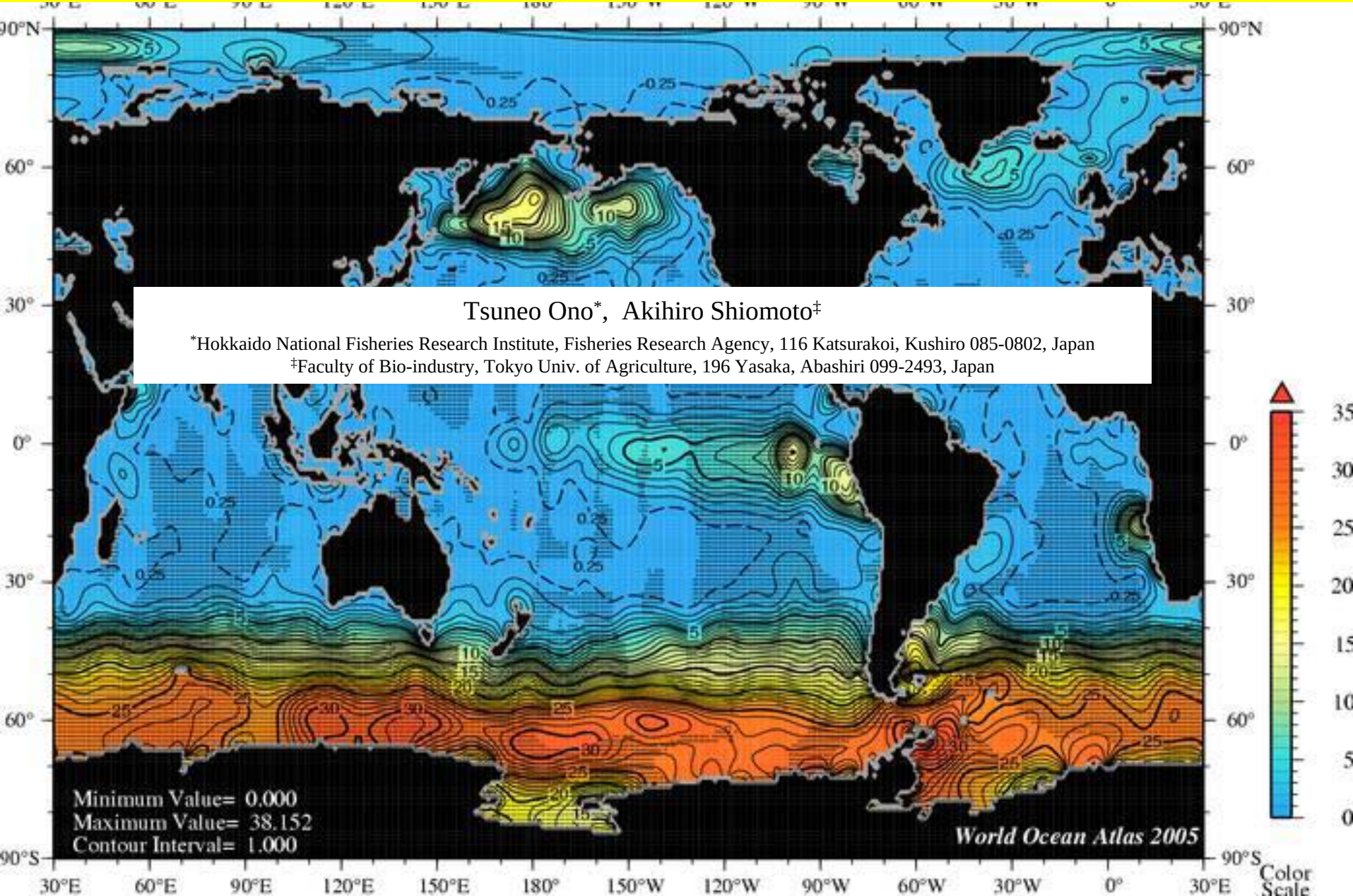
Decadal trend of summer nutrient content in the North Pacific HNLC region



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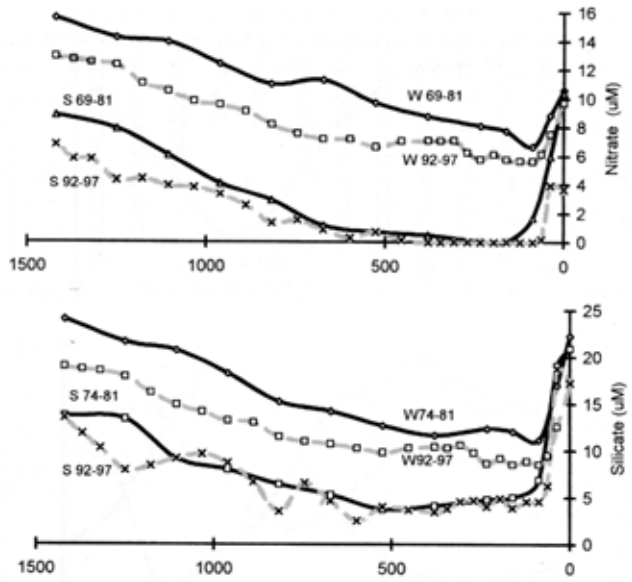
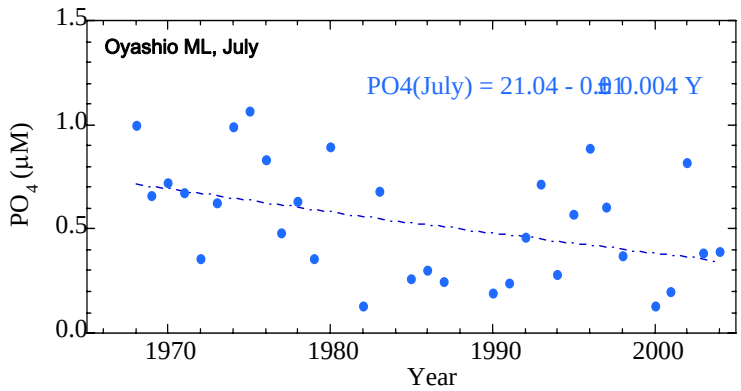
OCEANIC STRATIFICATION & SURFACE NUTRIENT DECREASE IN RECENT NORTH PACIFIC

Eastern North Pacific (Line P, Whitney & Freeland 1999)
ΔNO3 = 1.2 μM/15y



Western subarctic North Pacific (west of 155E, Ono et al.,2002)
ΔPO4 = 0.1 μM/decade



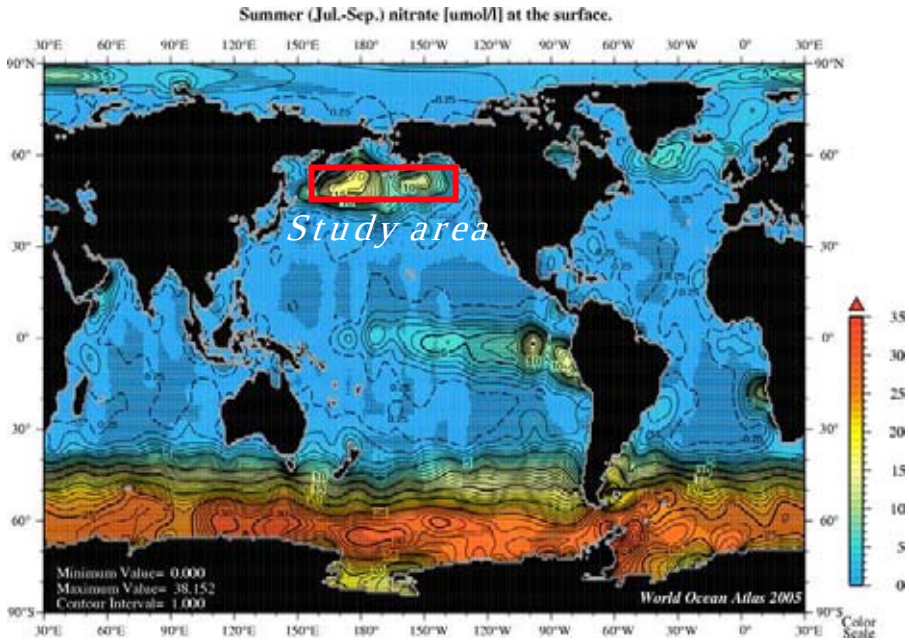
Objective of this study:

Assessment for basin-scale trend of nutrient in summertime mixed layer.....negative trend exist?
What is the cause of nutrient trend ?
What is the ecological consequence ?

