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Study of Polar Ice Cores

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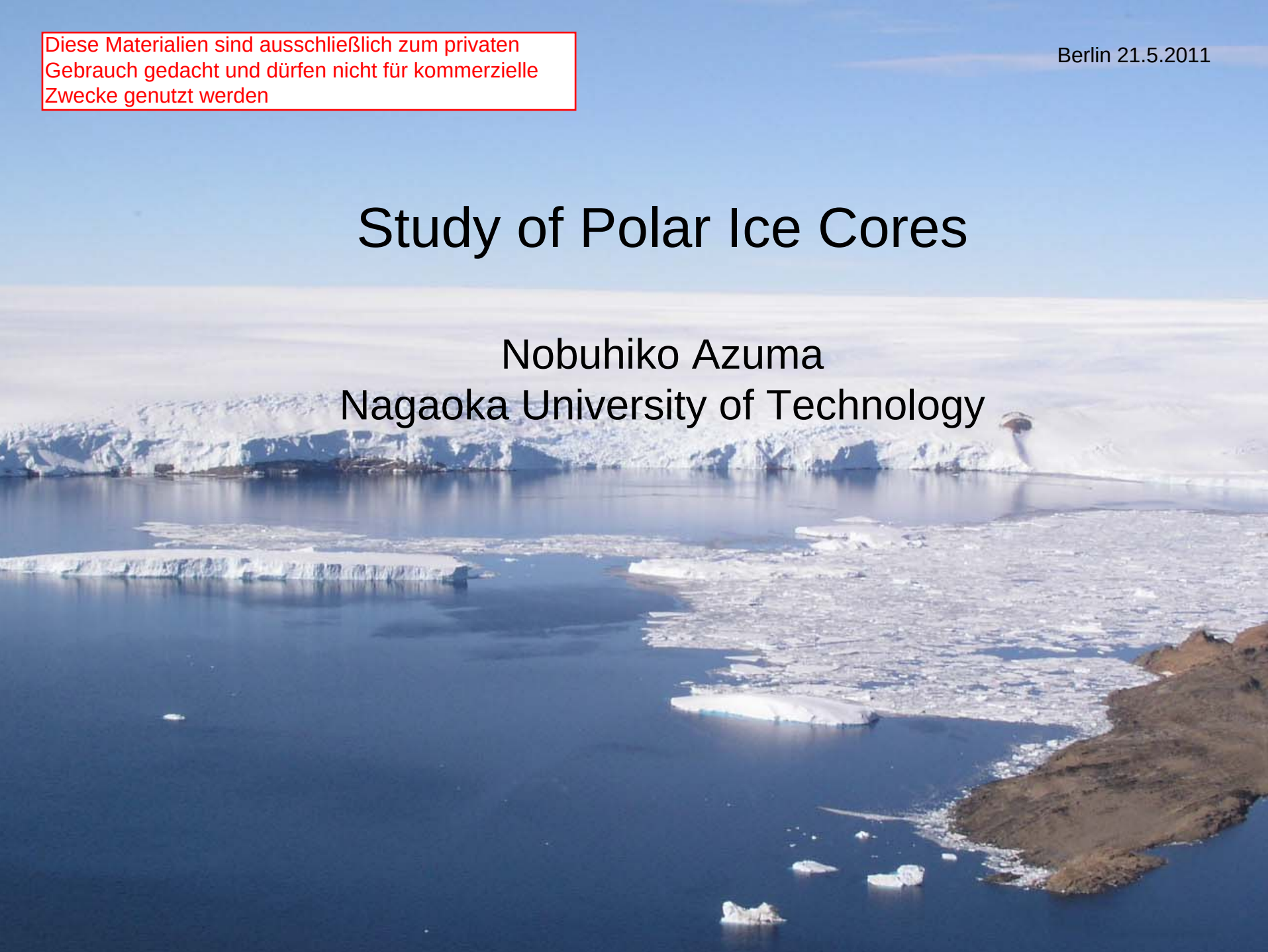

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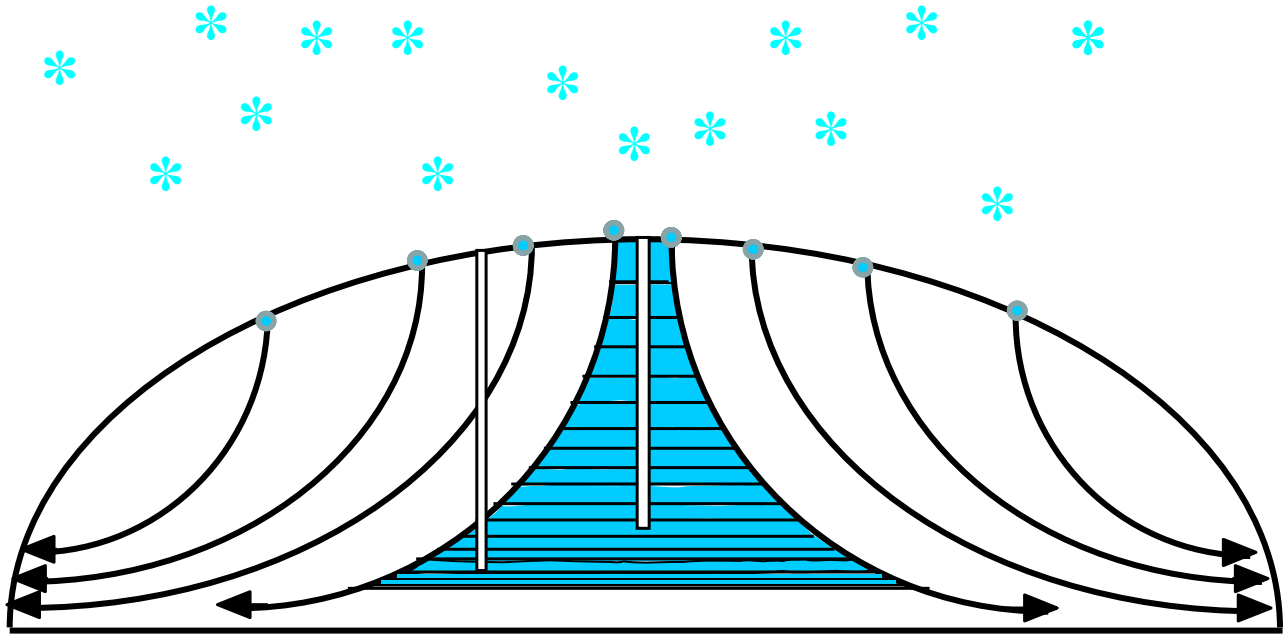
Talk overview:

- Why ice sheet drilling?
- History of ice core drilling projects in Antarctica and Greenland.
- Japanese ice core drilling project - Dome Fuji project – and German project – EDML project.
- Scientific results and future work.....

Why ice sheet drilling ?



New snow accumulates on the old snow.

Snow is compressed by the overburden pressure and turns into ice.

⇒Ice sheet is a fossil of ancient snow and air.

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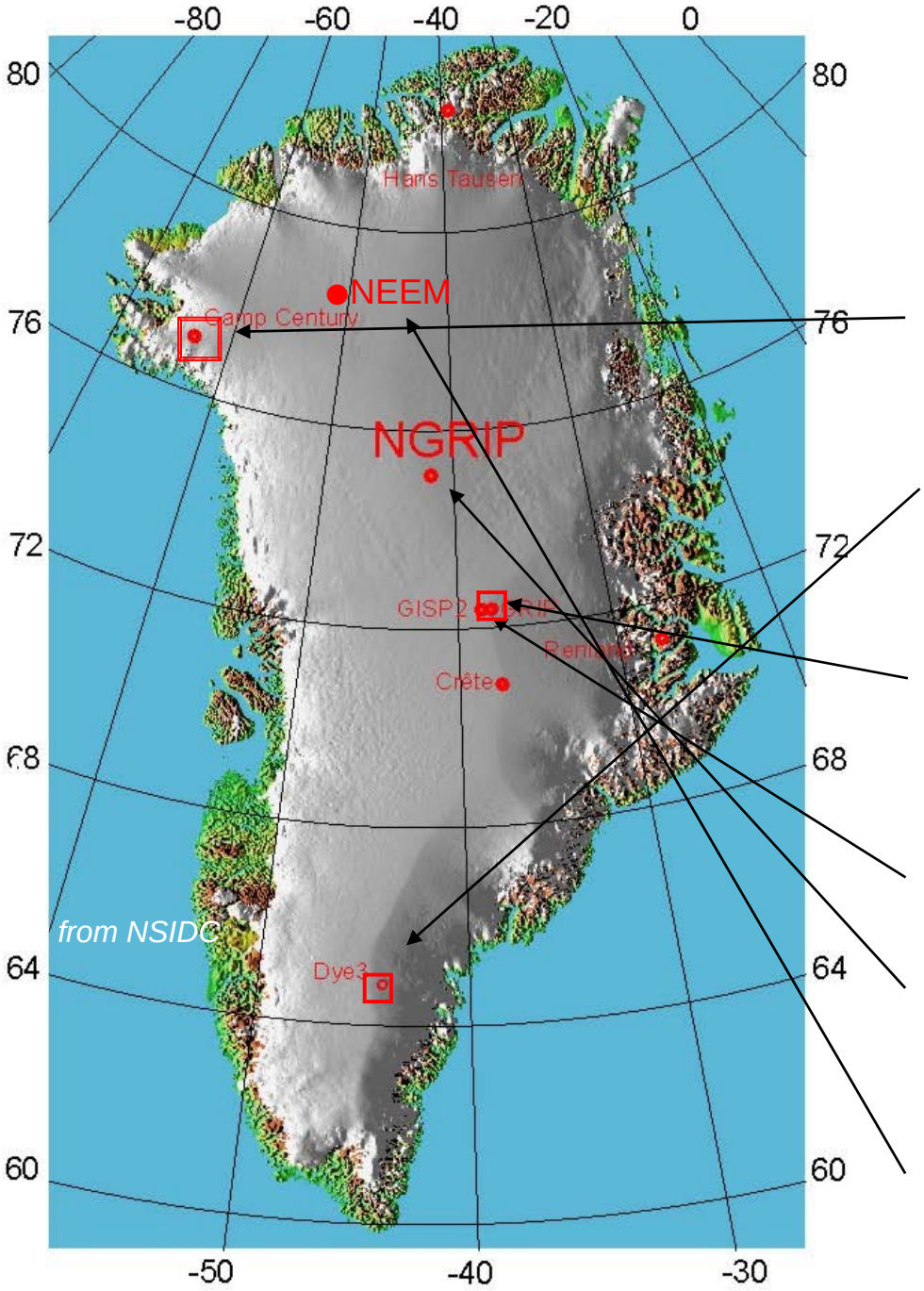
Ice core analysis gives us valuable information about the past climate and environment.



