Working Group Proposal to SCOR 2024

Oceanic Salt Intrusion into Tidal Freshwater Rivers (SALTWATER)

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Abstract

About two-thirds of global freshwater supplies come from surface waters such as the tidal fresh region of estuaries. A number of coastal and open-ocean processes may affect the oceanic salt intrusion into estuaries and tidal rivers, including sea-level rise, changing ocean circulation, changing tides, and wind events. However, we have little understanding of how these processes work in concert with extended drought to drive the extreme salt intrusion under climate change. This gap in scientific understanding has been exposed in a number of headline news reports on the salt contamination of drinking water supplies in tidal rivers. Three outstanding issues have been identified. First, there has been no international effort to synthesize the regionally distributed scientific findings on this emerging topic and identify priorities for future research. Second, the salt content of the riverine/seawater mixture includes salts produced during runoffs from the land surface and may have a relative salt composition different from that of seawater. Third, hydrodynamic models used to study the salt intrusion employ a number of numerical schemes, varying grid resolutions, and different parameterization schemes for unresolved subgrid processes. Best practices are needed to guide the model development.

This SCOR Working Group will bring together an international team of experts to discuss recent research on salt intrusion around the world. Our goal is to develop a global synthesis of this emerging topic, discern the roles of global climate change and local oceanic processes, and develop tools for observing, modeling and analyzing salt intrusion into tidal rivers.

1. Scientific Background and Rationale

1.1 Problem statement

About two-thirds of global freshwater supplies come from surface waters, including the tidal fresh region of estuaries. Prolonged drought and rapid sea level rise in a changing climate create a vulnerable combination that increases salt intrusion into estuaries and tidal rivers. Salt contamination of drinking water intakes has made headline news around the world. For example, the U.S. Army Corps of Engineers had to barge freshwater to water treatment facilities in New Orleans to dilute the salinity content to levels safe for drinking in 2023. Salt intrusion also occurred in the Changjiang River in 2022, contaminating drinking water supplies and leading to panic stockpiling of bottled water in Shanghai. The 2022 drought in Europe led to strong salt intrusion into the Rhine River and triggered emergency water conservation measures in the Netherlands.

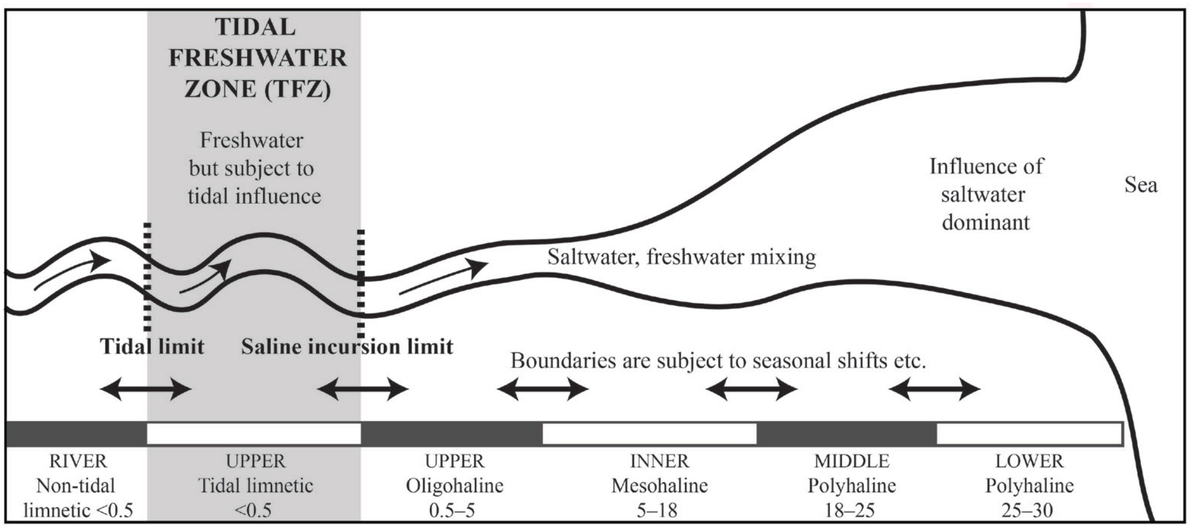

Fig. 1. A schematic of an estuary showing different subregions including the tidal freshwater zone where many drinking water intakes are located (from Little et al. 2022).

