

Measurements of dissolved inorganic carbon (DIC) in near-surface seawater

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Contributor:

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Ships:

Measurements have been made on board the following ships:

IB Shirase I, Japan Maritime Self-Defense Force

RV Kaiyo, Japan Marine Science and Technology Center

RV Hakuho Maru II, Ocean Research Institute, the University of Tokyo

RV Ryofu Maru II, Japan Meteorological Agency

RV Mirai, Japan Marine Science and Technology Center

(see cruise list)

Variables:

Variable_Name: Dissolved inorganic carbon (DIC)

Description_of_Variable: Total amount of CO₂ released from a unit mass (1 kg) of unfiltered near-surface seawater after strongly acidified with phosphoric acid.

Instrument_Design:

Detection_Type: Coulometry

Sample_processing: Automated DIC analyzers equipped with a carbon coulometer (UIC Co., Ltd., model 5011 or 5012 with Teledyne's VF converter) (Ishii *et al.*, 1998) or its improved design (Nippon ANS Co.) (Fig.1) have been used for the analysis of DIC in seawater. For underway measurements, a portion of seawater taken continuously from the seachest of the ship (ca. 5 m beneath the surface) was introduced into a 300 cm³ flow-through borosilicate glass bottles and, closing the stop-valves at both ends of the flow-through bottle, its aliquot (~22 cm³) was periodically (twice every 1 or 1.5 hour) taken into the pipette of the analyzer for DIC measurement.

Calibration:

To establish an identical DIC concentration scale among cruises and laboratories, we also analyzed DIC in the Certified Reference Material (CRM)

provided by Dr. A. G. Dickson of the Scripps Institution of Oceanography (http://www.mpl.ucsd.edu/people/adickson/CO2_QC/index.html) and in reference seawaters we prepared from western North Pacific oligotrophic water by a similar method to that of Dickson, *Unesco Technical Papers in Marine Science* 60, pp. 34–38, 1991. The concentration of DIC in our reference seawaters and their homogeneity and stability have been determined by occasional calibrations with suites of sodium carbonate solutions prepared with primary-standard-grade sodium carbonate powder and purified water such as those prepared by Milli-Q® SP-TOC, and concurrent analyses of the CRM (Ishii et al., 2000). The analytical results of CRM based on our calibration with sodium carbonate solutions usually agreed with their certified values within $\pm 1.5 \mu\text{mol kg}^{-1}$, but sometimes exceeded $\pm 3.0 \mu\text{mol kg}^{-1}$. The systematic errors in our calibrations were corrected if they were statistically significant. During the underway measurements and series of discrete samples' analyses, we also analyzed CRM or our reference seawater typically at least twice during the each run of the coulometric cathode- and anode-solution. The precision ($\pm 1\sigma$) of analysis estimated for each cruise ranged between ± 1.0 and $\pm 2.1 \mu\text{mol kg}^{-1}$.

Derived_parameter:

Total alkalinity was calculated from the data of DIC, $p\text{CO}_2\text{sw}$, temperature and salinity that have been concurrently measured using the dissociation constants of carbonic acid given by Roy et al., *Marine Chemistry* **44**, 249–268, 1993, and solubility of CO_2 given by Weiss, *Marine Chemistry* **2**, 203–215, 1974.

Method_References:

- Ishii, M., Inoue, H. Y., Matsueda, H., Tanoue, E., Close coupling between seasonal biological production and dynamics of dissolved inorganic carbon in the Indian Ocean sector and the western Pacific Ocean sector of the Antarctic Ocean. *Deep-Sea Research I*, **45**, 187–1290, 1998.
- Ishii, M., Inoue, H. Y., Matsueda, H., Coulometric precise analysis of total inorganic carbon in seawater and measurements of radiocarbon for the carbon dioxide in the atmosphere and for the total inorganic carbon in seawater. *Technical reports of the Meteorological Research Institute*, 41, 2000.

