EGUSPHERE-2026-1398 — Response to RC2

Reviewer comments are paraphrased in italics; author responses follow each point.

General Comments / Overall Impression

The manuscript investigates subsurface controls on groundwater flow and salinity stratification across a microtidal estuarine wetland transect using ERT, sediment analysis, and hydrological monitoring. The integration is commendable and addresses a critical knowledge gap. However, substantial revision is required, primarily concerning geophysical processing, interpretation, and quantitative uncertainty of the hydrological data. Recommendation: Major Revision.

[Author response] We thank Reviewer #2 for the careful, constructive assessment and for recognising the value of the dataset and the knowledge gap it addresses. We agree that the geophysical processing and uncertainty must be strengthened. We have brought in a geophysicist with expertise in time-lapse ERT and petrophysical (Archie's law) modelling: Dr Brady Flinchum (University of Newcastle, Australia) has joined the author team and led the ERT re-processing, time-lapse analysis and geophysical revisions. We propose revisions in detailed responses to the reviewer's comments below. We are confident these revisions fully address the concerns and substantially strengthen the manuscript.

Major Comments

1. Geophysical Inversion Methodology & Temporal Inconsistencies

Transects were collected at different times (Feb, Jun, Sep 2024) and under different hydrologic conditions (ERT-2 post-storm surge). EC_B is transient; stitching profiles across seasons and post-storm conditions into a single continuous representation without robust normalisation is geophysically unsound.

[Author response] We agree and apologise for the unclear wording. Each transect was inverted independently; "spatially aligned and combined" referred only to visual co-location used for monitoring-site selection, not to a merged or averaged subsurface model, and no quantitative interpretation drew on cross-date combinations. In the revision we will (a) remove the stitched representation entirely and present each inversion separately with its acquisition date and hydrological context, and (b) exploit the repeated ERT-1/ERT-2 line as intended — a quantitative time-lapse comparison.

During re-processing for this time-lapse comparison, we identified and corrected a field cabling artefact affecting ERT-1 and ERT-2. Adjacent electrodes 30 and 31 were effectively connected during current injection, so that current injection on one electrode also occurred on the other. This produced near-zero measured resistances and generated a spurious shallow conductive anomaly in the original inversions.

Correcting the electrode geometry by shifting all electrodes after electrode 30 by one position — shortening the affected line by 2.5 m — removed the large initial outliers and eliminated the artefact.

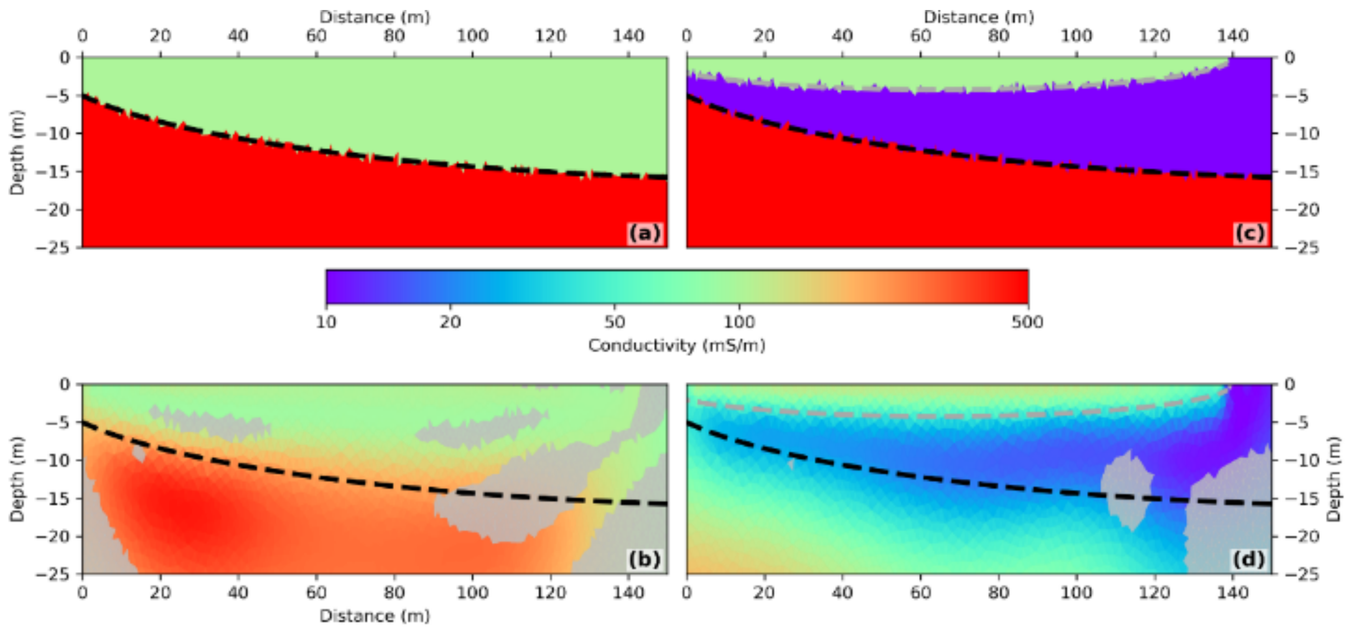
The re-processed ERT-1 and ERT-2 sections are now substantially cleaner. The localised highly conductive anomaly has disappeared, and the revised models instead show a gradual thickening of conductive material that terminates close to the Highest Astronomical Tide (HAT) extent. When placed on a common chainage, ERT-3 now matches ERT-1 and ERT-2 almost perfectly.

