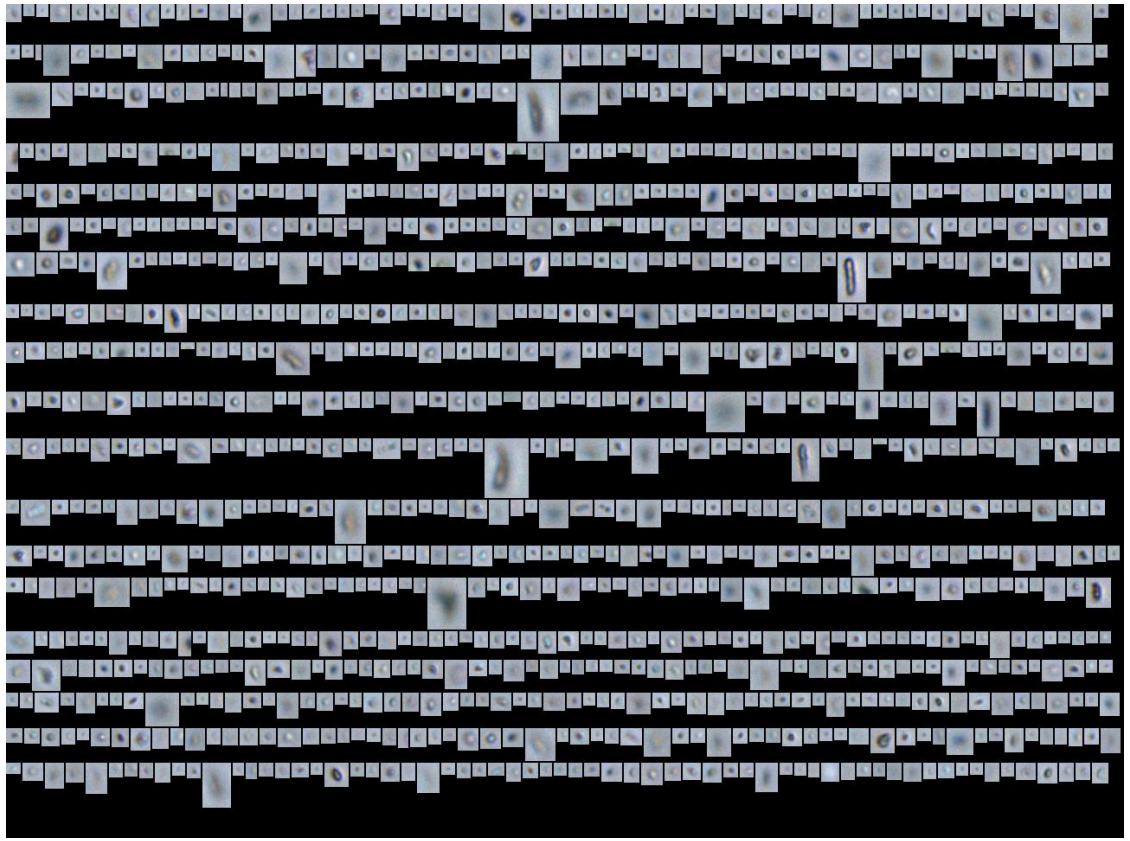
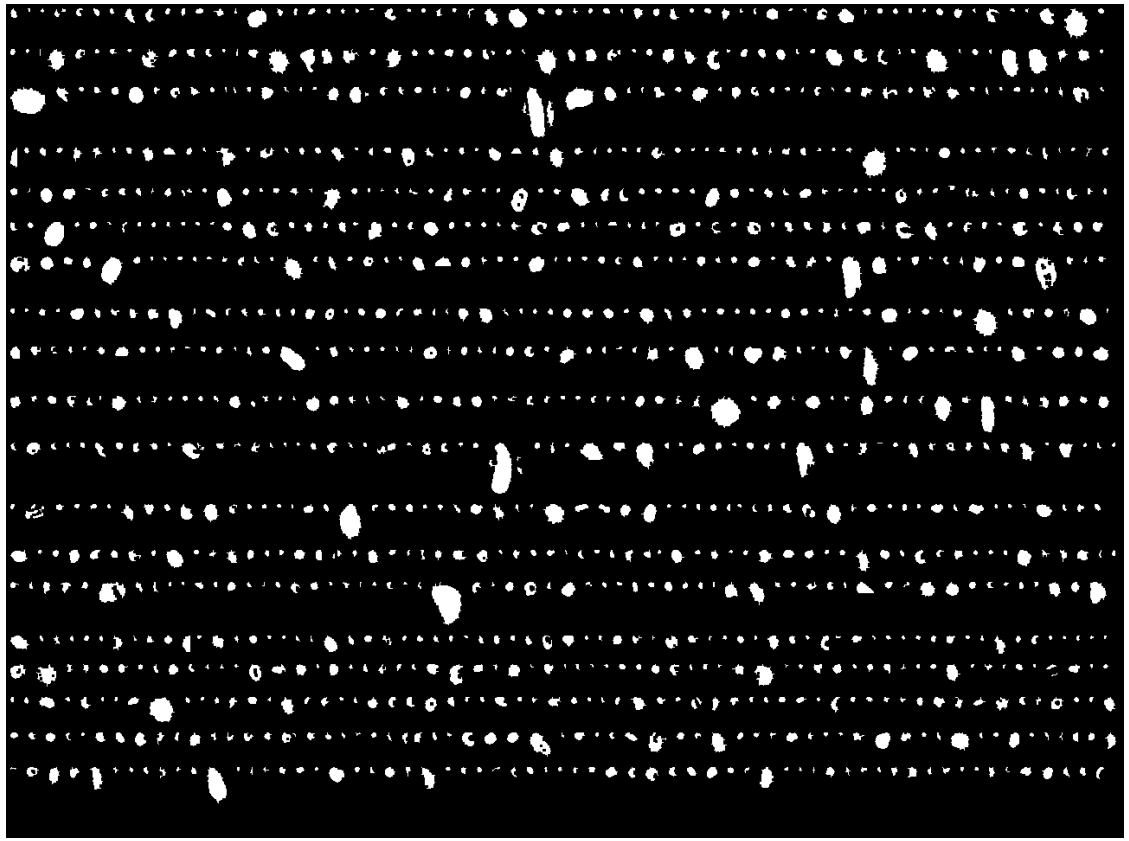
Assessing the utility of dynamic particle imaging in South Pole Ice Core dust analysis





