

# Influences of the seasonal Indian monsoons, 1900-1993 CE: Sub-annual sea surface temperature and precipitation reconstructed from laminated Pakistan Margin sediments

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European Research Council  
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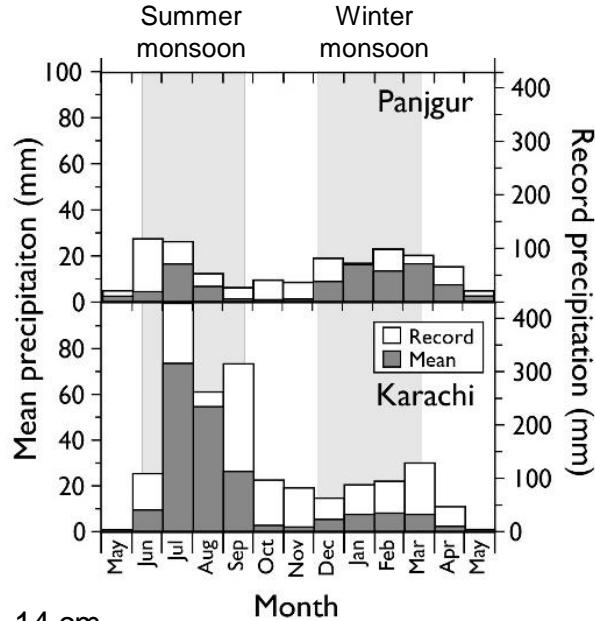
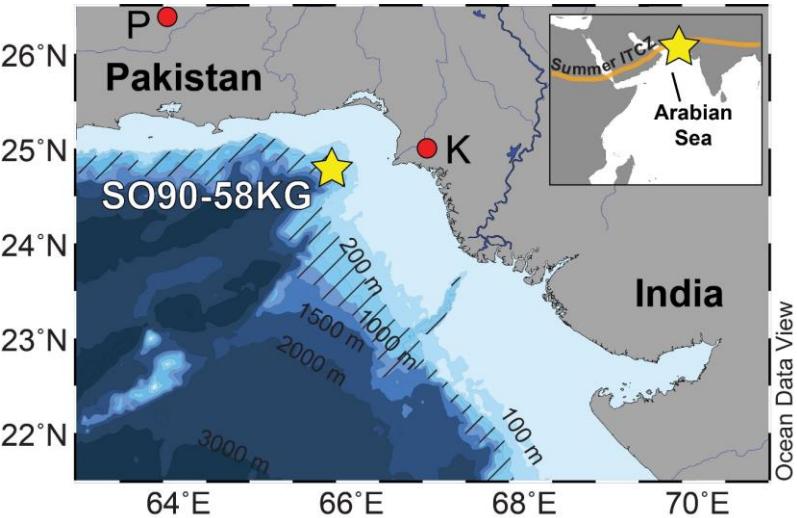
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# Southern Pakistan

- Climate
  - Hot summer
    - Monsoon rains
  - Warm winters
    - Westerly storms
- Sediment Inputs
  - Marine biogenics (high flux ~ $2x/yr$ )
  - Terrigenous detritus
    - Precipitation
- Marine core SO90-58KG
  - 876 m water depth (in oxygen minimum zone)
  - Laminated