Data_set_References:

Data_Set_Link:

Data taken on board JAMSTEC's RV Mirai are available from JAMSTEC's
 MIRAI DATA WEB: URL:<http://www.jamstec.go.jp/mirai/>

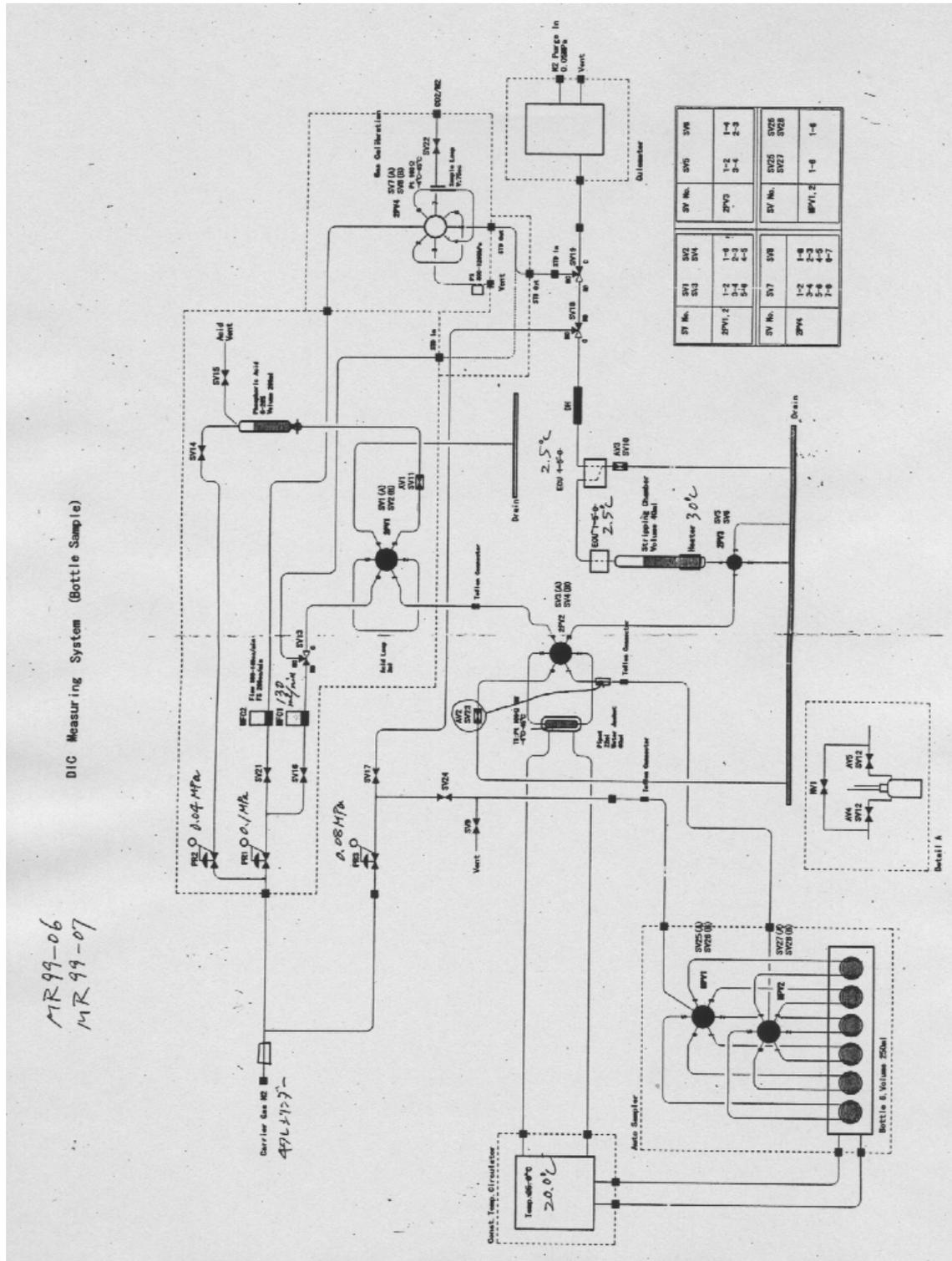


Fig.1 Schematic diagram of an automated DIC measuring system

Cruise List

Ship	Cruise	Place	Period	PIs	References
IB Shirase	JARE34	N.Pacific, E.Indian, Southern	Nov. 15, 1992 - Mar. 20, 1993	Ishii, M.	1
RV Kaiyo	KY9307	eqPac	Jan. 6, 1994 - Feb. 17, 1994	Ishii, M.	4
	KY9406	N.Pac, eqPac	Nov. 9, 1994 - Jan. 31, 1995	Ishii, M..	4
	KY9511	eqPac	Dec. 23, 1995 - Jan. 19, 1996	Ishii, M.	4
	KY9714	eqPac	Dec. 7, 1997 - Dec. 24, 1997	Ishii, M.	4
	KY9801	eqPac	Jan. 3, 1998 - Jan. 31, 1998	Ishii, M.	4
	KY9901	eqPac	Jan. 26, 1999 - Feb. 28, 1999	Ishii, M.	4
RV Hakuho Maru II	KH94-4	N.Pac, eqPac, S.Pac, Southern	Nov. 23, 1994 - Feb. 13, 1995	Ishii, M.	2,3