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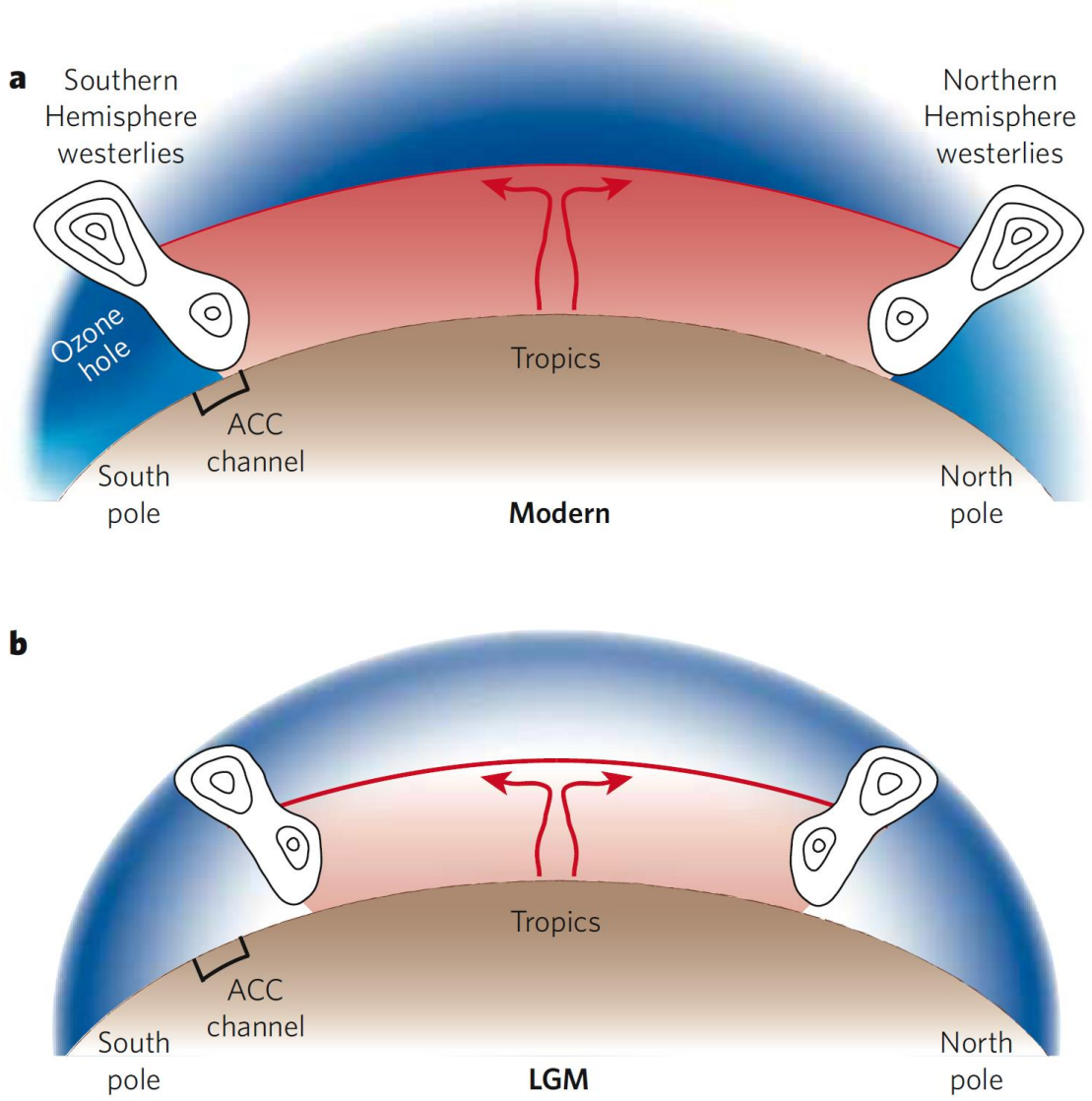
Changes in Southern Hemisphere Westerly Winds affect Southern Ocean CO_2 outgassing

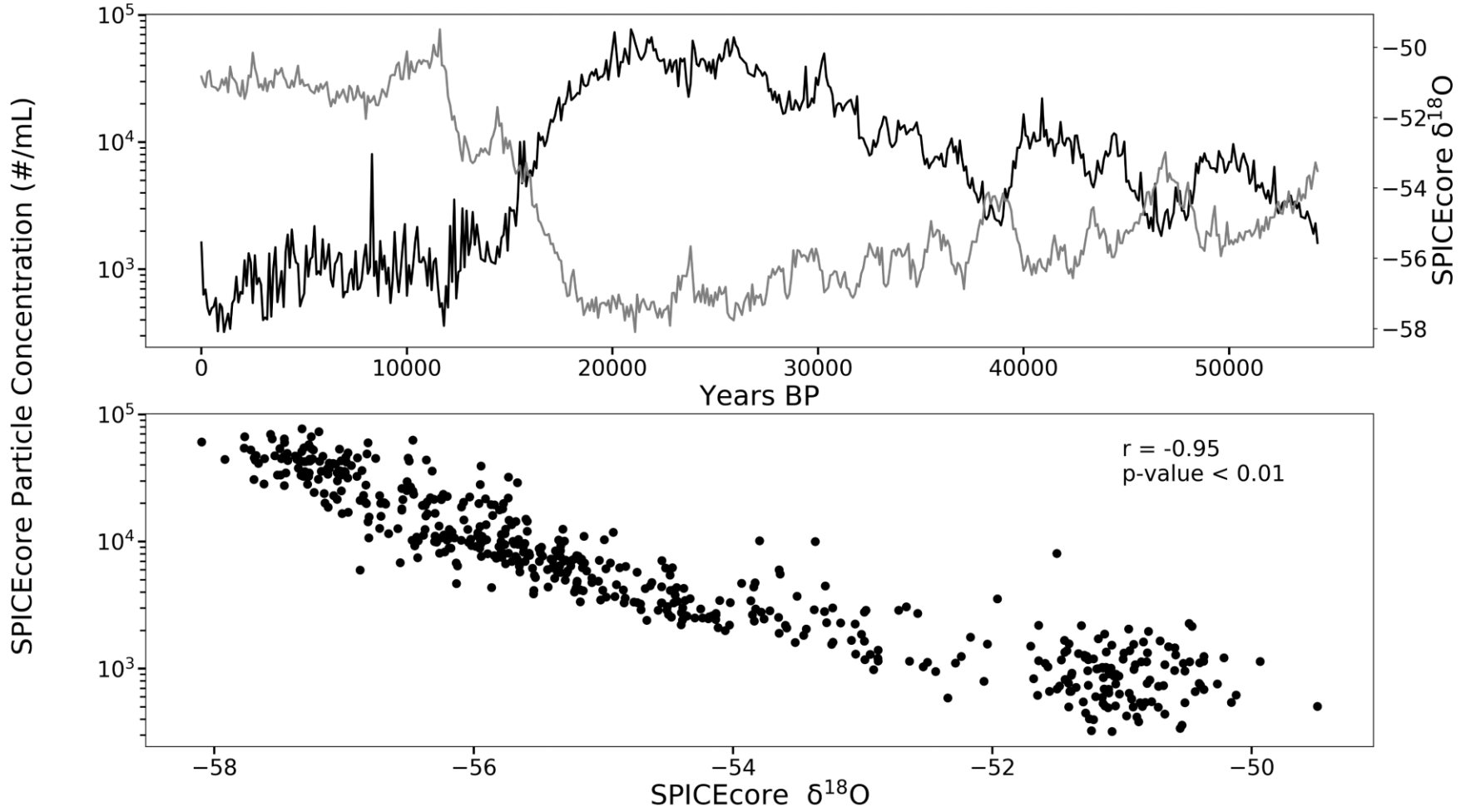
- Southern Hemisphere Westerly Winds are the strongest wind system on the planet
- Hypothesized changes in latitudinal position affect strength and/or intensity variability
  - Weakened northerly position
  - Strengthened southerly position
- Increasing strength and/or intensity affects Southern Ocean storage/release of CO_2



(Toggweiler and Russell, 2008)