For the time-lapse comparison, we compared only common points/nodes in the two data sets. The resulting percentage-difference images show a significant near-surface freshening in the June post-storm survey relative to the February baseline. We will present this time-lapse result in the supplement and discuss it in the main text. This converts the reviewer's concern into an additional, directly relevant result on the depth and magnitude of storm-surge/rainfall-driven change.

2. Petrophysical Interpretation & Clay Surface Conduction

High EC_B is interpreted almost exclusively as saline water/saltwater intrusion, ignoring litho-electrical properties. Clay minerals (high CEC) produce substantial surface conduction that can dominate the bulk response and mask freshwater in clay zones. A petrophysical model (e.g., Waxman–Smits, or Archie's law with a clay correction) must be incorporated or at least discussed.

[Author response] We agree this requires a formal treatment. We note that our interpretation was deliberately conservative in exactly this direction: we intentionally avoided attributing the shallow low-resistivity (high-EC_B) zone to salinity alone, treating it as an inseparable clay–salinity mixture (consistent with the silt–clay lithologies confirmed in our cores), and built our central argument on the opposite case — that the high-resistivity material imaged at depth can only be explained by quartz-rich sediment and/or freshwater. Nevertheless, the reviewer is correct that this must be made explicit and quantitative. In the revision we will add a petrophysical analysis following the Archie's law framework of Flinchum et al. (2020, HESS), plotting our measured pore-water EC (sediment cores) and groundwater/surface-water EC against ERT-derived bulk EC and saturation/porosity to calibrate the remaining empirical parameters and to bound the contribution of clay surface conduction, with Waxman–Smits-type behaviour discussed. Our multi-dataset design (pore-water EC, grain size, water EC) is unusually well suited to this calibration. The re-processed ERT models provide an additional constraint: after correction of the electrode cabling artefact, the shallow conductive zone is spatially coherent, thickens landward, and terminates close to the Highest Astronomical Tide (HAT) extent, consistent with a tidal/marine salinity contribution. The petrophysical analysis will nevertheless quantify how much of the bulk conductivity signal is attributable to pore-water salinity versus clay surface conduction. Interpretive language throughout will be revised to present EC_B as a combined fluid-salinity and lithology proxy.



3. ERT Data Resolution and Depth of Investigation (DOI)

Resistivity models are shown to 30 m depth and used to support a deep freshwater-dominated aquifer, yet sensitivity decays exponentially with depth. For 2.5 m and 5 m electrode spacings, interpreting structure at 30 m without a DOI assessment is unjustified. A DOI index map or sensitivity matrix should be plotted in ResIPy, and technical details (data levels, data points, reciprocal error statistics) tabulated.

[Author response] We agree. In the revision we will (a) compute the DOI index (and/or cumulative sensitivity) for each inversion in ResIPy and mask all model regions below the resolved depth in every figure; (b) restrict all interpretation — including the conceptual model — to the DOI-constrained volume, with the deeper structure explicitly presented as untested hypothesis (the manuscript already flags this with a question mark in the conceptual figure and calls for deep drilling; DOI masking will now define that boundary objectively); and (c) add a table reporting, for each survey, electrode count and spacing, line length, number of data levels, number of acquired data points, reciprocal error statistics, iteration count, and final RMS misfit. The table will also record the ERT-1/ERT-2 electrode cabling artefact and the correction applied — shifting all electrodes after electrode 30 by one position — including the resulting removal of near-zero resistance measurements and improvement in data quality. As a supporting test, we suggest a forward-model a conductor-over-resistor scenario using the same gradient array geometry as the field surveys, to demonstrate the depth to which the deep resistive layer is genuinely constrained by the data.

