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Modeling the seasonal cycle of iron and carbon fluxes in the Amundsen Sea Polynya, Antarctica

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- Tables S1 to S3 with their caption
- Figures S1 to S16 with their caption

Additional Supporting Information (Files uploaded separately)

- Caption for Video S1 (file `2018jcxxxxxx-ms01.mp4`)

Introduction

The Supporting information consists of three tables documenting the equations and parameters of the biogeochemical module (Tables S1 to S3), 16 figures providing model-data comparisons for all the ASPIRE stations where dissolved inorganic nitrogen (DIN) and particulate organic nitrogen (PON) data were available, and a video illustrating the evolution of the simulated summer bloom (Video S1). All figures originate from the model simulation described in the main manuscript (see Section Methods).

Video S1. Video file `2018jcxxxxxx-ms01.mp4`
The video illustrates the typical evolution of the simulated summer bloom. The four panels of the video are (in clockwise order and starting in upper-left corner): simulated sea ice concentration, surface nitrate (NO3), surface dissolved iron (dFe), and surface particulate organic nitrogen (PON) during austral summer 2010–2011 (November 1, 2010 to March 31, 2011).
Note: The movie must be downloaded onto your computer device and then played from your device. Under most browsers: Right-click on the link to the movie on the journal website, and select 'Save file as'.

Table S1: State variable equations for nitrogen and iron. Advective and diffusive terms are omitted for simplicity. Nitrogen terms have units of mmol-N m^{-3} day^{-1} while iron terms have units of μmol-Fe m^{-3} day^{-1}. The symbol + indicates a source term and the symbol − a sink. Arrows indicate fluxes between variables. The functions and parameters are further detailed in Tables S2,S3 (respectively). See Section Methods of the manuscript for additional information and justifications.

Var. (Symbol)	Term	Equation
Dissolved inorganic nitrogen (DIN)	Rate of change =	$\partial DIN/\partial t =$
	− Phyto uptake ($\rightarrow N_P$)	$-U\,N_P$
	+ Excretion ($\leftarrow N_Z$)	$+E\,G\,N_Z$
	+ Remineralization ($\leftarrow N_{SD}$)	$+R_{SD}\,N_{SD}$
	+ Remineralization ($\leftarrow N_{LD}$)	$+R_{LD}\,N_{LD}$
Phytoplankton nitrogen (N_P)	Rate of change =	$\partial N_P/\partial t =$
	+ Phyto uptake ($\leftarrow DIN$)	$+U\,N_P$
	− Grazing ($\rightarrow N_Z$)	$-G\,N_Z$
	− Mortality phyto ($\rightarrow N_{SD}$)	$-m_P\,N_P$
	− Aggregation ($\rightarrow N_{LD}$)	$-A\,(N_{SD}+N_P)\,N_P$
	− Sinking ($\rightarrow$ sediments)	$-w_P\,\partial N_P/\partial z$
Zooplankton nitrogen (N_Z)	Rate of change =	$\partial N_Z/\partial t =$
	+ Grazing ($\leftarrow N_P$)	$+G\,N_Z$
	− Excretion ($\rightarrow DIN$)	$-E\,G\,N_Z$
	− Mortality zoo ($\rightarrow N_{LD}$)	$-m_Z\,N_Z$
Small detrital nitrogen (N_{SD})	Rate of change =	$\partial N_{SD}/\partial t =$
	+ Mortality phyto ($\leftarrow N_P$)	$+m_P\,N_P$
	− Aggregation ($\rightarrow N_{LD}$)	$-A\,(N_{SD}+N_P)\,N_{SD}$
	− Remineralization ($\rightarrow DIN$)	$-R_{SD}\,N_{SD}$
	+ Disaggregation ($\leftarrow N_{LD}$)	$+\psi\,N_{LD}$
	− Sinking ($\rightarrow$ sediments)	$-w_{SD}\,\partial N_{SD}/\partial z$
Large detrital nitrogen (N_{LD})	Rate of change =	$\partial N_{LD}/\partial t =$
	+ Mortality zoo ($\leftarrow N_Z$)	$+m_Z\,N_Z$
	+ Aggregation ($\leftarrow N_{SD}+N_P$)	$+A\,(N_{SD}+N_P)^2$
	− Remineralization ($\rightarrow DIN$)	$-R_{LD}\,N_{LD}$
	− Disaggregation ($\rightarrow N_{SD}$)	$-\psi\,N_{LD}$
	− Sinking ($\rightarrow$ sediment)	$-w_{LD}\,\partial N_{LD}/\partial z$
Dissolved iron (dFe)	Rate of change =	$\partial dFe/\partial t =$
	− Phyto uptake ($\rightarrow Fe_P$)	$-U\,FeN\,N_P$
	− Scavenging ($\rightarrow Fe_{SD}$)	$-S_{SD}\,N_{SD}\,dFe$
	+ Remineralization ($\leftarrow Fe_{SD}$)	$+R_{SD}\,Fe_{SD}$
	+ Remineralization ($\leftarrow Fe_{LD}$)	$+R_{LD}\,Fe_{LD}$
Phytoplankton iron (Fe_P)	Rate of change =	$\partial Fe_P/\partial t =$
	+ Phyto uptake ($\leftarrow F_P$)	$+U\,FeN\,N_P$
	− Grazing ($\rightarrow F_{LD}$)	$-Fe_P\frac{G\,N_Z}{N_P}$
	− Mortality phyto ($\rightarrow F_{SD}$)	$-m_P\,Fe_P$
	− Aggregation ($\rightarrow F_{LD}$)	$-A\,(N_SD+N_P)\,Fe_P$
	− Sinking ($\rightarrow$ sediments)	$-w_P\,\partial Fe_P/\partial z$
Small detrital iron (Fe_{SD})	Rate of change =	$\partial Fe_{SD}/\partial t =$
	+ Mortality phyto ($\leftarrow Fe_P$)	$+m_P\,Fe_P$
	+ Scavenging ($\leftarrow dFe$)	$+S_{SD}\,N_{SD}\,dFe$
	− Aggregation ($\rightarrow Fe_{LD}$)	$-A\,(N_{SD}+N_P)\,Fe_{SD}$
	− Remineralization ($\rightarrow dFe$)	$-R_{SD}\,Fe_{SD}$
	+ Disaggregation ($\leftarrow Fe_{LD}$)	$+\psi\,Fe_{LD}$
	− Sinking ($\rightarrow$ sediments)	$-w_{SD}\,\partial Fe_{SD}/\partial z$
Large detrital iron (Fe_{LD})	Rate of change =	$\partial Fe_{LD}/\partial t =$
	+ Grazing ($\leftarrow Fe_P$)	$+Fe_P\frac{G\,N_Z}{N_P}$
	+ Aggregation ($\leftarrow Fe_{SD}+Fe_P$)	$+A\,(N_{SD}+N_P)\,(Fe_{SD}+Fe_P)$
	− Remineralization ($\rightarrow dFe$)	$-R_{LD}\,Fe_{LD}$

− Sinking (→ sediments)	$-w_{LD}\,\partial Fe_{LD}/\partial z$
− Disaggregation (→ Fe_{SD})	$-\psi\,Fe_{LD}$

Table S 2: Definition of functions used in state variable equations. See the section Methods of the manuscript for additional information and justifications.

Symbol	Description	Equation	Units
U	Phytoplankton growth rate	$P_{\max}\min\left(\frac{dFe}{k_F+dFe}, \frac{DIN}{k_N+DIN}\right)\frac{\alpha\, I}{\sqrt{\alpha^2 I^2+P_{\max}^2}}$	day^{-1}
I	Photosynthetically active radiation	$\partial I/\partial z = -k_{\mathrm{d}}\, I$	W m^{-2}
k_{d}	Light attenuation	$0.04 + 0.04 N_P$	m^{-1}
G	Grazing rate	$G_{\max}\frac{N_P^2}{k_P+N_P^2}$	day^{-1}

Table S 3: Definition of biogeochemical parameters used in state variable equations. The parameter values used in *Oliver et al.* (submitted) are indicated if they differ from the present study. See the section Methods of the manuscript for additional information and justifications.

