A meteoric water budget for the Arctic Ocean

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Introduction

Meteoric water (MW) = river runoff, precipitation minus evaporation (P-E), and glacial melt

Contributes > 5300 $km^3\ yr^{-1}$ out of > 8400 $km^3\ yr^{-1}$ total annual FW inflow[1]

Arctic-wide MW budget has not been attempted

6000-8400 km^3 increase in Arctic FWC between early 1990s and late 2000s[2]

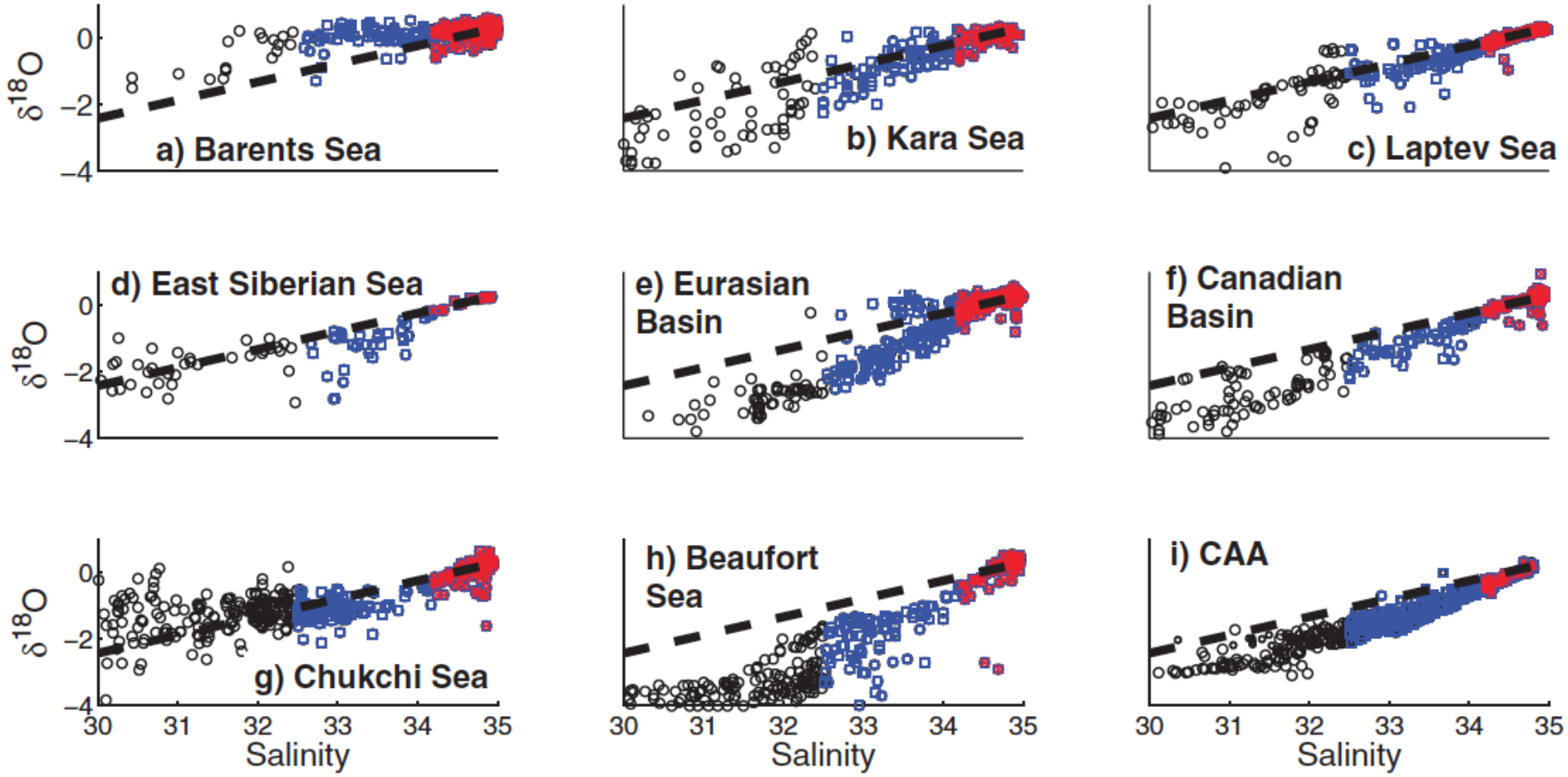
➔Source unknown

Large FWC increase in Canada Basin between 2003 and 2008[3;4;5;6]

