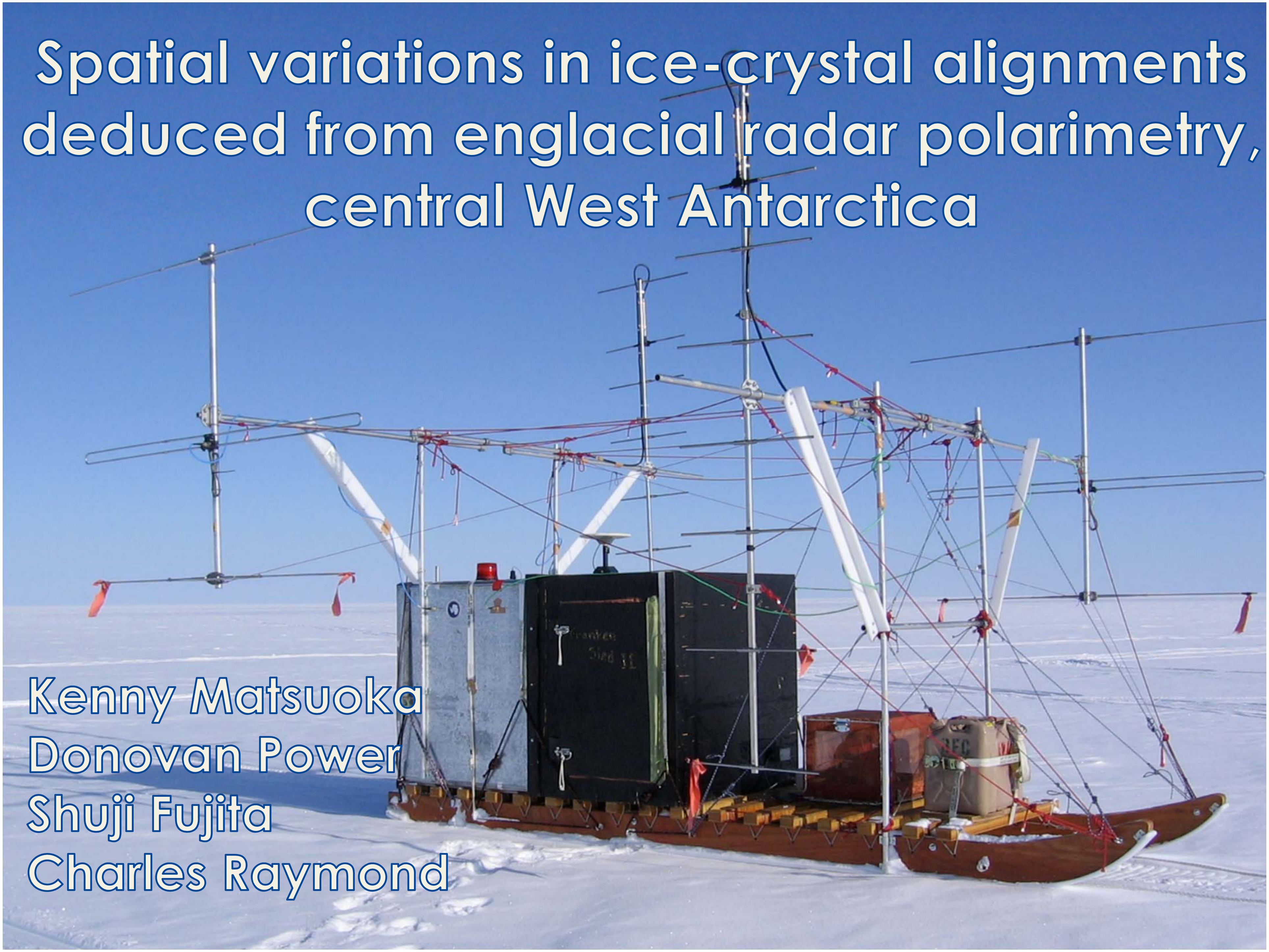
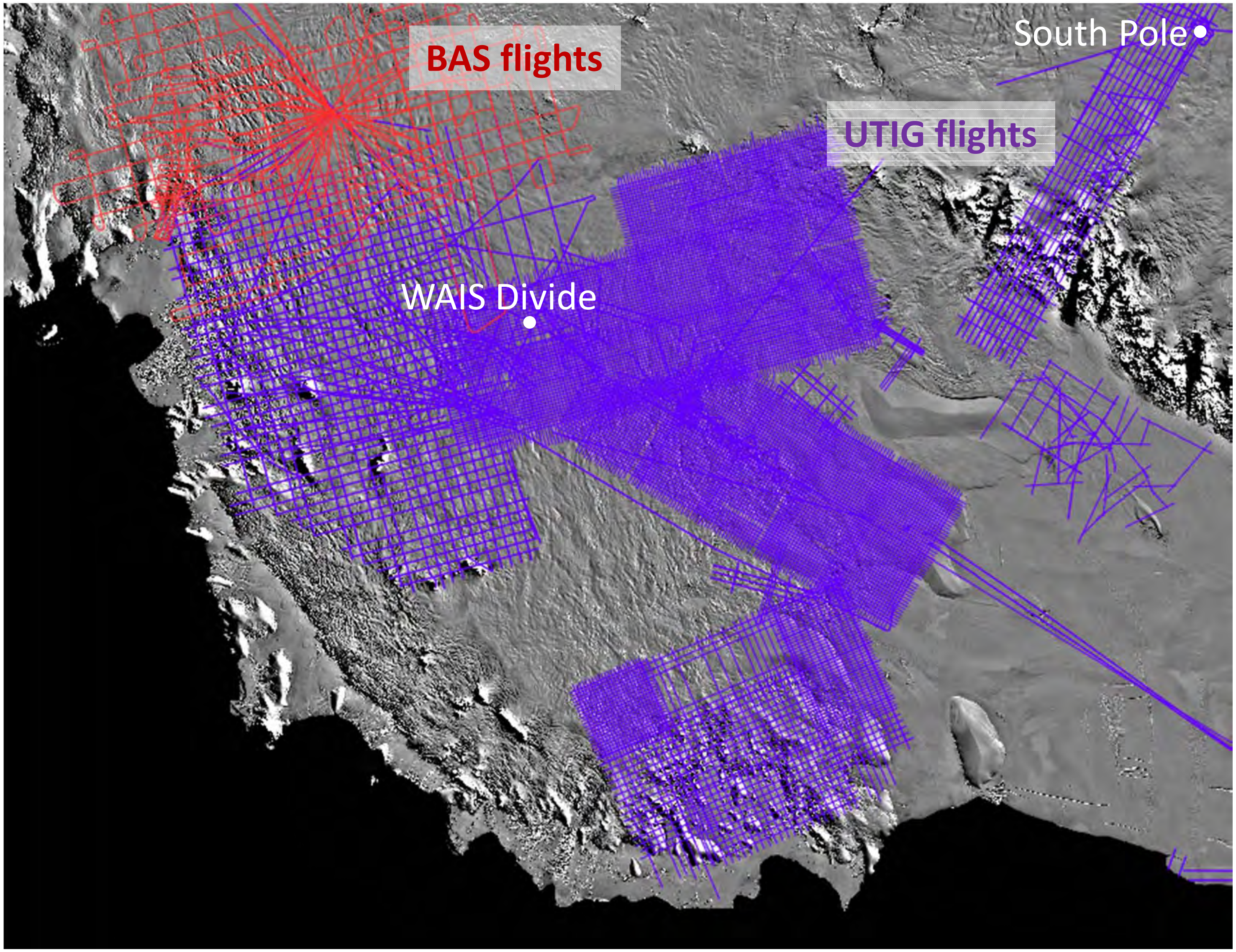
Spatial variations in ice-crystal alignments deduced from englacial radar polarimetry, central West Antarctica



