Evaluation of Net Precipitation in Reanalysis data: the Arctic Ocean, Antarctica, Amur River basin and Ice Cap on Mt. Wrangell

Oshima, K.[1], Y. Tachibana[2], T. J. Yasunari[3] and K. Yamazaki[1]
[1]Faculty of Environmental Earth Science, Hokkaido University, Sapporo, Japan
[2]Institute of Observational Research for Global Change, JAMSTEC, Yokosuka, Japan
[3]Graduate school of Environmental Science, Hokkaido University, Sapporo, Japan
Correspondence: kaz@ees.hokudai.ac.jp

1. Introduction

Precipitation and evapotranspiration are basis for studies of hydrological cycle. Net precipitation is precipitation minus evapotranspiration (P-E), which is a freshwater flux over land and ocean, or snow accumulation over ice sheet. It is difficult to estimate a net precipitation from direct observation of P and E for remote areas. In another way, we can estimate a net precipitation from the atmospheric moisture budget using objective analysis data. This is an effective estimation method, especially over the large-scale region and polar regions. Recently Bromwich et al. (2007) evaluated large atmospheric circulation, precipitation, radiation and cyclone activity on the reanalyses in the Polar Regions, however, the comparison study of reanalyses for hydrological cycle in the mid- and high-latitude is not enough. In this study, we estimated the net precipitation for four targets (Figure 1, Arctic Ocean, Antarctica, Amur river basin, and Ice cap on Mt. Wrangell, Alaska), and compared P-E from four reanalysis data (ERA40, ERA15, NCEP R2 and JRA25) and observations or previous studies.

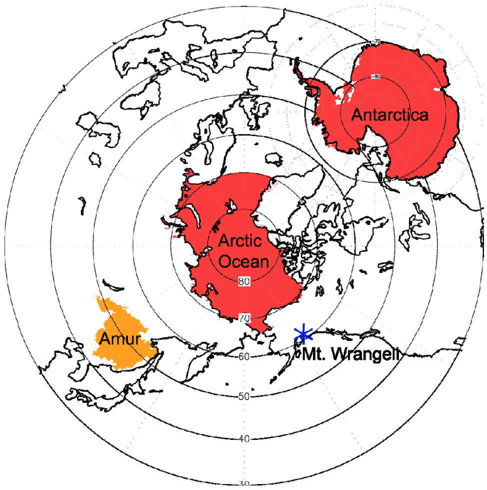

Figure 1. Maps of the Arctic Ocean, Antarctica, Amur River basin and the Ice cap on Mt. Wrangell.

2. Data and Methods

Four reanalyses data sets, ERA15, ERA40, JRA25, and NCEP-R2 are used to estimated the P-E. The resolutions and data periods are shown in Table 1.

Table 1. Description of reanalyses.

	Name	resolutions	time step and period	reference
ERA15	ECMWF 15-year Reanalysis	2.5°×2.5°, 17 levels	12 hourly, 1979/1-1993/12	Gibson et al. 1997
ERA40	ECMWF 40-year Reanalysis	2.5°×2.5°, 23 levels	6 hourly, 1957/9-2002/8	Uppala et al. 2005
NCEP-R2	NCEP/DOE Reanalysis 2	2.5°×2.5°, 17 levels	6 hourly, 1979/1-2005/12	Kanamitsu et al. 2001
JRA25	Japanese 25-year Reanalysis	1.25°×1.25°, 23 levels	6 hourly, 1979/1-2004/12	Onogi et al. 2007

(About the original model resolutions, refer to Bromwich et al., 2007)

Net precipitation (P-E) is estimated by the atmospheric moisture budget equation as follows:

$$\frac{\partial PW}{\partial t} = -\nabla < q\mathbf{v} > +E - P, \qquad (1)$$

∂PW/∂t and -▽<qv> can be estimated from the reanalysis data and P-E was obtained by subtracting the ∂pw/∂t from -▽<qv>. In this study, P-E is calculated by the area-weighted mean values of ∂pw/∂t and -▽<qv> over each region. In the land surface, water balance is written by the terrestrial water budget equation as follows:

$$\frac{\partial S}{\partial t} = P - E - R, \qquad (2)$$

For a long time period (i.e., annual mean), ∂S/∂t can be neglected and

$$R \approx P - E. \qquad (3)$$

The P-E estimated from the reanalyses and that in previous studies are compared over the Arctic Ocean and Antarctica. In the Amur River basin and the Ice cap on Mt. Wrangell, we compared the P-E estimated from the reanalyses with observations (the river discharge and the snow accumulation).