Symbol	Description	Value	Oliver et al.	Units
A	Aggregation rate phyto+small det.	0.0025	0.0014	$\left(\text{mmol-N m}^{-3}\right)^{-1}\text{day}^{-1}$
ψ	Disaggreg. rate of large particles	0.01	n/a	day^{-1}
E	Excretion of nitrogen by zoo	0.3	0.1	dimensionless
FeN	Fe:N ratio for phyto uptake	2×106 $/(16\times 1000)$		$\mu\text{mol-Fe (mmol-N)}^{-1}$
k_F	Half-sat. constant iron uptake	0.26		$\mu\text{mol-Fe m}^{-3}$
k_N	Half-sat. constant DIN uptake	2.5		mmol-N m^{-3}
k_P	Half-sat. grazing	2.00	0.56	$\left(\text{mmol-N m}^{-3}\right)^2$
α	Initial slope photo-irr. curve	0.06	0.12	$\left(\text{W m}^{-2}\right)^{-1}\text{day}^{-1}$
$P_{\max}$	Phyto growth rate (maximum)	1.6	0.82	day^{-1}
$G_{\max}$	Grazing rate (maximum)	0.3		day^{-1}
m_P	Mortality rate of phytoplankton	0.015	0.005	day^{-1}
m_Z	Mortality rate of zooplankton	0.050	0.140	day^{-1}
R_{SD}	Remineraliz. rate of small det.	0.010	0.005	day^{-1}
R_{LD}	Remineraliz. rate of large det.	0.010	0.050	day^{-1}
S_{SD}	Scavenging rate of dFe	0.05	0.03	$\left(\text{mmol-N m}^{-3}\right)^{-1}\text{day}^{-1}$
w_P	Sinking of phytoplankton	0.05		m day^{-1}
w_{SD}	Sinking of small detritus	0.71		m day^{-1}
w_{LD}	Sinking of large detritus	5		m day^{-1}

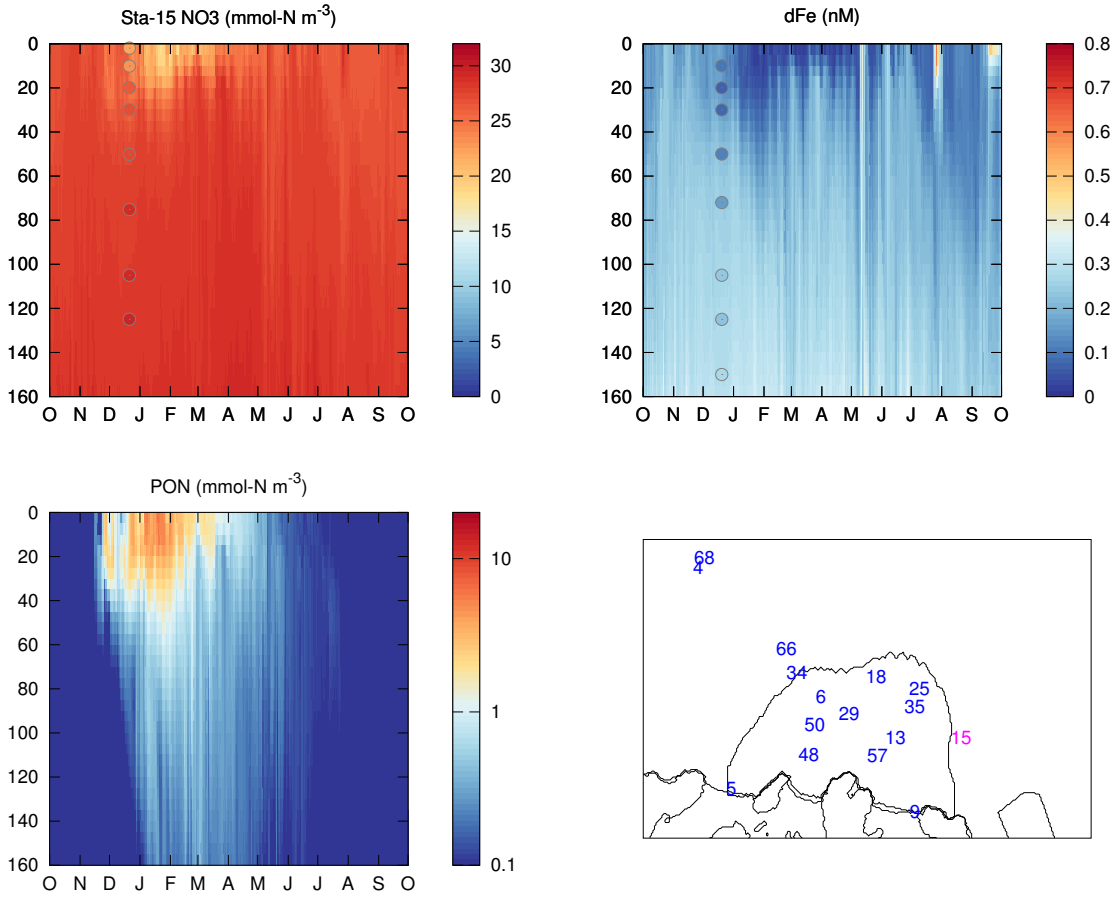

Figure S1: Seasonality of nutrients and particulate organic nitrogen (PON) at Station 15 during the year of the ASPIRE cruise (Oct. 2010 to Sep. 2011). (top left) Dissolved inorganic nitrogen (DIN), (top right) dissolved iron, (lower left) PON, (lower-right) location of the ASPIRE stations relative to the climatological extent of the polynya in January (black contour line). Observations from ASPIRE are represented by colored circles; contoured values are modeled fields. Note the log scale used for PON.

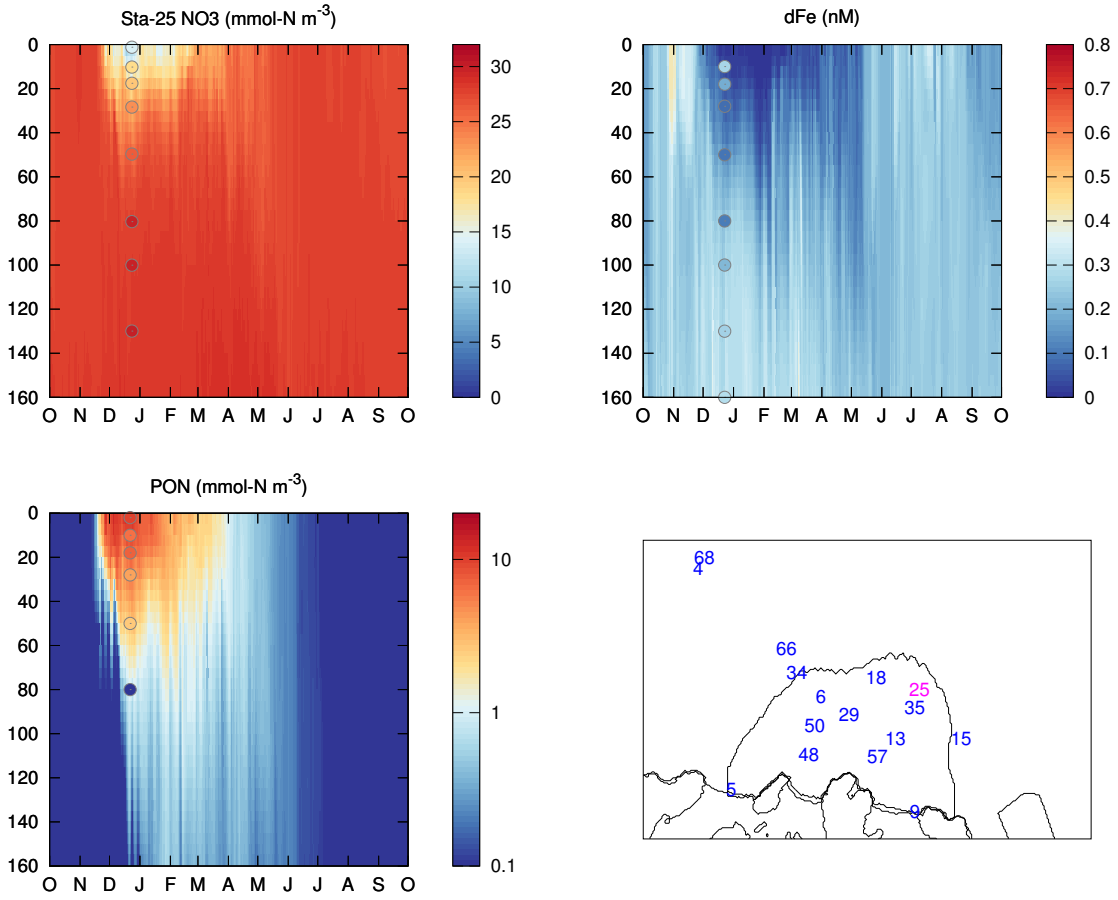

Figure S2: Same as Figure S1 but for Station 25.