Kenny Matsuoka
Donovan Power
Shuji Fujita
Charles Raymond

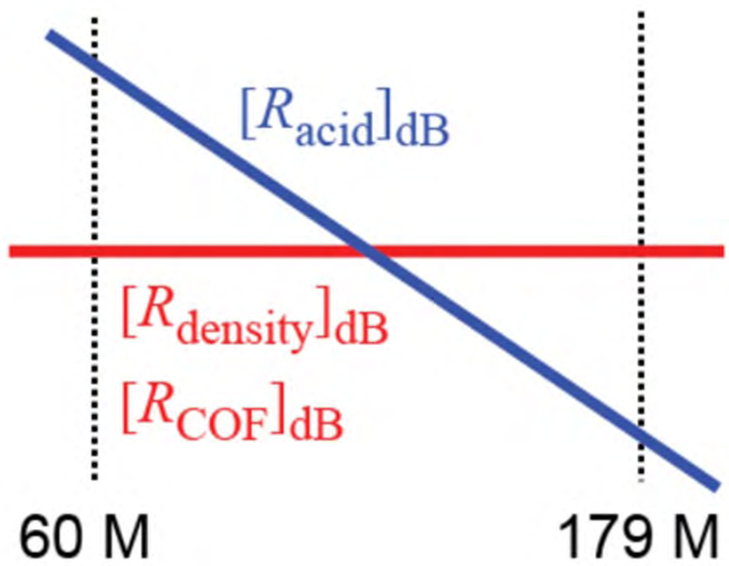
Need for new radar data?



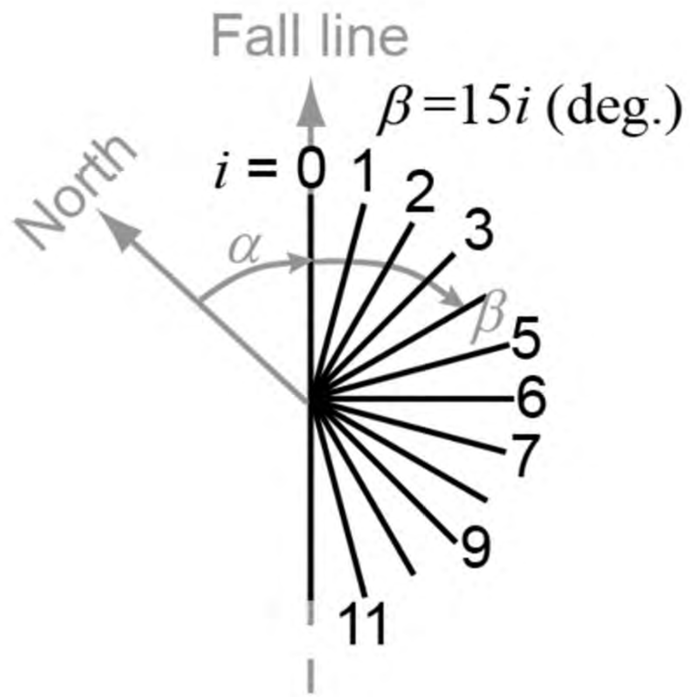
GIS dataset at http://icebridge.sr.unh.edu/icebridge/ant/

Radar technique characterizing ice properties

- Dual frequency to determine primary reflection causes
  - Density or crystal-orientation fabrics (COF)
  - Acidity



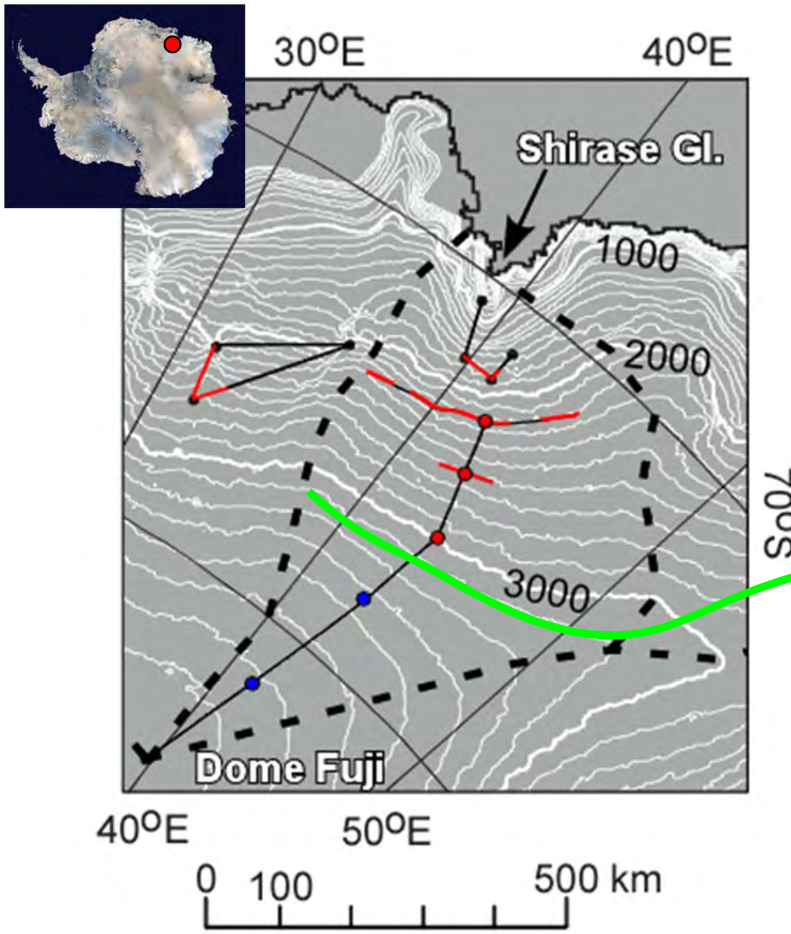
- Multi polarization planes to determine anisotropy in ice properties