Data

Data source:

World Ocean Data base 2005 (http://www.nodc.noaa.gov/OC5/WOD05/pr_wod05.html)
Japan Oceanographic Data Center / J-DOSS (http://jdoss1.jodc.go.jp/NEW_JDOSS_HP/FETI_scalar_doc_e.html)
CDIAC WOCE-ODV collections (http://cdiac.ornl.gov/oceans/pacific_ODV.html)
JGOFS-NPPS Data Set CD-ROM
JMA data CD-ROM



Selection criteria:

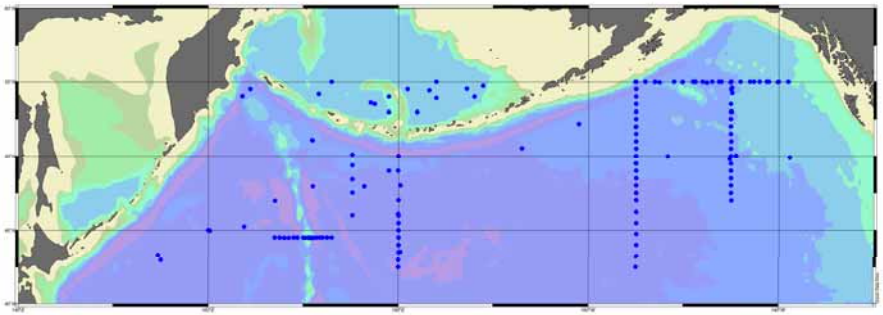
Time span: 1975 - 2002
=>divided to 1975-1990 & 1991-2002
Month: July-Sept.
Area: rectangle 42.5N - 55N, 155E-135W
coastal data (Bottom depth <1000m) are avoided
Depth: a single data nearest to 10m is selected as ML data for each station
Unit: All data are adjusted to μM unit

Obtained data numbers:

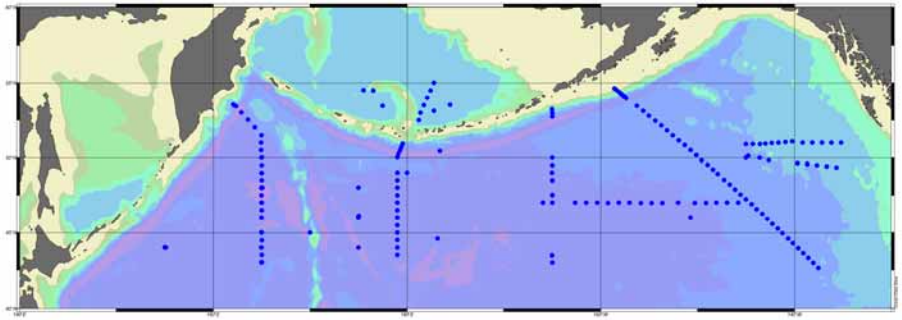
time group	Phosphate	Silicate
1975-1990	170	130
1991-2002	201	148
total	371	278