	KH01-3	N.Pac, eqPac, S.Pac, Southern	Nov. 28, 2001 - Jan. 21, 2002	Ishii, M.	5
RV Ryofu Maru III	RF9709	N.Pac, eqPac	Oct. 20, 1997 - Oct. 31, 1997	Ishii, M.	3
	RF9901	N.Pac, eqPac	Jan. 25, 1999 - Feb. 17, 1999	Ishii, M.	
	RF9906	N.Pac, eqPac	Jul. 12, 1999 - Jul. 21, 1999	Ishii, M.	
RV Mirai	MR9801	N.Pac, eqPac	Jan. 31, 1998 - Feb. 9, 1998	Ishii, M.	4
	MR98K2	N.Pac, eqPac	Dec. 24, 1998 - Jan. 30, 1999	Ishii, M.	4
	MR99K1	N.Pac, eqPac	Feb. 8, 1999 - Mar. 30, 1999	Ishii, M.	4
	MR99K6	N.Pac, eqPac	Oct. 15, 1999 - Nov. 18, 1999	Ishii, M.	4
	MR99K7	N.Pac, eqPac	Nov. 21, 1999 - Dec. 25, 1999	Ishii, M.	4
	MR00K8	N.Pac, eqPac	Dec. 27, 2000 - Feb. 6, 2001	Ishii, M.	4
	MR01K1	N.Pac, eqPac	Feb. 15, 2001 - Mar. 21, 2001	Ishii, M.	4

MR02K1	N.Pac, eqPac	Jan. 7, 2002 – Feb. 14, 2002	Ishii, M.	4
MR02K2	N.Pac, eqPac	Feb. 22, 2002 – Mar. 29, 2002	Ishii, M.	4
MR02K6	N.Pac, eqPac	Nov. 14, 2002 – Feb. 12, 2003	Ishii, M.	4