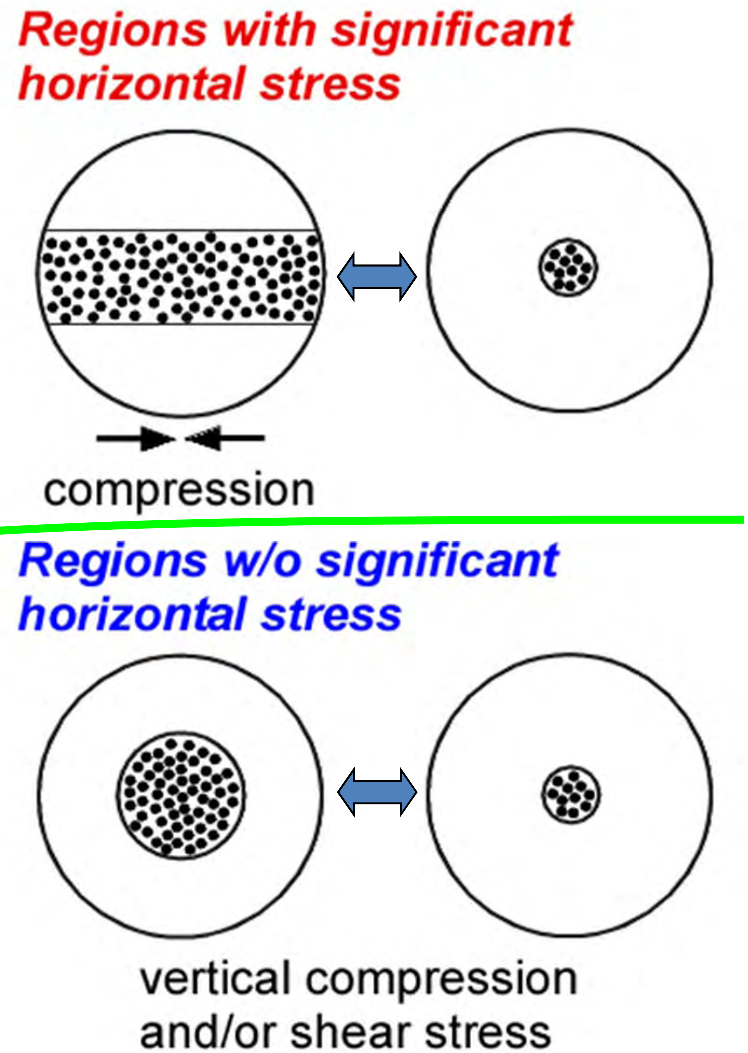


Motivations

- Detect Crystal-Orientation Fabrics (COF)
  - COF discontinuities? (radar reflection)
  - Anisotorpic COF patterns? (polarimetric patterns)
  - Depth trends or regional patterns in the COF?
- As ice deforms, non-uniform COF patterns are produced which, in turn, influence further deformation.
  - Infer variations of current ice rheology
  - Infer past ice topography

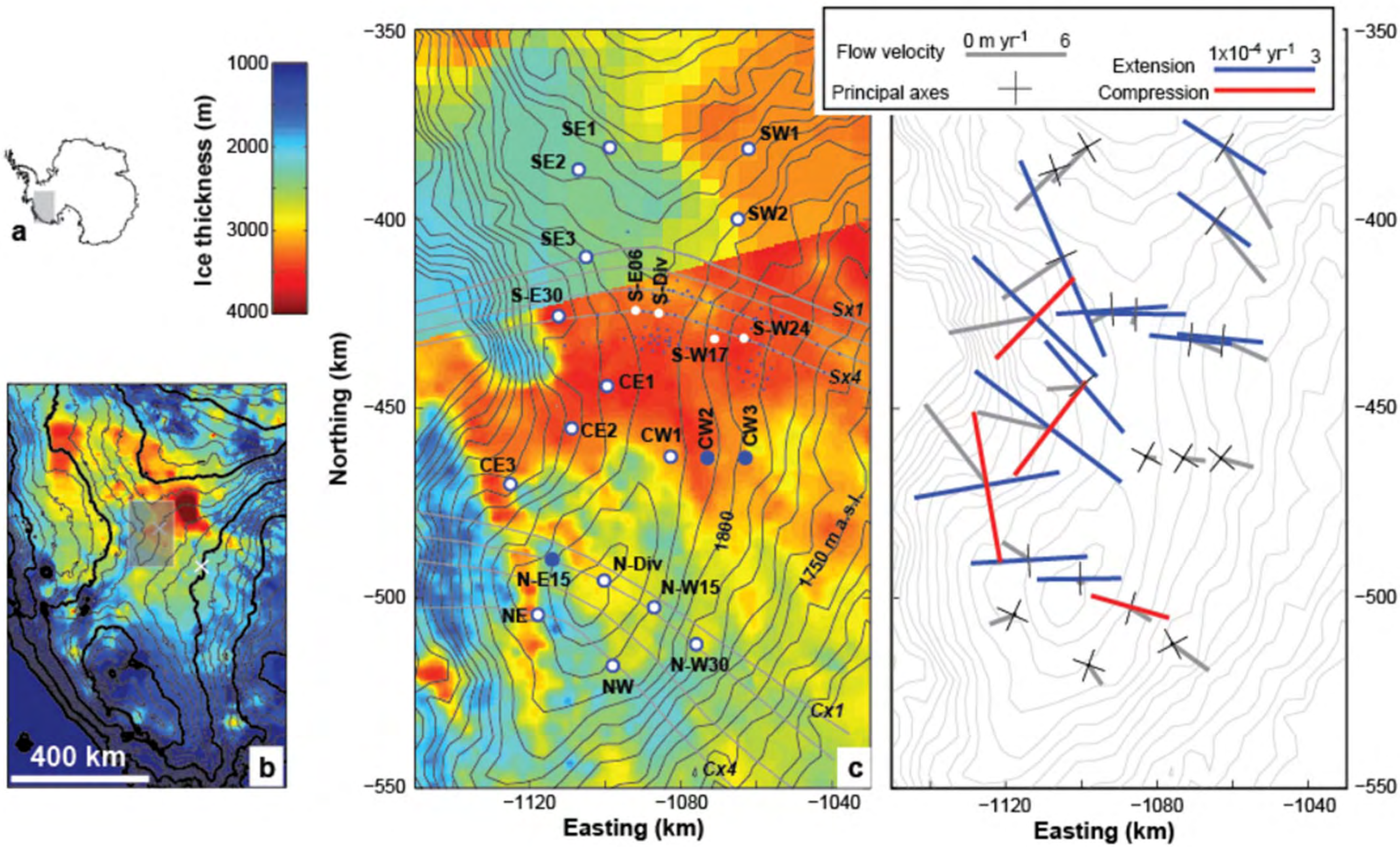
COF patterns deduced from radar





Matsuoka et al. (2003, JGR); Matsuoka et al. (2004, J. Glac)

