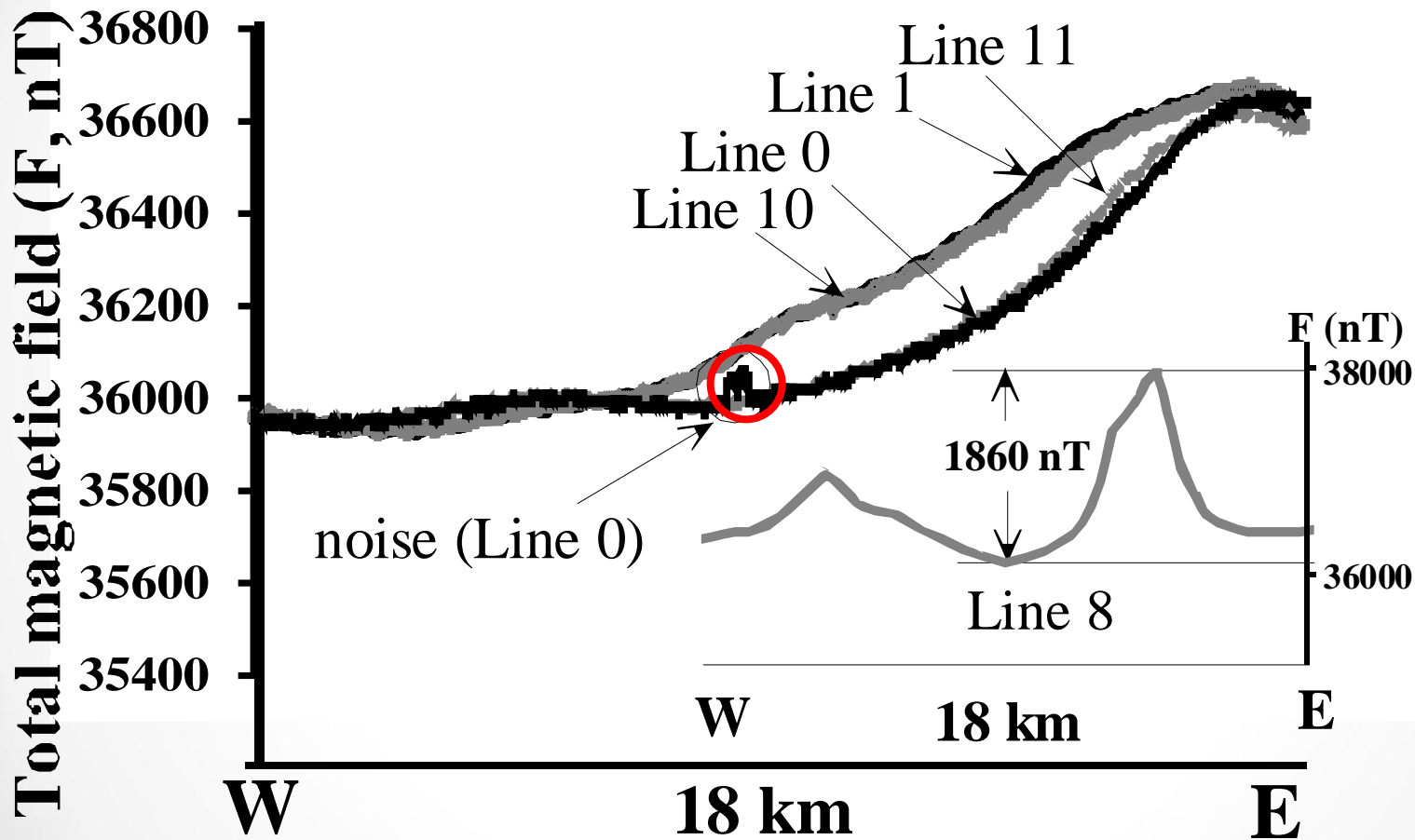


Dec.18, 2011. 2:20 – 5:27 (3h 07m)
302 km in distance
Fuel: 6 liter (~9 US\$)

