Reply to anonymous referee #3

Dear referee,

We appreciate your valuable replies on our reply of AC2. The point-by-point answers to the referee's replies are listed as follows.

Referee's reply to major issue 1: What authors should do is adding introduce about previous related research, instead of only adding several references.

Author's reply: Thanks your comment. We didn't make it clear about citing more references of influence of winds on saltwater intrusion in the estuary. We thought the revised manuscript will be uploaded and the referee will see the detailed modification. We certainly cited the references and briefly described them in the introduce section besides in the inferences section.

The sentences in the original manuscript were rewritten to the following sentences in introduce section in the revised manuscript (the green parts are the added contents): Saltwater intrusion is a common phenomenon in estuaries where fresh water and saltwater converge, and is mainly controlled by tide and river discharge (Prandle, 1985; Simpson et al., 1990; Geyer, 1993), but it can also be affected by wind stress (Chen and Sanford, 2009; Aristizábal and Chant, 2015; Duran-Matute et al., 2016; Giddings and Maccready, 2017) and vertical mixing (Simpson and Hunter, 1974; Prandle and Lane, 2015). Along-estuary winds can strain density gradients, and the associated destruction or enhancement of stratification depending on wind direction, and the entrainment depth ratio (Chen & Sanford, 2009). Wind-driven sea-level setups at the mouth of estuaries can produce landward flows that outcompete river runoff, resulting in the net, landward advection of salt (Aristizabal & Chant, 2015). For multi-inlet coastal systems, residual (horizontal) circulation is influenced by winds, which alters salt transports in each inlet (Duran-Matute et al., 2016). The upwelling and downwelling favorable wind can significantly influence the estuarine exchange flow (Giddings, and MacCready, 2017).

For the Changjiang Estuary, the sentences in the original manuscript were modified to the following sentences in introduce section in the revised manuscript (the green parts are the added contents): Saltwater intrusion in the Changjiang Estuary is also mainly determined by river discharge and tides (Song and Mao, 2002; Gu et al, 2003; Shen et al., 2003; Luo and Chen, 2005; Qiu et al. 2012; Chen et al, 2019a) but is also influenced by wind (Xue et al., 2009; Wu et al., 2010; Li et al., 2012; Ding et al., 2017; Zhang et al., 2019), and topography (Li et al., 2014; Chen et al., 2019b). The impact of wind on saltwater intrusion has been studied, but only with a climatic wind (Xue et al., 2009; Qiu et al. 2012; Chen et al, 2019a), and a strong northerly wind induced by ordinary cold fronts in winter lasting 1-2 days, which could cause a change in the observed salinity (Li et al., 2012). Xue et al. (2009) pointed out that a northerly wind tends to enhance the saltwater intrusion in the North Branch by reducing the seaward surface elevation gradient forcing. Wu et al. (2010) and Li et al. (2012) simulated the pure wind-driven current that flows into the North Channel and out of the South Channel with climatic wind to explain that the northerly wind can enhance saltwater intrusion in the North Channel, and weaken it in the South Channel. Zhang et al. (2019) reported that the frequency of saltwater intrusion events in the Changjiang Estuary is increasing in recent years due to increasing frequency of winter storms passing East China Sea.

Referee's reply to major issue 2: Authors added the wind speed curve at weather station in figure R3-2 and said that the data used was 2 minutes average. I also have the wind observations data. At this land-based station inside estuary, it is impossible that the 2 minutes average wind speeds are so large, persistent more than 10 m/s for long time and even larger than 15 m/s. In figure R3-1, why did authors present the modeled wind directions and speeds off the Subei coast, instead of off the Changjiang Estuary?

Author's reply: We established and managed the weather station at the Chongming eastern shoal for more than 15 years. The wind direction and speed was recorded with several forms, i.e., instantaneous, 2 minutes average, 10 minutes average, and maximum. We used the 2 minutes averaged wind direction and speed. The monthly mean wind in the Changjiang river mouth is 5.5 m/s during winter and 5.0 m/s in summer. February 2014 is a special month, occurred persistent and strong northerly wind. In Fact, the weather station is just on the river mouth (shown in Figure 1), not inside the estuary. The reviewer said he also has the wind observations data. Would you please draw a figure of the wind vector and speed curve to see how weak your wind is? And where is the weather station? This is a major issue the reviewer proposed, we will very appreciate you if the question can be figured out and what is the really wind.

