It's a wet, wet WAIS: Observations of current and historical snow accumulation from the Amundsen Sea sector

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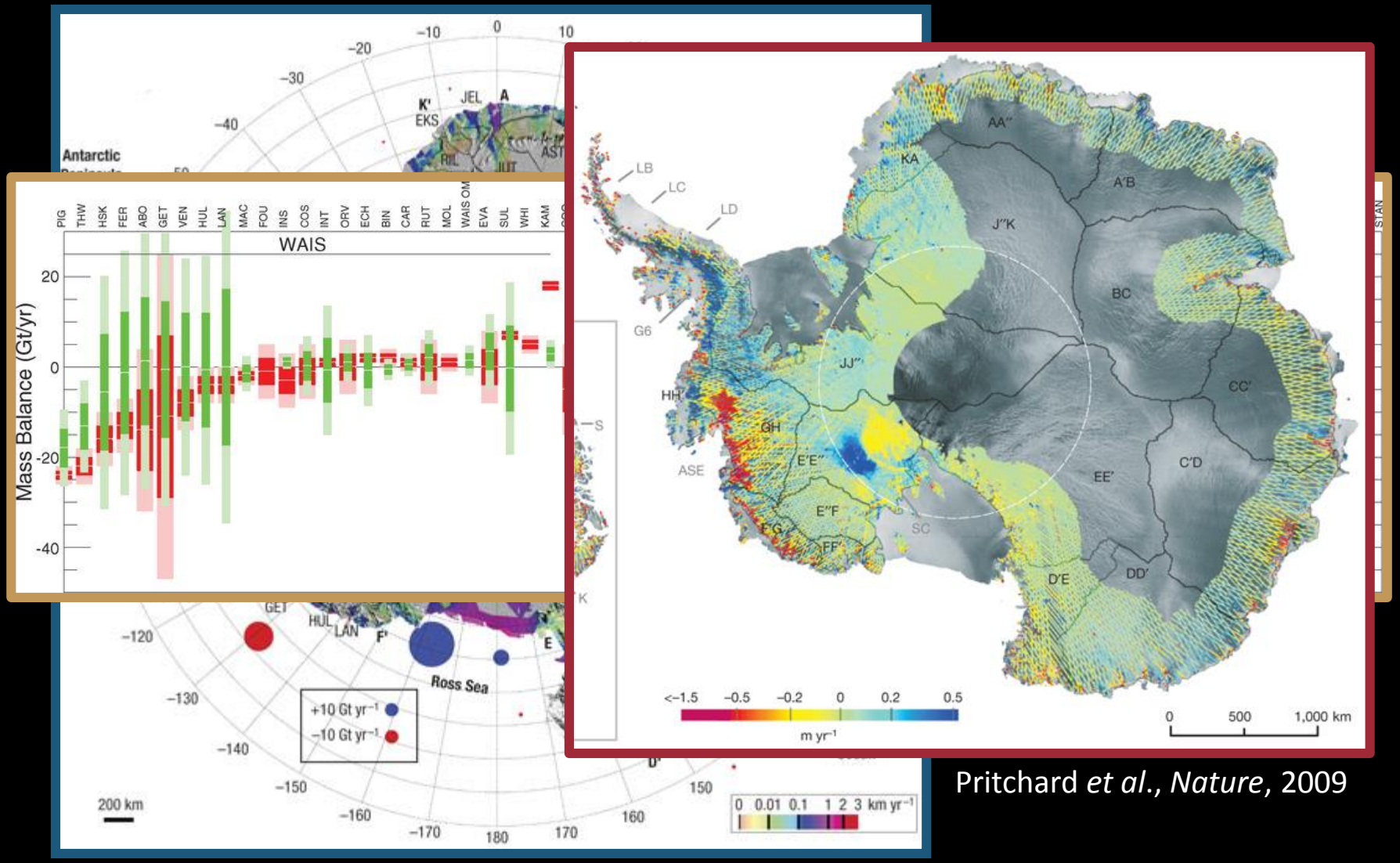
[1]NASA Goddard [2]U. Washington [3] WHOI [4]CReSIS [5]DRI [6]IMAU [7]OSU

Accumulation is important!



Pritchard *et al.*, *Nature*, 2009

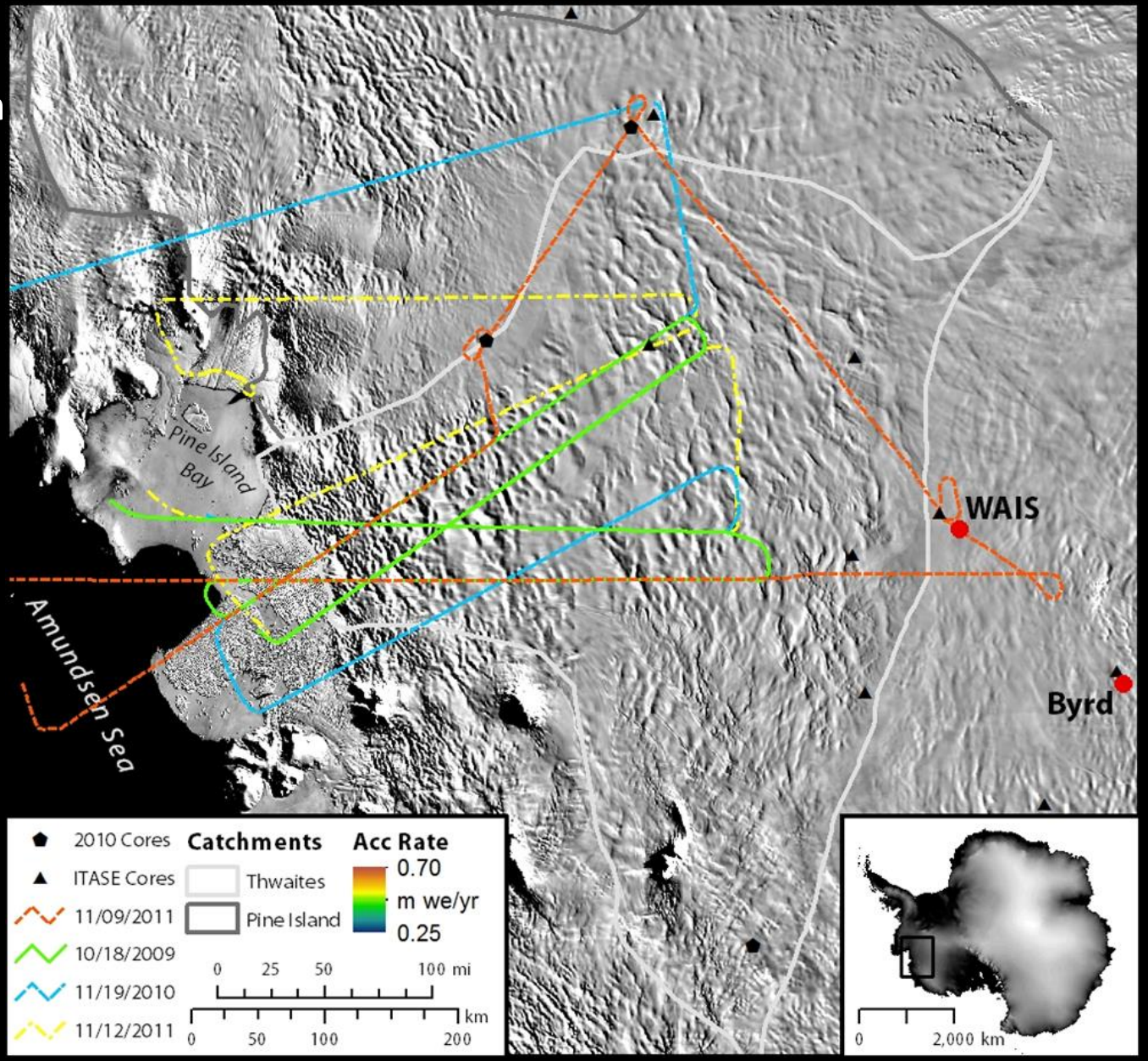
Rignot *et al.*, *Nat. Geosci.*, 2008

Overview

1. Recent	2. Historical	3. Firn Compaction
• 1980-2009 • OIB Snow Radar • Model comparison	• Past 300+ years • 15 firn cores	• OIB snow radar • Model comparison

