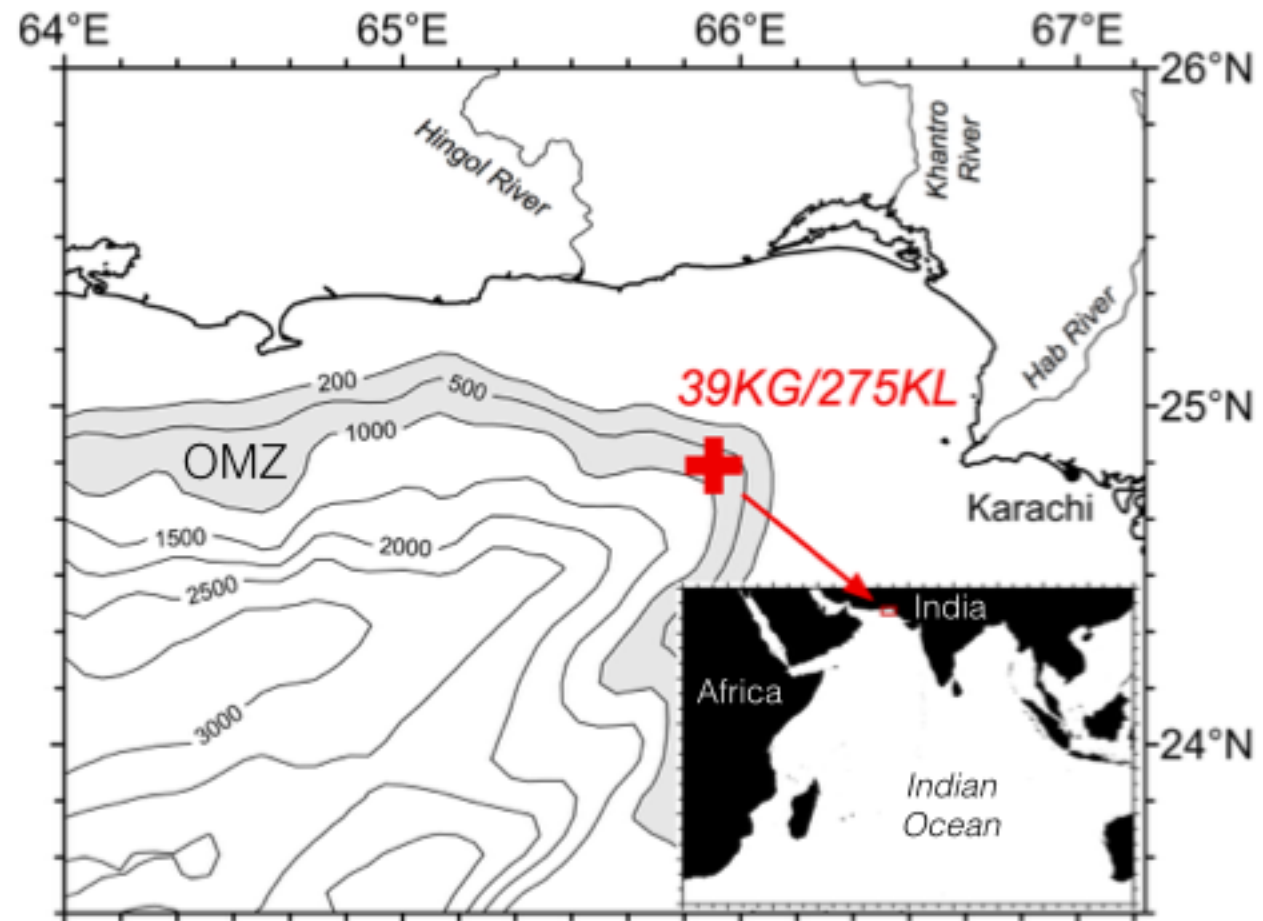
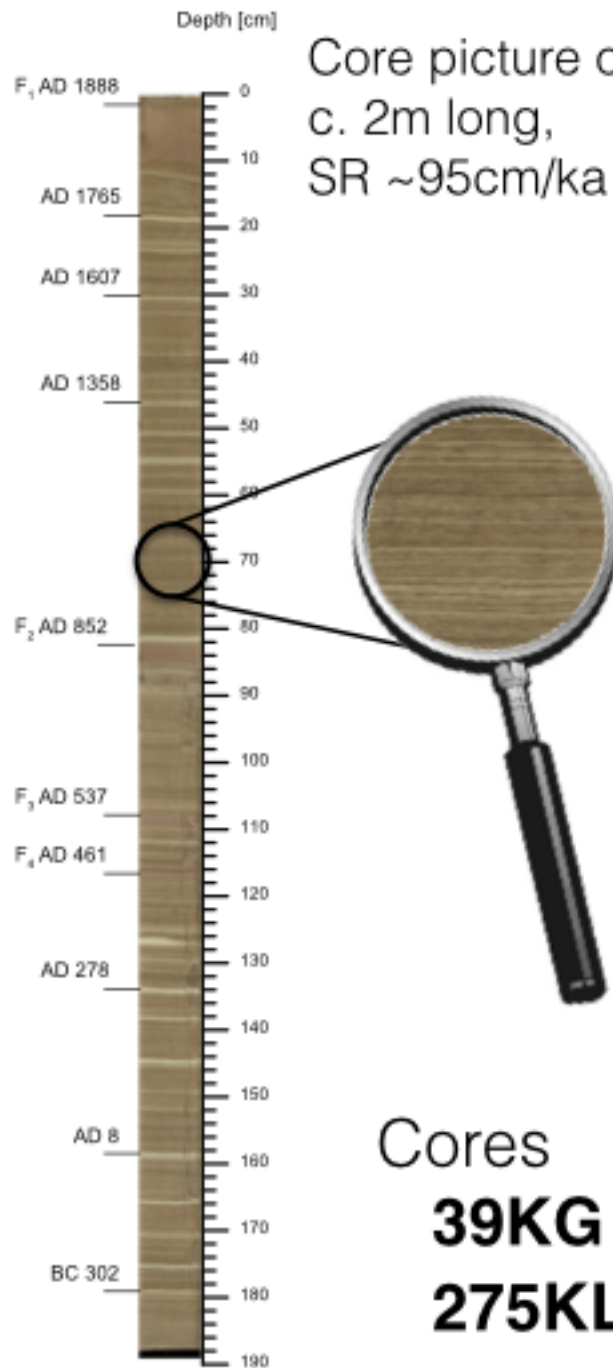