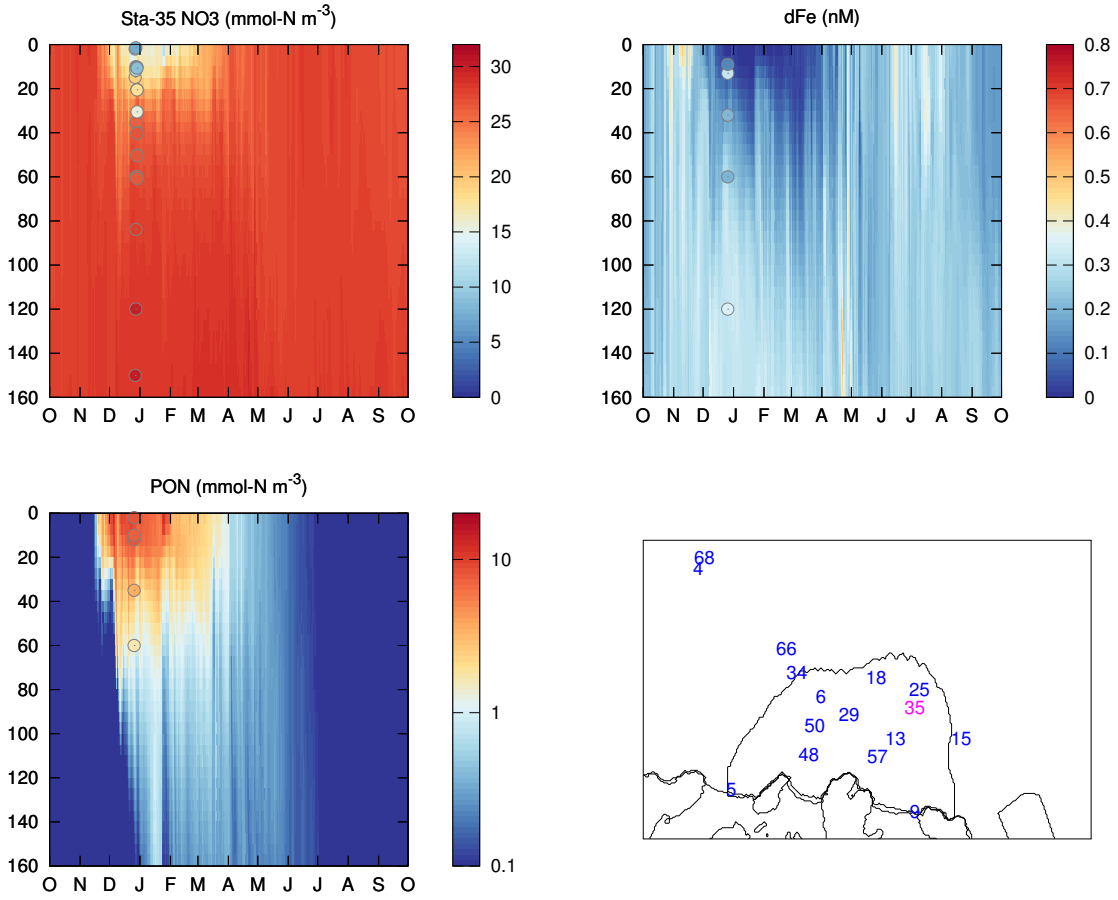

Figure S3: Same as Figure S1 but for Station 35.

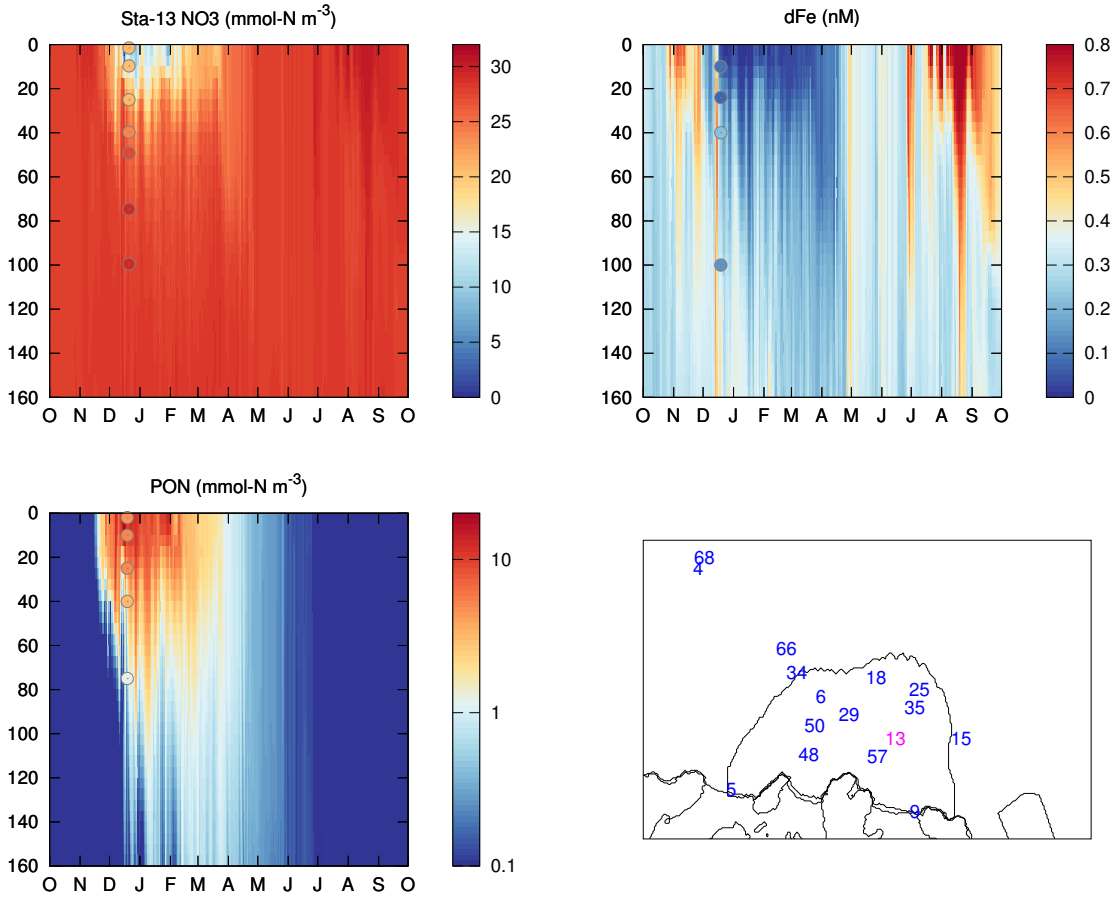

Figure S4: Same as Figure S1 but for Station 13.