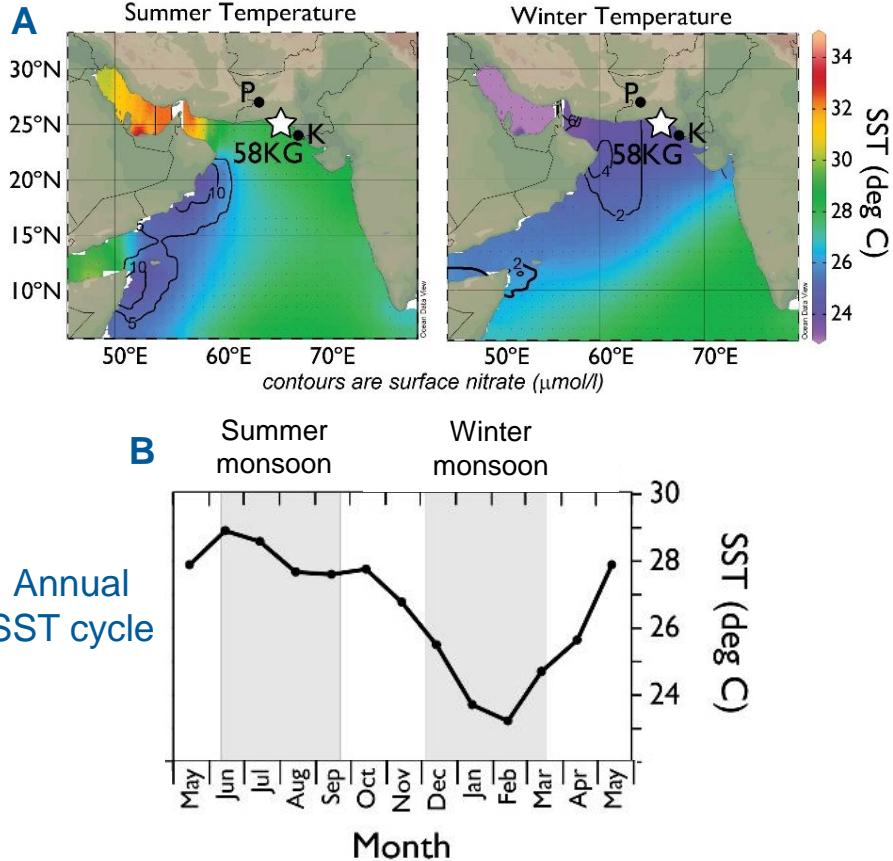


modified for clarity

Harris et al., 2014, Int. J. of Climatol.

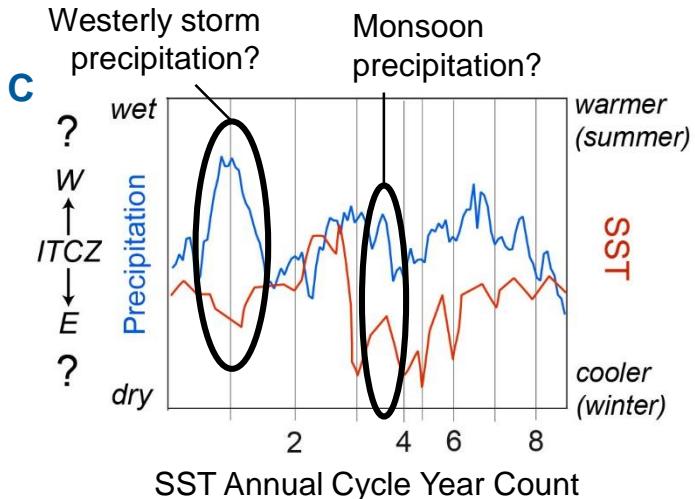
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# Southern Pakistan