➔due largely to a redistribution of freshwater from Eurasian Basin

[1]*Serreze et al.* [2006]; [2]*Rabe et al*. [2014]; [3]*Proshutinksy et al.* [2009]; [4]*McPhee et al.* [2009]; [5]*Morison et al*. [2012]; [6]*Krishfield et al*. [2014]

Oxygen-18 Data Base [*Schmidt et al*., 1999]

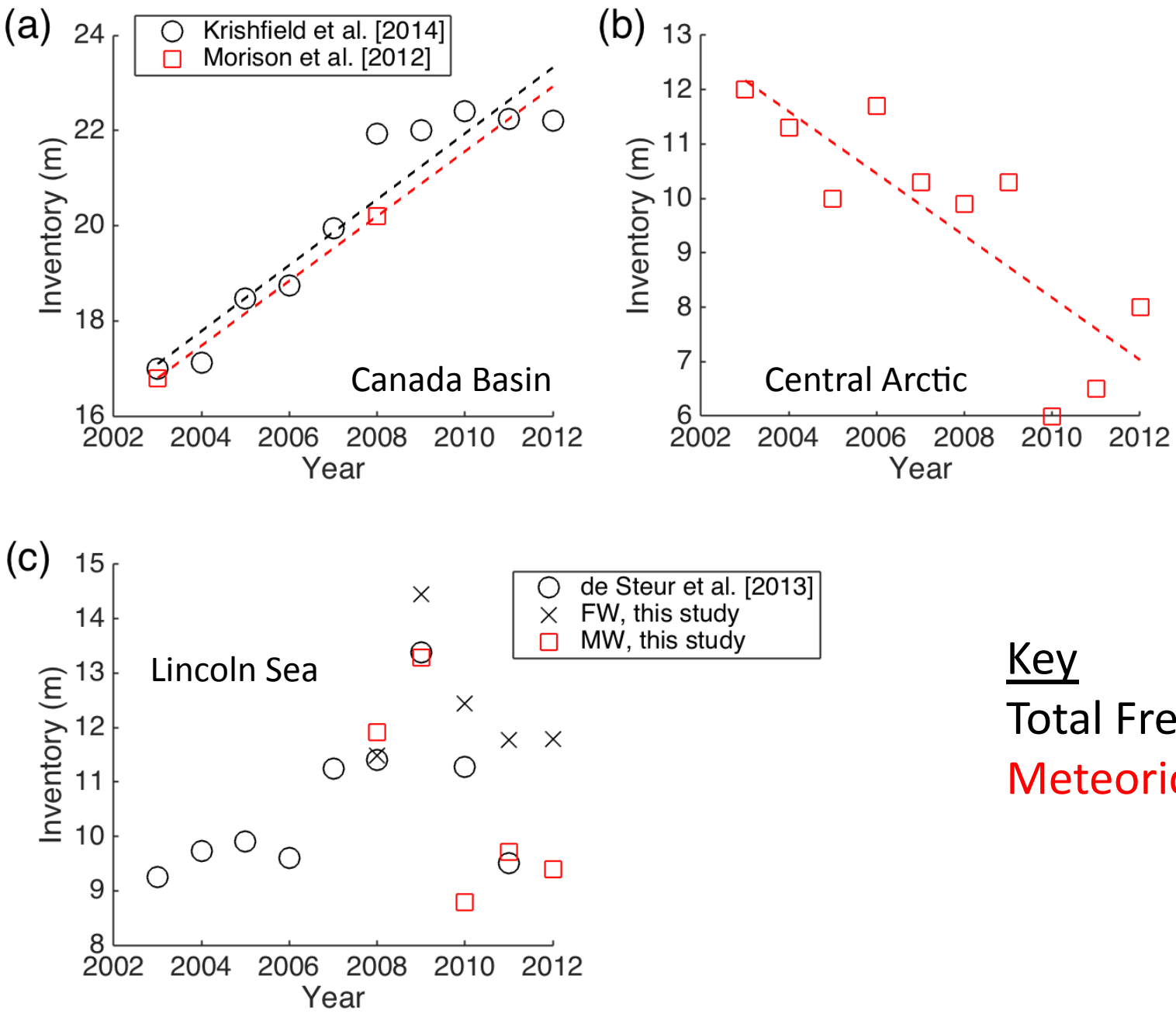