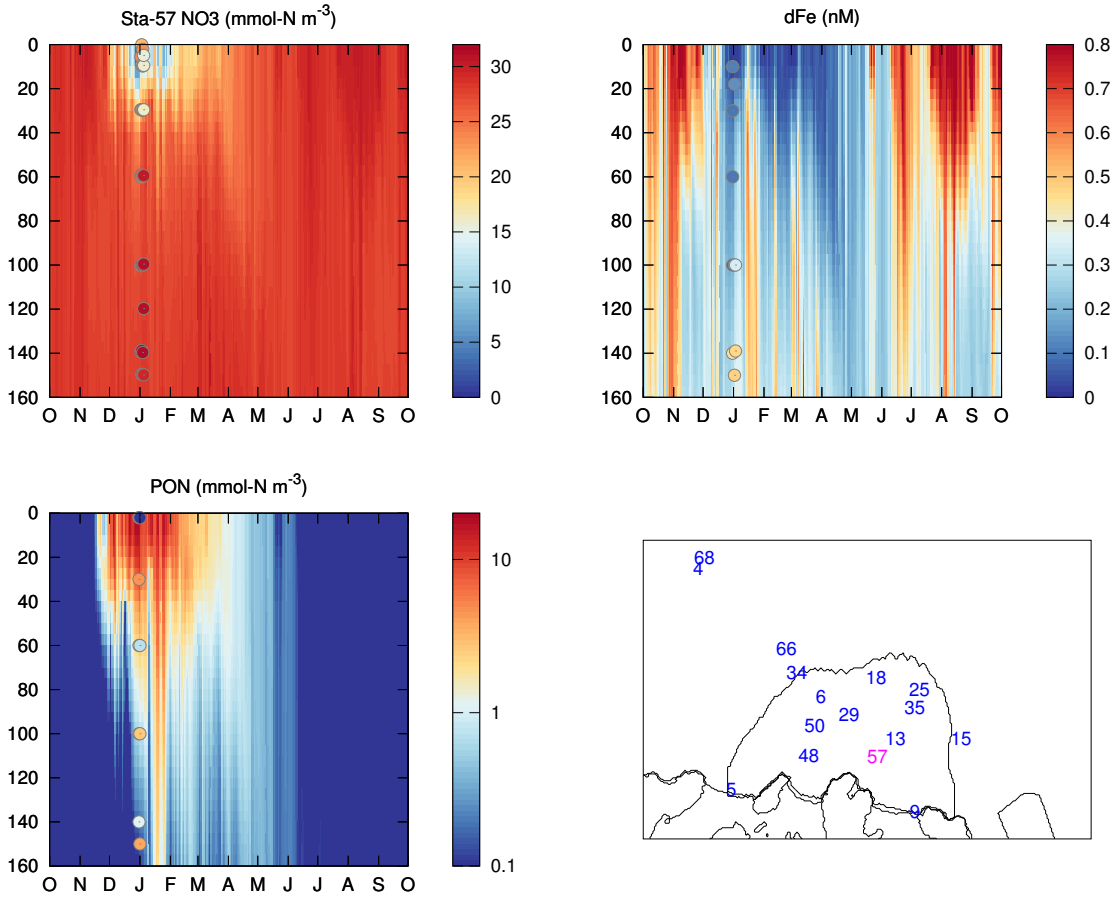

Figure S5: Same as Figure S1 but for Station 57.

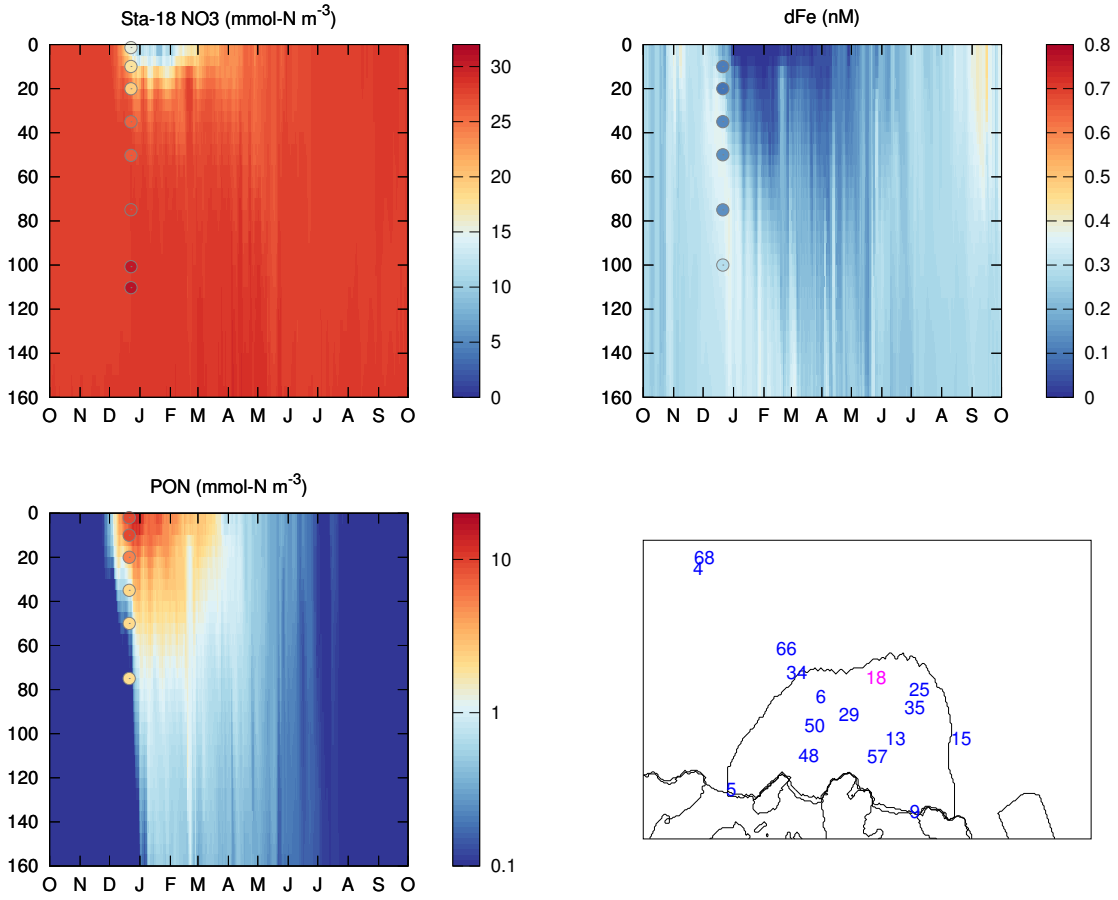

Figure S6: Same as Figure S1 but for Station 18.