4. Hydraulic Head Uncertainty & Error Propagation

Head time series (Eqs. 1–2) derive from several indirect measurements (atmospheric pressure, temperature, salinity, density, manual dips). Reported head differences (e.g., 0.025–0.085 m AHD) may be smaller than the cumulative measurement error from RTK-GNSS vertical accuracy, barometric sensor tolerance, tape errors, and density approximations. A formal error propagation scheme and uncertainty margins are required.

[Author response] We thank the reviewer for raising this point and agree that uncertainty quantification is important in principle. However, we respectfully clarify that the concern overstates how hydraulic heads are actually used in the manuscript, and we demonstrate below — using a conservative worst-case error budget, which is itself a first-order propagation of the uncertainties entering Eqs. (1)–(2) — that no head-based inference in the paper is sensitive to measurement error.

- First, what is (and is not) inferred from heads. The only quantitative use of absolute, cross-location heads is the observation that long-term mean groundwater heads span 0.025–0.085 m AHD (a ~6 cm spread) across the supratidal and terrestrial piezometers, while ground surface elevation spans ~0.6–1.15 m AHD (~0.57 m) across the same stations. This supports the statement that the shallow groundwater table is decoupled from local topography. Critically: (i) no pairwise head differences between piezometers are interpreted, and no flow directions or gradients are computed from them — the finding is the *absence* of the ~0.57 m signal that a topographically controlled water table would produce; (ii) the vertical-decoupling and salinity-stratification arguments — the core of the paper — rest on the attenuation of EC variability with depth and the ERT conductivity structure, not on heads; (iii) all temporal analyses (cross-correlations, event-scale responses) are mathematically invariant to the constant datum/offset errors that dominate the error budget; and (iv) inundation metrics compare water level against the local ground surface surveyed with the same RTK setup, so absolute datum errors cancel.
- Second, a conservative error budget. The dominant terms are systematic and largely common-mode: the single on-site barometric sensor imposes a common compensation error across all stations (cancelling in cross-location comparisons), the RTK-GNSS datum is common to all surveyed points, and density errors are largely absorbed by the offset anchoring of Eq. (2) — the same TEOS-10 density relation is applied at the manual anchor times, so only density *drift* between anchors propagates, and measured EC at the groundwater piezometers was stable over the monitoring period. Summing the remaining station-specific terms linearly (i.e., assuming worst-case correlation): RTK vertical accuracy (±12 mm), manual dip (±5 mm), pressure transducer tolerance (±5 mm), and density residual (±15 mm) gives ±0.04 m as an absolute worst case; a root-sum-square combination gives ±0.02 m.
- Third, the consequence for each head-based statement. Even under the worst-case linear sum, the admissible spread of the three groundwater heads is $\lesssim 0.06 + 0.08 = 0.14$ m — still more than four times smaller than the 0.57 m topographic range across the same stations. Had the water table followed the land surface (the behaviour expected of a topographically driven unconfined system), the head difference would have been ~0.57 m: a signal roughly 15 times the worst-case measurement

error, which no plausible error budget could mask. Equivalently, the data place an upper bound of $\sim 10^{-3}$ on the lateral hydraulic gradient across the ~100 m supratidal–terrestrial reach, several-fold below the topographic gradient ($\sim 5\times10^{-3}$). The same budget covers the two secondary head-based statements: maximum supratidal water levels exceed HAT (0.78 m AHD) by 7–12 cm — beyond even the worst-case error, and independently corroborated by synchronous rainfall peaks — and the ~0.1 m mean surface-water difference between SM and LSTF exceeds the budget by a wide margin. Accordingly, rather than a formal Taylor-series treatment of the continuous records — which would add considerable length without altering any conclusion — we can (i) add this worst-case budget as a supplementary table, (ii) state the combined uncertainty (±0.02 m RSS; ±0.04 m worst case) in the Methods, and (iii) report all mean heads with these estimated uncertainties in Table 1 and annotate Figure 5 accordingly. We hope the reviewer agrees that this demonstrates the robustness of the head-based inferences directly and transparently.

5. Spatial References & Temporal Comparisons

The exact tracks of ERT-1, ERT-2, and ERT-3 must be plotted on Figure 1. Additionally, the temporal overlap of ERT-1 (February baseline) and ERT-2 (June, post-storm surge) is a valuable asset: instead of qualitatively dismissing them as "very similar", generate a percentage-difference plot or ratio inversion to quantitatively isolate storm-surge infiltration depth or seasonal salinity changes.

