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Seasonal difference in relationship between the sea surface heat flux in the Kuroshio Extension region and the North Pacific Index

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Background:

In mid- and high-latitude regions, seasonal variation components are much more dominant than interannual variation components in various kinds of oceanic and atmospheric elements such as SST and wind.

Working Hypothesis:

Accompanied with year-to-year variations of seasonal means, seasonally different land-air-sea interaction processes among some elements may dominate not only the seasonal variations but also the interannual variations.

Objectives:

To examine the seasonal difference in the relationship between the satellite-derived net heat flux (HFN) in the Kuroshio Extension region, and the intensity of the Aleutian Low pressure represented by the North Pacific Index (NPI).

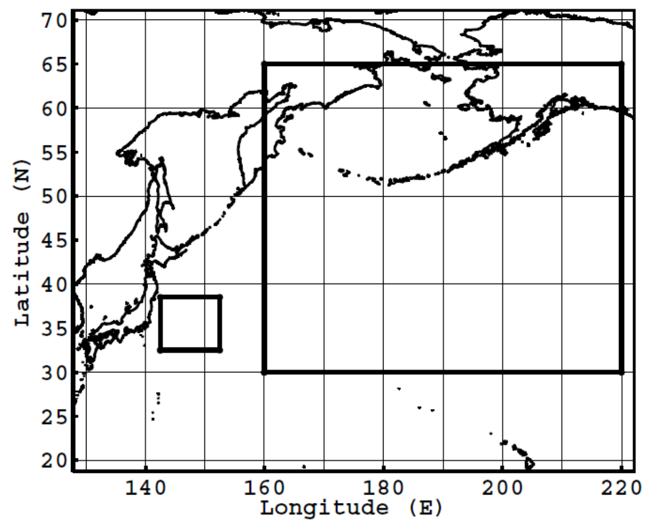

Fig. 1 Map showing the data regions of net heat flux in the Kuroshio Extension region (HFN) and NPI.

Data

Monthly mean HFN used in this study is area mean of satellite-derived HFN at 10 x 6 grid points with 1-degree interval in the Kuroshio Extension region of 32.5N-38.5N and 142.5E-152.5E (Fig. 1), in the data set called J-OFURO2 over the global ocean during 20 years from January 1988 to December 2007 (Tomita et al, 2010). HFN08 time series from January 1989 to December 2006 is calculated by applying twice, forth and back, the 3rd order Butterworth filter with half-power period of 8-month on the HFN anomaly from its 20-year monthly means. NPI08 time series is calculated by the same method as for HFN08.

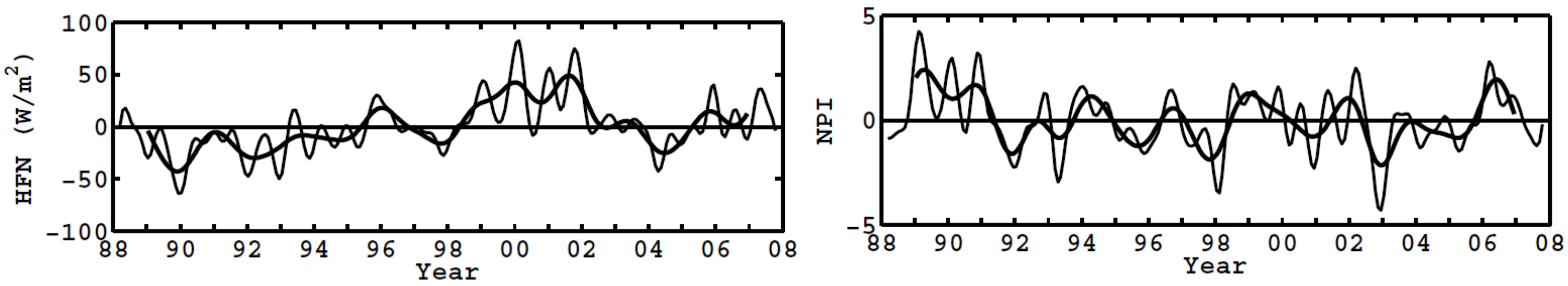

Fig. 2 Time series of HFN and NPI. Thin and thick lines indicate respectively the time series of anomalies from 20-year monthly means with periods longer than 8 months and those longer than 18 months. Ticks at each horizontal line indicate January of the year.

