Intercomparisons of turbulent heat fluxes at high-latitudes in the Northern Hemisphere

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1. Introduction

Accurate global estimation of these fluxes is extremely important for understanding the climate system. Also, recently air-sea interaction in the high-latitudes is considered to be a critical issue for understanding the global climate variability. However, There are few in situ observation data related to turbulent heat fluxes in the high-latitudes. Therefore, the reliability of the data provided by many products should be investigated. Although Liu et al. (2011) investigated consistency and discrepancy of air-sea turbulent heat fluxes in the Southern Ocean, such kinds of study concerned about in the northern high-latitudes are few. Our objectives in this study are to investigate consistency and discrepancy of air-sea turbulent heat fluxes in the northern high-latitudes.

2. Data

In this study we analyze five kinds of reanalysis products, four kinds of satellite products and a hybrid product as shown in Table.1. As shown in this table, the data period is different from each other. The analysis period for all the datasets is from 1996 to 2005 in this study. Also we only use the data where all the products have a value. Therefore, the data number is same for all products. Moreover, the spatial and temporal resolutions are unified into 1°x1° and one month, respectively. It is noted that some physical variables are not provided by some products.

Table 1. Reanalysis products

	NRA1	NRA2	ERA interim	JRA25 JCDAS	MERRA
Period	1948 / 1~ 2011 / 12	1979 / 1~ 2011 / 12	1979 / 1~ 2011 / 10	1979 / 1~ 2011 / 12	1979 / 1~ 2007 / 12
Temporal resolution	6 hourly Daily Monthly	6 hourly Daily Monthly	3 hourly 4 hourly 6 hourly 12 hourly Daily	6 hourly Daily Monthly	Daily Monthly
Spatial resolution	T62 Gaussian grid	T62 Gaussian grid	T255 Gaussian grid	T160L40 Gaussian grid	2/3°×1/2°
Reference	Kalnay et al. (1996)	Kanemitsu et al. (2000)	Dee et al. (2011)	Onogi et al. (2007)	Rienecker (2011)

Table 2. Satellite and hybrid products.

	J-OFURO2	HOAPS3	GSSTF2c	IFREMER	OAFlux
period	1988 / 1~ 2006 / 12	1987 / 7~ 2005 / 12	1987 / 7 / 9~ 2008 / 12 / 31	・weekly 1992 / 1 / 6~ 2007 / 12 / 31 ・monthly 1992 / 3~ 2007 / 12	1985 / 1~ 2011 / 12
Temporal resolution	Daily Monthly	Twice Daily, Monthly	Daily Monthly	Weekly Monthly	Daily Monthly
Spatial resolution	1°x1°	1°x1°	1°x1°	1°x1°	1°x1°
Reference	Kubota and Tomita (2008)	Andersson et al. (2010)	Shie and Savtchenko (2011)	Bentamy et al.(2008)	Yu et al. (2004) Yu et al. (2008)