Target altitude: 800 m
Speed: 33.3 m/s



Reliability of the magnetic measurement



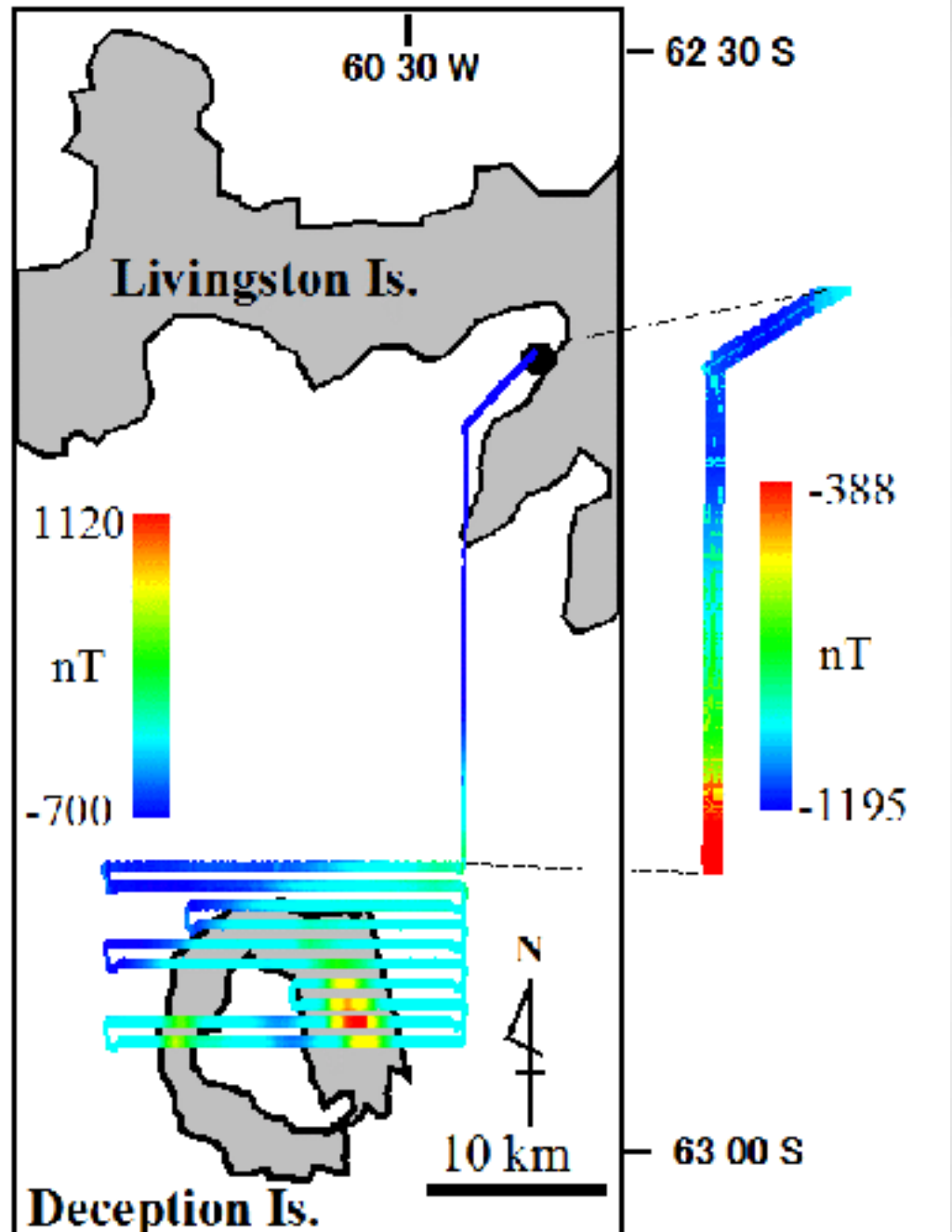
Data processing

Avoidance of the data during turning flight and spiky change

Subtracting the IGRF F value from the data

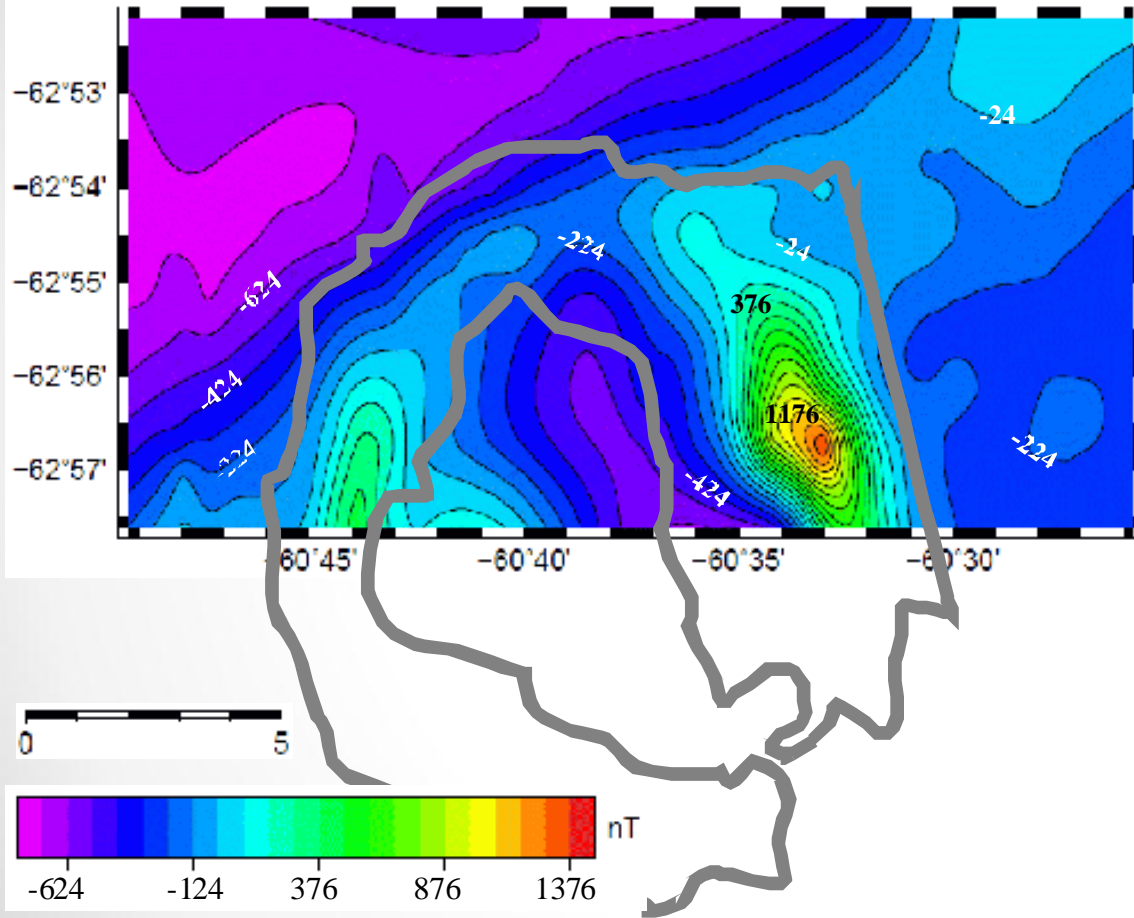
IGRF-11 (international geomagnetic reference field) at the center of Deception Island for 2010 above 800 m