S > 30

S > 32.5

S > 34.2

Alkire et al. [2010]



Key

Total Freshwater

Meteoric water

Alkire et al. [2015]

$$dMW_S/dt = R_S + P_S - V_1 - V_2 + NCC \quad (1)$$

$$dMW_E/dt = P_E + V_2 - X_E \quad (2)$$

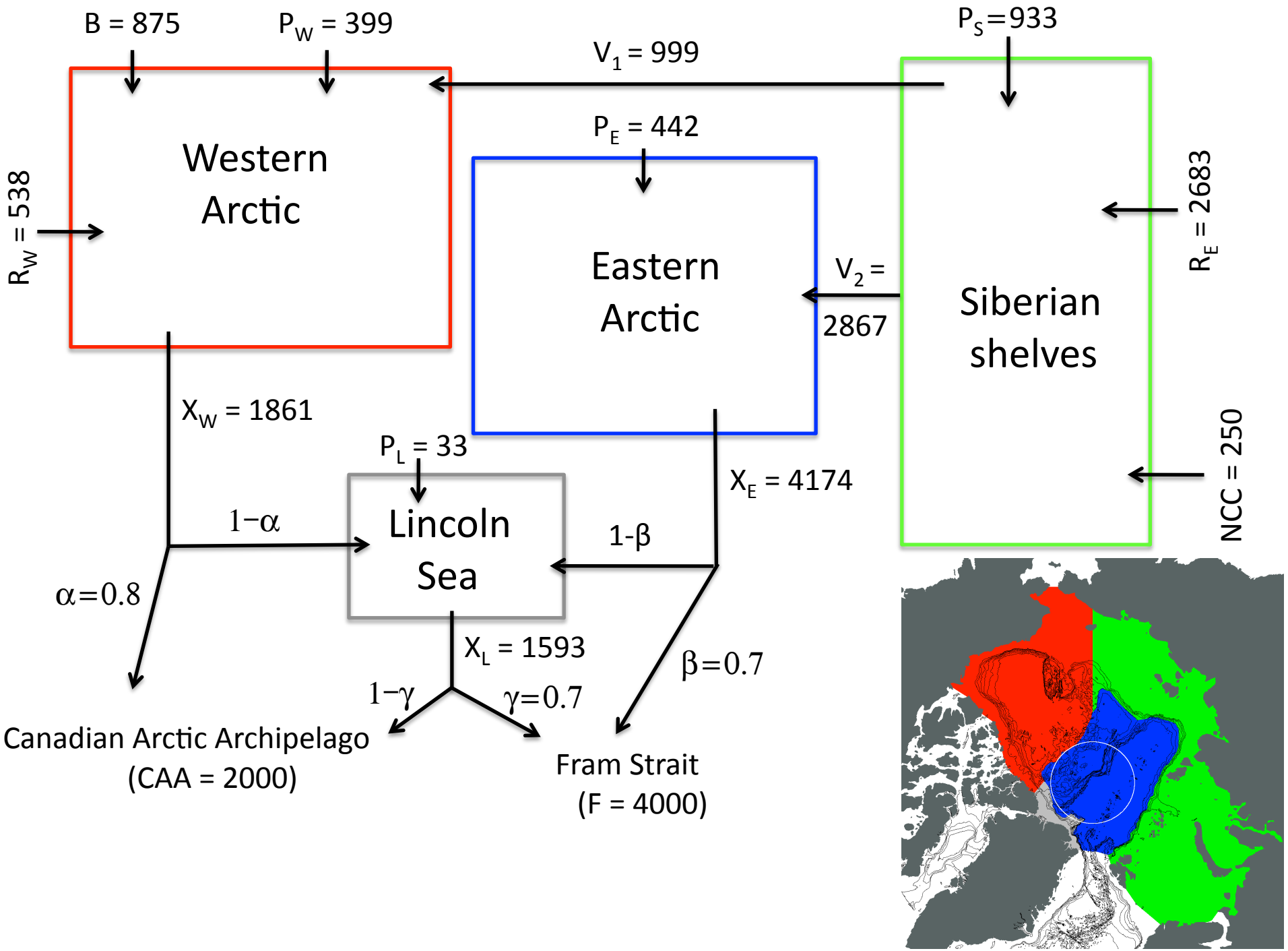
$$dMW_W/dt = R_W + B + P_W + V_1 - X_W \quad (3)$$