Indeed, salt intrusion is a global problem affecting many countries. Several rivers in Africa are affected, including the Pungue River between Zimbabwe and Mozambique and the Incomati River in southeast Africa (Hoguane 2000). The impact on Europe spreads from the Mediterranean countries to Western Europe, including the Po River Delta in Italy (Bellafiore et al. 2021), the Garonne, Loire and Seine Rivers in France, the Rhine River in the Netherlands, and the Elbe, Weser and Ems estuaries in Germany (Kolb et al. 2022). Many of Asia's megacities are vulnerable to salt contamination of water supplies, including the Changjiang River (Zhu et al. 2020) and the Pearl River (Payo-Payo et al. 2022) in China and the Ganges-Brahmaputra-Meghna Delta in India (Bricheno et al., 2021). In South America, salt intrusion affects the Valdivia River in Chile (Garcés-Vargas et al. 2020), the São Francisco River in Brazil and the Magdalena River in Colombia (Ospino et al. 2018). In North America, salt intrusion affects rivers that drain into all three coasts, including the Delaware River, the Hudson River (Hogland et al. 2020), San Francisco Bay–Delta and the Papaloapan River.

Salt intrusion into estuaries depends primarily on the balance between the seaward freshwater transport due to river flows and the landward salt transport from the ocean. While estuarine circulation and shear dispersion dominate salt transport in the mesohaline region of estuaries, tidal pumping, oscillatory shear dispersion and lateral trapping may be more important in the oligohaline and tidal fresh zones (Fig. 1). A number of coastal and open-ocean processes may affect the salt transport, including (1) sea-level rise; (2) regional sea level fluctuations due to changing ocean circulation; (3) inflow salinity from coastal oceans; (4) changes in tides; (5) wind events and storm surges (Perales-Valdivia et al. 2018; Yang and Zhang 2023). Moreover, local anthropogenic activities such as channel deepening have amplified tides and salt intrusion (Ralston and Geyer 2019; Kolb et al., 2022).

Sea-level rise can cause stronger salt intrusion into estuaries. Analysis of monitoring data in Chesapeake and Delaware Bays showed a clear connection between sea-level rise and estuarine salinity increases (Hilton et al. 2008; Ross et al. 2015). In the San Francisco Bay the effects of sea-level rise on salt intrusion were stronger during periods of low river flows (Chua and Xu 2014). Climate change increases the risk of extreme salt intrusion across European estuaries, with sea-level rise as important as summer drought in many mid-latitude estuaries such as Loire, Scheldt, Rhine-Meuse, Elbe and Hummer (Lee et al. 2024). In Asia sea-level rise is a major factor enhancing salt intrusion into the Changjiang, Pearl, Mekong, Gorai and Gangers Rivers (Hong et al. 2020; Eslami et al. 2019).

Salt intrusion could be also driven by rising coastal sea levels due to changing ocean circulation. The accelerated sea-level rise along the U.S. east coast north of Cape Hatteras during 1950-2009 was attributed to the weakening of Atlantic Meridional Overturning Circulation and the Gulf Stream (Sallenger et al. 2012; Ezer et al. 2013) whereas the rapid sea-level rise in the U.S. southeast and Gulf coast in recent years was thought to be either associated with sterodynamic effects due to warming of coastal currents (Domingues et al. 2018) or amplified by internal climate variability in the tropical North Atlantic (Dangendorf et al. 2023). Significant correlation has been found between El Niño-Southern Oscillation and extreme sea levels across the Pacific (Muis et al. 2018), including the west coast of North America (Hamlington et al. 2015) and South China Sea (Gong et al. 2022).

The salinity of oceanic water entering estuaries can affect salt intrusion. For example, salinity on the Mid-Atlantic Bight showed decadal oscillations and co-varied with the bottom salinity inside Chesapeake Bay (Lee and Lwiza 2008). Also, episodic events such as upwelling or downwelling can change the inflow salinity. In the Western Baltic Sea salinity outside an estuary can increase from 10 to 20 g/kg within a few hours (Lange et al. 2020). River plumes could also interact and change the inflow salinity (Flöser et al. 2011).

Tides affect salt intrusion through turbulent mixing and tidal dispersion in estuaries. Tidal amplitudes in shelf seas can vary seasonally and over longer terms due to changes in stratification. A stratified water column will experience less frictional dissipation and allows for stronger coastal tides. An example is the strong seasonality of semi-diurnal tides in the North Sea (Müller 2012) such that quarter-diurnal tides are enhanced in summer in support of stronger salt intrusion (Gräwe et al. 2014). Moreover, sea-level rise has been shown to amplify tides in San Francisco Bay, Chesapeake and Delaware Bays if shorelines are kept rigid but decrease tides if low-lying areas are flooded (Holleman and Stacey 2014; Lee et al. 2017).