Atmospheric dust properties are used as proxy for atmospheric reconstructions

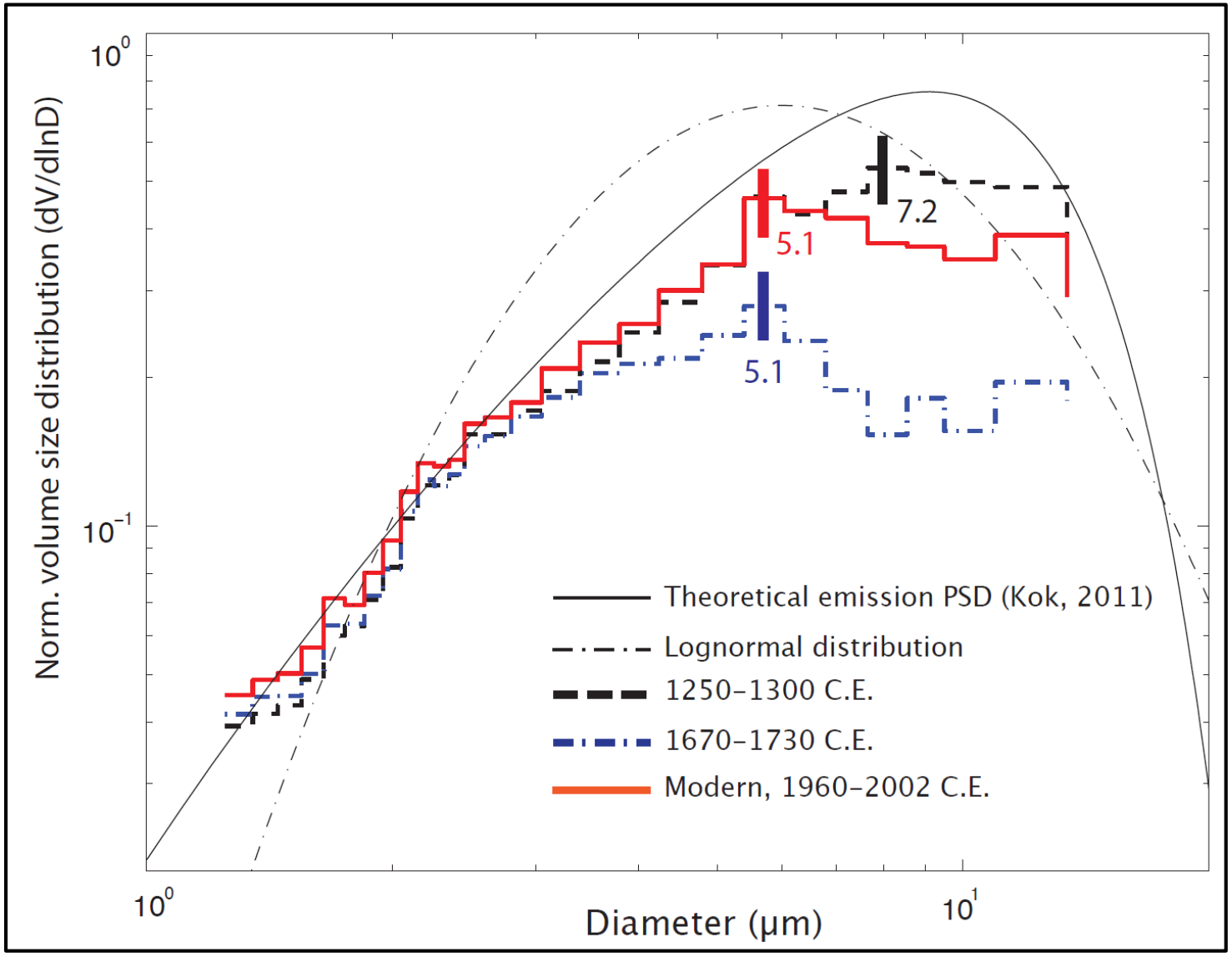
- Dust and temperature are anticorrelated
- Increase in dust related to increases in:
  - Aridity
  - Glacial activity
  - Decreases in sea level



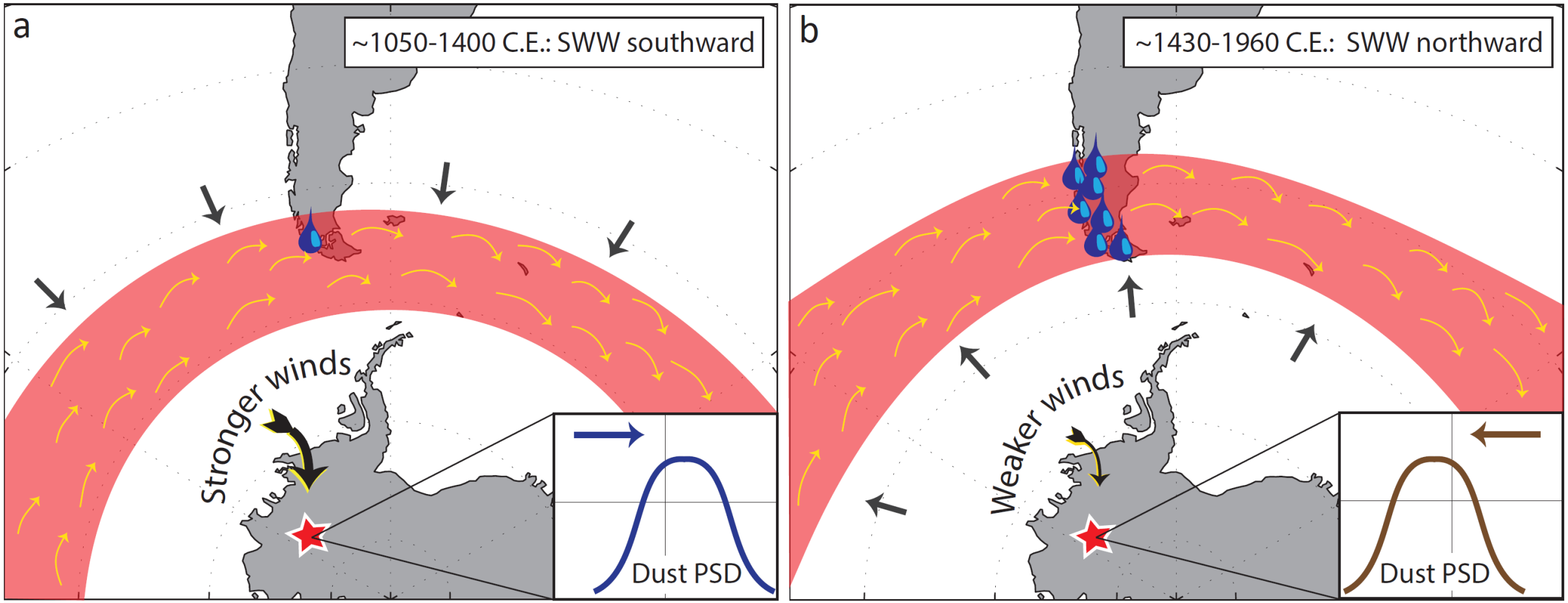
(Steig et al, 2020)

Particle volume metrics provide climatic information

- Changes in mode particle volume/diameter occur at different climatic periods
- Koffman et al. (2014) used relationship to assess Southern Hemisphere Westerly Wind variability



Particle volume metrics have been used to reconstruct Westerly Wind variability



Koffman et al. (2014)

Previous dust volume analyses have been made under the assumption of spherical particles

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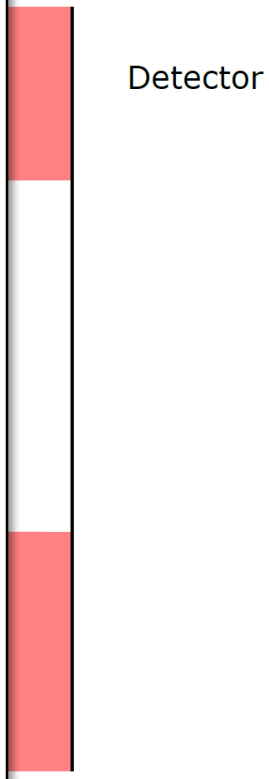
Questions:

1) How is particle shape a factor, is there a pattern to the variability or is it noise?

2) How does this affect the Koffman hypothesis?



(Simonsen et al., 2018; *Supplementary Material*)

Abakus laser particle counter measures backscatter imaging

- Continuously measured particles
- Particle shape is assumed to be sphere
- Particles are sorted by diameter measurements