History of ice sheet drilling

1966 Camp Century（USA）
Depth: 1375m

1981 Dye3（USA）
Denmark/Swiss/USA team
Depth: 2037m

1992 GRIP（EU）
International team
Depth: 3029m

1993 GISP2 (USA)
Depth: 3053m

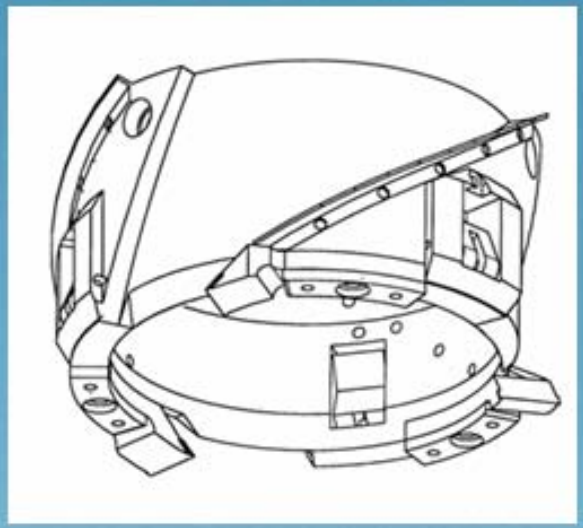
2003 NGRIP（EU）
International team
Depth: 3085m

2010 NEEM（EU,USA,ASIA）
International team
Depth: 2537m

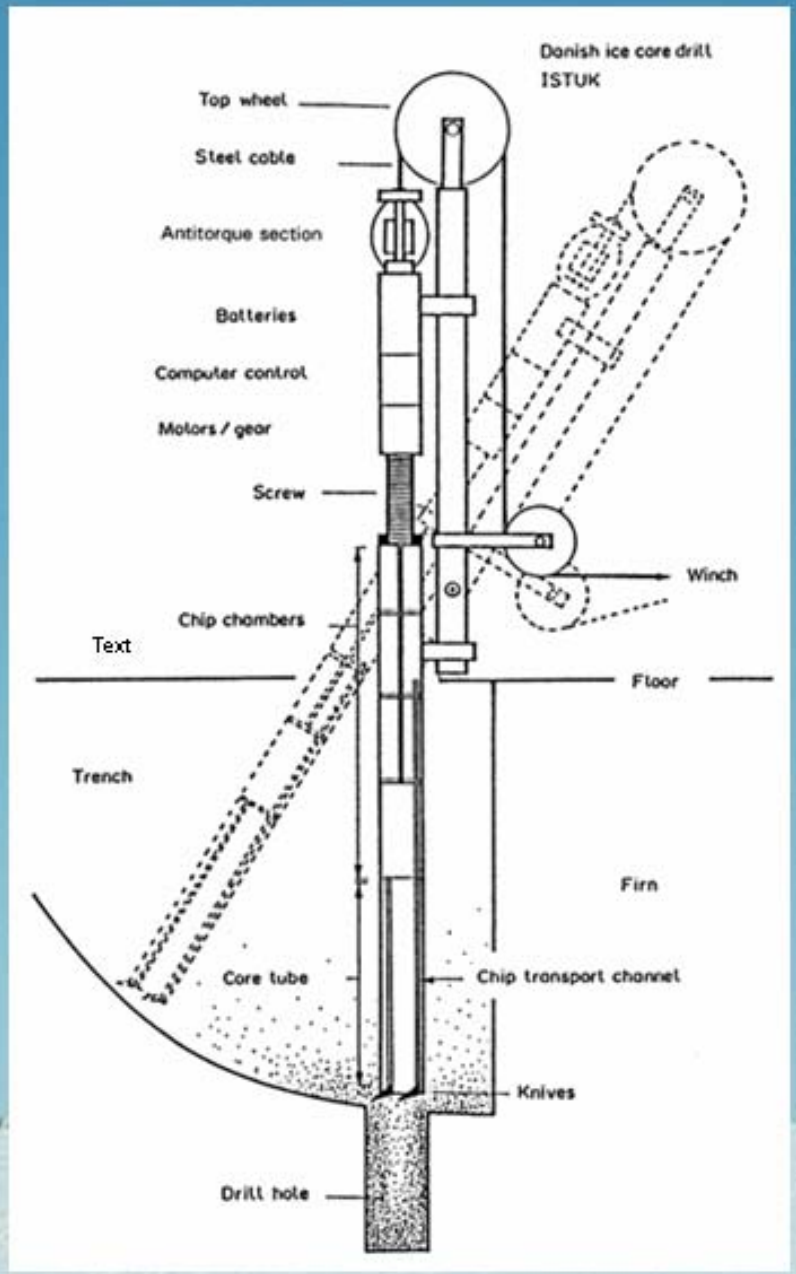
1966　Camp Century（USA）
Depth: 1375m

1981 Dye3（USA）
Denmark/Swiss/USA team
Depth: 2037m

Tilting tower deep drill 1979



- Core diameter: 98 mm
- Hole diameter: 130 mm
- Drill length: 10 m
- Run length: 3.5 m



Science trench

introduced in Dye-3 1979

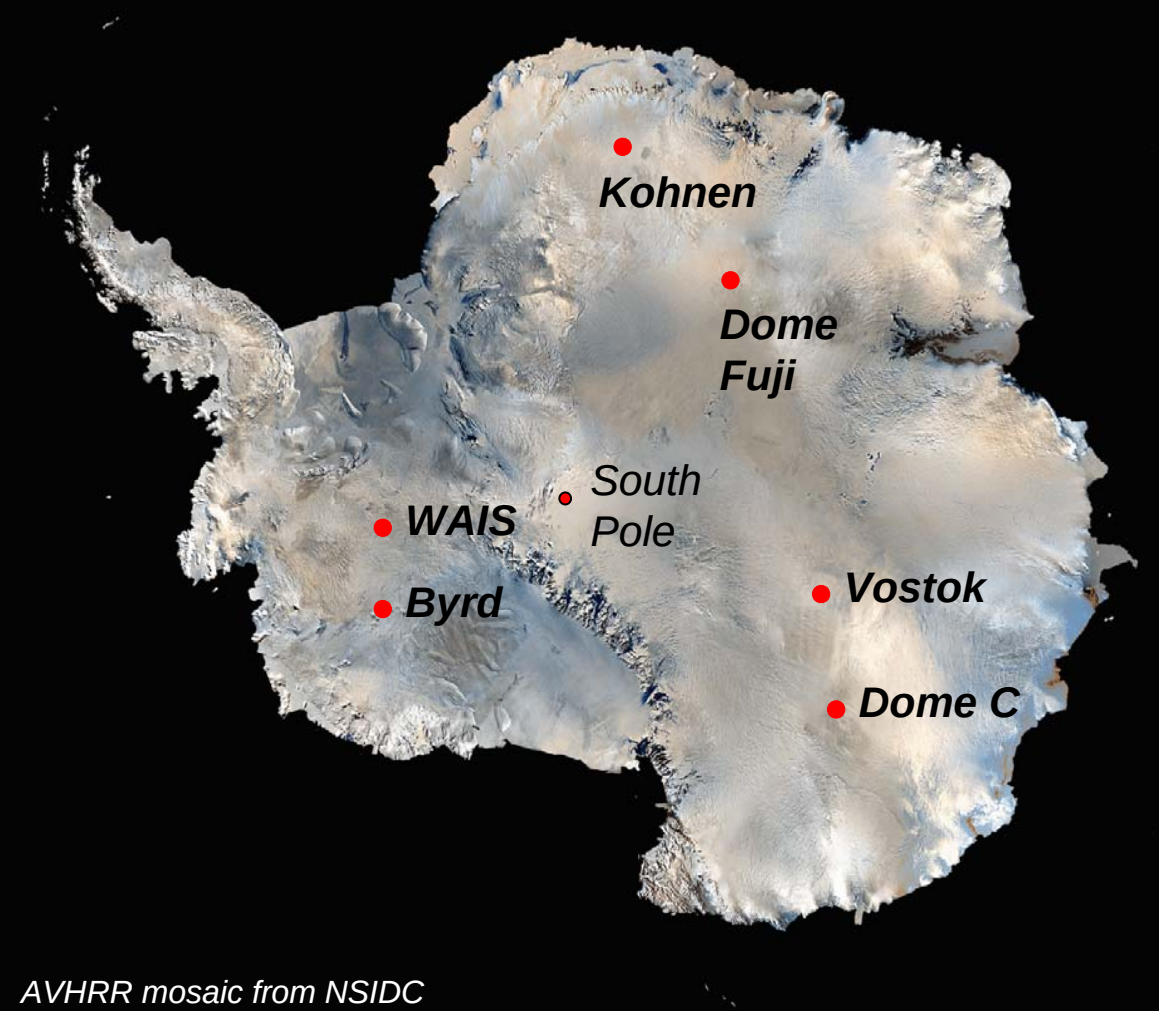
GRIP bottom silty ice core, 1992

1992 GRIP（EU）
International team
Depth: 3029m

2003 NGRIP（EU）
International team
Depth: 3085m


2010 NEEM International team
Depth: 2537m
Iceland
Denmark
USA
Belgium
France
Japan
Germany
South Korea
Switzerland
United Kingdom
The Netherlands
Sweden
China
Canada
NEEM

