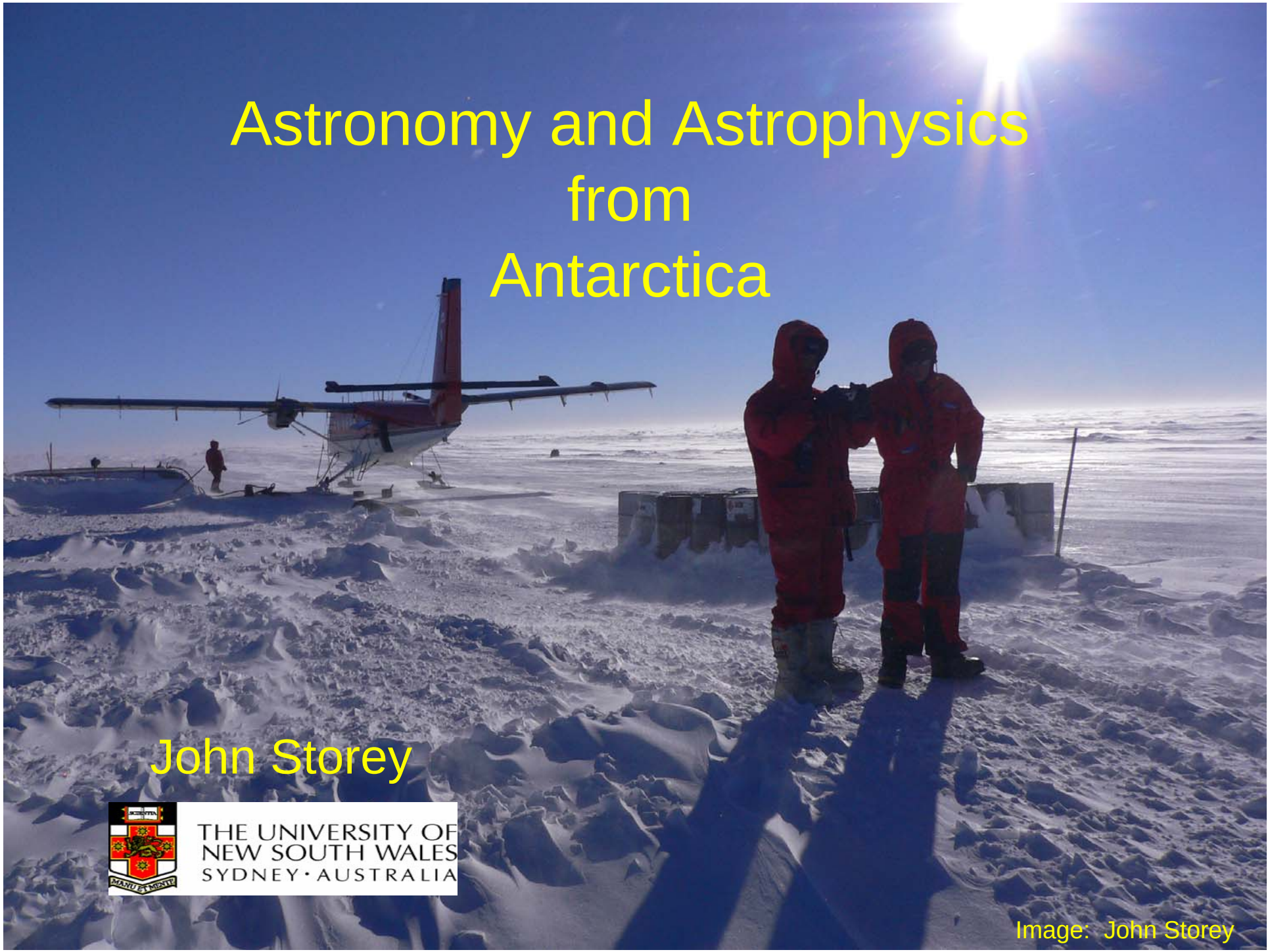
Astronomy and Astrophysics from Antarctica



John Storey

THE UNIVERSITY OF NEW SOUTH WALES
SYDNEY · AUSTRALIA

Image: John Storey

Launch costs to Low-Earth Orbit

- Rocket $15,000/kg
- Shuttle $60,000/kg

- Antarctica $4/kg

Outline

- Why Antarctica?
- South Pole
- Dome F
- Dome C
  - PILOT
- Dome A
  - PLATO
- Long-duration balloons
- AAA

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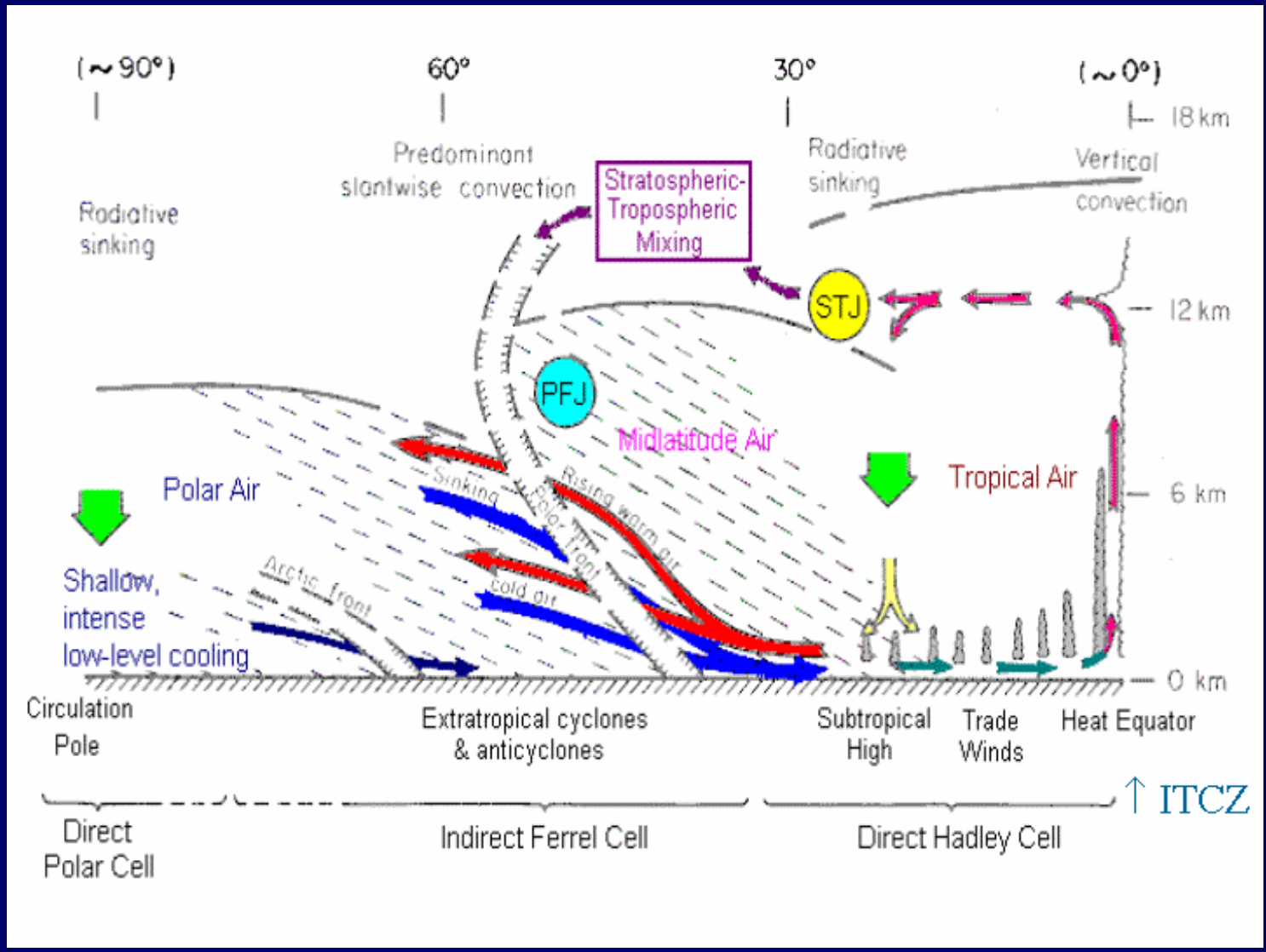
Why Antarctica? (for optical astronomers)

- Image quality twice as good as at temperate sites
- Photometric precision twice as good
- Infrared sky 20 – 50 times darker
- Long periods of uninterrupted darkness
- “Big science” with small telescope

Unique opportunity for wide-field, high precision astronomy

Image: Camillo Calvaresi

Not just cold, but clear and calm.

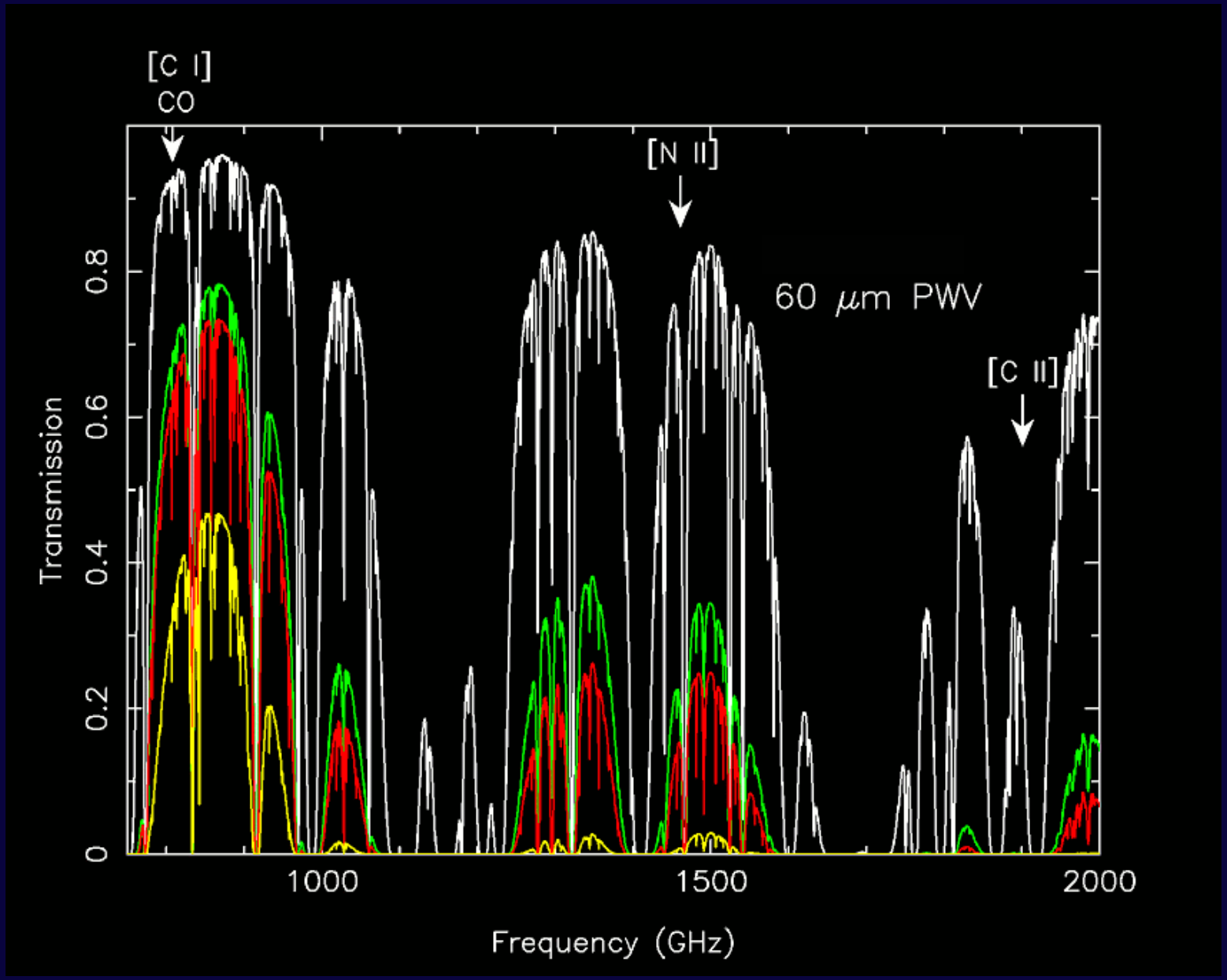


Why Antarctica? (for sub-mm astronomers)

- Water vapour is extremely low
- Sky emission is extremely stable
- There's plenty of room

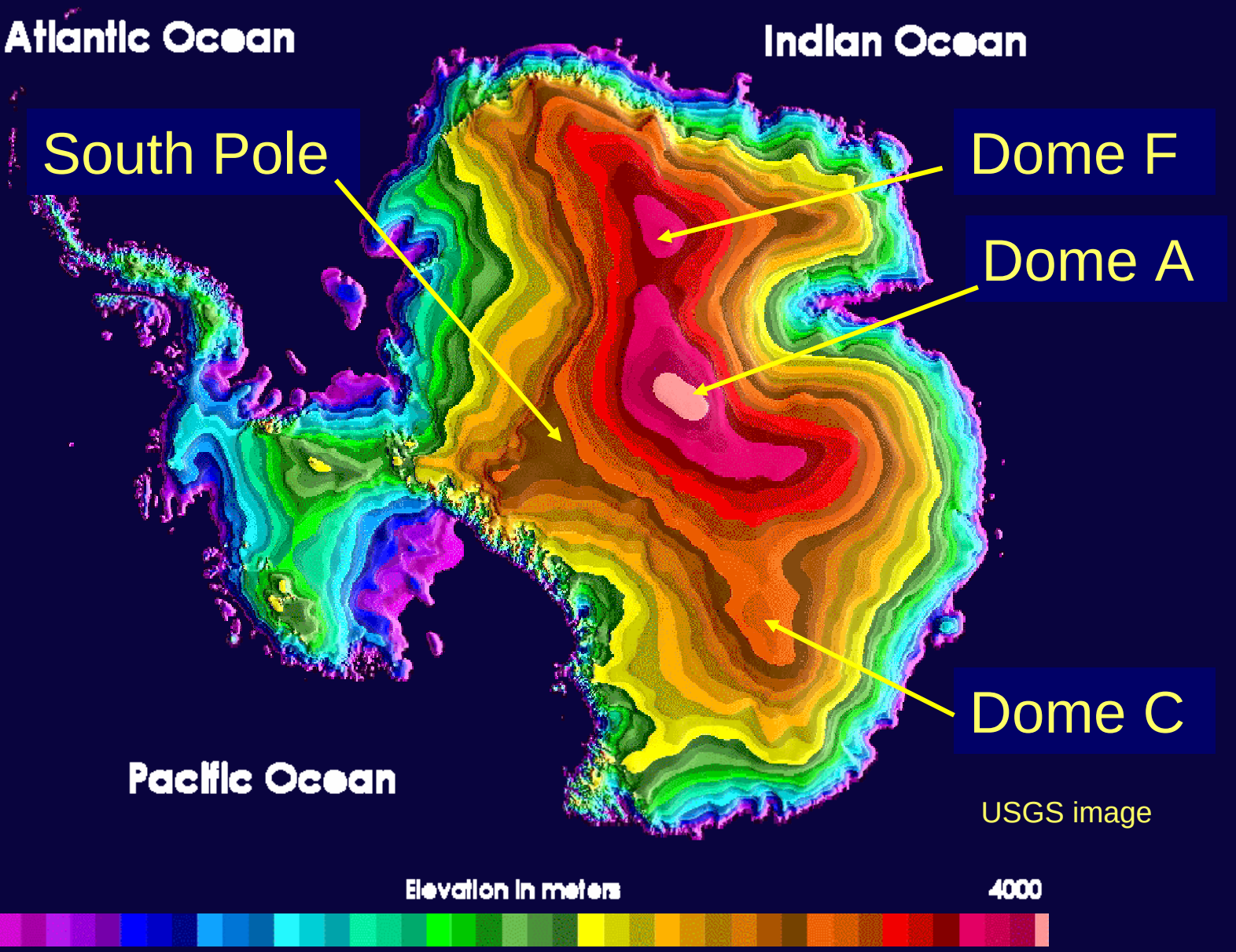
Unique opportunity for big dishes, big interferometers

Image: Camillo Calvaresi



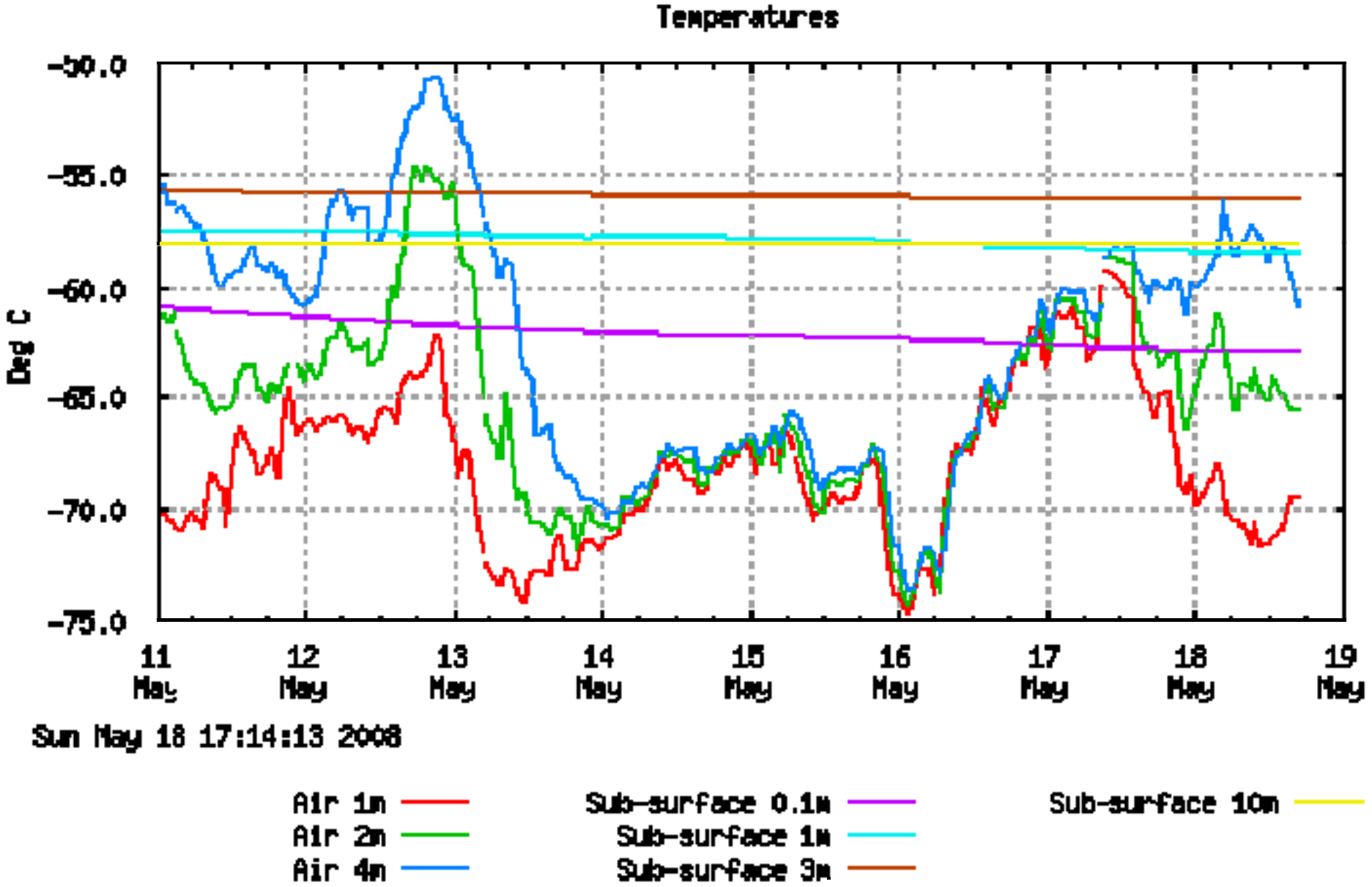
Kulesa et al (in prep.)