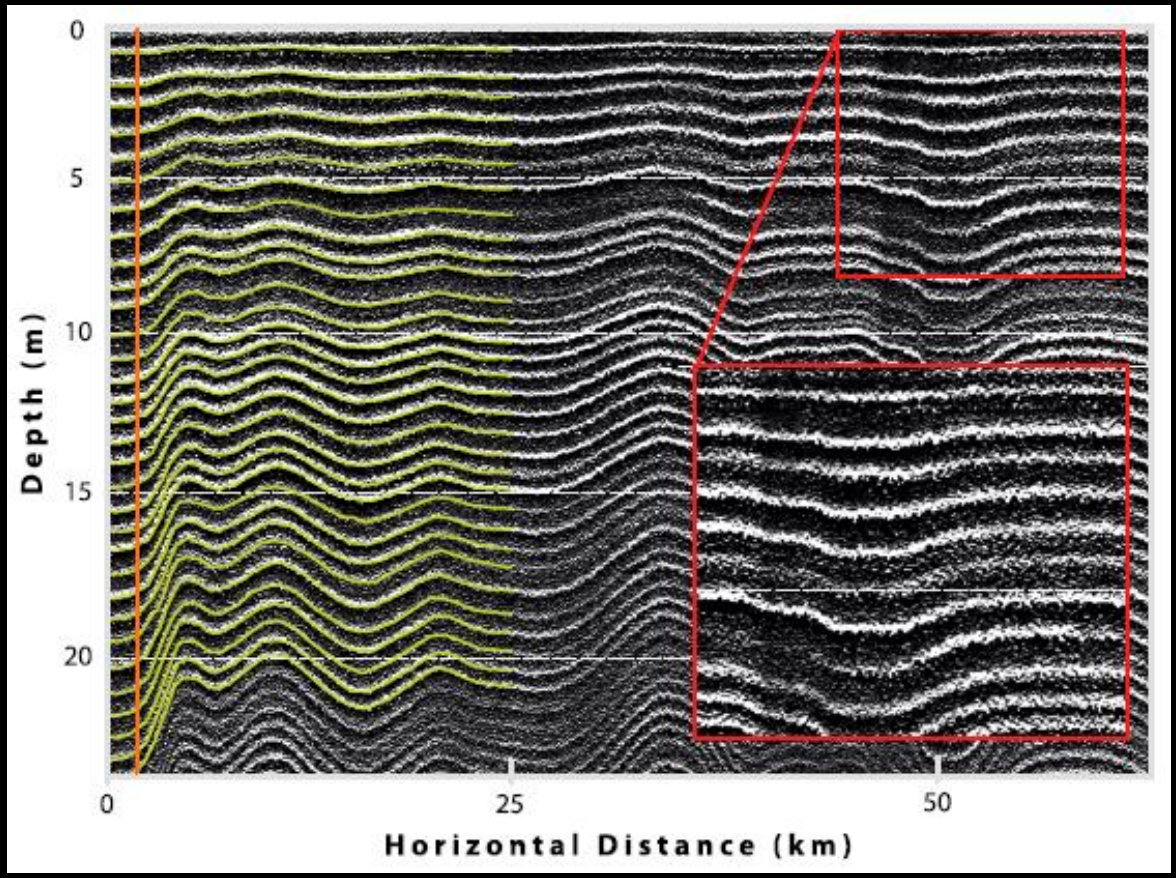
1. Recent accumulation rates

Annual accumulation from OIB snow radar



Annual accumulation from OIB snow radar

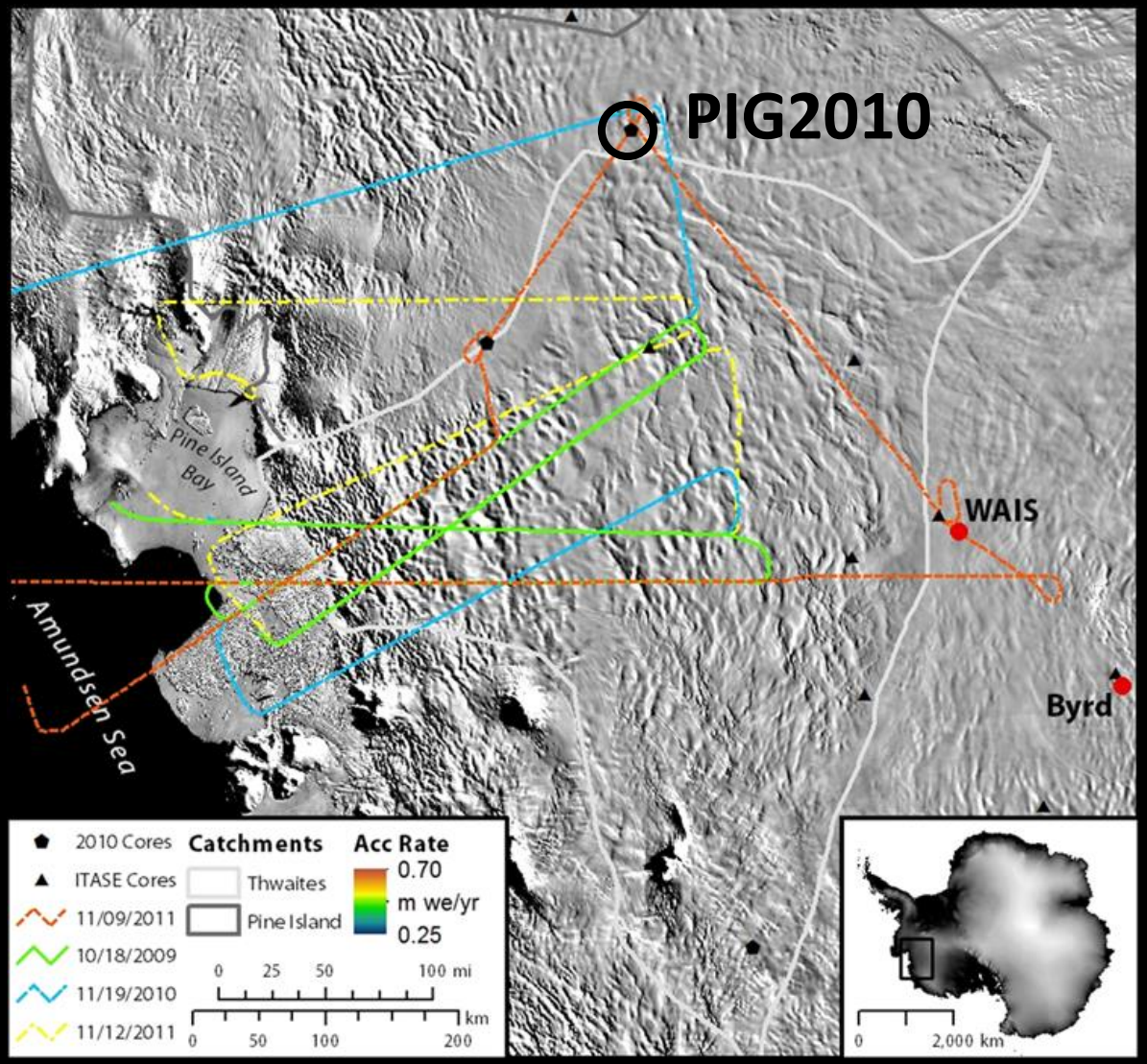
1. Track several internal horizons



Medley et al., *GRL*, 2013

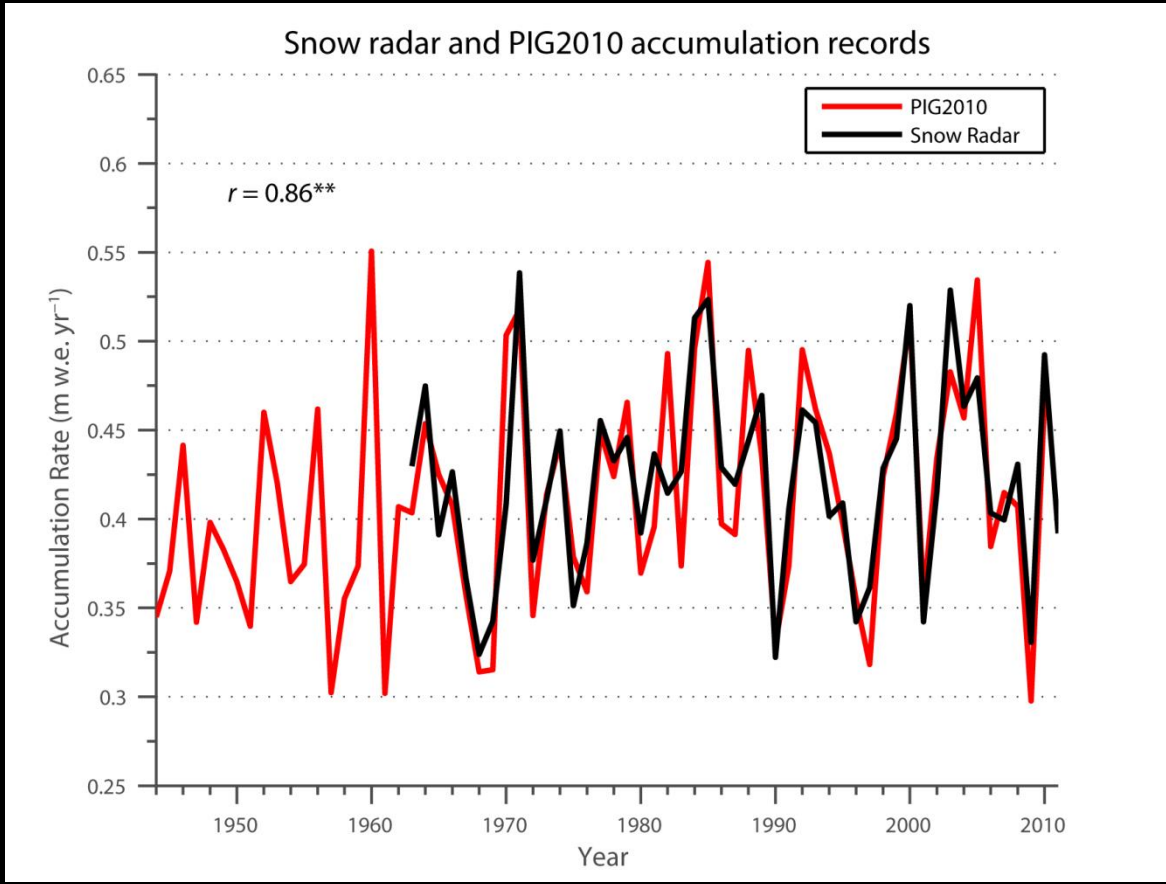
Annual accumulation from OIB snow radar

1. Track several internal horizons
2. Confirm horizons are annually spaced



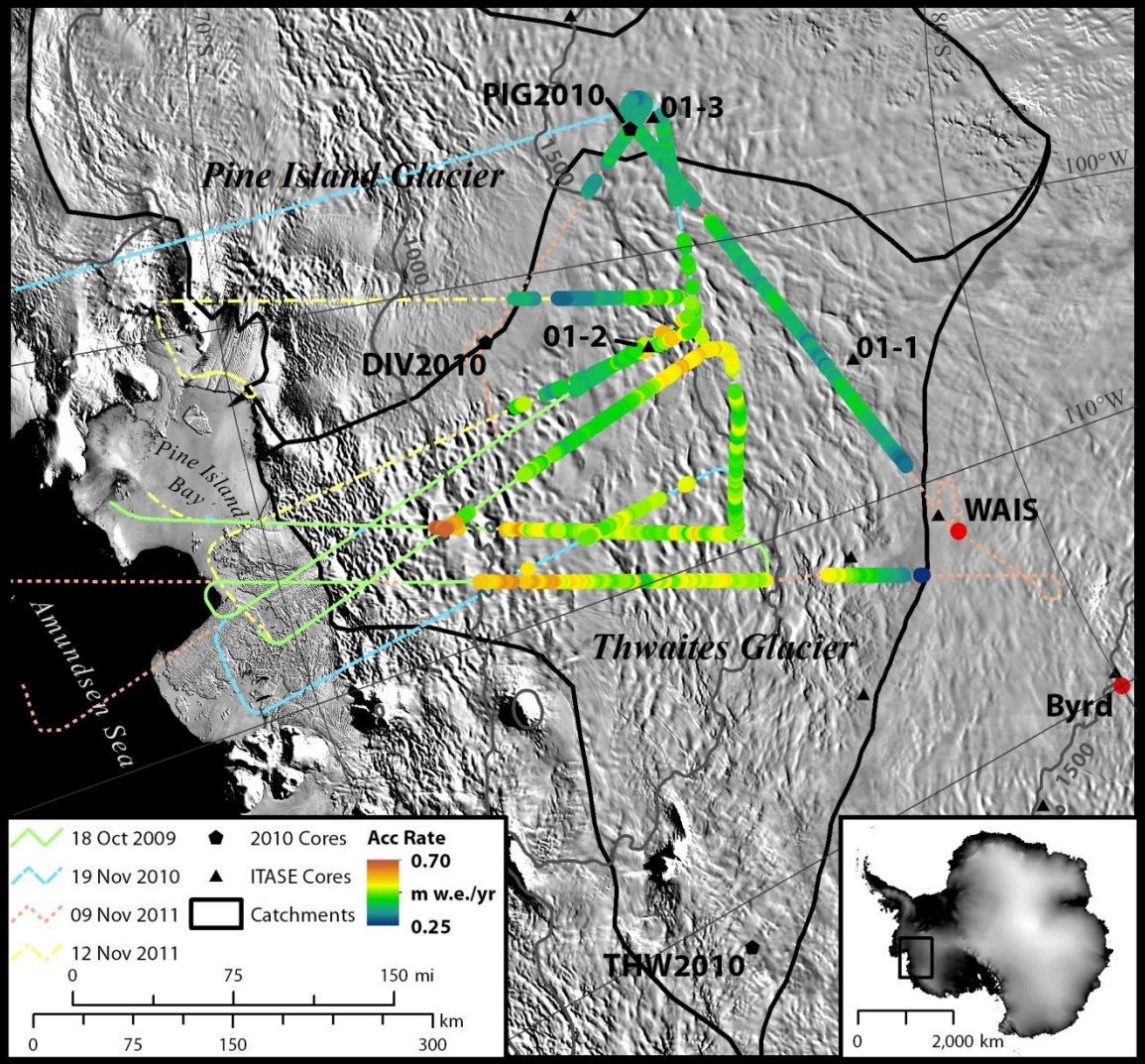
Annual accumulation from OIB snow radar

1. Track several internal horizons
2. Confirm horizons are annually spaced

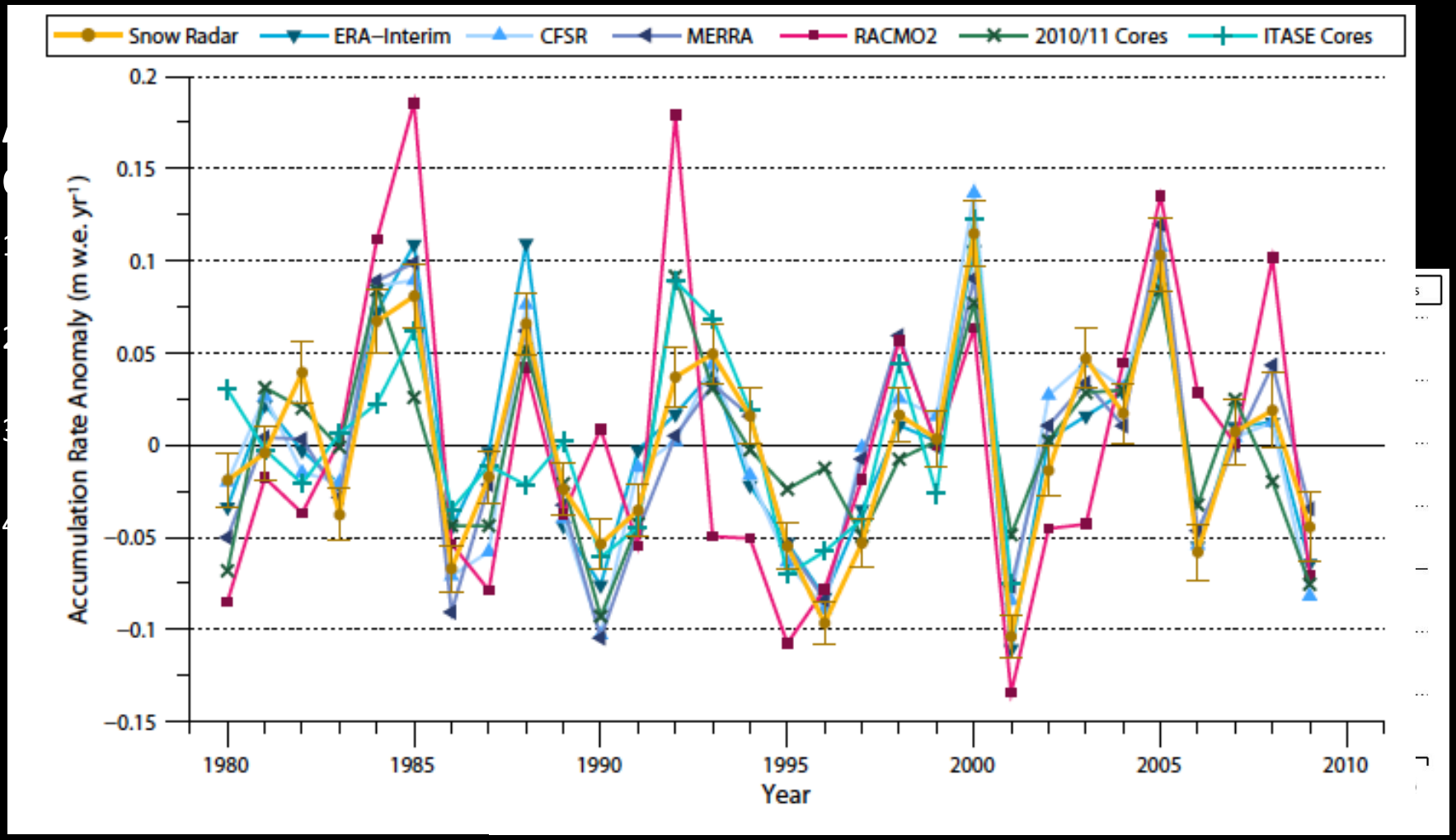


Annual accumulation from OIB snow radar

1. Track several internal horizons
2. Confirm horizons are annually spaced
3. Generate >6,000 30-yr records



Medley et al., *GRL*, 2013



Medley et al., *GRL*, 2013

- No recent accumulation trend
- Evaluation of temporal variability in modeled accumulation