Antarctica deep drilling



1968 Byrd（USA）
Depth: 2164m

1993 Vostok（USSR）
Depth: 2755m

1996 Dome F (Japan)
Depth: 2503m

2004 Dome C (EU, France and Italy)
Depth: 3270m

2006 Kohnen (EU,Germany）
Depth: 2775m

2007 Vostok（Russia）
Depth: 3658m

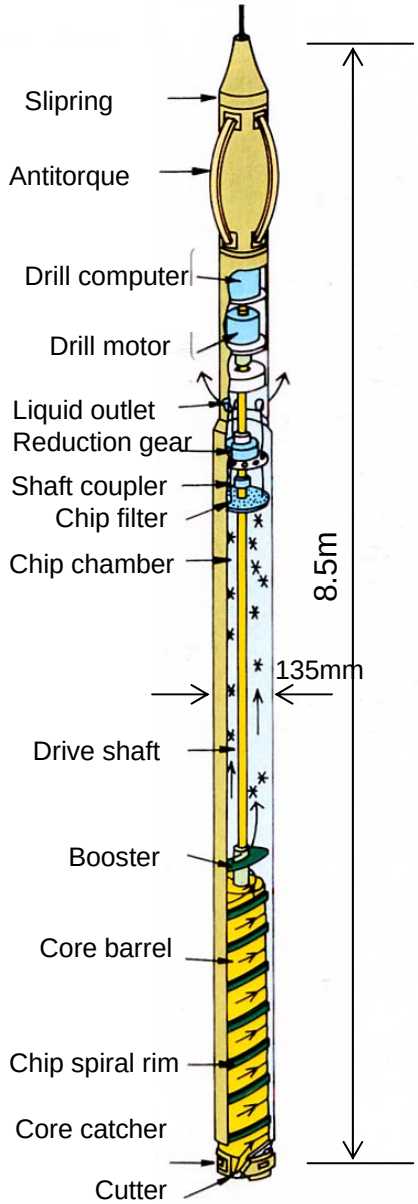
2007 Dome F (Japan)
Depth: 3035m

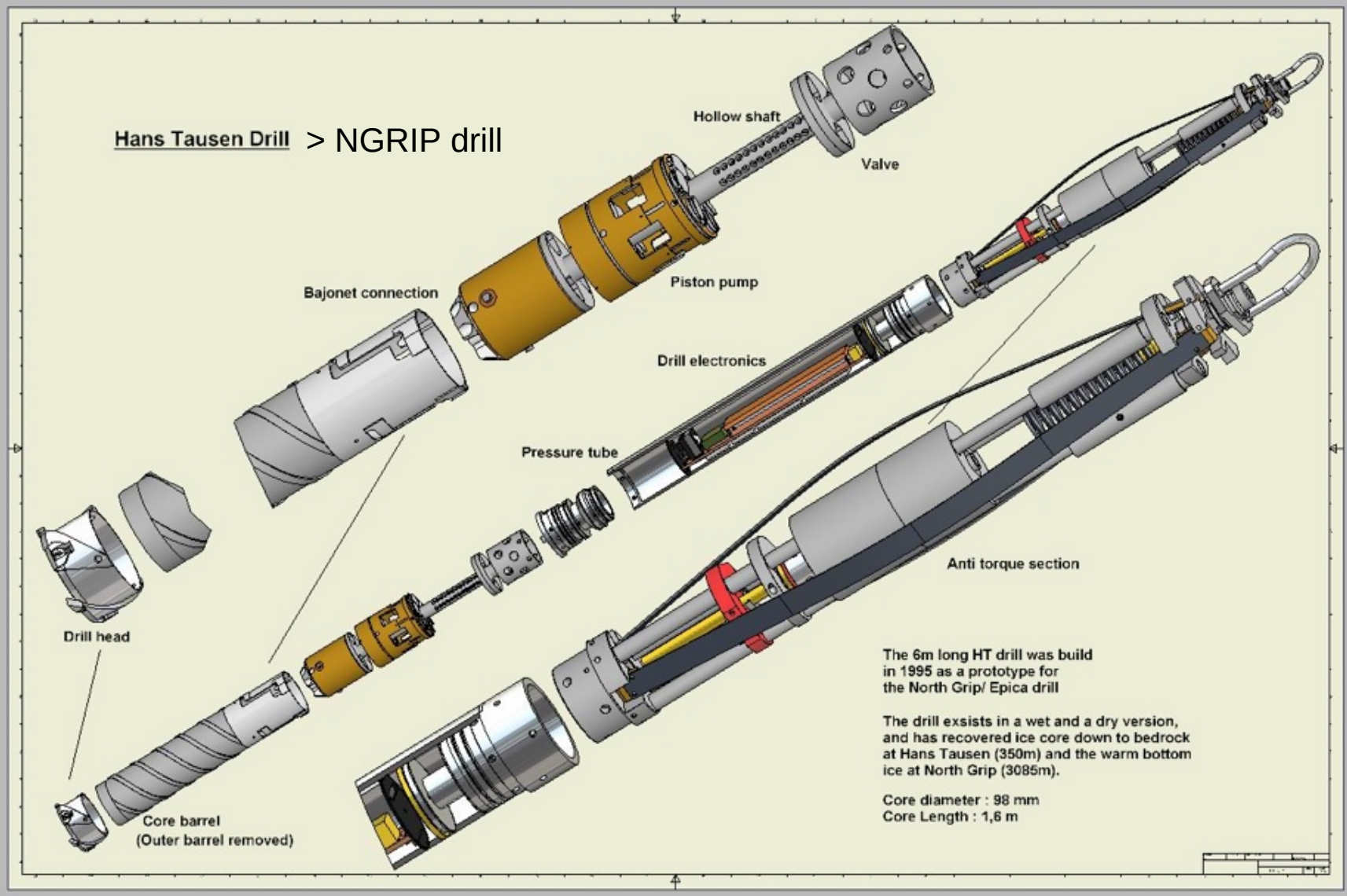
2011 WAIS (USA)
Depth: 3331m

Drilling technology developments:

- Bern, 1974-2004, Henry Rufli, shallow drill systems
- CRREL, 1974, John Rand, shallow drill
- Copenhagen, 1974-, Sigfús Johnsen, shallow drill, deep drills: Istuk, Hans Tausen and NGRIP/EPICA drills
- St. Petersburg, 1987-2002, Vostok drills
- Japan, Suzuki et al. 1969-1987, thermal drill and various shallow drills
- Japan, 1987-2006, JARE deep drill partly based on concepts from Suzuki drills
- USA, PICO, 1990-2000 shallow drill and deep drill
- USA, ICDS, 2003-, new deep “monster” drill under development

JARE deep ice core drill



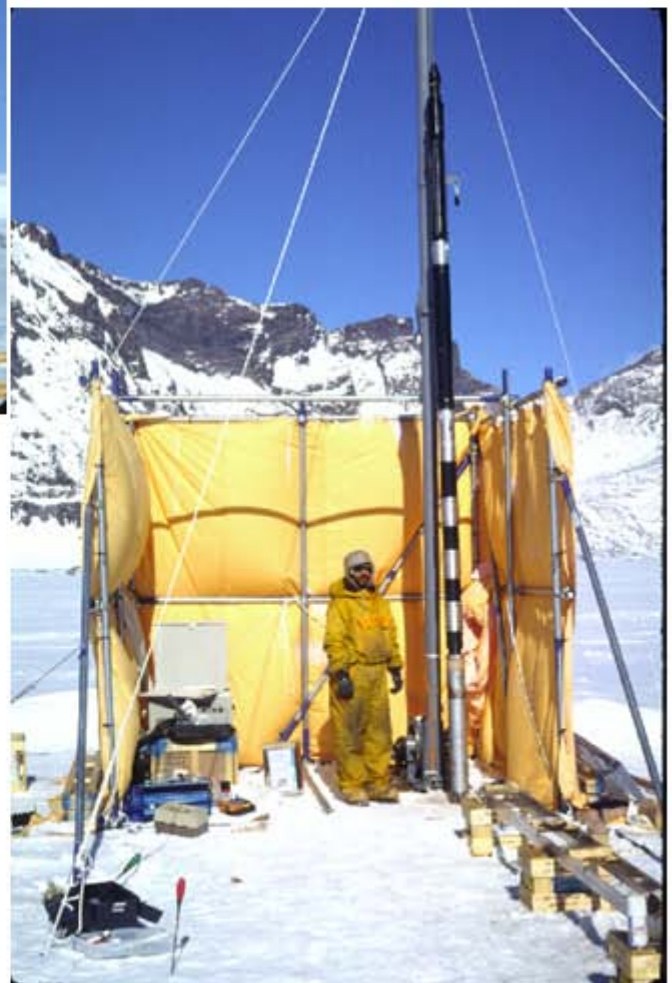

Hans Tausen Drill > NGRIP drill
Hollow shaft
Valve
Piston pump
Bajonet connection
Drill electronics
Pressure tube
Anti torque section
Drill head
Core barrel
(Outer barrel removed)
The 6m long HT drill was build
in 1995 as a prototype for
the North Grip/ Epica drill
The drill exsists in a wet and a dry version,
and has recovered ice core down to bedrock
at Hans Tausen (350m) and the warm bottom
ice at North Grip (3085m).
Core diameter : 98 mm
Core Length : 1,6 m

History of Dome Fuji project

1985 Exploration of Dome Fuji, Shallow drilling.
1988 Start of drill development.
1989 First testing of deep ice core drill.
1991 Fuel transportation to Dome Fuji.
1991-92 Testing of deep ice core drill at GRIP.
1992 Survey around Dome Fuji.
1993 Pilot hole drilling. Construction of Dome Fuji Station.
1994 Transportation and construction of Dome Fuji Station.
1995 First wintering at Dome Fuji and start of deep drilling.
1997 Drill stuck at 2503 m depth.
2002 New drill site construction.
2004 Start of the second deep drilling at Dome Fuji.
2006 Drilling reached 3028 m depth.
2007 Reached the bottom at 3035 m depth.

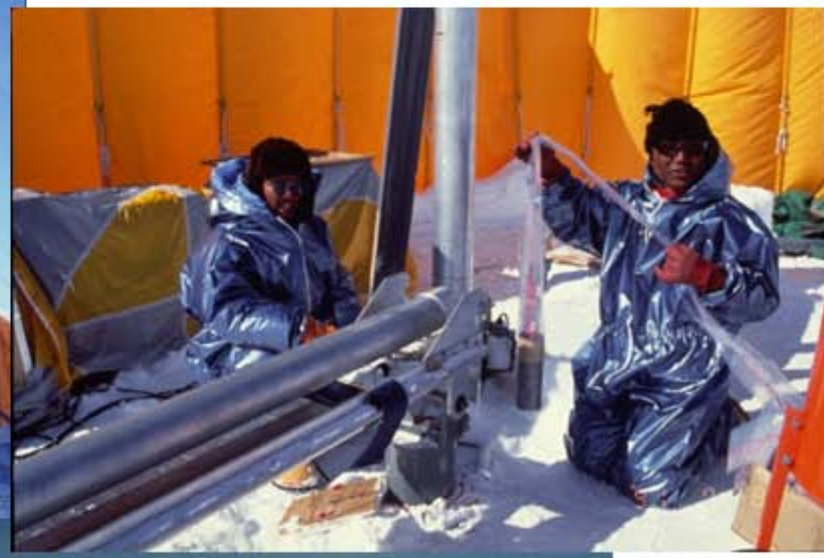
Deep ice core drill test in Antarctic (1988/89-1989/90)

Antarctica:Sϕr Rondane Mts
Liquid filled deep ice core drill test
1989-1990 (JARE31)



Deep ice core drill test in Greenland (1991,1992)

Greenland ice sheet
liquid filled deep ice core drill test
1991, 1992



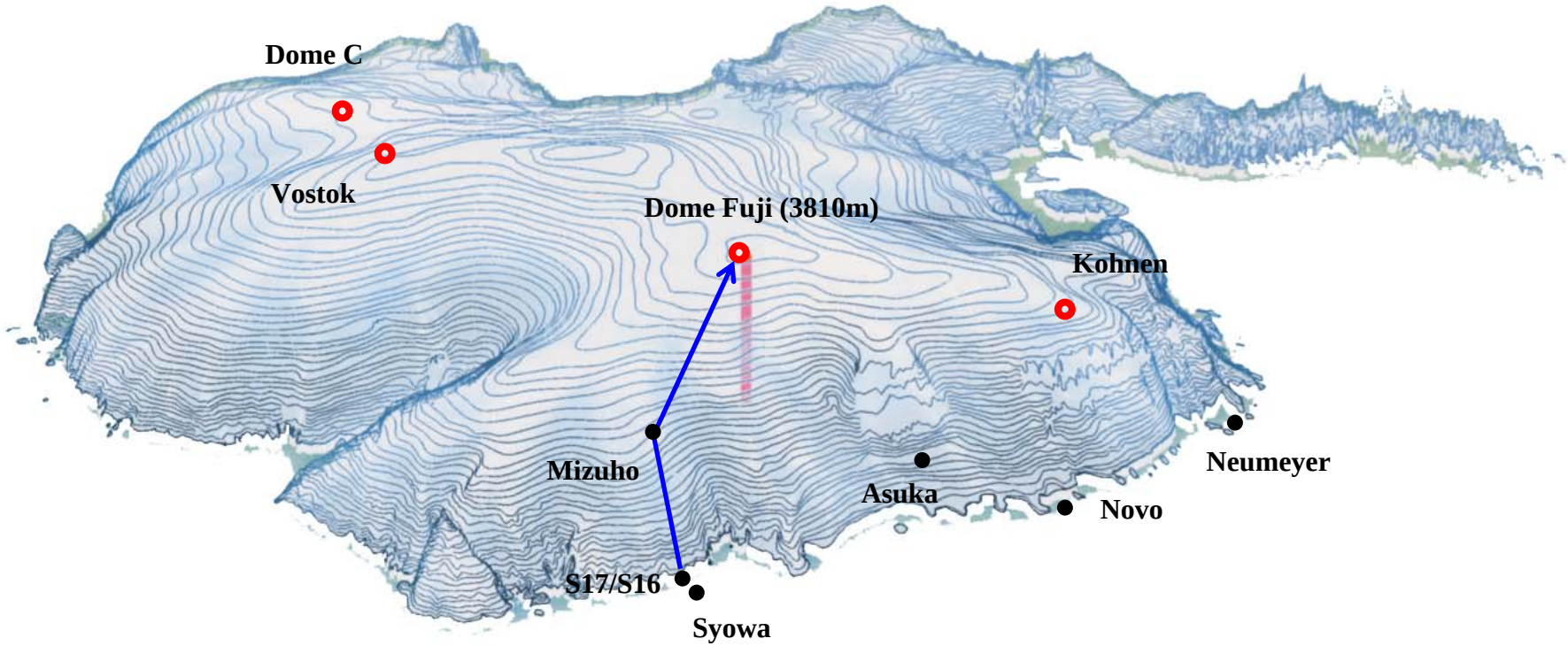
GISP2

GRIP

Deep ice core drill test in Japan (1992, 1993, 1994, 2003)