Contour map of Antarctica



Why Antarctica is *different*

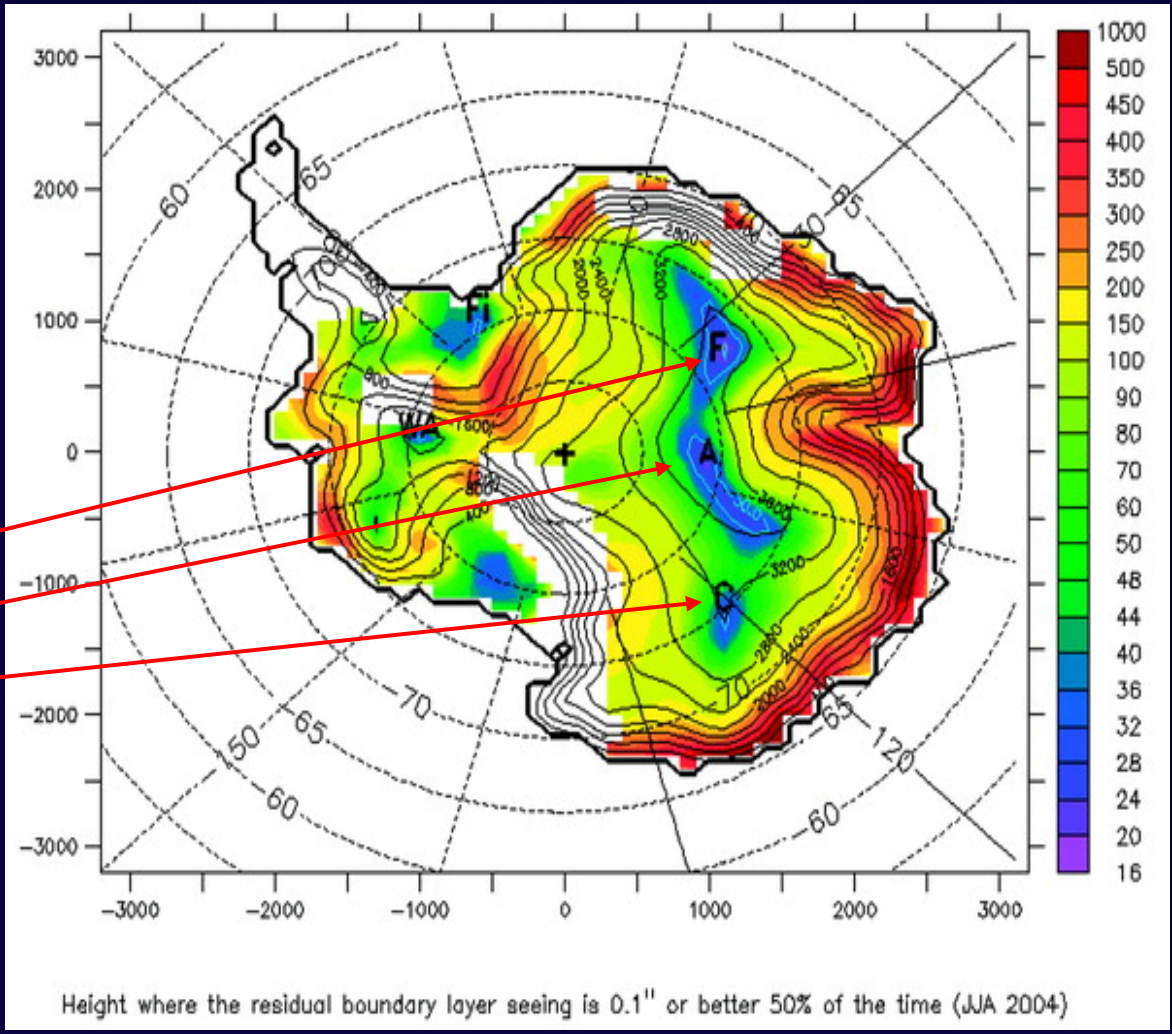
- The temperature inversion is huge (often 5ºC/metre)
- The Stable Boundary Layer is thin (~ 25 metres)
- As a result, the Stable Boundary Layer is *stable*



Data: AAD/CHINARE AWS

Boundary layer height

~18 m
~21 m
~27 m



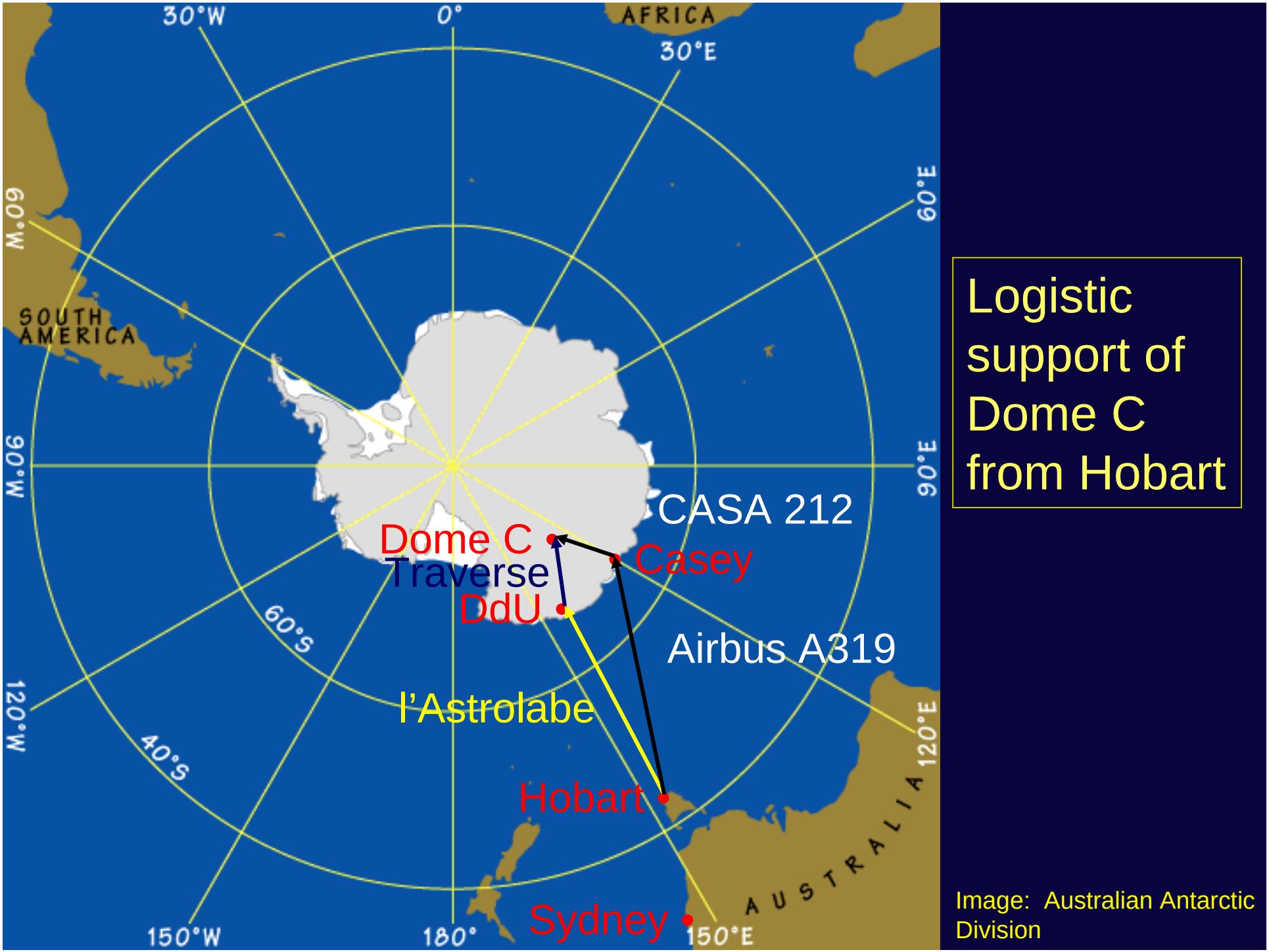
Swain and Gallee, 2006

Dome C

Frequency of occurrence

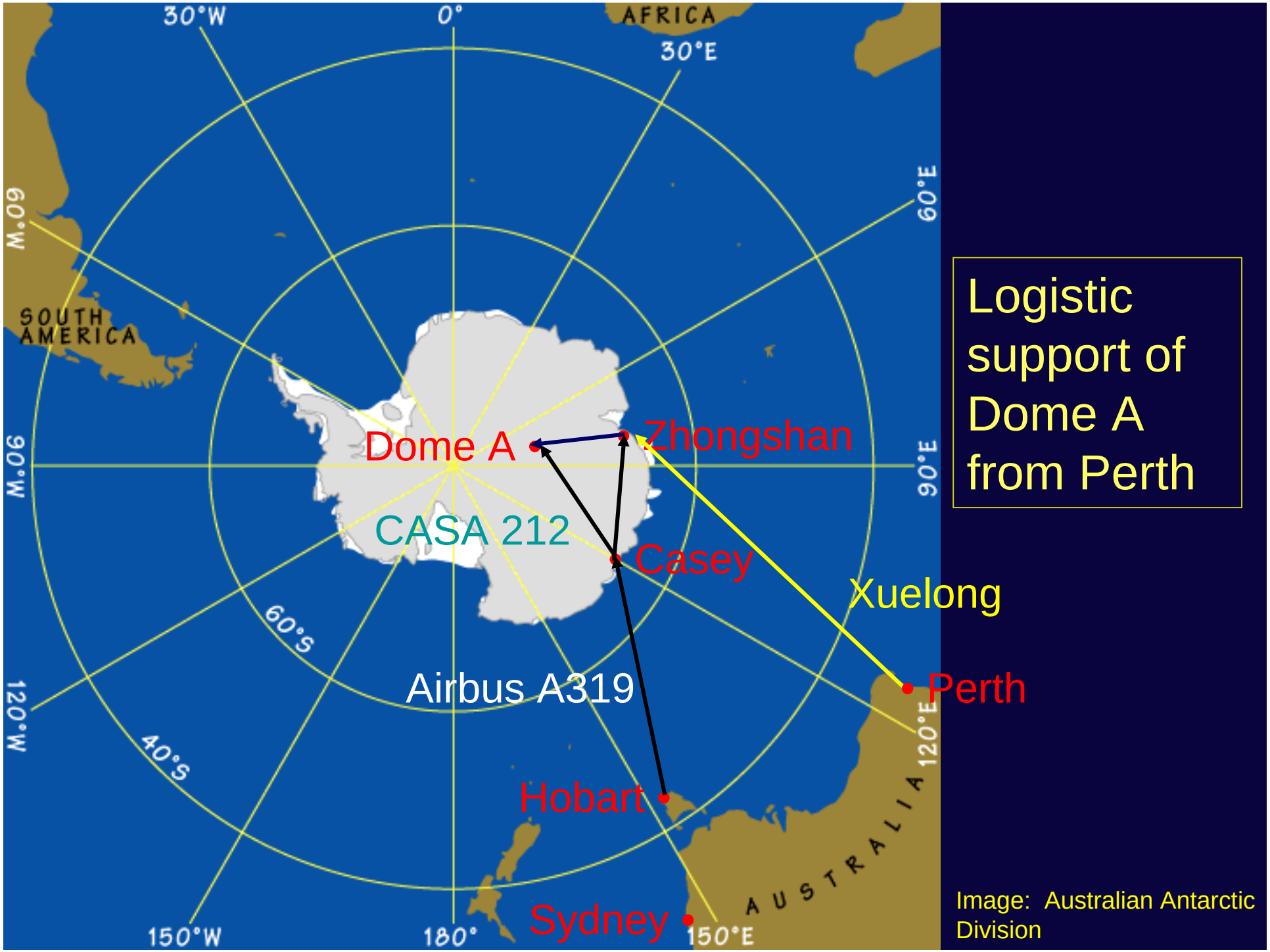
Seeing (arcsec)

Data: Eric Fossat et al



Logistic support of Dome C from Hobart

Image: Australian Antarctic Division


30°W
0°
AFRICA
30°E
60°W
SOUTH AMERICA
60°E
90°W
90°E
120°W
120°E
60°S
40°S
150°W
180°
150°E
AUSTRALIA
Dome A
Zhongshan
CASA 212
Casey
Xuelong
Airbus A319
Perth
Hobart
Sydney
Logistic support of Dome A from Perth
Image: Australian Antarctic Division

Airlink

- Established 2007 with Australian government funding of $46m
- Hobart – Casey in 4.2 hours in Antarctic Division A319 Airbus
- Intra-continental flights in ski-equipped CASA 212 aircraft

Image: Australian Antarctic Division

Wilkins runway, ~70 kms SE of Casey Station

Image: Australian Antarctic Division

Image: Australian Antarctic Division


Image: Australian Antarctic Division

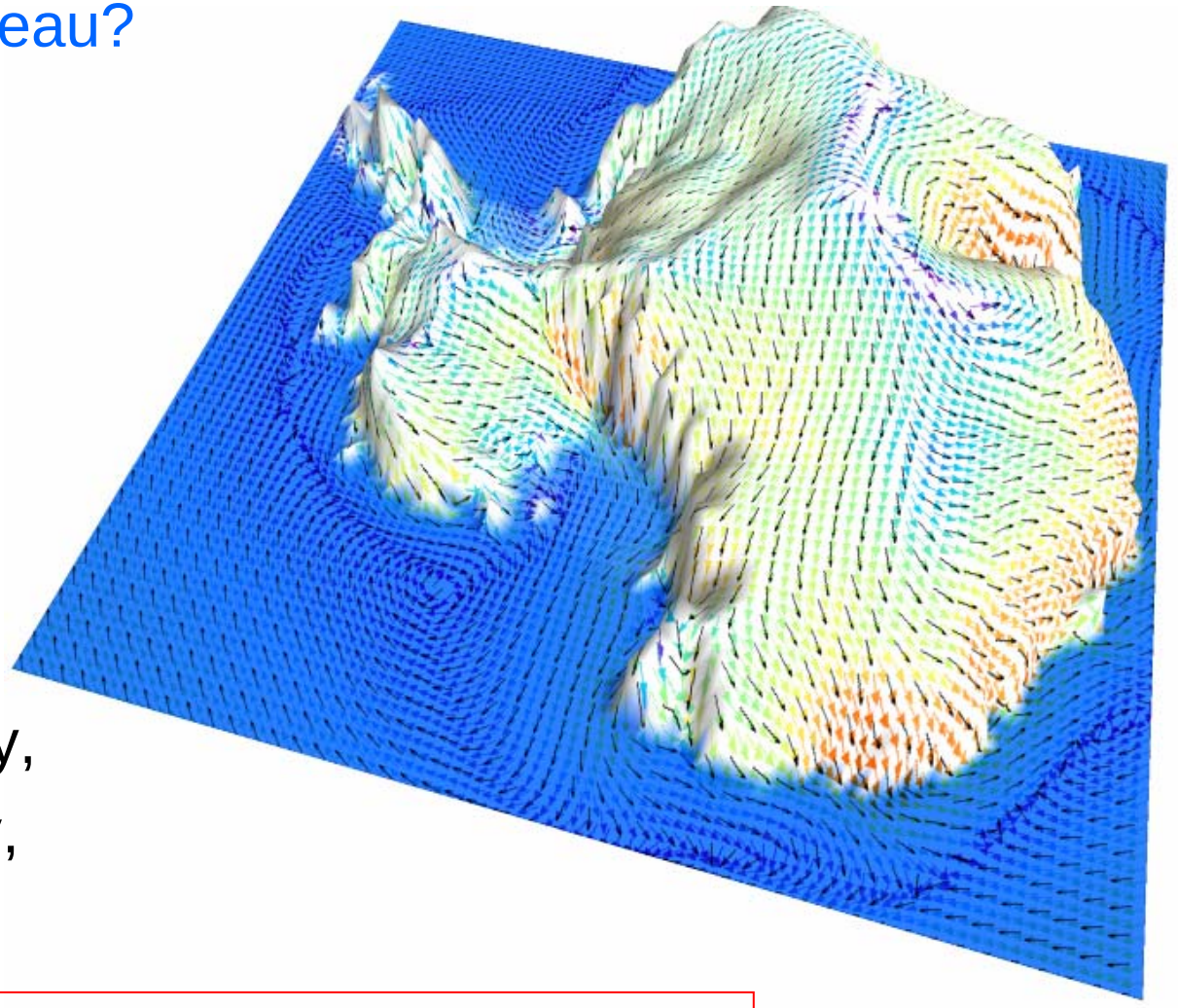
Australia also has two ski-equipped CASA 212 aircraft

Image: Skytraders

Australian postage stamp issued September 2008

The ideal site for astronomy

- Why the Antarctic plateau?
  - high,
  - low surface winds,
  - no jet stream
  - cold,
  - very dry,
  - cloud free,
  - high latitude,
  - low seismic activity,
  - low human activity,



BUT *WHERE* ON THE PLATEAU ???

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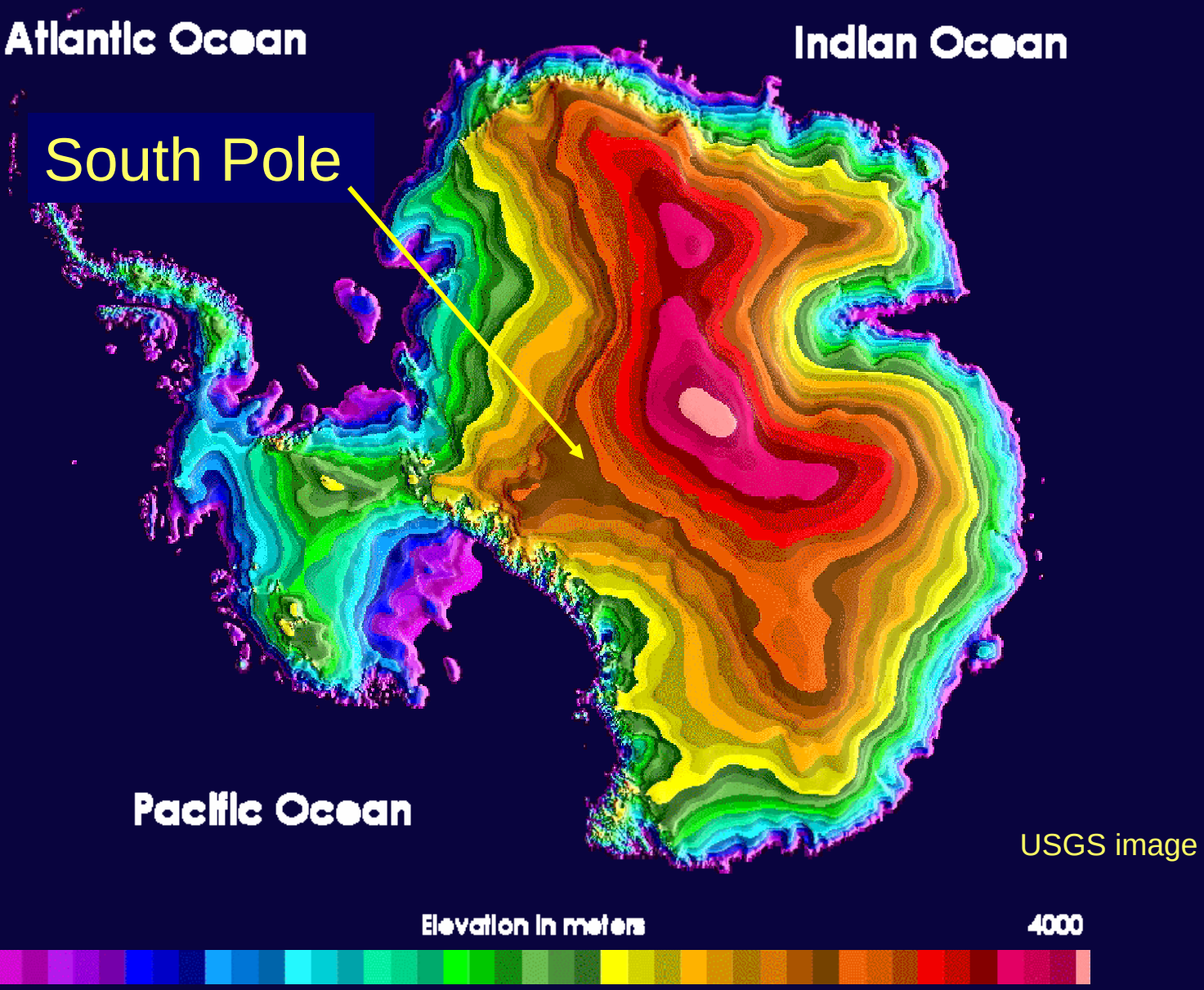
Contour map of Antarctica



The South Pole experience shows that Antarctica *is* a cost-effective site for astronomy.