Despite the global impacts of salt contamination of water supplies, we have limited understanding of how the oceanic processes affect salt intrusion into estuaries and tidal rivers. Most of our current knowledge comes from case studies by individual researchers around the world. Several major challenges have been identified. First, there has been no international effort to synthesize major scientific findings on this emerging topic and identify priorities for future research. Second, the salt content of the riverine/seawater mixture includes salts produced during runoffs from the land surface (Kaushal et al. 2018) and may have a relative salt composition different from that of seawater (Pawlowicz 2015). The standard seawater equation of state may not be accurate enough for calculating water density distributions in tidal fresh rivers (Pawlowicz and Feistel 2012). Third, hydrodynamic models are widely used to study saltwater intrusion and develop salinity management strategies but they employ a number of numerical schemes, varying grid resolutions, and different parameterization schemes for subgrid processes. It is important to conduct model inter-comparisons and establish "best practice" approach for model configurations.

1.2 Rationale for the SCOR working group

Over the past few years there has been active research activities on the problem of salt intrusion, but many are site-specific studies. Little is known of the commonalities among these systems. With the salt contamination of freshwater supplies making headline news, it is urgent and timely to bring together an international community of researchers to share and discuss recent studies on the salt intrusion. The proposed study topic is so rich and complex that it is impossible to address it at a session in a conference. It requires sustained discussions over time. The SCOR Working Group (WG) can bring together an international team of experts to engage in regular discussions over 4 years.

2. Terms of Reference (ToR)

This SCOR WG will synthesize case studies of salt intrusion into estuaries and tidal rivers around the world and develop best practice approaches for measuring, modeling and analyzing salt intrusion. The overall goal is to advance scientific understanding and produce actionable scientific information. Specifically, it aims to:

ToR1 Conduct a comparative analysis of selected case studies on the salt intrusion into estuaries and tidal rivers, gain a better understanding of the coastal and open-ocean processes that influence the salt intrusion, and identify gaps in knowledge and priorities for future research.

ToR2 Synthesize existing modeling studies of estuaries and tidal rivers, conduct model inter-comparison studies, and produce a best practice manual for model configurations such as grid resolutions and mixing/dispersion parameterizations.

ToR3 Analyze chemical composition of riverine/oceanic water mixtures using a global database of river chemistry and the data collected by the WG members. Develop an improved equation of state for the riverine-seawater mixture.

ToR4 Conduct data analysis to identify conditions conducive to enhanced salt intrusion in different types of estuaries by leveraging site-specific studies conducted by the SCOR WG members and their collaborators. Build a Github for sharing the data analysis programs.

ToR5 Develop a global synthesis of oceanic salt intrusion into estuaries and tidal rivers and discern the roles of river flows, sea-level rise, regional sea level fluctuations, changes in tides, and winds in driving extreme salt intrusion and salt contamination of water supplies.

ToR6 Build capacity, share knowledge and transfer technical skills, particularly to scientists in developing nations.

3. Deliverables

From ***ToR1***:

1. An initial review/perspective paper summarizing the current research on salt intrusion into estuaries and tidal rivers, identifying important coastal and open-ocean processes that affect the salt intrusion, highlighting the key unknowns and critical gaps in our current understanding, and suggesting priority future research directions.

From ***ToR2***:

2. A review paper on modeling salt intrusion into estuaries and tidal rivers and comparing the performance metrics among different numerical models.
3. A best practice manual for model configuration including grid resolution and mixing parameterizations, published in an open-access journal.

From ***ToR3***:

4. A methods paper on an improved equation of state for the riverine-seawater mixture in different types of tidal rivers.
5. A best practice manual for measuring salts in tidal rivers.

From ***ToR4***:

6. A GitHub repository for the data analysis codes used to analyze and interpret the salt intrusion into estuaries and tidal rivers by assembling tools and codes developed by the WG members.

From ***ToR5***:

7. A high-impact paper to provide a global synthesis of salt intrusion in estuaries and tidal rivers, identify key oceanic and hydrological processes that contribute to extreme salt intrusion and salt contamination of water supplies, and discern the effects of global climate change (e.g. sea-level rise) and local estuarine and coastal processes (e.g. tidal amplification, channel dredging).

From ***ToR6***:

8. On-line training courses and resources (e.g. video recordings, GitHub repositories) on modeling, data-analysis and observational approaches to study salt intrusion for scientists and water resource managers, particularly those from developing nations.

4. Working plan

To deliver ToR1

We will collate existing studies on salt intrusion into estuaries and tidal rivers. Initially each WG member will lead case studies in Asia, Europe, Africa, South America and North America. We will then identify similarities and commonalities among these systems and group them in terms of physical characteristics and forcing regimes such as the magnitudes of river flow and tidal range, the topography of estuaries and rivers (e.g. dendritic versus axonic, sinuosity of rivers, presence or absence of intertidal flats and salt marshes) and estuarine stratification strength. We will analyze how different coastal and open-ocean processes (e.g. sea-level rise, changing ocean circulation, changes in tides, wind events, local anthropogenic processes such as channel dredging) affect the salt intrusion into the estuaries and salt transport from the oligohaline to the tidal fresh zone. Gaps in understanding and key unknowns will also be identified.