Data distribution : geographically

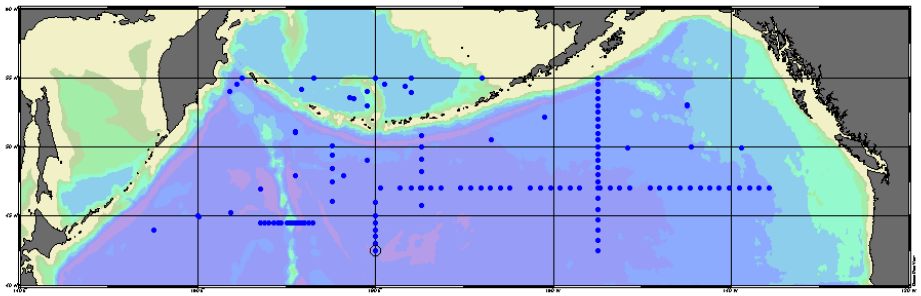
PO4: 1975-1990



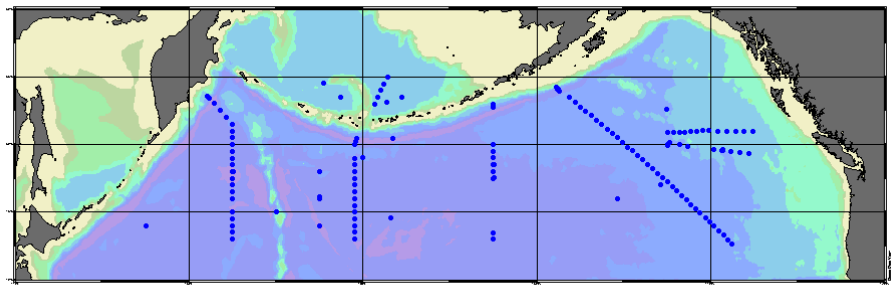
PO4: 1991-2002



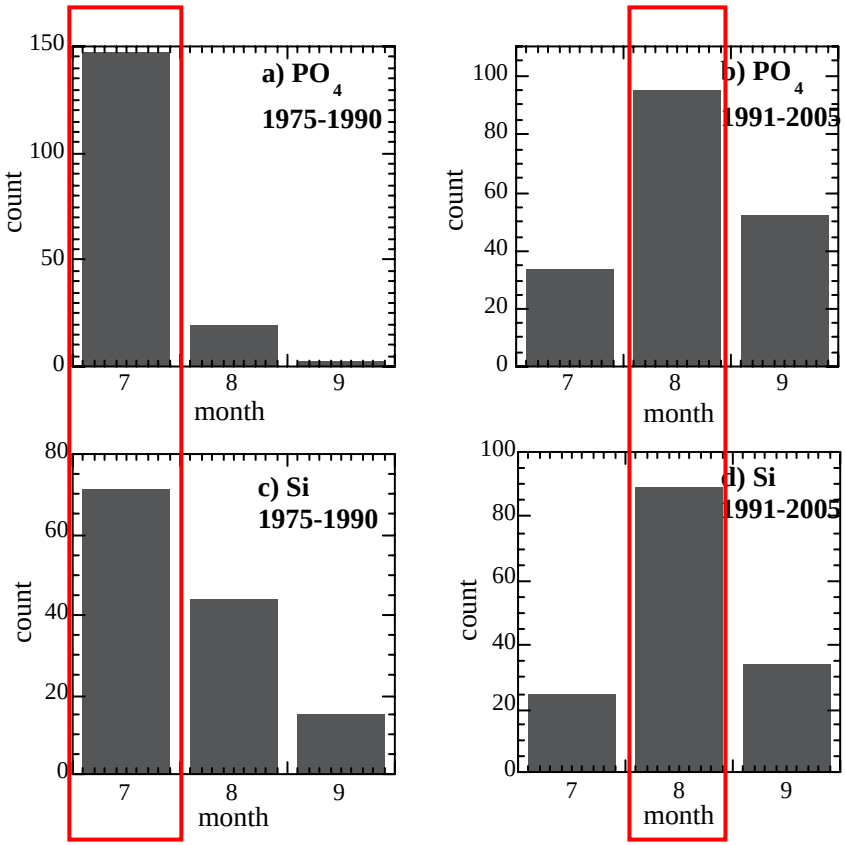
Si: 1975-1990



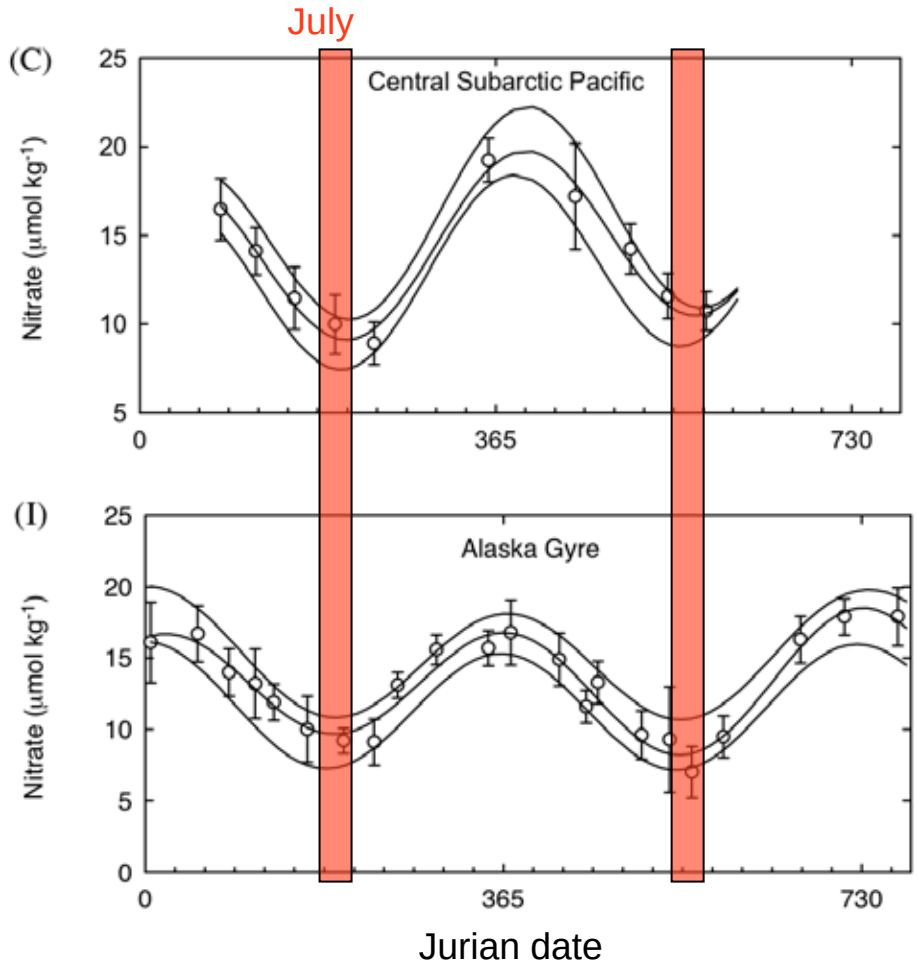
Si: 1991-2002

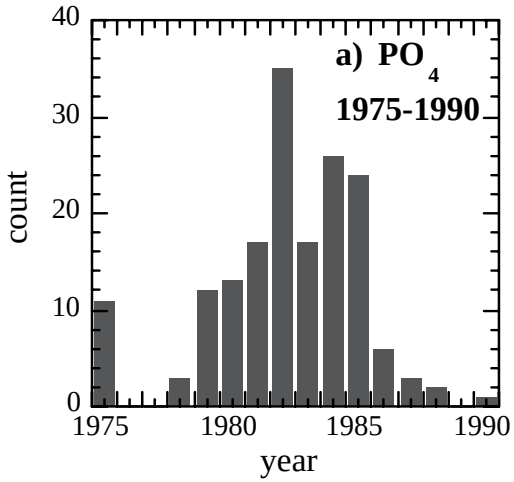


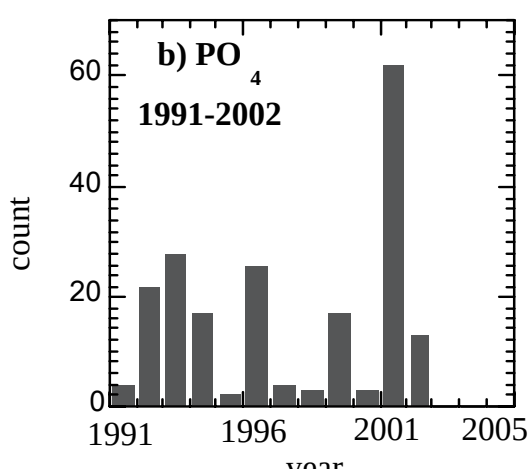
Data distribution : temporaly

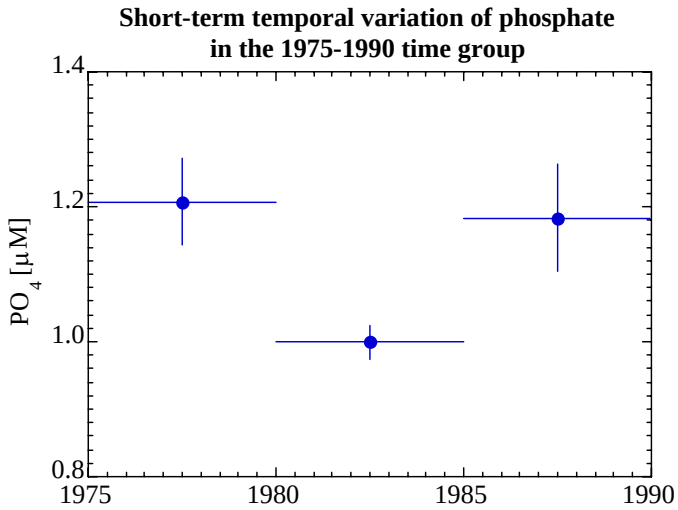


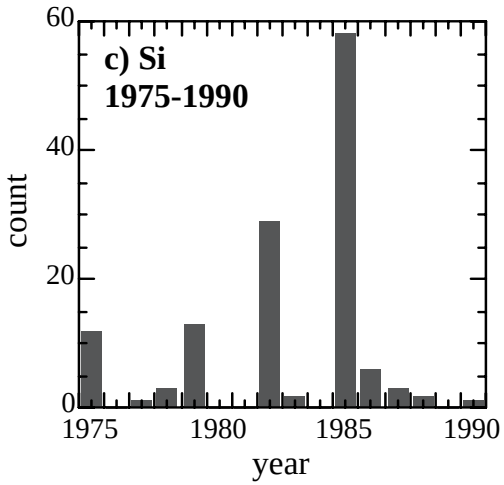
Climatology of surface nitrate at central subarctc North Pacific and Alaskan Gyre [Wong et al., 2002]