$$\text{IGRF } F = 36623.5 \text{ nT}$$

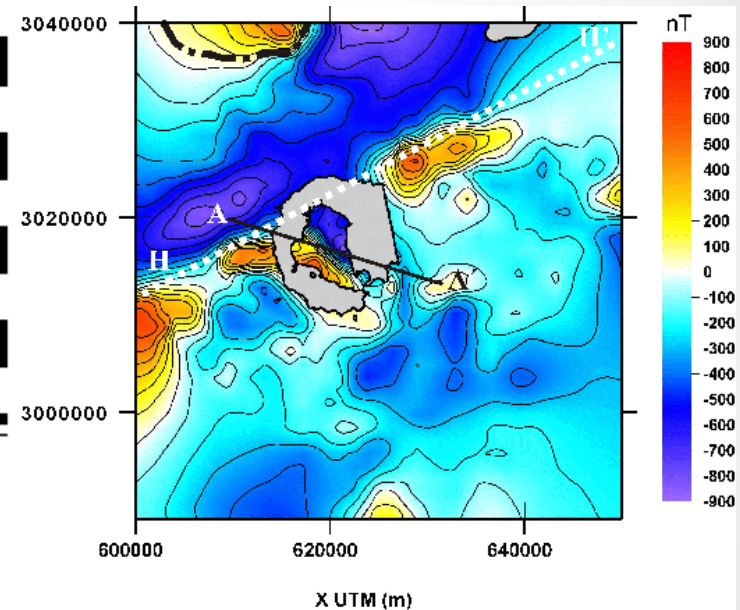


Magnetic anomaly around Deception Island

airborne survey by Ant-Plane 6-3



Seaborne survey



Cost-effectiveness

fuel consumption: 50km/l for gasoline

gasoline of 1.5 US\$/l

manpower fees: 4 members of 400 US\$/day

- 1) 0.03 US\$/km
fuel consumption
- 2) 1.04 US\$/km
full mobilization costs (including test flight and
manpower charge)
- 3) 21.2 US\$/km
including down-time (16 days of manpower charge)
- 4) 102.5 US\$/km
total budget of this project (31,000 US\$.)
- 5) 168.7 US\$/km
total budget and airplane cost (20,000 US\$)

We cannot conclude whether the cost-effectiveness of the airborne survey by UAV is significantly better than that of manned flight

For remote locations in the Antarctic storm zone, Ant-Plane may be more cost-effective compared with manned flights

Points to note regarding UAV flights in Antarctica

- disruption of satellite signals when the plane banked quickly by affecting strong turbulence
 - several GPS antennae oriented in different directions
- accidentally released parachute due to the breakage of a plastic latch
 - using a metal latch with enhanced rigidity
- icing when flying in cloud at an air temperature of ca -10° C
 - Flights in cloud should be avoided
- the ground-snow conditions vary with the weather
- Chipping of a wooden propeller by granular snow during taxiing
- serious problem of metal fatigue
 - requires maintenance before each 10 h of flight time

Conclusion

1. Safety and high cost-effectiveness were achieved in airborne survey by Ant-Plane in Antarctica
 2. Various kinds of geophysical devices less than 2.0 kg in weight can be on board
 3. Available flight is 1108 km in distance and 5700 m in altitude by Ant-Plane 4 in Japan
 4. More than 300 km of flight by Ant-Plane 6 was confirmed beyond the horizon at the storm zone in Antarctica
 5. Aeromagnetic map of Deception Island was obtained
 6. Successful flights in Antarctica require low winds and cloud-free conditions to avoid icing
 7. it is advisable to operate UAVs in remote areas away from existing infrastructure
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