To deliver ToR2

We will assemble the modeling papers on salt intrusion. A large volume of papers have been published in recent years. We will perform a literature review in the Web of Science and conduct a meta-analysis by framing queries and searches. This will be complemented by model inter-comparison exercises on selected estuaries and tidal rivers where multiple models are available. These analyses will reveal how numerical schemes, grid resolutions and choices of subgrid-scale parameterization schemes affect the model's prediction. We will produce a best practice manual for the model configuration.

To deliver ToR3

We will analyze newly available global databases of river major ion chemistry (Hartmann et al. 2014; Muller et al. 2021) and add conductivity and ion-specific measurements which the WG members and their collaborators have collected for their own research projects. The current TEOS-10 standard for properties of seawater includes procedures for incorporating the effects of dissolved salts produced by chemical weathering and human inputs but they are still only poorly tested (Pawlowicz and Feistel 2012; Pawlowicz 2015). Many rivers in Europe and North America have experienced significant freshwater salinization whereas most of Africa and significant regions of South America and Asia have older soils that can store major ions and salts over a longer time. We will select the rivers that have experienced varying degrees of freshwater salinization, analyze the chemical composition of the riverine/seawater mixtures, and further refine river-modified equations of state. A best practice manual will be written up to provide guidance on the salt measurements in tidal rivers and their effects on thermodynamical water properties.

To deliver ToR4

We will discuss the findings from the case studies and develop a global synthesis of salt intrusion into tidal rivers. Specifically, we will identify major coastal and open ocean processes that affect the salt intrusion into estuaries and tidal rivers, including global sea-level rise, regional accelerated sea-level rise due to changing ocean circulation or sterodynamic effects, changes in tides and winds. Given the diversity of estuaries and tidal rivers, we may group them into different categories and conduct cross-comparisons. For example, we may compare large rivers with high river flows and strong tides, dendritic delta systems, rivers and estuaries in arid climate that may turn hypersaline during the dry seasons, and systems that have been subjected to major morphological changes or engineering activities such as channel dredging.

To deliver ToR5
We will organize online workshops and in-person tutorials on salt measurements, data analysis and numerical modeling. We will establish peer-to-peer mentoring of early career scientist and promote research collaborations between the developed and developing countries.

To deliver ToR6
We will organize online workshops and in-person tutorials on salt measurements, data analysis and numerical modeling. We will establish peer-to-peer mentoring of early career scientist and promote research collaborations between the developed and developing countries.

Timeline:

Year 1 – 2025
Hold bi-monthly zoom meetings to review the existing observational and modeling studies of salt intrusion into tidal rivers around the world (ToR 1 and 2). This may alternate with the bi-monthly virtual panel discussions that are being planned for a related conference project on the salt contamination of water supplies funded by the US National Science Foundation (NSF) (Li as the lead PI). The SCOR WG members will serve as panelists at these virtual discussions and interact with a larger group of oceanographers, hydrologists and water resource managers. A workshop will be held in December 2025, possibly associated with American Geophysical Union Fall meeting. Prepare an initial review/perspective paper summarizing the current research on the salt intrusion into tidal rivers and identifying key unknowns and future research directions (Deliverable 1).

Year 2 – 2026
Hold bi-monthly zoom meetings to review the modeling studies of salt intrusion and write up the review paper on the modeling (Deliverable 2). Produce the best practice manual for model configuration (Deliverable 3) and offer an on-line tutorial (ToR 2 and 6, Deliverable 8). Hold the second SCOR workshop in October 2026, possibly associated with the Physics of Estuaries and Coastal Seas (PECS) which estuarine oceanographers including most of the WG members attend regularly.

Year 3 – 2027
Hold bi-monthly zoom meetings to review the existing observational techniques and analyze the riverine/oceanic water mixtures for a revised equation of state (ToR 3). Complete the methods paper and best practice manual on salt measurements (Deliverables 4, 5, 8, ToR 6).

Year 4 – 2028
Hold bi-monthly zoom meetings to develop a global synthesis of salt intrusion into estuaries and tidal rivers (ToR 5 and Deliverable 7). Hold the final workshop, conduct a review of salinity management in tidal rivers, and organize a side event at the UN Ocean/Water Conference (ToR 6

and Deliverable 8).

5. Capacity Building

This SCOR WG will bring together scientists to share knowledge, insights and lessons. The twenty WG members come from 15 countries in Asia, Europe, Africa, South and North America and Australia, consisting of 8 developed countries and 7 developing countries. Our reach to developing countries is not limited to these 7 countries, however. Some of our WG members have established international collaborations or are leading regional or international programs. For example, John Largier (USA) has long term collaborations with African countries such as South Africa, Senegal and Mozambique. Arnoldo Valle Levinson (USA) has mentored many young scientists in Central and South America. Charita Pattiaratchi (Australia) has been supervising coastal and estuarine research in Sri Lanka for decades. We will leverage these international relationships to foster knowledge sharing and research collaborations.