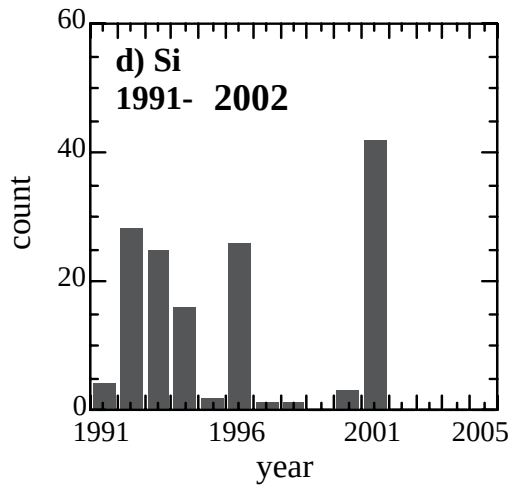


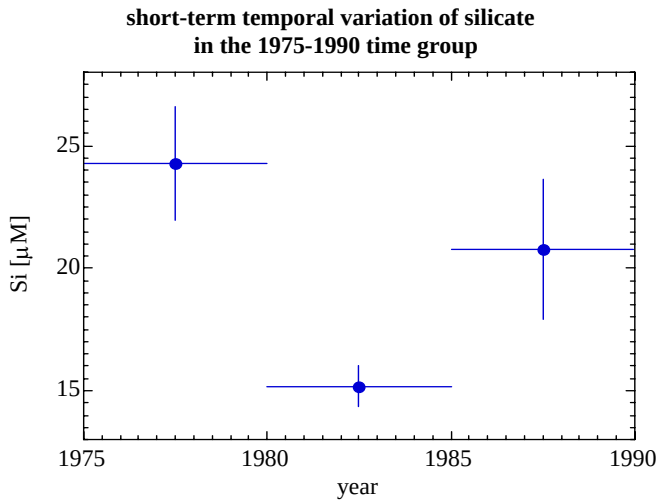

a) PO 4
1975-1990
count
year
0
10
20
30
40
1975
1980
1985
1990


b) PO 4
1991-2002
count
0
20
40
60
1991
1996
2001
2005

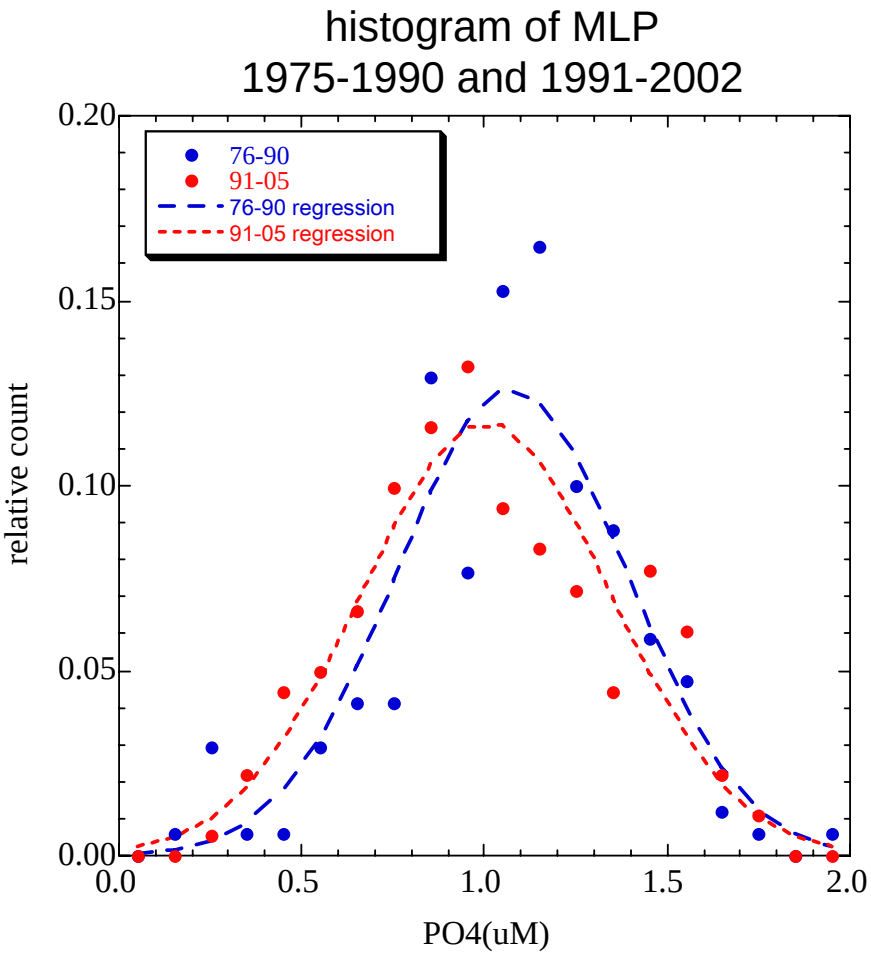

Short-term temporal variation of phosphate
in the 1975-1990 time group
PO 4 [µM]
0.8
1.0
1.2
1.4
1975
1980
1985
1990


c) Si
1975-1990
count
year
0
20
40
60
1975
1980
1985
1990

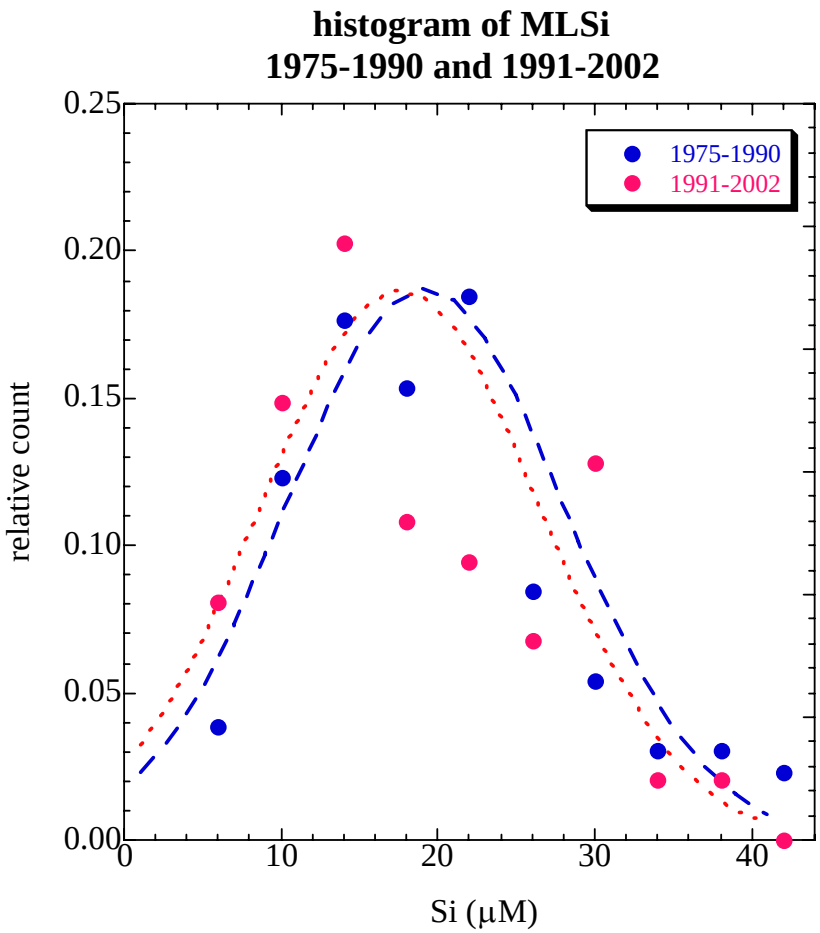

d) Si
1991- 2002
count
year
0
20
40
60
1991
1996
2001
2005


short-term temporal variation of silicate
in the 1975-1990 time group
Si [µM]
15
20
25
1975
1980
1985
1990
year