3. 1 Arctic Ocean

Polar regions are moisture flux convergence areas and net precipitation is important as a freshwater flux from the atmosphere. The P-E over the Arctic Ocean was estimated using rawinsonde data and surface observation in some previous studies (Table 2). We compared the observations with P-E from the reanalyses. Periods of Annual and monthly mean values are from 1979 to 1993 in ERA15 and those in ERA40, JRA25 and NCEP-R2 are from 1979 to 2001. Annual mean values of P-E from all reanalyses are comparable with previous studies (Table 2). P-E is large in boreal summer (JJA) and small in winter (DJF) due to the large seasonal cycle of PW. Seasonal cycles of P-E in all reanalyses are similar (Fig. 2). Interannual variations of P-E are also similar among the reanalyses and there are no significant trends (Fig. 3).

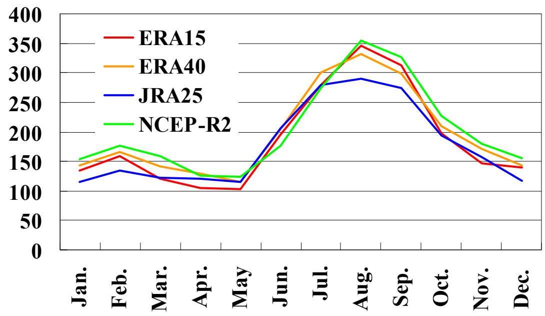

Figure 2. Seasonal cycle of P-E over the Arctic Ocean. Unit is mm/year.

Table 2. Annual mean P-E over the Arctic Ocean. Comparison with previous studies. Unit is mm/year.

	Arctic Ocean	70-90N
Based on atmospheric data		
Peixoto and Oort, 1983 (rawinsonde): 1963-1973	-	116
Serreze and Barry, 2000 (HARA, rawinsonde): 1974-1991	153	161
Gober et al., 2003 (HARA, rawinsonde): 1979-1993	-	164
Groves and Francis, 2002 (TOVS satellite): 1979-1998	145	151
Bromwich et al., 2000 (ERA15): 1979-1993	179	182
Bromwich et al., 2000 (NCEP-NCAR): 1979-1993	194	195
Oshima and Yamazaki, 2004 (ERA15): 1979-1993	186	178
Oshima and Yamazaki, 2004 (NCEP R2): 1979-2002	198	198
Oshima, 2006 (ERA40): 1979-2001	195	188
This study (ERA15): 1980-2001	187	-
This study (ERA40) : 1980-2001	196	-
This study (JRA25) : 1980-2001	177	-
This study (NCEP R2): 1980-2001	203	-
Based on surface data		
Sellers (1965) multiyear	120	50
Baumgartner and Reichel (1975)	44	58

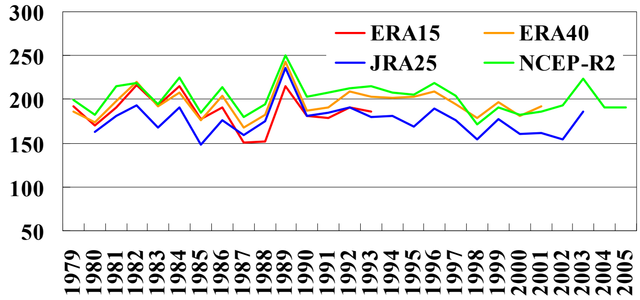

Figure 3. Interannual variation of P-E over the Arctic Ocean. Unit is mm/year.

