Seasonal cycling of iron in the Celtic Sea

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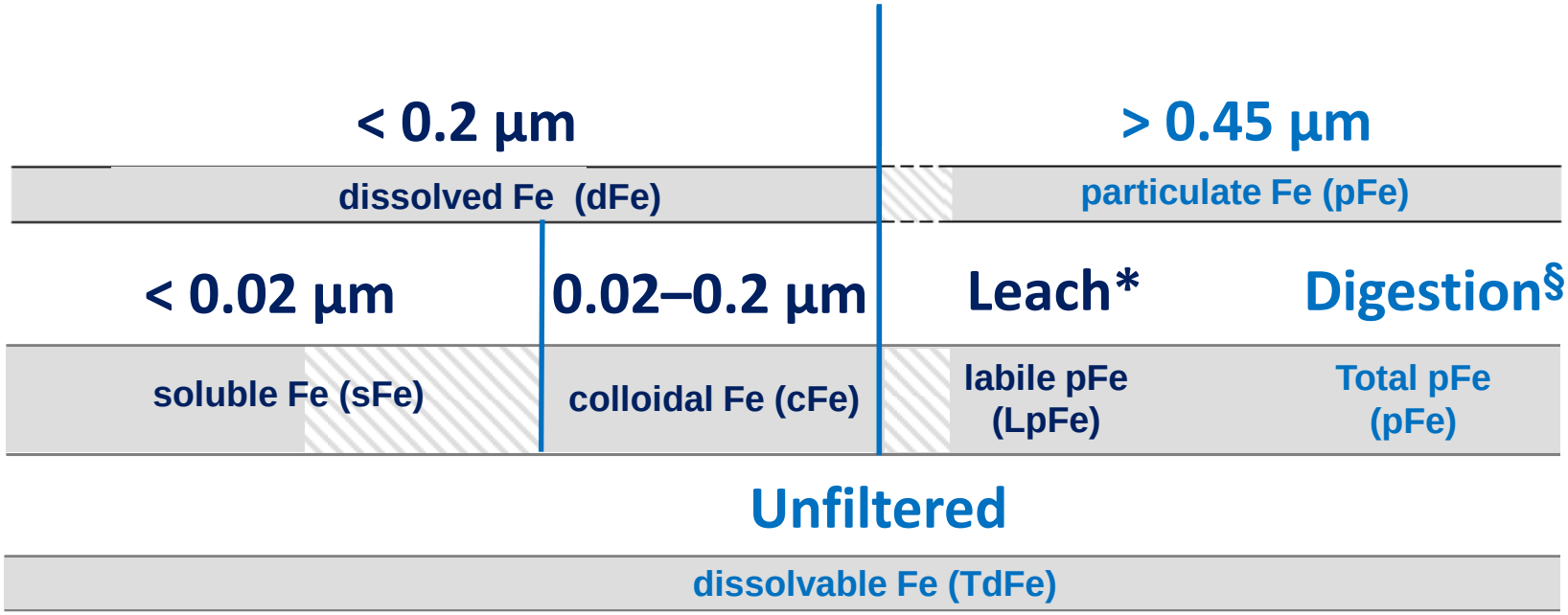
Iron Fractions