Method

Owing to a shortage of available common data duration length of 216 months (18 years), the seasonal differences of relationship between HFN08 and NPI08 are examined by estimating lagged correlations $R_{HN}(L, m)$ or $R_{NH}(L, m)$, e.g., lagged correlation between HFN08 in January and NPI08 in March after 14 months, $R_{HN}(+14, 1)$ is calculated as a covariance between HFN08 in January from 1989 to 2005 and that of NPI08 in March from 1990 to 2006, which coincides with $R_{NH}(-14, 3)$.

Results

>HFN08 has dominant periods longer than 10 years in November to February while NPI08 has dominant periods of about 5-years in January to May. HFN08 in May to July (NPI08 in September to January and May) have close relations only with HFN08 (NPI08) in a few lag months while HFN08 and NPI08 in other months have close relations in lags more than 7 months.

> Interannual variation of January HFN08 has the dominant significant negative correlation with that of March NPI08 before 34 months which is likely affected by Nino3.4 variation.

> Interannual variation of October HFN08 has the dominant significant negative correlation with that of November NPI08 after 13 months which is likely accompanied with PDO variation.

➡ It is found that, under the influences of PDO and Nino3.4, interannual variation of winter NPI has close relation with that of HFN in winter after three years while fall HFN has close relation with NPI after 13 months.

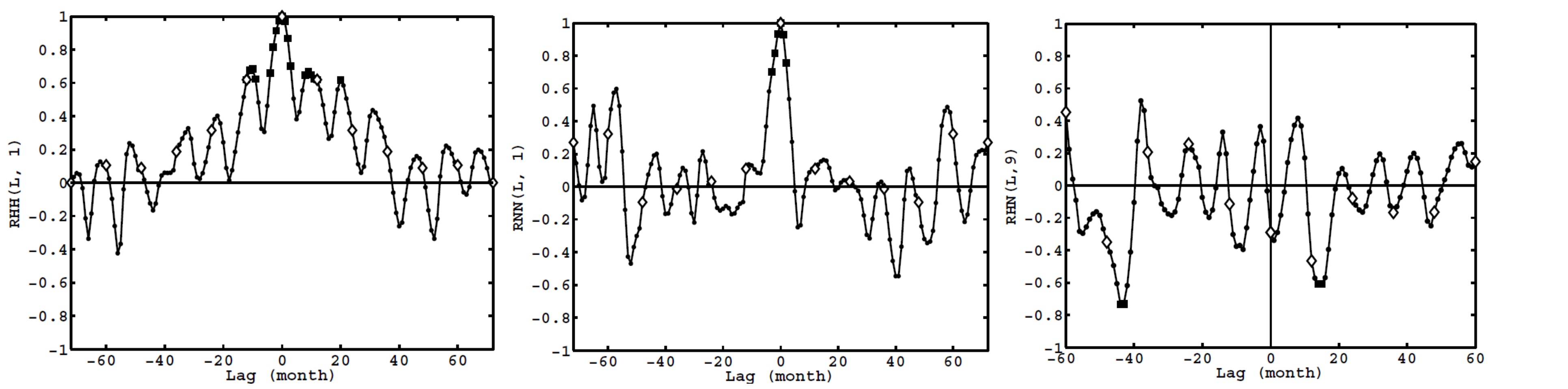

Fig. 3 Lagged correlations as a function of lag month. (a) January HFN08 with other HFN08; (b) January NPI08 with other NPI08; (c) September HFN08 with NPI08 in other months. Square indicates that its p-value is smaller than 0.01, and diamond indicates that correlation between time series in the same month with L=12 x N.

Table 1 Lags where correlations are significant ($p < 0.01$). Positive lag indicates NPI08 leads HFN08 by L months. Underline indicates that correlation is negative.

		NPI08											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HFN08	Jan		-35	-34									
	Feb			-35	-34								
	Mar												
	Apr												
	May												
	Jun												
	July												
	Aug	-43	-42										
	Sep	-44*	-43									+14	+15
	Oct	-45	-44									+13	+14
	Nov												
	Dec												

Table 2 Dominant relations between NPI08and HFN08.

Month of HFN08	Month of NPI08	Lag	Correlation	P-value
~~September~~	~~January~~	~~-44~~	~~-0.7351~~	~~0.0018~~
January	March	-34	-0.6952	0.0040
October	November	+13	-0.6178	0.0082

Table 3 Seasonal differences of dominant relations of HFN/NPI with PDO or Nino3.4.