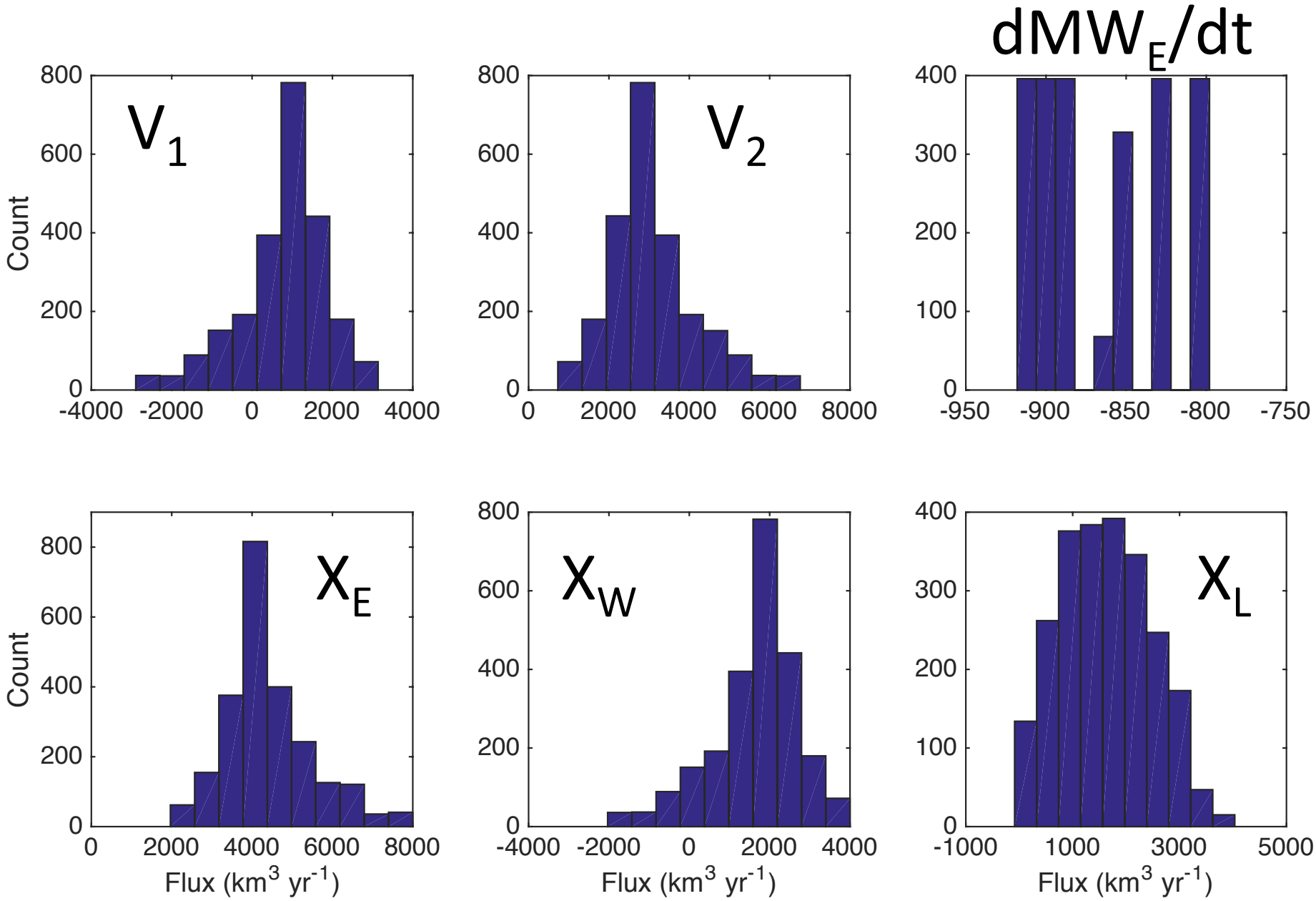
$$dMW_L/dt = P_L + (1-\beta)*X_E + (1-\alpha)*X_W - X_L \quad (4)$$