Acidified (pH 1.8) for >6 months
Analysed by FI-CL

Analysed by ICP-MS

*Leach: 25% Acetic acid + reducing agent

§ Digest: HNO_3/HCl/HF

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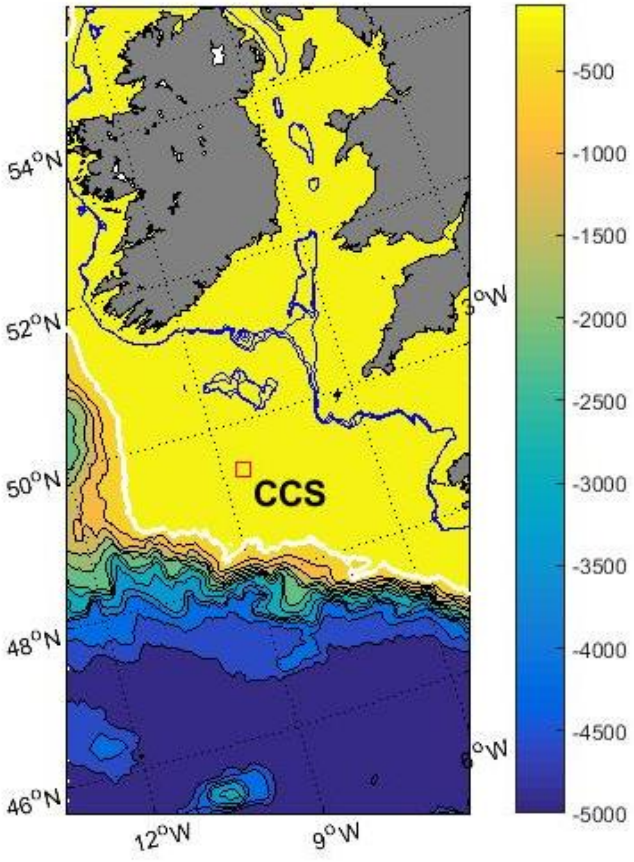
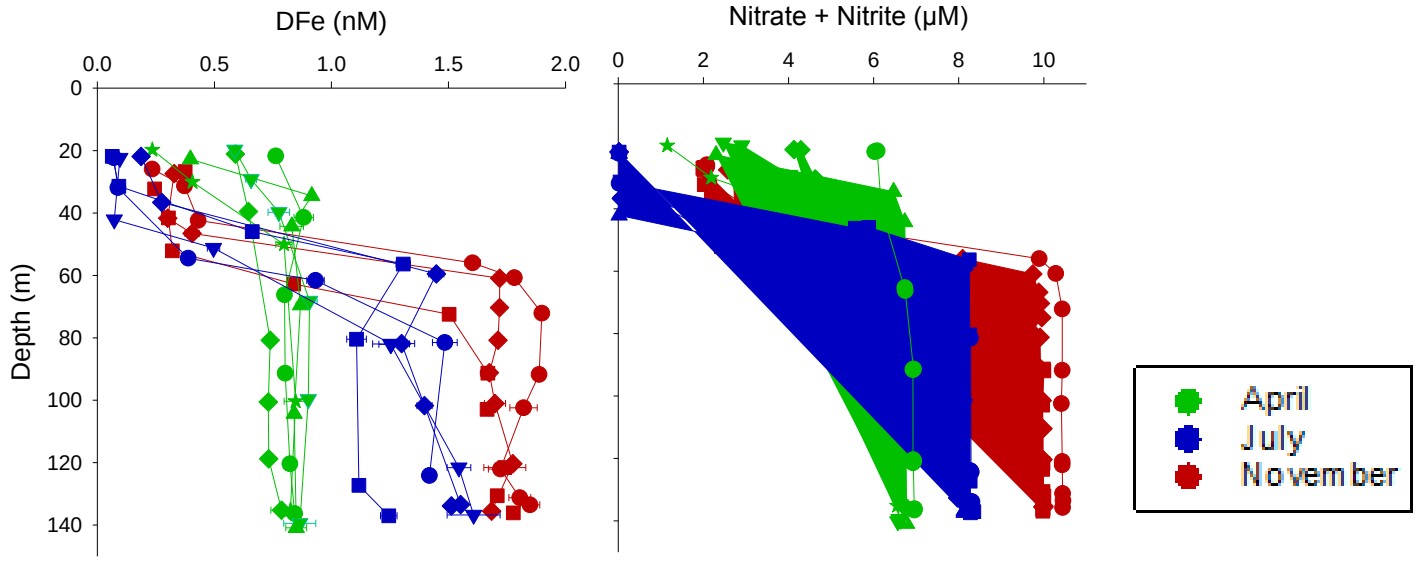