3. Results

(1) Total Mean

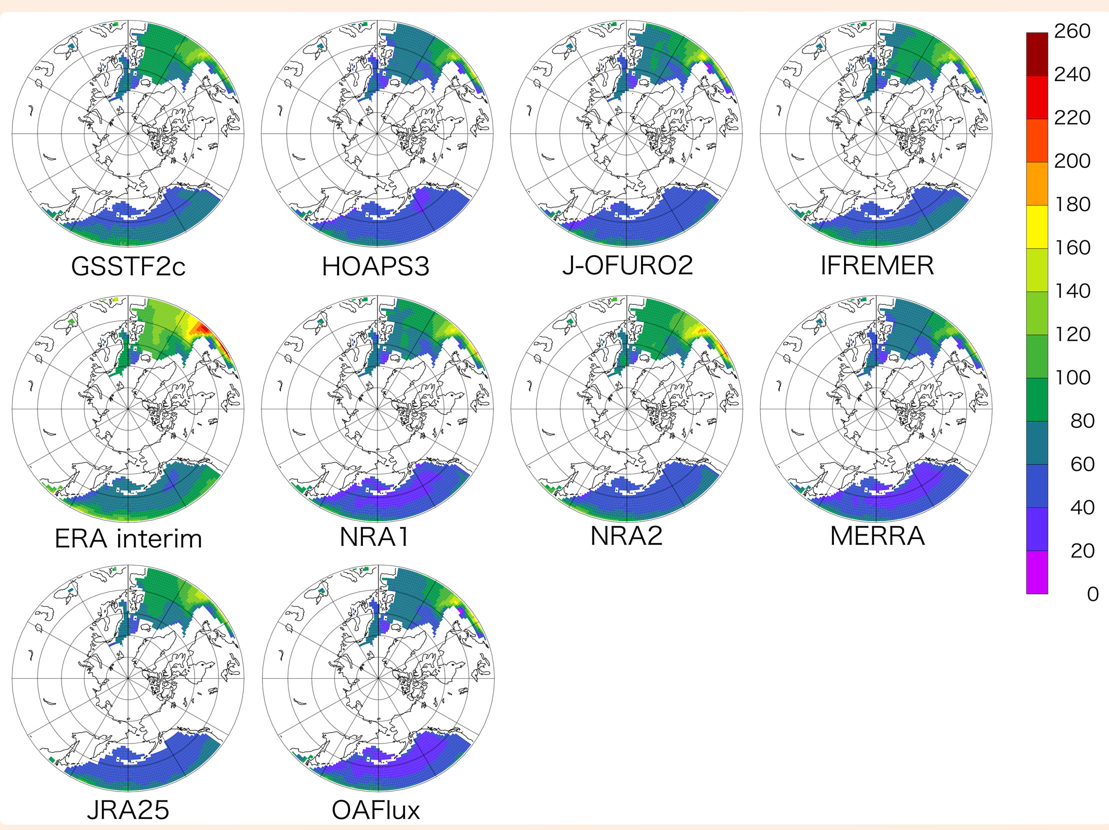


Figure 1. Spatial distribution of the total mean LHF (Wm-2) north of 40°N during 1996 and 2005 for each individual flux product.

The east-west difference is remarkable in the Atlantic, while the north-south difference is remarkable in the Pacific. The values in the Atlantic are larger than those in the Pacific, and the differences between each product are large in the Atlantic compared with in the Pacific. Generally reanalysis products show large values compared with other products. In particular ERA interim shows considerably large values compared with other products.