N.Pac: the North Pacific Ocean

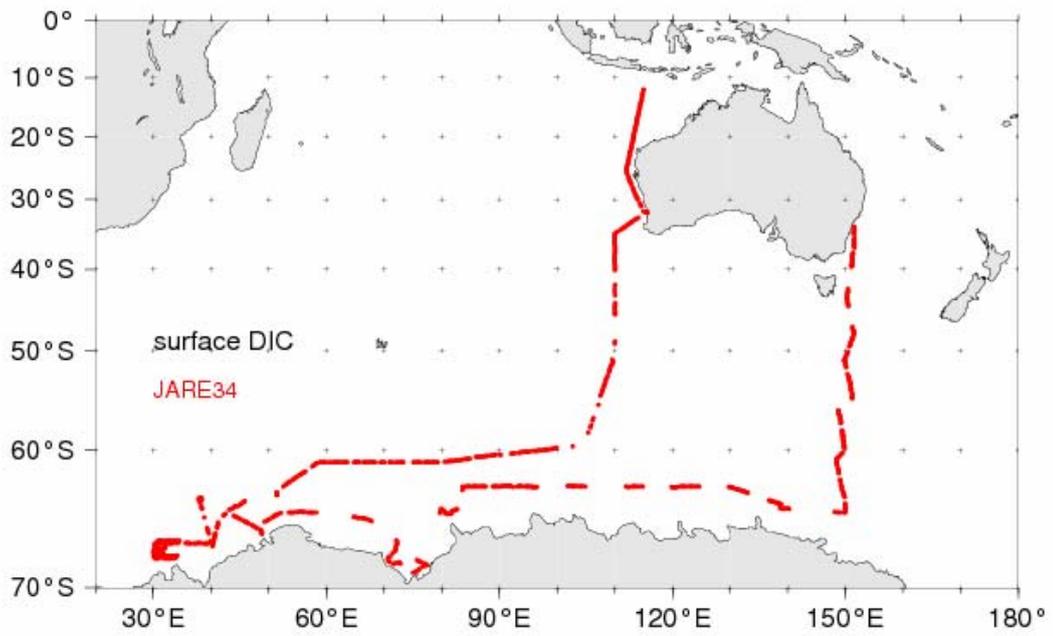
eqPac: the equatorial Pacific Ocean (10°S – 10°N)