- Fe essential for phytoplankton growth
- In seawater at pH 8.1 sub-nanomolar concentrations are typical for dFe
  - Limits growth in 20-40% of the ocean

- Growing awareness that Fe (co)-limitation more widespread:
  - Shelf systems
    - Californian upwelling, Shelf regions of the Bering Sea, Southern Ross Sea, New England shelf
  - Sub-Arctic North Atlantic
  - At the sub-surface chlorophyll maximum

- Seasonal cycle of iron in temperate shelf systems not presently constrained
  - **Is it necessary to consider Fe as potentially growth limiting nutrient in the Celtic Sea?**

Seasonal cycling of dFe in the central Celtic Sea



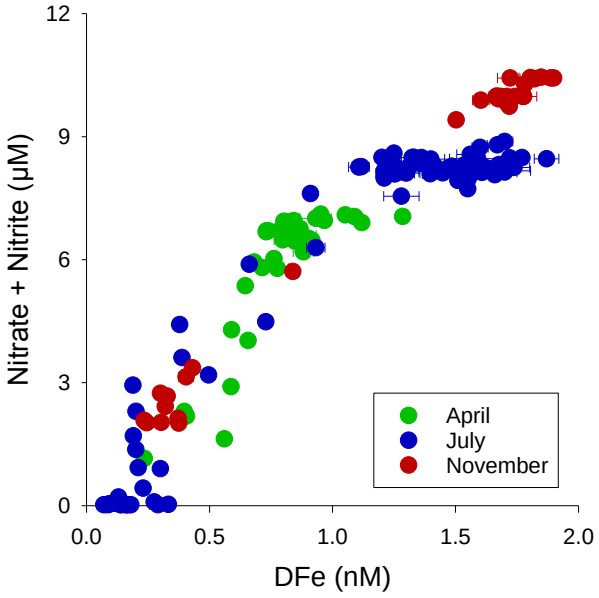
- dFe similar seasonal cycle to that of nitrate

Surface Mixed Layer

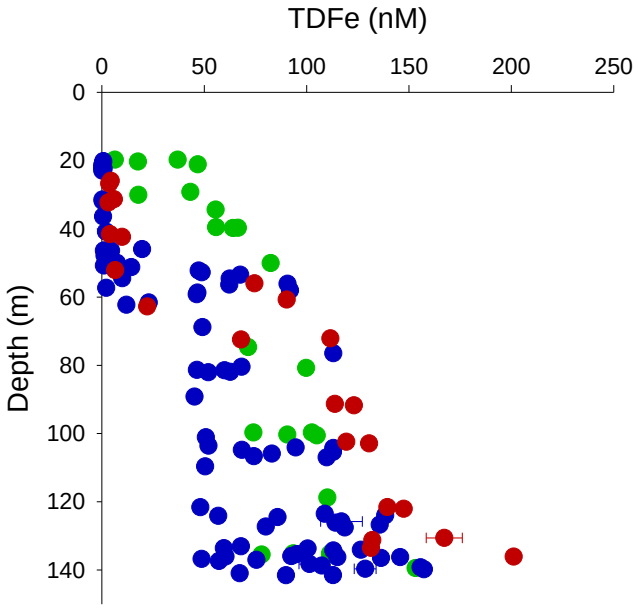
- ➢ Depletion during the spring bloom
- ➢ Lowest concentrations during summer stratification
- ➢ Increase in concentration during autumn as stratification weakens