temporal variation of nutrient : Results



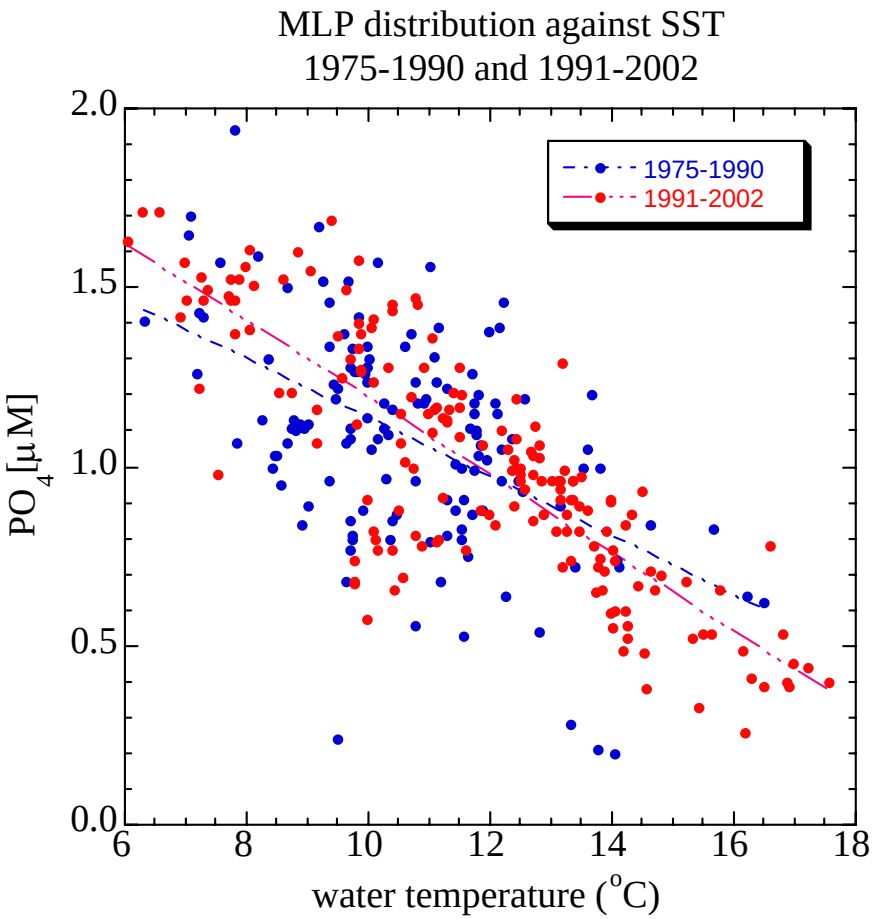
MLPavg = 1.07± 0.02 μM [1975-1990]
1.00± 0.03 μM [1991-2002]
ΔMLPavg = 0.07± 0.05 μM (α =0.05)

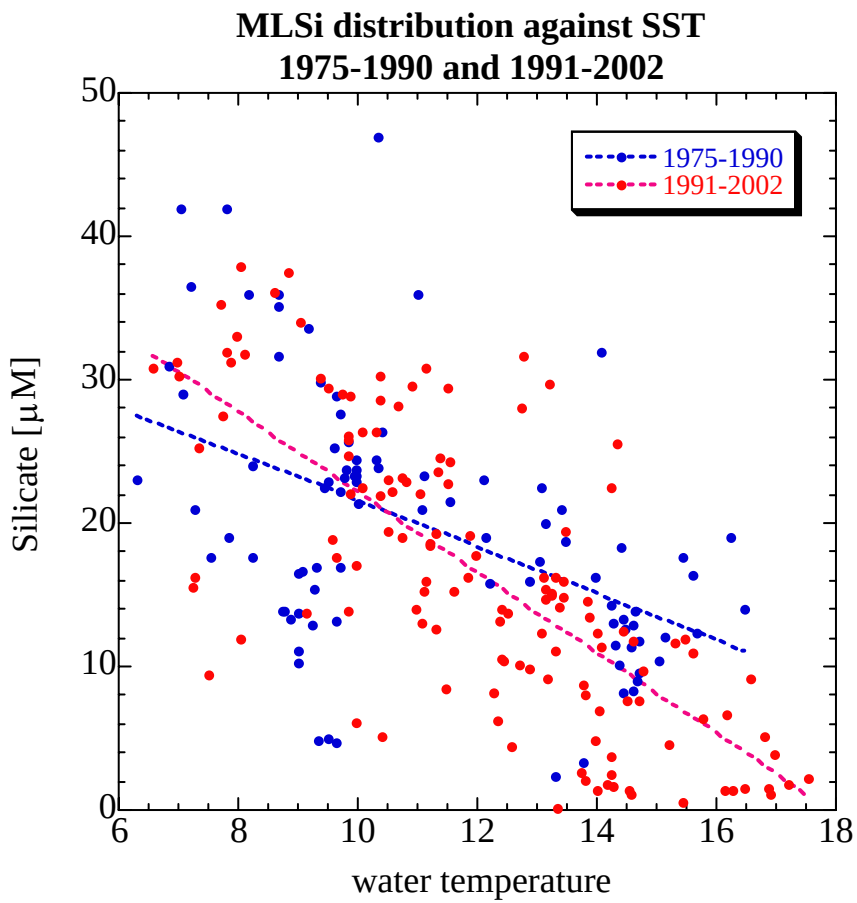


MLSiavg = 19.16± 0.78 μM [1975-1990]
17.61± 0.77 μM [1991-2002]
ΔMLSiavg = 1.55± 1.55 μM (α =0.1)

statistically significant nutrient decrease between 1975-90 and 1991-02 time groups is observed both in P and Si.