$$CAA = \alpha*X_W + (1-\gamma)*X_L \quad (5)$$

$$F = \beta*X_E + \gamma*X_L \quad (6)$$

Adapted from the literature: R_S, NCC, R_W, CAA, F, dMW_W/dt
Computed for this study: B, P_S, P_E, P_W, P_L, dMW_S/dt
Unknowns/computed from model: dMW_E/dt, V_1, V_2, X_W, X_L, X_E
Optimized parameters: α, β, γ, dMW_L/dt


B = 875
P_W = 399
V_1 = 999
P_S = 933
Western Arctic
P_E = 442
Eastern Arctic
Siberian shelves
R_W = 538
R_E = 2683
V_2 = 2867
X_W = 1861
P_L = 33
X_E = 4174
NCC = 250
Lincoln Sea
1−α
1-β
α=0.8
X_L = 1593
1−γ
γ=0.7
β=0.7
Canadian Arctic Archipelago (CAA = 2000)
Fram Strait (F = 4000)


dMW_E/dt
V_1
V_2
X_E
X_W
X_L
Count
Count
Flux (km^3 yr^-1)
Flux (km^3 yr^-1)
Flux (km^3 yr^-1)
800
600
400
200
0
-4000
-2000
0
2000
4000
6000
8000
400
300
200
100
-950
-900
-850
-800
-750
-1000
1000
3000
5000

Results

Imports = 6153 ± 253 $km^3\ yr^{-1}$

Exports = 6000 ± 1222 $km^3\ yr^{-1}$

MW budget in approximate balance

Freshwater increase over the Arctic NOT due to MW

dMW_W/dt = +950 $km^3\ yr^{-1}$ (prescribed from literature)
dMW_S/dt = 0 $km^3\ yr^{-1}$
dMW_E/dt = -873 $km^3\ yr^{-1}$
dMW_L/dt = +76 $km^3\ yr^{-1}$

Results cont.

MW export through Fram Strait:

2922 km^3 yr^{-1} from Eastern Arctic

1115 km^3 yr^{-1} from Lincoln Sea

MW export through CAA:

1489 km^3 yr^{-1} from Western Arctic

478 km^3 yr^{-1} from Lincoln Sea (*Nares Strait*)

Residence times of MW

- Western Arctic: 6-8 yrs
- Eastern Arctic: < 4 yrs
- Lincoln Sea: 1-2 yrs
- Siberian Sea: assuming τ_{res} = 3.5 ± 2 yrs [*Schlosser et al*., 1994], a MW volume of ~13,500 km^3 is estimated for the Siberian shelves
- Total MW storage: ~42,400 km^3 (~57% of FW)

Conclusions

- MW budget balanced; therefore, large FW increase in Canada Basin due to a redistribution and not an overall gain by the Arctic Ocean
- Arctic Ocean FW gain due to Pacific and/or SIM
- MW exported mainly via Fram Strait
- Lincoln Sea receives MW mostly from Eastern Arctic; MW export from Lincoln Sea via Fram St.
- Simple box models can improve understanding of freshwater storage, export, and redistribution