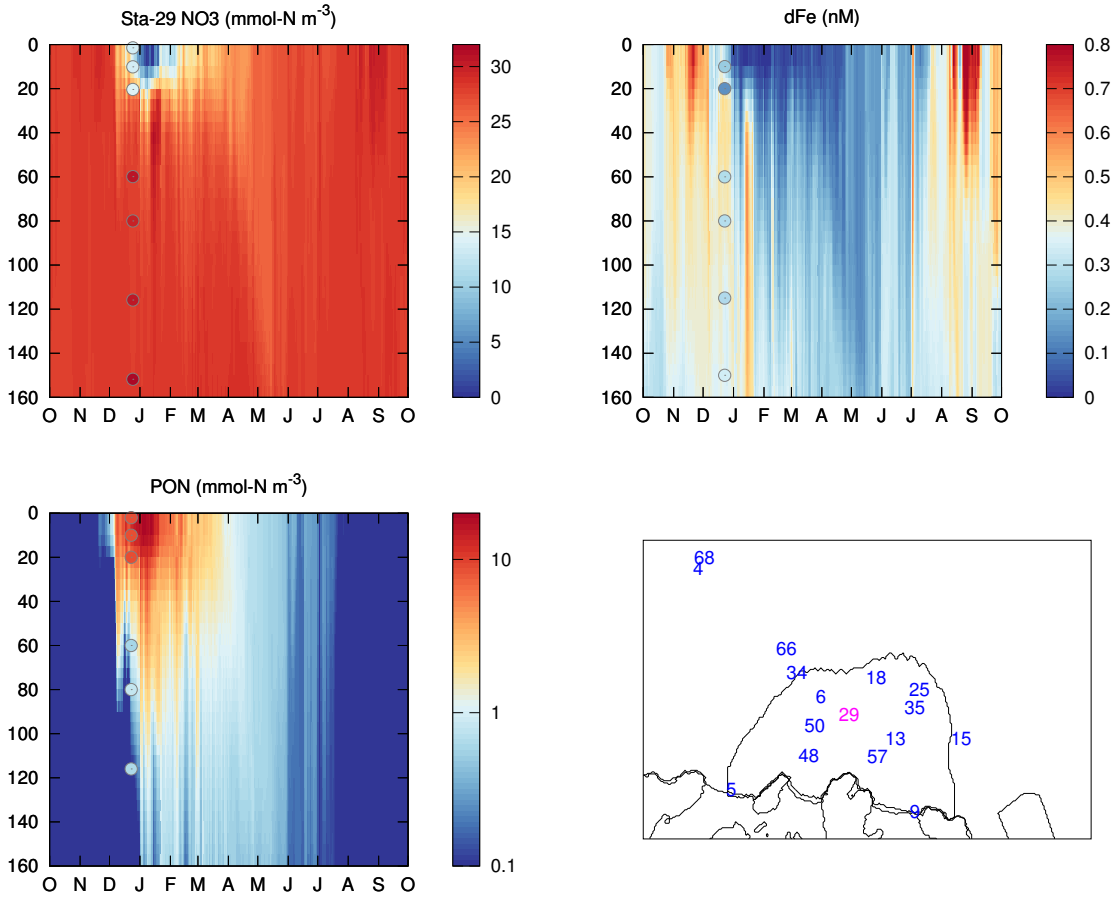

Figure S7: Same as Figure S1 but for Station 29.

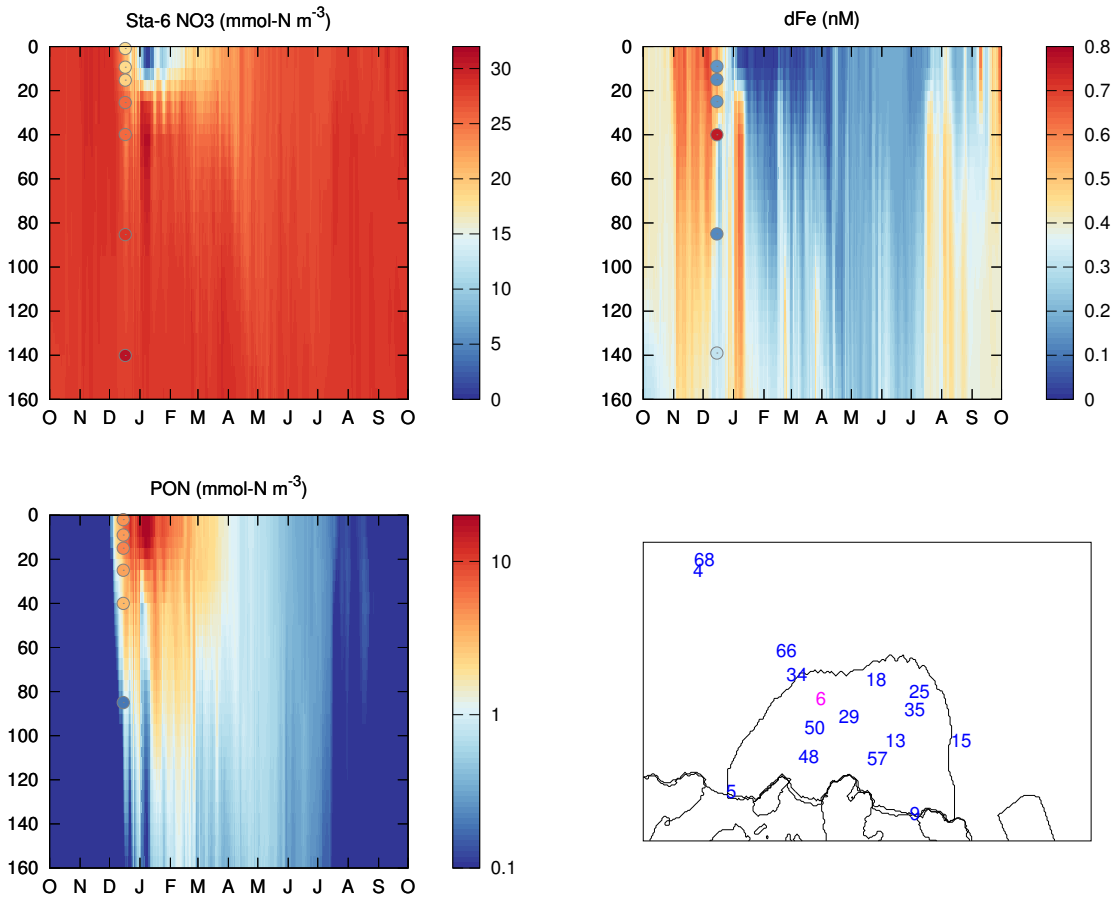

Figure S8: Same as Figure S1 but for Station 6.

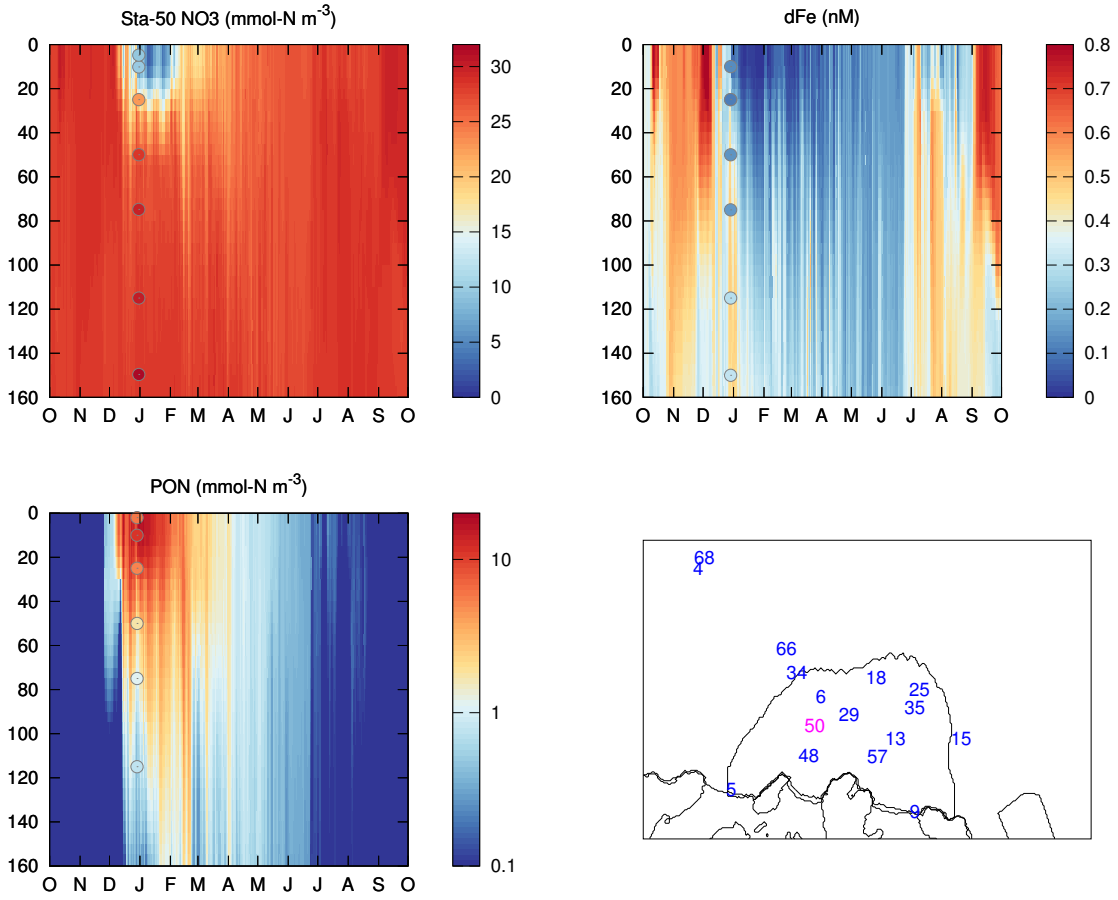

Figure S9: Same as Figure S1 but for Station 50.