WAIS Divide area



Flow/strain measurements (right panel) were made with GPS surveys

Returned power analysis

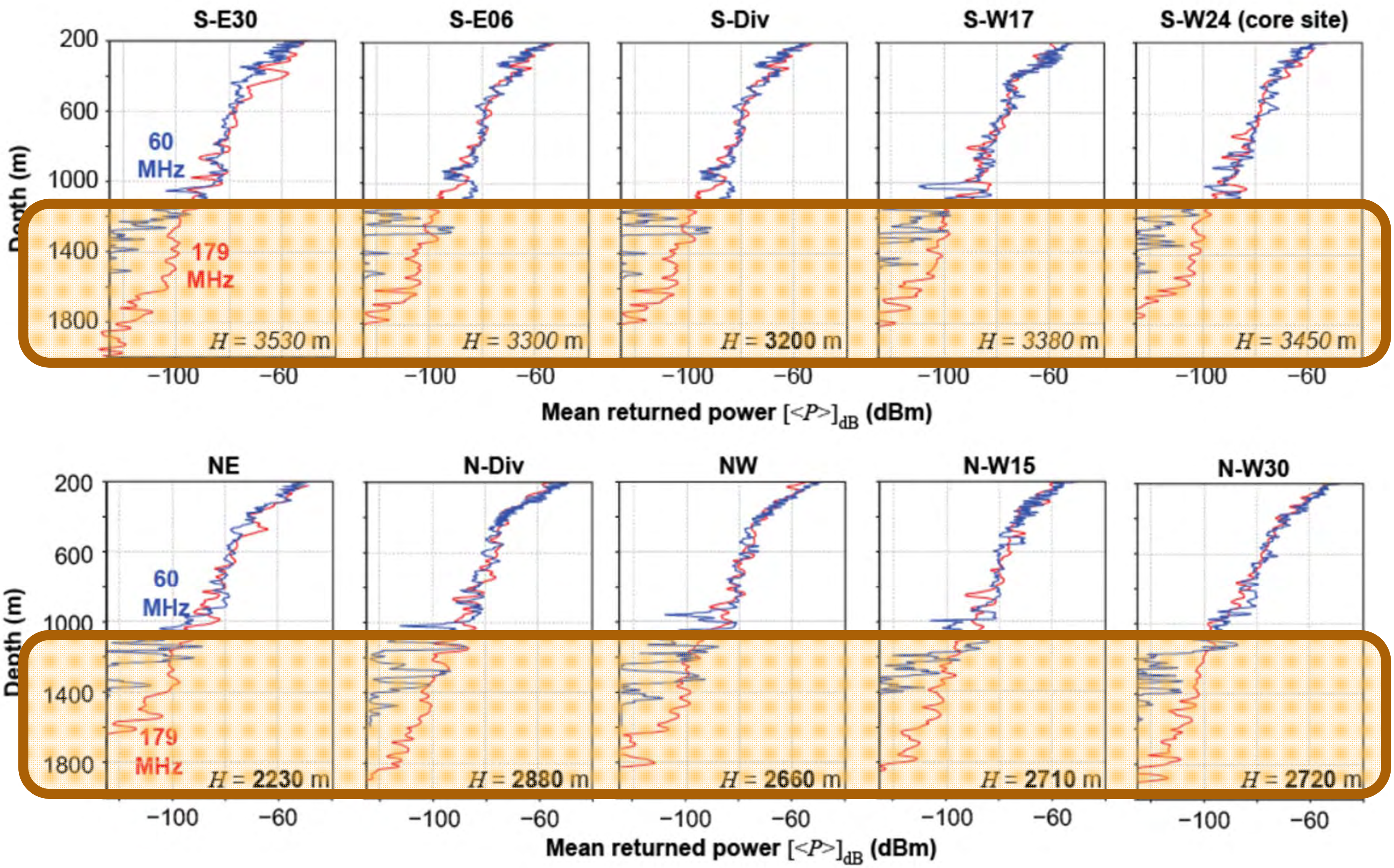
The anomaly $\delta[P_i]_{dB}$ of the returned power at the i-th polarization plane from the polarization-mean returned power $[<P>]_{dB}$ can be defined as:

$$\delta[P_i]_{dB} = [P_i]_{dB} - [<P>]_{dB}, \qquad (2)$$

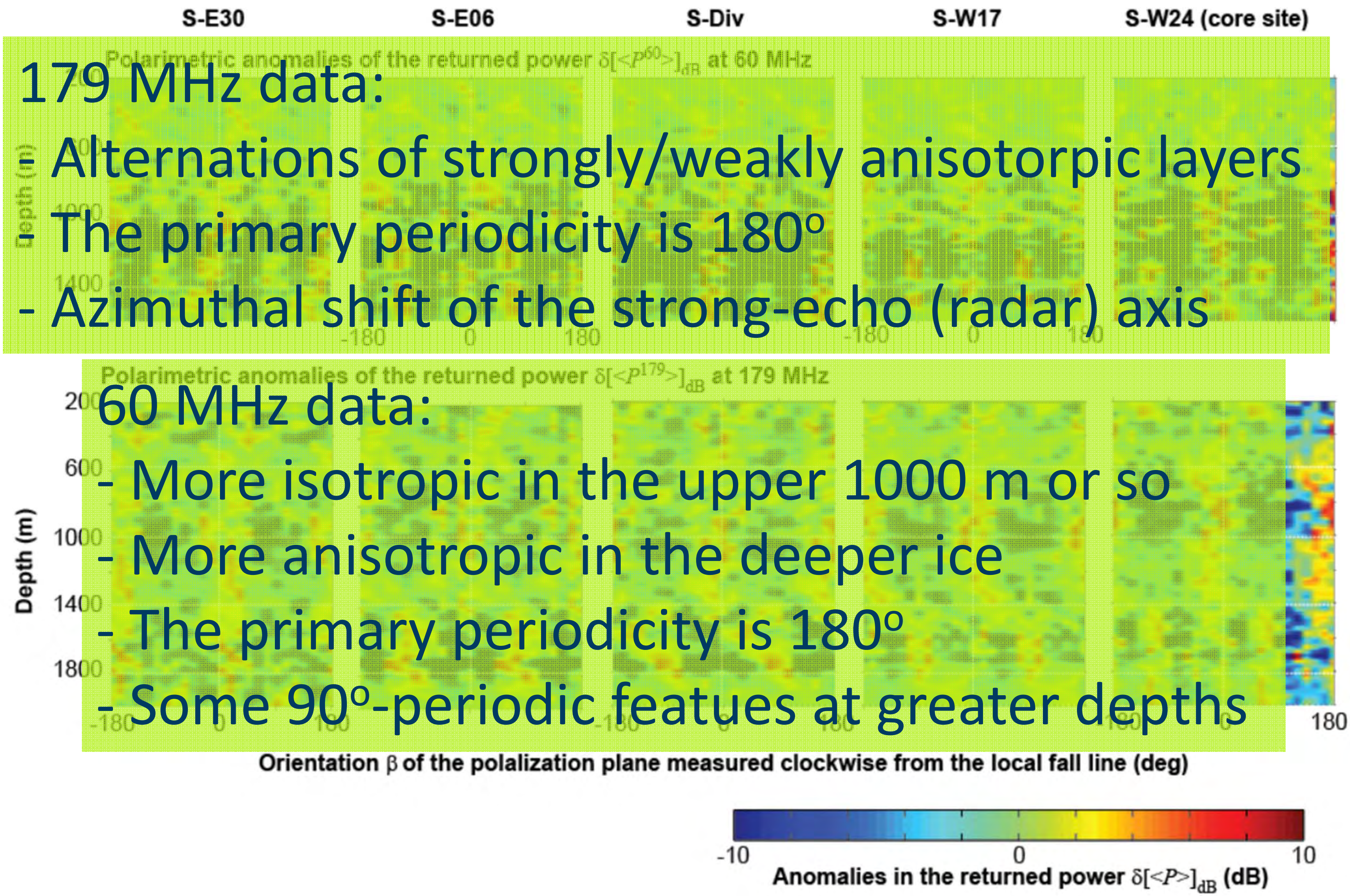
where

$$[\langle P \rangle]_{dB} = 10\log_{10}\left(\frac{1}{12}\sum_{i=0}^{11} P_i\right). \qquad (3)$$

Polarization-mean returned power



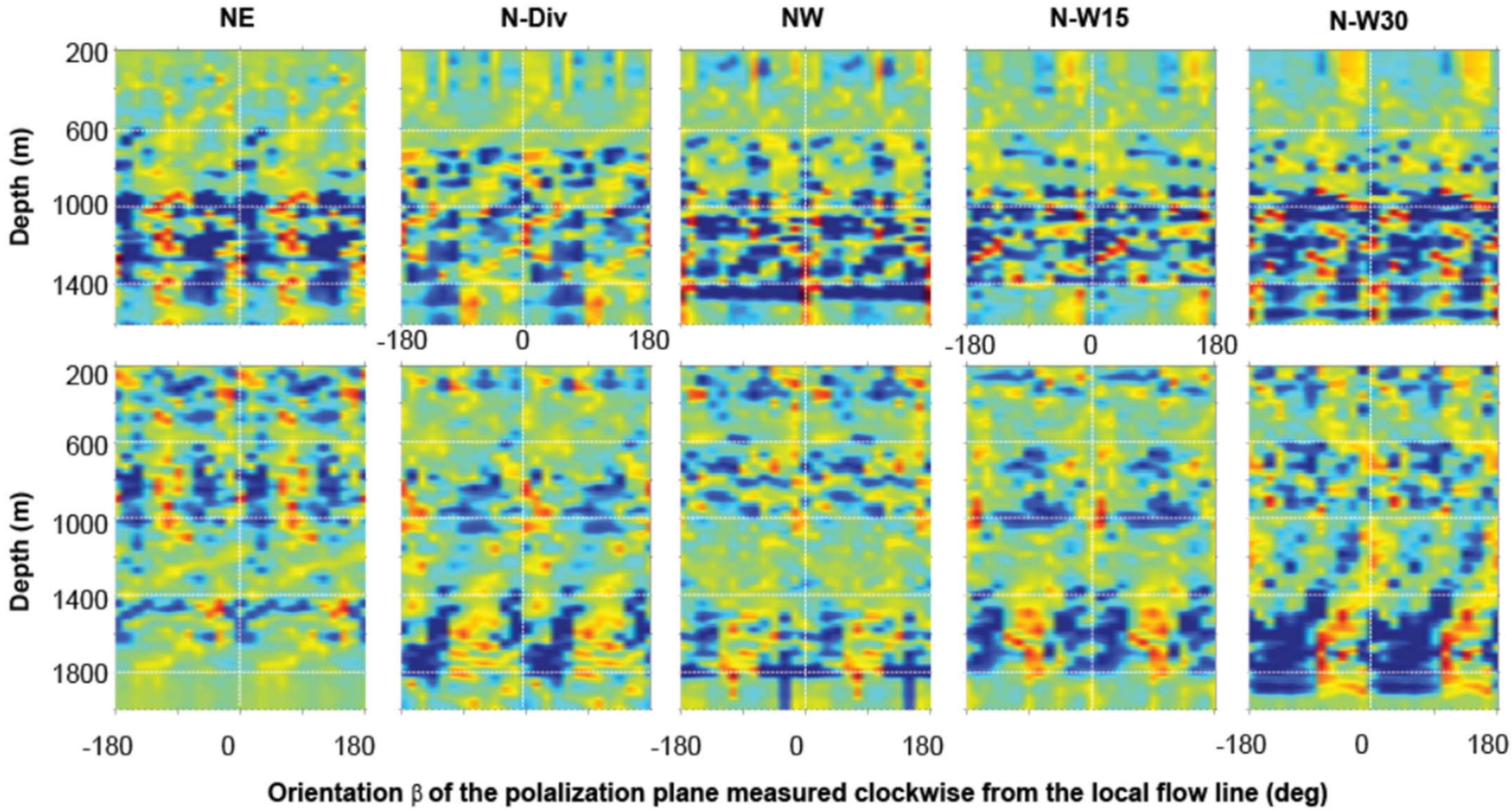
Polarimetric variations (I)



179 MHz data:
- Alternations of strongly/weakly anisotorpic layers
- The primary periodicity is 180^o
- Azimuthal shift of the strong-echo (radar) axis

60 MHz data:
- More isotropic in the upper 1000 m or so
- More anisotropic in the deeper ice
- The primary periodicity is 180^o
- Some 90^o-periodic featues at greater depths