Image: Seth White

South Pole Telescope

Big engineering projects *are* possible in Antarctica

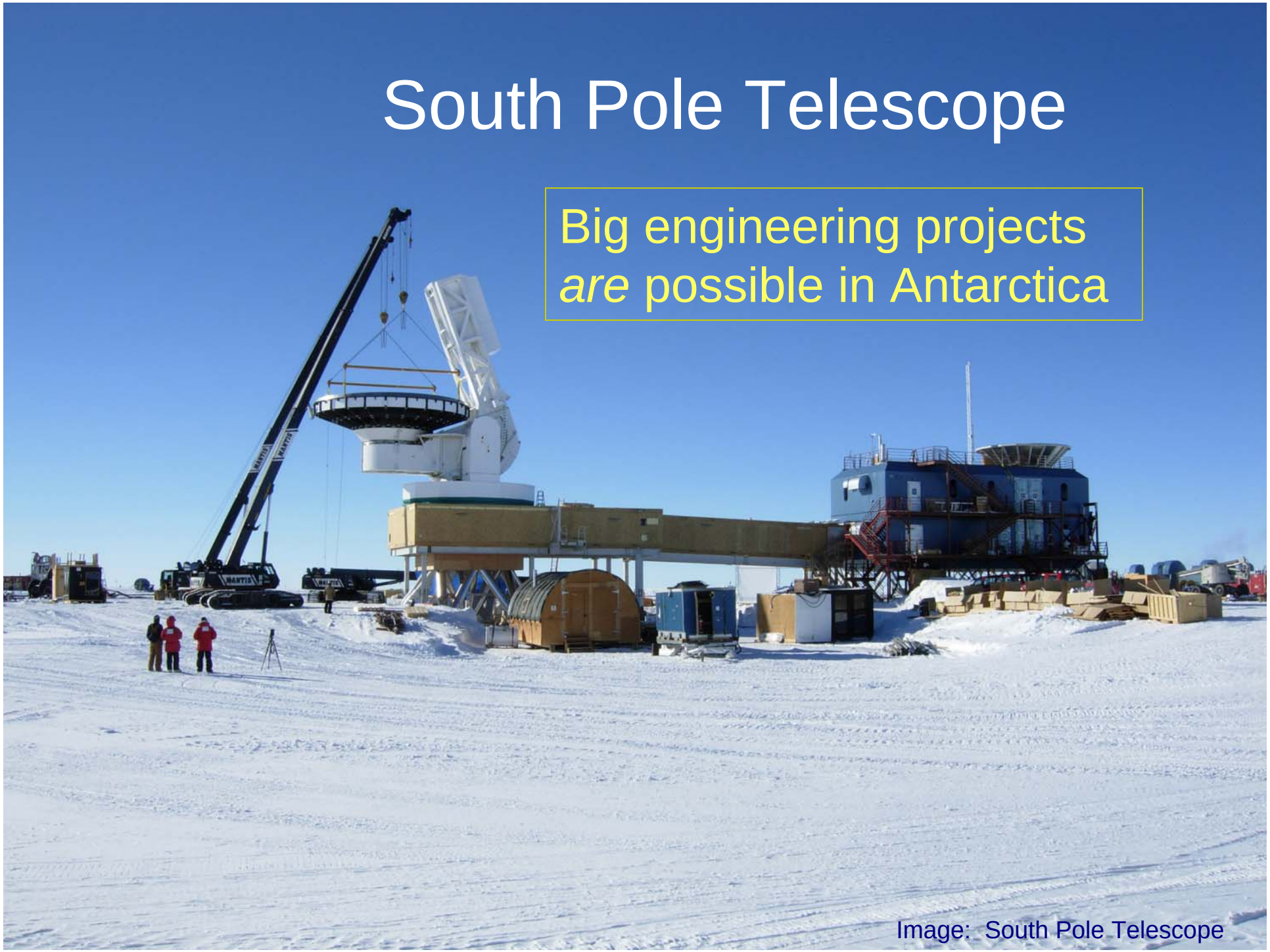
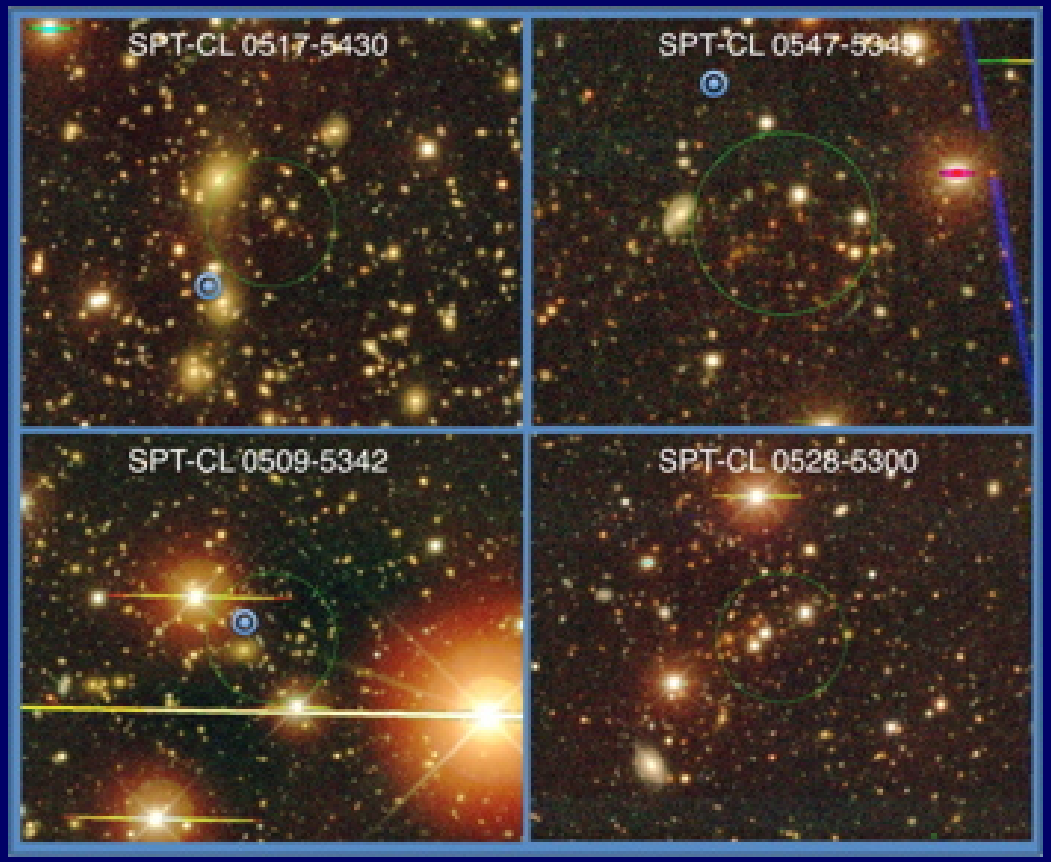


Image: South Pole Telescope

Galaxies clusters detected with the SPT via the Sunyaev-Zel'dovich effect



Z. Staniszewski et al, in press 2009


These folk are astronomers, too.
Image: http://icecube.wisc.edu

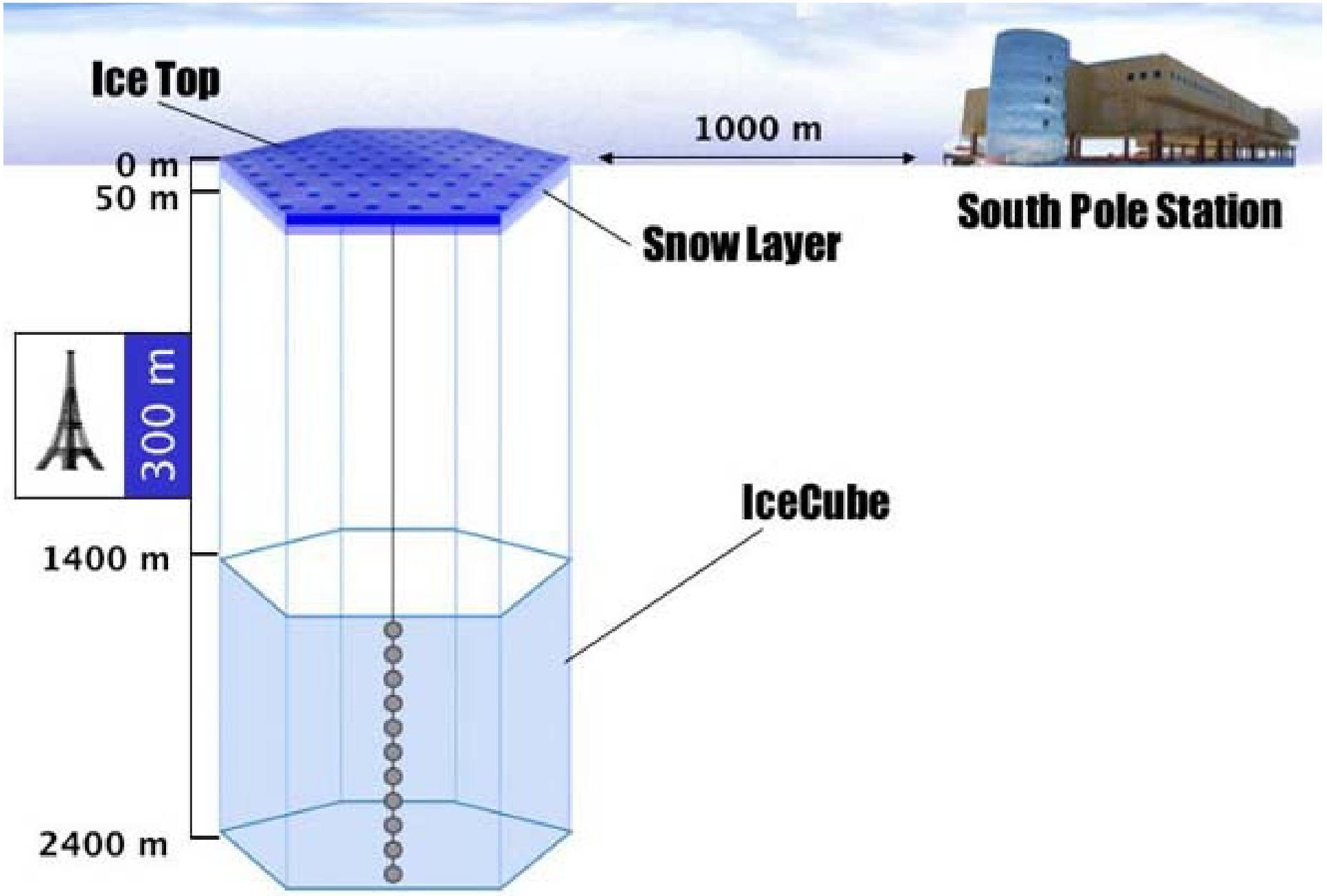


Image: http://icecube.wisc.edu

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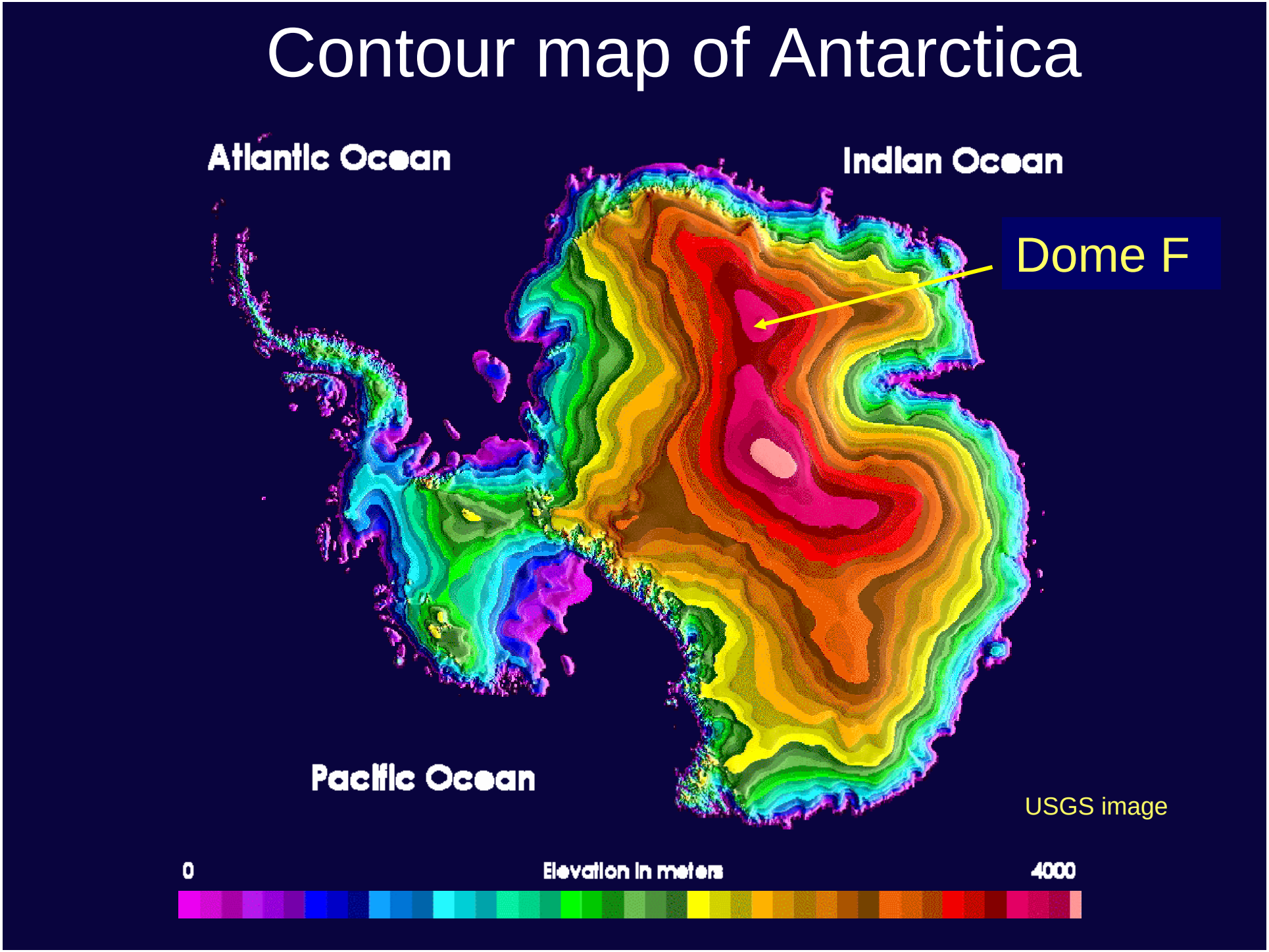


Dome F


Mid Winter Greetings
from Dome Fuji Station
The 44th Japanese Antarctic Research Expedition, 2003

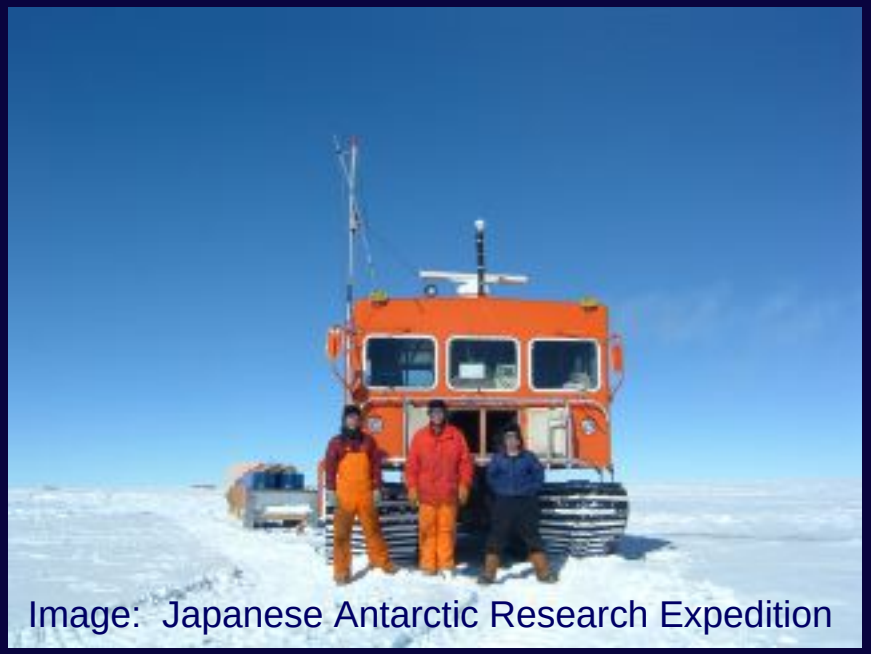


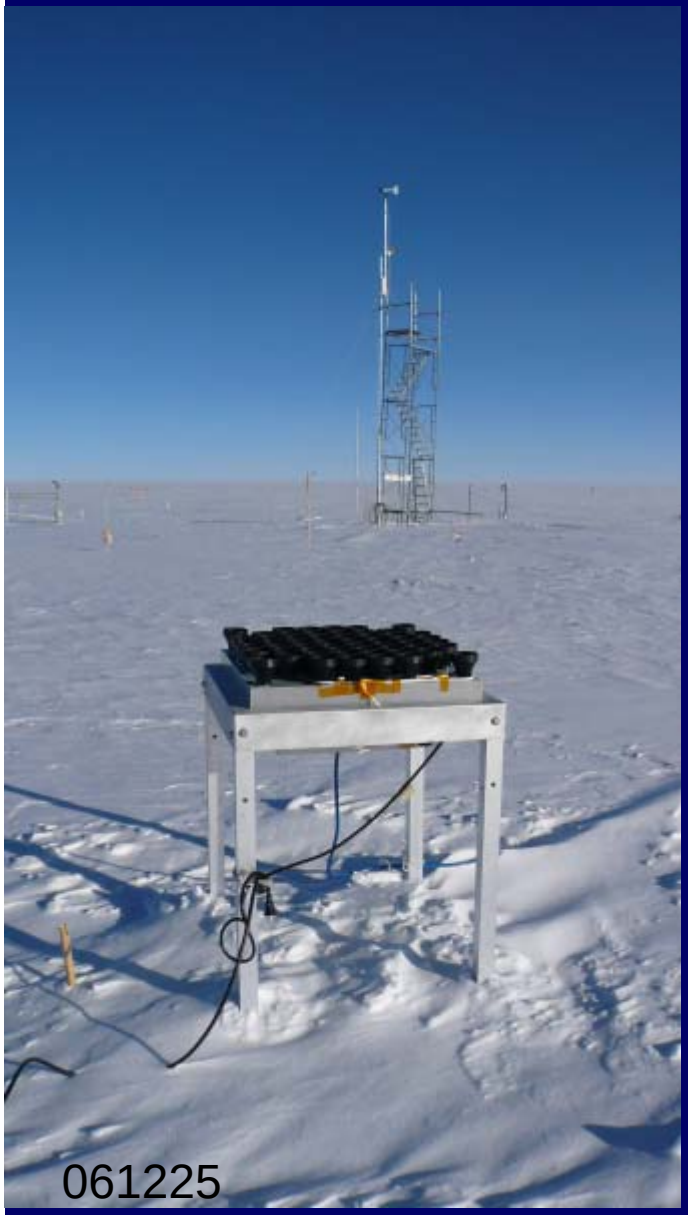
Image: Japanese Antarctic Research Expedition