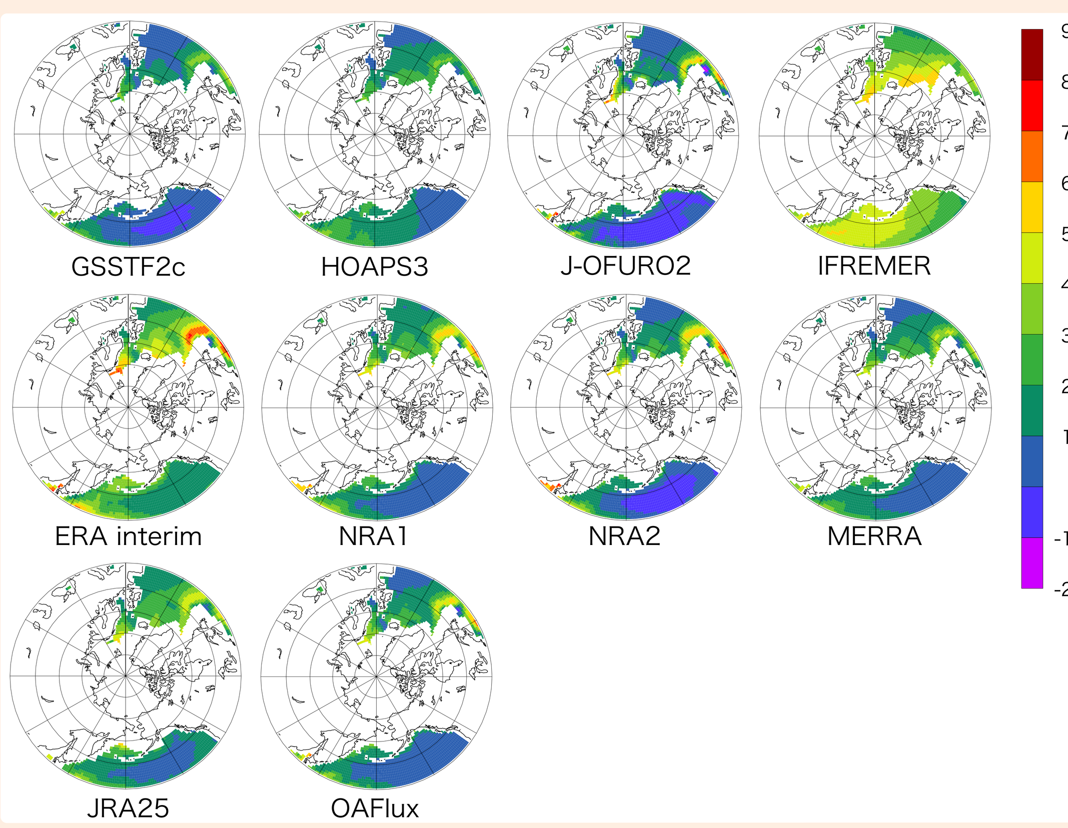


Figure 2. Spatial distribution of the total mean SHF (Wm-2) north of 40°N during 1996-2005 for each individual flux product.

The qualitative difference between each SHF product is larger than that between each LHF product. The east-west difference is remarkable even in the Pacific. SHF of IFREMER is extremely large, and ERA Interim shows considerably large values in the western Atlantic, compared with other products.

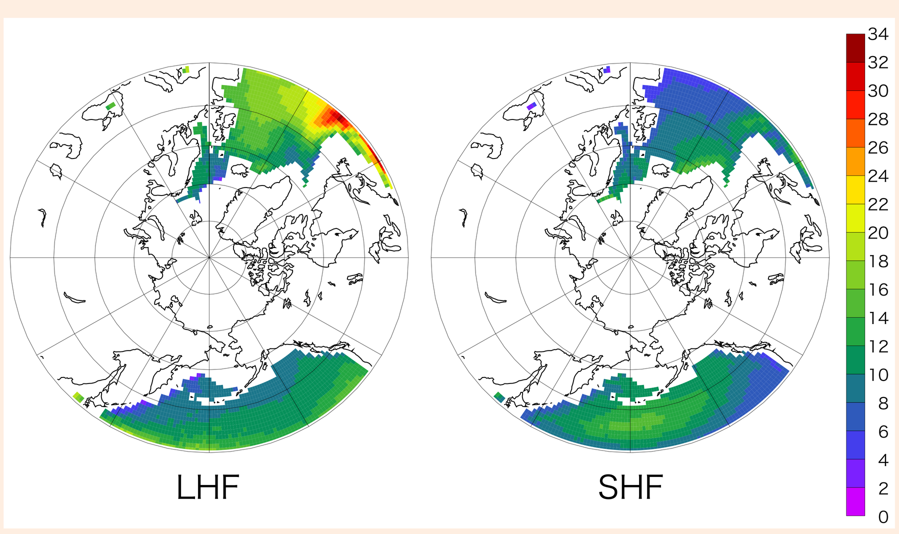
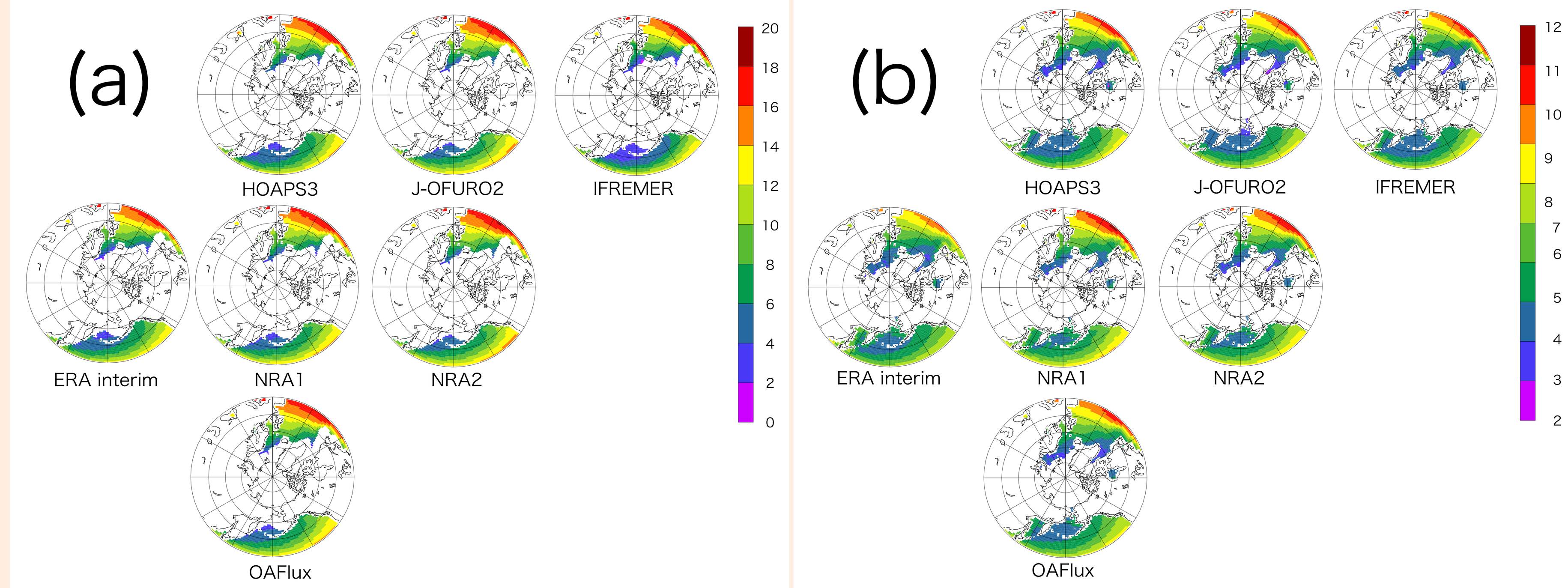