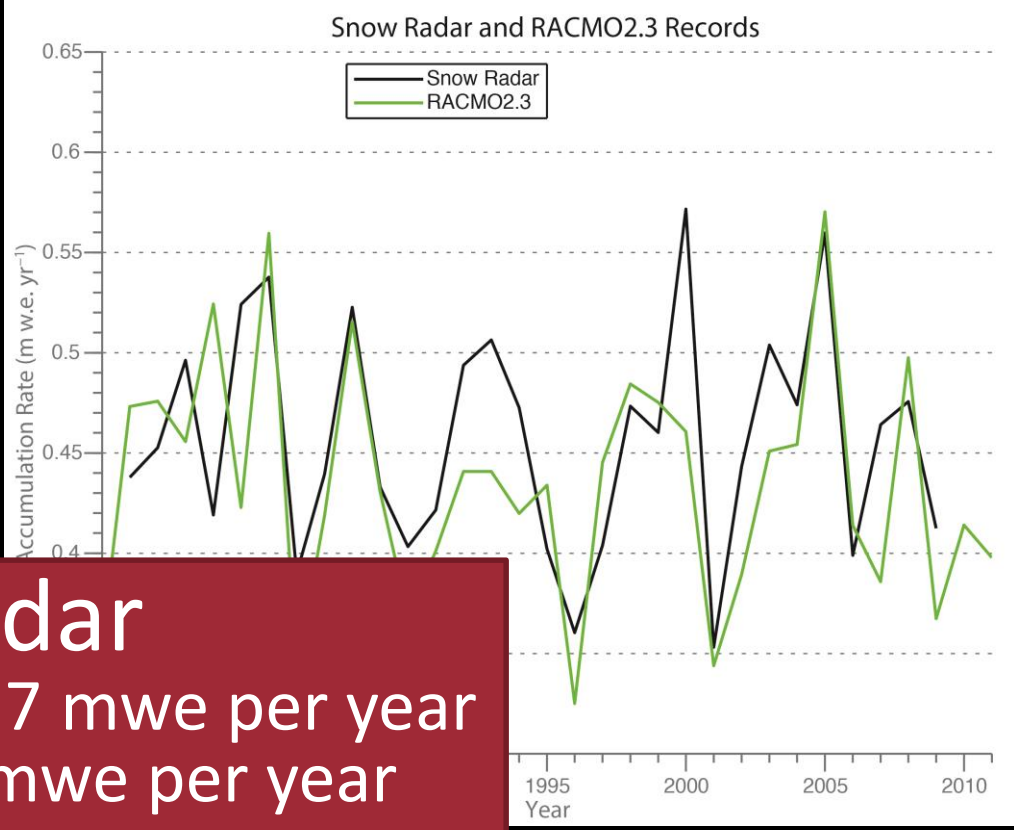
RACMO 2.3

Van Wessem et al., *J. Glac.*, 2014

mean = 0.440 mwe per year

std = 0.060 mwe per year

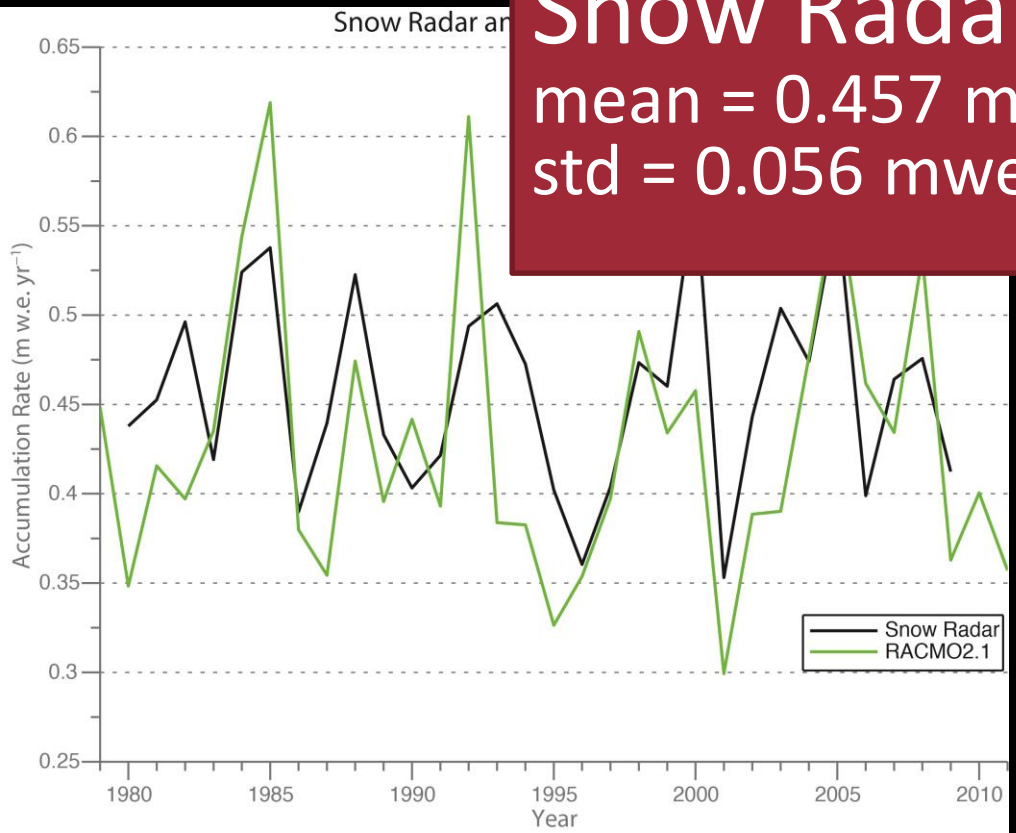
r_{SR} = 0.68



Snow Radar

mean = 0.457 mwe per year

std = 0.056 mwe per year



RACMO 2.1

(Lenaerts *et al.*, *GRL*, 2012)

mean = 0.432 mwe per year

std = 0.080 mwe per year

r_{SR} = 0.67

Climate model comparison over Thwaites catchment

- *Temporal variability*
  - *REANALYSES are spot on!* $r > 0.9$
  - *RACMO2 underperforms relatively* $r = 0.68$
- Provides the ability for user to discriminate between models based on need
  - *RACMO2 has finest spatial rez.,* $r = 0.86$
- *Magnitude*
  - *REANALYSES underestimate*
  - *RACMO2 is about spot on!*

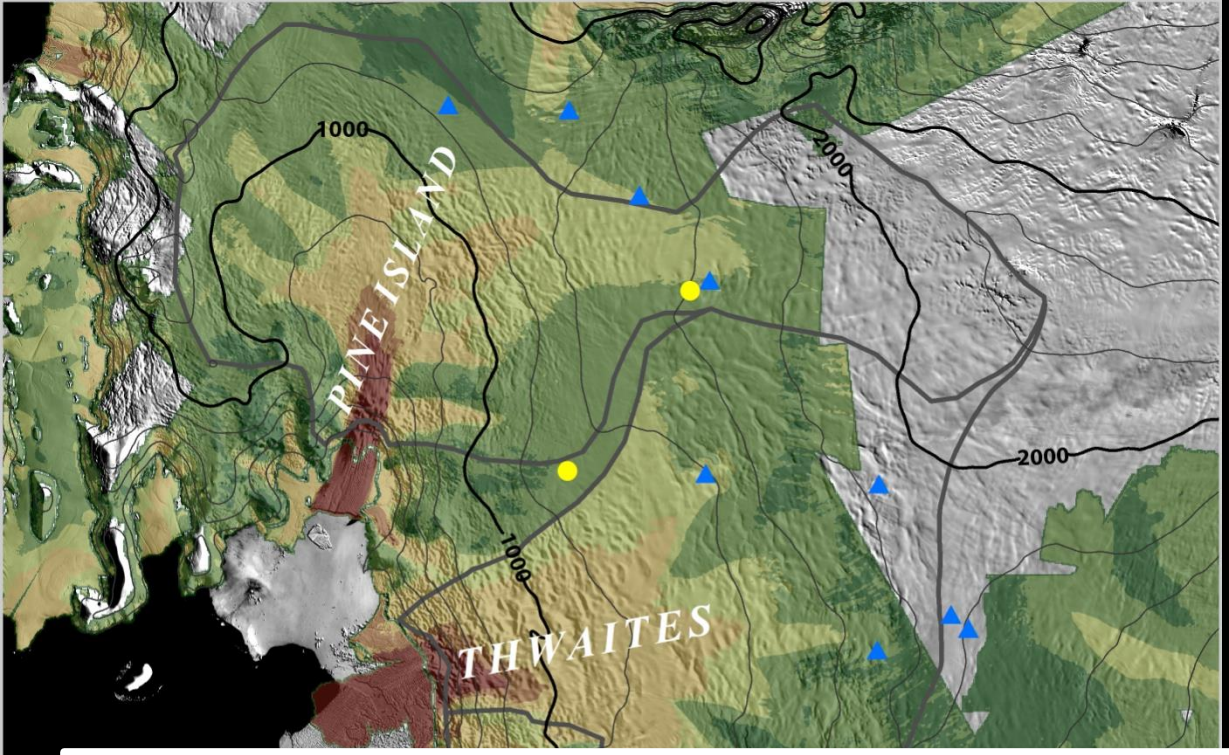
2. Historical accumulation rates

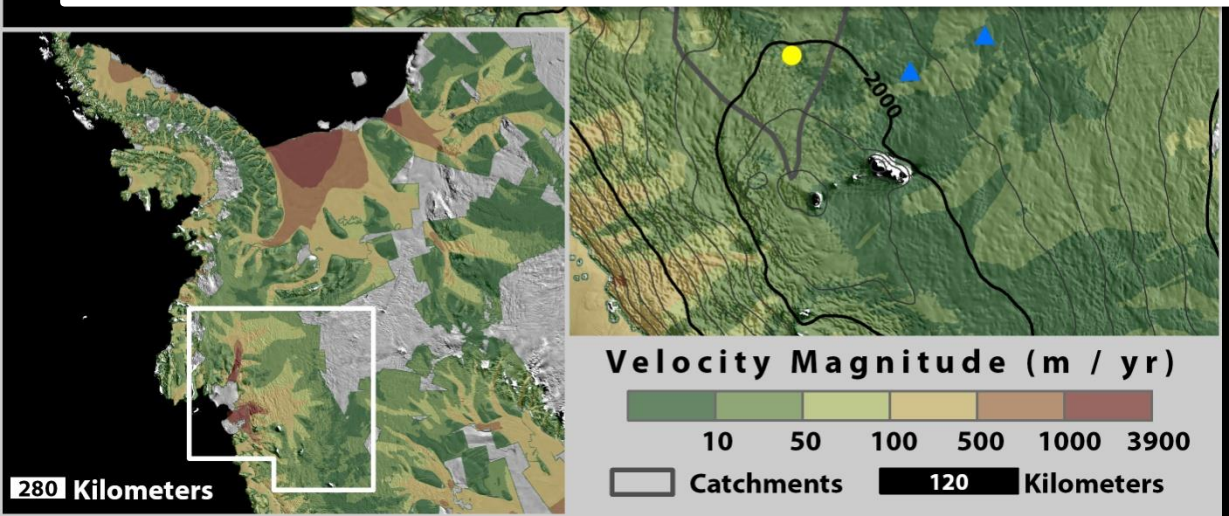
Long-term core records

ITASE (2000/2001)
(Kaspari et al., *J. Glac.*, 2004)

WDC05A/Q (2005)
(Banta et al., *GRL*, 2009)

Stack the records with weights based on their average correlation with ERA-Int *P-E* for each grid cell within the PIG/THW drainage