Image: Obi Doc

Image: Koj Fujita

Image: Kei “Musen” Nakano

Dome F



REMTECH PA-1

Naruhisa Takato, Fumihiro Uraguchi (Subaru Telescope),
Hideaki Motoyama, Kotaro Fukui (NIPR)

ケープタウン出発前イリューシン76

ノボラザレフスカヤ滑走路着イリューシン76

損傷前のバスラーBT67

南極の
航空機
あれこれ

レスキューに来たツインオッター（ALE)

新バスラーBT67

S17の新バスラーBT67

Naruhisa Takato, Fumihiro Uraguchi (Subaru Telescope),
Hideaki Motoyama, Kotaro Fukui (NIPR)

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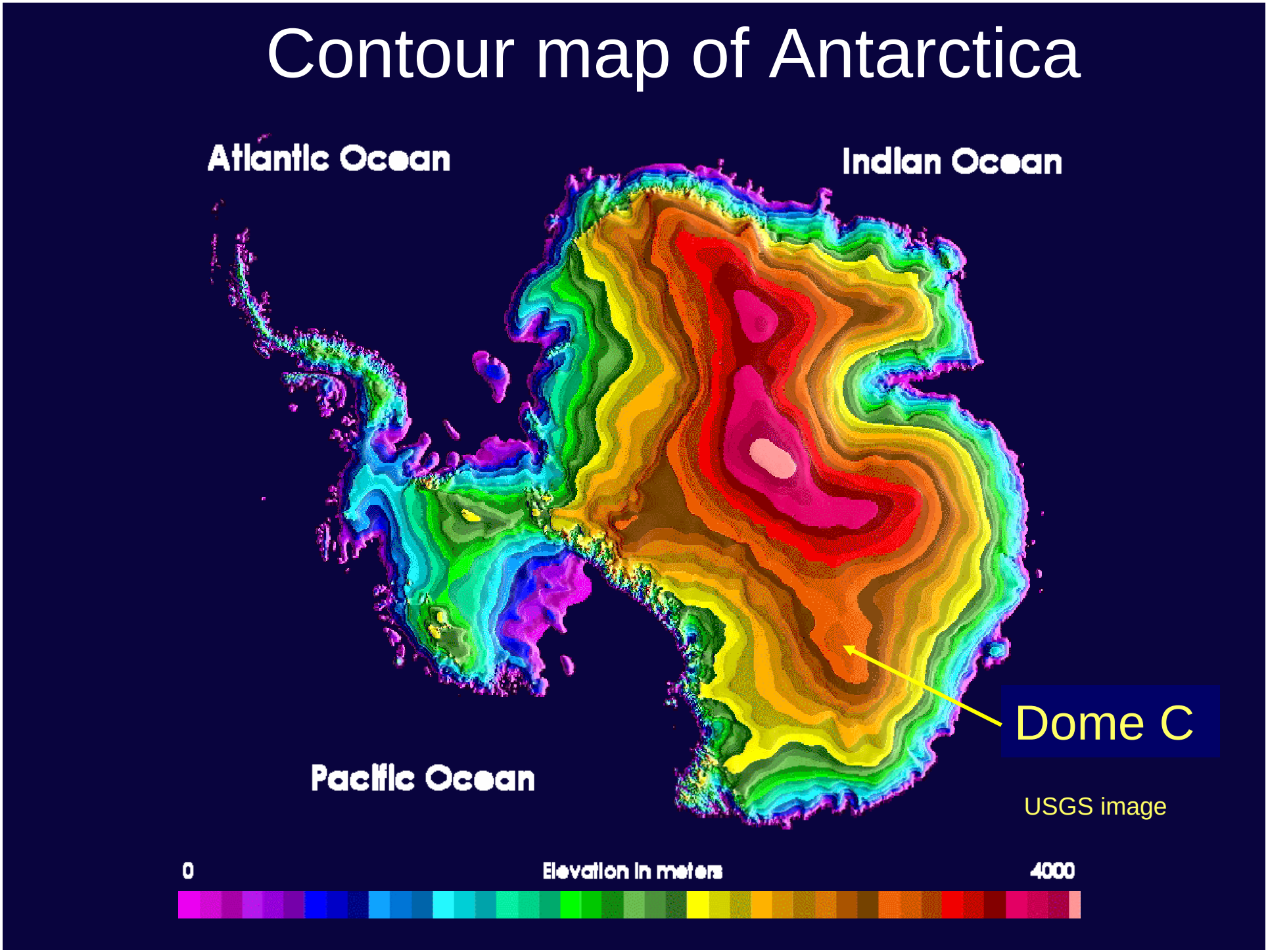


Basic Dome C facts

1. The free-atmosphere seeing is the best in the world
2. There is a Stable Boundary Layer approx 30m thick
3. The relative humidity is ~120%
4. Access is limited to 3 months/year
5. Hobart to Dome C could take as little as 8 hours
6. Deployment costs 0.1% as much as space, per kg
7. Communications bandwidth is limited

Image: Paolo Calisse

Concordia station, Dome C

- French/Italian station, opened year-round in 2005
- Astronomy is one of the key sciences
- Equidistant from Dumont d'Urville, Baia Terra Nova and Casey stations

- ~16 people in winter, up to 80 people in summer
- Station operating cost of €5.5m/year

Images: John Storey, Jon Lawrence


The AASTINO
Image: John Storey

PILOT
PATHFINDER FOR AN INTERNATIONAL LARGE OPTICAL TELESCOPE

- 2.5 metre optical/infrared telescope
- Dual role: pathfinder and unique science
- International project
- Sited at Concordia Station, Dome C, Antarctica

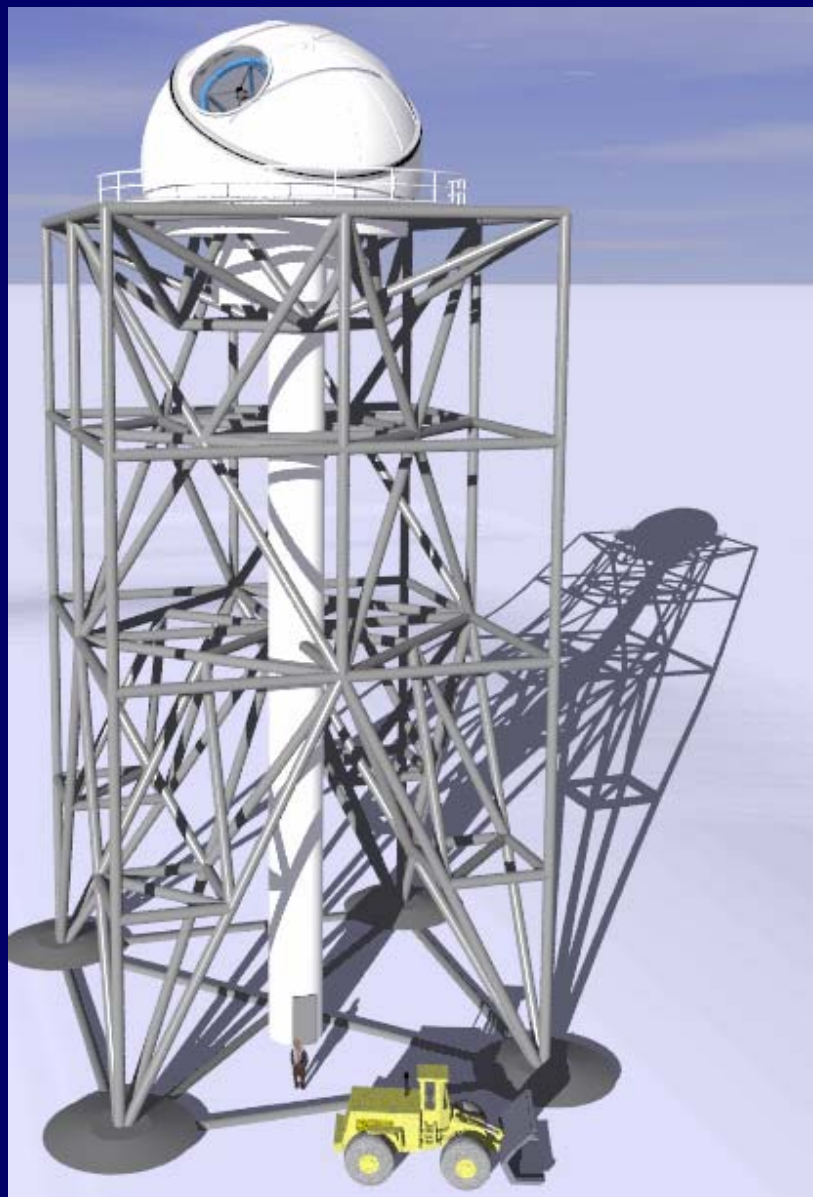


Image: Andrew McGrath

The PILOT Phase A study

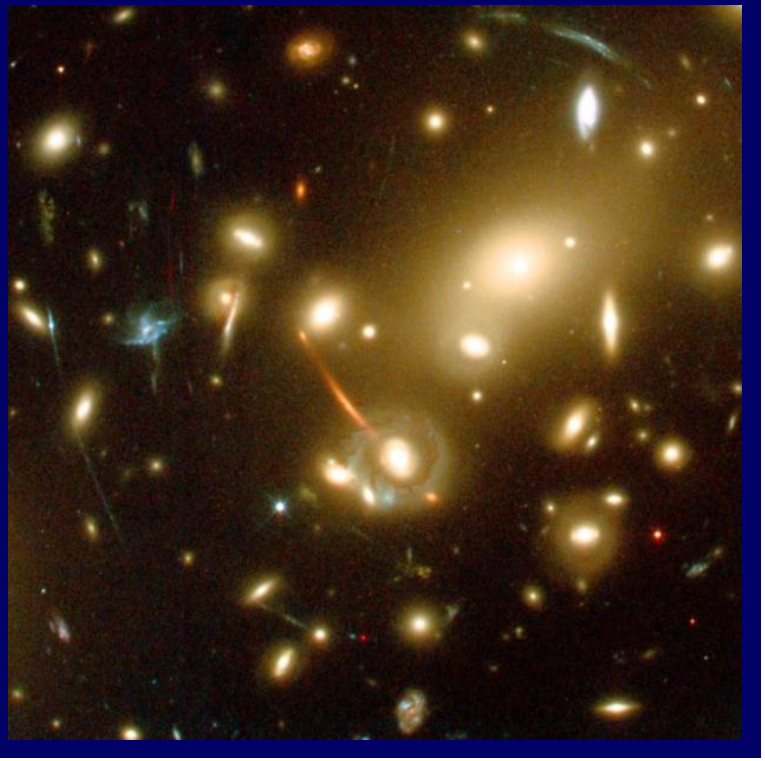
- NCRIS funding of $1m awarded to UNSW for 2007
- Additional $250k from UNSW
- Technical study subcontracted to Anglo-Australian Observatory
- Additional resources contributed by AAO
- Additional resources contributed by ARENA partners
- Report submitted 31 July 2008.

Image: Guillaume Dargaud

PILOT science

PILOT has unique capabilities in:

- Wide-field, high resolution imaging
  - 5 ~ 20 times the survey speed of VISTA
  - 10 times survey speed (to given depth) of the 8 m VLT *FIRES*
- Terahertz astronomy
- Time-series astronomy
- Asteroseismology



Four identified “big science” drivers:

– H_2 in our Galaxy
– The first light in the Universe
– The earliest stellar populations
– The Equation of State of the Universe

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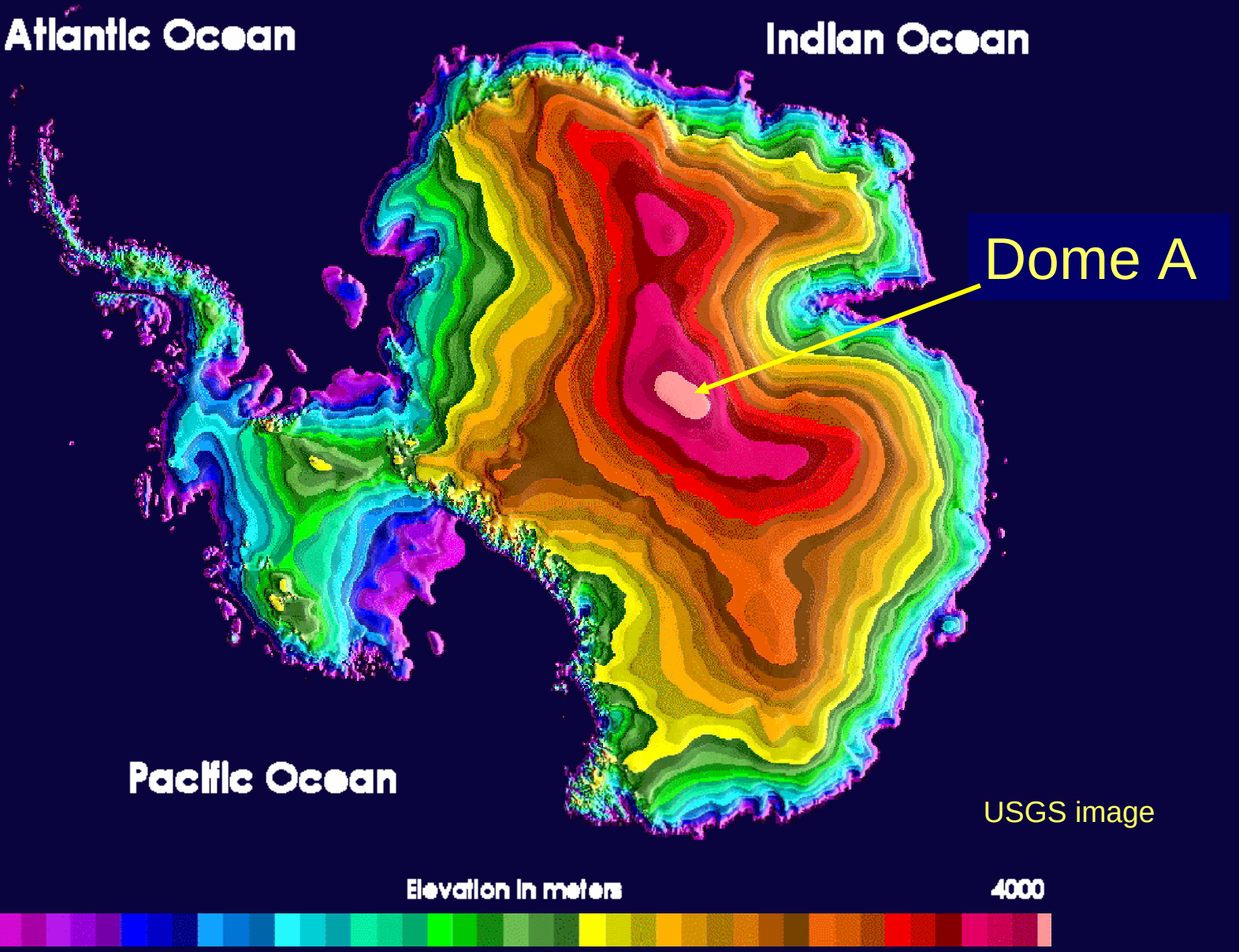


Dome A in 2008

Image: Li Yuansheng

Dome A in 2011

Image: CHINARE

Dome A four weeks ago

Images: CHINARE

PLATO is a collaboration between China, Australia, USA and UK.

Image: CHINARE

The PLATO team

Michael Ashley, Colin Bonner, Jon Everett, Shane Hengst, Jon Lawrence, Daniel Luong-Van, John Storey University of New South Wales, Australia

Anna Moore, Tony Travouillon California Institute of Technology, USA

Jingyao Hu, Zhaoji Jiang, Xu Zhou National Astronomical Observatory of China, China

Xiangqun Cui, Xuefei Gong, Xiangyan Yuan Nanjing Institute of Astronomical Optics Technology, China

Longlong Feng, Zhenxi Zhu, Ji Yang, Xu-Guo Zhang, Jun Yan Purple Mountain Observatory, China

Yuansheng Li, Weijia Qin, Bo Sun, Huigen Yang, Zhanhai Zhang Polar Research Institute of China, China

Graham Allen Solar Mobility, Australia

Nicholas Suntzeff, Lifan Wang Texas A&M University, USA

Reed Riddle Thirty Meter Telescope Project, USA

Zhaohui Shang Tianjin Normal University, China

Craig Kulesa, Chris Walker University of Arizona, USA

Stuart Bradley University of Auckland, NZ

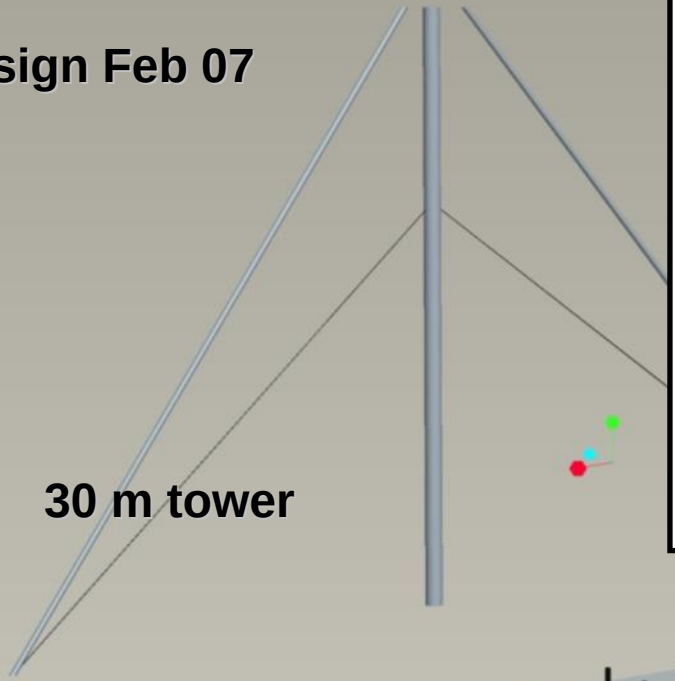
Donald York University of Chicago, USA

Carlton Pennypacker University of California at Berkeley, USA

Nick Tothill University of Exeter, UK

PLATO design

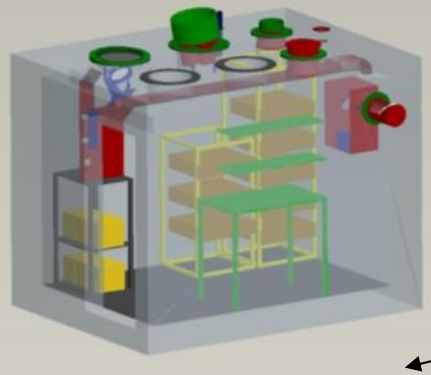
Concept design Feb 07



30 m tower

PLATO Requirements:

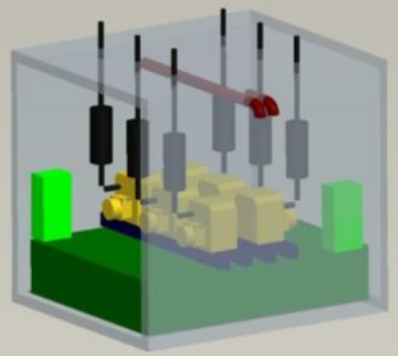
- Power: 400 W summer, 1 kW winter
- Heat: 400 W summer, 1 kW in winter
- Control: Autonomous and reliable supervisor computer system
- Communications: Low bandwidth (300bps x 2) via Iridium satellite
- Logistics: footprint of 20-foot shipping container, plus weight limits