## Targets:

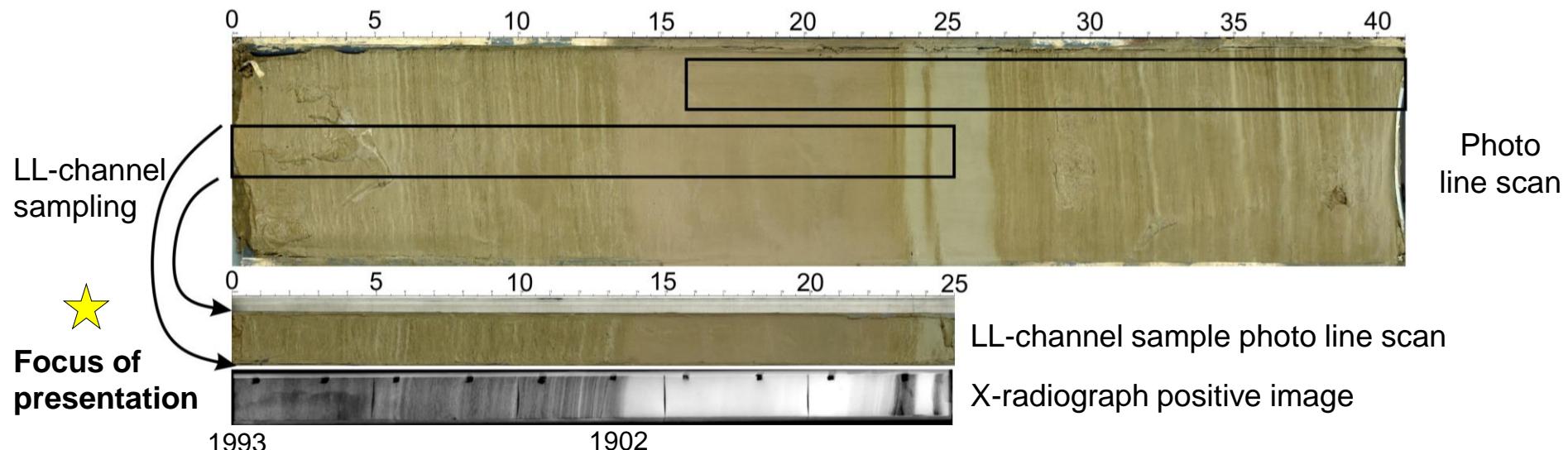
- **Monsoon intensity variability**
  - Winter Monsoon drives yearly SST cycle
  - Summer Monsoon – Precipitation in onshore catchments?
- **Seasonality of rainfall**
  - Summer Monsoon
  - Winter westerly storms



# Materials

- Marine core SO90-58KG

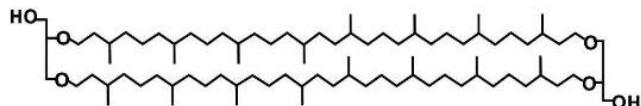
- 876 m water depth (OMZ)
- Laminated
  - Annual **varves** (von Rad et al., 1999; Lückge et al., 2002; von Rad et al., 2002; Schulz and von Rad 2014)



# Methods: Biomarker-based Sea Surface Temperature (SST) Proxy

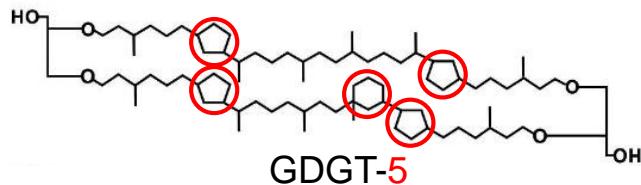
Cooler SSTs

GDGTs (glycerol dialkyl glycerol tetraethers)



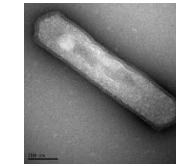
GDGT-0

Warmer SSTs



GDGT-5

Thaumarchaeota



$$\text{CCaT} = \frac{\text{GDGT-5}}{\text{GDGT-0} + \text{GDGT-5}}$$

modification of  $\text{TEX}_{86}$

$$\text{SST} = -21.916 * \left( \frac{1}{[1.056 * \text{CCaT} - 0.017]} \right) + 54.428$$