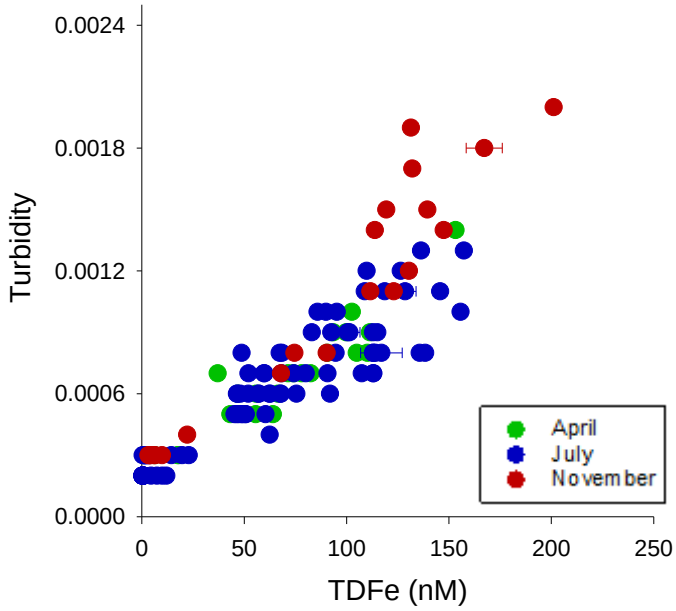
Bottom Mixed Layer

- ➢ Seasonal regeneration of dFe in bottom mixed layer



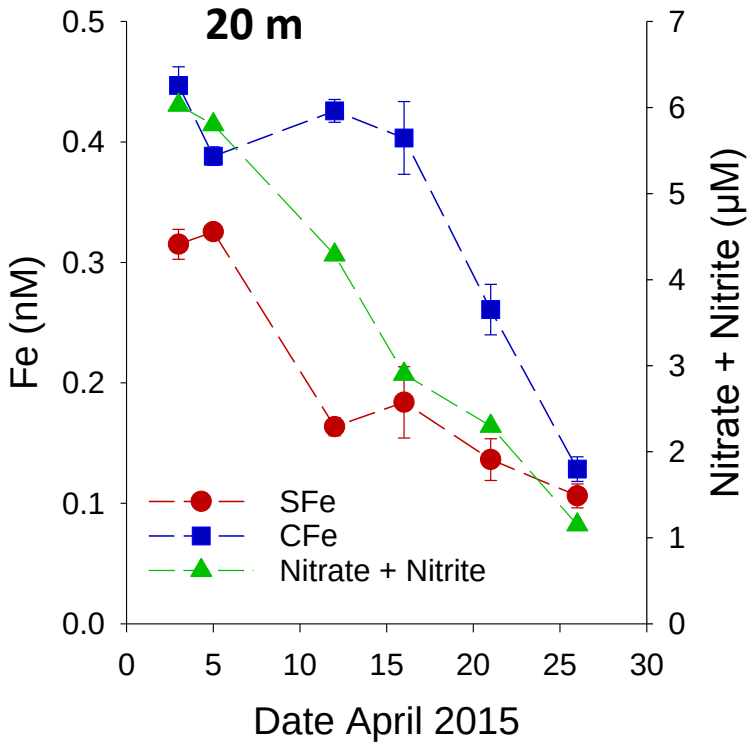
Cycling of pFe in the central Celtic Sea





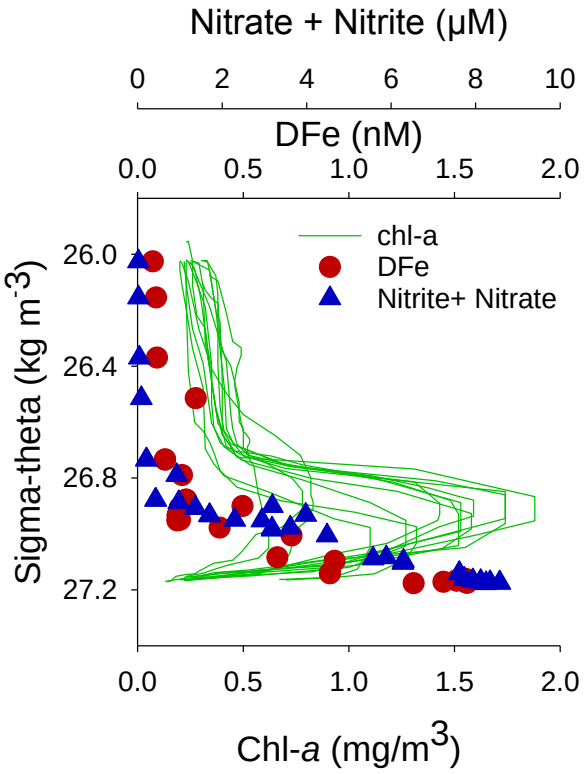
- Particulate Fe controlled by short term resuspension events- much bigger pool of Fe
  - Driven by processes occurring on shorter timescales than the seasonal cycle e.g. tide
- Depletion in surface mixed layer- stratification restricting vertical mixing
- 15-20 % of particulate Fe in a labile ‘exchangeable’ form