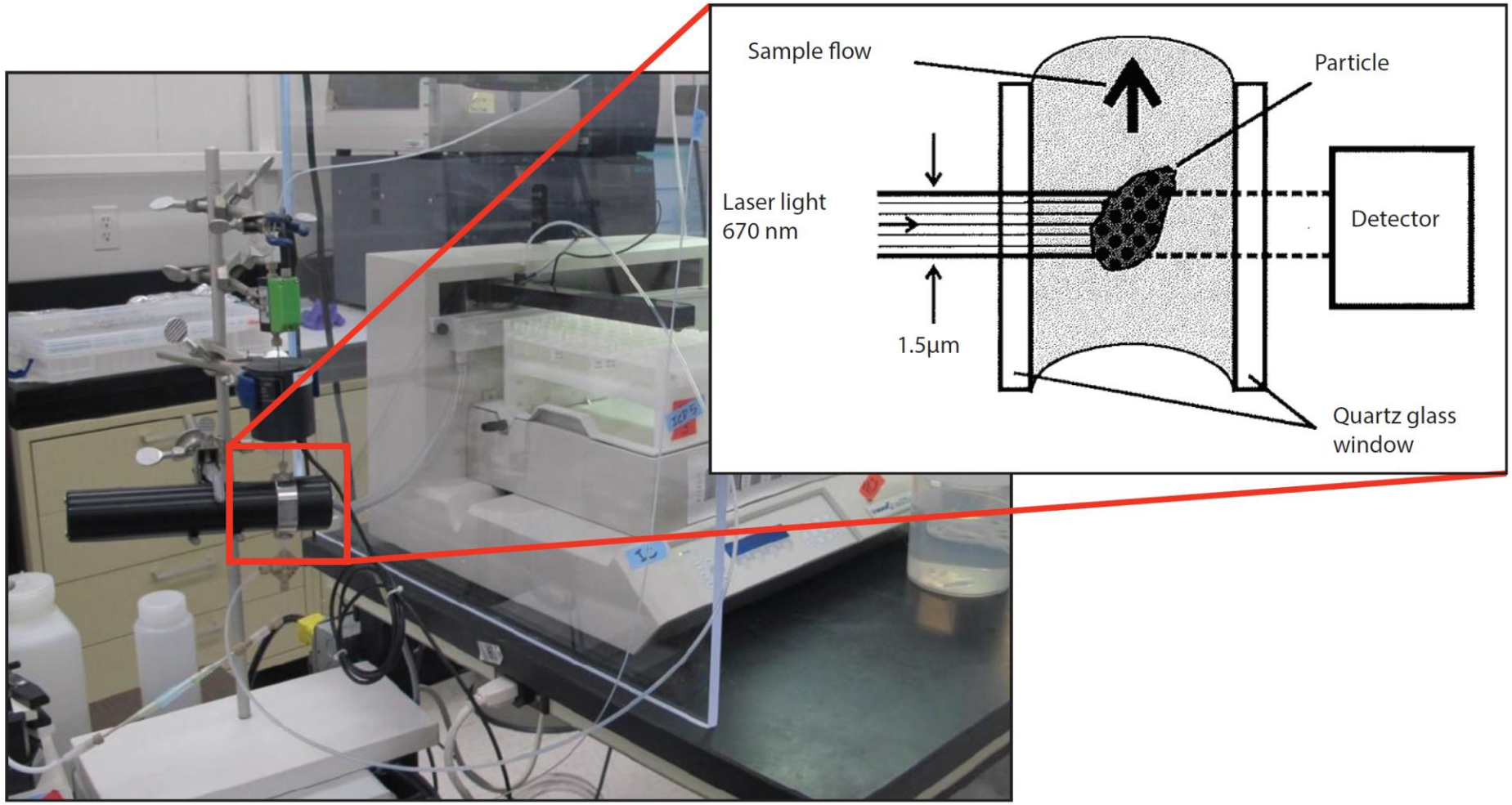
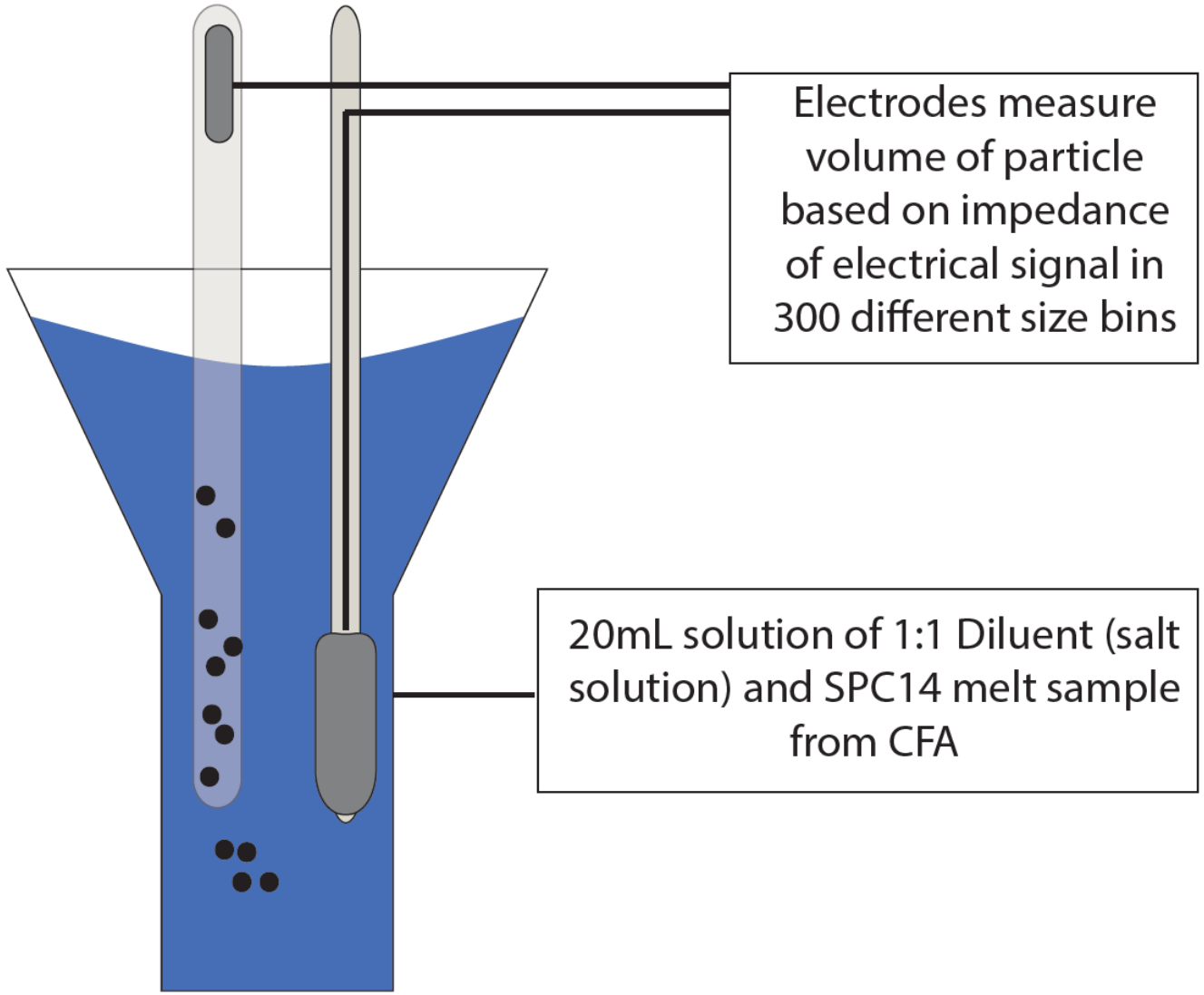


Image adapted from Ruth et al. (2002)

Coulter Counter measures particles based on electrical resistivity

- Electrical resistance is proportional to particle volume
- Discrete measurements rather than continuous