Figure 3. Spatial distribution of the standard deviation of the LHF and SHF across the all flux products..

The regions showing large across-data standard deviations are consistent with those showing large average values. The largest LHF discrepancy is found in the eastern Atlantic, and the maximum value is more than 30W/m2. The large LHF discrepancy in the western Atlantic might be primarily associated with the large scatter of the wind speed (Fig. 4c). On the other hand, we cannot find such kind of zonal asymmetry in the Pacific, although the significant large scatter of the wind speed can be found there.

The across-data standard deviation of SHF is generally small compared with that of LHF. The values in the Pacific are a little bit larger than those in the Atlantic. The large discrepancy is found in the central Pacific, while that is found in the western Atlantic.



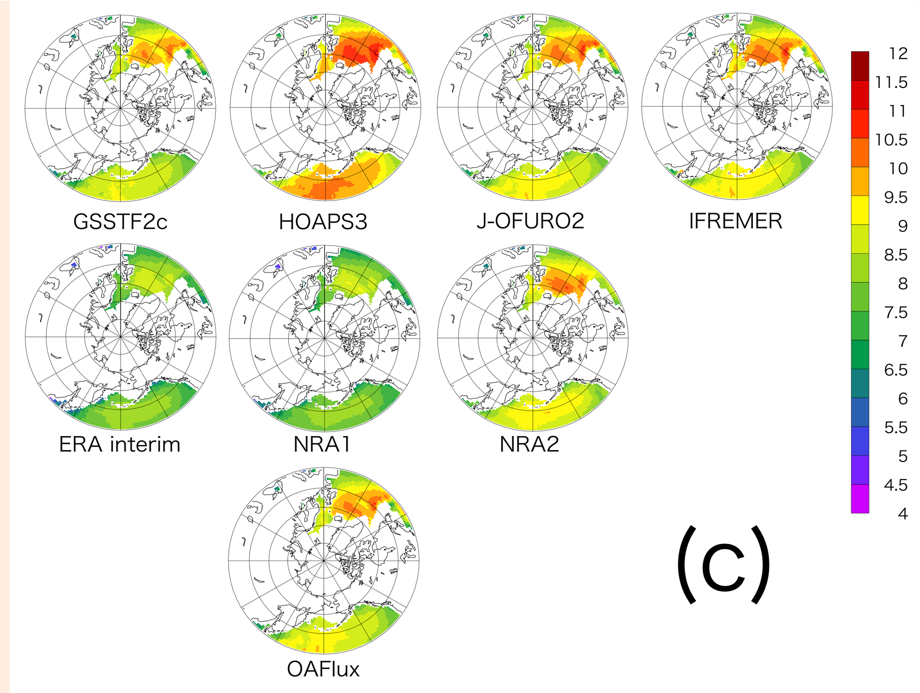


Figure 4. Total-mean of (a) air temperature, (b) specific humidity, and (c) wind speed during 1996-2005 for some products.