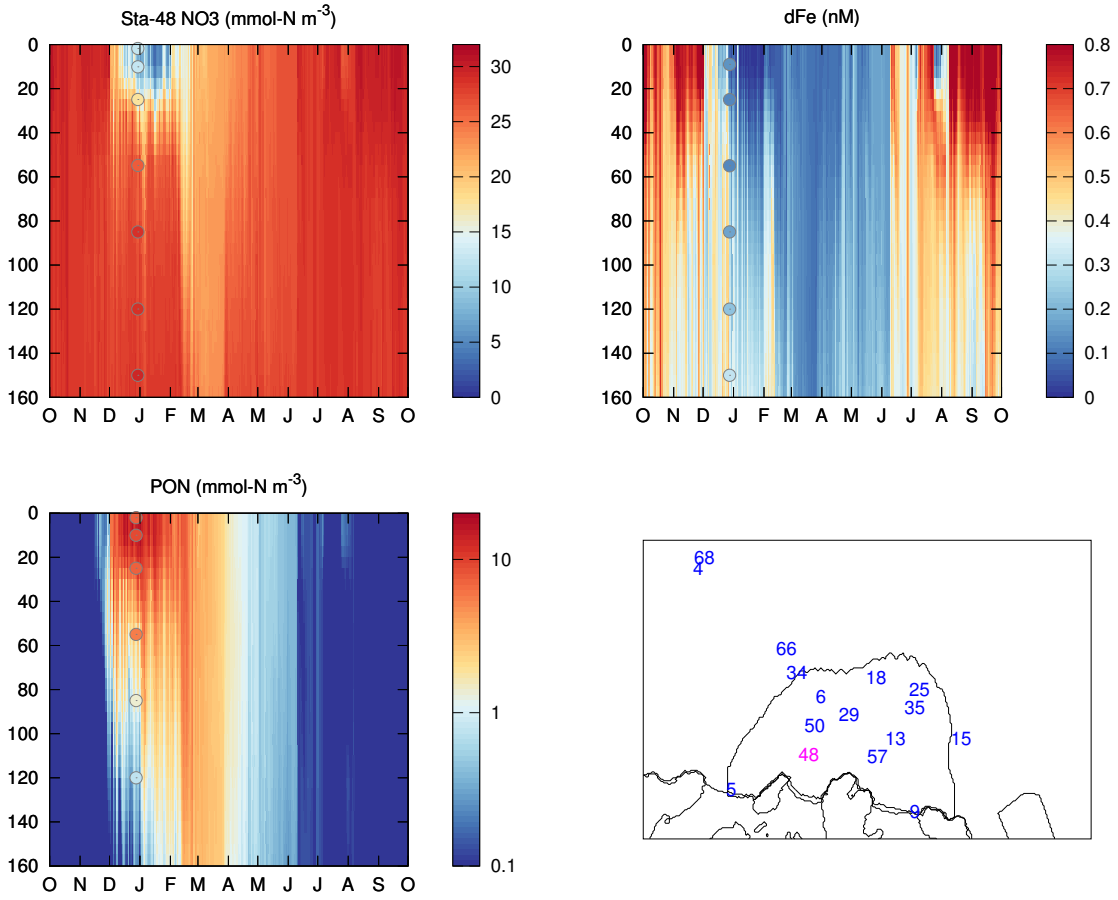

Figure S10: Same as Figure S1 but for Station 48.

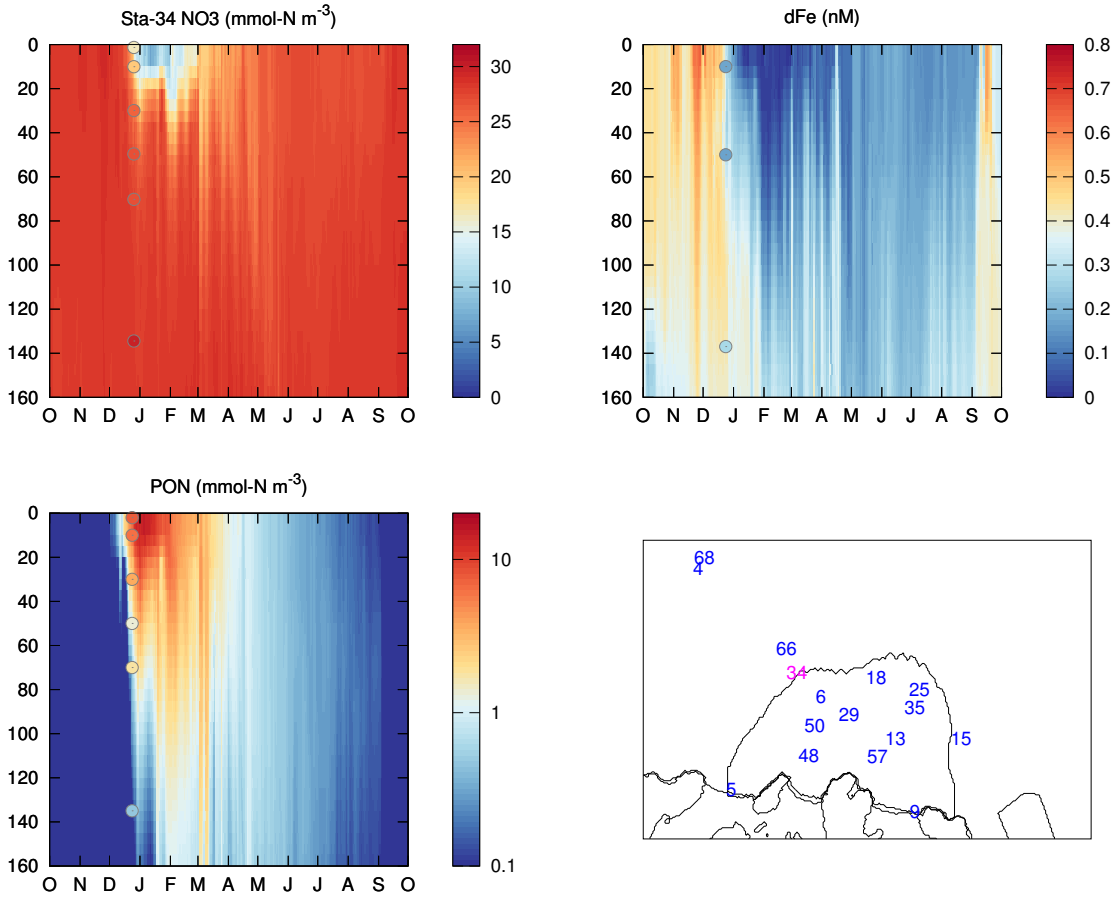

Figure S11: Same as Figure S1 but for Station 34.