Deep ice core drill test in Rikubetsu, Hokkaido
1992, 1993, 1994, 2003

Antarctica



In 1995, we started the Dome Fuji deep drilling by the first wintering at Dome Fuji.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29 Jan. 1995
Started the first wintering at Dome Fuji

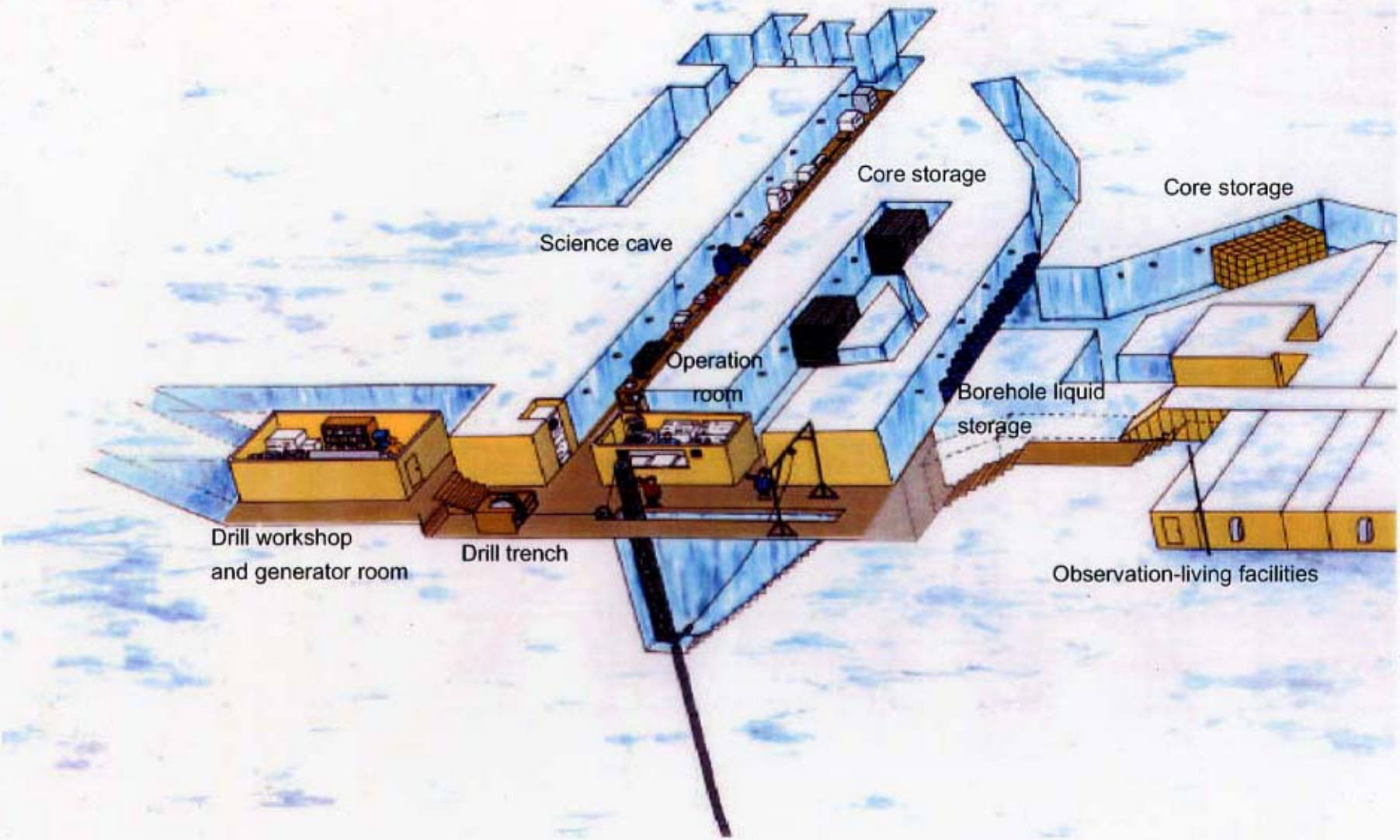
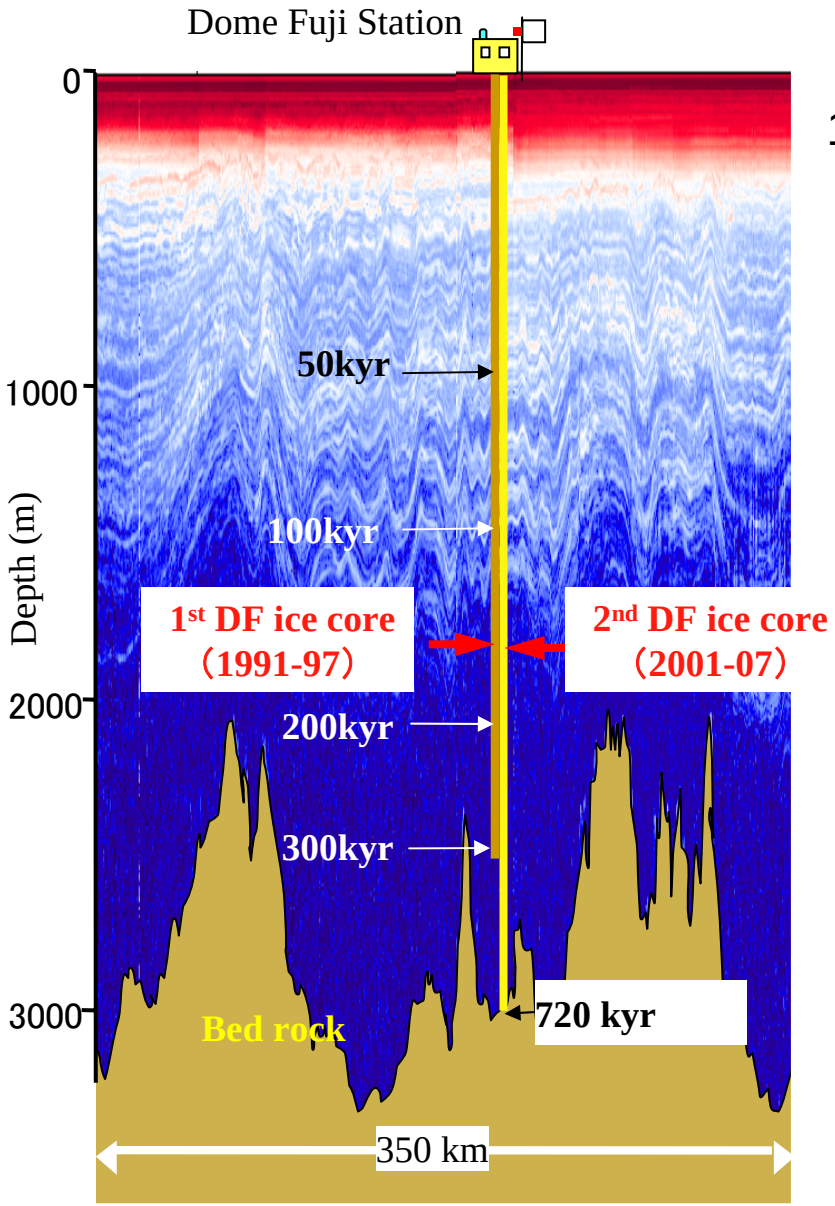


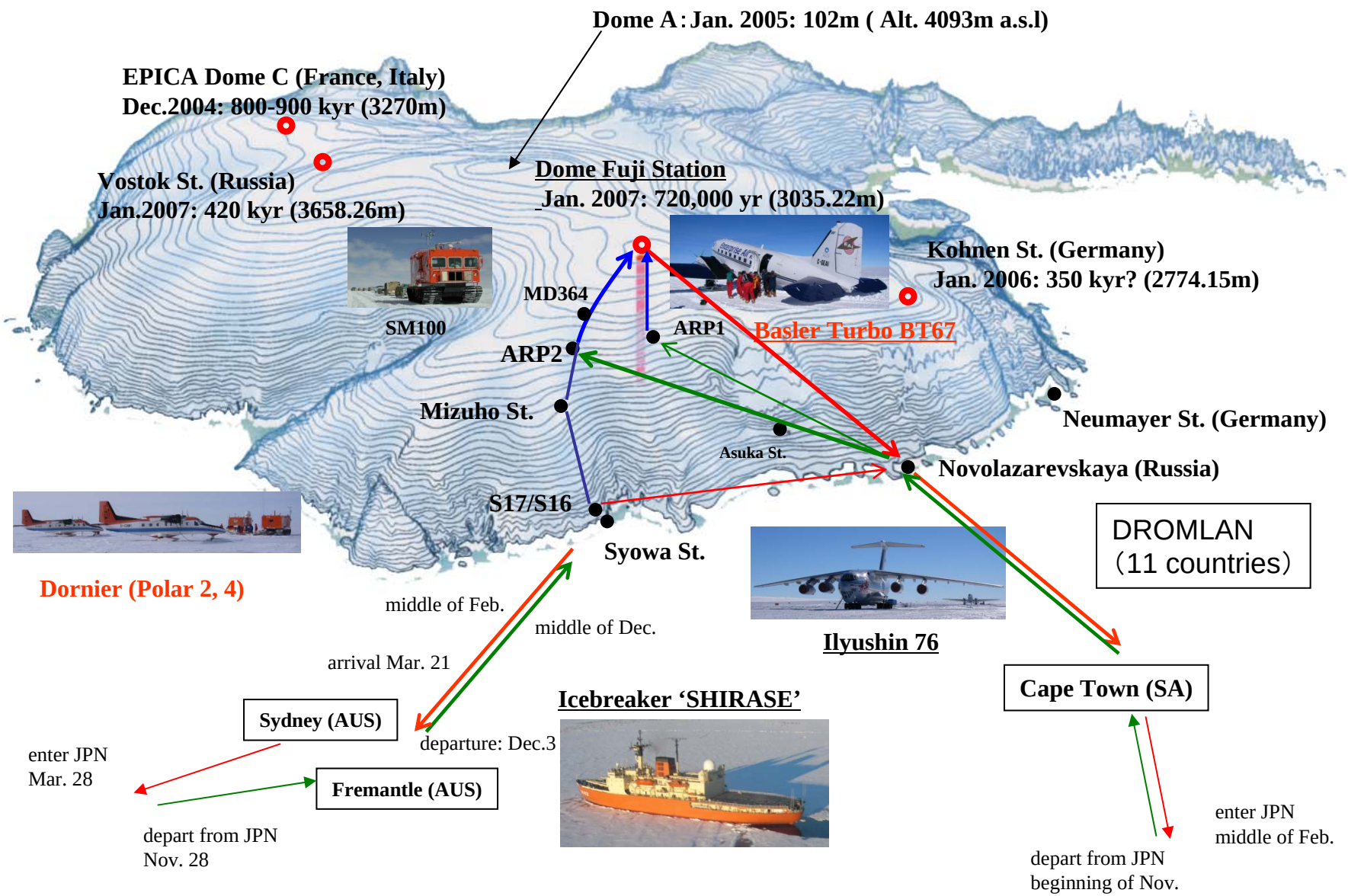
Fig. 1 (Fujii et al.)