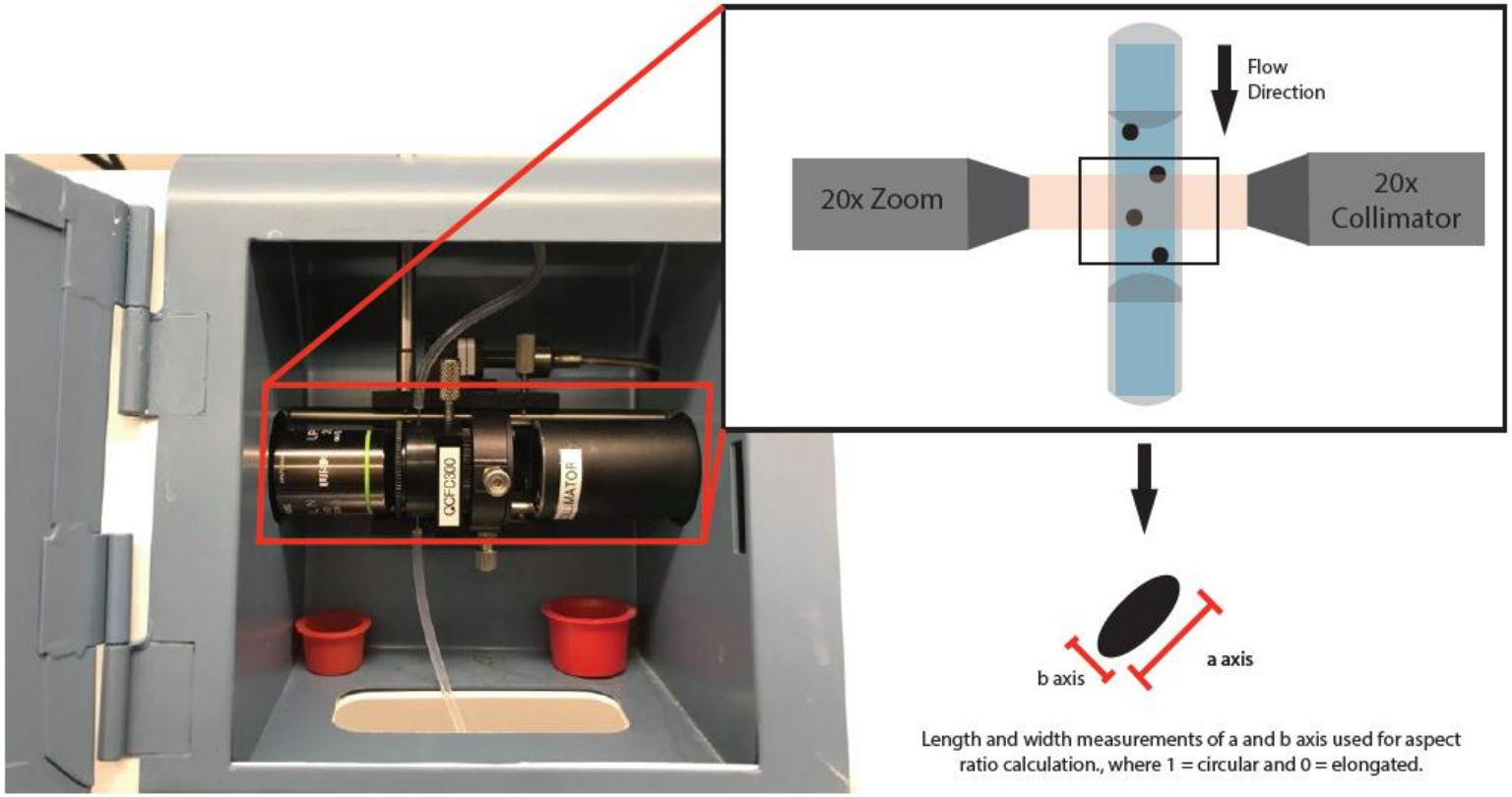


Use of Dynamic Particle Imaging (DPI) as a tool for shape analysis

- FlowCAM uses dynamic particle imaging technique to measure particle properties

- Used by biological and pharmaceuticals analyses
  - Biological community to assess phytoplankton populations (Sieracki et al., 1998)
  - Pharmaceuticals community to measure microparticles (Matheas et al., 2020)

- Aspect Ratio is measured via b:a axis
  - 1 = circular/square
  - 0 = elongated particle



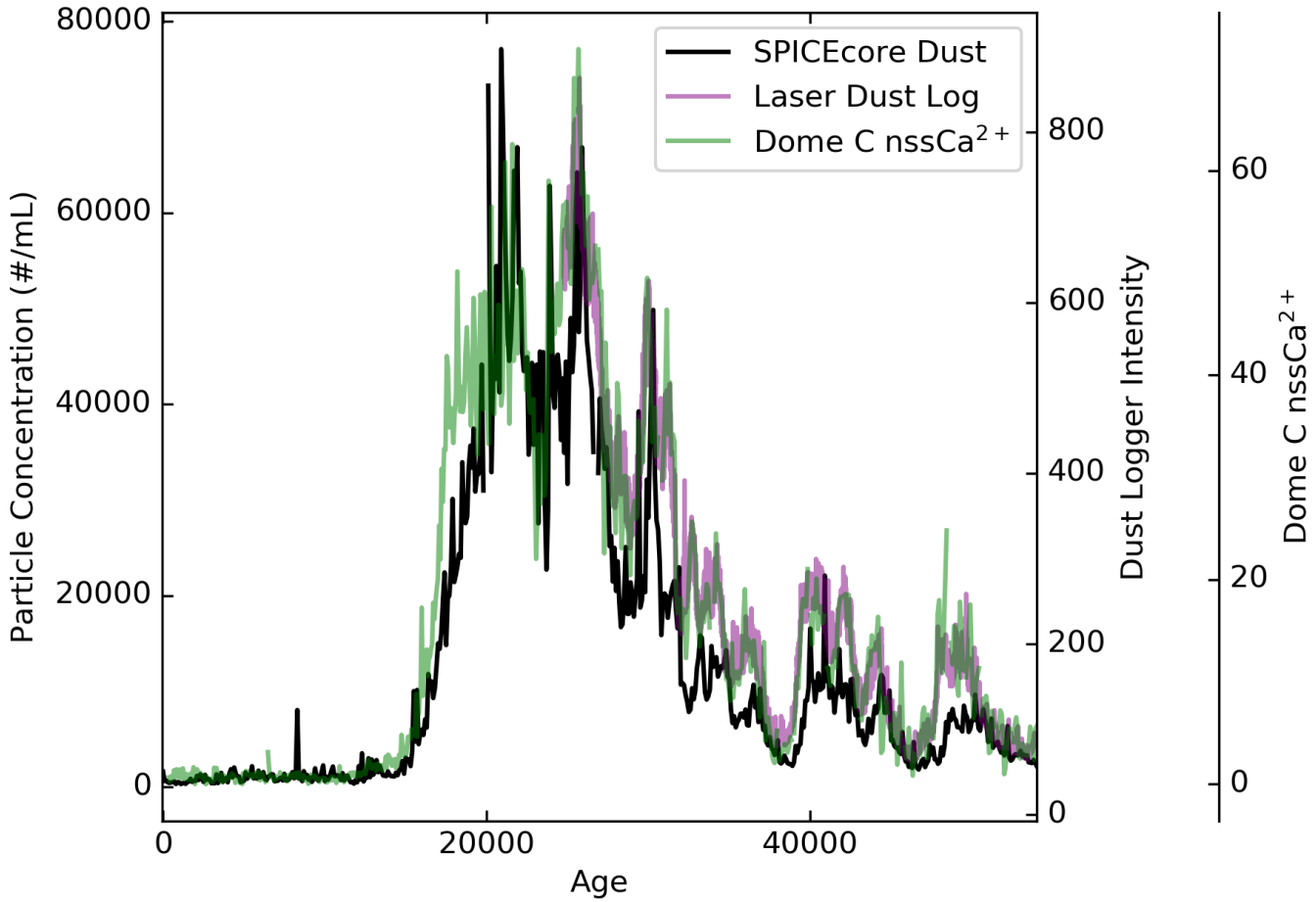
Length and width measurements of a and b axis used for aspect ratio calculation., where 1 = circular and 0 = elongated.

SPICEcore Abakus dust concentrations are similar to previous records

- SPICEcore dust concentration similar to other South Pole and Antarctic dust and dust proxy profiles