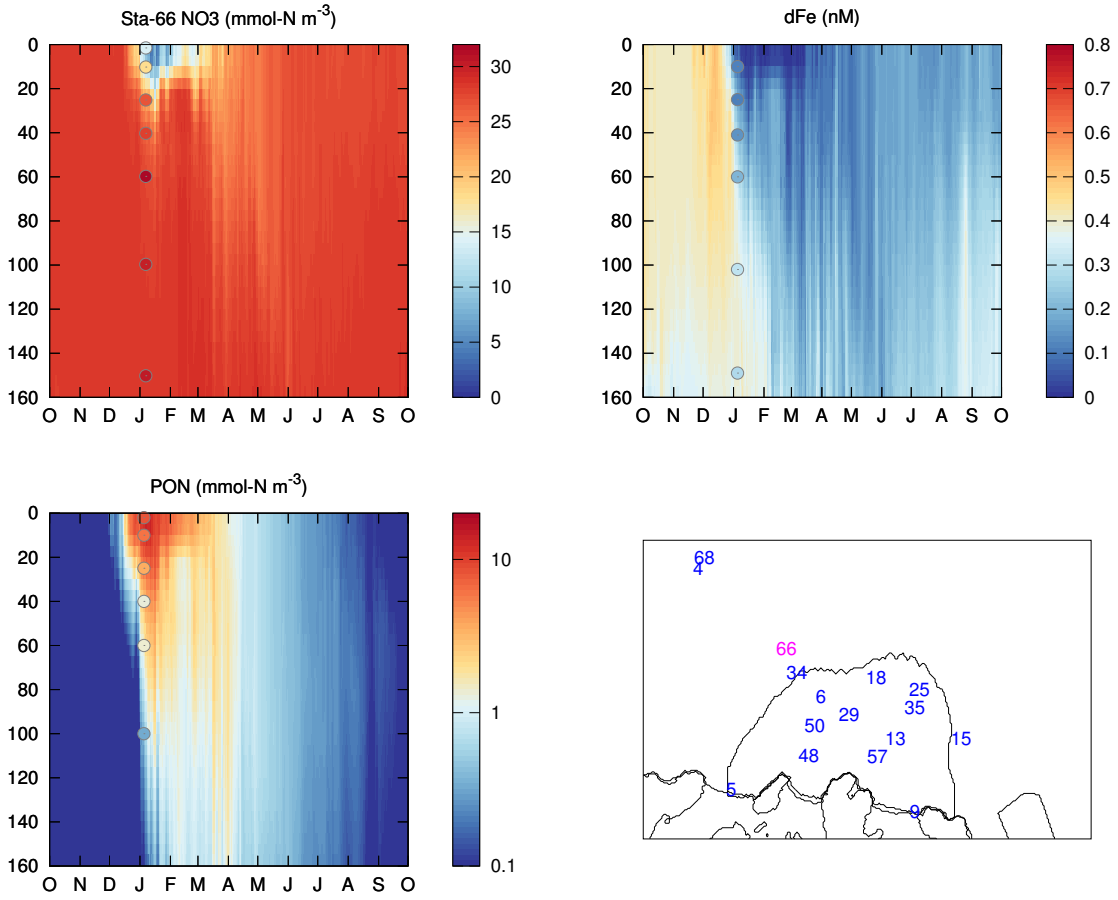

Figure S12: Same as Figure S1 but for Station 66.

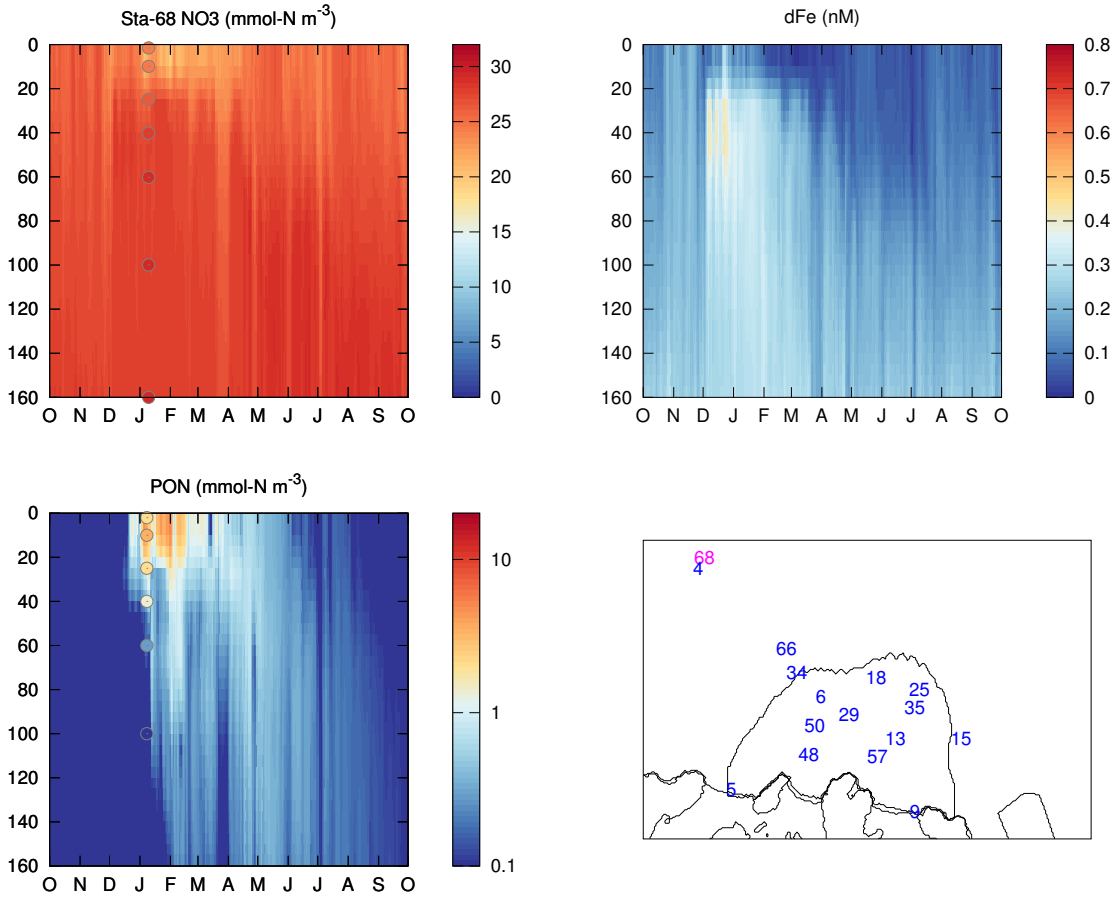

Figure S13: Same as Figure S1 but for Station 68.