# A decadal-scale record of Indian Ocean winter monsoon intensity over the last two millennia

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## Cores

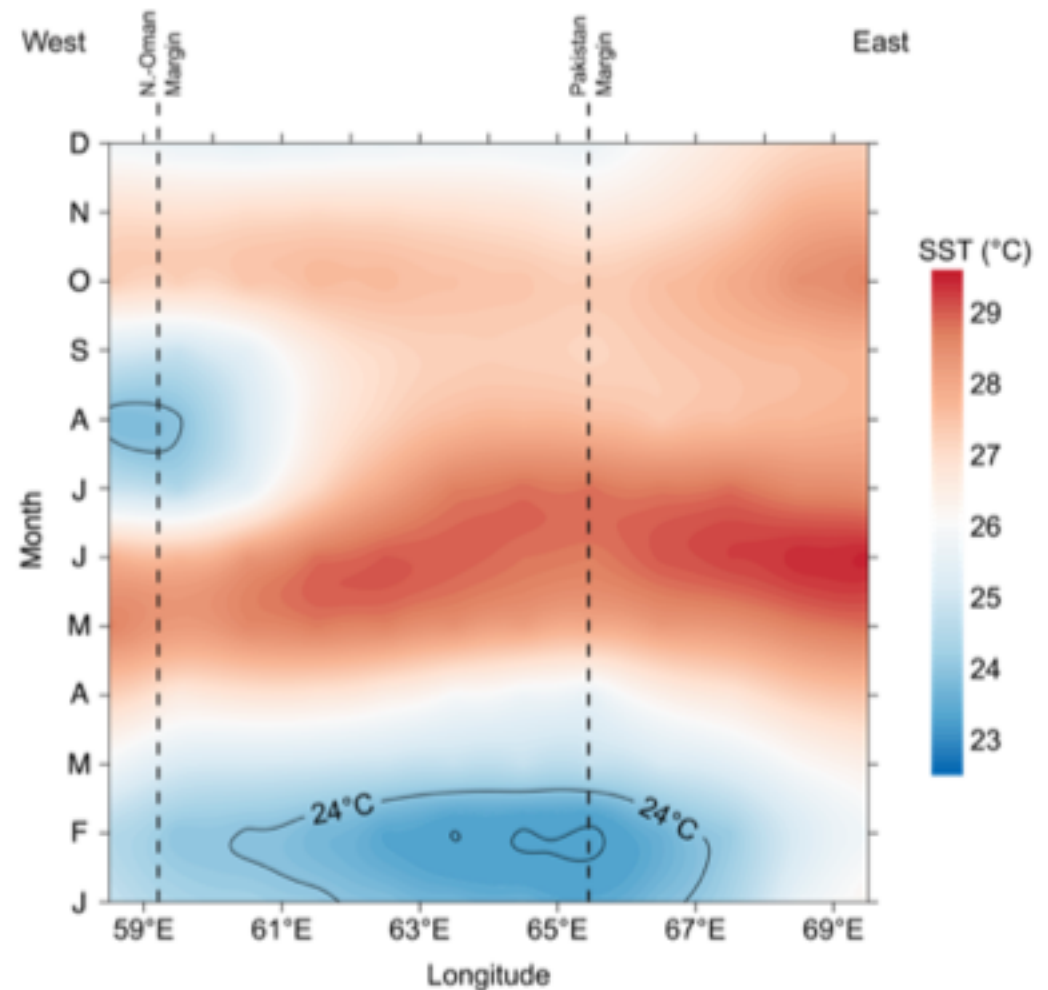
**39KG** (1993 CE – 1762 CE) with  $\varnothing$  2.3 years resolution