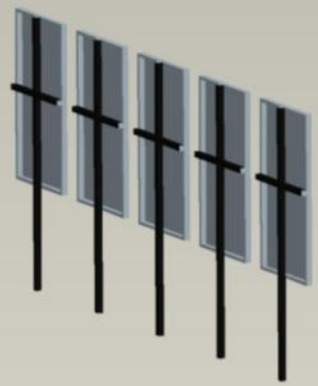
2 m

50 m

Instrument module



engine module



solar panel array


PLATO power module
Image: Graham Allen

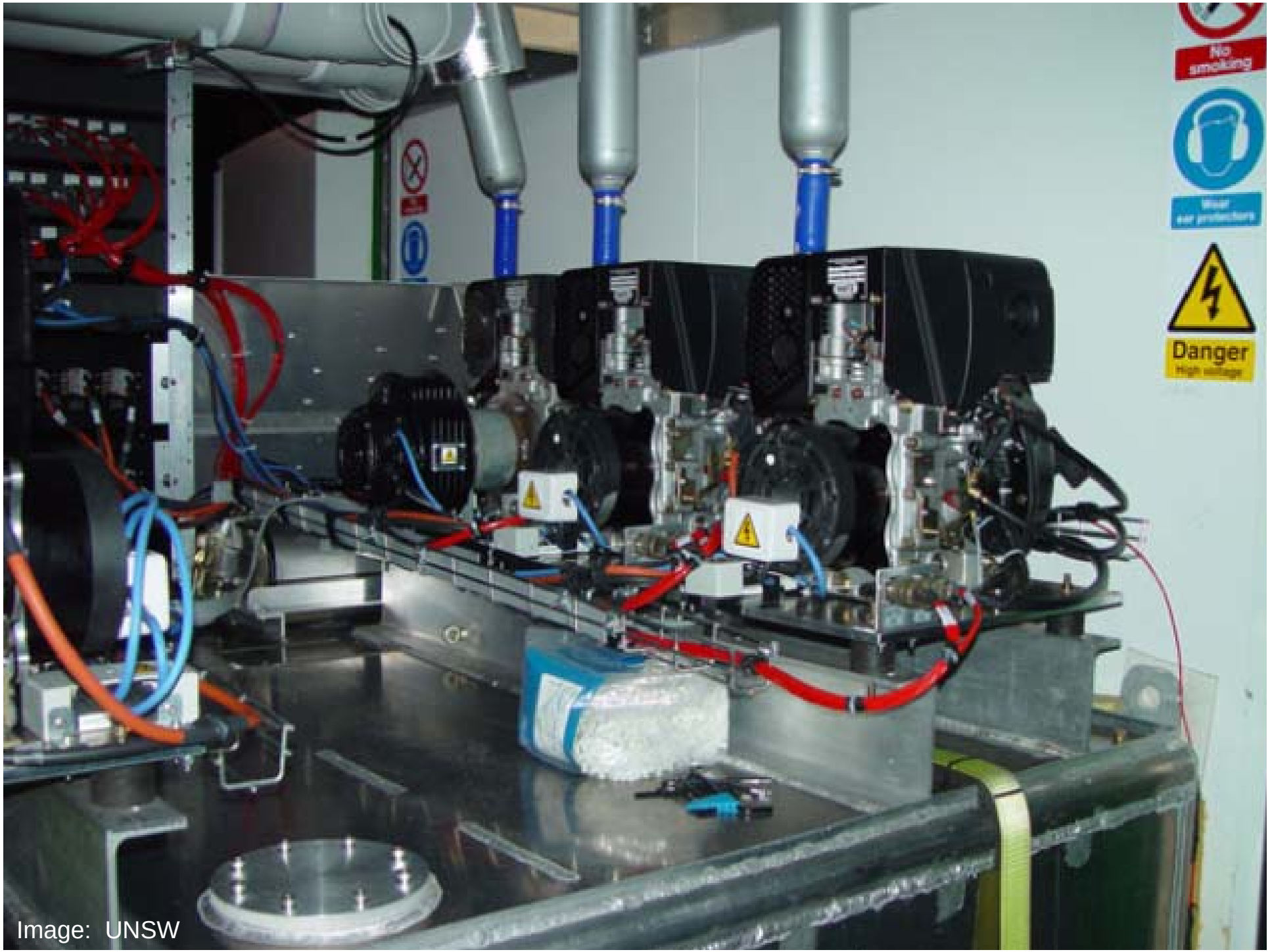


Image: UNSW

Capacitors

10^{-5} Farads

10^{-9} Farads

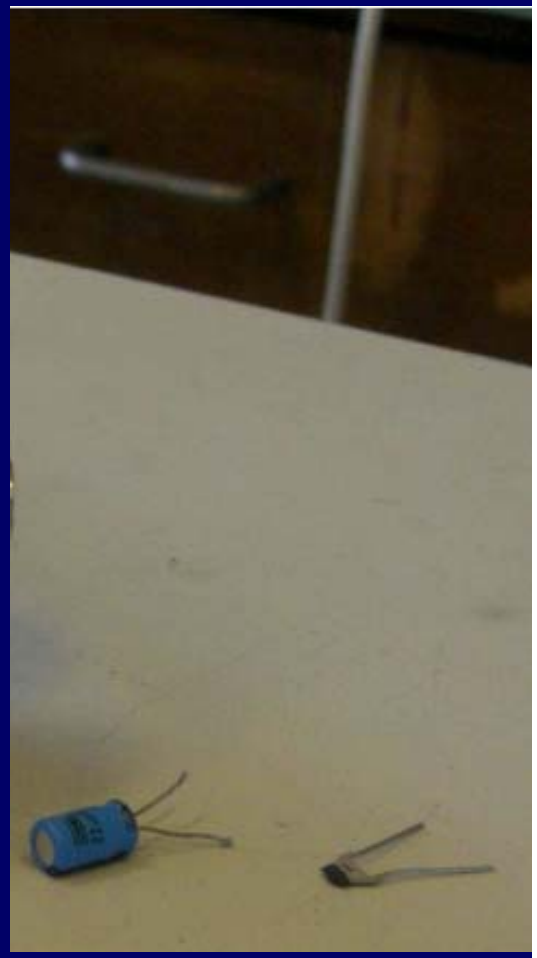


Image: Diane Castel

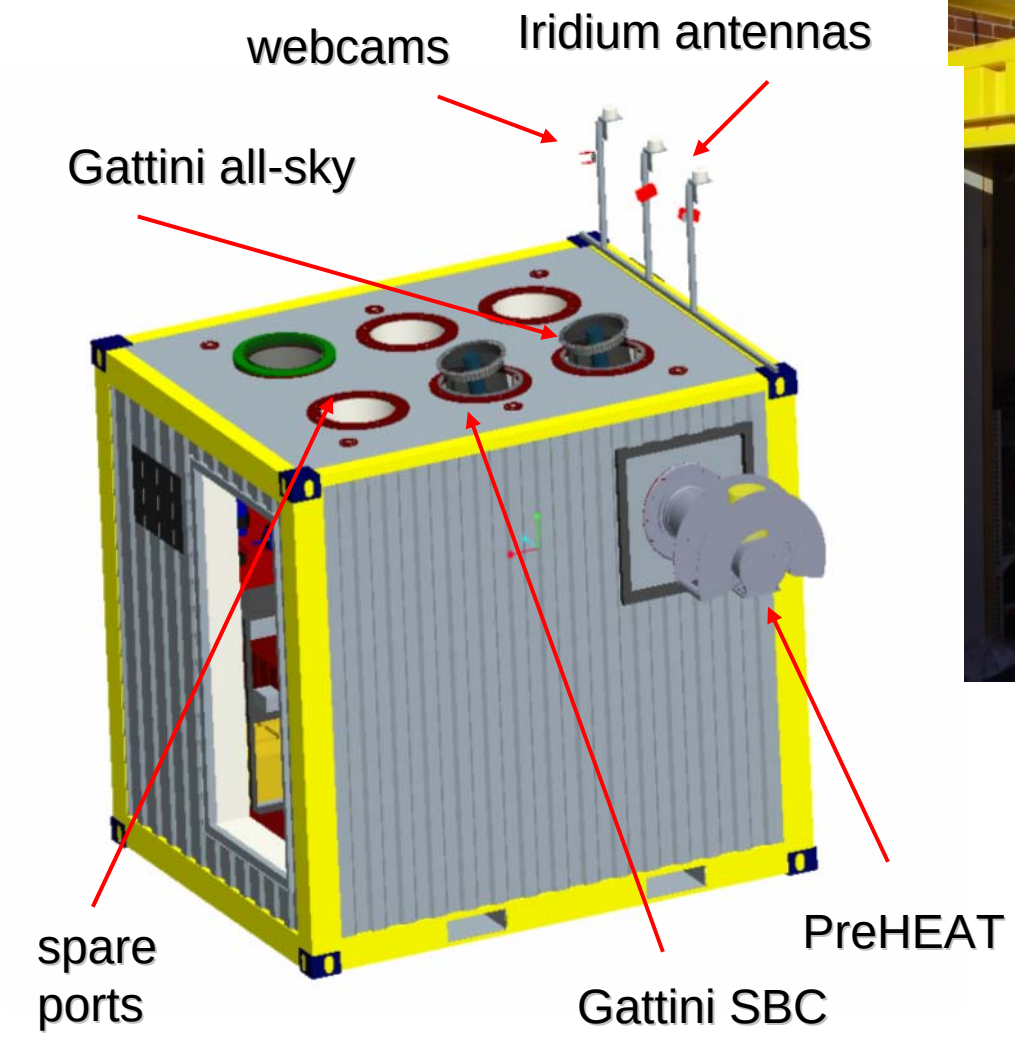
Capacitors

Image: Diane Castel

Image: Diane Castel

Engine testing

Instrument module



CSTAR, SNODAR, Sonics located externally on snow surface

Instrument module

Supervisor nodes (x2)

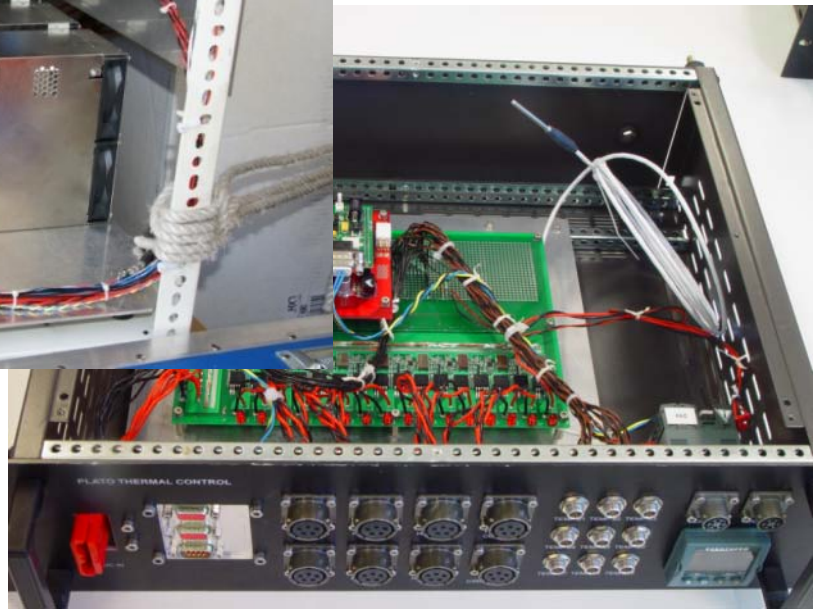
- PC104 computer
- CAN microcontroller
- Iridium L band transceiver

Control units

- Power switching
- Analog monitoring
- Thermal control
- Engine monitor and control
- Ethernet hub

Power electronics system

- 24 VDC 320 Ahr battery bank
- 4 x high power 110→24 V DC/DC
- 2 x solar power MPPT




26 Nov 2007:
PLATO departs UNSW
TYNE 001006
PLATO
PLATO
VOLVO
TILT LOGISTICS
FM9
TILT
LOGISTICS
0417 21 22 77
YYH·971

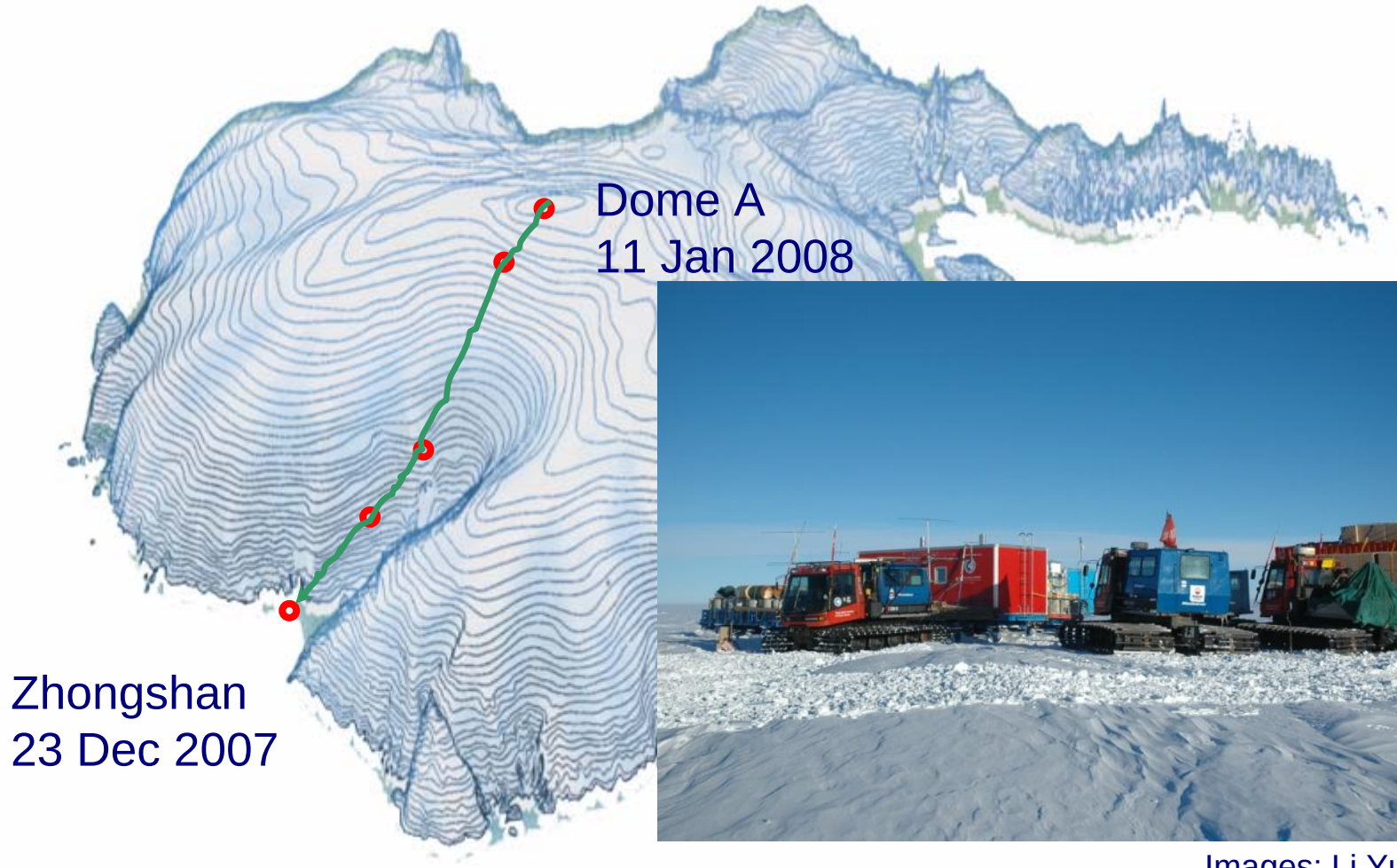
30 Nov 2007: Xuelong loading and departure


PLATO

Dome A traverse

Polar Research Institute of China tractor traverse 2008:

- 18 expedition members
- 2 astronomers: Zhou Xu (NAOC), Zhenxi Zhu (PMO)