Medley et al., *TC*, 2014

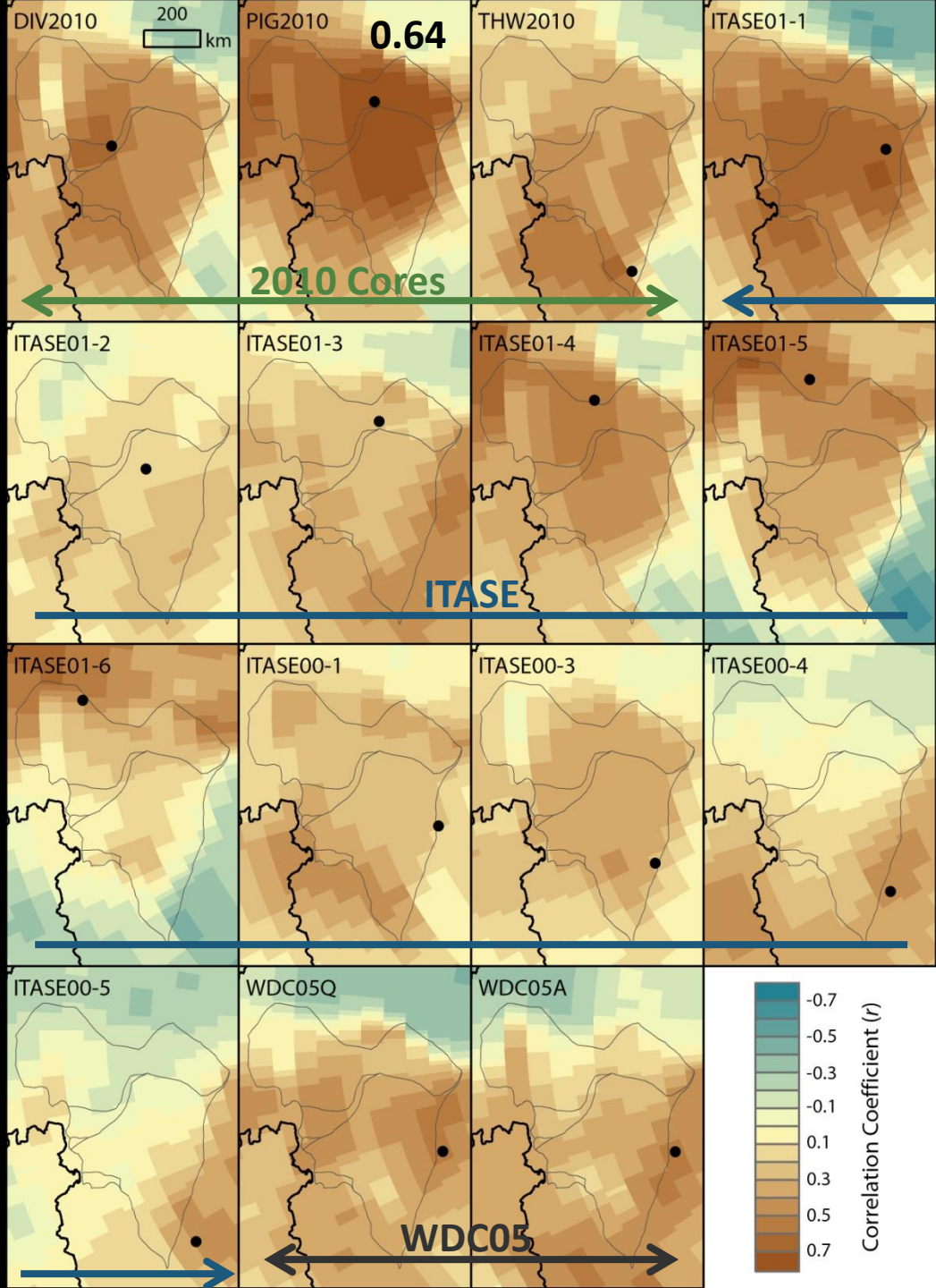
Correlation maps for each core record

Black dot show core location

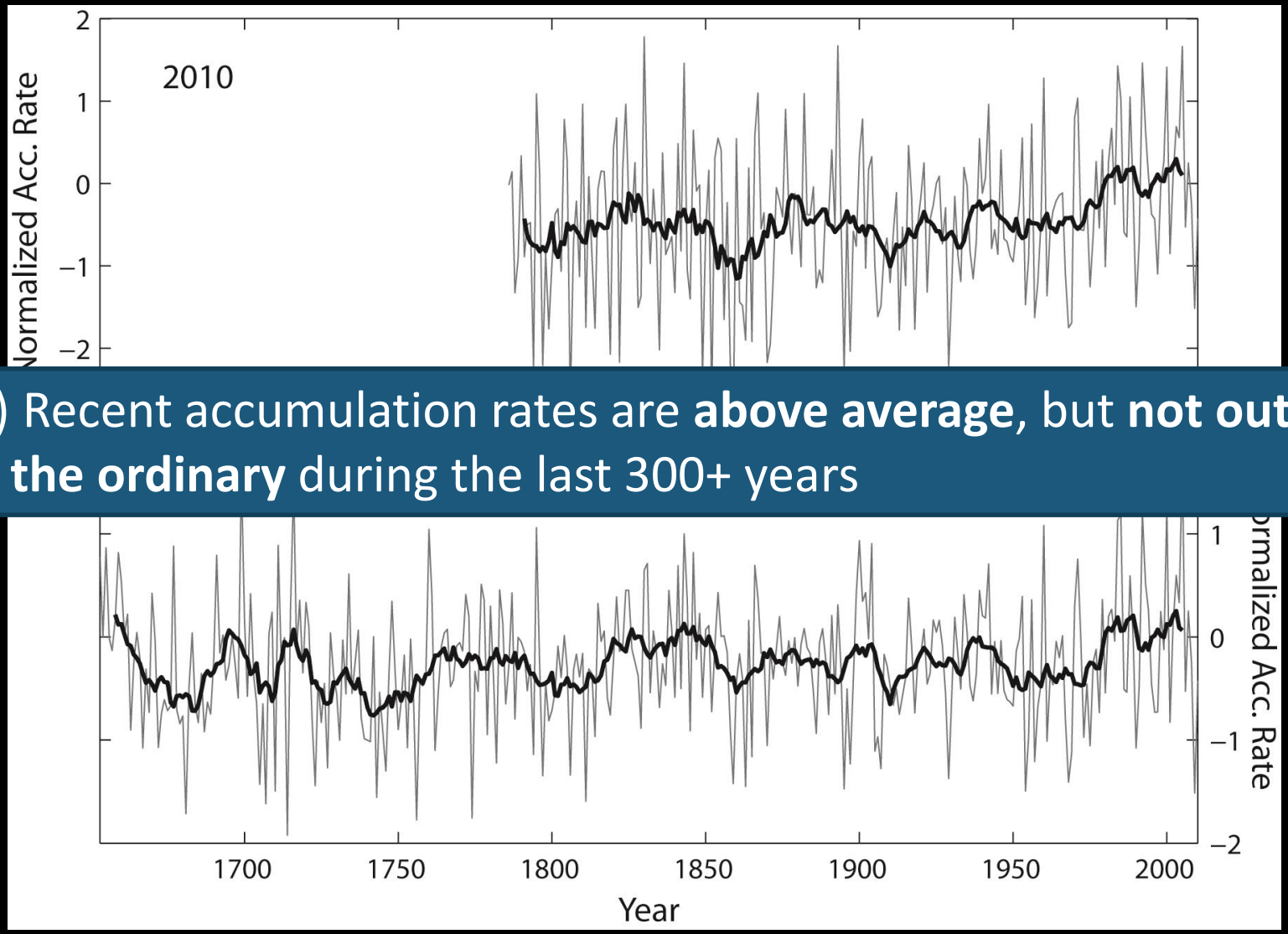
Note strong decrease in correlation beyond the drainage divides

Find the average *r* for each core within PIG/THW boundary

Stack the records weighted accordingly

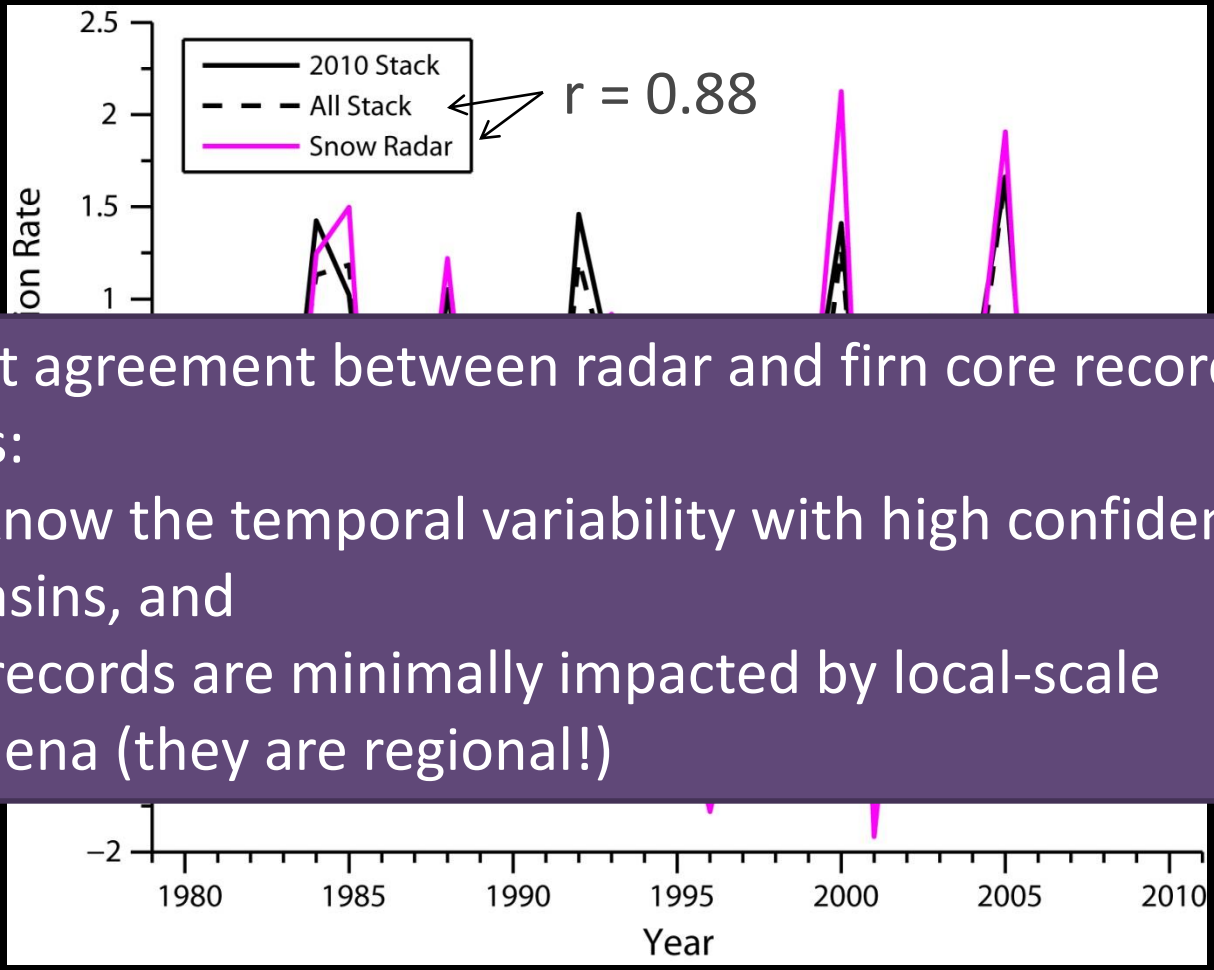


Stacked Records



(5) Recent accumulation rates are **above average**, but **not out of the ordinary** during the last 300+ years

Stacked vs. radar-derived records

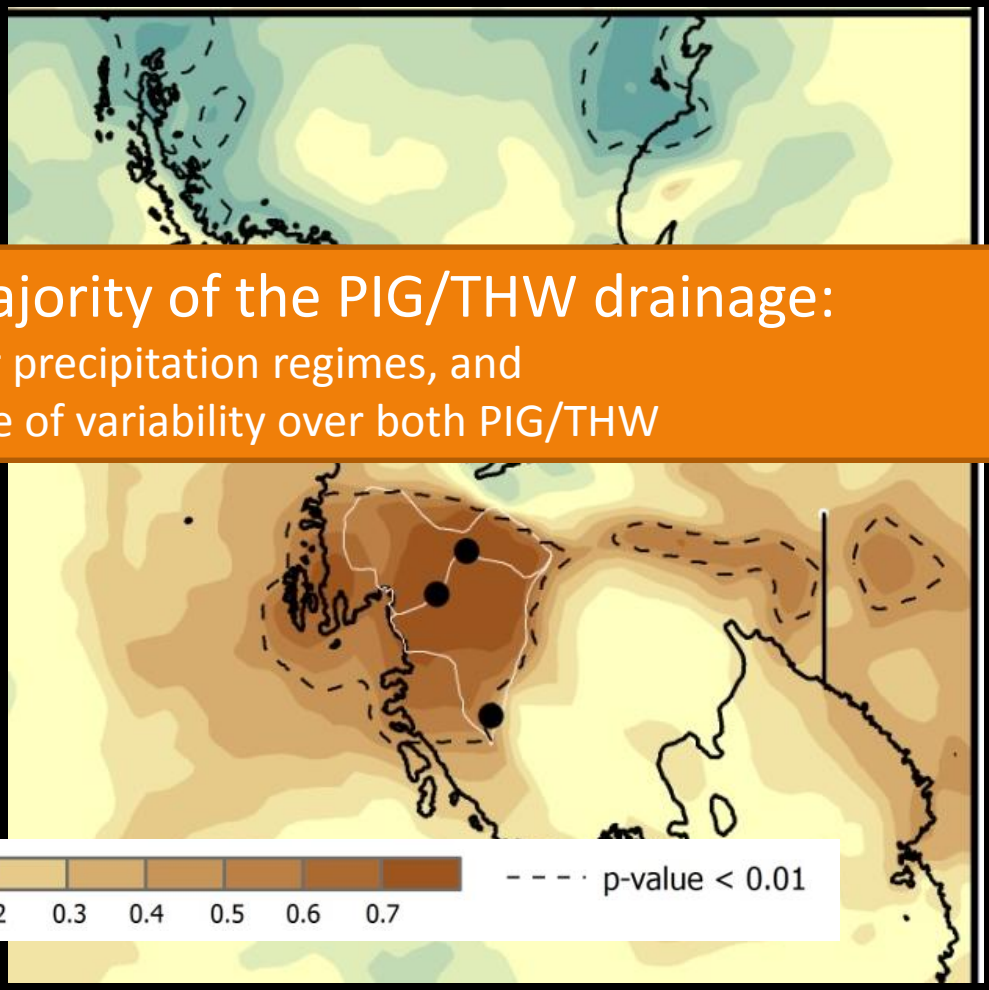


Excellent agreement between radar and firn core records suggests:

(7) We know the temporal variability with high confidence over these basins, and

(8) The records are minimally impacted by local-scale phenomena (they are regional!)