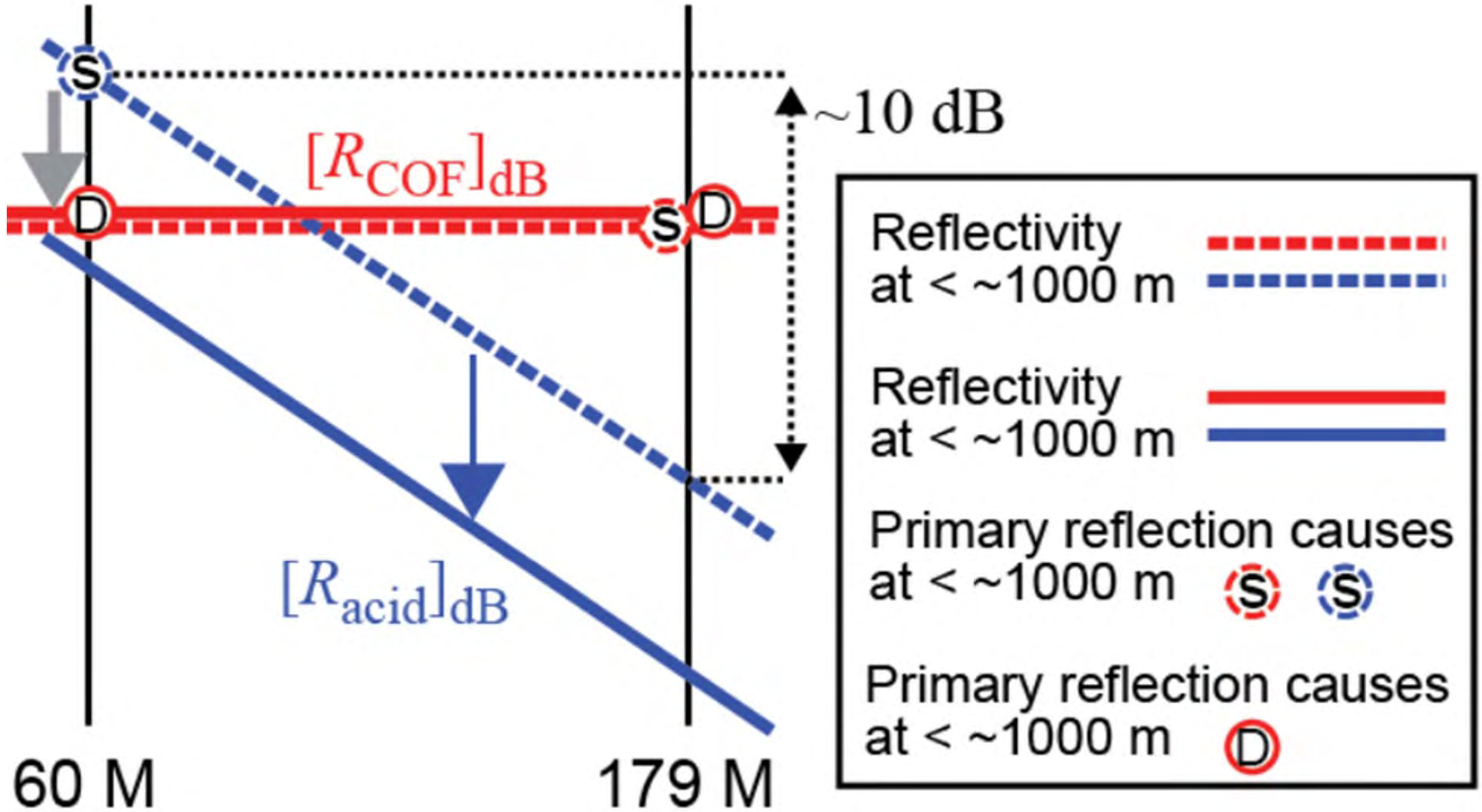
Polarimetric variations (II)



60M: isotropic shallow layer and 180°-periodic deep layer

179M: 180°-periodic features with distinct azimuthal shifts

Causes of reflection

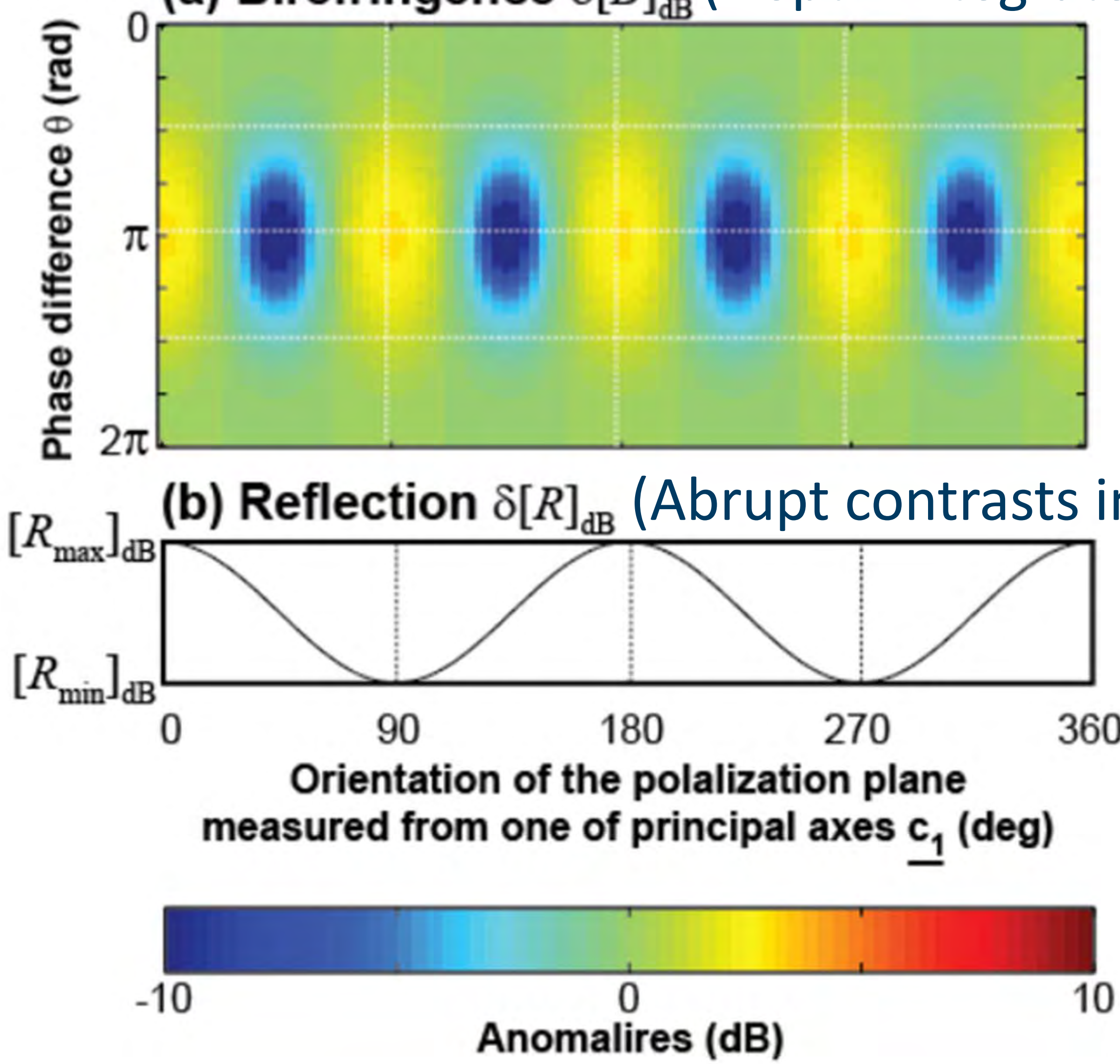


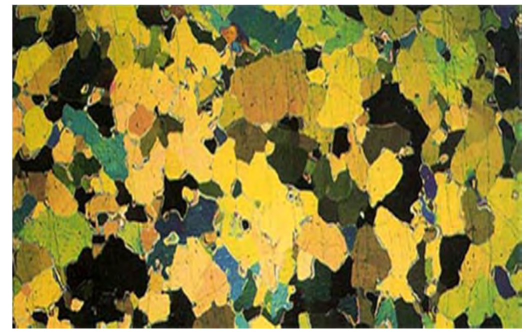
- Nearly isotropic 60-MHz retunred power at < 1000 m
- Only 60 MHz returned power decreased with depth
- Anisotorpic 179-MHz returned power at all depths