Images: Li Yuansheng, PRIC


Images: Xhenxi Zhu and Zhou Xu


PLATO
PLATO


24
CHINARE
中国第二十四次
南极科学考察队


PLATO
PLATO


PLAT
PLAT

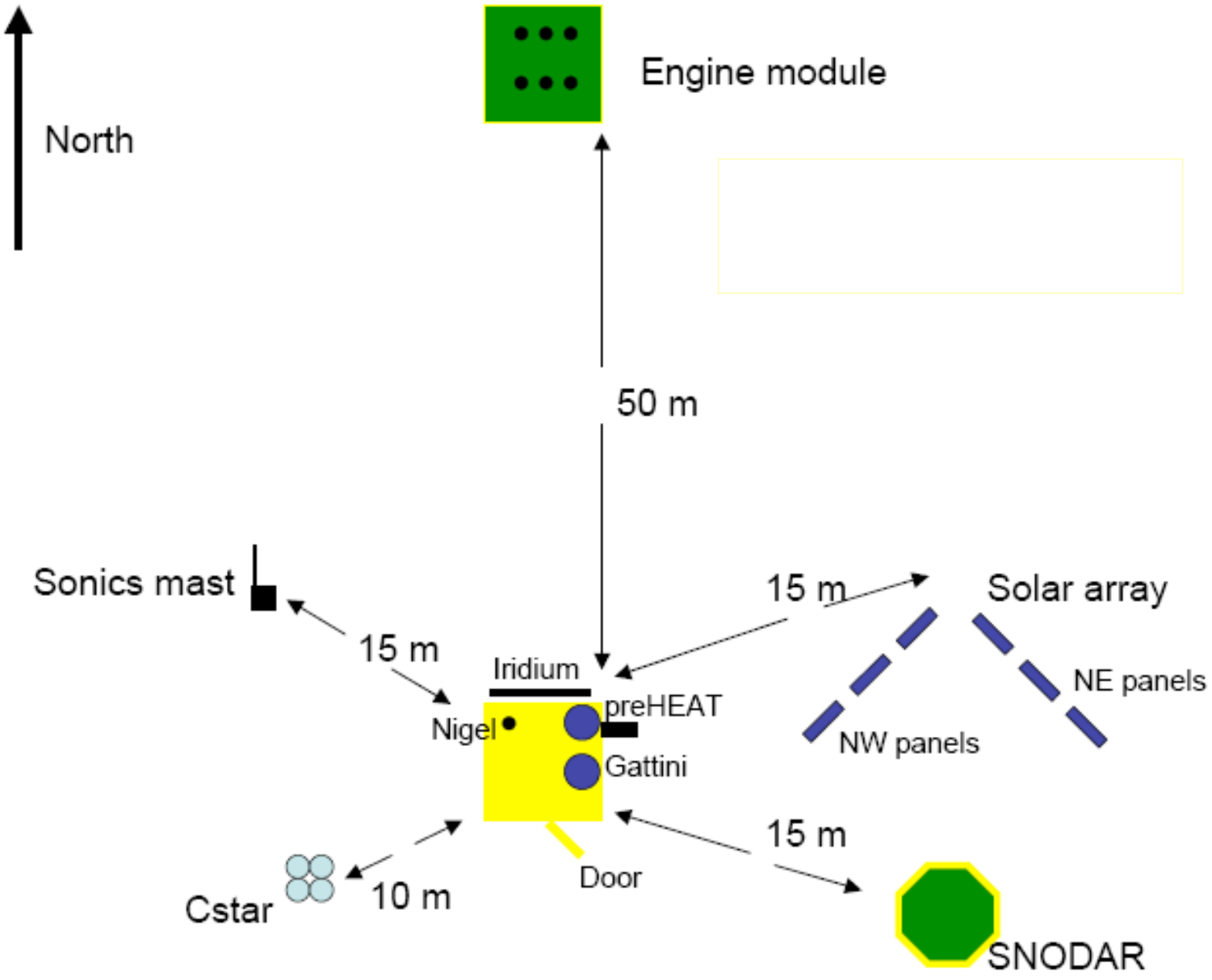

PLATO
PLATO

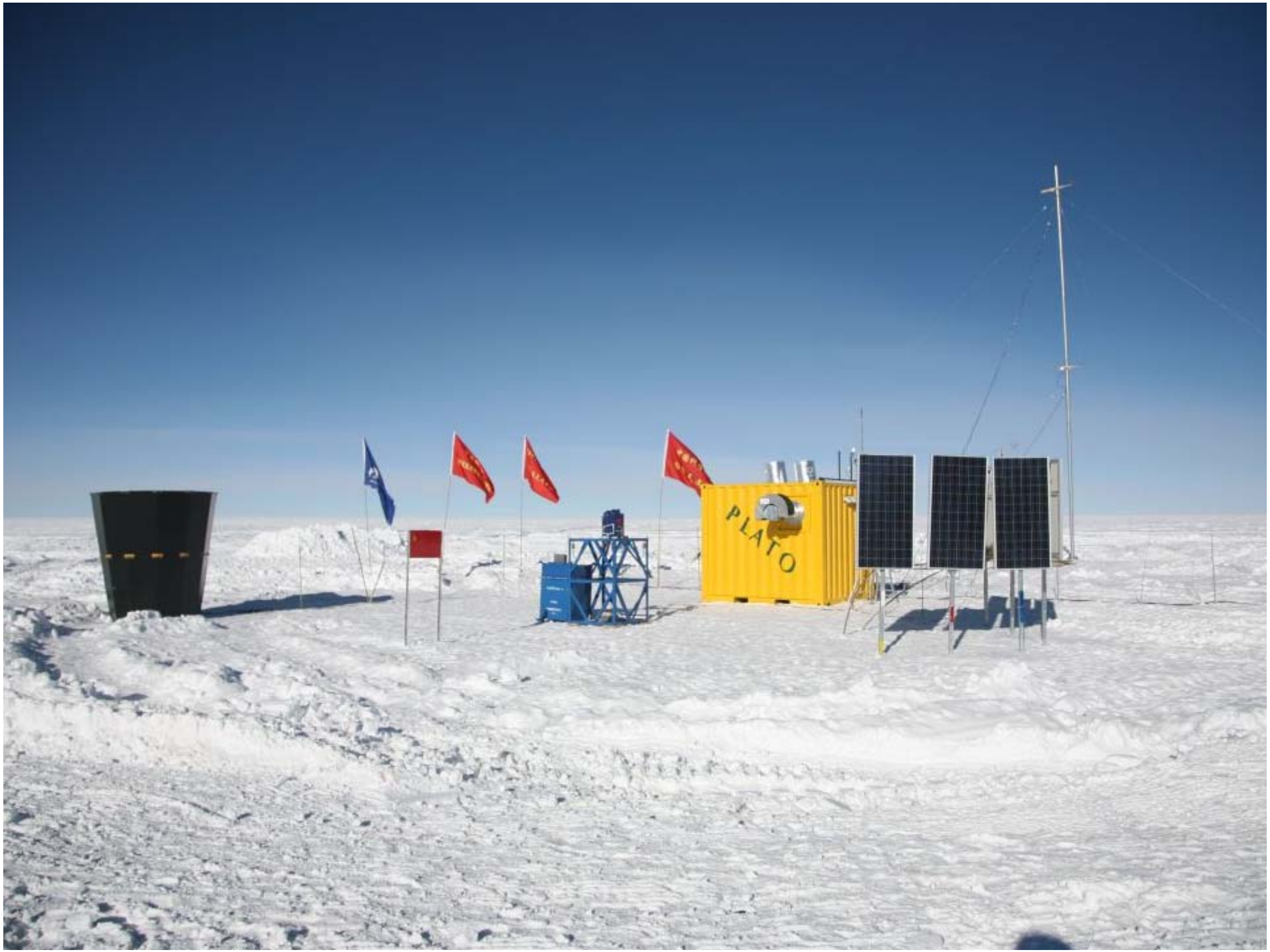

24


payload 8 to

PLATO at Dome A

PLATO at Dome A




PLATO

PLATO status

- PLATO ran remotely from January 2008 until August 8 (204 days).
- Iridium communications using Short Burst Data and Direct Internet; 20MB/day; 3GB transferred.
- Over 100 parameters logged every 5 mins.
- Real-time web display of a dozen critical parameters, typically 3 minutes old.
- First servicing mission in January 2009 has just concluded.
- PLATO has now run for 57 days in 2009…

PLATO Webcameras

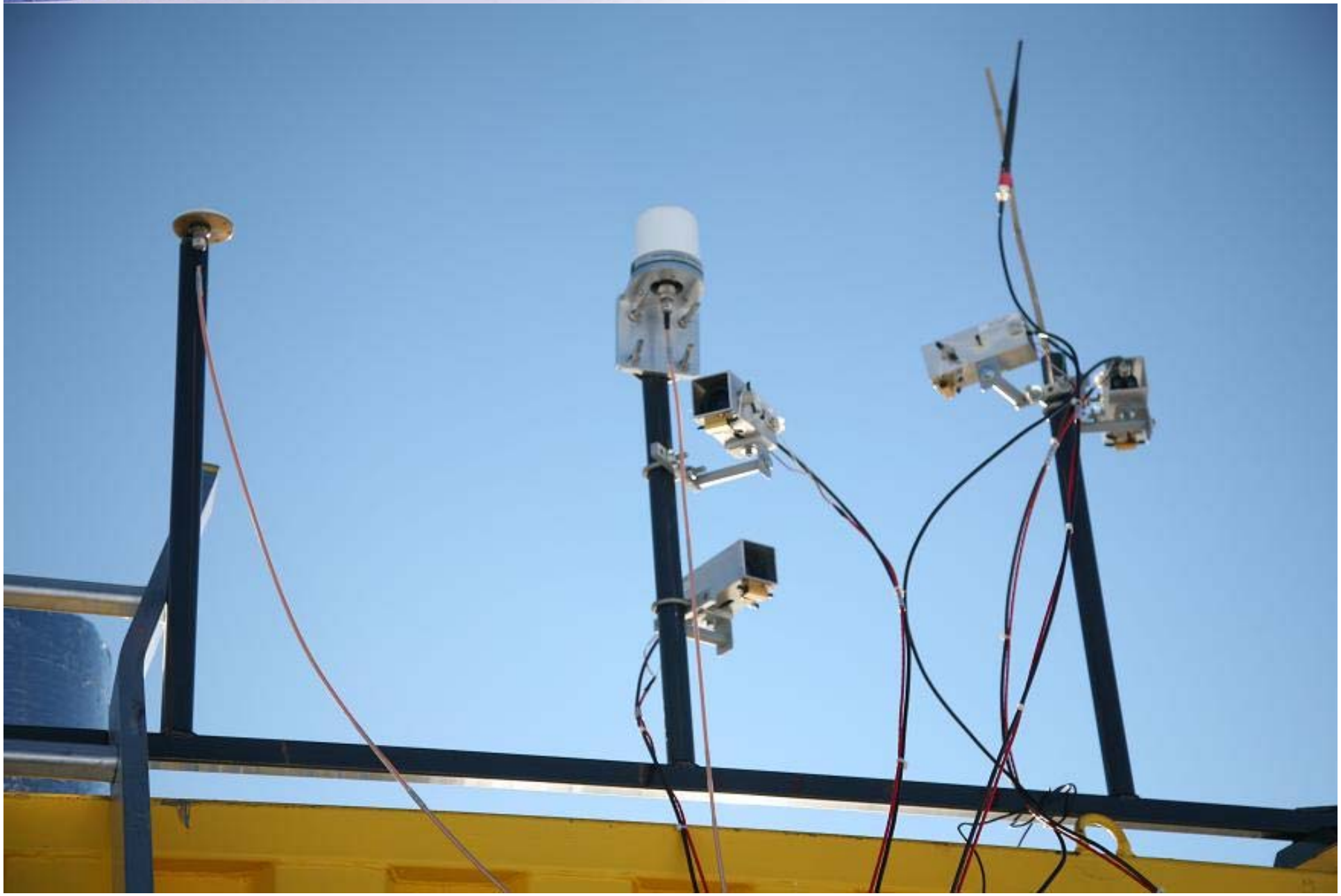


Image: PLATO

Image: PLATO

Image: PLATO

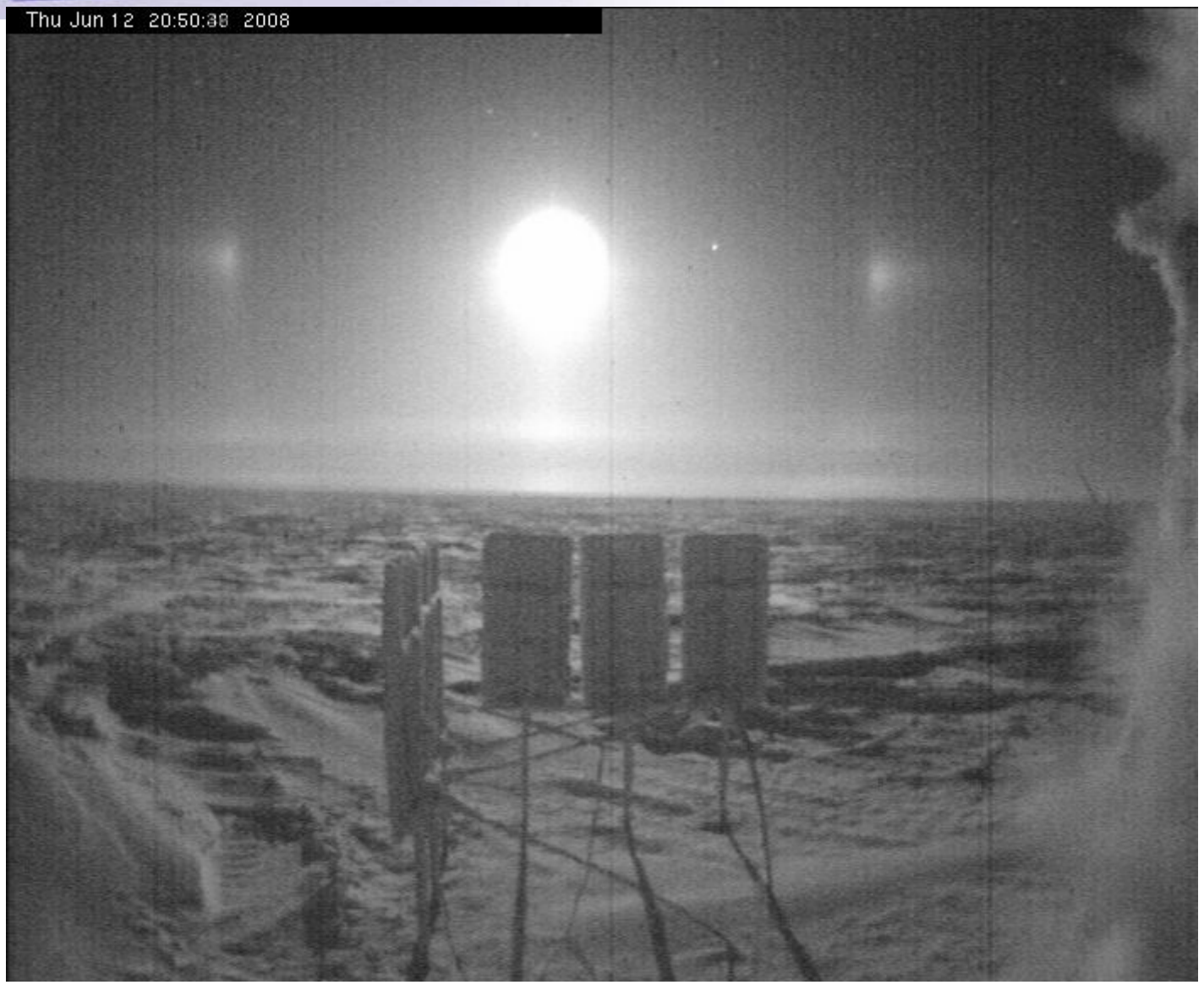


Image: PLATO

Image: PLATO

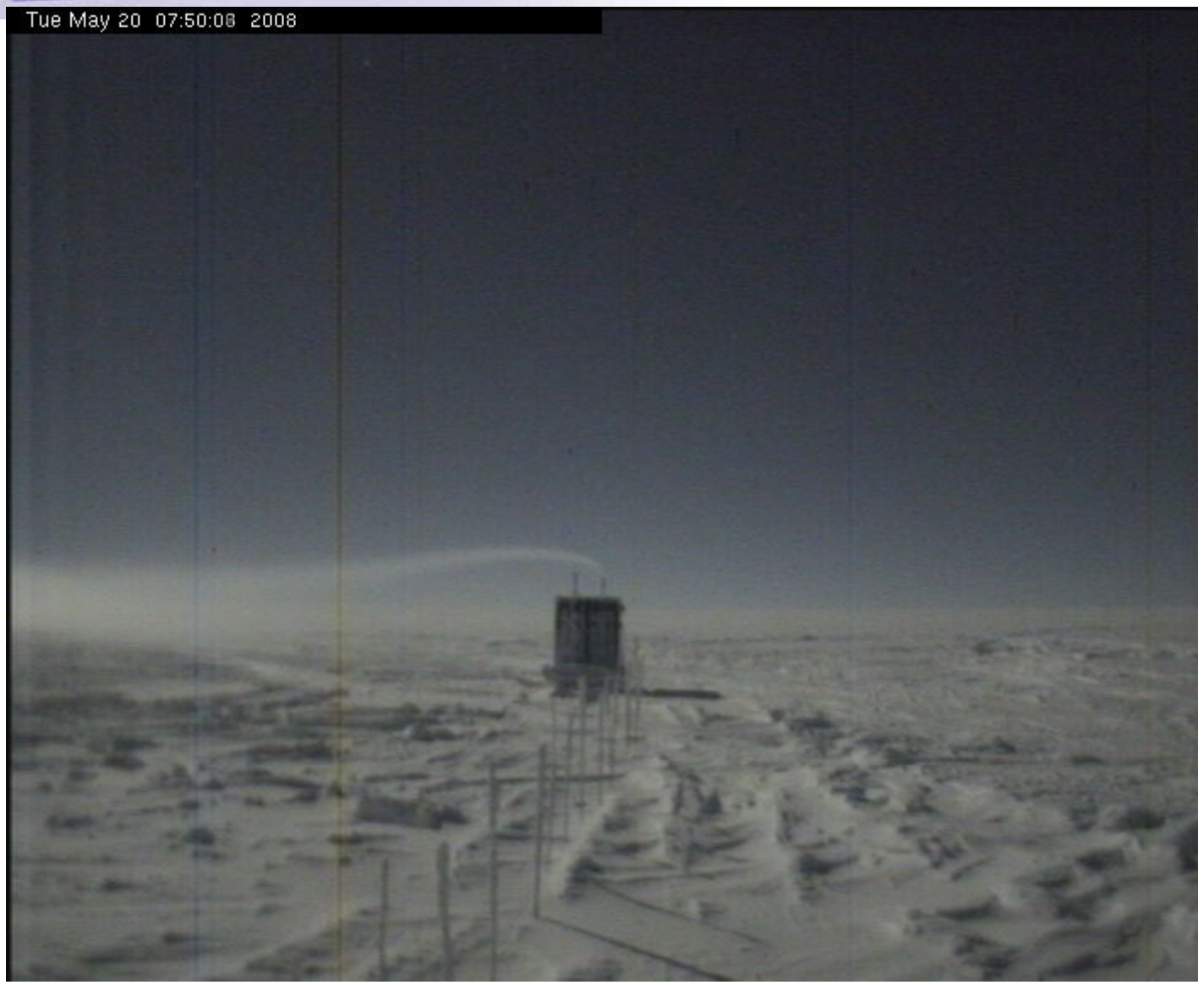


Image: PLATO

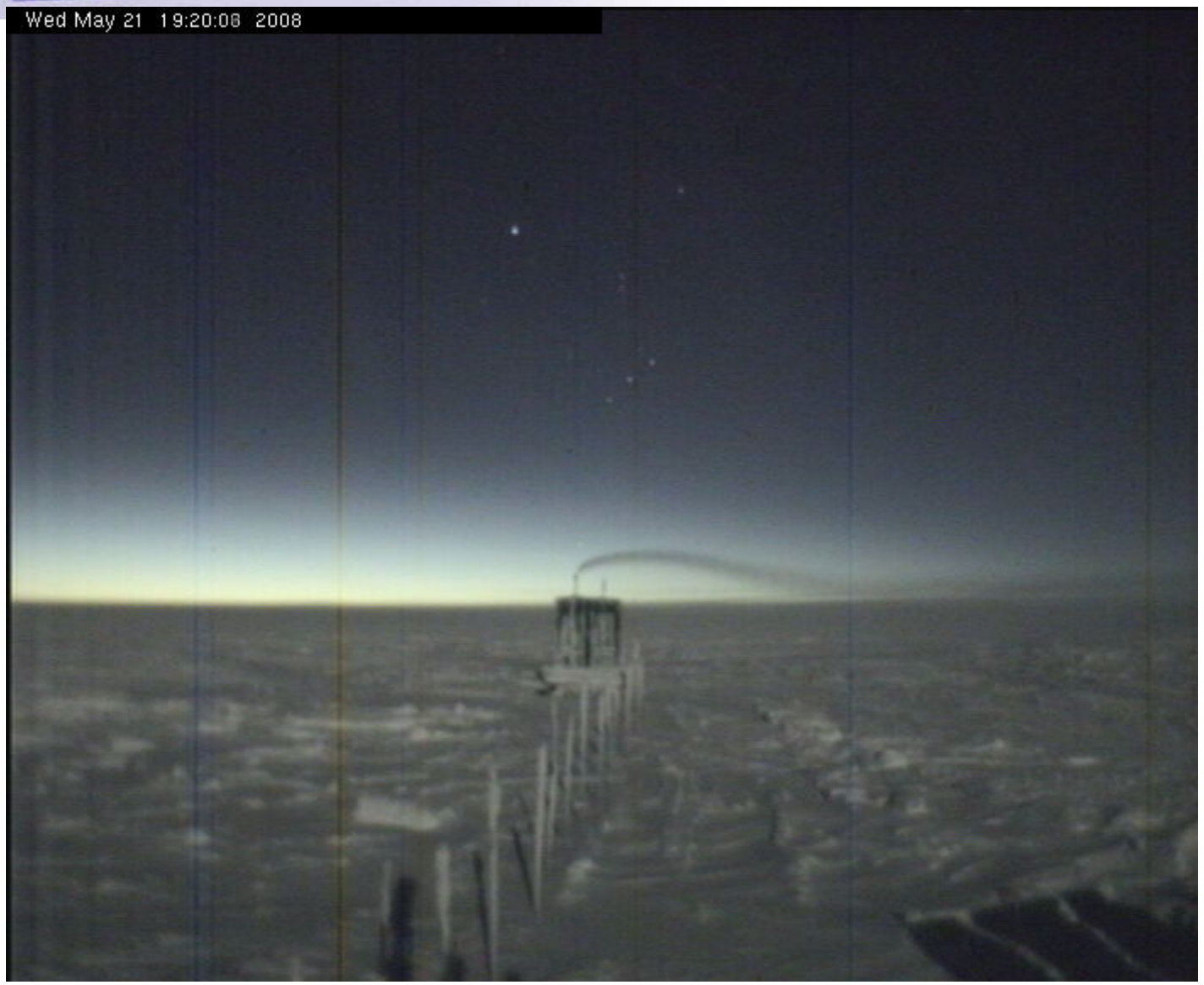


Image: PLATO

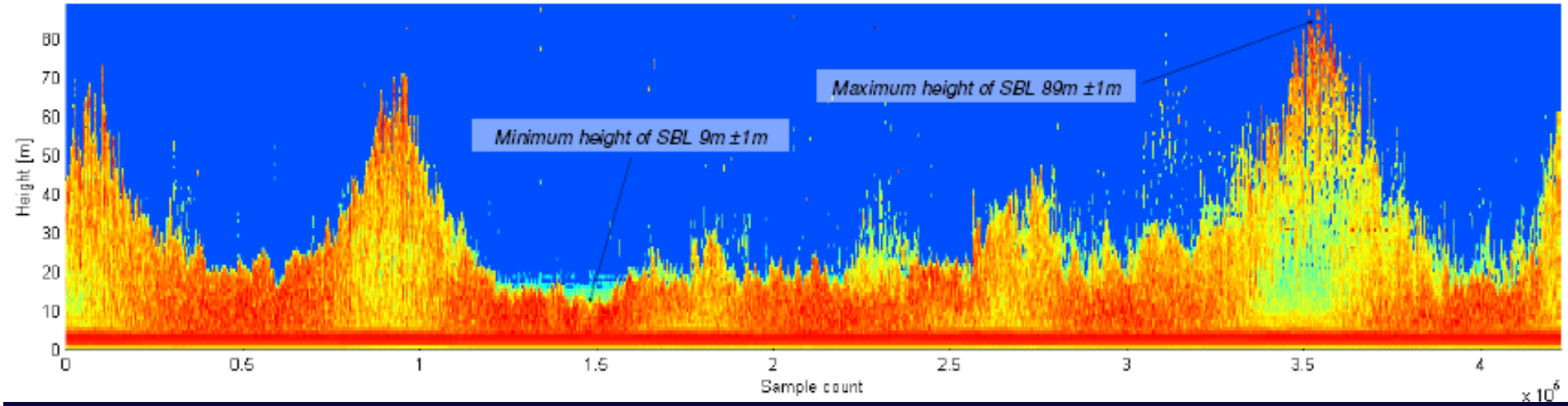
Image: PLATO

Image: PLATO

PLATO site testing

- **Turbulence (Snodar)**
  - Boundary layer height, distribution and variability
- **Sky emission (Gattini, Nigel)**
  - Visible sky background versus sun/moon elevation, auroral spectral intensity and distribution,
- **Sky transmission (Pre-HEAT)**
  - Transparency and noise in long wave (submillimetre) windows
- **Science (CSTAR)**
  - Optical transients: variable stars, transits, microlensing, GRB, etc