[Author response] We agree on both points. (a) Figure 1 will be revised to show the exact surface tracks of all three ERT lines, including the corrected ERT-1/ERT-2 line extent after the electrode-cabling correction, together with the monitoring locations. (b) We have now performed a quantitative time-lapse comparison of ERT-1 and ERT-2. As detailed in our response to Major Comment 1, this re-processing revealed and corrected a field cabling artefact affecting electrodes 30 and 31. After this correction, both surveys are referenced to a common chainage tied to the fixed, surveyed line endpoints, and the percentage-difference analysis uses only common points/nodes. The resulting comparison is robust and shows a significant near-surface freshening between the February baseline and the June post-storm-surge survey. We will present the time-lapse section in the supplement and use it to discuss the depth of storm-surge/rainfall-driven infiltration and short-term versus longer-term salinity retention.

Specific Comments

Figure 1 caption — *Define the coloured circles (piezometer locations? rough locations or precise boundaries?).*

[Author response] Agreed. The caption will explicitly state that the coloured circles mark the surface-water/groundwater monitoring (piezometer) locations, one per vegetation zone, surveyed by RTK-GNSS (coordinates in Table 1); they are measurement points, not vegetation-unit boundaries.

Line 125 — *Add peer-reviewed references justifying the gradient array over Wenner or dipole–dipole; state the exact number of levels and raw data points for each survey.*

[Author response] Agreed. We will cite the geoelectrical literature on array performance (e.g., Dahlin and Zhou, 2004, numerical comparison of 2-D resistivity imaging arrays) to justify the gradient array's advantages in multi-channel acquisition efficiency and data redundancy. The number of data levels and raw data points for each of the three surveys will be added to the new acquisition QC table (see earlier comment).

Line 136 — *Topography (~1.1 m relief) was not included in the inversion; this can distort current flow in the shallow, high-sensitivity zone. Justify or, preferably, re-run inversions in ResIPy with RTK-GNSS topography.*

[Author response] We agree that topography should be incorporated into inversions where it materially affects the result, but we respectfully suggest that this does not apply here, for three reasons.

- First, the relief actually traversed by the ERT lines is considerably smaller than the cited figure: the ~1.1 m spans the full transect from the mangrove to the terrestrial zone, whereas the ERT lines cover only the supratidal–terrestrial reach. Relief along ERT-1/ERT-2 (LSTF → TR) is ~0.49 m over ~146 m, and along ERT-3 (ET → LSTF) ~0.36 m over ~185 m — mean slopes of 0.2–0.35% (≤0.2°). Adjacent electrodes therefore differ in elevation by less than 1 cm, and the total relief amounts to only ~1.5–5% of the investigated depth and a small fraction of the 2.5–5 m electrode spacing. At such slopes, topographic distortion of the apparent resistivities is of the order of the slope itself (≪1%) — an order of magnitude below the reciprocal errors and the 3% RMS data misfit, and far below the slope thresholds (several degrees) at which terrain corrections become standard practice in 2-D ERT. Besides, the elevation difference between individual electrodes was much larger due to the undulated land surface at the site.
- Second, all interpretations in the manuscript rest on sub-horizontal stratigraphic architecture several metres thick — the shallow conductive unit and the underlying resistive body. A sub-metre geometric warping of the section can neither generate this architecture nor displace layer boundaries by more than a small fraction of their thickness. Moreover, with the DOI masking now applied (see earlier comment), interpretation is restricted to high-sensitivity regions where residual geometric effects are smallest.
- Third, there is a practical constraint: fixed RTK-GNSS elevations could not be obtained along the electrode layouts beneath the dense supratidal forest canopy. As noted in the Methods, RTK accuracy degraded under canopy and fixed solutions were achieved only at the monitoring locations themselves. The only alternative elevation source, the 5 m state DEM, has a vertical accuracy in vegetated terrain comparable to the relief itself (~±0.5 m), so incorporating it would inject uncertainty rather than remove it.

In the revision we will replace the sentence "Changes in elevation across the transect were not considered during the inversion" with an explicit justification quantifying per-line relief, slopes, and the resulting negligible distortion, and we will state the canopy limitation on electrode-level elevation surveying. The inversions themselves, and all interpretations drawn from them, remain unchanged.

Line 138 — *Explain the physical validity of combining profiles from different seasons/hydrologic conditions*

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[Author response] Please see our response to Major Comment 1. The transects were inverted independently and the combined panel was used only for site selection; the stitched representation will be removed. The repeated ERT-1/ERT-2 line is now treated as a formal time-lapse comparison after correction of the electrode cabling artefact, and temporal interpretation is restricted to the common line and common nodes.