by radar echo soundings

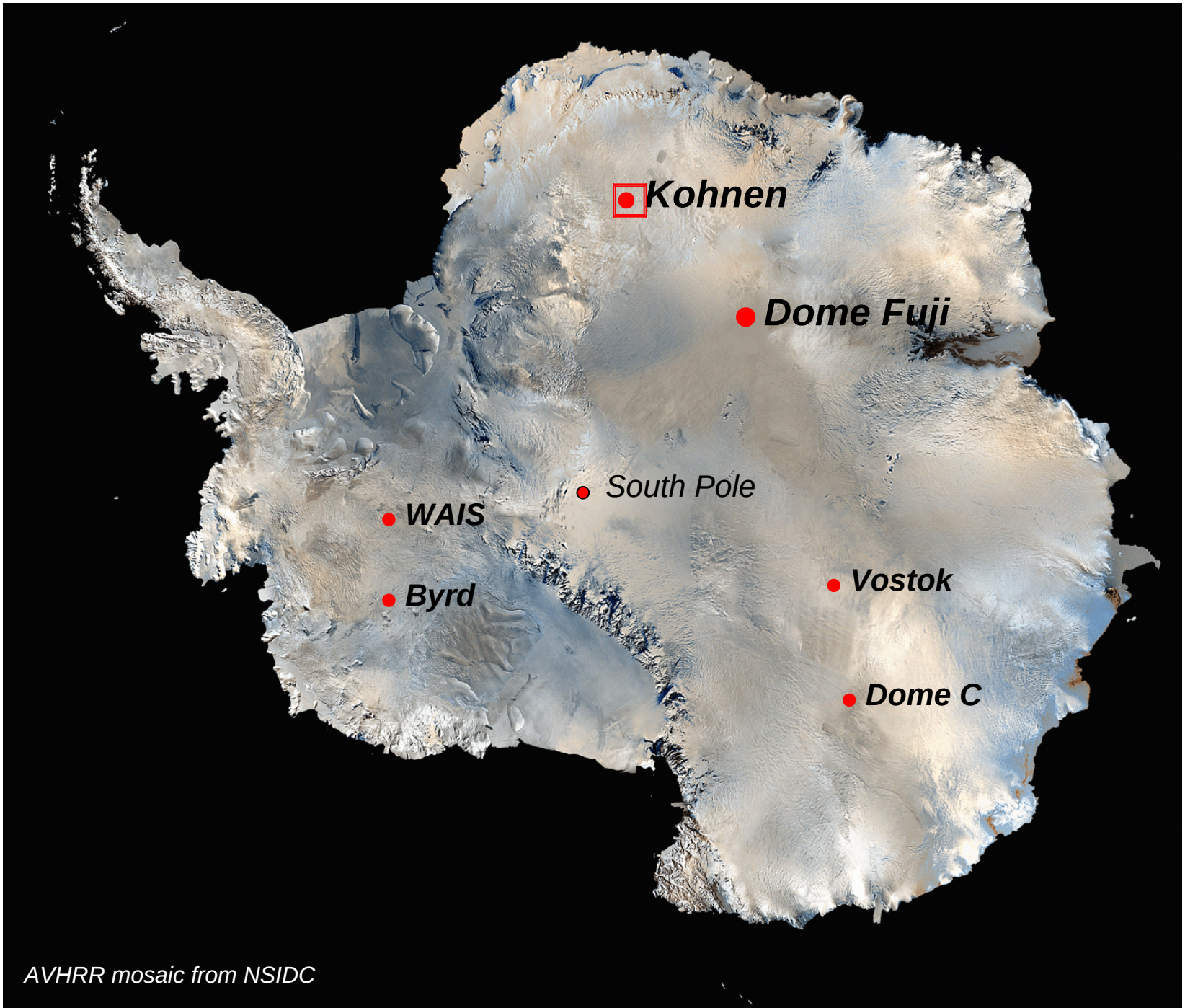
1997 Drill got stuck at 2503 m depth.

Dome Fuji flight operation from 2003 to 2007



Flight support by AWI from Novo st. to Dome Fuji.

German support for Dome Fuji drilling project


Kohnen
Dome Fuji
South Pole
WAIS
Byrd
Vostok
Dome C
AVHRR mosaic from NSIDC


Prof. Heinrich Miller
Prof. Frank Wilhelms


Results from Dome Fuji and other deep cores…

O_2/N_2 ratio in the Vostok cores recording local summer insolation (not atmospheric composition)

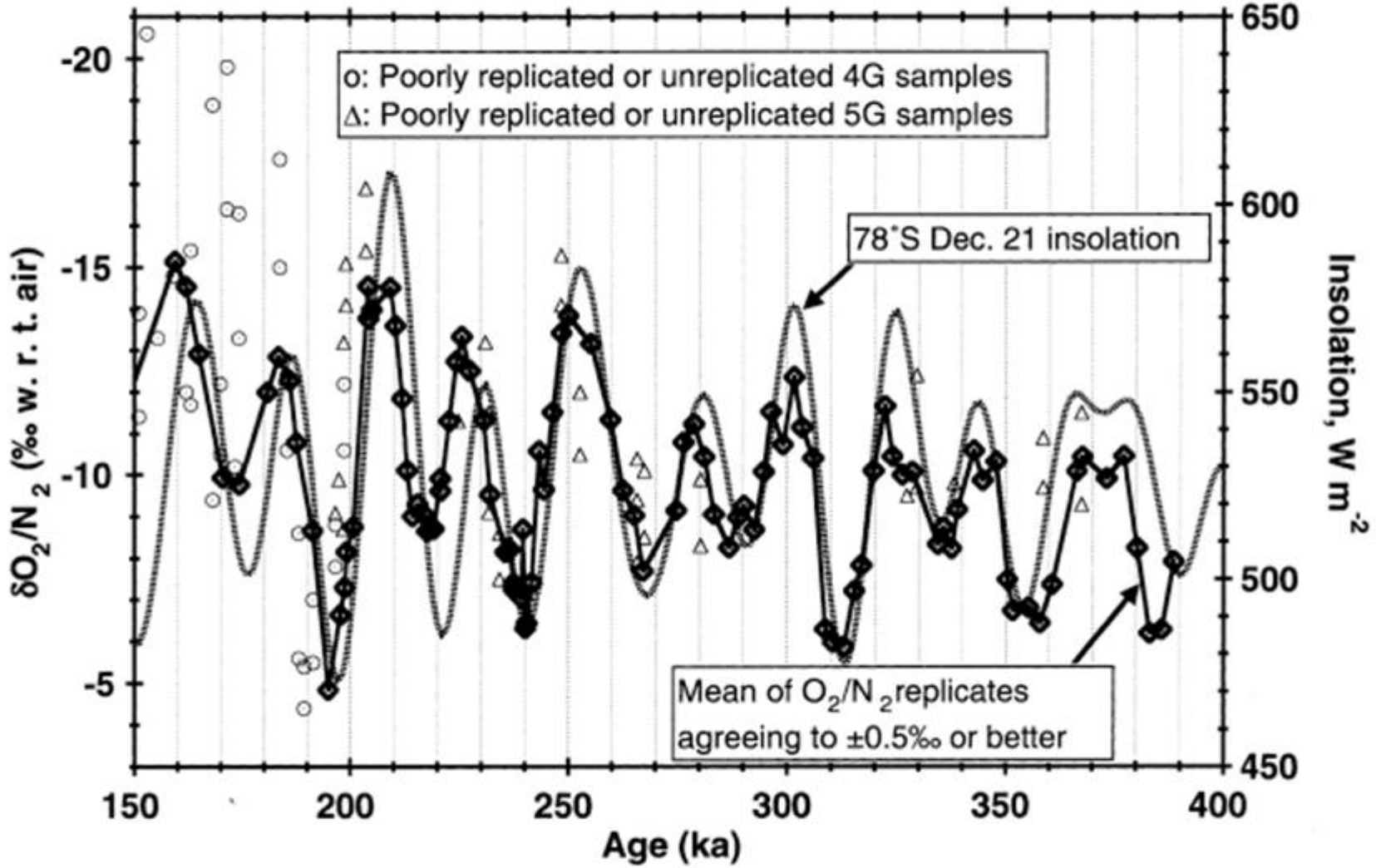
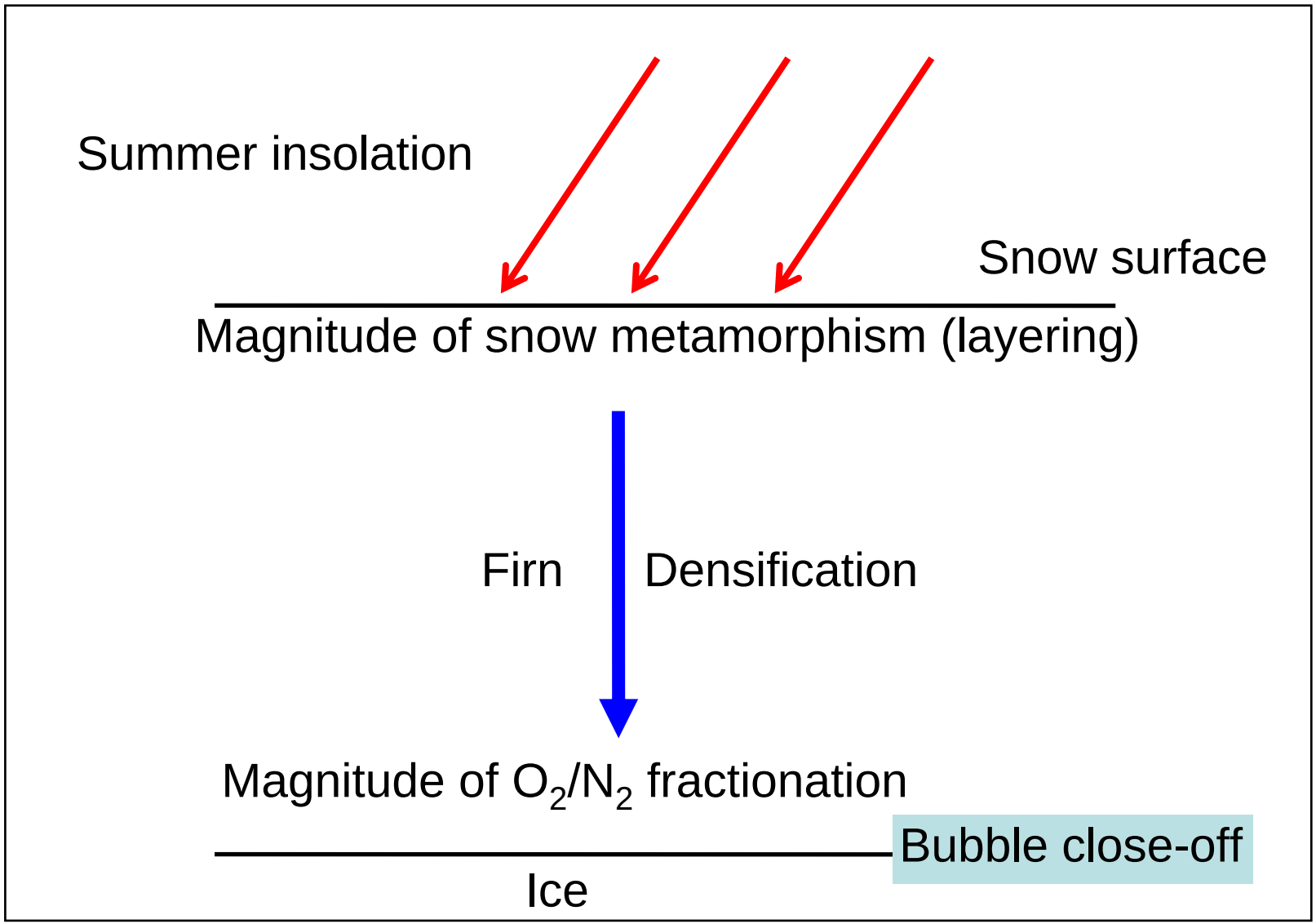