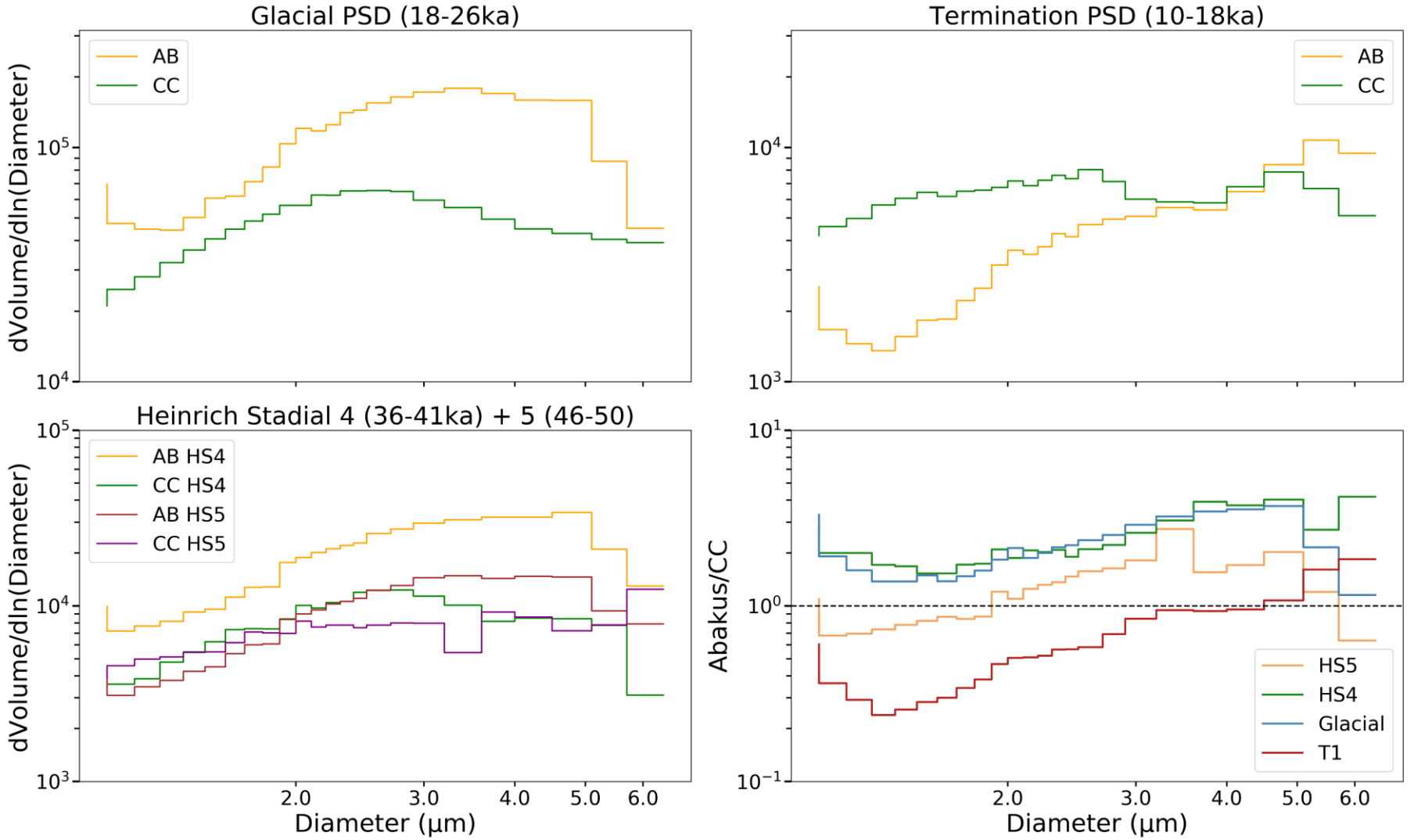
- IceCube Dust logger
  - r = 0.82
  - p-value < 0.001

- Dome C nssCa^{2+}
  - r = 0.89
  - p-value < 0.001



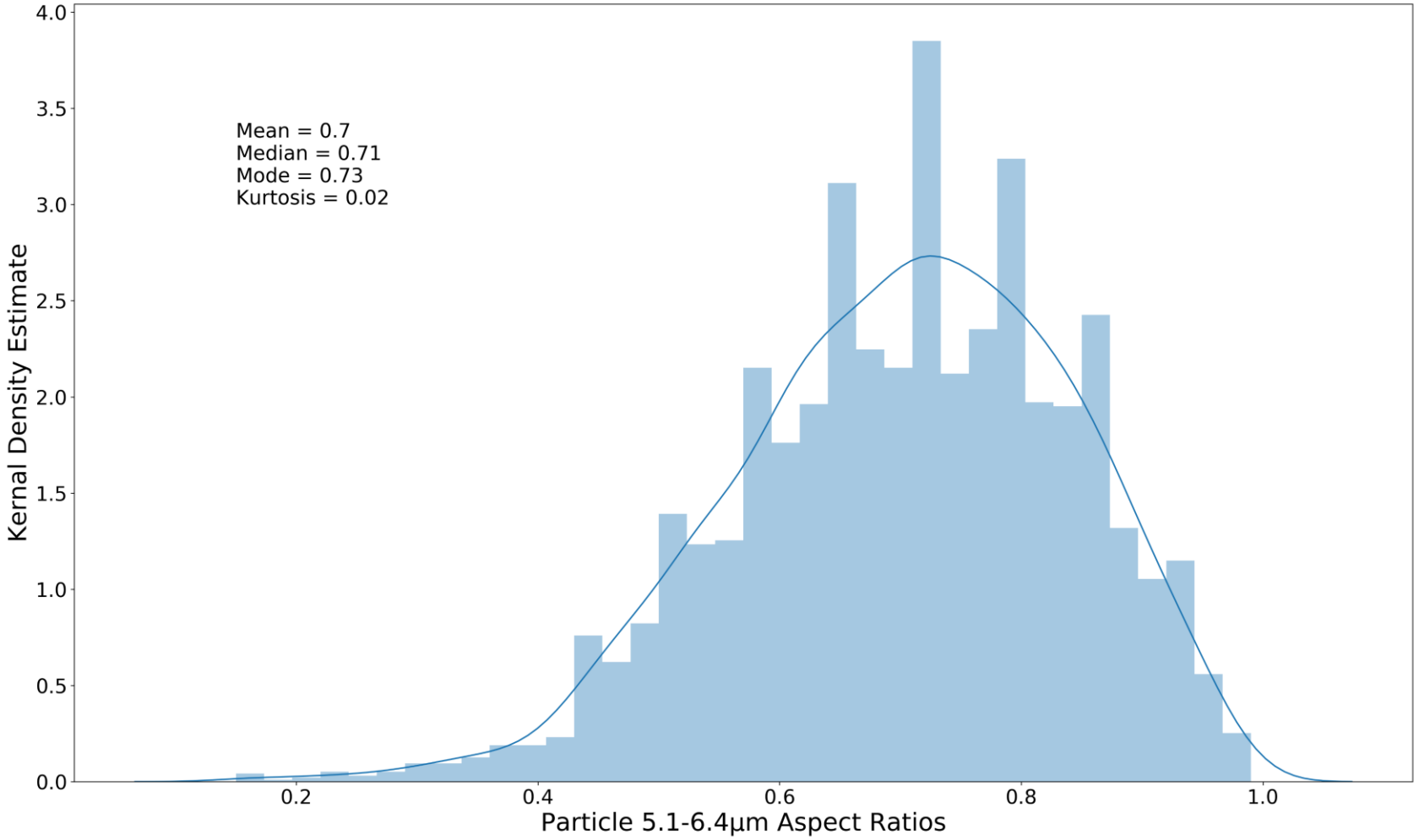
(Fischer et al., 2007; IceCube Collaborators, 2013)