Spatial correlation of the 2010 stack with ERA-Interim *P-E*

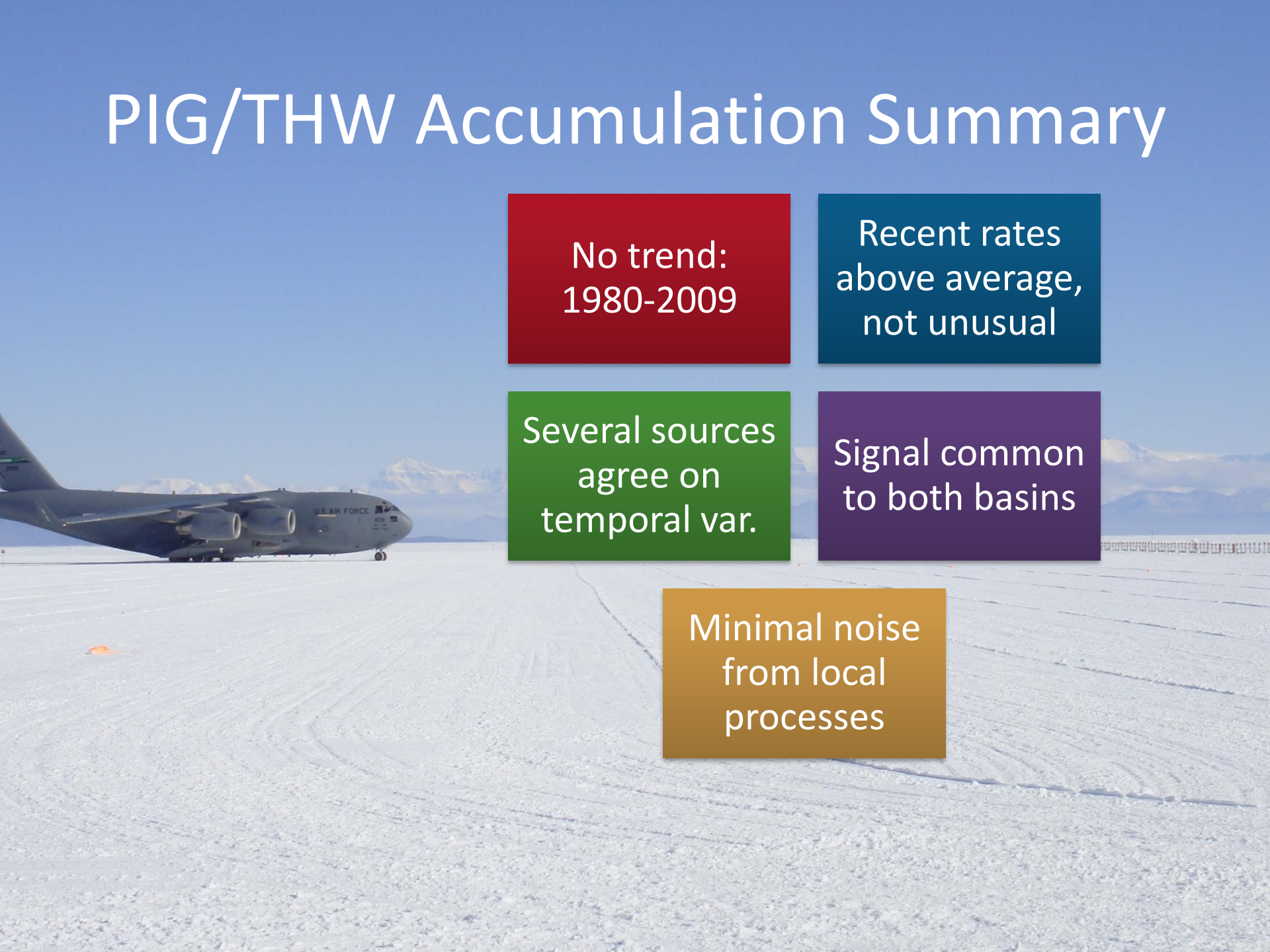


Strong correlation over majority of the PIG/THW drainage:

(3) These basins experience similar precipitation regimes, and

(4) The stack is likely representative of variability over both PIG/THW

PIG/THW Accumulation Summary



No trend: 1980-2009

Recent rates above average, not unusual

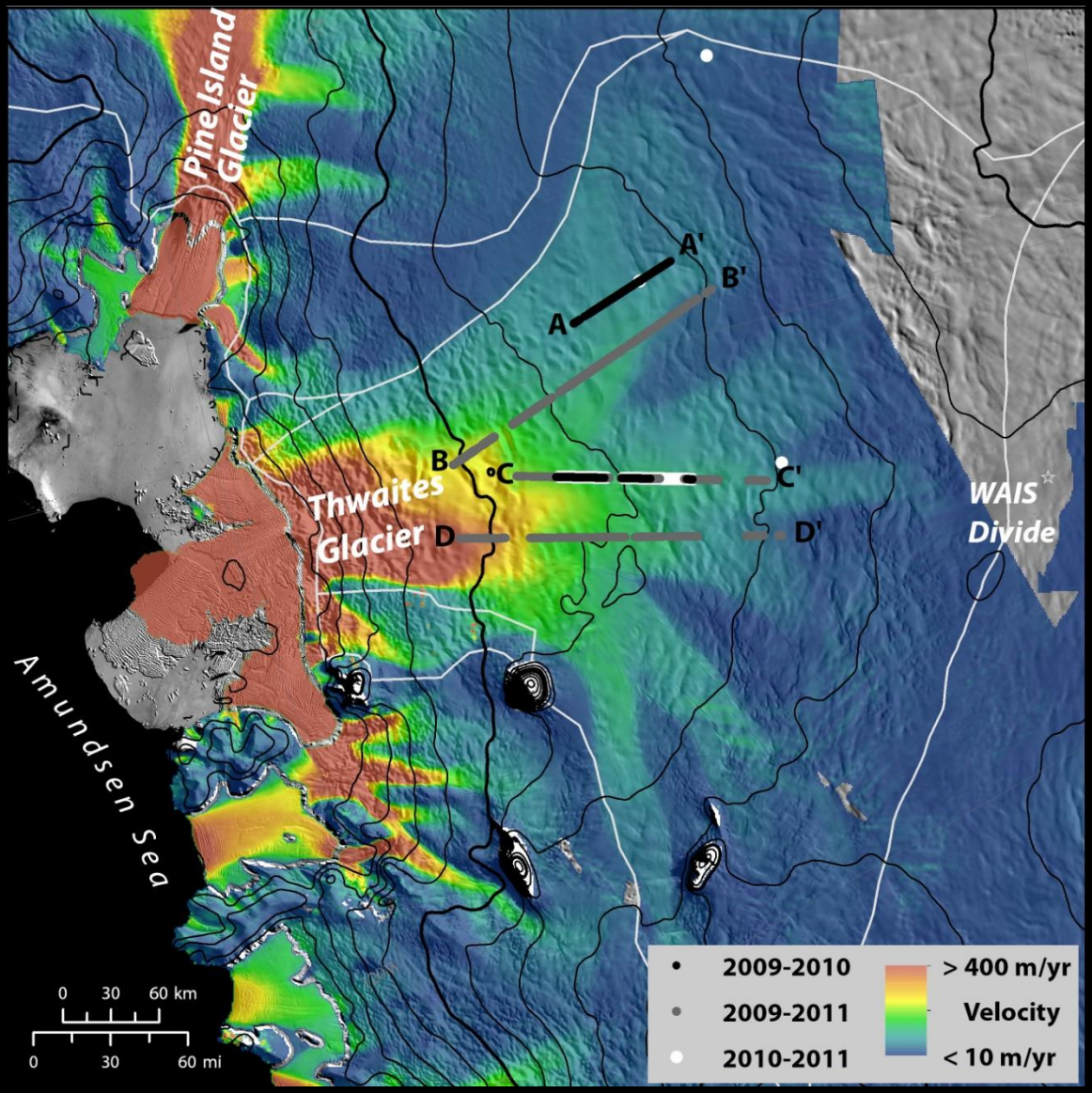
Several sources agree on temporal var.