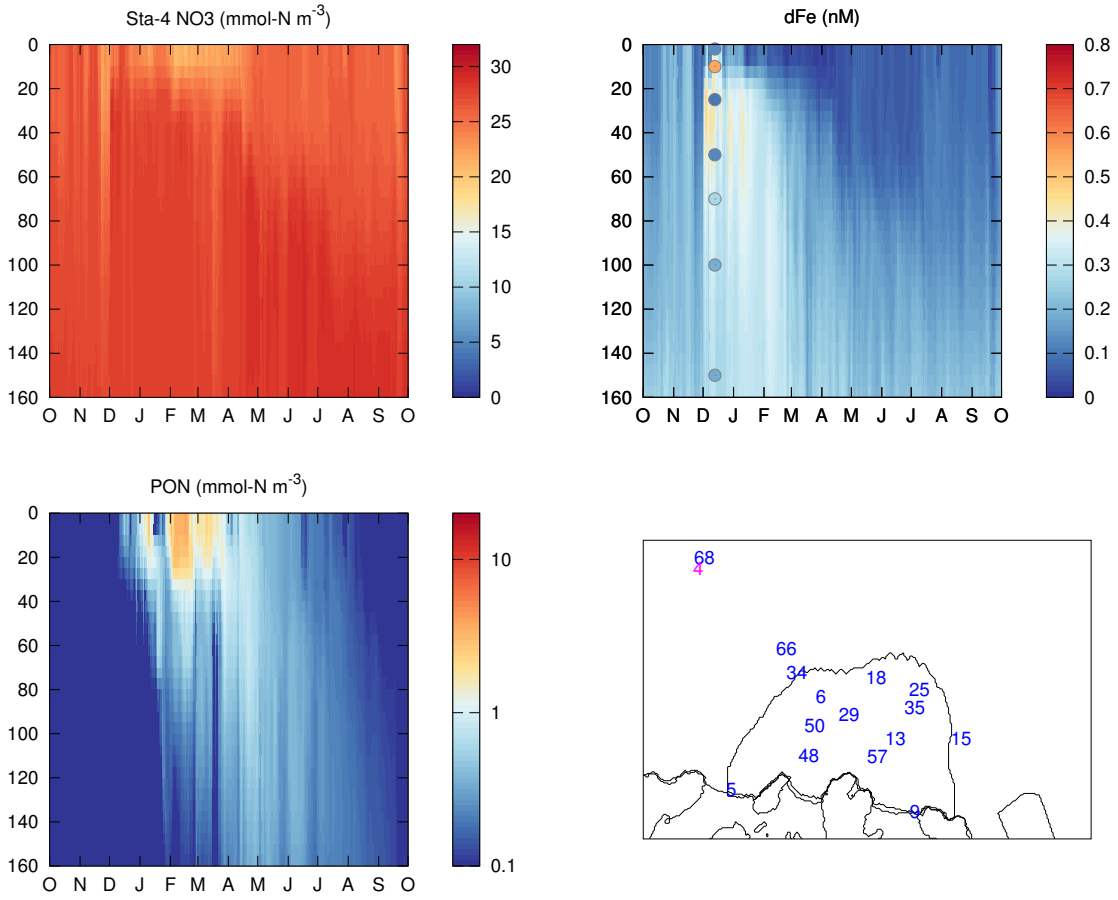

Figure S14: Same as Figure S1 but for Station 4.

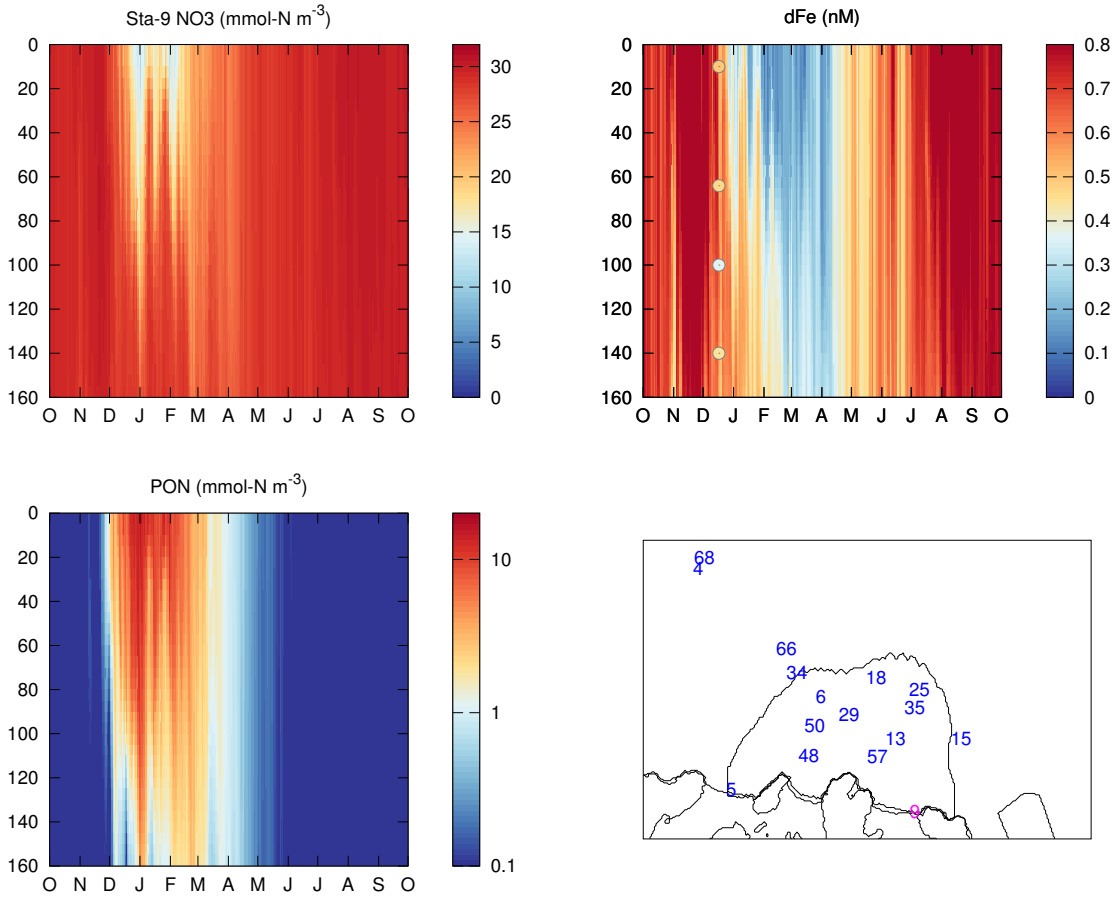

Figure S15: Same as Figure S1 but for Station 9.

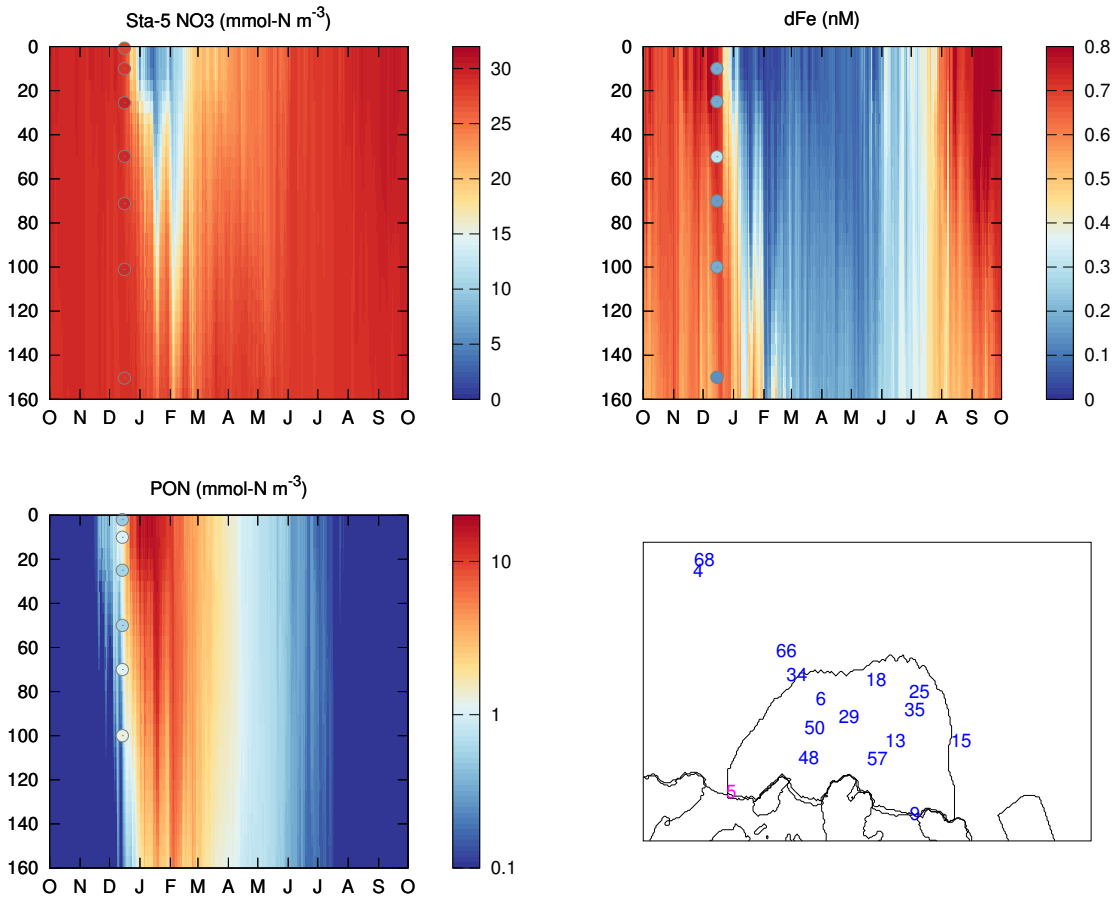

Figure S16: Same as Figure S1 but for Station 5.