Temporal differences in Abakus and Coulter Counter relationships

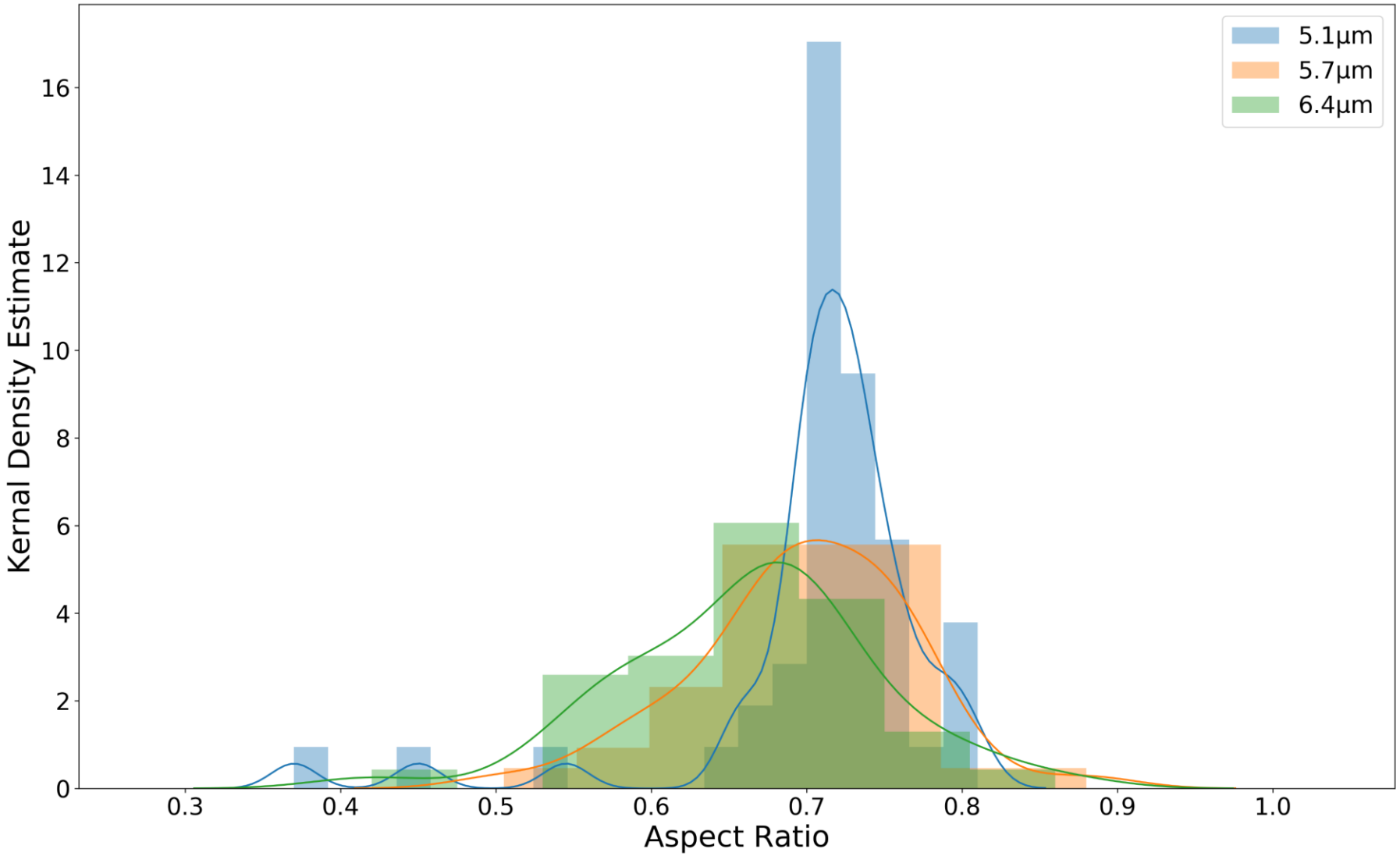


South Pole particle shape are normally distributed and semi-circular

- All particles measured via FlowCAM
- Particle shapes are semi-circular
- Particles are separated into:
  - Abakus size bins
  - Sample Time

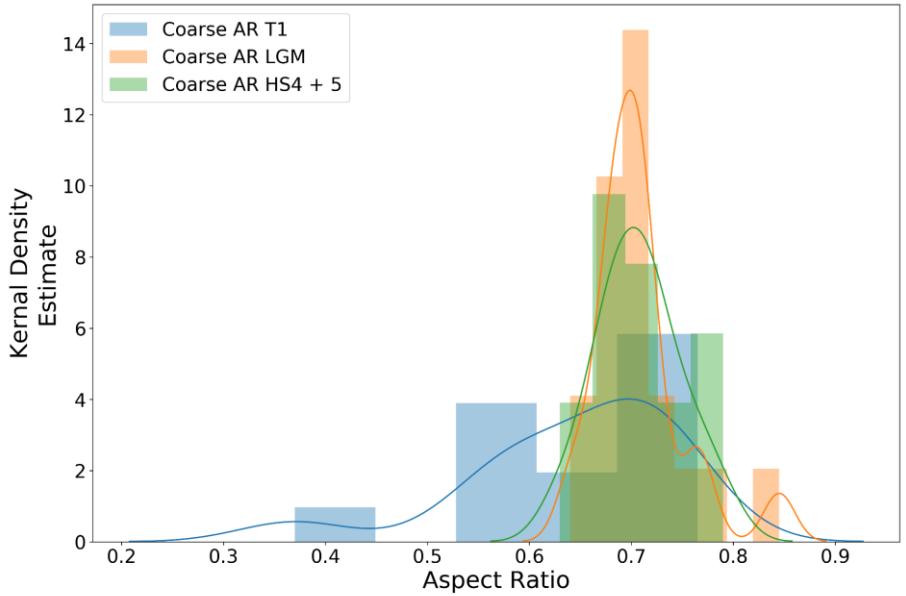


Mode coarse particle size distributions



Coarse particle shape varies temporally

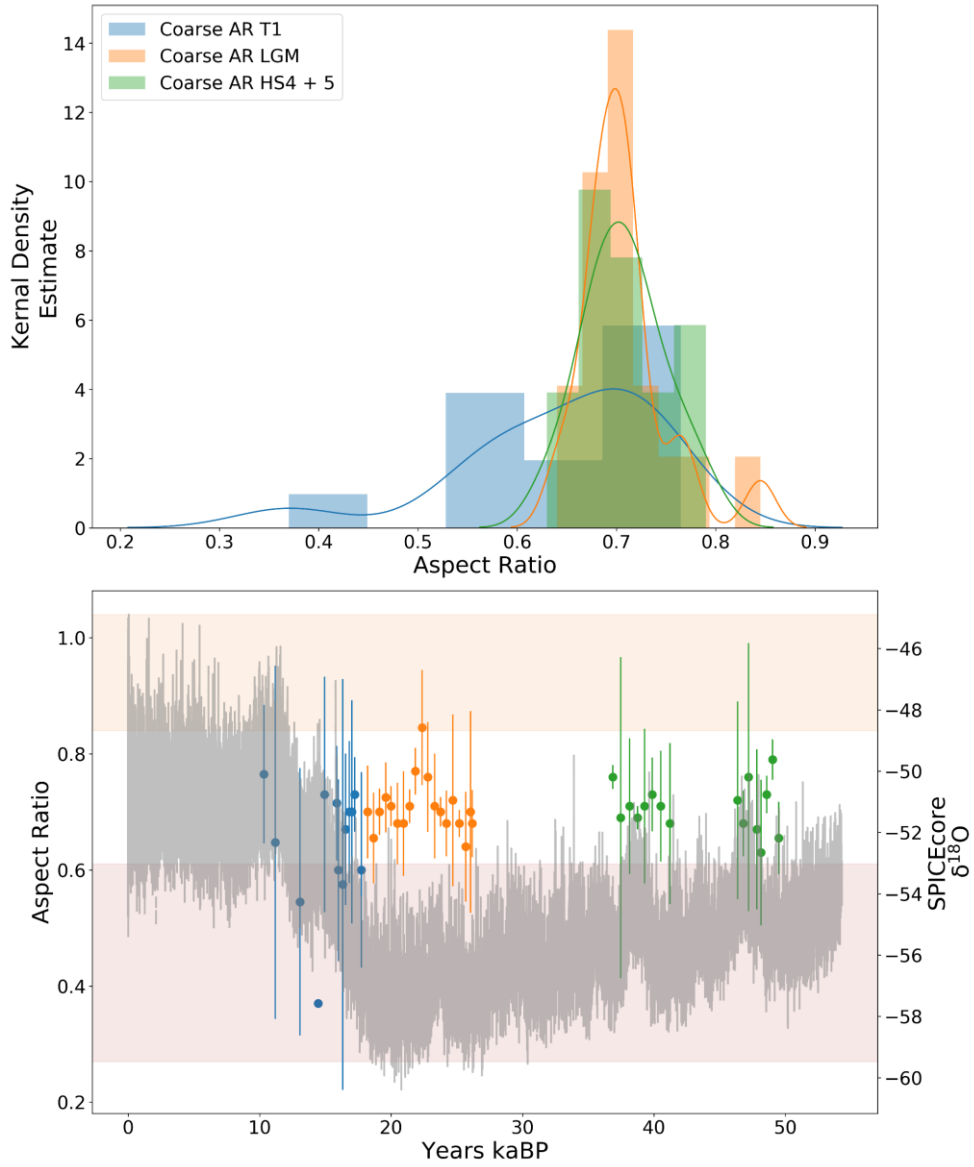
- Temporal distributions are statistically different
  - Student t-test
  - Termination I compared to LGM and Heinrich Stadial 4+5 are statistically different
  - LGM and Heinrich Stadial 4+5 are similar