Wörmer et al., 2014 PNAS; Rohrls 2019, M.Sc. Thesis

# Methods: Mass Spectrometry Imaging (MSI) on sediments

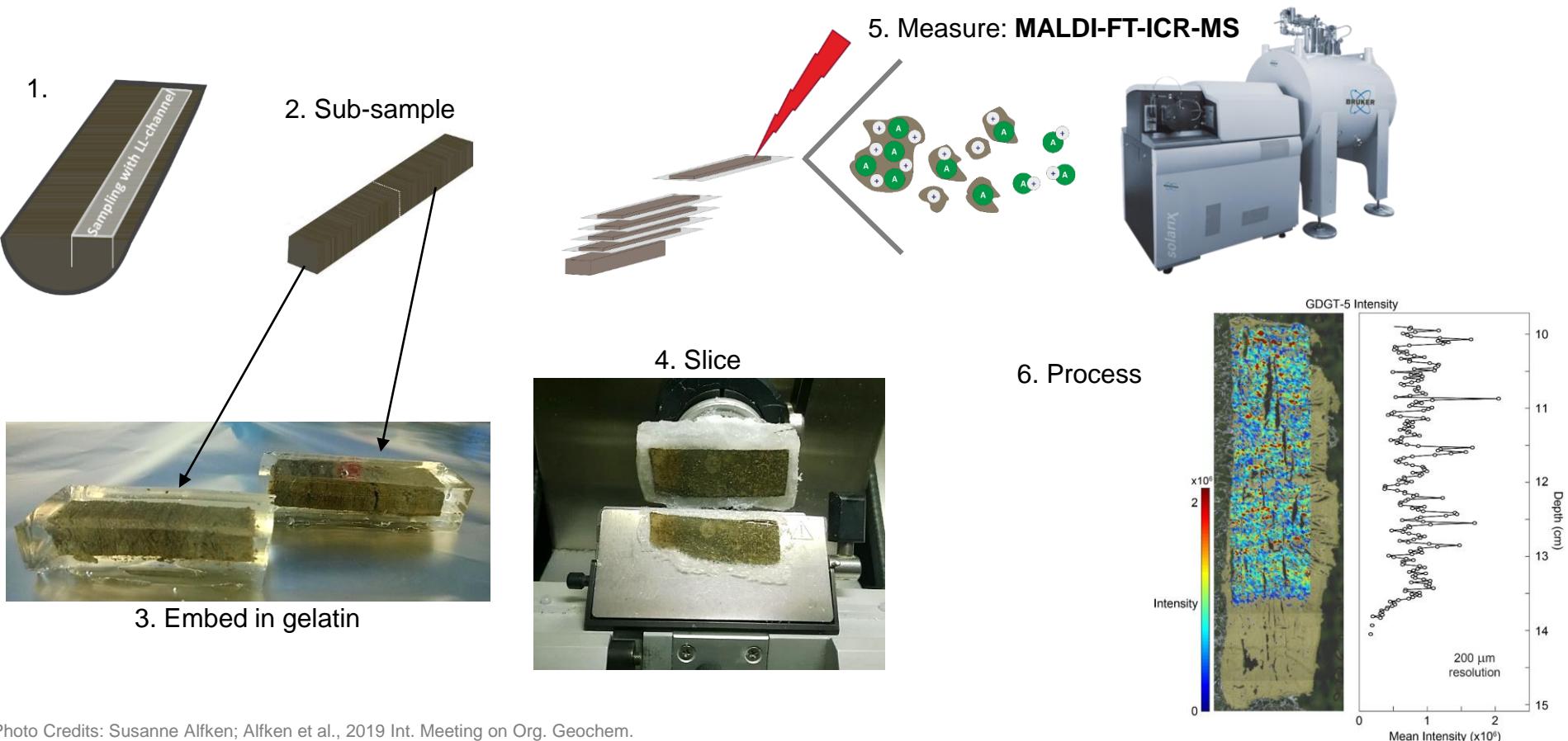


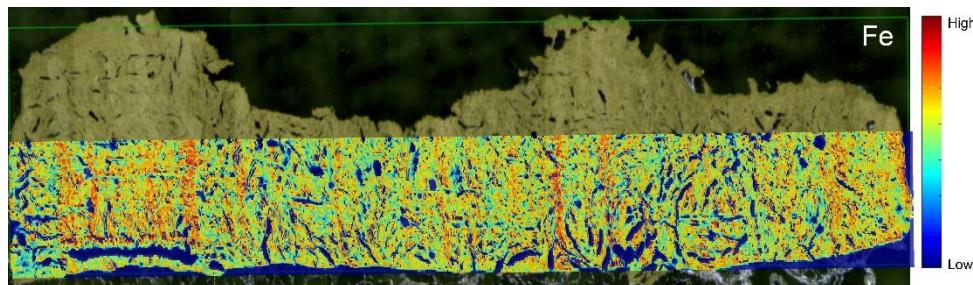
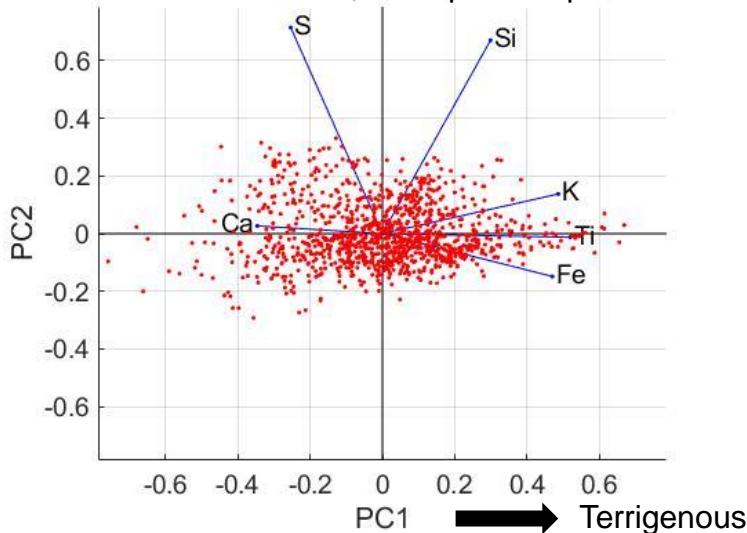
Photo Credits: Susanne Alfken; Alfken et al., 2019 Int. Meeting on Org. Geochem.

# Methods: Elemental Maps

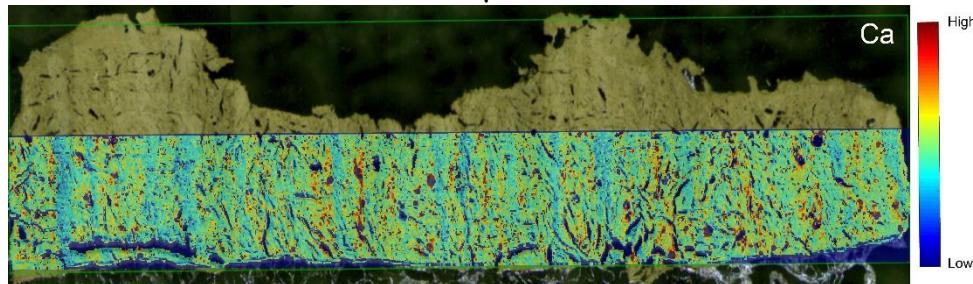
## ▪ micro-XRF mapping

- 50  $\mu\text{m}$  spatial resolution = Sub-annual temporal resolution
- Principal Component Analysis
  - PC1 = Terrigenous component/signal