Spring bloom- preferential drawdown of sFe



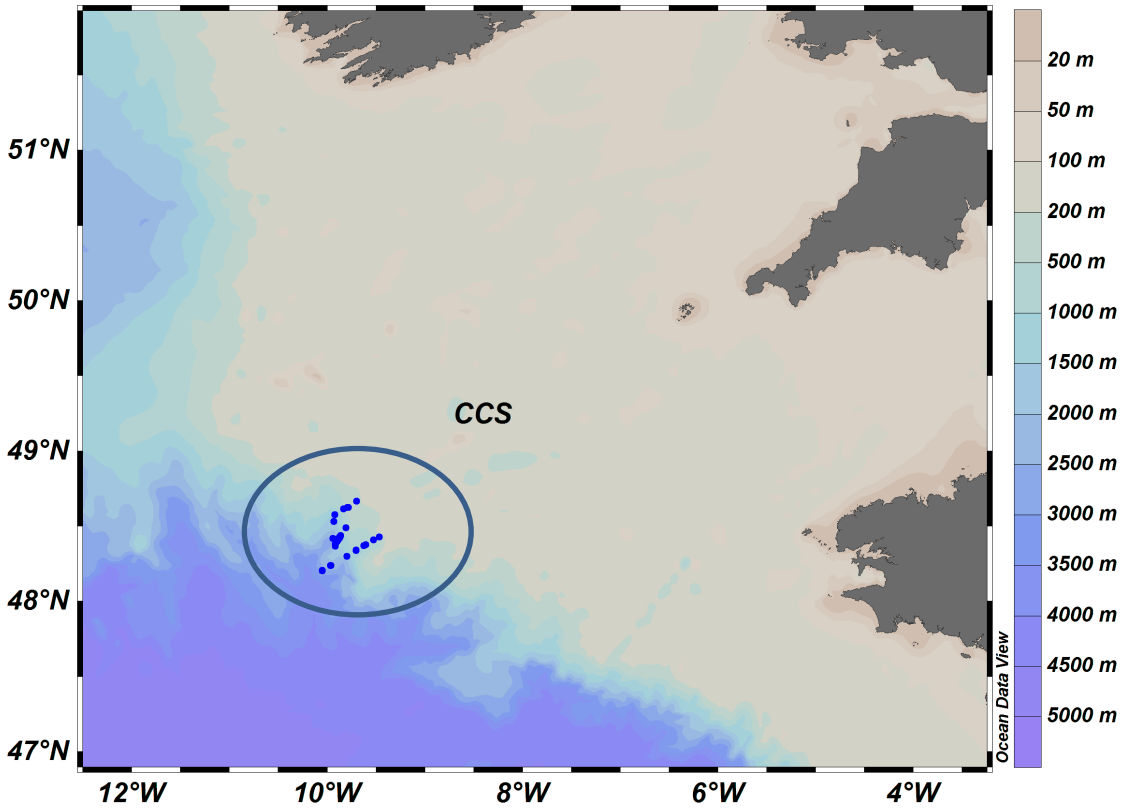
- sFe removed before cFe indicating that cFe is more bioavailable
  - ➢ Contrasts to observations in the open ocean where a depletion in cFe is observed, we suggest that this is net result of uptake and removal processes