We plan to promote capacity building by pursuing the following activities:

5.1 Enhancing research capacity in developing countries by fostering research partnerships

Although estuaries are highly diverse, there are similarities among certain types of estuaries in which research progress in some can inform understanding of less studied systems. For example, the Hudson River, the São Francisco River, the Lorie River, the Rhine River, the Seine River, the Changjiang River, the Mekong River, and the Fraser River have all undergone significant bathymetric changes due to human activities such as channel deepening, shoreline hardening, land reclamation and land use changes. A comparative study of these systems may shed lights on the effects of local anthropogenic processes on the salt intrusion. Another group of estuaries well suited for a comparative study are estuaries located in the arid climate, including the Pearl River Delta, the Indus River Delta, the Po River Delta, the Guadalquivir River, and San Francisco Bay-Delta. A third group consists of relatively smaller estuaries where mouth closure or shoaling can trap a lower layer of saline water and lead to strong stratification, such as those in the Mediterranean-climate coasts in South Africa, Chile and California and artic/Antarctic fjords. The case studies and synthesis proposed for this SCOR WG will identify these common characteristics. Subgroups of the WG will be formed to collaborate on these different types of estuaries and form research partnerships between the developing and developed nations. This collaboration can take various forms, such as joint authorships on papers or joint applications for research grants to international programs.

5.2 Training the next-generation modelers on salinity management

Many countries rely on numerical models to develop strategies to manage salt contamination of water supplies in tidal rivers, particularly in anticipation of extended drought and rapid sea level rise under climate change. The synthesis paper and the best practice manual for modeling salt intrusion into tidal rivers will provide much needed guidance on the appropriate use of numerical models in designing salinity management strategies. Some of the WG members are seasoned modelers and will take a lead in organizing online tutorials that will be open to everyone. Towards the end of year 2, we plan to offer a live zoom tutorial which will be recorded and made available online. Depending on the feedback from audiences, we may give another online modeling tutorial that will include an extensive Q&A session.

5.3 Capacity building on salinity measurements in tidal fresh rivers

Currently reports of salt contamination of water supplies are based on measurements of various quantities. The proposed best practice manual on salt measurements will help set a standard approach for detecting salt contamination of water supplies. The manual and paper will be made available to everyone and the standard can become a "Common" for the ESFRI DANUBIUS RI, contributing to the increase of interoperability among different river-sea systems. Some of the WG members have extensive experience in observational techniques and will take a lead in developing the online training tutorials. In year 3 we plan to offer a live zoom tutorial and make the recording available. A follow-up Q&A session will also be offered in year 4 to solicit feedback from the user community.

5.4 Enhancing data analysis skills

We will develop and share tools for the data analysis such as machine learning algorithms. The salinity time series will be accompanied by the time series of river flows, sea level fluctuations, and winds as well as other environmental changes, with the goal to interpret the salinity time series data, identify the conditions conducive to the salt intrusion, and develop empirical statistical models for forecasting salt intrusion. A Github repository will be set up to share computer codes and will be made freely available.

5.6 Mentoring early-career scientists

Six WG members are early-career female scientists (ECRs). We will pair them up with senior WG members with similar research interests for one-to-one peer mentoring as well as group meetings devoted solely to issues related to career developments. The senior WG members will listen to the concerns raised by the ECRs and share their successes and lessons in fund-raising and peer-reviewed publications. The mentoring could also have a more technical focus. For example, senior modelers (Burchard, Li, Pietrzak, Wu, Gong, Bellafiore) could team up with ECR modelers (Cordona, Sanay, Musgrave) to discuss how to develop research projects that have a modeling focus. Senior observational oceanographers (Valle-Levinson, Largier, Pawlowicz, Diez-Minguito, Schettini) could team up with ECR observationalists (Jalon-Rojas, Williams, Guerra) to explore how to develop a field program.

5.7 Enhancing salinity management strategies through knowledge sharing at UN

Although SCOR WGs focus primarily on advancing the oceanographic research, the scientific advances to be made in this WG will not only build scientific capacity but also may contribute to better strategies for managing freshwater supplies under climate change. A common salinity management approach is the storage and regulated releases of freshwater from reservoirs during low river flows, but this approach is becoming difficult to implement in regions featuring a long duration of drought punctuated by short periods of intense precipitation (e.g. California and Mediterranean-like climate). Alternative measures have been implemented. For example, a pipeline has been constructed in the Greater Bay Area, China to transport water from upstream reservoirs to downstream cities such as Macau and Zhuhai. Physical barriers, whether temporary or permanent, have been used to separate freshwater from oceanic water, but at the risk of jeopardizing ecosystems and fish migration, such as The Haringvliet Gates built for storm surge protection in the Netherlands. Other approaches involve water resource planning rather than engineering. For example, the U.S. Army Corps of Engineers is studying whether to release water from a Pennsylvania reservoir to the Delaware River during times of drought. Additional options include building desalination plants, curbing water consumption by industrial users such as nuclear power plants and agriculture, or even moving drinking intakes farther upstream. All these water management strategies are costly and involve tradeoffs and difficult decisions.