**275KL** (1893 CE – 100 BCE) with  $\varnothing$  9 years resolution



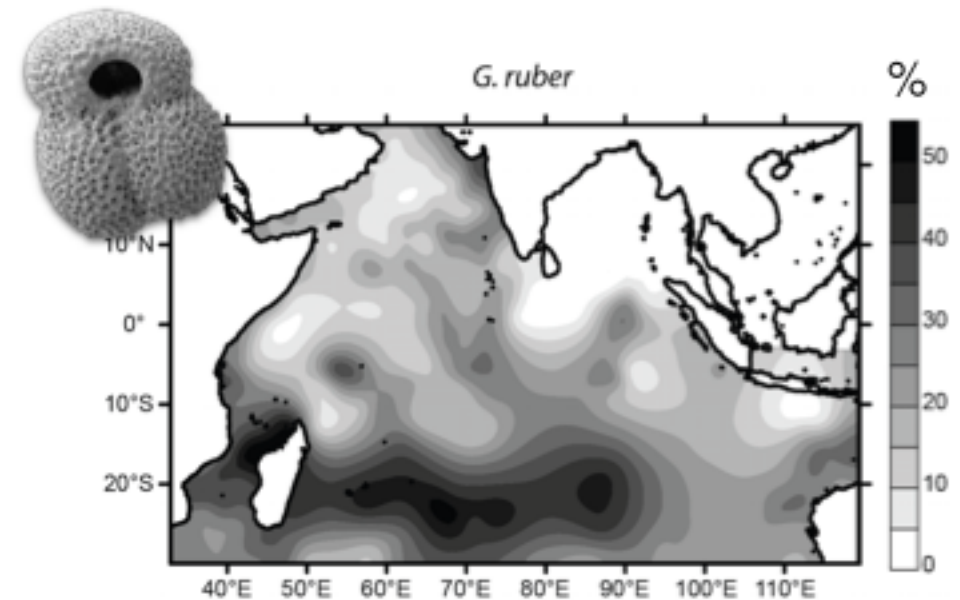
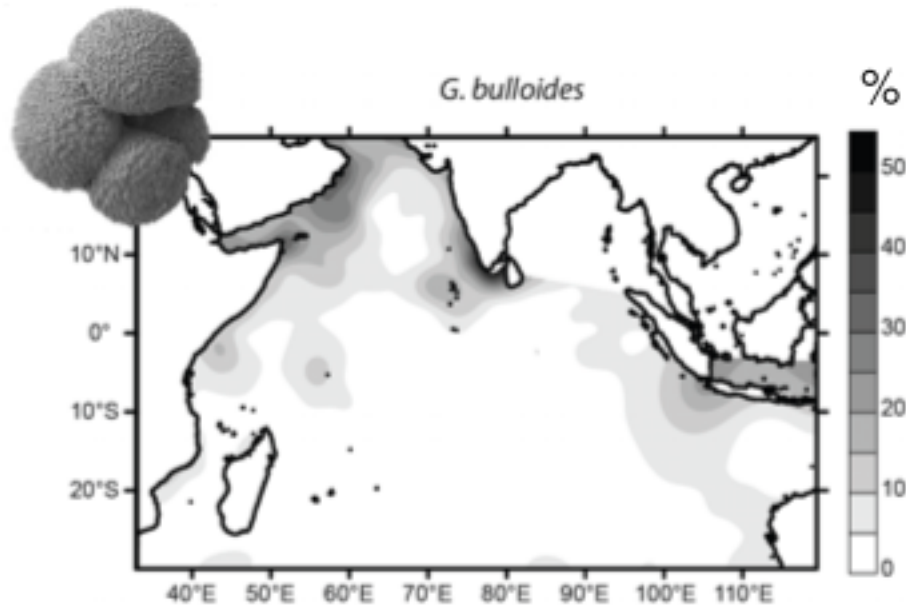
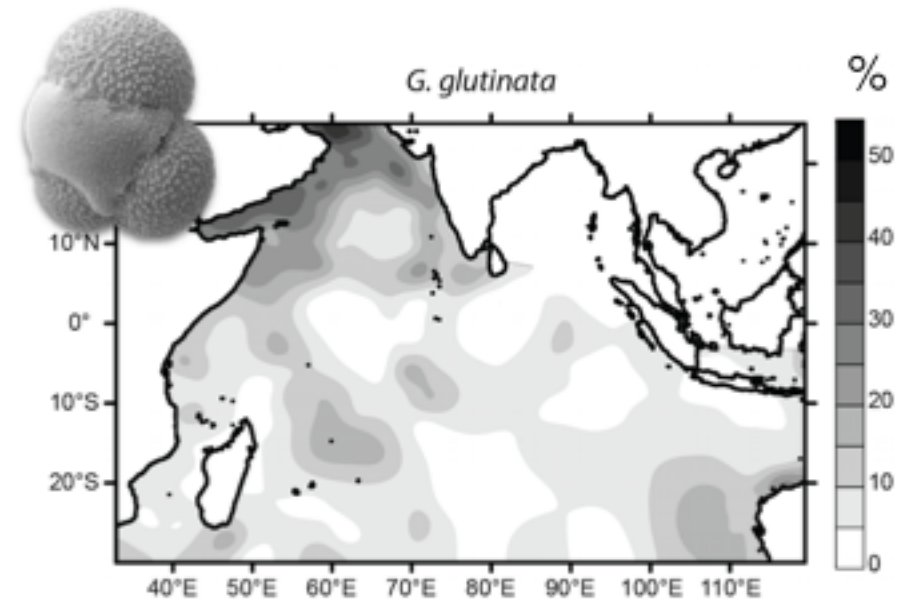
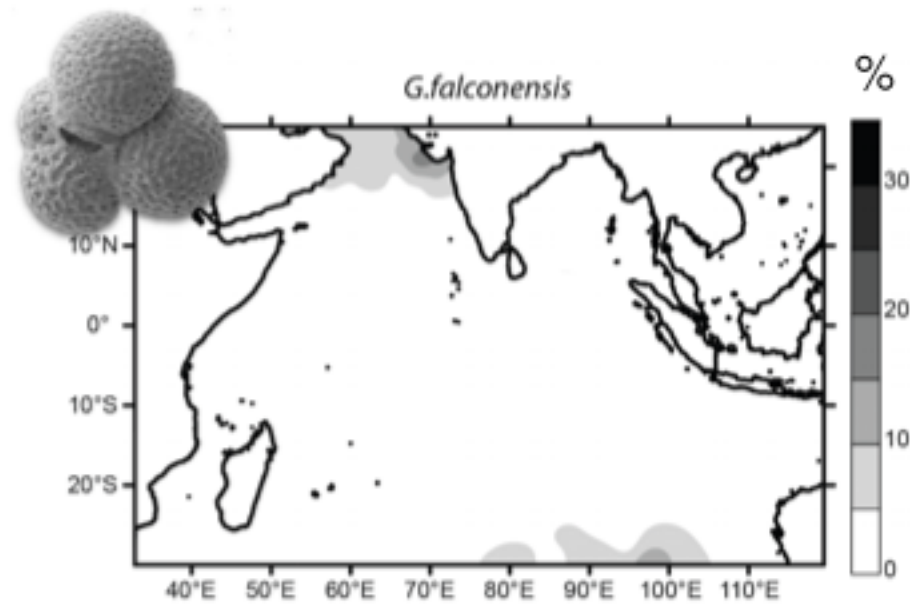
## Arabian Sea transect