Summer stratification- depletion of bioavailable Fe in surface waters



- Surface mixed layer deplete in bioavailable iron:
  - dFe typically < 0.2 nM (> 50 % sFe)
  - LpFe < 0.2 nM
- Sub-surface chlorophyll maximum:
  - Lower light level increases Fe demand to build photosynthetic redox proteins
  - The ratio of Fe:N supplied by the diapycnal flux is lower that uptake in cultured phytoplankton (Ho et al. 2003)

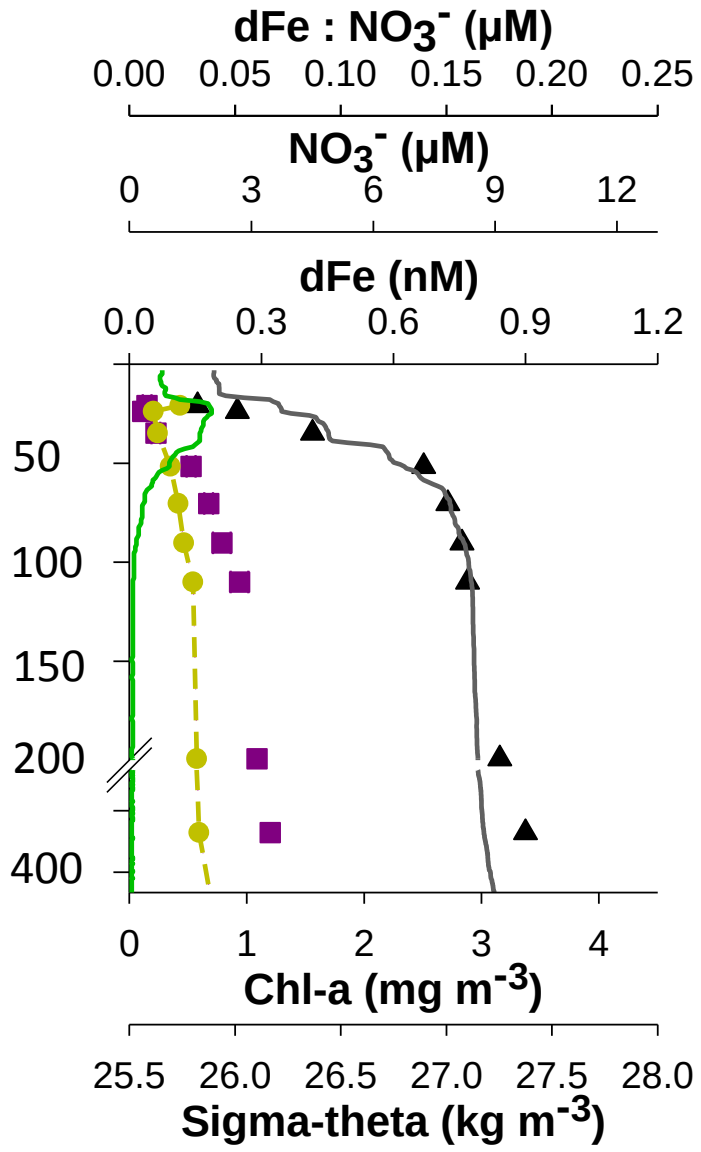
Shelf break transects- Summer stratification



- Fe cycling in the surface waters overlying the shelf slope during July 2015
  - Most Fe deplete time

- 250 to 2500 m water depth
  - ➢ All within 50 km of 200 m isobath

Shelf break transects- Summer stratification



- Furthest station from shelf break (≈49 km)

- Very low Fe:N (<0.01 nM:µM) in surface chlorophyll maximum

- Much lower than uptake observed in cultured phytoplankton (Ho et al 2003, Sunda and Huntsman 1997)

dFe: NO_3^-
NO_3^-
dFe
Chl-a
Sigma-theta

Shelf break- Summer stratification

Surface water values (upper 100 m)