We presented the figure R3-1 only to indicate the wind was much stronger on the sea than at Chongming eastern shoal for the reviewer. This picture is not used in the manuscript, only appears in the author's reply. We did not instead of the observed wind at the weather station with the modeled wind on the seas. We want to emphasize again that the observed wind data is only used to illustrate the wind status, and the wind used in the saltwater intrusion model was the simulated wind field by the WRF. The model domain is large, and wind has spatial variation. A point wind cannot represent a wind field. It can been seen in from the figure 7a that the temporally averaged wind field from February 7 to 14, 2014 simulated by the WRF reached more than 15 m/s in the Yellow Sea and off the Changjiang river mouth, indicating that there did exist a long persistent and strong northerly wind in February, 2014.

Referee's reply to major issue 3: About why the water level rise inside estuary is small, authors said that I misunderstood and water level rise at Sheshan and Luchaogang stations in Figure 2d was almost same as the one in 2 Figure 5a. Authors clearly said in the manuscript that the water level rise at Sheshan and Luchaogang are distinct with a peak value more than 0.5 m (line 91), which is shown in plot d of figure 2 as well. But at Baozhen the relatively large rise during neap tide 7-11 is about 0.15 m (line 135), which can be seen from plot a of figure 5 as well. So, what is the real situation?

About the method used calculating water level rise in plot d of figure 2, authors said that they subtracted the data in the tide table from the measured water level value. The obtained water level rises based on this method could have much error because the forecasted water levels in tide table have error as well.

About much more water level rise inside the estuary in plot b of Figure 4 and Figure 7, authors said that in plot b of Figure 4 and plot b of Figure 7, the time-averaged water level was shown, not the water level rise. But it can be seen clearly that “water level rise” was labeled in the legend.

Author’s reply: Thanks again.

We checked the water level rise in Figure 2d and water level in in Figure 5a, and concluded that the water level rise at Sheshan and Luchaogang are distinct with a peak value more than 0.5 m (Figure 2d). At Baozhen station, the difference between the observed water level and modeled water level under climatic wind can be roughly considered the water level rise by the northerly strong wind. It is seen from the Fig. 5a that the water level rise at low water level from February 5 to 12, 2014 was approximately 0.35.

We agree the reviewer’s opinion. The forecasted water levels in tide table have error. Because the water level can be directly measured, the water level rise cannot be obtained by direct observation, and the forecasted water levels in tide table without no strong northerly wind considered, the water level rise is roughly reasonable with the method subtracted the data in the tide table from the measured water level value.

Thank you pointing out the mistake. The legend in Figure 4b and in Figure 7b should be mean water level. Now we modified it in the revised manuscript.

Referee's reply to major issue 4: About already presented in previous work and unmentioned mechanism proposed in this manuscript, authors argued that the previous work was pure wind-driven and the work in this manuscript was not only wind-driven. But the proposed mechanism is the same. There is no the new thing, such as interaction between wind, tide, and river discharge. If you thought they were different, why did you not mention the previous work? Even if they are the same, it is ok only if you introduce and discuss the work. But you did not do this.

Authors said that if the wind directions were not always northerly, even southerly in some periods, the saltwater intrusion would be more severe and more serious impact on the Qingcaosha reservoir. Why? If it is true, the mechanism should be shown as well.

In addition, it can be seen clearly from figure R3-4 that at Chongxi station the increase of salinity relative to the normal situation on 3-4 was more than the "extreme event" period. On 3-4 the strong northerly or northeasterly winds occurred as well. Why was the saltwater intrusion in the North Branch during the extreme event period is not extremely serious? During 13-17, salinity was similar to the normal situation, which means that there is no increase of saltwater intrusion. However, saltwater intrusion at other stations did not occur on 3-4, but was very serious on the "extreme event" period. What is the difference between mechanisms of winds influencing the North Branch and the North Channel?