*** ΔMLSi / ΔMLP = 22**
this correspond to observed Si:P ratio at subarctic NP surface [Wong et al., 2002])



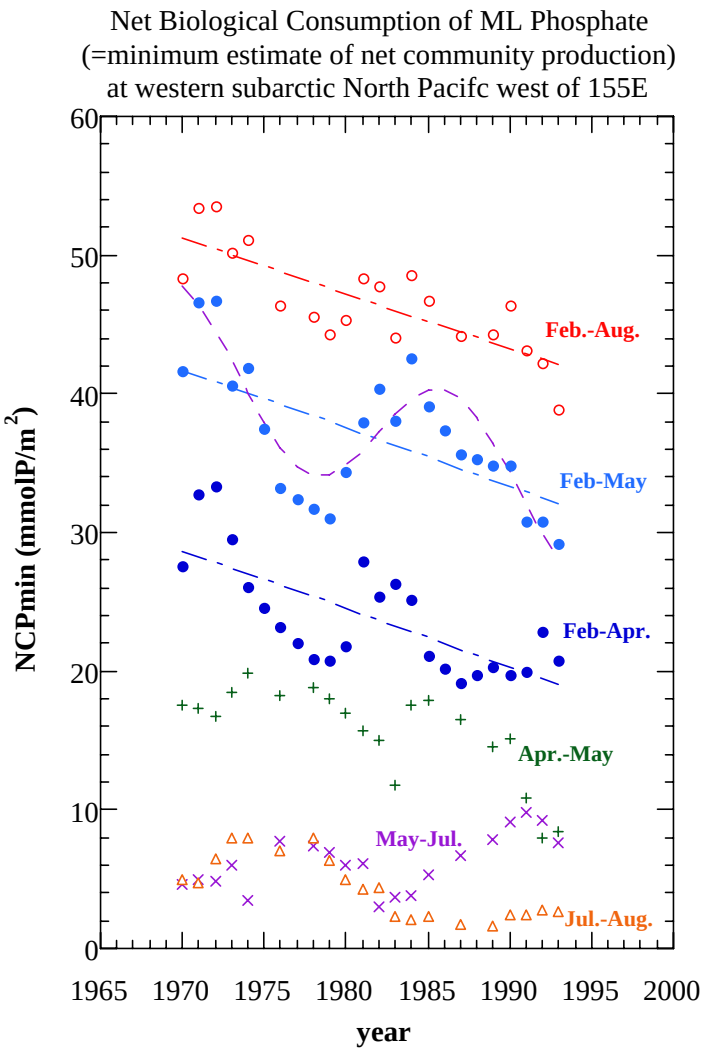


 # no significant change in SST-MLP relationship before 1990 and after then

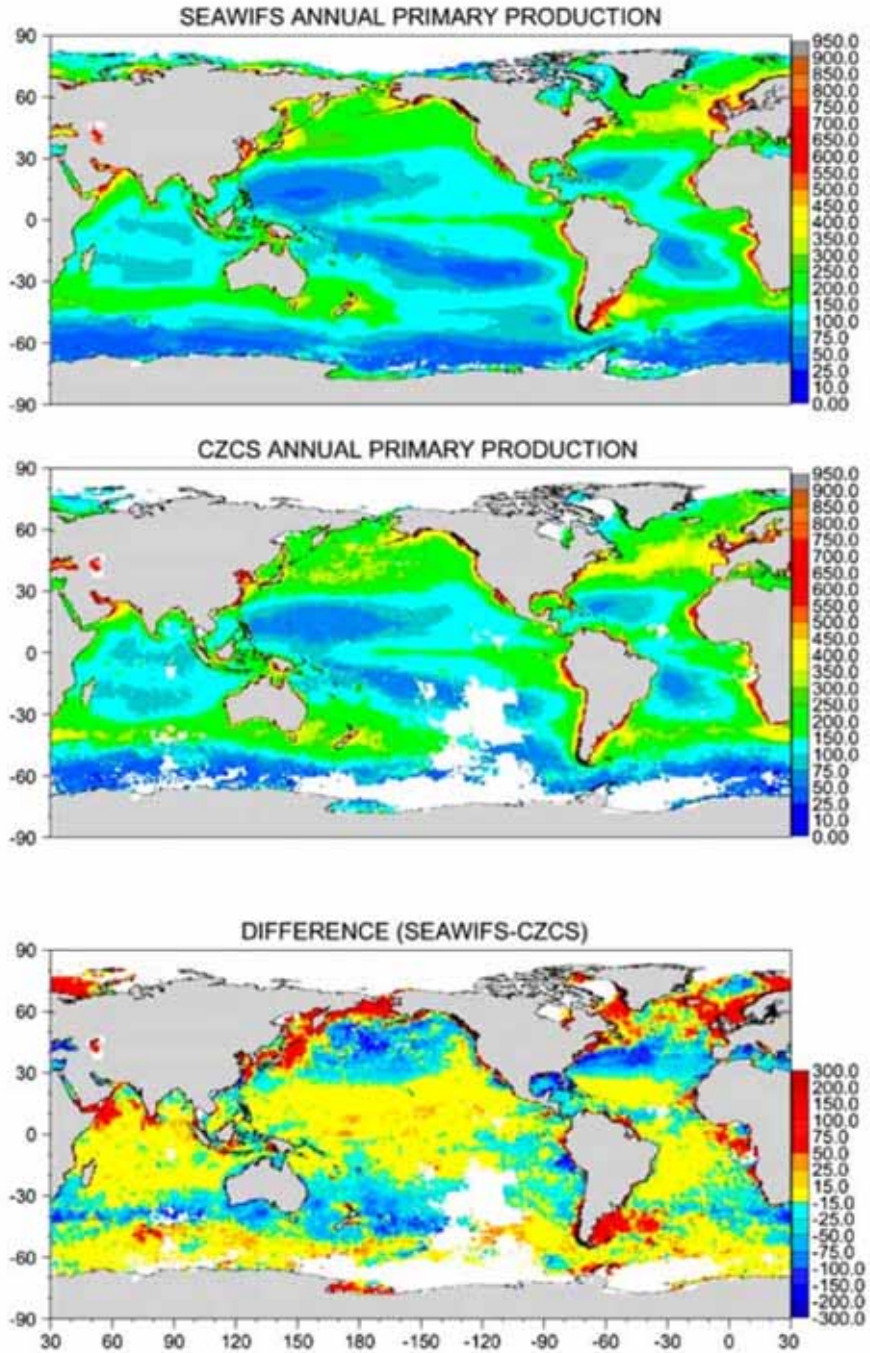
=>observed nutrient decrease must be associated with SST changes

Cause of MLP&MLSi trend

Possibility [1]: decrease in NPP
.....but this is negative



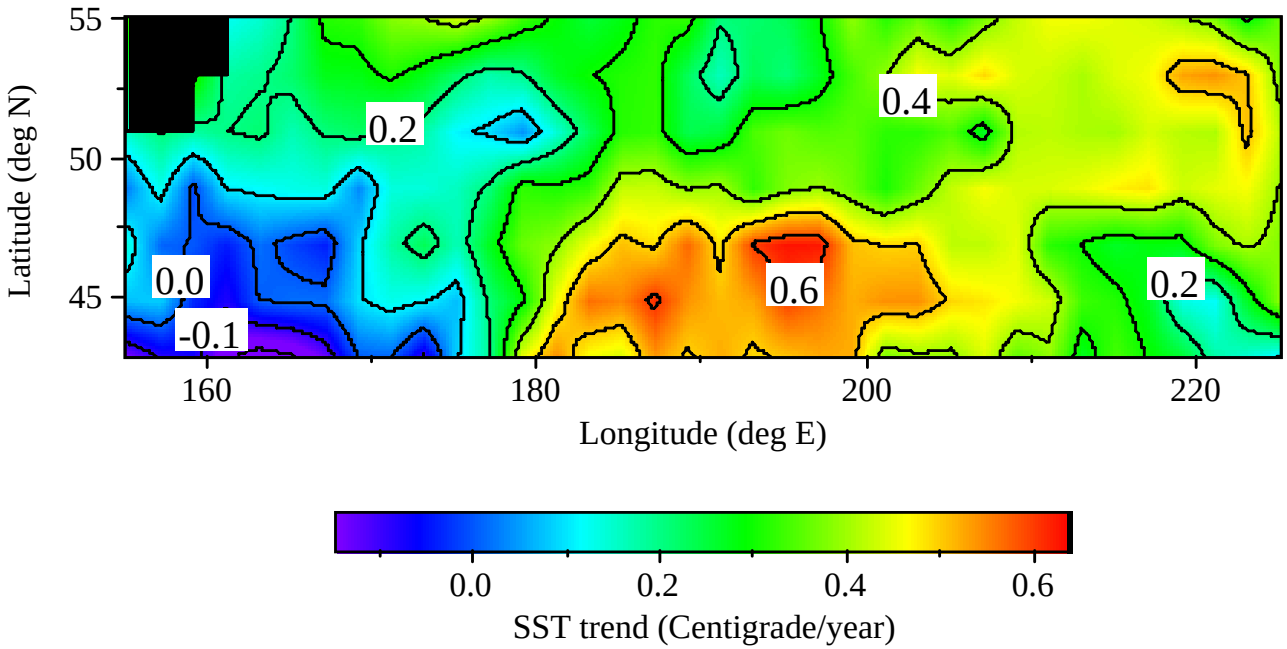
[Ono et al., 2002]