3. 2 Antarctica

Over the Antarctica, the annual means of P-E from all reanalyses are reasonable, compared with previous studies (Table 3). P-E in the NCEP-R2 is very small and we have to confirm that estimation. So, it is not listed in Table 3. Unlike the Arctic, seasonal cycle of P-E over the Antarctica shows austral winter (JJA) peak. In this region, seasonal cycle of PW is small and the strong transient cyclone transports much water vapor into the Antarctica. Therefore P-E is large in austral winter. The seasonal cycles of P-E are reasonable in the reanalyses (Fig. 4). The interannual variations of P-E are similar in all reanalyses and they have no notable trends (Fig. 5).

The variations of P-E over polar regions, are discussed in Oshima and Yamazaki (2004) for the interannual variation and in Oshima and Yamazaki (2006) for the seasonal variation.

Table 3. Same as Table 2 but for Antarctica.

	Antarctica	70-90S
Based on atmospheric data		
Peixoto and Oort, 1983 (rawinsonde): 1963-1973	-	81
Yamazaki, 1992 (NMC): 1986-1990	135	162
Bromwich et al., 1995 (ECMWF): 1985-1992	157	140
Bromwich et al., 1995 (NMC): 1985-1992	108	134
Cullather et al., 1998 (ECMWF): 1985-1995	151	-
Oshima and Yamazaki, 2004 (ERA15): 1979-1993	166	150
Oshima and Yamazaki, 2004 (NCEP R2): 1979-2002	112	160
Oshima, 2006 (ERA40): 1979-2001	167	165
This study (ERA15): 1980-2001	107	-
This study (ERA40) : 1980-2001	111	-
This study (JRA25) : 1980-2001	116	-
Based on surface data		
Sellers (1965) multiyear	30	35
Baumgartner and Reichel (1975)	141	147
Giovinetto and Bull (1987)	143	-
Giovinetto and Zwally (2000)	149	-
Based on satellite data		
Vaughan et al. (1999)	149	-

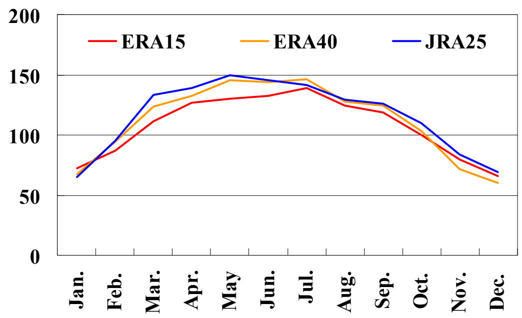

Figure 4. Same as Figure 2 but for Antarctica.

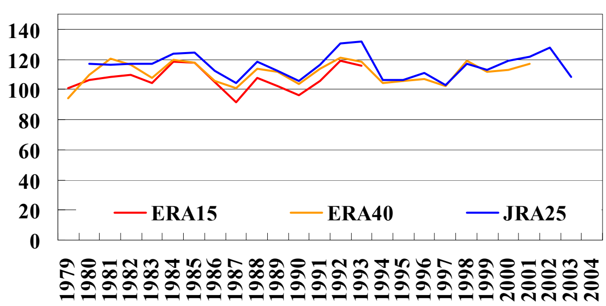

Figure 5. Same as Figure 3 but for Antarctica.

3.3 Amur River basin

Over a river basin, P-E approximately equals to the river discharge (Eq. 3). Annual mean of P-E over the Amur River basin in ERA40 and NCEP-R2 agrees very well with the river discharge (Table 4). ERA15 underestimates P-E and that in JRA25 is a little bit small. River discharge of the Amur River basin has unique seasonal cycle, which is double peak, one in spring and the other in fall (Fig. 6). The spring peak is probably caused by snow melt and the fall peak is a delayed response of the summer maximum of P-E. Interannual variations of P-E correspond to the discharge. The interannual variation of river discharge also corresponds well to that of the P-E (Fig. 7). They do not have significant trends. P-E in summer and winter also correspond well with the discharge in the each season. Therefore P-E is useful to investigate the hydrological process in this river basin. These discussions are shown in Tachibana et al. (2008).

Table 4. Annual mean and standard deviation of P-E over the Amur river basin from 1981 to 2001. Correlation coefficient between discharge and P-E are also shown. Unit is mm/year.