Author's reply: Thanks your comment. Now we added the previous work of the wind impact on the saltwater intrusion in the Changjiang Estuary in introduction section. Xue et al. (2009) pointed out that a northerly wind tends to enhance the saltwater intrusion in the North Branch by reducing the seaward surface elevation gradient forcing. Wu et al. (2010) and Li et al. (2012) simulated the pure wind-driven current that flows into the North Channel and out of the South Channel with climatic wind to explain that the northerly wind can enhance saltwater intrusion in the North Channel, and weaken it in the South Channel. In the discussion section in the revised manuscript, we added the following sentences: The wind-driven estuarine current can enhance saltwater intrusion in the North Channel, and weaken it in the South Channel. Previous studies revealed the dynamic mechanism of northerly wind on the saltwater intrusion by the pure wind-driven current in the estuary (Wu et al., 2010; Li et al, 2012). In this study, the horizontal estuarine circulation was a total (net) circulation forced by the river discharge, tide and persistent and strong northerly wind (Fig. 8a), which surpassed the strong seaward runoff.

I'm sorry we didn't make it clear of the impact of wind direction on saltwater intrusion. The correct expression is: If the wind directions were always northerly, and the southerly in some periods is northerly, the saltwater intrusion would be more severe and more serious impact on the Qingcaosha reservoir.

Thank you asking a very good question of the different performance of saltwater intrusion between at Chongxi station and at Nanmen, Baozhen station. The saltwater intrusion at Chongxi station is completely from the North Branch (SSO, saltwater-spill-over from the North Branch into the South Branch), but at Namen and Baozhen station is mainly from the SSO under normal wind condition. Because the North Branch is very shallow, the landward wind-driven Ekman water transport in it was weaker, flowing along the north side and flowing out along the south side only near the river mouth (Fig. 8b), the persistent and strong wind cloud enhance the SSO, but not such significant as in the North Channel. The North Channel is deeper and wider and located on the north side of the South Branch, which is in favor of producing strong landward Ekman water transport in the North Channel, resulting in severe saltwater intrusion. Therefore, the saltwater intrusion in the North Branch during the extreme event period is not extremely serious.

At Chongxi station the increase of salinity relative to the normal situation on 3-4 was more than the “extreme event” period, this is because the northerly wind was strong which has somewhat influence on the saltwater intrusion, but the major cause was the asymmetry of the semi lunar spring tide. This can be confirmed in Figure 5a that the high water level was higher on 3-4 than on 18-19 in the spring tide.

In order to better the contribution of the SSO in the saltwater intrusion event in February 2014, we added a subsection in the discussion section in the revised manucript. The contents are as follows.

4.1 How much contribution the SSO had in the saltwater intrusion event?

The most feature of saltwater intrusion in the Changjiang Estuary is the SSO. Previous studies showed that the SSO is the main source of saltwater intrusion in the upper and middle reaches of the South Branch and the main saltwater source of the reservoirs (Shen et al. 2003; Wu et al. 2006; Zhu et al., 2013; Lyu and Zhu, 2018). How much contribution the SSO had in the extremely severe saltwater intrusion in February 2014? A transect Sec 2 at the upper reaches of the North Branch (location labeled in Fig. 1) was set to calculate water and salt flux.

In Exp 1 (under climatic wind and residual water level conditions at open sea boundaries) the water flux from February 6 to 8, 2014 and salt flux on February 7, 2014 was transported from the South Branch into the North Branch. This phenomenon was occurred in neap tide (indicated by the water level in Fig. R3-2-1), while in the other tidal patterns the water and salt flux was transported from the North Branch into the South Branch, especially during the spring tide from February 14 to 17, 2014. This is the SSO occurring during middle and spring tide in dry season.

In Exp 2 (under a realistic wind and residual water levels at the open sea boundaries), the seaward water flux on February 7 became smaller and the landward water flux became larger from February 4 to 6 and from February 8 to 14, and the salt flux from February 4 to 14 was landward, under strong northerly wind, which was distinctly larger than the result under climatic wind and residual water level conditions at open sea boundaries. Therefore, the strong northerly wind enhanced the SSO.