Signal common to both basins

Minimal noise from local processes

Measuring firn compaction rates from OIB snow radar

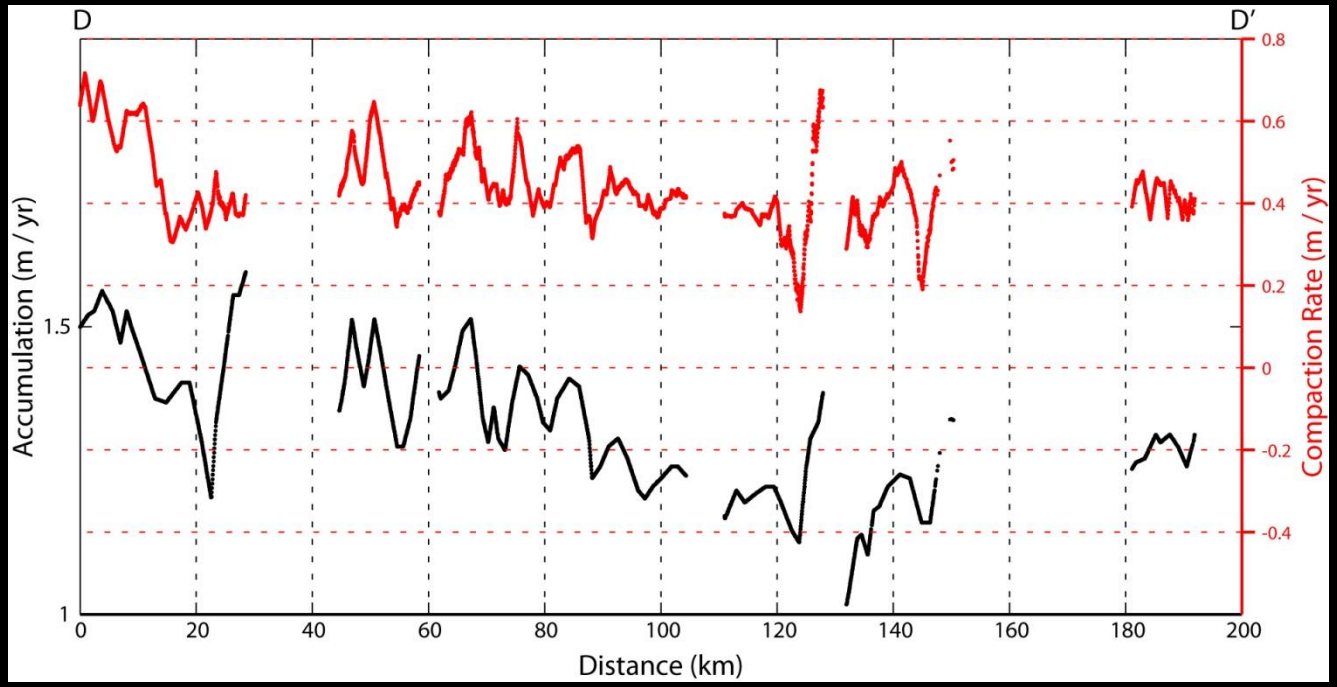
1. Find repeat OIB surveys



Medley et al., *in review*

Measuring firn compaction rates from OIB snow radar

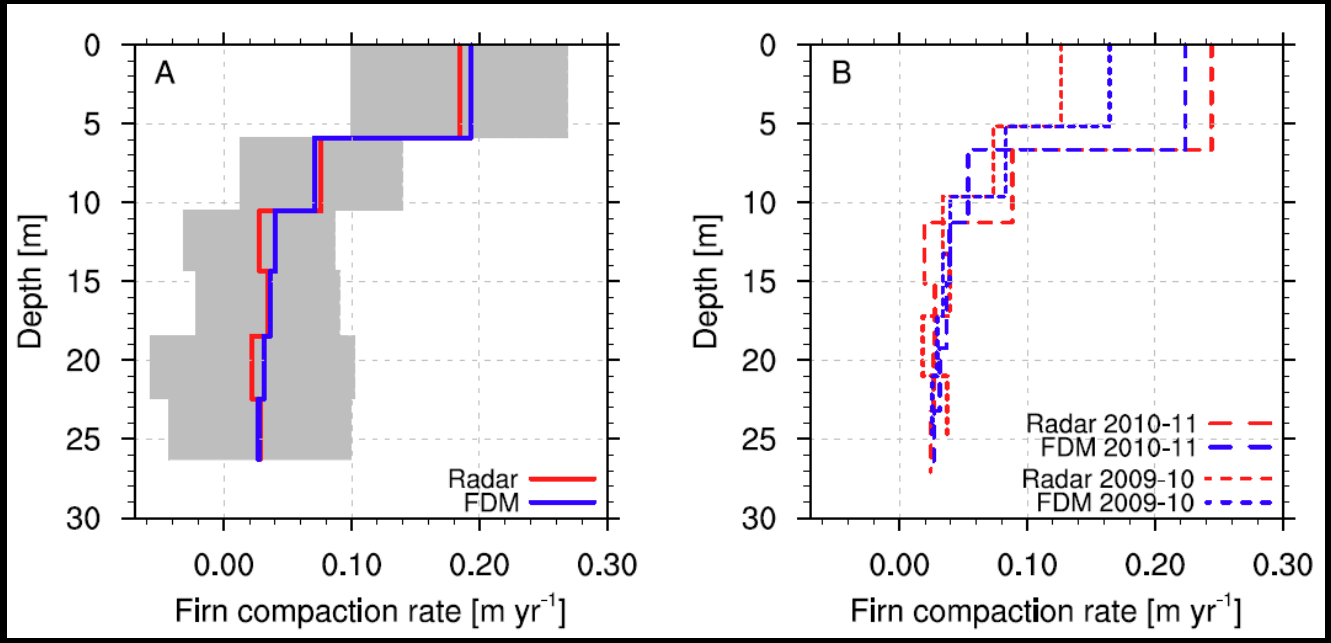
1. Find repeat OIB surveys
2. Calculate compaction rates



Medley et al., *in review*

Measuring firn compaction rates from OIB snow radar

1. Find repeat OIB surveys
2. Calculate compaction rates
3. Evaluate modeled compaction rates



Ligtenberg et al., *in review*

- Unique evaluation: typically assess model ability through comparison with measured density profiles

Summary

- We know the temporal var. in accumulation over the past 3 decades over PIG/THW!
  - Radar, firn cores, climate models ALL agree!
- While above average, the recent decades are not out of the ordinary
  - Combines strength of firn core records & models
- FDM performs well, must have good climate input though.

Thanks!

Field Team:
Lou Albershardt
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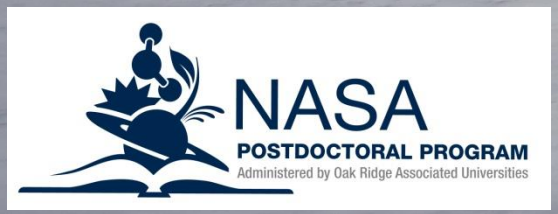
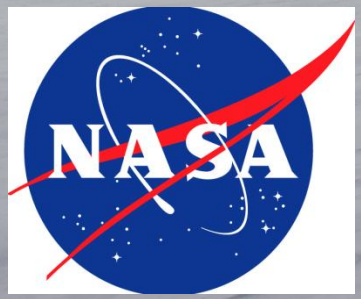
Howard Conway
Sarah Das
Ian Joughin
Luke Trusel

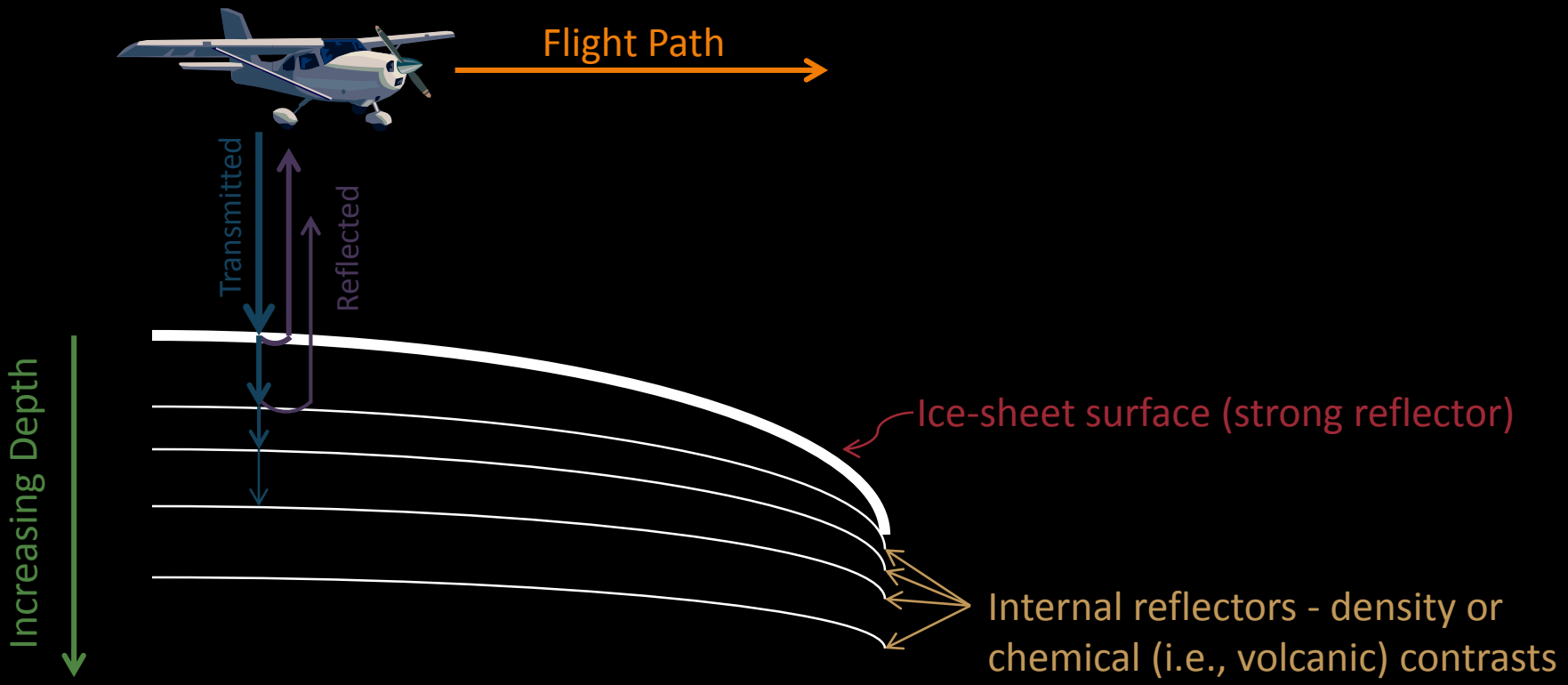
Core Processing:
Twila Moon
NICL Staff

Travel:
WAIS Workshop
NASA NPP





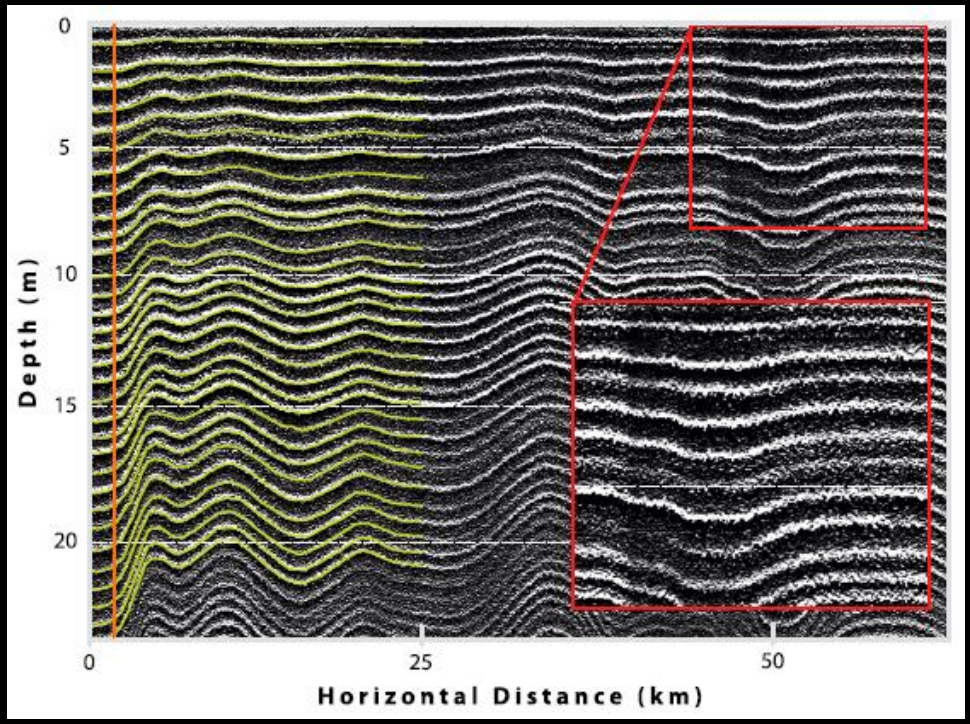
Airborne radar



Allows us to image internal horizons beneath the ice surface, which are used to estimate accumulation, over large distances