Fig. 2. O_2/N_2 and insolation vs. age for the period from 150–400 ka.

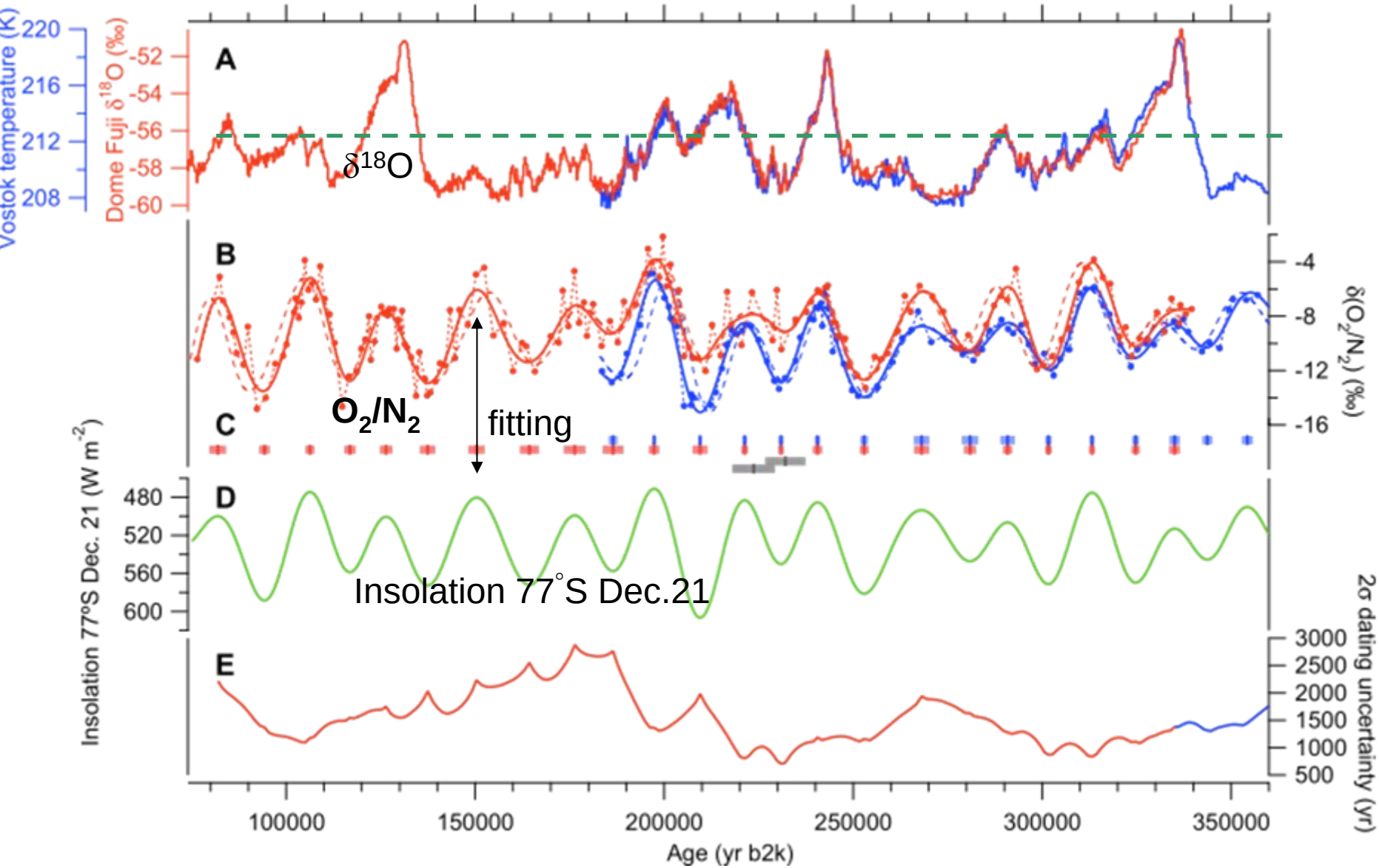
Bender, 2002, EPSL

O_2/N_2 is a proxy of local summer insolation.

Physical link without climatic influence ---> Ideal tool of orbital tuning

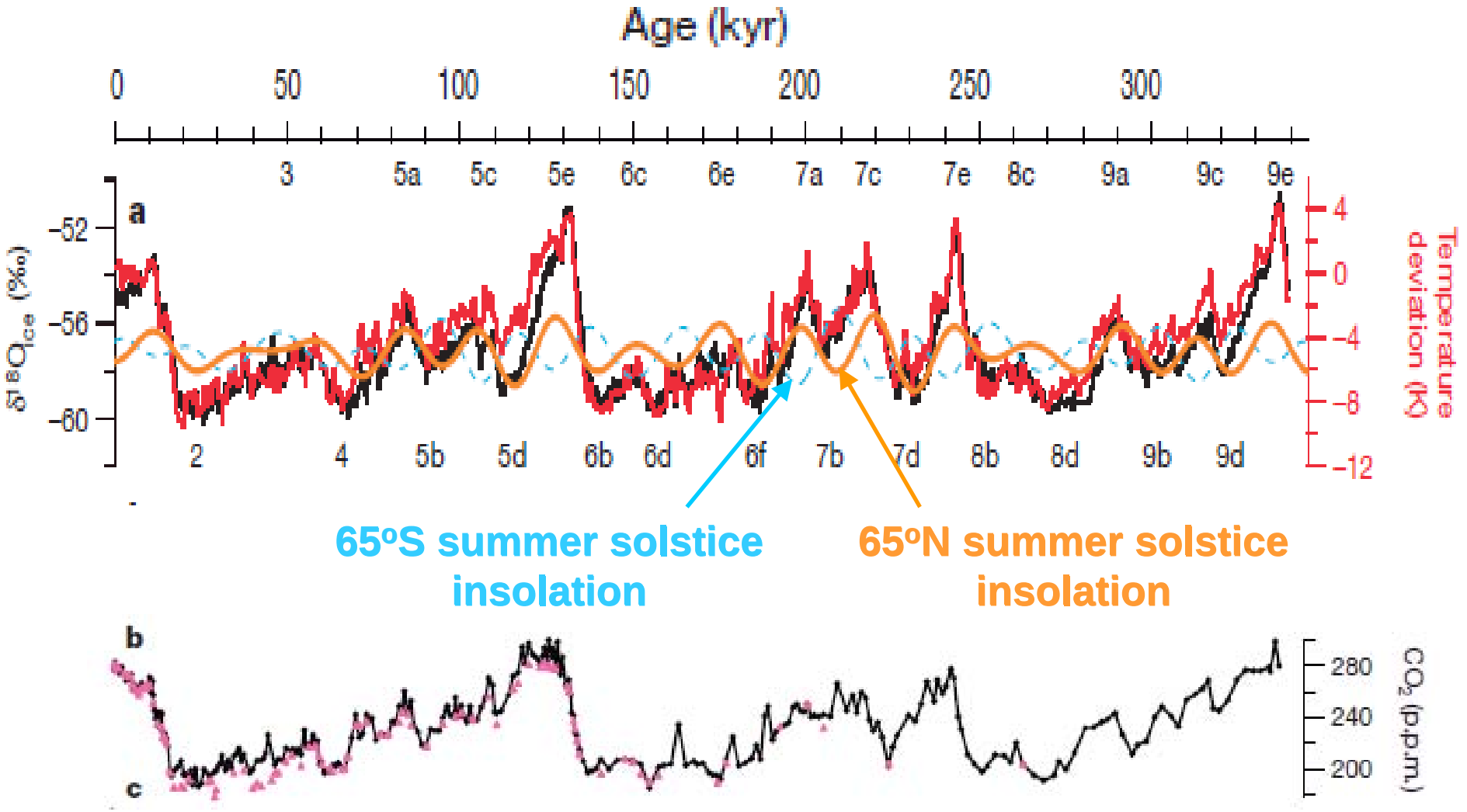


O_2/N_2-orbital tuning of Dome Fuji (red) and Vostok (blue)