S.Pac: the South Pacific Ocean

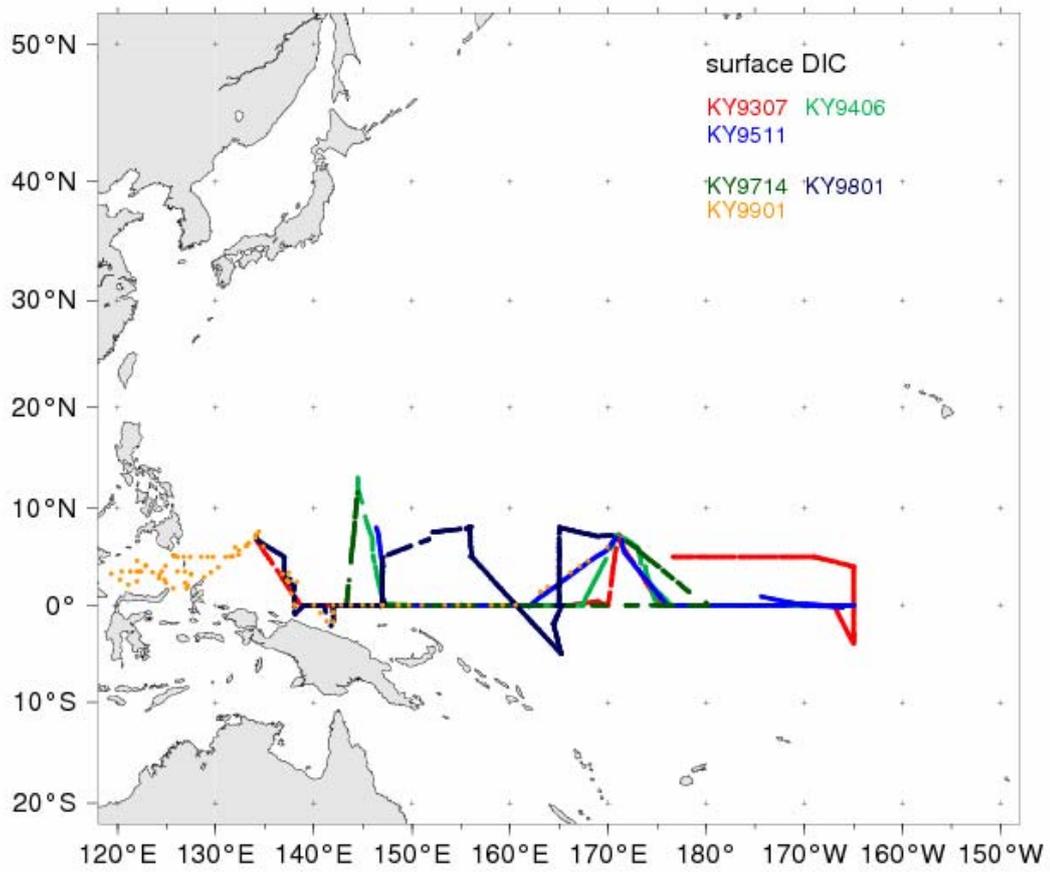
E.Indian: the eastern Indian Ocean

Southern : the Southern Ocean

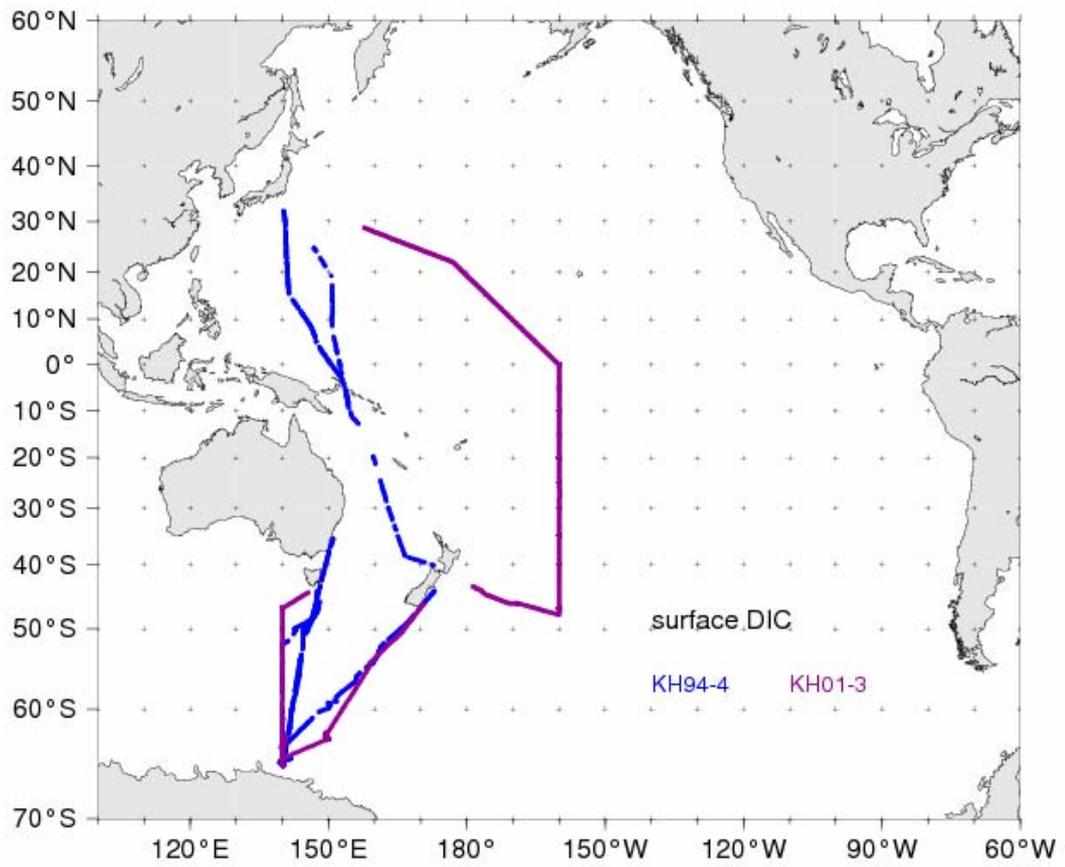
IB Shirase I (JMSDF)