Annual accumulation from OIB snow radar

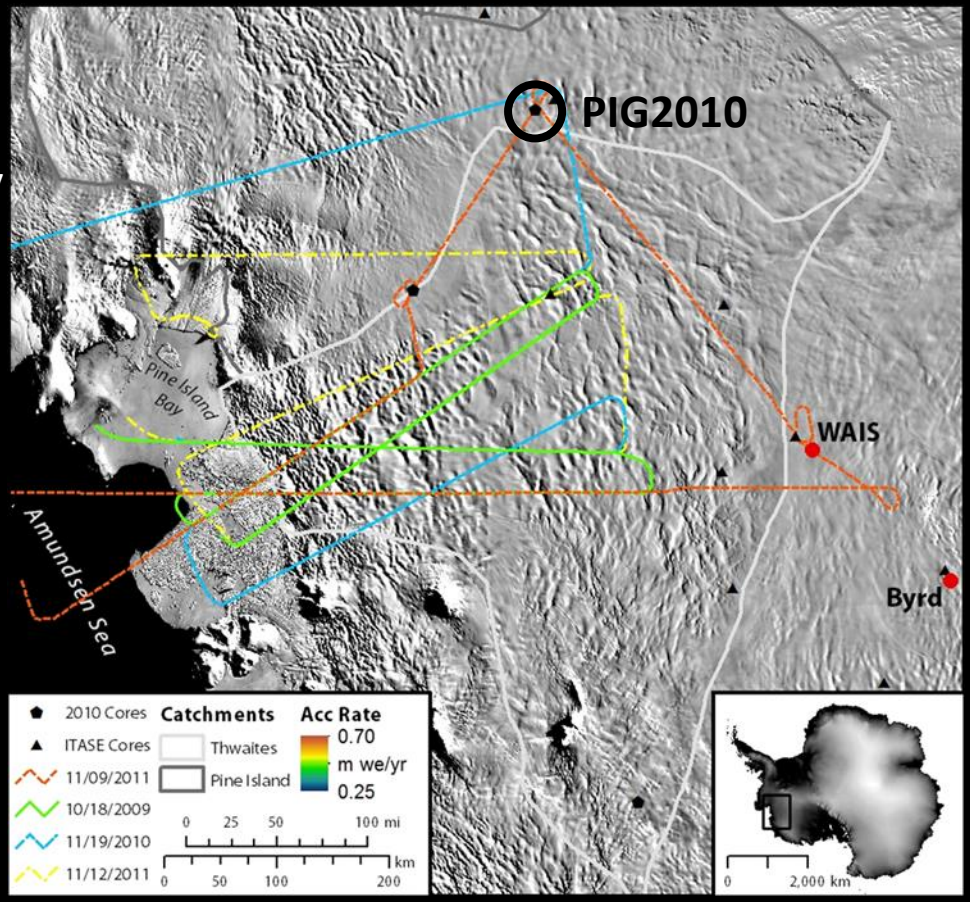
1. Track several internal horizons



Medley et al., *GRL*, 2013

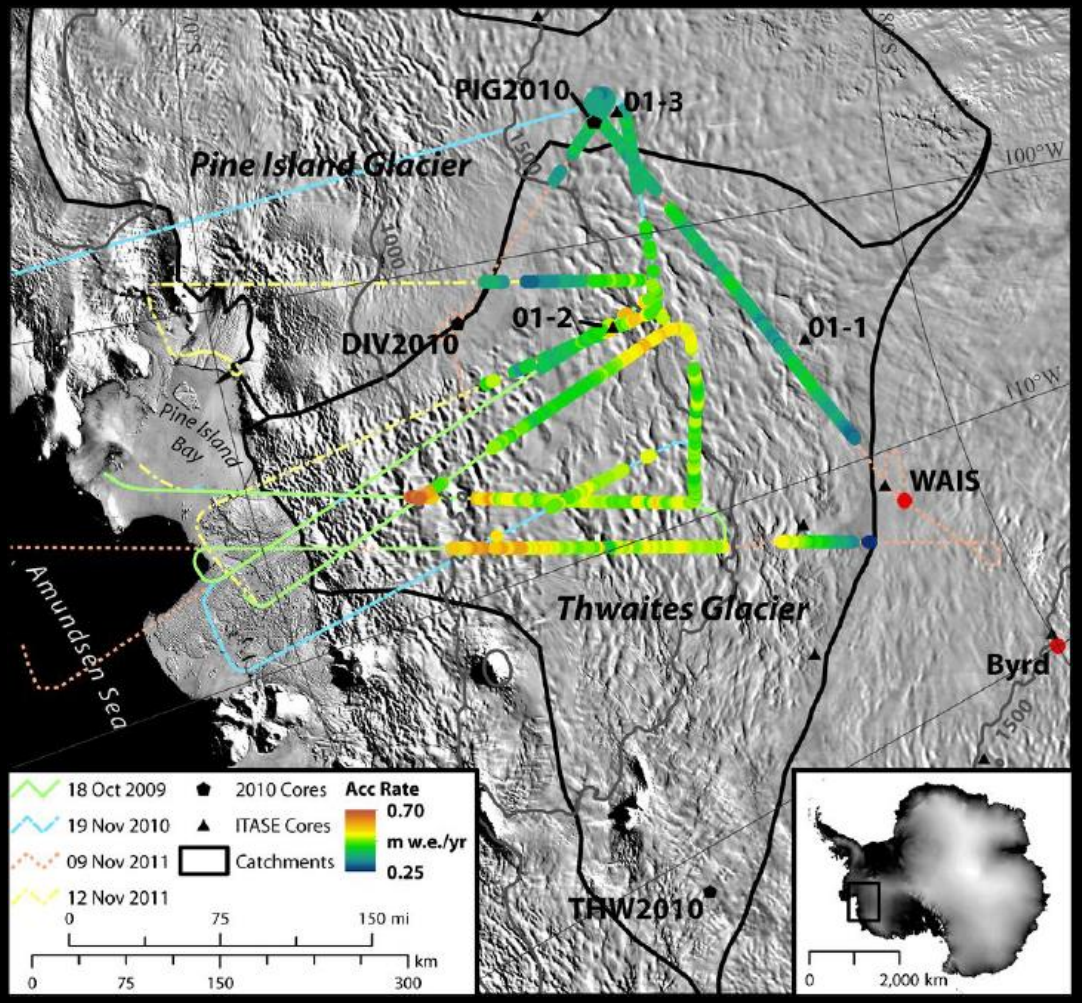
Annual accumulation from OIB snow radar

1. Track several internal horizons
2. Confirm horizons are annually spaced



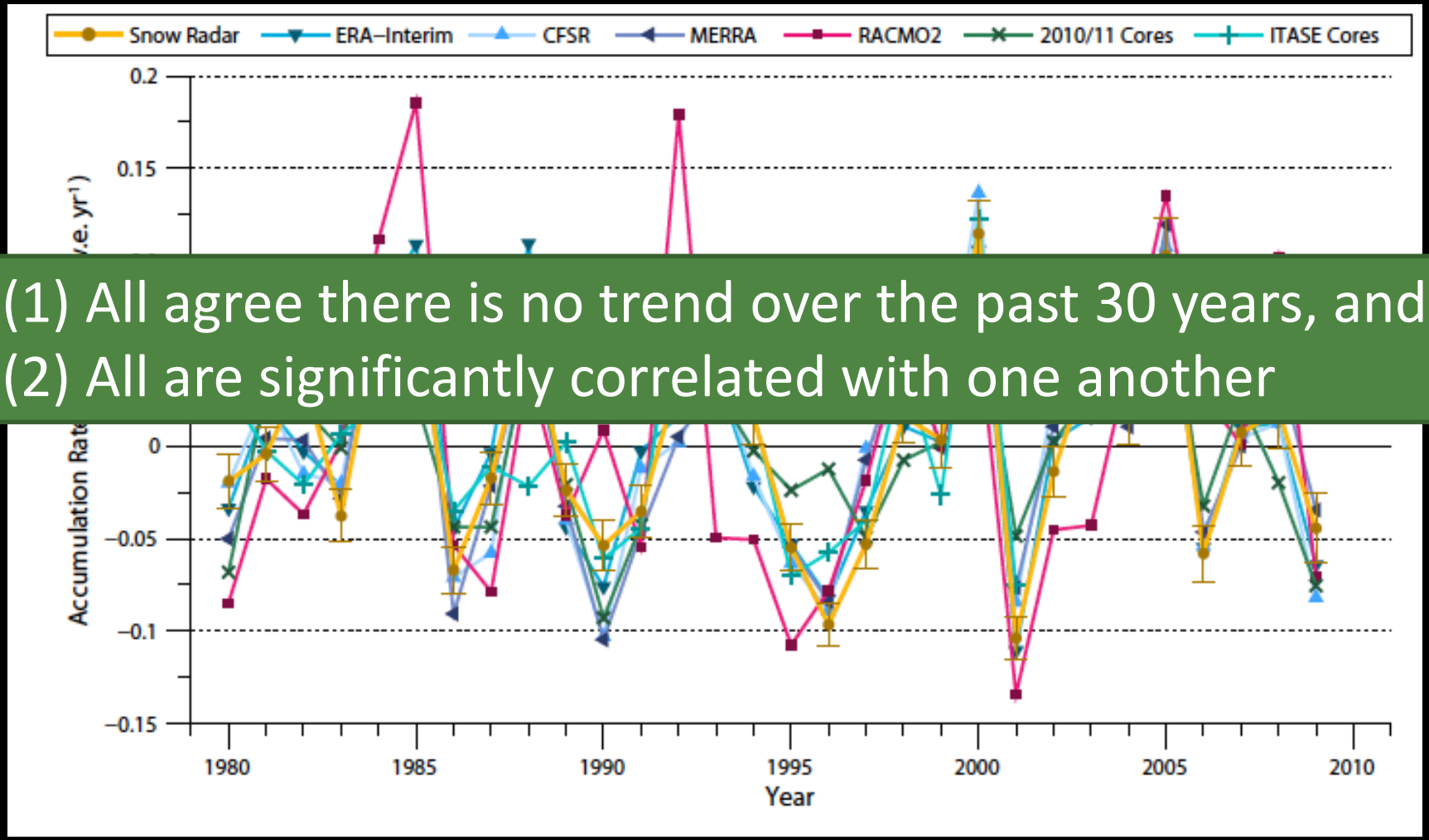
Stable over past ~30 years

- Airborne OIB snow radar: each point represents a 30-yr accum. record (> 6,000)
- Independent of ice core chronology



Medley et al., *GRL*, 2013

Comparison of various accumulation records

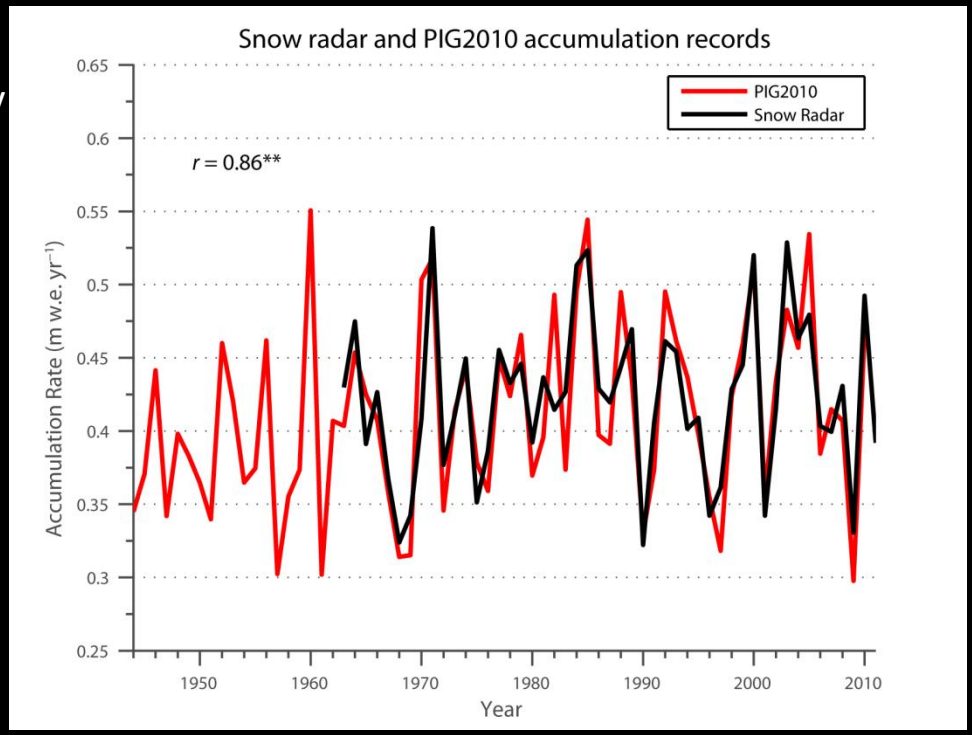


(1) All agree there is no trend over the past 30 years, and
(2) All are significantly correlated with one another

Medley et al., *GRL*, 2013

Annual accumulation from OIB snow radar

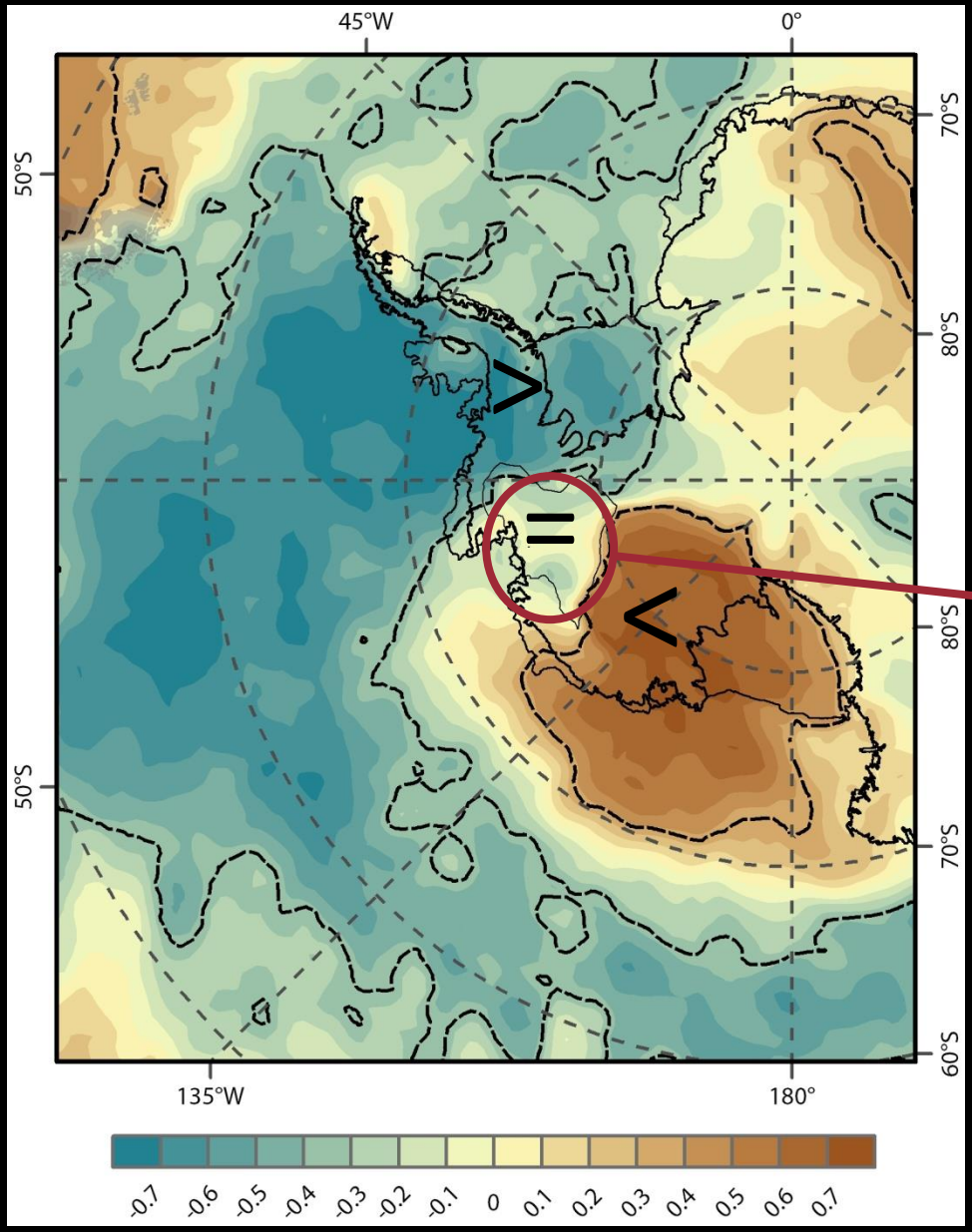
1. Track several internal horizons
2. Confirm horizons are annually spaced