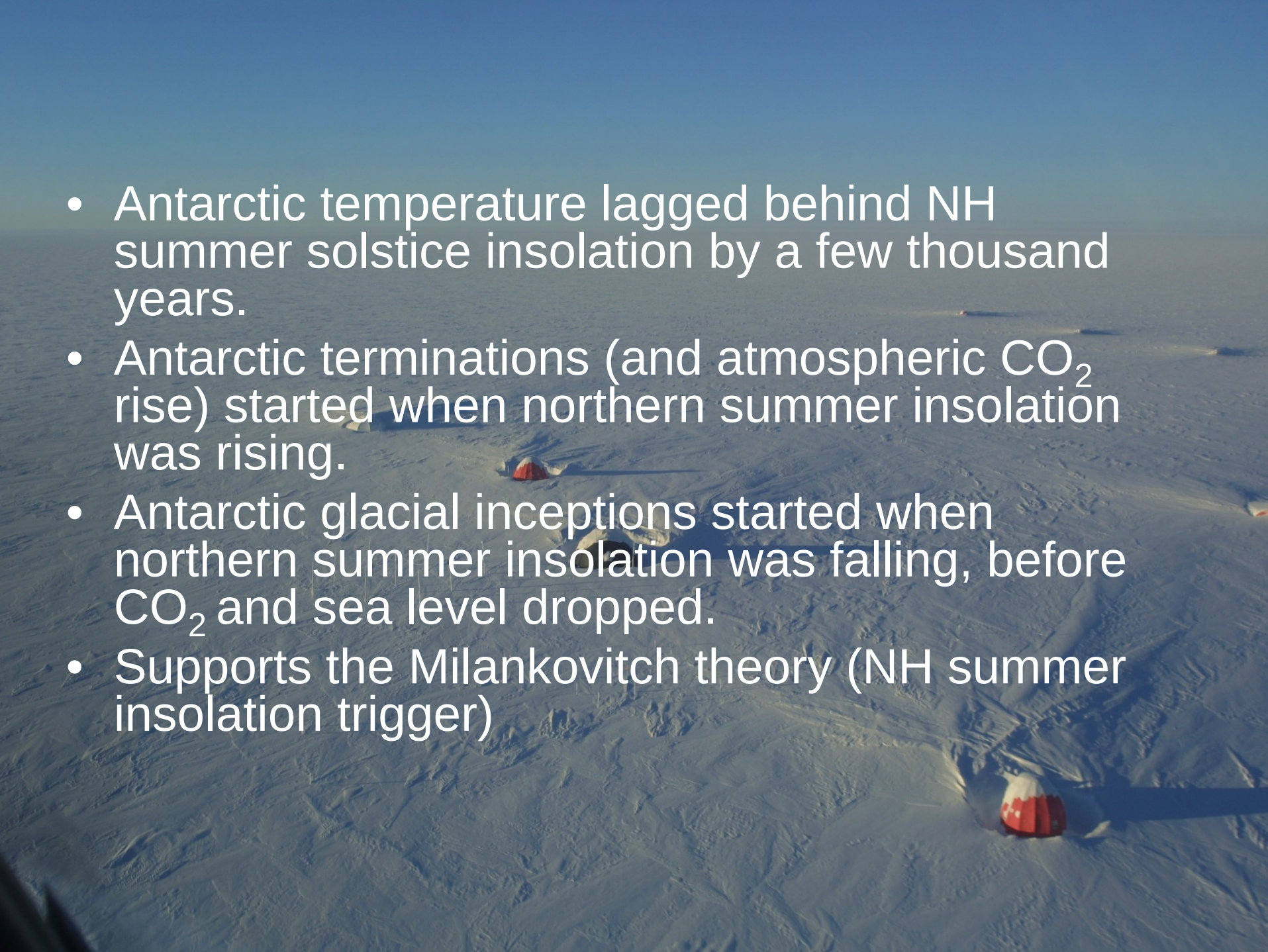


Kawamura et al., 2007, Nature

➢The Antarctic temperature agrees with the northern hemisphere high latitude summer insolation, not with the southern summer insolation.



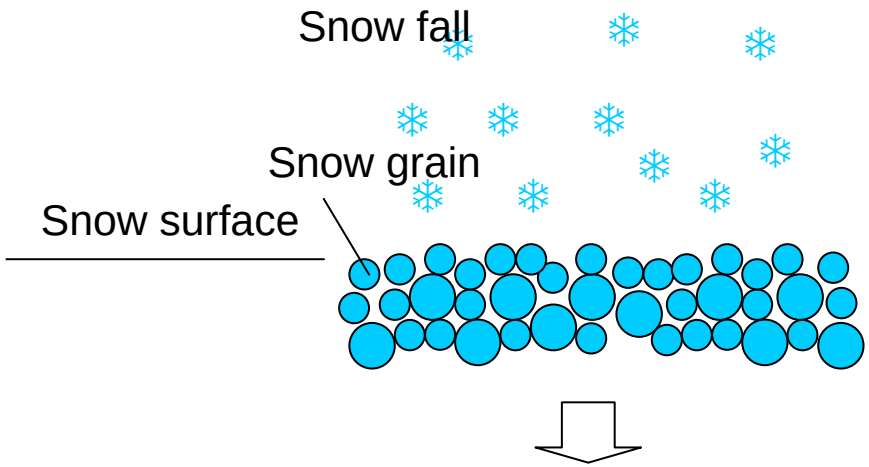
Kawamura et al. (Nature, 2007)



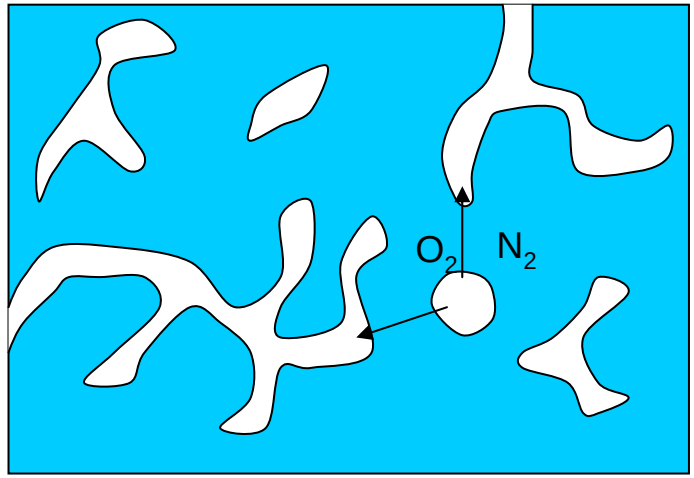
- Antarctic temperature lagged behind NH summer solstice insolation by a few thousand years.
- Antarctic terminations (and atmospheric CO_2 rise) started when northern summer insolation was rising.
- Antarctic glacial inceptions started when northern summer insolation was falling, before CO_2 and sea level dropped.
- Supports the Milankovitch theory (NH summer insolation trigger)

➢**Unsolved problems:**

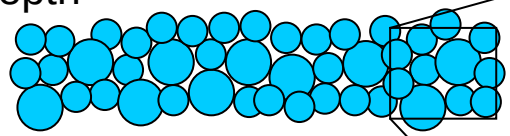
Why does summer insolation relate to diffusion of air molecule?