[Gregg, 2003]

Possibility [2]: decrease of nutrient supply under relatively constant NPP

SST trend in the analyzed field from 1975 to 2005based on the JMA 2^0x2^o gridded SST field [http://goos.kishou.go.jp/rrtdb/datainfo.html]

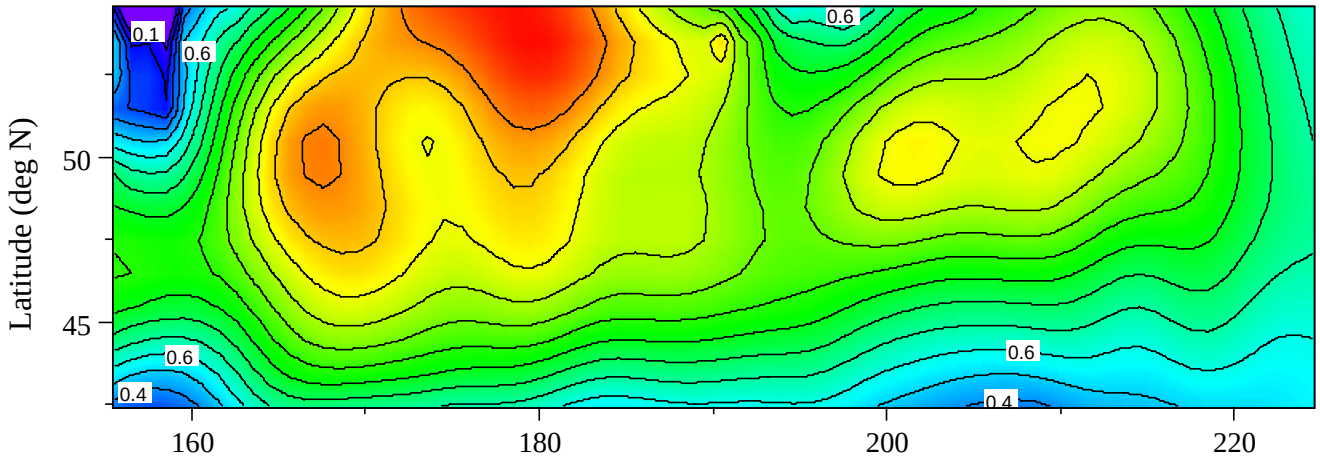


area-average SST trend : 0.30 ± 0.18 ^{0}C/decade
present nutrient-SST relationship at subarctic NP: -0.095 μMP/°C and -2.34 μMSi/°C

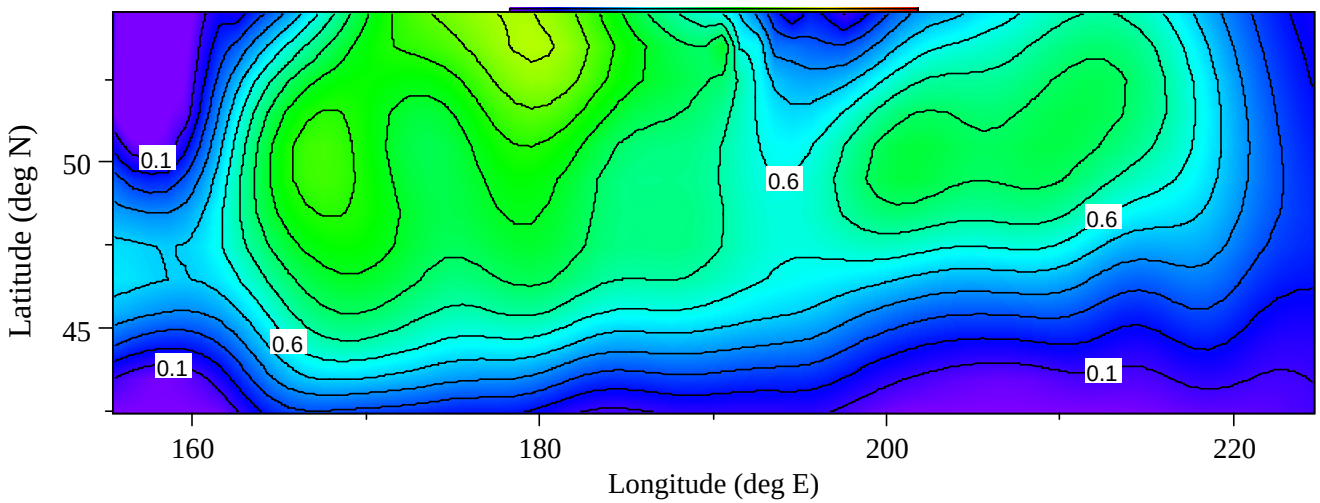
=>expected nutrient trend under the constant nutrient-SST relationship:
-0.03 μMP/decade and -0.7 μMSi /decade
(observation: -0.047± 0.03 μMP/decade and 1.0± 1.0 μMSi/decade)

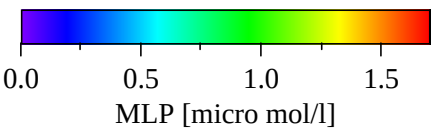
if this trend sustains to 2101.....

Present summer MLP in NP (drown after WOA 2001 grid data)



Predicted summer MLP in 2101 [assuming -0.047μMP/decade decrease]