SO90-58KG 0-13.3 cm, Principal Components

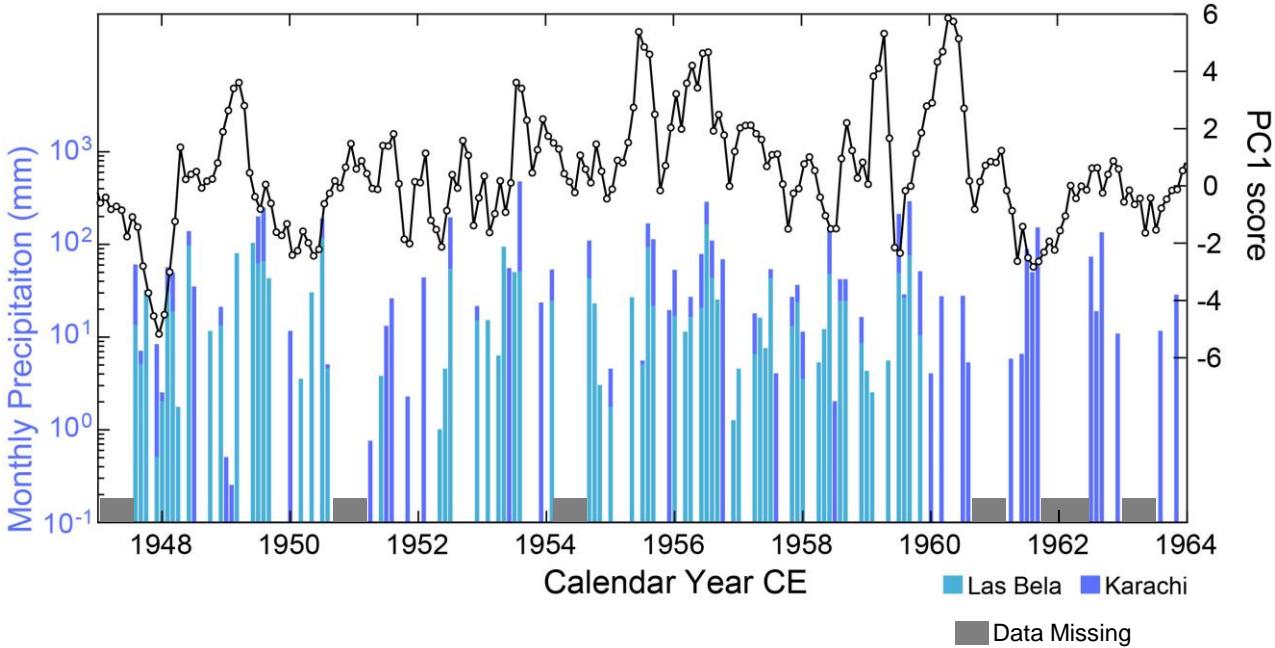


5 cm slice; 50  $\mu\text{m}$  resolution



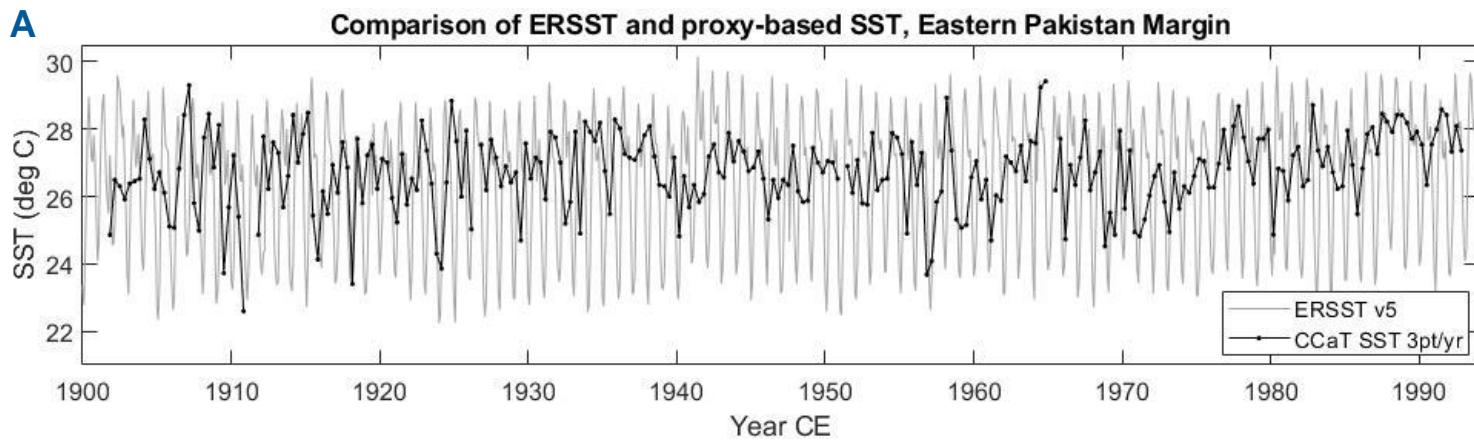
# Precipitation Proxy?