Line 140 — *Specify exactly which EC_B spatial patterns and which vegetation indices were used to choose drilling locations.*

[Author response] Agreed. The revised methods will state that drilling/monitoring locations were selected to intersect (i) the lateral EC_B boundary between the shallow high-EC_B intertidal sediments and the lower-EC_B landward deposits, (ii) the vertical EC_B contrast between the conductive shallow layer and the underlying resistive material, and (iii) vegetation community boundaries defined by dominant-species transitions (mangrove → ecotone → saltmarsh → lower/upper supratidal forest → terrestrial), with the lower/upper supratidal split itself guided by both vegetation morphology and the ERT-derived conductivity contrast.

Line 145 — *State in the Figure 1 caption that the coloured points correspond to the piezometer locations.*

[Author response] Agreed — see our response to the Figure 1 caption comment above.

Line 157 — *Specify the exact depth of the screened interval relative to ground surface (not only m AHD).*

[Author response] Agreed. Table 1 will be extended to report screen depths in metres below ground level (m bgl) alongside m AHD (groundwater piezometers were installed to 3–5 m bgl with a 0.5 m screen at LSTF, USTF, and TR).

Lines 174–193 — *A formal Taylor series error propagation must be computed to establish confidence intervals of the final hydraulic head values.*

[Author response] Agreed — please see our response to Major Comment 4. A first-order Taylor series propagation of all input uncertainties will be applied to Eqs. (1)–(2), and heads will be reported with confidence intervals.

Figure 4 caption — *ERT-1 and ERT-2: same location, different times. Were the exact same electrode positions used? If not, how was the spatial offset handled? Detail this in the methodology.*

[Author response] Agreed. The revised caption and methods will state that ERT-1 and ERT-2 occupied the same approximate line with the same surveyed start point and orientation, but that electrode positions were re-established rather than permanently marked. The February survey used 60 electrodes and the June survey used 59 electrodes, both with 2.5 m spacing.
Re-processing identified a field cabling artefact in both surveys: electrodes 30 and 31 were effectively connected during current injection, producing near-zero resistance measurements and a spurious shallow conductive anomaly. Correcting this artefact required shifting all electrodes after electrode 30 by one position, which shortened the repeated line by 2.5 m. Both data sets are therefore referenced to a common chainage tied to the fixed line endpoints, and the time-lapse comparison uses only common points/nodes. This correction removes the artefact and constrains the residual spatial uncertainty to ≤2.5 m.

ResIPy DOI & visualisation — *Run a DOI analysis in ResIPy and mask low-sensitivity zones; present the bulk conductivity scale in logarithmic format.*

[Author response] Agreed — DOI masking will be applied to all inverted sections (see Major Comment 3), and all EC_B sections will be re-plotted with a logarithmic colour scale to better resolve the high-contrast boundaries.

Model Quality Control — *Provide measured vs. forward-modelled apparent-resistivity pseudosections (at least as supplementary material).*

[Author response] Agreed. Measured and modelled apparent-resistivity pseudosections (with misfit distributions and reciprocal error statistics) for all three surveys will be provided as supplementary material. The measured and modelled apparent-resistivity pseudosections will be generated from the corrected, artefact-free data sets.

ERT-1 vs. ERT-2 comparison — *Exploit the pre/post-storm-surge pair to discuss short-term vs. long-term salinity retention.*

[Author response] Agreed — we have now exploited the pre/post-storm-surge pair. After correcting the electrode cabling artefact and restricting the comparison to common points, the ERT-1/ERT-2 percentage-difference images are substantially cleaner and show a significant near-surface freshening in the June survey relative to the February baseline. We will use this time-lapse difference section to discuss short-term dilution/freshening following the storm-surge/rainfall event and the persistence of salinity at depth, strengthening the paper's central argument about shallow salinity retention in fine-grained intertidal and supratidal sediments.

Discussion literature integration — *Integrate the findings of https://doi.org/10.5194/hess-24-2121-2020 and https://doi.org/10.1016/j.jhydrol.2020.125050.*

[Author response] We thank the reviewer for these excellent suggestions. Palacios et al. (2020, HESS) on time-lapse cross-hole ERT monitoring of seawater intrusion dynamics, and Folch et al. (2020, J. Hydrol.) on combining fibre-optic DTS, cross-hole ERT and time-lapse induction logging in a coastal aquifer, are directly relevant to both our planned time-lapse analysis and the petrophysical interpretation of clay-rich estuarine sediments. Both will be cited and discussed in the revised methods and discussion.

Technical Corrections & References

Ensure commas between author and year in in-text citations (e.g., lines 223–225); the bibliography duplicates Kumbier et al. 2021a/2021b (same paper).

[Author response] This issue is related to LaTeX styling and will be resolved during the typesetting stage of the manuscript.