Month of HFN/NPI	Month of PDO	Lag	Correlation	P-value
January NPI*	March*	+2	-0.8175	0.0000
December NPI	February	+2	-0.7461	0.0006
June NPI	July	+1	-0.6641	0.0027
May NPI	June	+1	-0.6556	0.0031
September NPI	August	-13	+0.6377	0.0059
December HFN	September	-3	-0.6701	0.0023
June Nino3.4	September	+3	+0.7230	0.0007

Data period: Jan. 1988 - Dec. 2007 except * (Jan. 1949 - Dec. 2006).

Month of HFN/NPI	Month of NIN3.4	Lag	Correlation	P-value
December HFN	April	+4	-0.7293	0.0009
February HFN	December	-2	-0.7114	0.0014
March NPI	January	-2	-0.6537	0.0033
February NPI	May	+39	+0.6969	0.0039

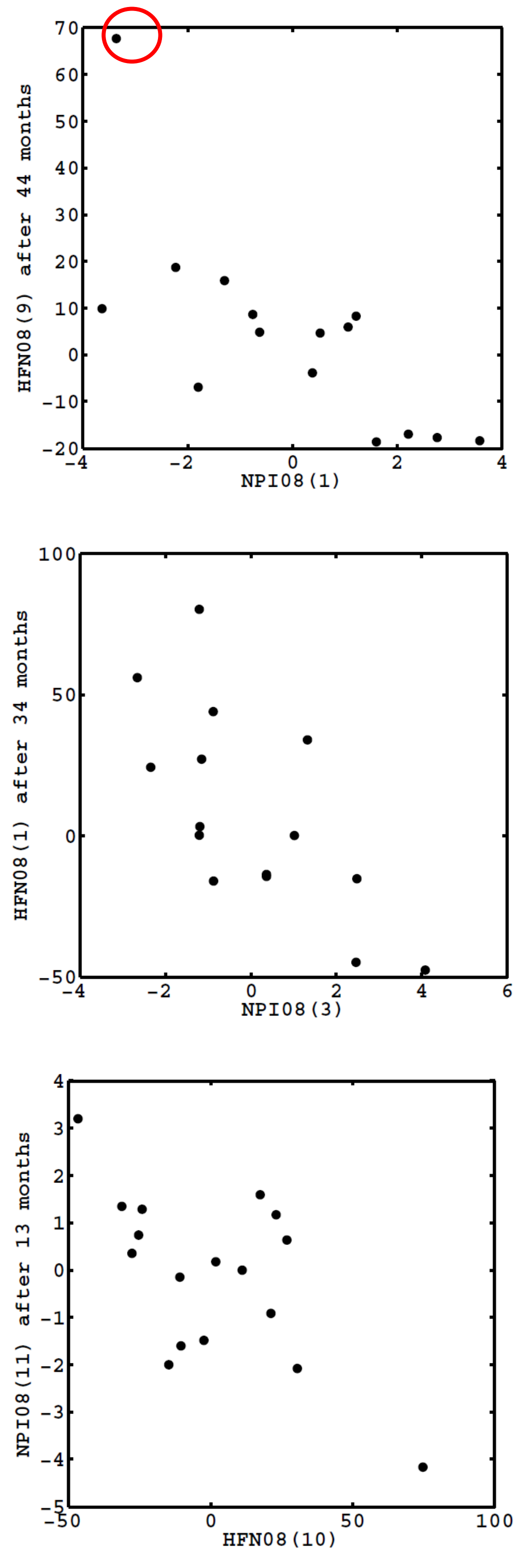

Fig. 4 (a) Scatter diagram between January NPI08 and September HFN08 after 44 month, (b) between March NPI08 and January HFN08 after 34 month, and (c) between October HFN08 and November HFN08 after 13 month.

Decrease of February [March] NPI → Decrease of May Nino3.4 after 39 months

(Decrease of December Nino3.4 after 34 months) → Increase of February [January] HFN after 34+2 [34] months

Decrease of September PDO → Increase of December HFN after 3 month

Decrease of August PDO → Decrease of September NPI after 13 months

→→ Increase of December [October] HFN → Decrease of September [November] NPI after 10 [13] months