Another potential but often overlooked mitigation strategy is the management of salt intrusion from the ocean side where this SCOR WR is well positioned to contribute. Tides and tidal-induced dispersion are ultimately responsible for the salt intrusion into tidal rivers. It is now well known that channel deepening increases tidal ranges whereas land reclamation/infilling reduces tidal ranges, such as in the Changjiang River estuary. This prompts an economic evaluation on the costs and benefits of ports and shipping versus those of water supplies such as those currently being carried out in the Netherlands. Similarly, hardening shorelines using sea walls and levees to protect against coastal flooding tends to amplify tides whereas nature-based flood mitigations such as salt marshes and water retention ponds can reduce tides and hence the upstream salt transport. Consequently, the mitigation strategy developed to bolster coastal resilience against sea level rise and coastal flooding must be weighted against the salinity management strategy intended to protect water supplies further upstream.

We will discuss these strategies and summarize our findings on salinity management as a side event at a UN Ocean/Water Conference in year 4 (2028). Annual UN Ocean Conferences are hosted by different countries: e.g. France (2025). We will reach out to UNESCO and conference organizers, and inquire about the possibility of a side event at the UN Ocean Conference in 2028. UN held its first-ever water conference in New York City in March 2023. We will also make inquires to the organizers of the UN Water Conference and explore the feasibility of incorporating our theme. This outreach to the UN will serve multiple purposes: (1) raise the awareness of this issue as salt contamination has not received as much attention as other water quality issues (e.g. metals, coliforms, harmful algal blooms) in some countries; (2) promote research and monitoring of salt intrusion across both developing and developed countries; (3) provide a source of reliable and actional information for countries that are resource-limited.

6. Working Group composition (as table).

This WG has expertise in the fields of estuarine and coastal oceanography, large-scale ocean circulation and mesoscale processes, climate change, anthropogenic impacts on estuaries, ocean observations, data analysis, numerical modeling, and interdisciplinary research on water quality.

Geographical spread: The 20 members originate from 15 countries, including 8 developed and 7 developing countries.

Participation of early-career researchers: Early-career researchers (ECRs) are well represented in our working group, with 3 ECRs among the Full members (Cardona, Williams, Jalon-Rojas), and 3 ECRs among the Associate members (Musgrave, Sanay, Guerra).

Gender balance: Our WG is comprised of 5 female and 5 male Full members, and 4 female and 6 male Associate members. All of 6 ECRs are female.

Full Members

Name	Gender	Early Career Status	Place of work	Expertise relevant to proposal
Ming Li	M		University of Maryland Center for Environmental Science, Co-Chair. **USA**	Estuarine and coastal dynamics, regional impacts of climate change, interdisciplinary research on water quality
Hans Burchard	M		Leibniz Institute for Baltic Sea Research, Co-Chair. **Germany**	Estuarine and coastal physics, anthropogenic impacts on coastal oceans, sediment dynamics, turbulence modeling, ocean modeling
Julie Pietrzak	F		Delft University of Technology. **Netherlands**	Physical oceanography, shelf and coastal dynamics, salt intrusion into estuaries
Nadia Pinardi	F		University of Bologna **Italy**	Ocean predictions, data assimilation, large-scale circulation and mesoscale processes
Isabel Jalon-Rojas	F	Yes	Bordeaux University. **France**	Coastal oceanography, morphodynamics, impacts of climate change on estuaries
Yuley Cardona	F	Yes	Universidad Nacional. **Colombia**	Ocean modeling, mesoscale processes, estuarine dynamics
Megan Williams	F	Yes	Pontificia Universidad Católica de Chile. **Chile**	Estuarine dynamics, salt transport, field observations, remote sensing, anthropogenic influence on coastal freshwater delivery
Rich Pawlowicz	M		University of British Columbia. **Canada**	Coastal oceanography, observations, salinity measurements
Antonio M. Hoguane	M		Eduardo Mondlane University. **Mozambique**	Estuaries, hydrology, climate change
Wenping Gong	M		Sun Yatsen University. **China**	Modeling and field measurements of saltwater intrusion

Associate Members

Name	Gender	Early Career Status	Place of work	Expertise relevant to proposal
John Largier	M		University of California, Davis. **USA**	Estuarine dynamics, field observations, data analysis