- PC1 = Precipitation-driven river runoff?
  - Monthly resolution = **12 data points per year**
- Compare to historical precipitation
  - Aug 1947 – Jan 1964 (data gaps)
  - *Perhaps PC1 lags precipitation?*
  - *Or age model errors?*

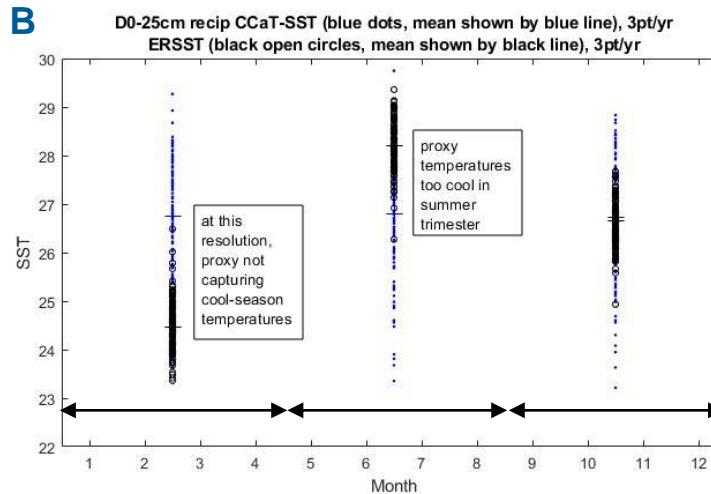


# SST

3 data  
points per  
year



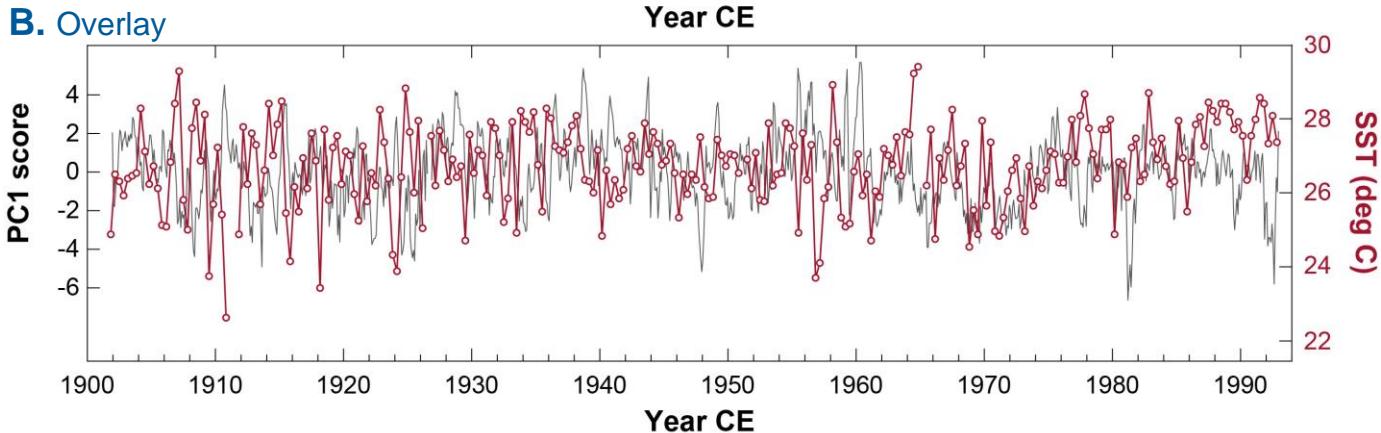
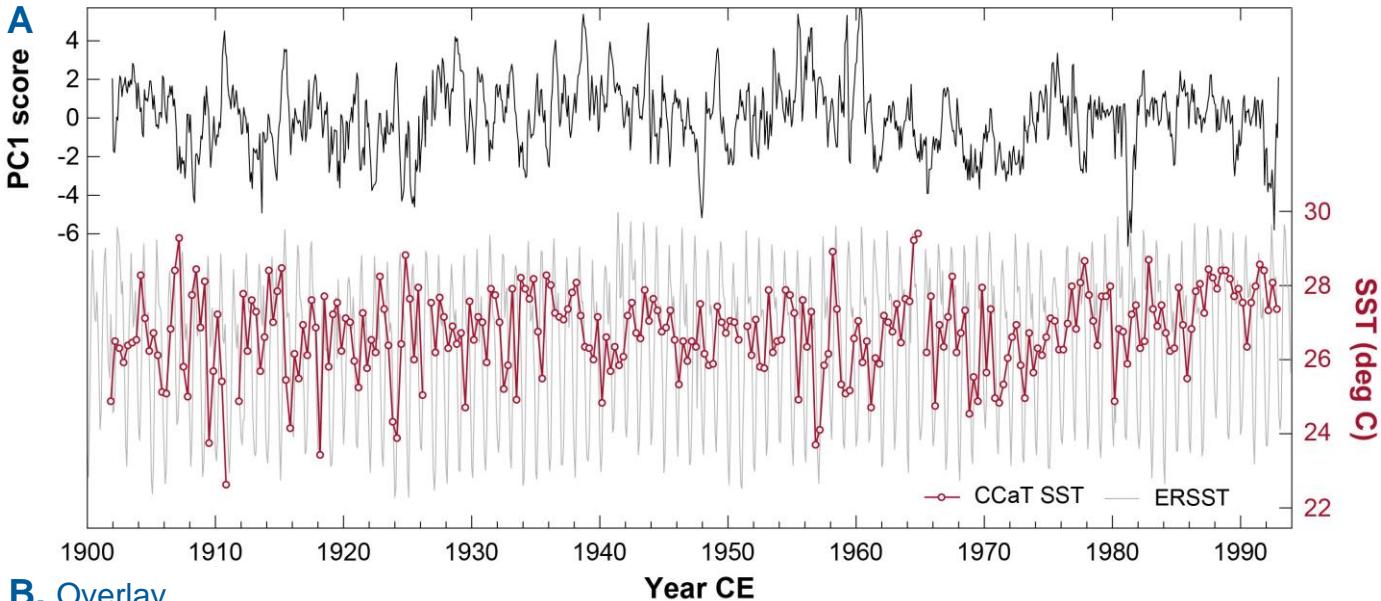
- Annual peak is often captured (**A**)
- SST proxy not capturing full instrumental SST range (**A-B**)
  - *Bias toward productive seasons?*
  - Proxy SST too warm in winter (**B**)
  - Proxy SST too cool in summer
  - Proxy autumn SSTs comparable to instrumental SSTs