Dome A stable boundary layer



Six days of processed data from acoustic radar (Snodar)

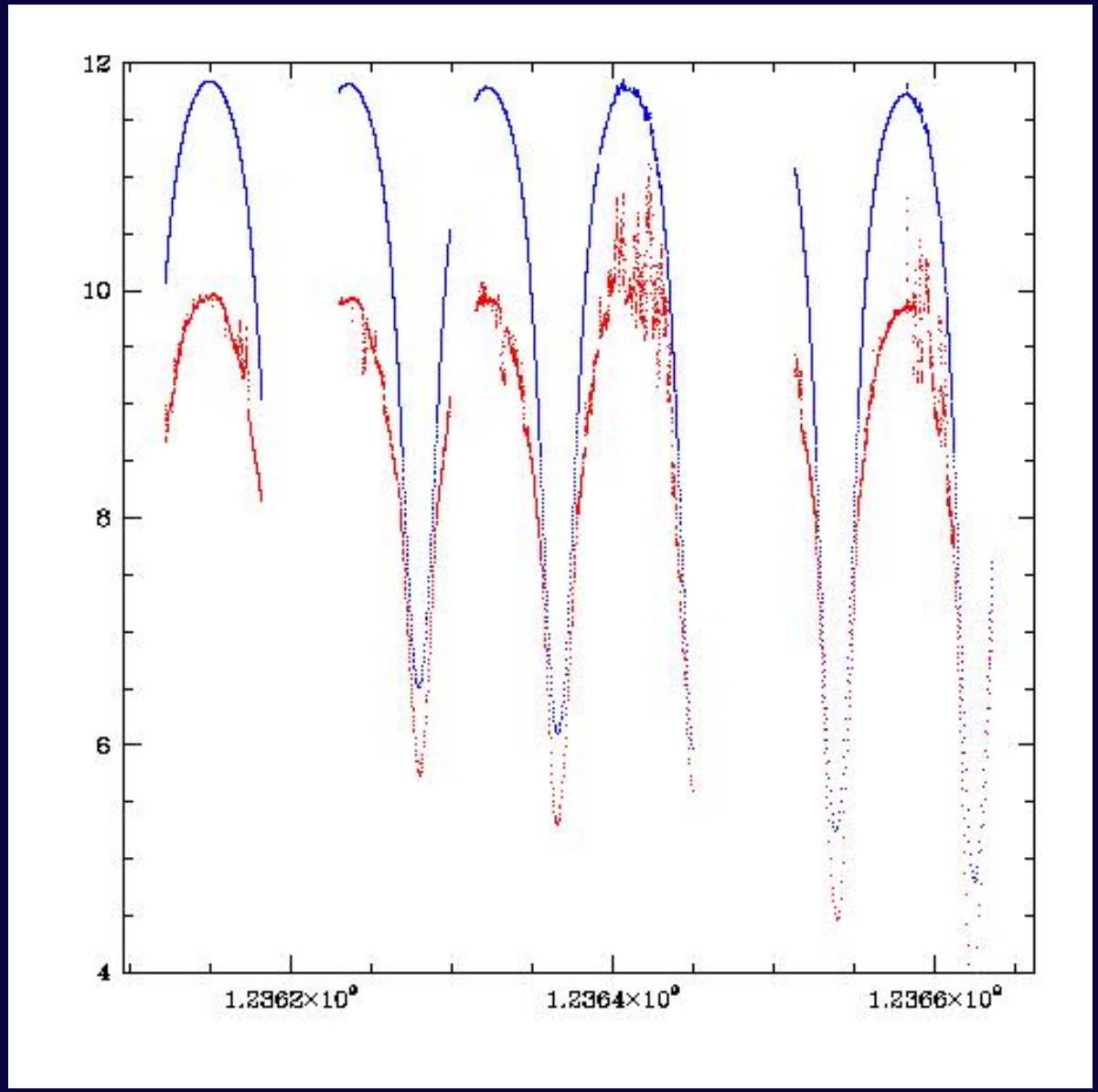
Data: AACC/PMO/PRIC/UNSW

Nigel, the optical spectrometer

Six optical fibres
250 - 850 nm
2.4 nm resolution

Data: PLATO collaboration

Six days of *Nigel* data



Data: PLATO collaboration

Pre-HEAT

- **Pre-HEAT**
  - Developed by University of Arizona
  - Measures: transmission, galactic plane CO map
  - 450 micron sky-dipping radiometer using Schottky receiver
  - Mounting: through PLATO wall port

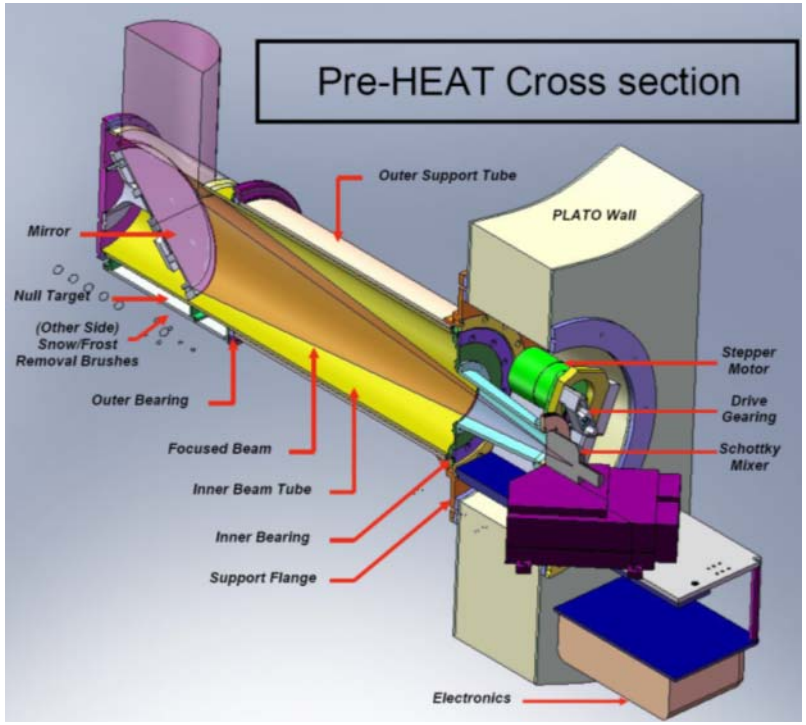
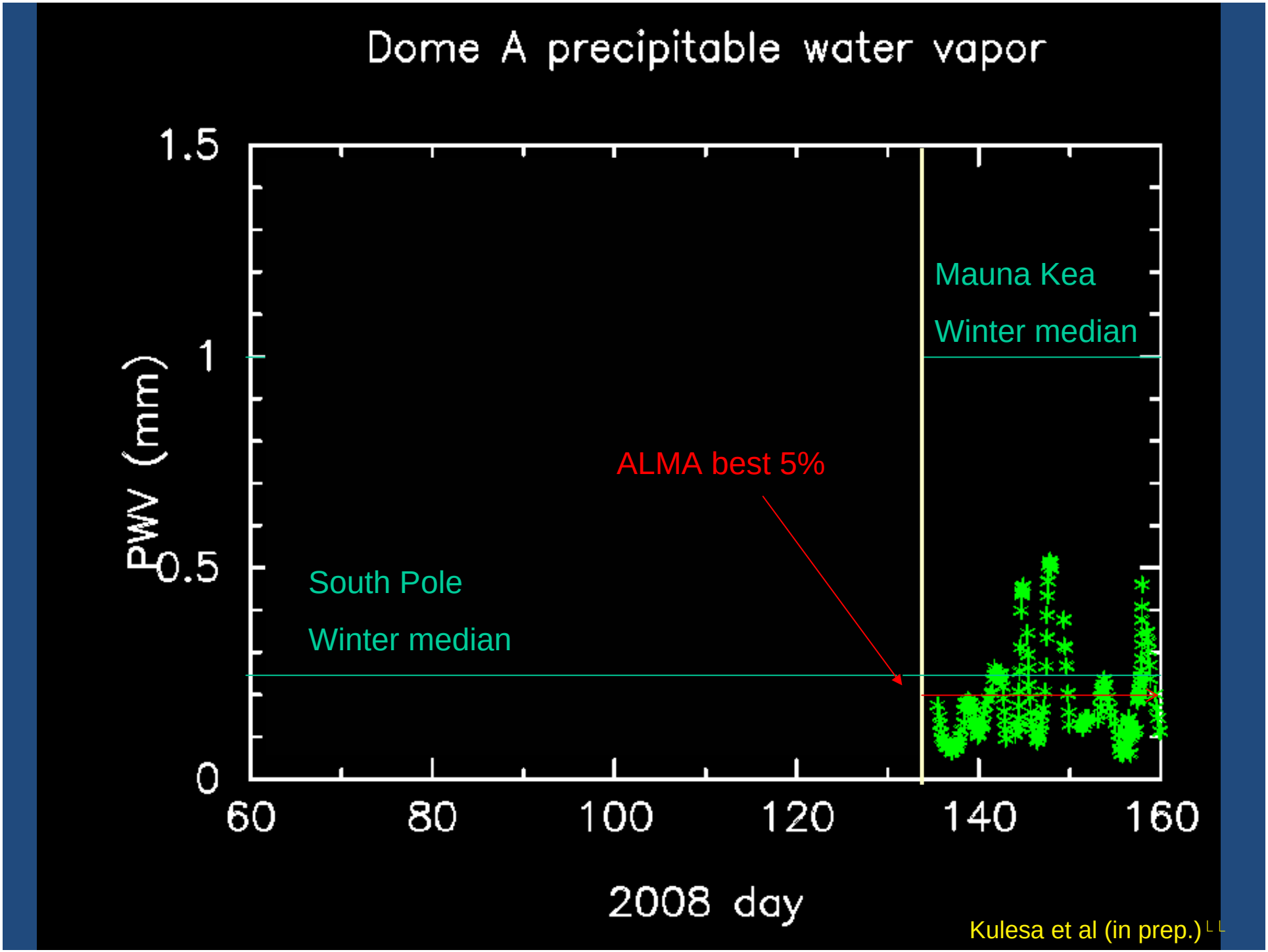
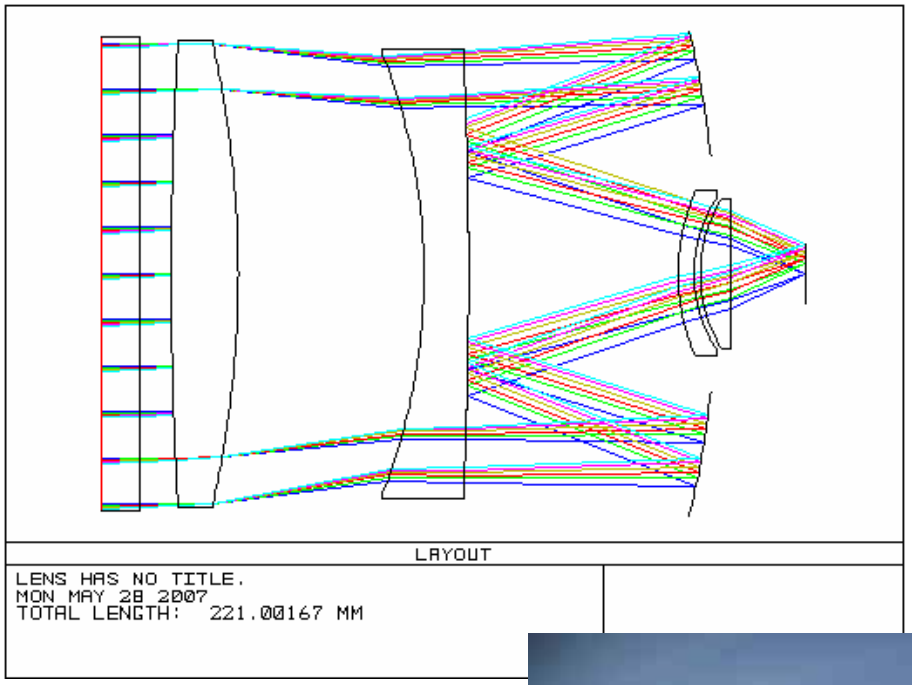


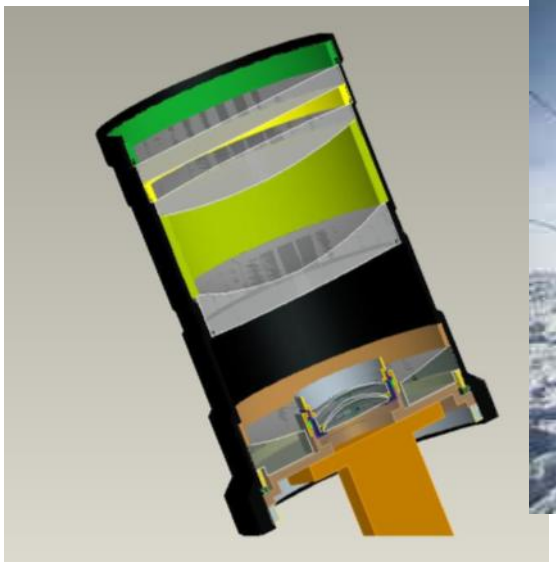
Image: PLATO

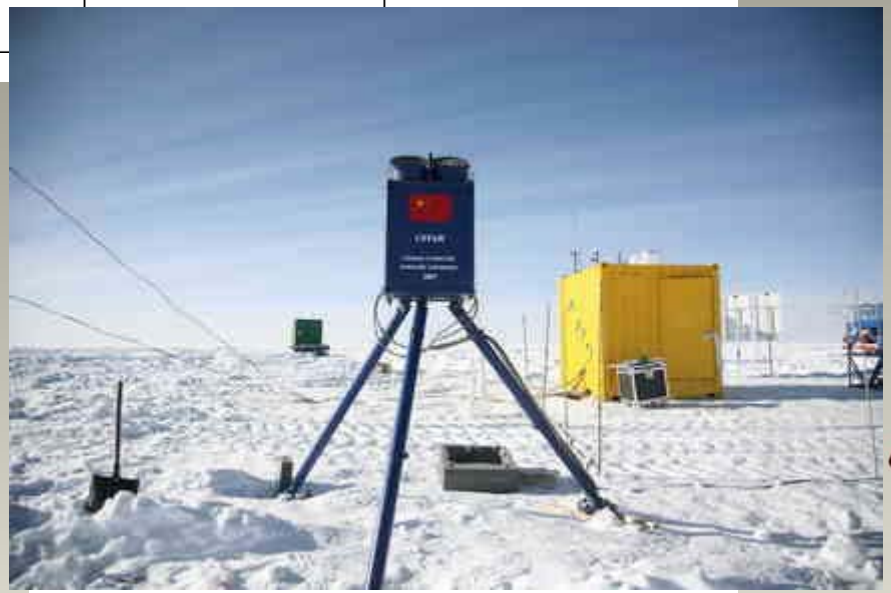

Dome A precipitable water vapor
1.5
1
0.5
0
PWV (mm)
60
80
100
120
140
160
2008 day
Mauna Kea
Winter median
ALMA best 5%
South Pole
Winter median
Kulesa et al (in prep.)

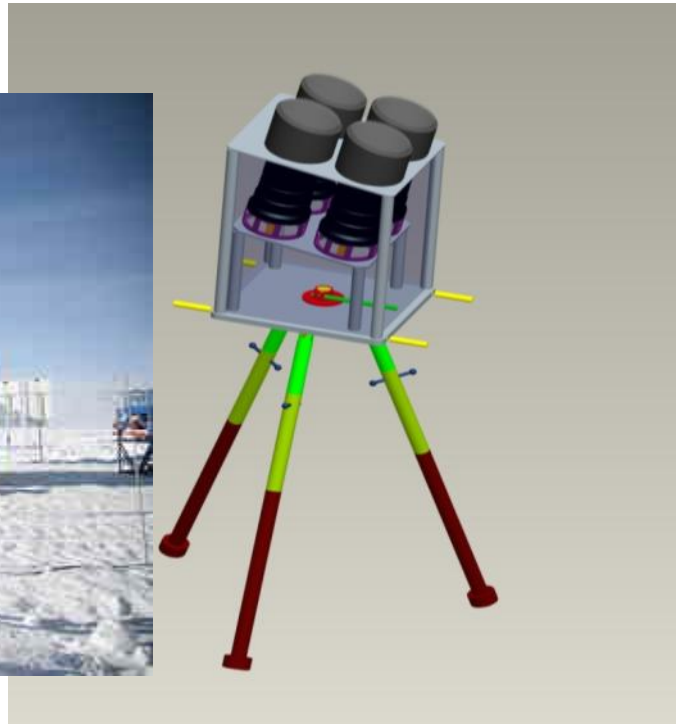
CSTAR



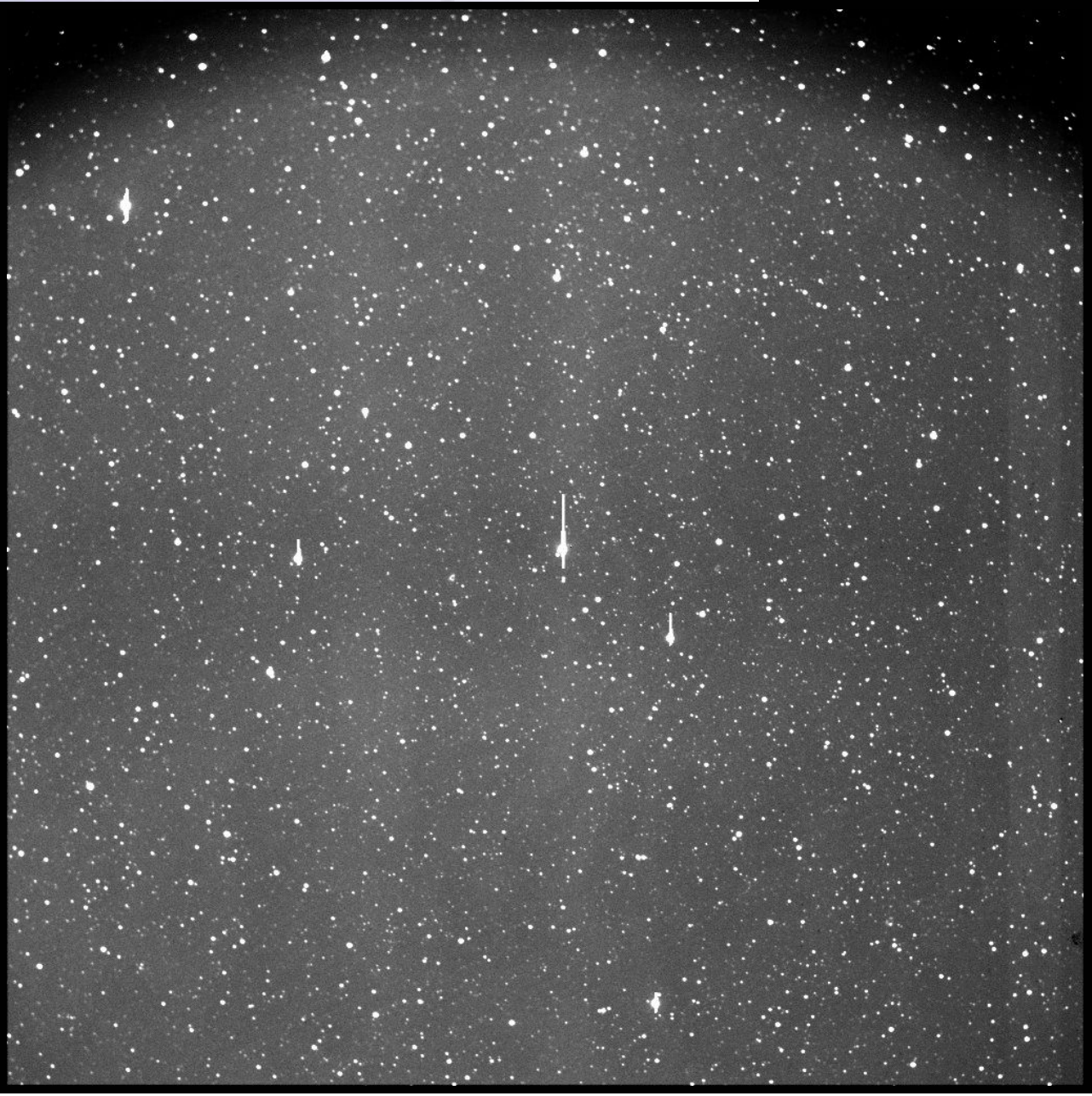
- CSTAR specification
  - Supplied by NIAOT, NAOC, PMO, TNU
  - 4 x 145 mm Schmidt (Fl = 175 mm)
  - Andor 1k x 1k frame transfer CCD
  - 20 sq deg FOV (4.5 x 4.5 degrees)
  - g, r, I, unfiltered