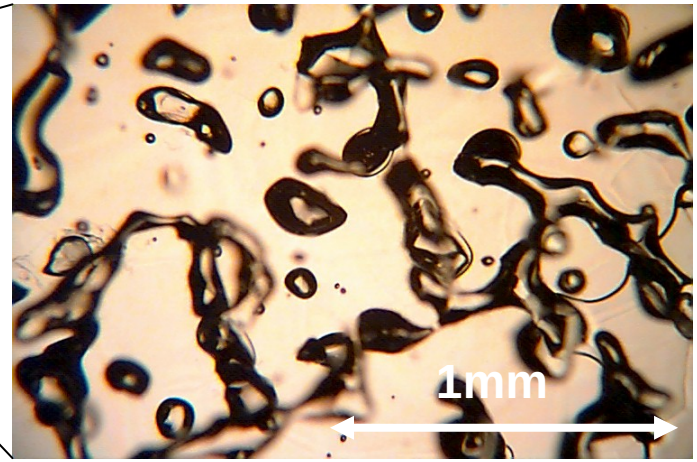


Diffusion of air molecule



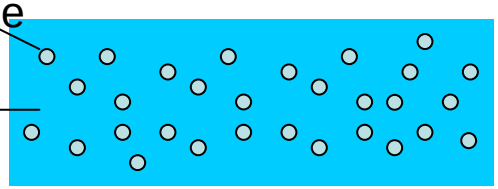
Pore close-off depth
≃100m





Bubble

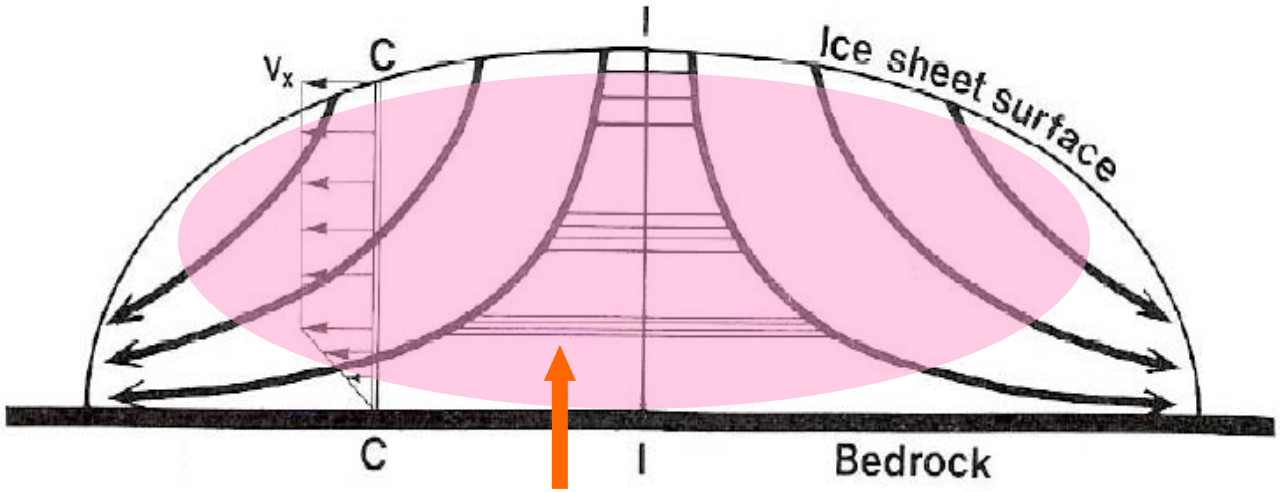
Ice



Dome Fuji 120m depth

➢**Moreover:**

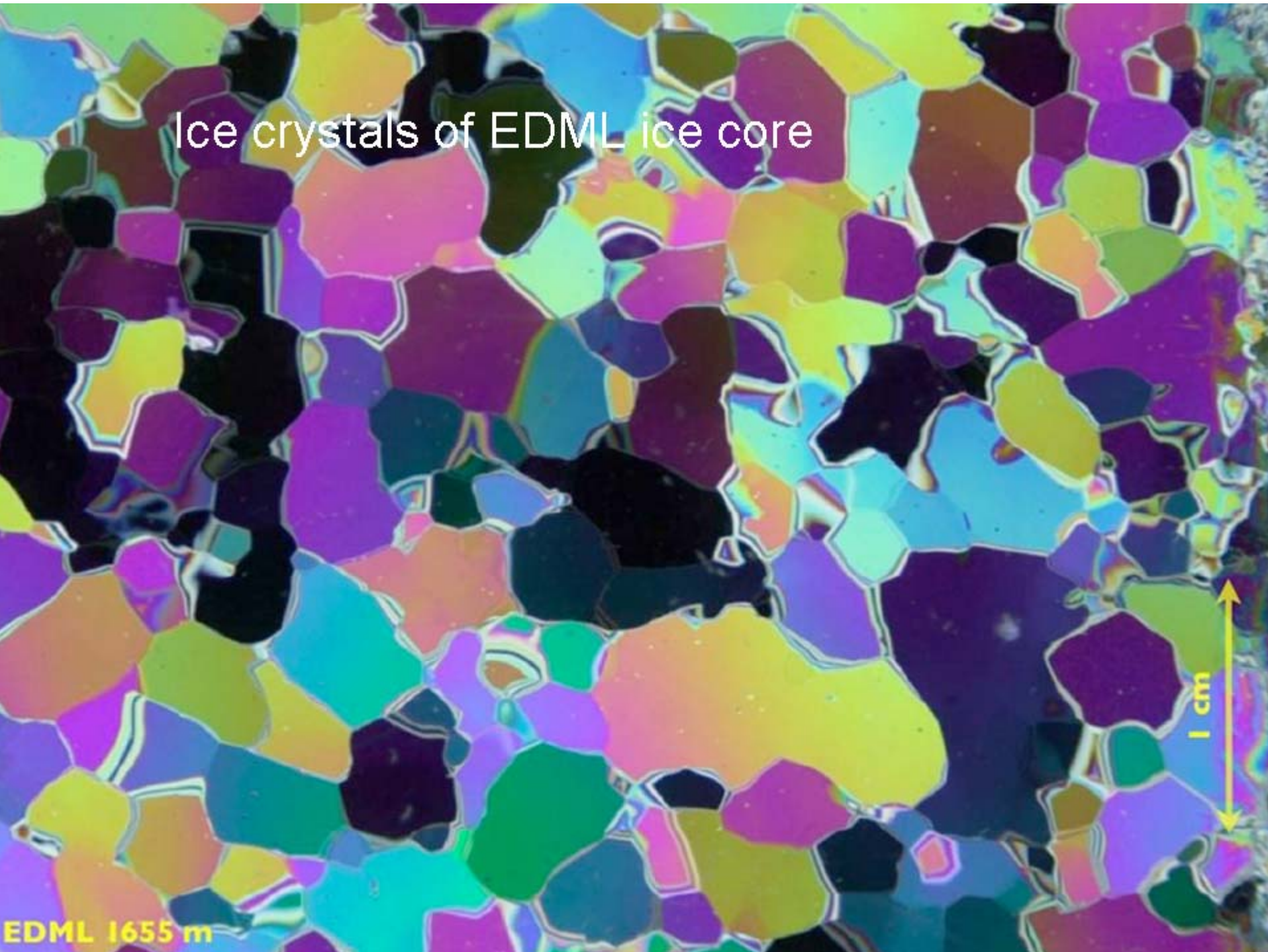
☆We don't know yet:
How do ice sheets really flow?



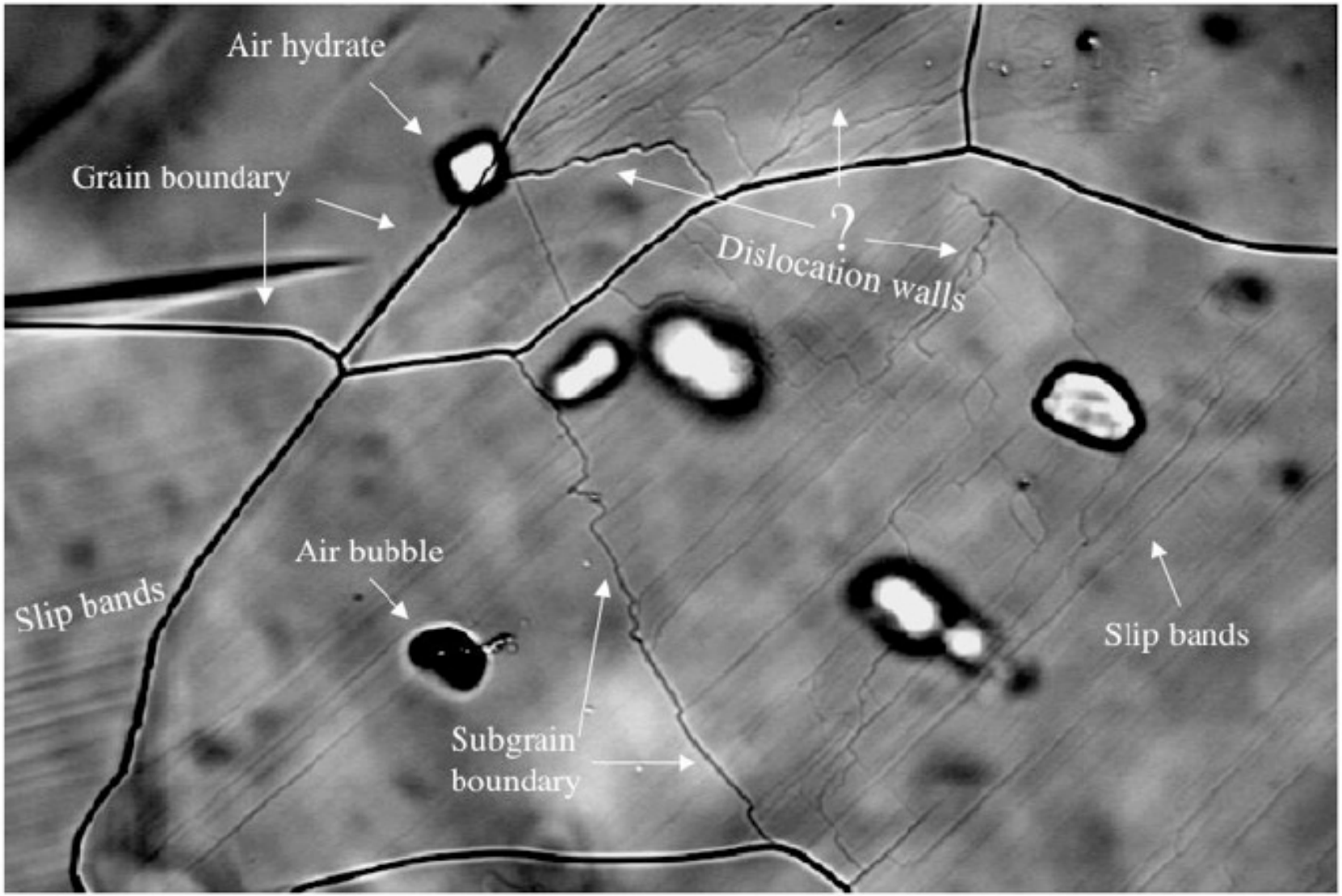
- **Mechanisms of ice deformation.**
- **Ice flow law in ice sheets.**
- **Alteration, migration and reaction of constituents in ice sheets.**

➢**Understanding of past climatic/environmental records.**

➢**Prediction of the future behavior of ice sheets.**

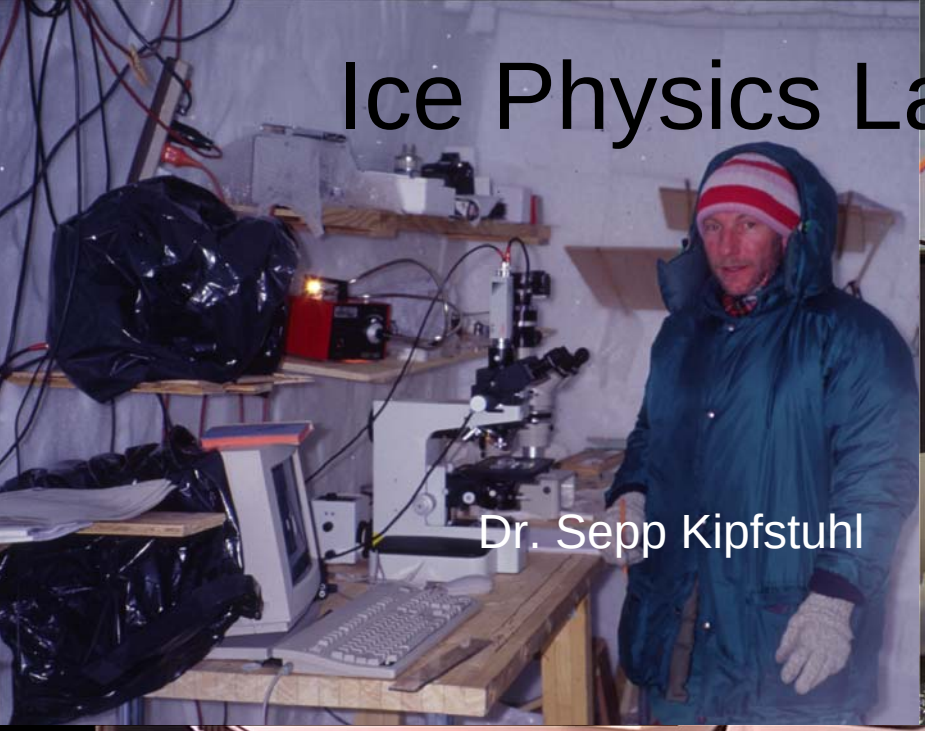

Ice crystals of EDML ice core
1 cm
EDML 1655 m

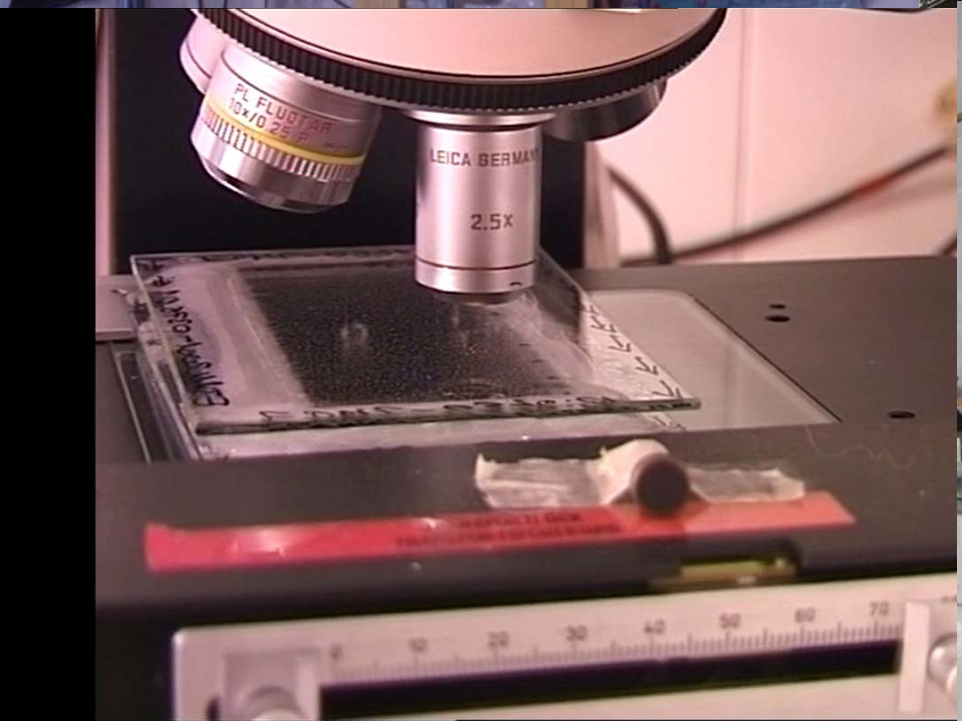
Surface of ice sheet



Scale: 2.5 mm

Ice Physics Lab in a snow cave





There is still a lot to do!

Thanks for your attention.