Distance from shelf break (km)	dFe (nM)	LpFe (nM)	NO_3^- (µM)	Si (µM)	PO_4^{3-} (µM)
49	0.03-0.14	0.10 ± 0.01	<0.02-7.2	0.6-2.2	0.2-0.5
43	0.05-0.16	0.13 ± 0.00	<0.02-4-8.4	0.3-2.8	0.1-0.5
21	0.04-0.09	0.17 ± 0.00	<0.02-2-6.6	0.3-1.9	0.1-0.4

- Nutrients describe oligotrophic environment during summer stratification:
  - Nitrate below LOD
  - Silicate < 2µM
  - dFe as low as 30 pM- very low- comparable to HNLC regions
  - LpFe < 0.2 nM
  - Previous work shows similar depletion of other trace elements during summer (Cotte-Krief et al 2002)
  - Likely that phytoplankton community structure sensitive to availability of multiple nutrients, including Fe

Conclusions

Is it necessary to consider Fe as potentially growth limiting nutrient in the Celtic Sea?

- **central Celtic Sea**

1. Dynamic nutrient type seasonal cycling of dFe in the central Celtic Sea leading to depletion of bioavailable Fe from surface waters during summer stratification

2. Preferential utilisation of sFe during the spring bloom

3. Seasonal regeneration of dFe in bottom mixed layer

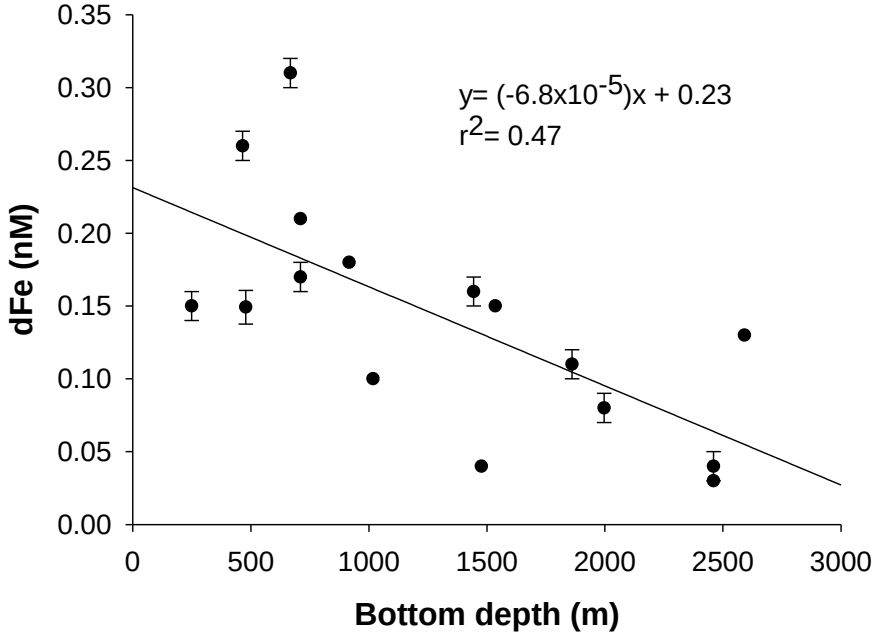
- **Shelf break**

1. Vanishingly low dFe concentrations in the surface mixed layer during summer stratification

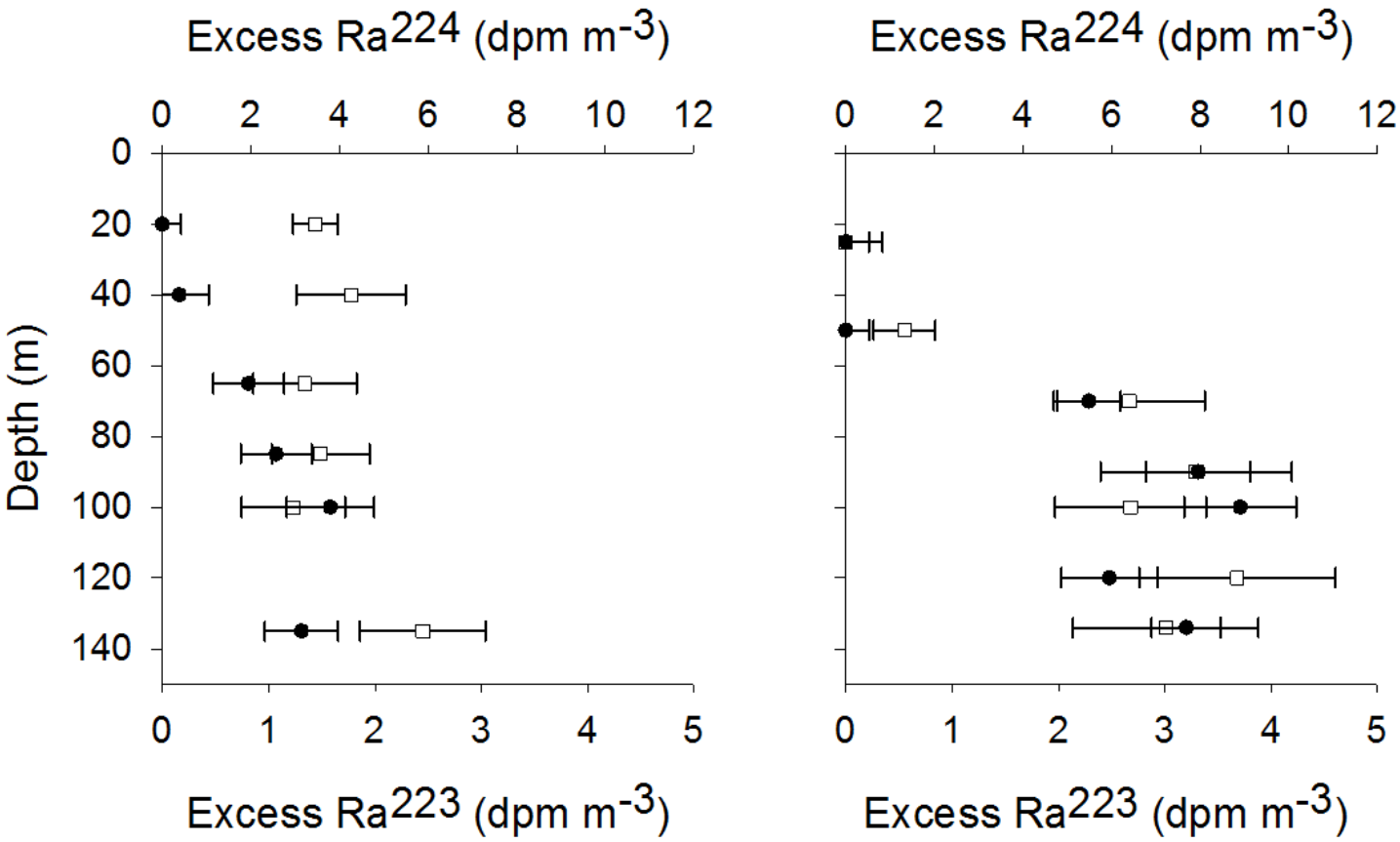
2. Surface nutrient concentrations describe oligotrophic environment where the phytoplankton community structure is likely sensitive to both macro and micro nutrient availability

Shelf break- horizontal gradient in Fe stress?

v.low concentrations



- Near surface concentrations, July 2015
- Increased vertical mixing over shelf break previously shown to enhance nitrate flux to surface waters (Sharples et al 2007)
- Near surface dFe concentrations increased over upper shelf slope
- Postulate that the degree of Fe stress increases with distance from shelf slope


Excess Ra224 (dpm m-3)
0
2
4
6
8
10
12
Depth (m)
0
20
40
60
80
100
120
140
0
1
2
3
4
5
Excess Ra223 (dpm m-3)
Excess Ra224 (dpm m-3)
0
2
4
6
8
10
12
0
1
2
3
4
5
Excess Ra223 (dpm m-3)