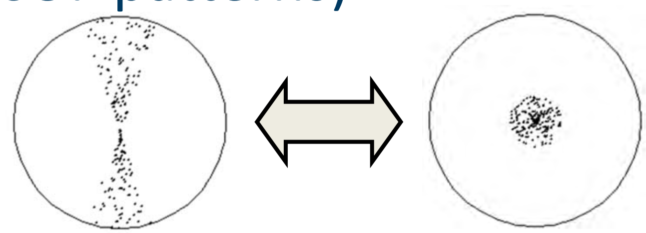
Two different effects of COF

(Depth-integrated COF anisotorpy)

(Abrupt contrasts in COF patterns)





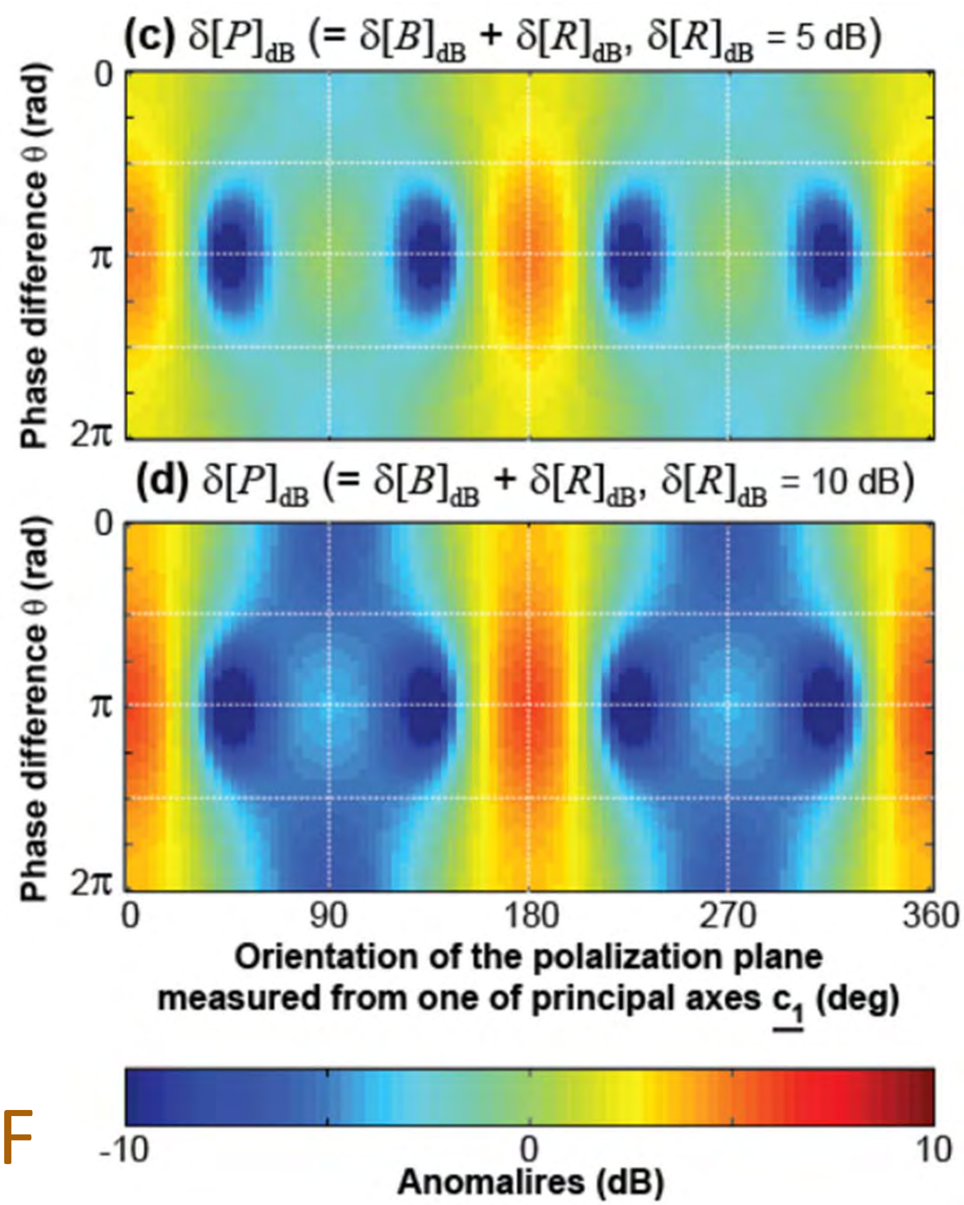


Expected effects of COF (theory)