The air temperature of IFREMER in the Pacific is significantly low. The large SHF of IFREMER is caused by this low air temperature. The air specific humidity decreases as the latitude decreases, in both of Oceans. The specific humidity values of ERA interim are a little bit small and of NRA1 are slightly large compared with other products. The general pattern of wind speed is in common, but the value is considerably different depending on individual product. In particular, ERA interim and NRA1 show smaller values than other products. Also, HOAPS gives larger values in both of Oceans.

Spatial distribution of SHF is mainly determined by the temperature difference. While SHF is not correlated with wind speed in the reanalysis products, SHF is weakly correlated with wind speed in the satellite and hybrid products. Particularly, IFREMER gives a fairly high correlation coefficient.

Table. 3 Correlation coefficients between SHF and temperature difference and wind speed

	ERA interim	HOAPS3	IFREMER	J-OFURO2	NRA1	NRA2	OAFlux
Ts-Ta	0.977	0.946	0.969	0.961	0.972	0.980	0.986
WND	0.018	0.371	0.699	0.219	−0.113	−0.048	0.287

(2) Standard deviation of the monthly mean LHF and SHF

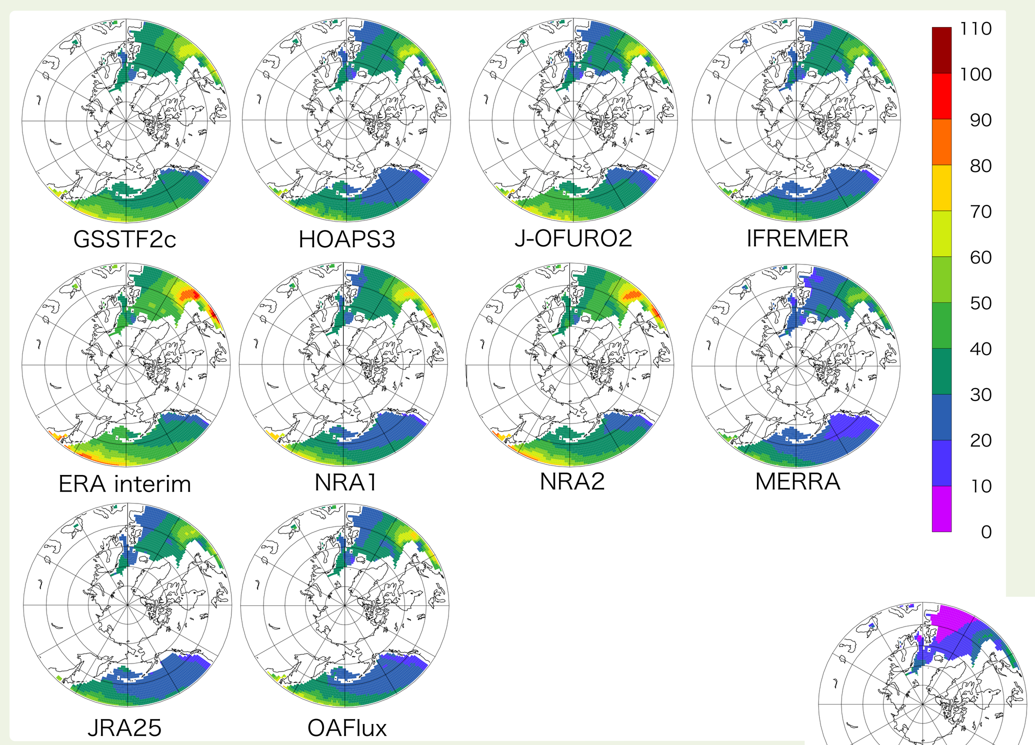
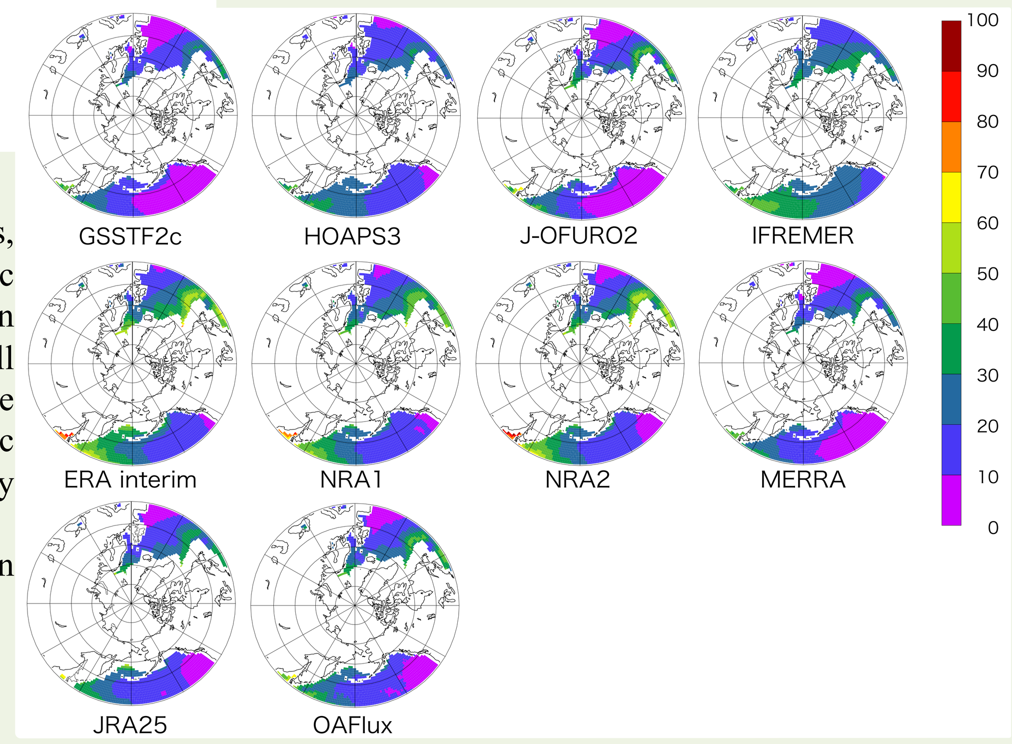