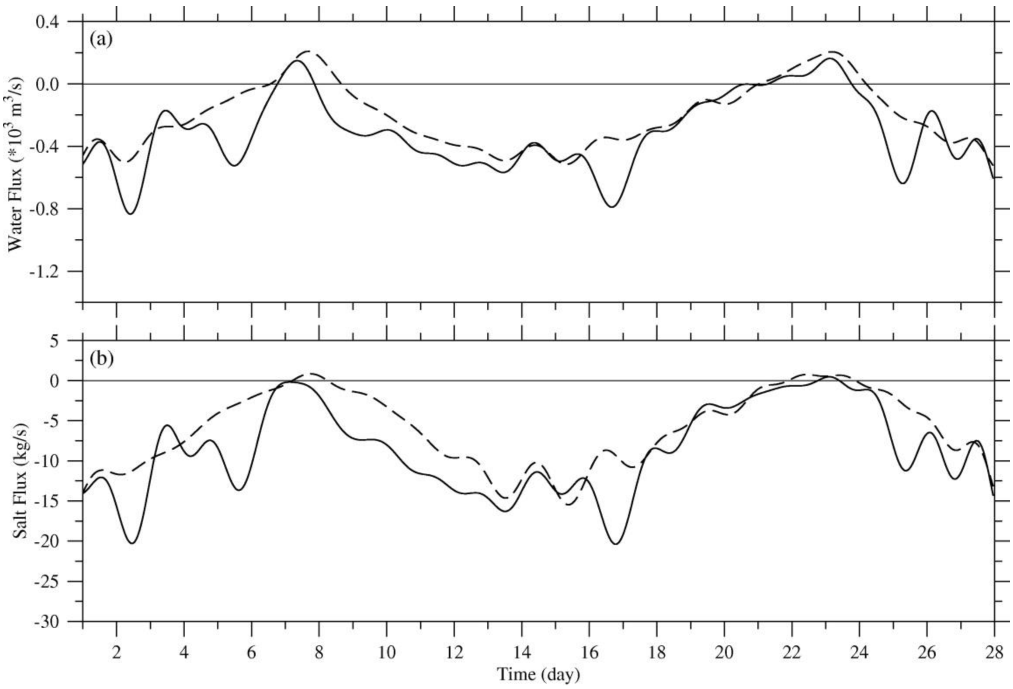

Figure R3-2-1: Temporal variations in residual water flux (a) and salt flux (b) across Sec 2 at the North Branch in February 2014. Dashed line: Exp 1; solid line: Exp 2. A positive value represents seaward flux, and a negative value represents landward flux.

A numerical experiment was designed in which the upper reaches of the North Branch is blocked (location labelled in Fig. 1) to further distinguish the contribution of SSO in the saltwater intrusion event. The distribution of time-averaged surface salinity from February 10 to 13, 2014 (Fig. R3-2-2a) and the temporal variations in salinity from February 8 to 22, 2014 at Chongxin station (Fig. R3-2-2b) show that the SSO was completely disappeared, while the salinity in the river mouth and near the Qingcaosha reservoir, and at the Baozhen, Nanmen and Qingcaosh stations were almost same as the results with Exp 2 (Fig. 8c, Fig. R3-2-3), indicating that the SSO almost had almost no contribution in the saltwater intrusion event in February 2014.

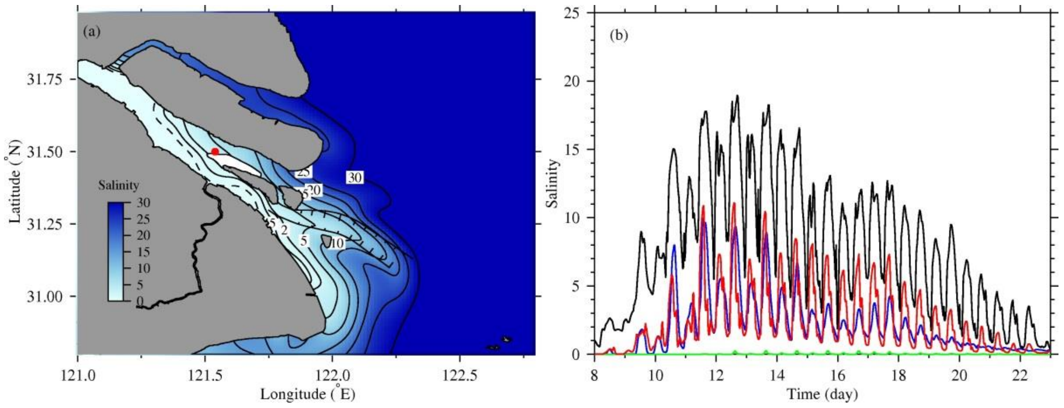

Figure R3-2-2: Distribution of time-averaged surface salinity from February 10 to 13, 2014 (a); and temporal variations in salinity from February 8 to 22, 2014 at hydrologic stations (b) if the upper reaches of the North Branch is blocked, and under a realistic wind and residual water levels at the open sea boundaries. Black line: Baozhen; red line: Nanmen; green line: Chongxi; blue line: Qingcaosha.