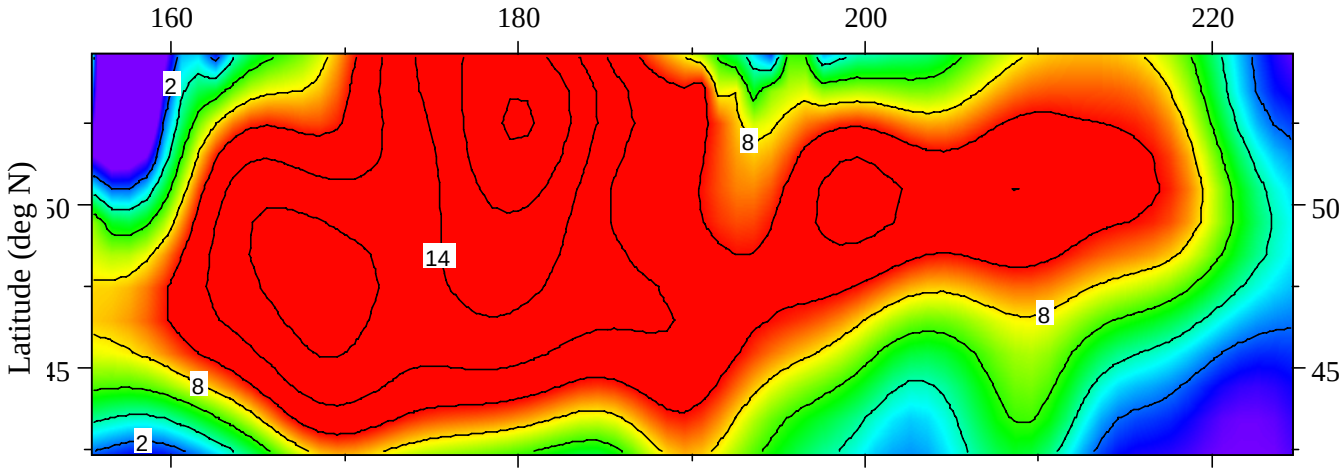




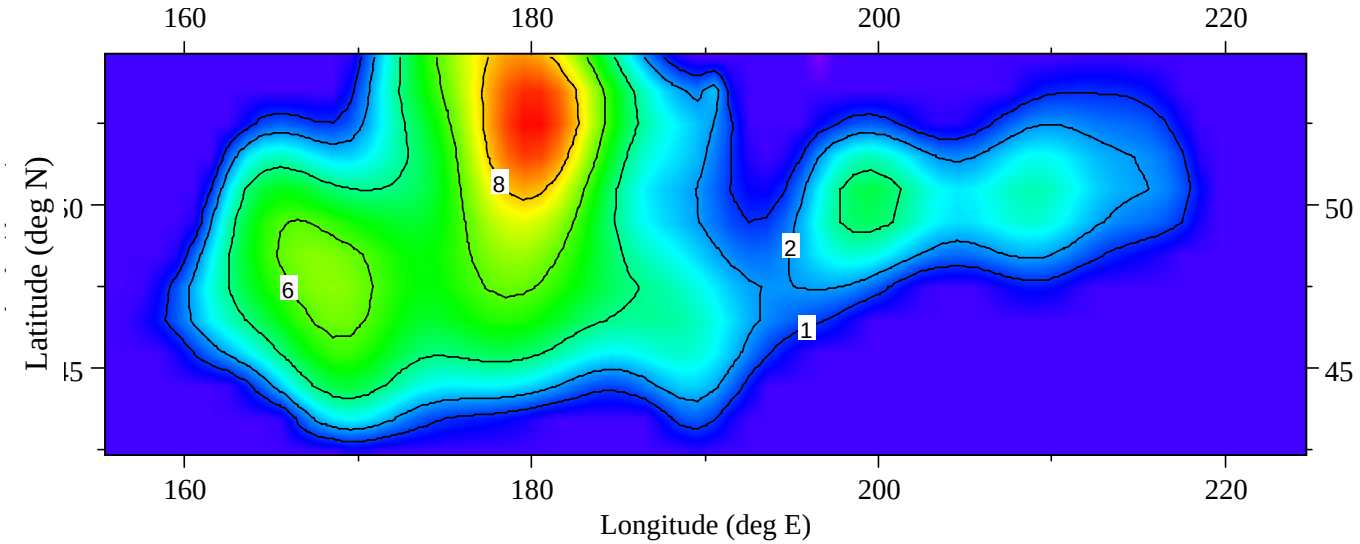
15% of present HNLC turns to non-HNLC (ca: P<0.2μM) in 2101

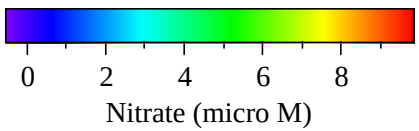
if N also decrease proportional to P&Si.....

Present summer MLN in NP (drown after WOA 2001 grid data)



Predicted summer MLP in 2101 [assuming -0.8μM N/decade decrease]





assumption:
$\Delta NO_3 = 18\Delta PO_4$
$= -0.8\ \mu M$ N/decade

conclusion:
48% of present HNLC turns to non-HNLC (ca: $NO_3 < 1\mu M$) in 2101

Summary

We have made first basen-scale assessment for the decrease of summer ML nutrient in the North Pacific HNLC region. The results are:

*Significant decrease trend of Phosphate (-0.047± 0.03 μMP/decade) and silicate (-1.0± 1.0 μMSi/decade) are detected between 1975-1990 and 1991-2002 time groups.

*SST vs. nutrient plot doesn't changes despite of significant changes in average nutrient concentration, indicating that nutrients have decreased with corresponding SST increase.

*NP-HNLC SST had increased at the rate of 0.30 ± 0.18 ^{0}C/decade. From this result, corresponding decrease of phosphate and silicate (-0.03 μMP/decade and -0.7 μMSi /decade, respectively) are expected based on the present SST-nutrient relationship. This value is well close to the observed nutrient decrease, indicating that ocean warming and consequent near-surface stratification is the primary cause of HNLC nutrient decrease.

*Thus, nutrient decrease is expected to continue as NP ocean warming continues.

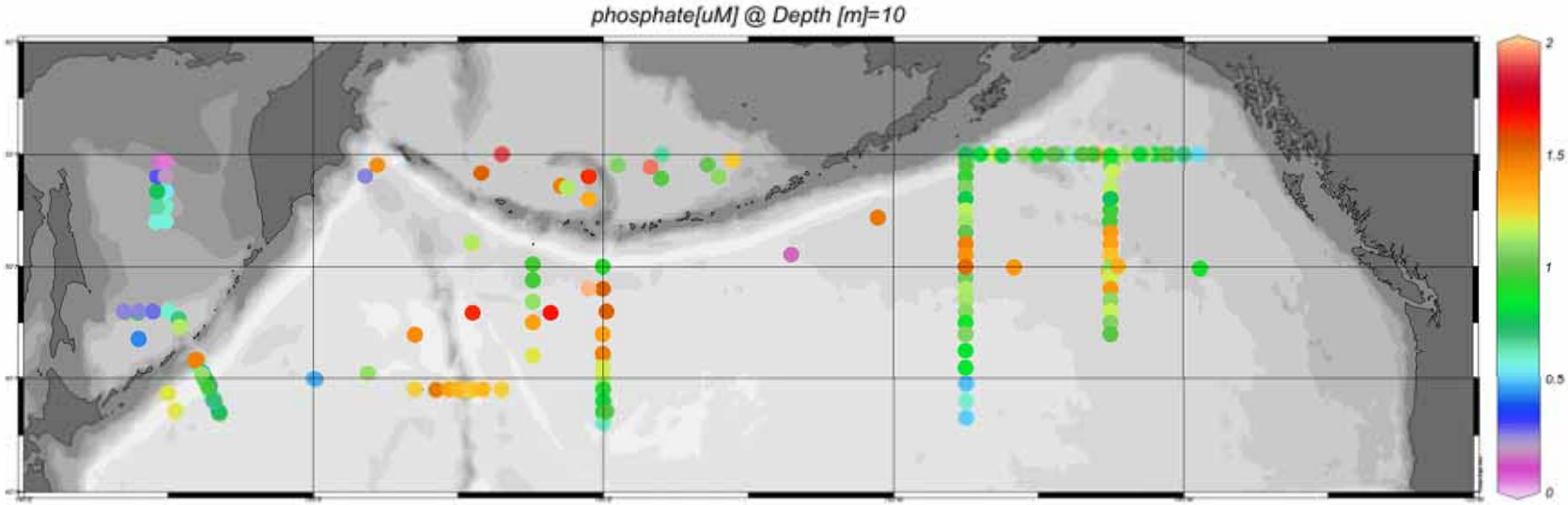
*If we assume the observed rate of phosphate decrease has sustained until 2101, **~15% of present HNLC region becomes P-limited** by that year.

*If we further assume that nitrate is similarly decreasing with the present Si/N/P ratio, **~48% of present HNLC will no more be HNLC in 2101.**

Next action:

*make assessment for the NP-HNLC nitrate, and any nutrients in other HNLC regions
*make assessment for the biological consequence of HNLC condition change.
*get more & more nutrient data to follow trends!

PO4 1975-1990 : raw data distribution



1991-2002