Figure. 5. Spatial distribution of the standard deviation of the monthly mean LHF(left) and SHF(right) from each yearly mean . Therefore, the values mainly mean the amplitudes of seasonal variability.



ERA interim and NRA2 gives larger values, particularly in the western part of both of Atlantic and Pacific Oceans. OAFlux gives smaller values, in particular in the eastern part of the Atlantic. All products show that the values in the western part are larger than the eastern part in both of the Atlantic and Pacific Oceans. The east-west gradient given by reanalysis products is larger than other products. IFREMER gives fairly large seasonal variation in most regions compared with other products.

(3) Meridional profile of zonal mean

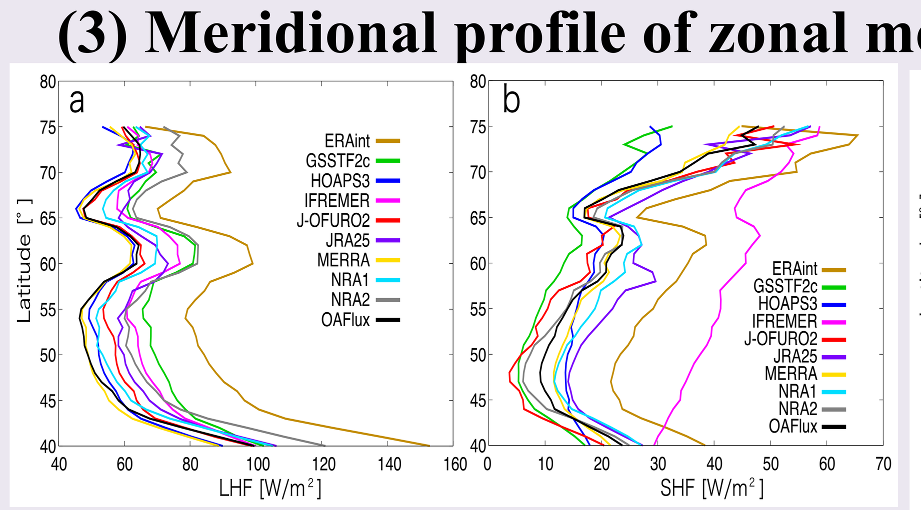


Figure 6. Meridional profile of the zonal mean of the total mean for (a) LHF and b) SHF during 1996 and 2005 for each individual flux product .