CSTAR image, 16 April 2008



PLATO Dome A Robotic Observatory

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最近500小时

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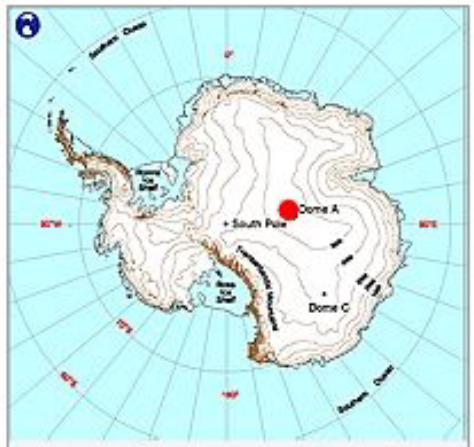
冰穹A

在过去10年中，研究发现南极点和冰穹C对于天文观测是极优良的站址，远远优于中纬度的站点。南极高原的最高点冰穹A，预计那里的大气温度更低、风速更小、湍流边界层也更接近地面。

作为国际极地年(IPY)的一部分的PANDA和Astropoles计划，中国科学院国家天文台(NAOC)、中国极地研究所(PRIC)、新南威尔士大学(UNSW)合作进行研制和放置自动天文观测站PLATO于冰穹A的计划。PANDA科考队于2008年1月成功地将PLATO运送到冰穹A。一个大国际团队参与其中，铱星通讯由美国南极项目(USAP)提供。

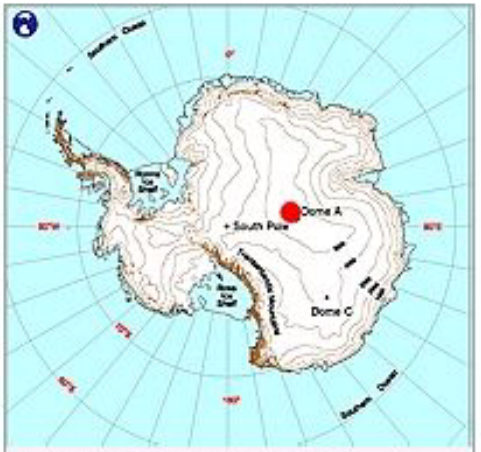


冰穹 A (点击放大)

PLATO Dome A Robotic Observatory

Dome A

Over a decade of site testing in Antarctica has shown that both South Pole and Dome C are exceptional sites for astronomy, with certain atmospheric conditions greatly superior to those at existing mid-latitude sites. The highest point on the Antarctic plateau, Dome A, is expected to experience even colder atmospheric temperatures, lower wind speeds, and a turbulent boundary layer that is confined even closer to the ground.



Dome A (click to enlarge)

As part of the PANDA and Astropoles programs of the International Polar Year (IPY), an agreement was signed between the the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC), the Polar Research Institute of China (PRIC), and the University of New South Wales (UNSW) to develop and deploy an autonomous observatory called PLATO to Dome A. The PANDA traverse successfully delivered PLATO to Dome A in January 2008. A large international team has contributed to PLATO and its instruments, with Iridium satellite communication being provided by the U.S. Antarctic Program (USAP).

One year later…

Image: Michael Ashley

Not much has changed!

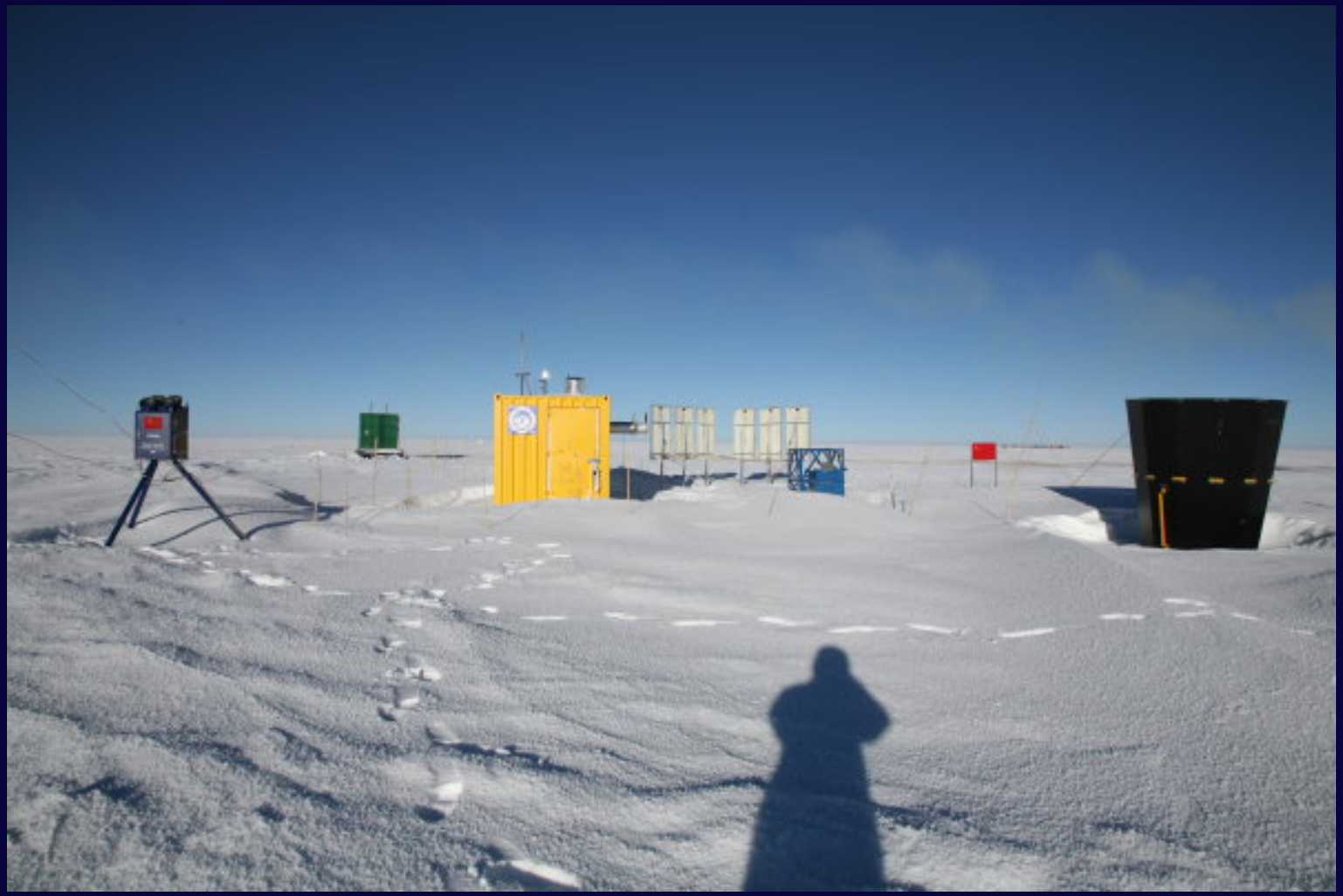


Image: Xuefei Gong

A few days later…

Image: Xuefei Gong

Today, around lunchtime…

Note: paper now published in PASP Feb 2009 (Yang et al.)

Image: PLATO collaboration

Outline

- Why Antarctica?
- South Pole
- Dome F
- Dome C
  - PILOT
- Dome A
  - PLATO
- Long-duration balloons
- AAA

Long-duration balloons are launched from McMurdo to study the cosmic microwave background.

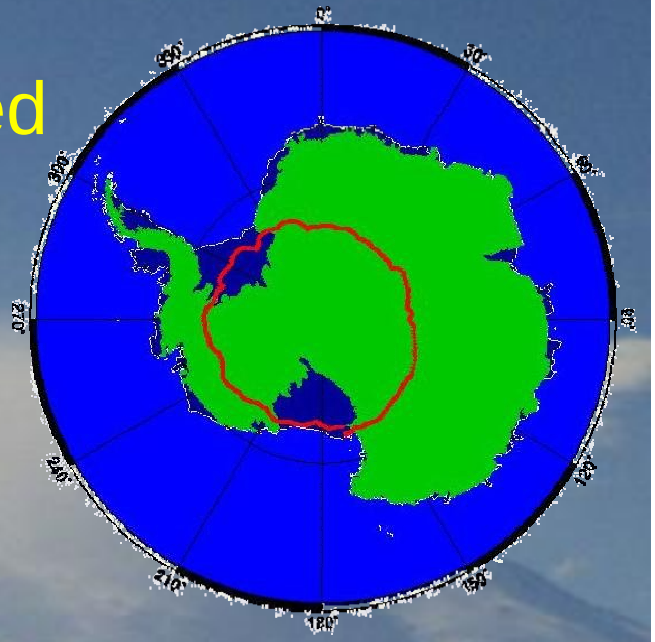
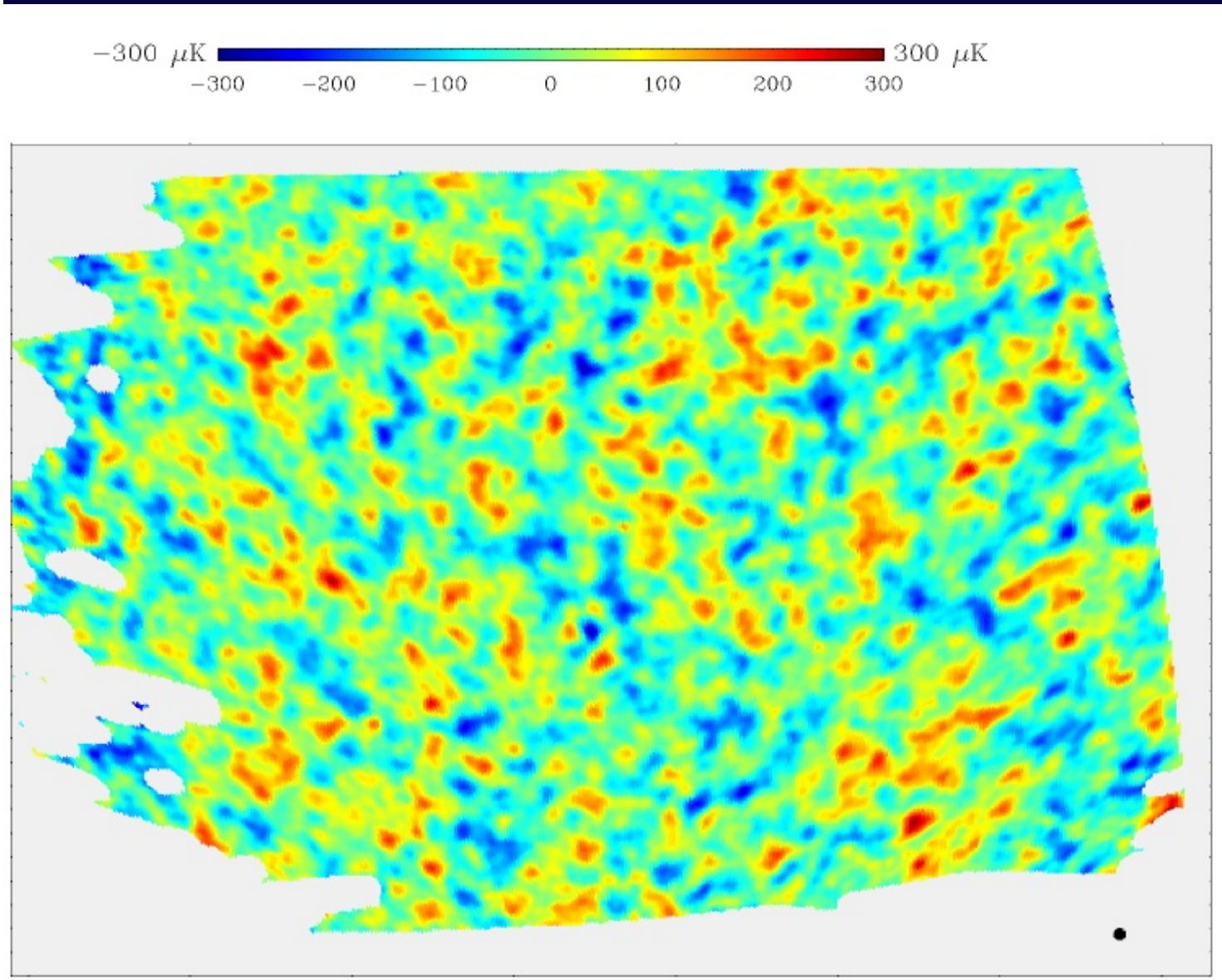


Image: Boomerang group

In 1998, *Boomerang* showed that the Universe is “flat”.



Data: Boomerang group

Outline

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Astronomy & Astrophysics
from Antarctica
a new SCAR Scientific Research Program
Image: David A. Hardy

Scientific Committee on Antarctic Research

Astronomy & Astrophysics from Antarctica (AAA)

Proposal to establish the AAA Scientific Research Programme

VERSION: 18 June 2008

Expected Duration: 2008 – 2012

Estimated SCAR funding: $US60,000

Astronomy & Astrophysics from Antarctica

Scientific Research Programme

The following Steering Committee has been approved:

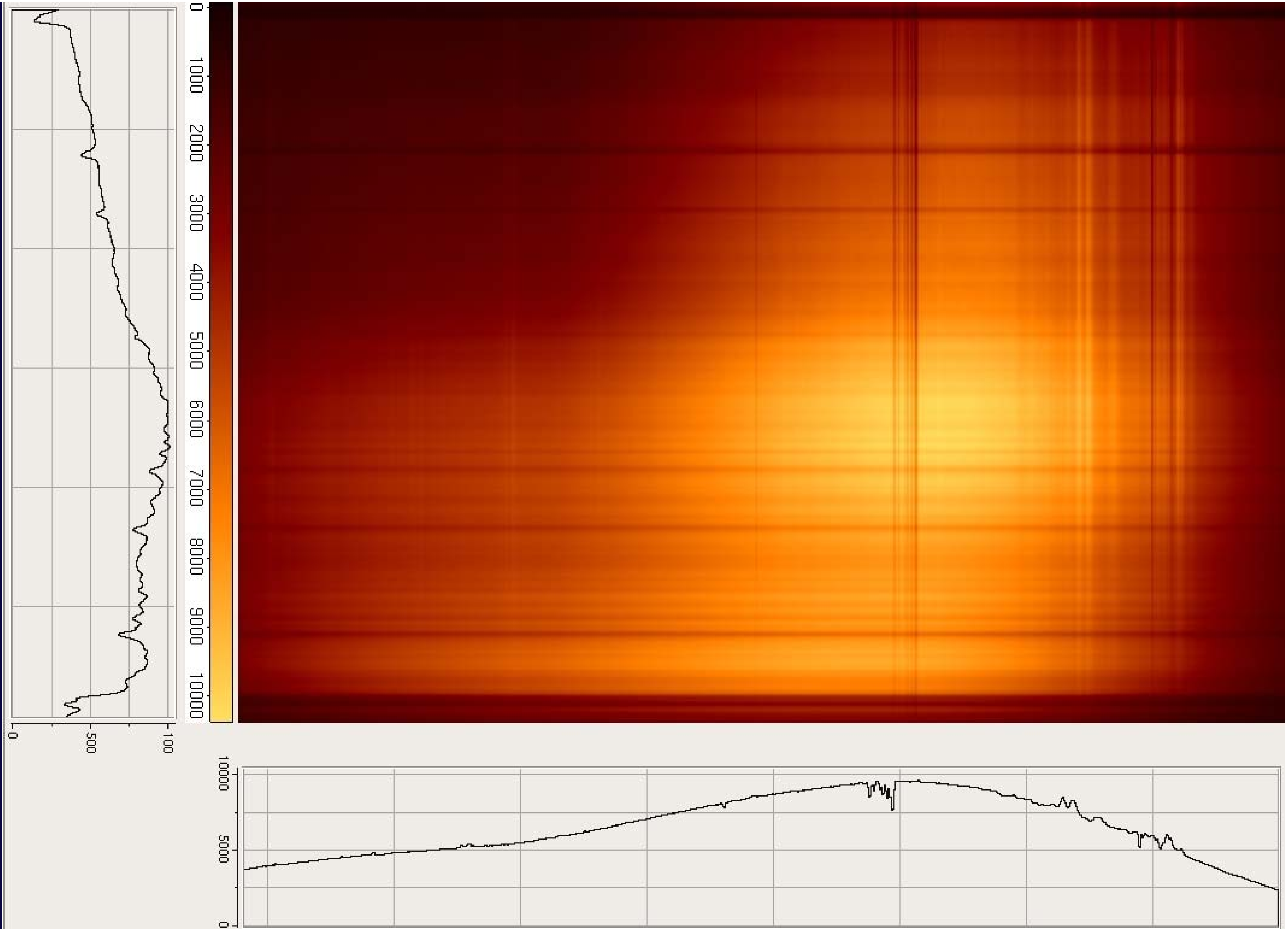
- Michael Andersen (Denmark)
- Philip Anderson (United Kingdom)
- Michael Burton (Australia)
- Xiangqun Cui (China)
- Nicolas Epchtein (France)
- Takashi Ichikawa (Japan)
- Albrecht Karle (USA)
- James Lloyd (USA)
- Silvia Masi (Italy)
- John Storey (Australia – Proposed Chief Officer)
- Lifan Wang (China/USA)

Summary

1. Their exist great opportunities for optical/IR astronomy.
2. There exist great opportunities for sub-mm astronomy.
3. It’s cold.
4. Deployment and operational costs are relatively modest.
5. However, communications bandwidth is limited and there are other challenges.

Image: Paolo Calisse


Thank you!
Image: John Storey



Wavelength

Time

Data: PLATO collaboration