Huang et al., 2017, NOAA ERSST v5

# Sub-annual Proxies

- PC1 pattern often visually similar to SST proxy pattern
  - *Summer monsoon precipitation?*
- Occurrences of PC1 peaks during SST minima
  - *Winter westerly precipitation?*



# Summary

- Mass Spectrometry Imaging generates sub-mm biomarker maps
  - Sub-annual temporal resolution
- PC1 driven by K, Fe, Ti variability
  - Terrigenous elements
- PC1 may be a proxy for precipitation and river runoff
  - Apparent offset between PC1 peaks and instrumental precipitation record
    - *Depositional lag or age model error?*
- SST proxy often captures annual cycle, but does not record full range of instrumental SSTs
  - *Bias toward productive seasons?*
- Sub-annual SST and precipitation proxies provide potential to elucidate season of precipitation occurrence in southeast Pakistan
  - Summer monsoonal rains
  - Winter westerly storms

***This project is ongoing. We are still collecting and analyzing data.***

# Acknowledgements

Susanne Alfken (U. Bremen)

Julius Lipp (U. Bremen)

Heidi Taubner (U. Bremen)

Igor Obreht (U. Bremen)

Vera Bender (U. Bremen)

Ulrich von Rad (formerly BGR, Hannover)

R/V Sonne

Crew, Scientific Staff

## Funding Sources

EU ERC Advanced Grant (No. 670115, ZOOMecular,  
PI K.-U. Hinrichs)

University of Bremen Central Research Development  
Fund (T.J. Napier)



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