Arnoldo Valle-Levinson	M		University of Florida. **USA**	Coastal hydrodynamics, sea level rise, data collection & analysis, salt intrusion
Ruth Musgrave	F	Yes	Dalhousie University, **Canada**	Coastal oceanography, shelf processes, internal waves
Debora Bellafiore	F		National Research Council - Institute of Marine Sciences **Italy**	Modelling, coastal and transitional environment oceanography
Manuel Diez-Minguito	M		University of Granada. **Spain**	Environmental fluid dynamics, estuarine dynamics
Carlos Augusto Schettini	M		Universidade Federal do Rio Grande. **Brazil**	Dynamics of estuaries, coastal plumes and inner shelf, observations
Rosario Sanay	F	Yes	Universidad Veracruzana. **Mexico**	Coastal oceanography, microtidal salt wedge estuaries, data analysis
Gisselle Guerra	F	Yes	Universidad Tecnologica de Panama. **Panama**	Environmental and coastal engineering, salt intrusion
Charitha Pattiaractchi	M		University of Western Australia, **Australia**	Coastal circulation and mixing, coastal currents, field measurements and modeling
Hui Wu	M		East China Normal University. **China**	Estuarine dynamics, coastal circulations, biophysical interactions

7. Working Group contributions

Ming Li is a physical oceanographer who studies the impacts of climate change on estuaries and conducts interdisciplinary research on water quality, hypoxia, harmful algal blooms and ocean acidification. He has established a Research Coordination Network (RCN) to advance interdisciplinary research for building resilience in estuaries and bays in the US and is leading two NSF-funded projects on the global synthesis of salt contamination of water supplies in tidal rivers and the development of decision support tools for salinity management.

Hans Burchard is a coastal ocean hydrodynamic modeler who has developed and applied numerical models of various complexity to understand mixing and exchange flow in estuaries. He has recently developed diahaline mixing concepts that explain processes of salt intrusion into estuaries and consequences for sediment transport.

Julie Pietrzak is a physical oceanographer who has worked on shelf seas and ocean basins using field observations and numerical models. She is currently leading a large Dutch research project titled SALTISolutions "Salt Intrusion in urbanising deltas – Solutions" that seeks to understand and mitigate salt intrusion in the Dutch Delta under current and future climate conditions.

Nadia Pinardi is a physical oceanographer with expertise in numerical modeling and forecasting, data assimilation, numerical modeling of marine physical-biological interactions as well as the study of pollutant behavior in marine environments. Her major achievement is the practical implementation of ocean and coastal forecasting systems worldwide.

Isabel Jalon-Rojas studies the hydro-morpho-sedimentary evolution of tidal rivers, with a focus on French hyper-turbid systems. She investigates the impact of climate variability and human activities on the retroactions between hydrodynamics, sediment transport, morphology and saltwater intrusion.

Yuley Cardona uses various numerical models to understand regional and coastal ocean processes, with a particular interest in mesoscale ocean dynamics and their connection with tracer transport. She has also investigated transport of nutrients and sediment in the Mississippi and Magdalena river plumes.

Megan Williams uses *in-situ* and remote sensing measurements to study hydrodynamics and sediment transport estuaries, fjords, and coastal wetlands. Current work focuses on effects of strong stratification on estuarine and river plume dynamics, analyzing climate change effects on semi-arid coastal basins, and assessing the impact of drought and human activity on freshwater delivery in Mediterranean climate coastlines.

Richard Pawlowicz studies river plumes and salt wedge dynamics, especially in the Fraser River, Canada. He is also a world-leading expert on the relationship between the chemical composition of salts in rivers and coastal seawaters, and their density and conductance, co-authored the TEOS-10 standard, and is the current chair of the Joint SCOR/IAPSO/IAPWS Committee on the Properties of Seawater (JCS).

Antonio Hoguane conducts interdisciplinary research on tropical estuaries including physics, ecology, and energy in these systems. He has also worked on salt intrusion and environmental flows for the health and integrity of marine coastal ecosystems.

Wenping Gong has expertise in numerical modelling, field measurements and theoretical analysis, with a focus on estuaries and coastal oceans. Recently he has investigated how climate change and human activities affect the salt intrusion into the Pearl River estuary.

8. Relationship to other international programs and SCOR Working groups

UN Decade of Ocean Science for Sustainable Development (2021-2030) seeks transformative ocean science solutions for sustainable development. This SCOR WG addresses Challenge 5 to generate knowledge and solutions to mitigate, adapt and build resilience to the effects of climate change. The WG also addresses Challenge 6 to enhance community preparedness and resilience to climate and anthropogenic coastal hazards as salt contamination of water supplies affects the lives of many millions of people around the world.