- Regional differences in temperature patterns caused by **seasonally** alternating wind directions
- **Oman** margin recording **summer**
- **Pakistan** margin recording **winter**





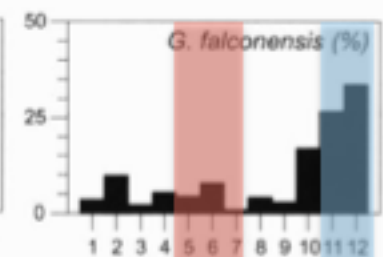
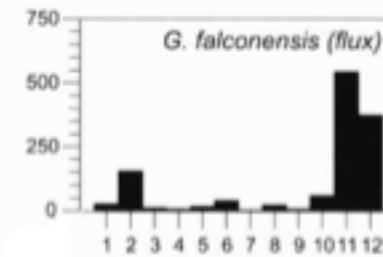
Can we see a response of planktic foraminifera to seasonal environmental changes?



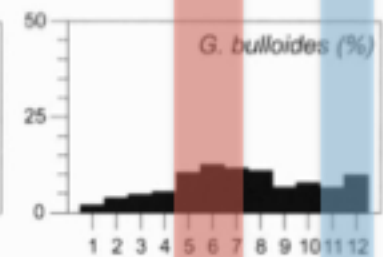
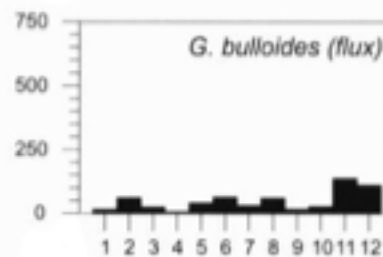
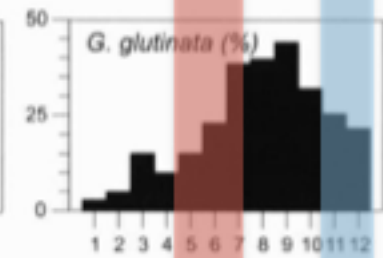
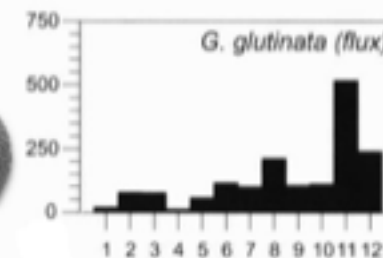
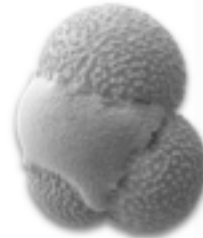