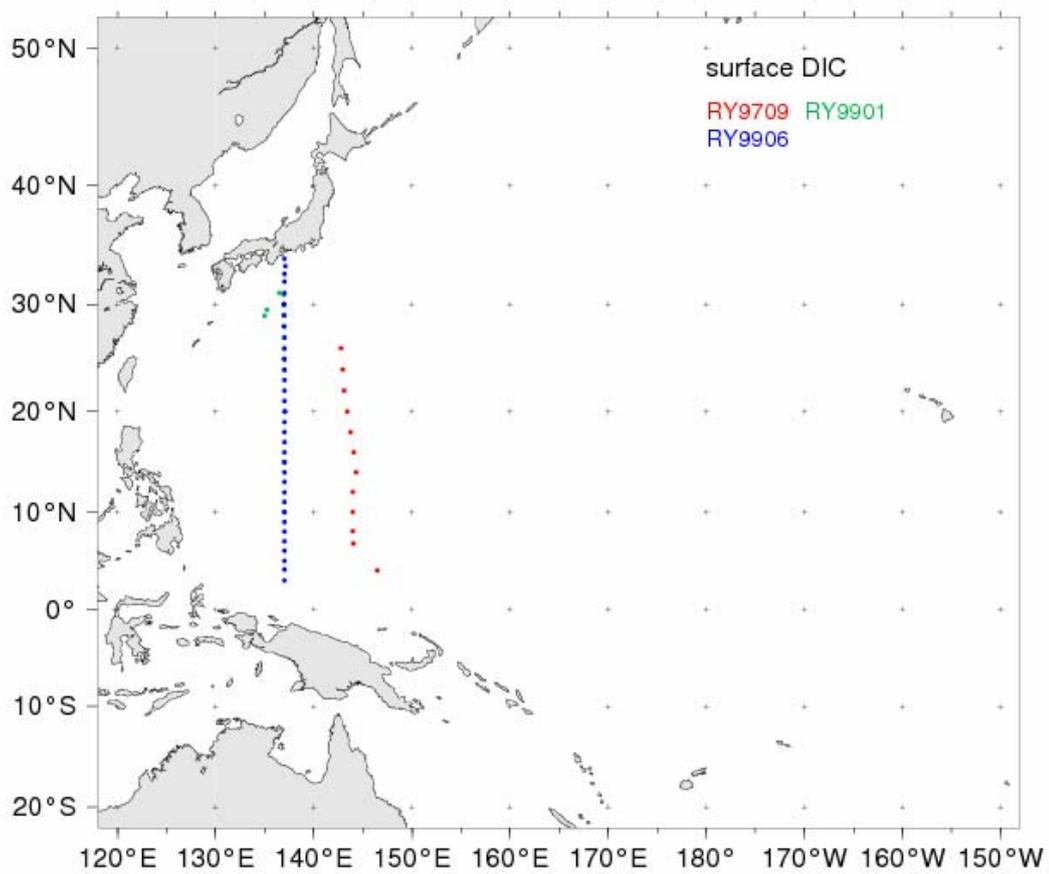
RV Kaiyo (JAMSTEC)