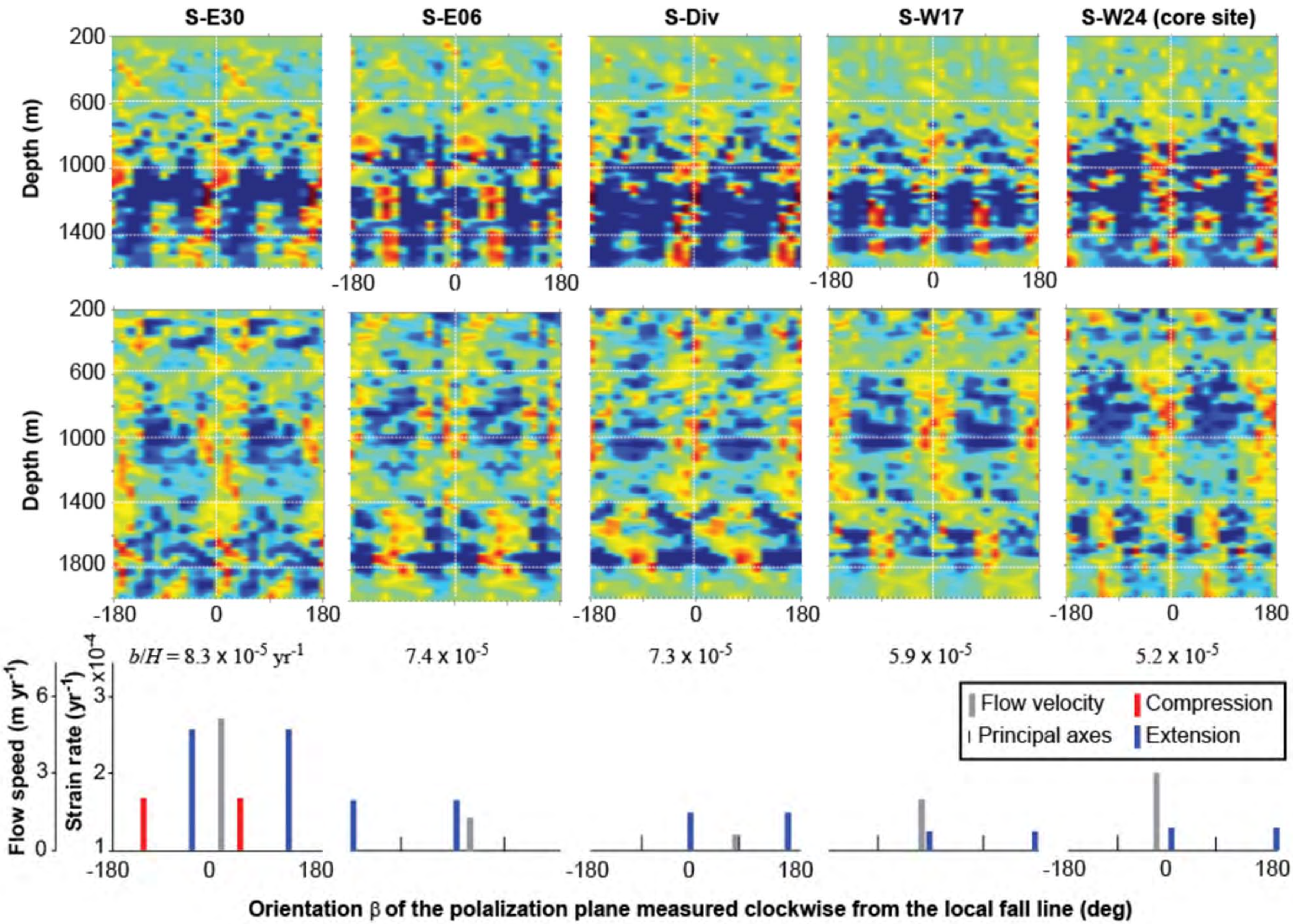
Weakly anisotropic reflection + birefringence
180° periodic
+ 90° periodic

Strongly anisotropic reflection + birefringence
180° periodic
(distorted)

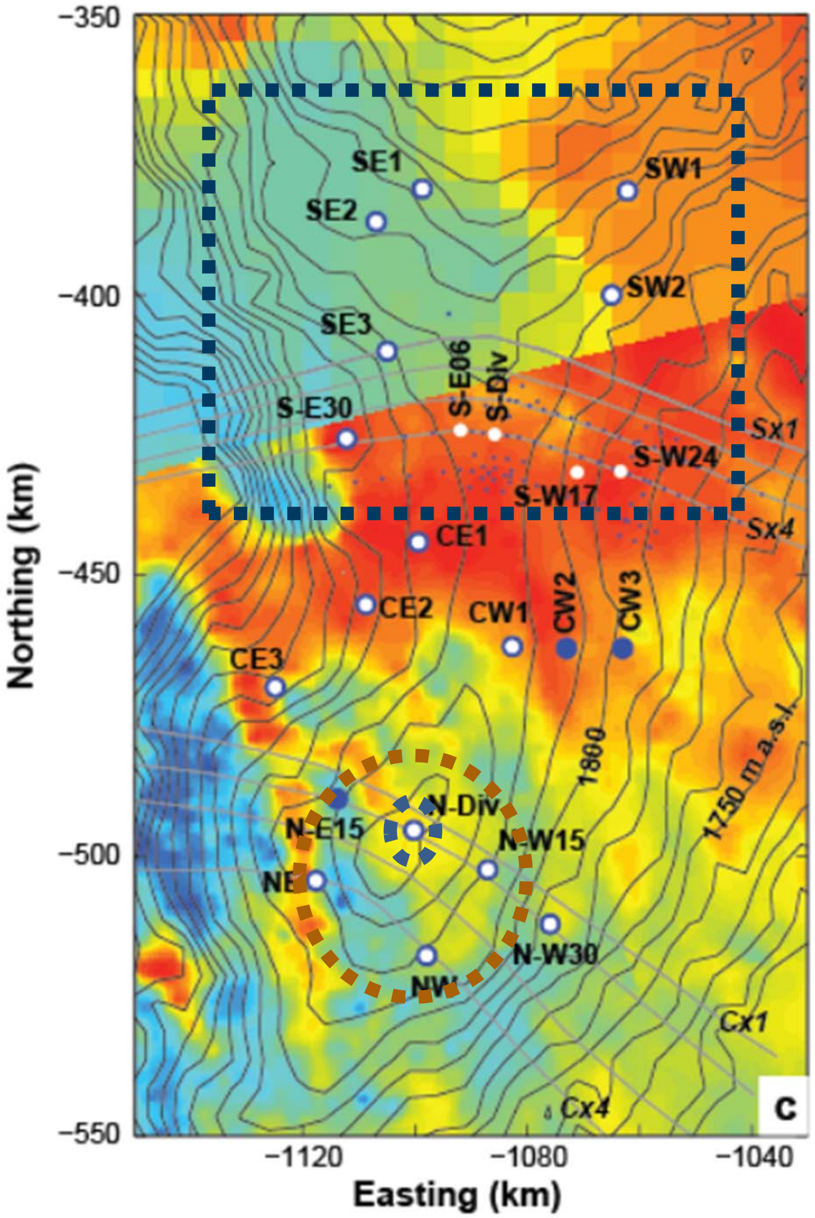
Stronger returned power at the principal axes of COF



Radar axis and current strain/vel.



Regional patterns of the radar axes



The radar axes show azimuthal shifts in the southern region and in the vicinity of the flow divide.

The radar axes are depth uniform around the local ice dome (except for the divide site).

Summary

- Regionally consistent features are found in englacial polarimetric, dual-frequency radar data.
- Distinct properties of the radar data agree with theoretical predictions of COF's effects on the radio-wave propagation.
- COF contrasts make reflections as shallow as 200-500 m.
- COF patterns are more complicated at greater depths (but in the upper half to two thirds of the ice thickness).
- Azimuthal shifts of the radar (COF) axes infer that flowline through the WAIS Divide core site has likely migrated.

Acknowledgements

US National Science Foundation
NASA Space Grant at the University of Washington
National Institute of Polar Research, Tokyo

Field participants

P. Braddock, M. Conway, R. Eastman, L. Hormen,
J. A. MacGregor, HC Steen-Larsen, V. Palmer

Instrument development & data interpretation

H. Conway, A. Rasmussen, P. Vaswani, E. Waddington

UNAVCO
Raytheon Polar Services
Air National Guard
Kenn Borek Air