	ERA15	ERA40	JRA25	NCEP-R2	Amur (Obs.)
mean	62	181	113	177	194
std.	47	57	56	46	28
c.c.	0.69	0.74	0.67	0.67	-

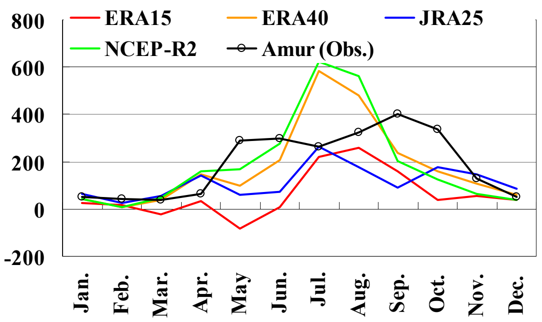

Figure 6. Same as Figure 2 but for the Amur River basin.

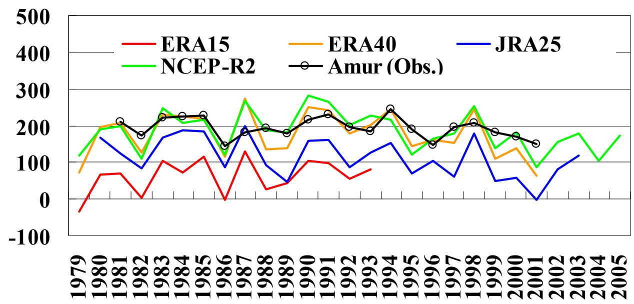

Figure 7. Same as Figure 3 but for the Amur River basin.

3.4 Ice cap on Mt. Wrangell

P-E is a source of snow accumulation over ice cap. Yasunari et al. (2007) estimated the snow accumulation (SA) in 5 seasons from ice core in Mt. Wrangell. Periods of annual and monthly means are from 1992 to 2002. For the monthly mean of SA, the values in 1992 and 2002 are not included, because the seasonal cycle of SA in that years are different, compared with SA in other years. Annual mean values of P-E are smaller than the snow accumulation by one third (Table 5). In the ice cap on Mt. Wrangell, snow accumulation shows the maximum in fall (Fig. 8). Seasonal cycles of P-E from reanalyses have also peaks in fall (September, Fig. 9). This means the reanalyses roughly captured seasonal cycle of snow accumulation in this region. For the interannual variations, the snow accumulation from ice core and JRA25 correspond well each other (Fig. 10). They do not have trends.

The estimate of P-E from a grid point near the Mt. Wrangell have some difficulty, because of difference of resolutions between ice core and reanalysis, representativeness of estimation by ice core, underestimation of P-E in reanalyses and so on. At the same time these results indicate a possibility to discuss seasonal pattern and interannual variation of P-E in a grid scale.

Table 5. Same as Table 4 but for Ice cap on Mt. Wrangell.

	ERA40	JRA25	NCEP-R2	Ice core
mean	884	703	739	2451
std.	142	99	155	403
c.c.	0.29	0.71	0.17	-

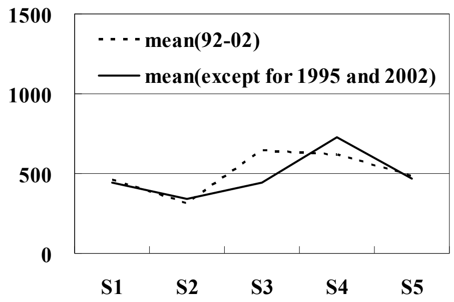

Figure 8. Seasonal cycle of snow accumulation from ice core. Unit is mm. Note that these are integrated values in each season. Lengths of time are different in 5 seasons.

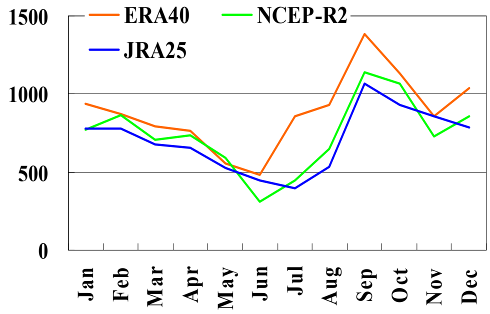

Figure 9. Same as Figure 2 but for Ice cap on Mt. Wrangell. Unit is mm/year.