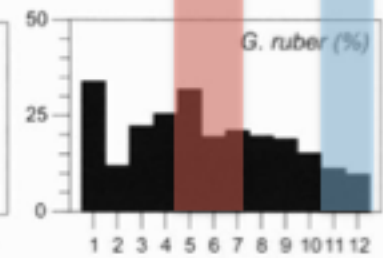
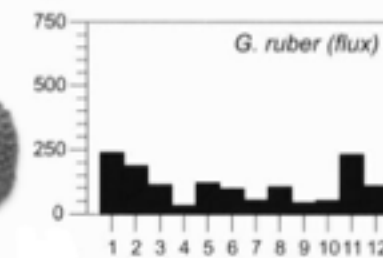
winter



summer



inter-monsoon, but  
more or less  
annual



month M J J A S O N D J F  
spring summer autumn winter

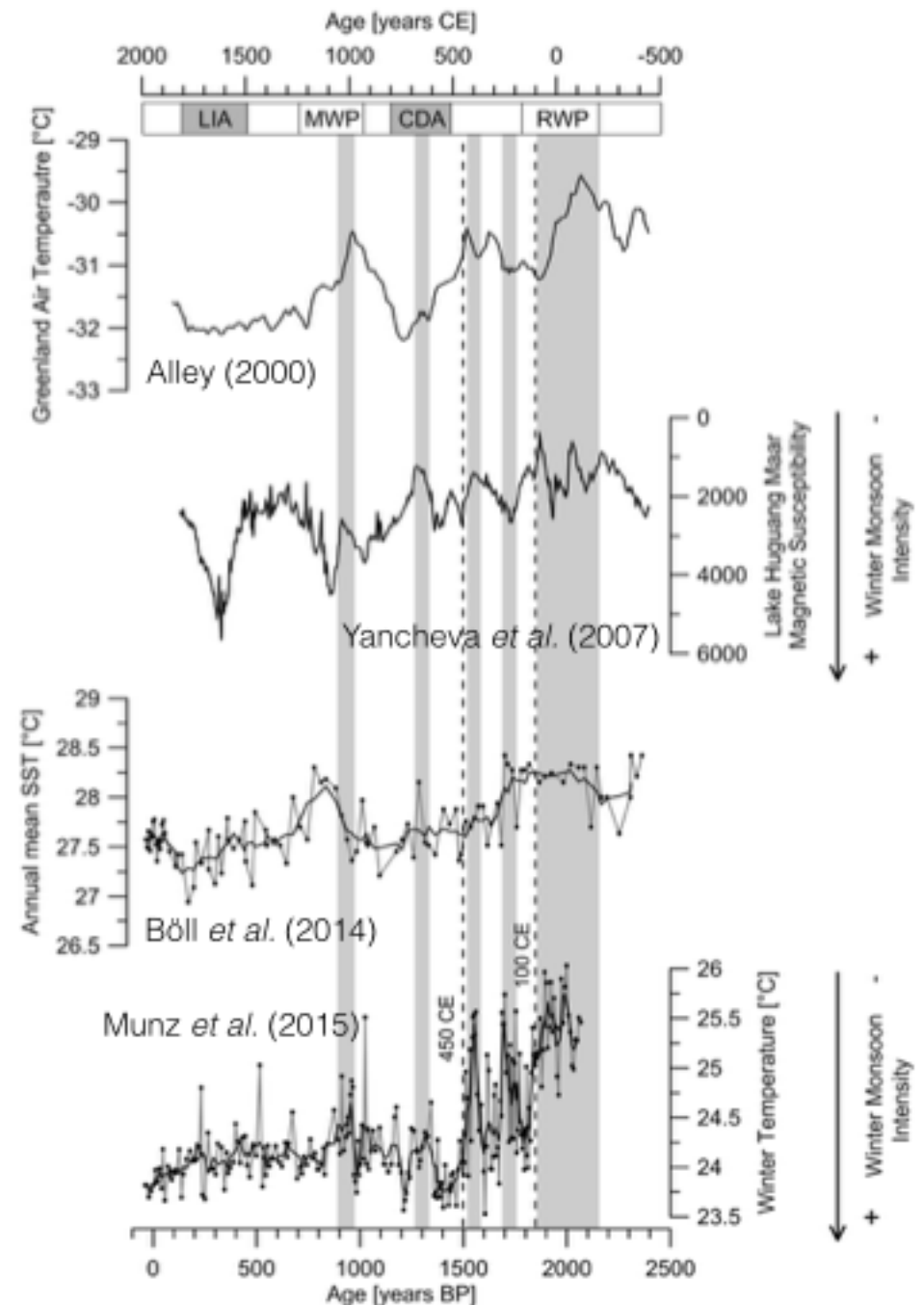
EPT-2 sediment trap in the  
proximity of the core site

from Schulz *et al.* (2002)



Reconstruction results over the last 2ka:

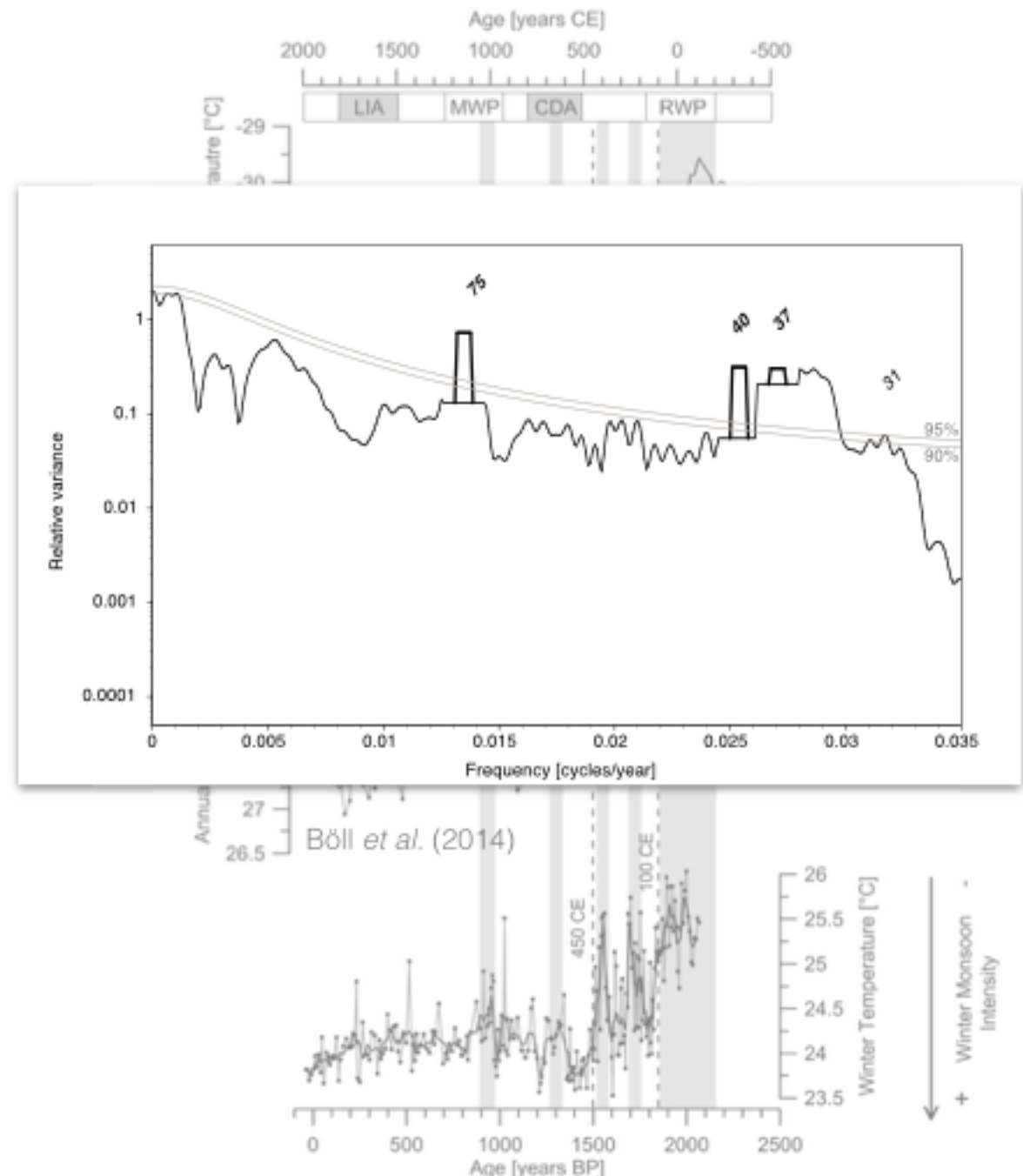
- **Major changes** at 100 and 450 CE from weak to strong winter monsoon
- Changing monsoon conditions **~1.5 ka BP** also evident from other records
- Weaker winter monsoon during the **Medieval Warm Period**





Reconstruction results  
over the last 2ka:

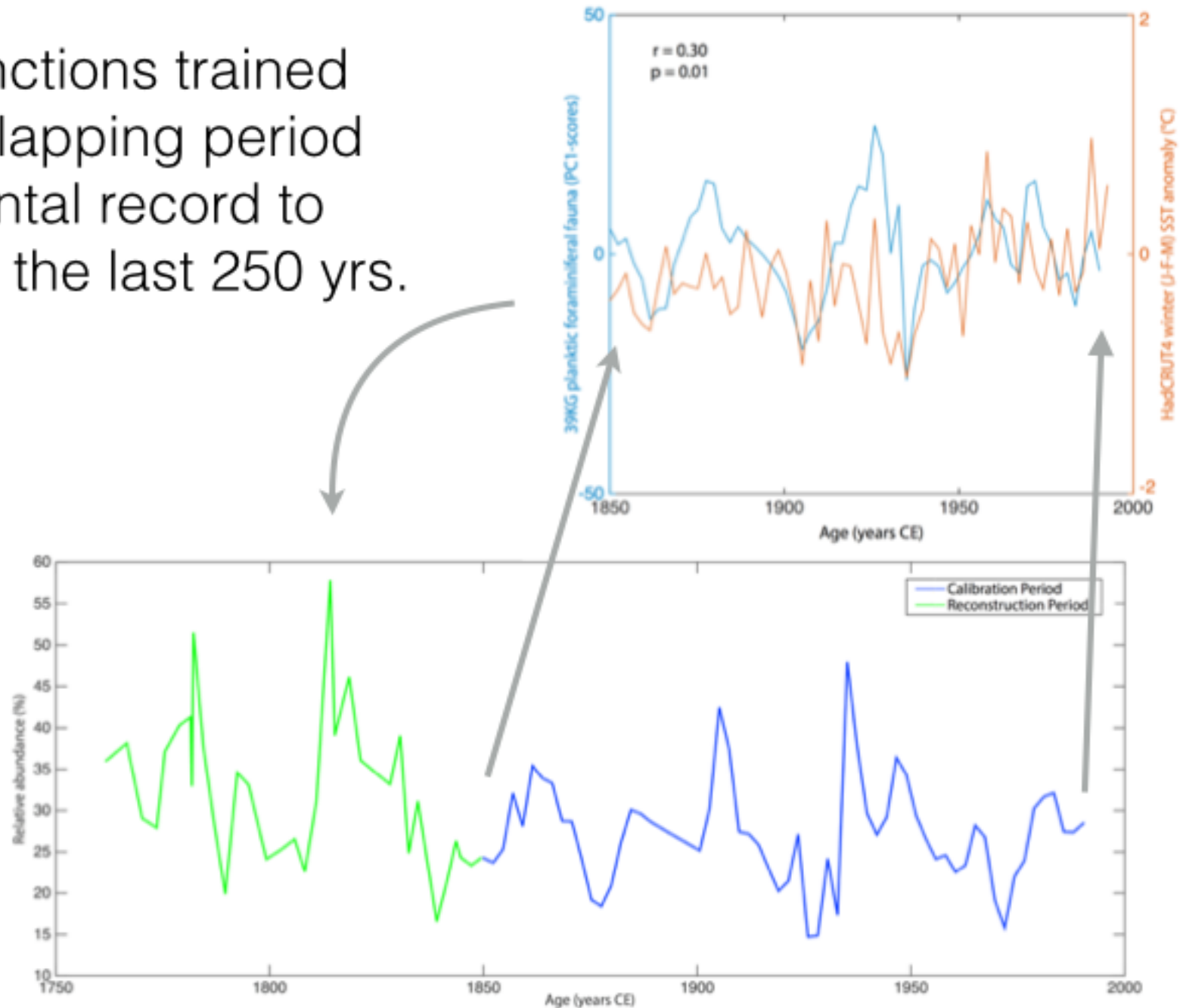
- 75 year periodicity closely matching major **sunspot cycle**
- 40, 37 and 31-year cycles less clear but could also be of **Pacific origin**







Transfer functions trained on the overlapping period of instrumental record to reconstruct the last 250 yrs.





1816/17:

- Europe: “The year without a summer”
- Snowfall in June
- Poor harvests and famine
- Delayed monsoon season in Asia