All the products show similar meridional variations. The meridional profiles of all LHF products have a local maximum values around 62°N and 72°N and a local minimum values around 65°N. MERRA shows similar values to satellite products. Most reanalysis products gives large values. In particular, ERA interim gives extremely large values.

The meridional profiles of all SHF products have a minimum value around 47°N and 67°N. However, IFREMER shows extremely large and loses the local minimum around 47°N. ERA Interim, HOAPS3 and GSSTF2 show about 30W/m2, while other products show larger larger than 40W/m2 around 65°N.

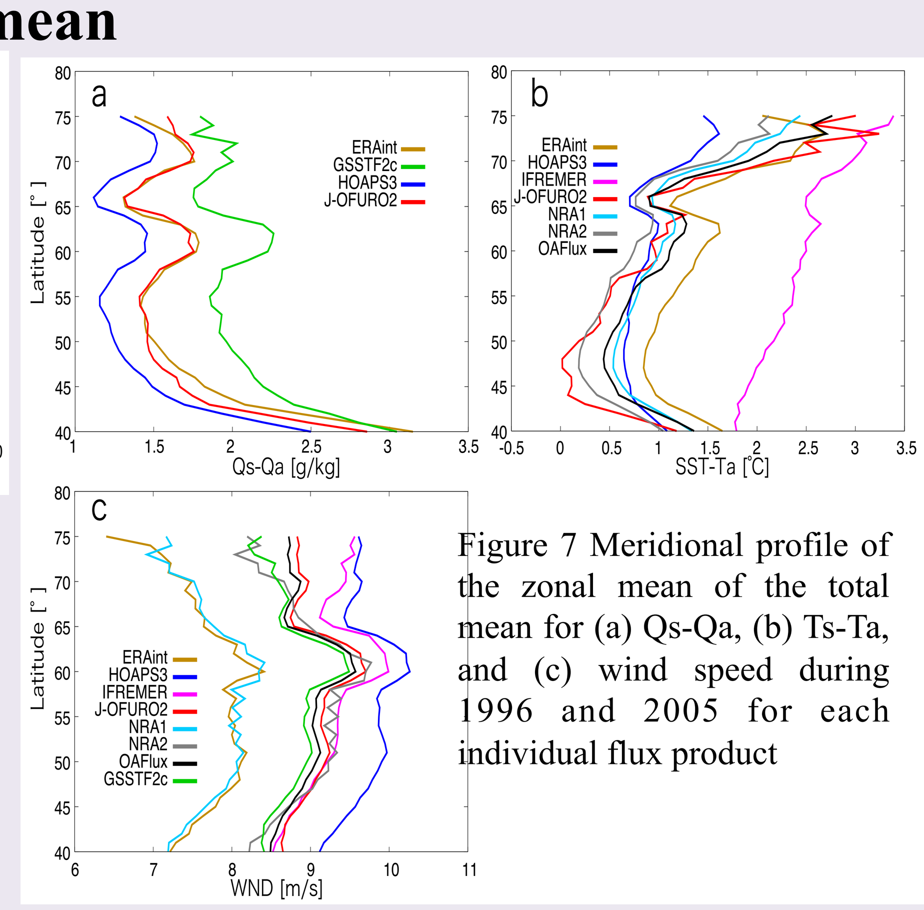


Figure 7 Meridional profile of the zonal mean of the total mean for (a) Qs-Qa, (b) Ts-Ta, and (c) wind speed during 1996 and 2005 for each individual flux product

The latitudes of maxima and minimum for specific humidity difference are similar to those for LHF. However, the values are different between each product and HOAPS gives the smallest values and GSSTF2 gives the largest values. The meridional profile of temperature difference is similar to that of SHF. IFREMER gives extremely large values and small meridional variation. ERA interim and NRA1 underestimate wind speed compared with other products. On the other hand, HOAPS overestimates wind speed, satellite products and a hybrid product show a minimum

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