	Termination I	**Last Glacial Maximum**	**Heinrich Stadial 4 + 5**
Termination I	--	p-value <0.05	p-value <0.05
Last Glacial Maximum		--	p-value >0.97
Heinrich Stadial 4 + 5			--

Coarse particle shape varies temporally

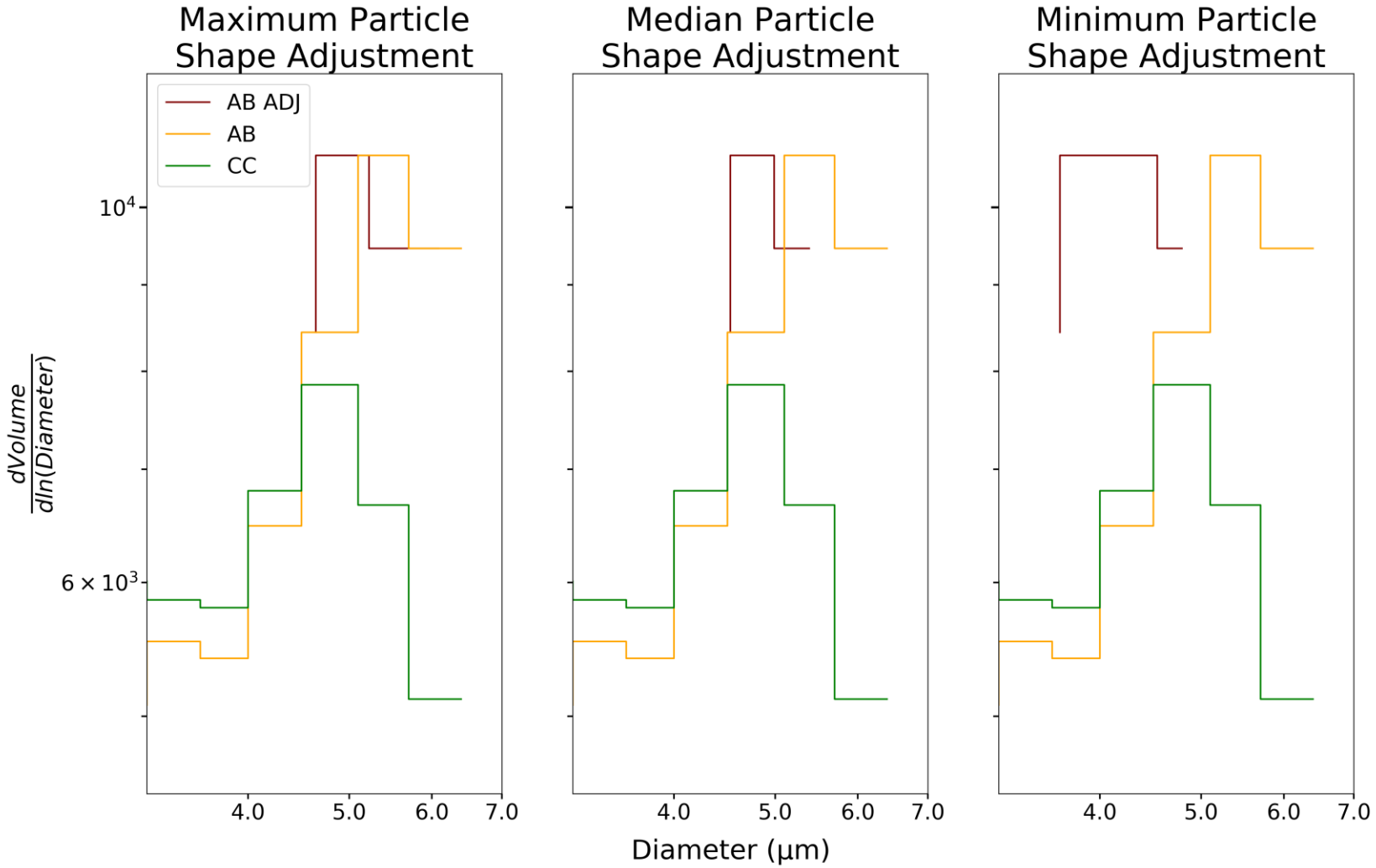
- Increase in median and standard deviation variability during Termination I
- Particle shape prior and during LGM are semi-spherical
- Particle shapes during Termination I range from spherical to elongated



(Steig et al., 2020)

Max, Median, and Minimum shape adjustments for coarse particles

- Median shape calibration adjusts Abakus distribution mode to match Coulter Counter mode
- Median particle shape adjustment coarse mode is most similar to Coulter Counter distribution

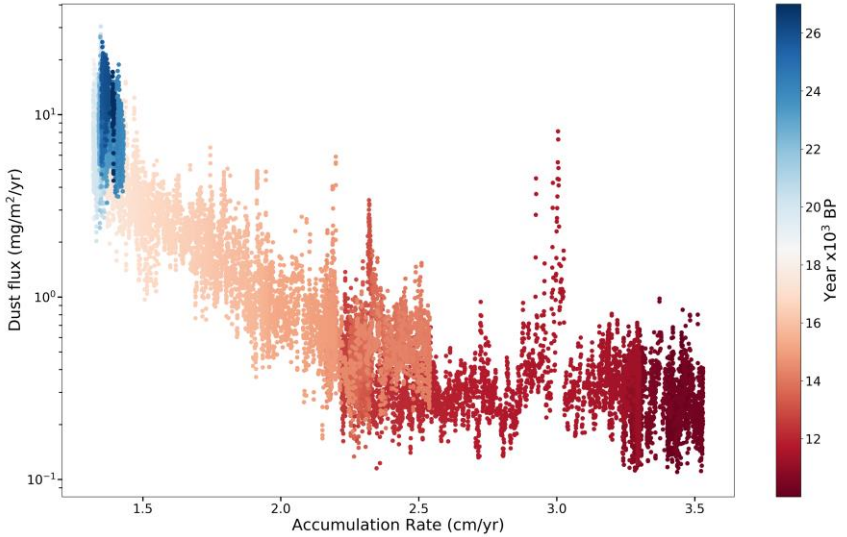


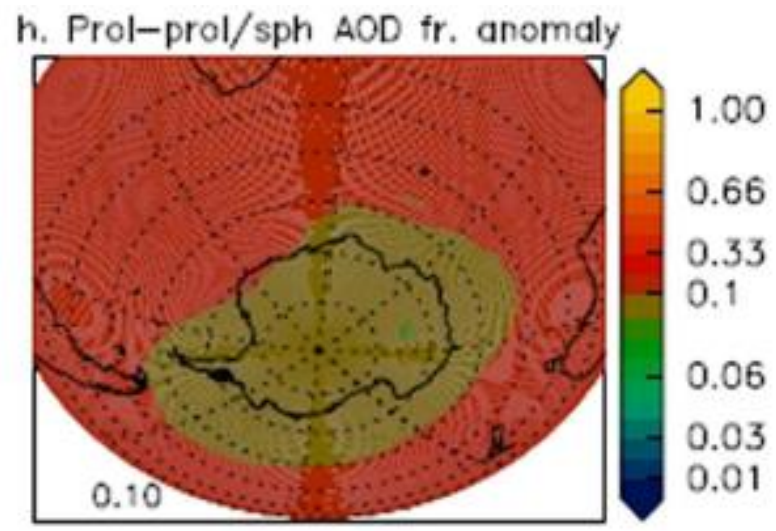
Assessing implications of increased particle shape heterogeneity?

- Calibration implications
  - Longest record of particle shape
  - Particle shape is temporally variable on millennial scales

- Climatic implications
  - Elongated particle orientated along long axis have lower settling velocities (Saxby et al., 2018)
  - What climatic parameter(s) are responsible?
    - Changing depositional style (dry/mixed/wet)?

- Shape effects light scattering
  - +/-Δ dust of aerosol optical depth gradients (Potenza et al., 2016)
  - +Δ extinction efficiency in elongated particles relative to spheres (Kalashnikova and Sokolik, 2004)





(Potenza et al., 2016; Lambert et al., 2012; Schwander et al., 2001)

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