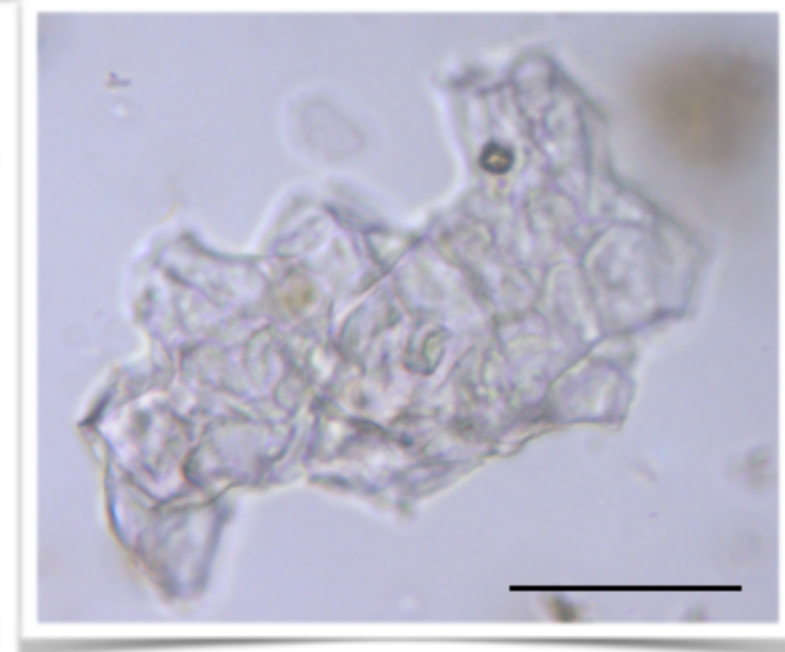
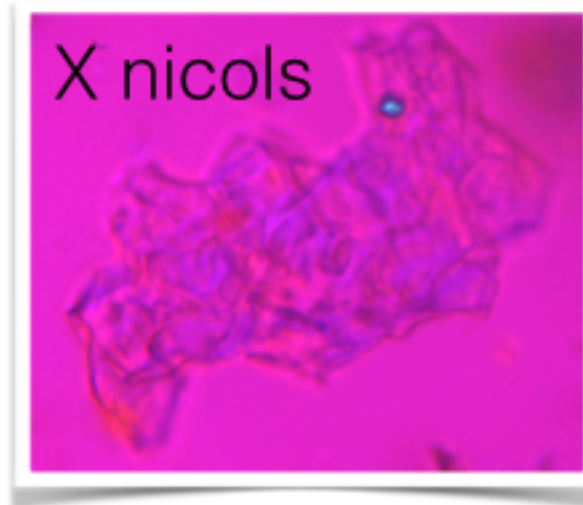
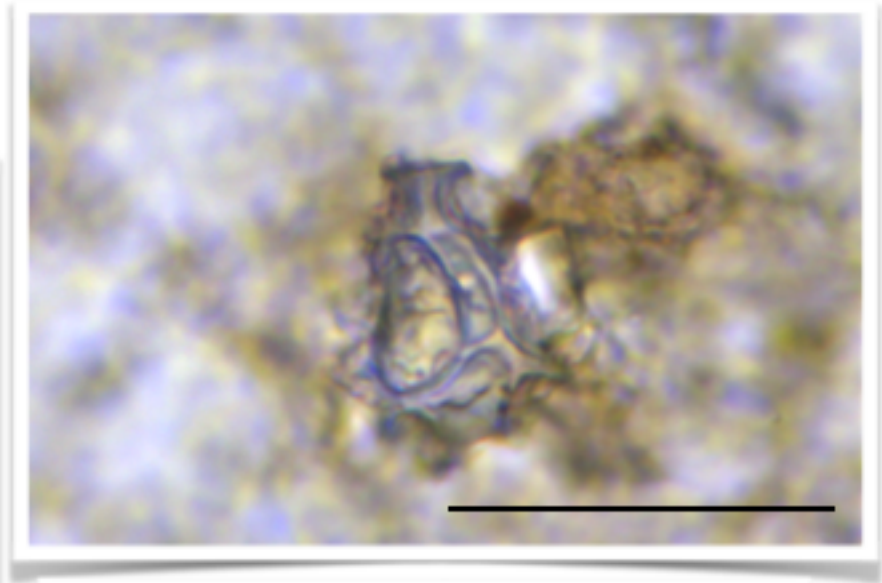
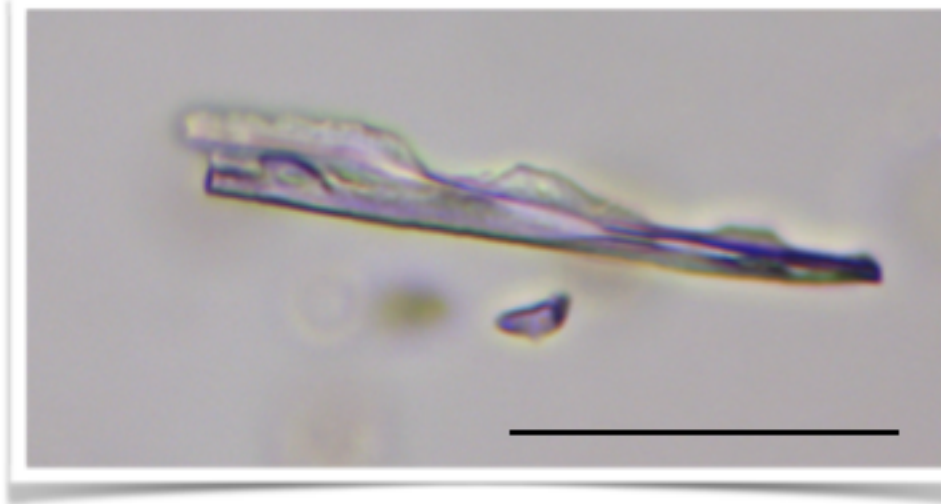
JWM Turner “The Scarlet Sunset”  
c. 1830

tate.org.uk

→ evidence for strong winter monsoon during the  
“**Great Tambora Eruption**” 1815



~1815: isotropic vesicular and shard-shaped objects  
→ test for volcanic origin





What did we learn about the monsoon system that we did not know before?

- Winter monsoon record over the last 2ka suggests teleconnections with warm Northern Hemisphere climate phases, i.e. Roman Warm and Medieval Warm.
- Conditions similar to today prevailed since c. 450 CE.
- Periodicities of winter monsoon intensity suggests solar forcing
- Multidecadal- and inter-decadal variability could be of Pacific origin





Thank you for your attention!

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Tim Rixen and Sven Forke, Bremen