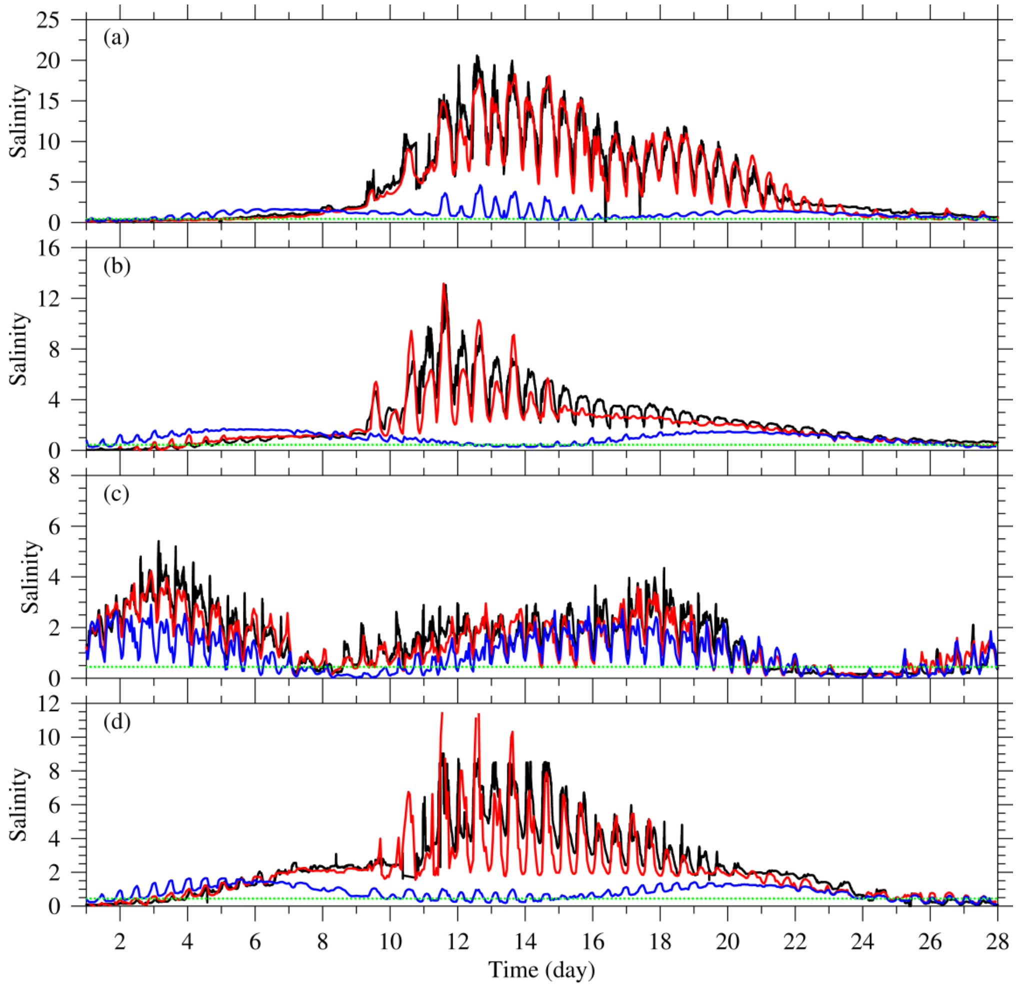

Figure R3-2-3 Temporal variations in salinity in February 2014 at hydrologic stations. a: Baozhen station; b: Nanmen station; c: Chongxi station; c: Qingcaosha station. Black line: measured salinity; blue line: Exp 1; red line: Exp 2. The dashed green line represents salinity of 0.45, which is the standard for drinking water.