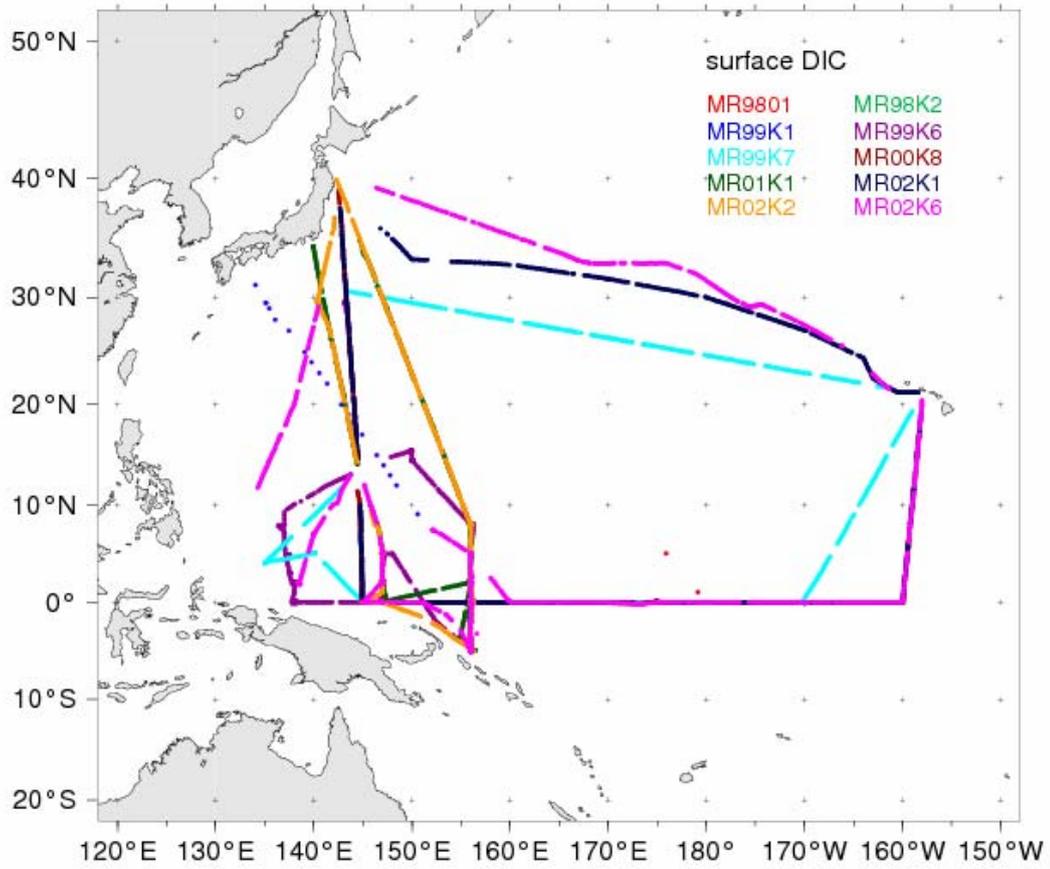
RV Hakuho Maru II (ORI, Univ.Tokyo)



RV Ryofu Maru III (JMA)



RV Mirai (JAMSTEC)



References

- 1) Ishii, M., Inoue, H.Y., Matsueda, H., Tanoue, E., Close coupling between seasonal biological production and dynamics of dissolved inorganic carbon in the Indian Ocean sector and the western Pacific Ocean sector of the Antarctic Ocean. *Deep-Sea Research I*, 45, 1187–1209. 1998.
- 2) Ishii, M., Inoue, H.Y., Matsueda, Net community production in the marginal ice zone and its importance for the variability of the oceanic $p\text{CO}_2$ in the Southern Ocean to the south of Australia. *Deep-Sea Research II*, 49, 1691–1706, 2000.
- 3) Ishii, M., Inoue, H. Y., Matsueda, H., Saito, S., Fushimi, K., Nemoto, K., Yano, T., Nagai, H., Midorikawa, T., Seasonal variation in total inorganic carbon and its controlling processes in surface waters of the western North Pacific subtropical gyre. *Marine Chemistry*, 75, 17-32, 2001.
- 4) Ishii, M., Saito, S., Tokieda, T., Kawano, T., Matsumoto, K., Inoue, H. Y., Variability of Surface Layer CO_2 Parameters in the Western and Central Equatorial Pacific. In: *Shiyomi et al. ed. Global Environmental Change in the Ocean and on Land*. Terrupub, Tokyo, pp 59-94, 2004.
- 5) Inoue, H.Y., M. Ishii, Variations and trends of CO_2 in the surface seawater in the Southern Ocean south of Australia between 1969 and 2002, *Tellus* **57B**, 58-69, 2005.