Radar Properties

	Accumulation	Snow
Frequency spectrum	550 – 900 MHz	2 – 6.5 GHz
Range resolution (ice)	40 cm	5-10 cm
Deepest horizon mapped	145 m (425 yrs)	52 m (42 yrs)
Temporal spacing	Multi-year to decadal	Annual*
Survey design	Targeted	Operation IceBridge
Distance flown	9,650 km	16,350 km

Center for Remote Sensing of Ice Sheets (CReSIS; www.cresis.ku.edu)



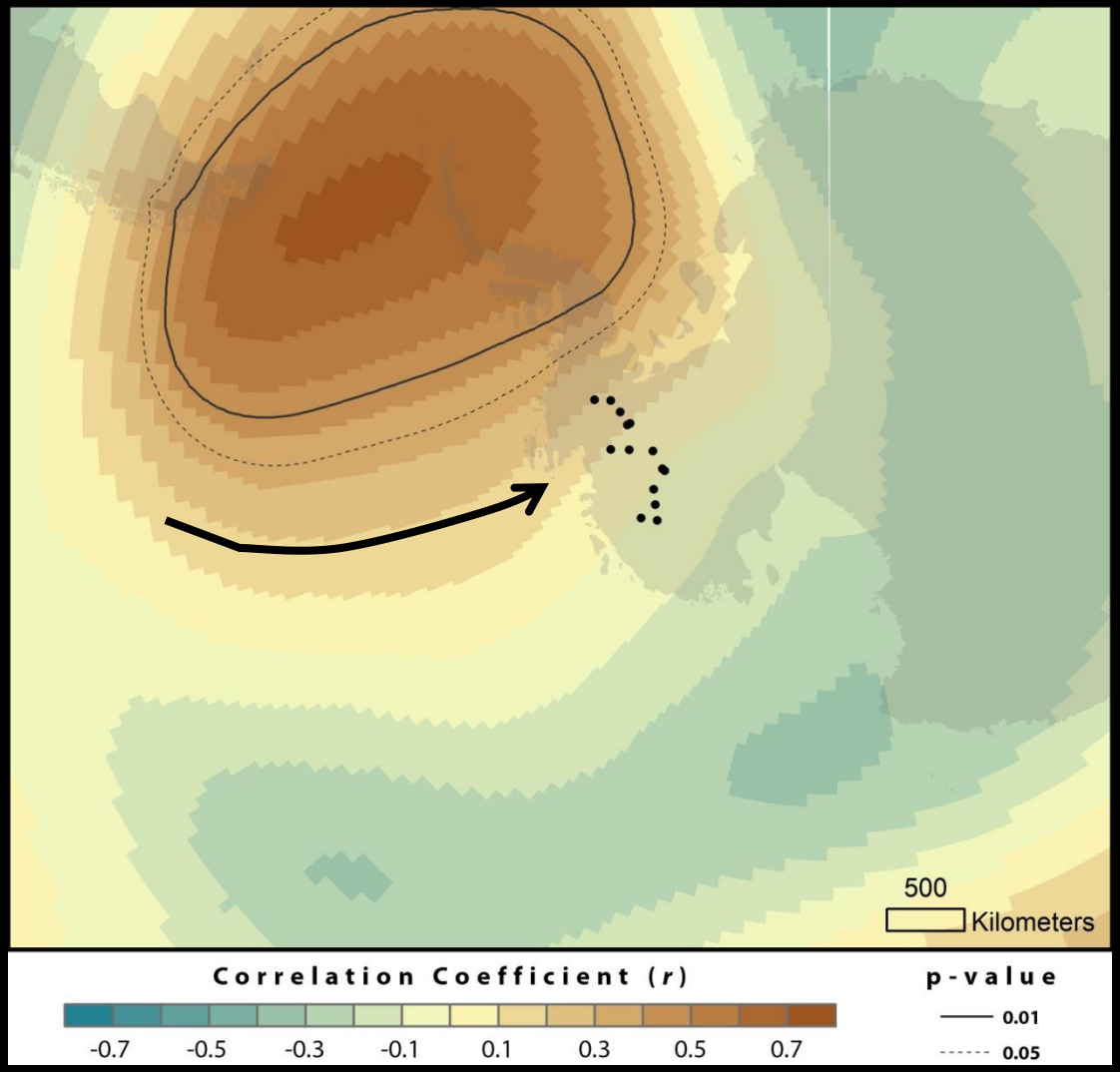
ASL and WAIS Accumulation

When ASL is deeper, accumulation is…

PIG/THW acc. is NOT significantly correlated

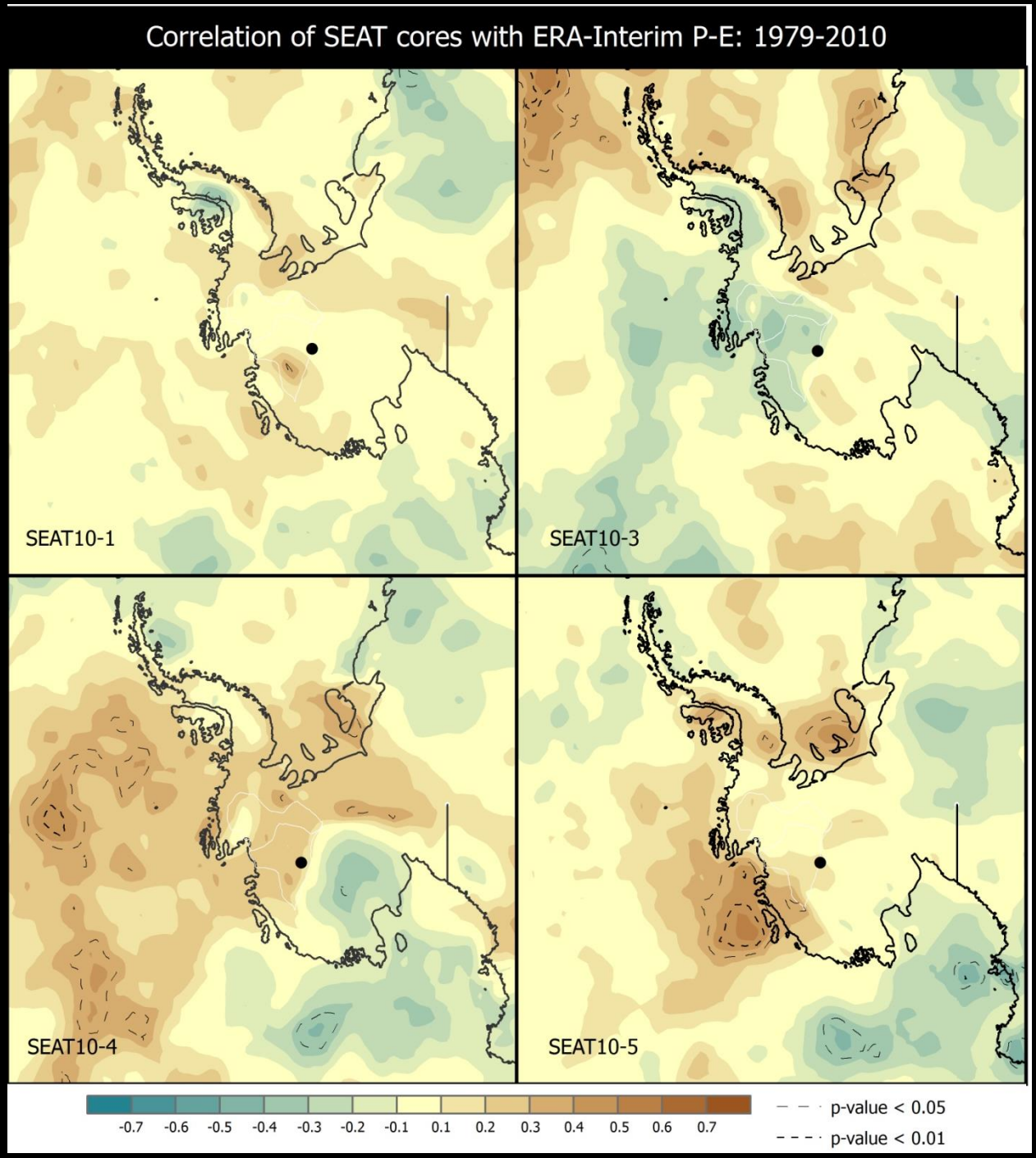
Correlation of the ASL center pressure from **XXXXXXX** and ERA-Interim *P-E*

Correlation of stacked record with ERA-Interim z500 Geopotential Heights

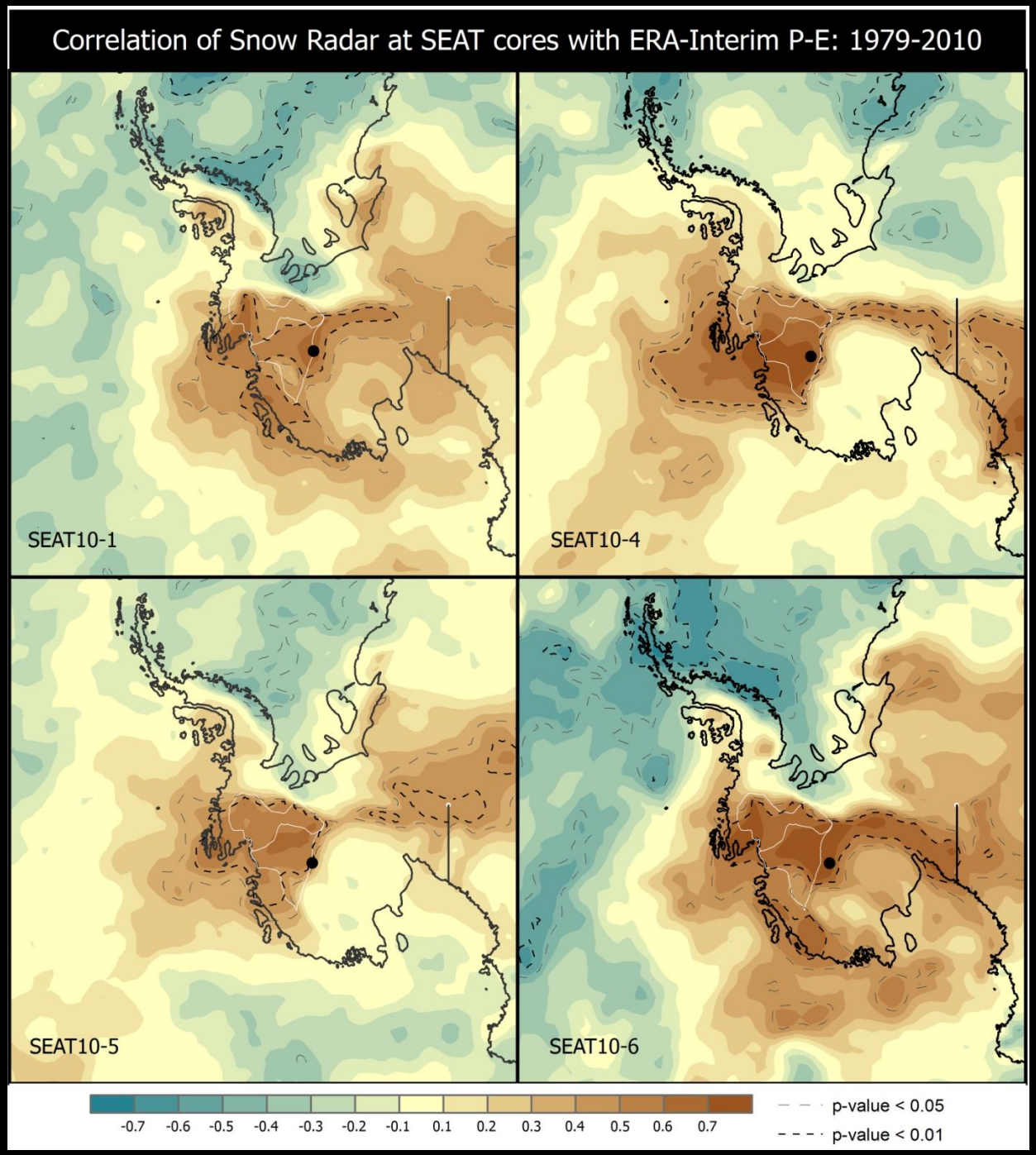


Higher accumulation in PIG/THW when high pressure blocking system exists centered over Drake Passage

It generates anomalous flow up and into these basins


Correlation of SEAT cores with ERA-Interim P-E: 1979-2010
SEAT10-1
SEAT10-3
SEAT10-4
SEAT10-5
-0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0.1 0.2 0.3 0.4 0.5 0.6 0.7
p-value < 0.05
p-value < 0.01

SEAT


Correlation of Snow Radar at SEAT cores with ERA-Interim P-E: 1979-2010
SEAT10-1
SEAT10-4
SEAT10-5
SEAT10-6
-0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0.1 0.2 0.3 0.4 0.5 0.6 0.7
p-value < 0.05
p-value < 0.01

Radar @ SEAT