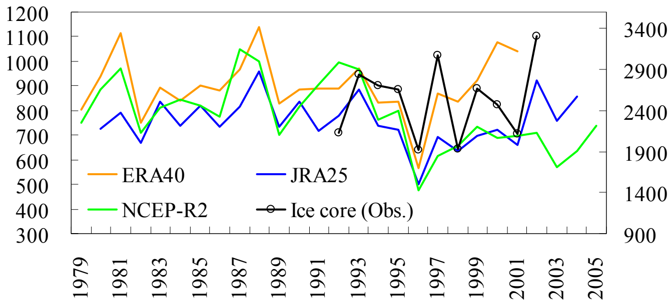

Figure 10. Same as Figure 3 but for Ice cap on Mt. Wrangell.

4. Summary

Net precipitations (P-E) estimated from "recent" reanalyses data are generally valid to discuss the seasonal cycle or inter-annual variation of the freshwater flux, river discharge and snow accumulation. However, it is still needed to compare quantitatively with the observations. It is also important to continue meteorological and hydrological observations. As was expected, a grid scale is hard to estimate P-E from a reanalysis, but not so bat. On the other hand, for large scale, river basin, Antarctica, Arctic Ocean, the P-E provide reasonable annual mean values, seasonal cycle and interannual variations are also consistent with observations and previous studies. Thus, the reanalyses are useful data set for the analysis of the hydrological processes.

Acknowledgements

The authors thank people concerned with the observations of the Amur River discharge and ice core in Mt. Wrangell.

References

Bromwich D. H., R. L. Fogt, K. I. Hodges, J. E. Walsh, 2007: A tropospheric assessment of the ERA-40, NCEP, and JRA-25 global reanalyses in the polar regions, J. Geophys. Res., 112, D10111, doi:10.1029/2006JD007859.

Gibson, J. K., K°allberg, P., Uppala, S., Nomura, A., Hernandez, A. and Serrano, E. 1997 'ERA Description'. In ECMWF ERA-15 Project Report Series, No. 1. European Centre for Medium-Range Weather Forecasts, Shinfield, Reading, UK (available from www.ecmwf.int/ publications)

Kanamitsu, M., W. Ebisuzaki, J. Woollen, S. K. Yang, J. J. Hnilo, M. Fiorino, and G. L. Potter, 2002: NCEP-DOE AMIP-II reanalysis(R-2), Bull. Am. Meteorol. Soc., 83, 1631-1643.

Onogi, K, J. et al. 2007: The JRA-25 Reanalysis, J. Meteor. Soc. Japan, 85, 369-432.

Oshima, K., and K. Yamazaki, 2004: Seasonal variation of moisture transport in the polar regions and the relation with annular modes. Polar Meteorology and Glaciology, 18, 30-53.

Oshima, K., and K. Yamazaki, 2006: Difference in seasonal variation of net precipitation between the Arctic and Antarctic regions. Geophys. Res. Lett., 33, L18501, doi:10.1029/2006GL027389.

Tachibana, Y., K. Oshima and M. Ogi, 2008: Seasonal and interannual variations of Amur River discharge and their relationships to large-scale atmospheric patterns and moisture fluxes. Submitted to J. Geophys. Res..

Uppala, S. M., et al. (2005), The ERA-40 reanalysis, Q. J. R. Meteorol. Soc., 131, 2961-3012, doi:10.1256/QJ.04.176.

Yasunari, T. J., T. Shiraiwa, S. Kanamori, Y. Fujii, M. Igarashi, K. Yamazaki, C. S. Benson, and T. Hondoh, 2007: Intra-annual variations in atmospheric dust and tritium in the North Pacific region detected from ice core from Mount Wrangell, Alaska. J. Geophys. Res. 112, D10208, doi:10.1029/2006JD008121.