The UN General Assembly convened a Water Conference in 2023 to develop a Water Action Agenda that calls for voluntary commitments to address the global water challenges. Safe-guiding water supplies in coastal regions was recognized to be an important issue. This SCOR WG will help address this issue.

Nadia Pinardi is the Chair of the UN Decade of Ocean Science for Sustainable Development Program "CoastPredict" and the director of the UN Decade Collaborative Center for Coastal Resilience (DCC-CR) hosted by the University of Bologna. This SCOR proposal will contribute directly to the Global Coastal Ocean Network, which is under development by CoastPredict and the DCC-CR.

Rich Pawlowicz chairs the Joint Committee on the Properties of Seawater among SCOR, IAPSO and IAPWS which provides the official source of information about the Thermodynamic Equation of Seawater – 2010 (TEOS-10) adopted by the Intergovernmental Oceanographic Commission. The modified equation of state for the riverine/seawater mixtures to be developed in this WG will improve TEOS-10.

Findings from this SCOR WG will be of interest to the International Centre for Advanced Studies on River-Sea Systems (DANUBIUS-RI), a pan-European distributed research infrastructure supporting interdisciplinary research on River-Sea Systems. Debora Bellafiore coordinates the DANUBIUS Modelling Node and is working on a report assessing the impacts of saltwater intrusion on coastal communities.

Case studies of the delta systems in this WG will be of interest to the Mega Delta program endorsed by the UN Ocean Decade, involving comparative studies between the Chanjiang Delta, the Ganges Delta, the Indus Delta, Nile Delta and the Danube Delta. The case studies will also be of interest for the DITTO-Digital Twins of the Ocean UN Decade endorsed Program.

This SCOR WG topic is closely related to the US NSF-funded conference project "salt contamination of water supplies in tidal rivers" that involves oceanographers as well as hydrologists (Ming Li).

We will also seek collaborations with the World Association for Waterborne Transport Infrastructure (PIANC) which had a working group on saltwater intrusion mitigation in inland waterways.

This SCOR WG will also benefit smaller international projects, including a joint France-Canada (Quebec) EMPHASE program on hydro-sedimentary dynamics in harbor-estuaries (Isabel Jalon-Rojas), the Colombia-Germany collaboration on the Rio Magdalena Delta (Yuley Cardona), and the China-U.K.-Netherlands collaboration on the Pearl River estuary (Wenping Gong).

Related SCOR Working Groups are listed below:

SCOR Working Group 145. Modelling Chemical Speciation in Seawater to Meet 21st Century Needs (MARCHEMSPEC)

SCOR Working Group 127. Thermodynamics and Equation of State of Seawater

SCOR Working Group 122. Mechanisms of Sediment Retention in Estuaries

SCOR Working Group 121. Ocean Mixing

9. Key References

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Appendix

Five key publications related to the proposal are indicated for each Full Member. Bold face is used to highlight the name of each WG member within her/his list of publications. The google scholar or research gate profiles of WG Full Members can be found by clicking the hyperlinks attached to their names.

Ming Li (Co-Chair):

Valle-Levinson, A., **M. Li.** 2023. Climate change and saltwater intrusion in estuaries. Chapter 6 in Climate Change and Estuaries edited by M. J. Kennish, H.W. Paerl, J. R. Crosswell. CRC Press. 99-112. doi: 10.1201/9781003126096-7.

Ross, A.C., R.G. Najjar, **M. Li**. 2021 A metamodel-based analysis of the sensitivity and uncertainty of the response of Chesapeake Bay salinity and circulation to projected climate change. *Estua. Coast.*, 44, 70-87, https://doi.org/10.1007/s12237-020-00761-w.

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Schulte, J.A., R.G. Najjar and **M. Li**. 2016. The influence of climate modes on streamflow in the Mid-Atlantic Region of the United States. *J. Hydrol.-Reg. Stud.*, 5, 80-99.

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Hans Burchard (Co-Chair):

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Lange, X., **H. Burchard**, K. Klingbeil. 2020. Inversions of estuarine circulation are frequent in a weakly tidal estuary with variable wind forcing and seaward salinity fluctuations. *J. Geophys. Res.*, 125, 10.1029/2019JC015789.

Li, X., M. Lorenz, K. Klingbeil, E. Chrysagi, U. Gräwe, J. Wu, **H. Burchard**. 2022 Diahaline mixing and exchange flow in a large multi-outlet estuary with islands. *J. Phys. Oceanogr.*, 52, 2111-2127.

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Rijnsburger S., R. P. Flores, **J. D. Pietrzak**, K. G. Lamb, N. L. Jones5, A. R. Horner-Devine, A. J. Souza. 2021. Observations of multiple internal wave packets in a tidal river plume. *J. Geophys. Res.,* 126, https://doi.org/10.1029/2020JC016575

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