Author's answers to comments of the first revision and changes applied to the new version of the manuscript

Most notable changes made

We added the analysis of the time component of our model to the results& analysis as well as the discussion and the conclusion, with this we address comments made by all 3 referees.

Answers to extended comments

Rev 1

1. A proper comparison with the real-world scenario
   The aim of the authors is to test if their simplified model predicts whether the salt units (gypsum and halite) in marginal and deep basins could have been precipitated concurrently. Even though they briefly explain the existing hypotheses for the depositional patterns within the MSC, I suggest that proper definitions of marginal versus deep basins should be provided prior to elaborating their experiments, with suitable diagrams of existing models for depositional units in each setting (for example, a simplified version of Roveri et al (2014) synthesis). Such insight would make it easier for the reader to follow the author's intentions, in relation to their model experiments. I propose that the same diagram may be used to show the ambiguity in horizontal continuity of the PLG, as the authors indicate in their introduction.
   We have added a new figure to visualize the differences between the two conceptual models we are exploring and have added a clarification in the introduction.
2. Organization
   Added to my above suggestion, the manuscript may be ordered in the following sequence: A general introduction to the MSC, with explanations on marginal versus deep basins; Existing hypotheses for the different timing of sedimentary unit deposition (including diagrams); Methods; Results; Discussion – here, I suggest including a better explanation of their model results with respect to actual observations they provided in the revised introduction. Under implications, the authors combine their different configurations to develop a timeline of salinification. I suggest adding a new diagram to explain their timeline, as this is one of their final interpretations, and Conclusions**.**
   We have added a figure to visualize the timeline. Our discussion of the time component also strengthens our message now.
3. Timescales
   A majority of MSC researchers suggest that the PLG unit was developed as an alternating sequence of gypsum-marl couplets, with up to 17 units paced by insolation (Lugli et al., 2010,

Manzi et al., 2013). For someone who may try to compare the suggested scenarios with existing timescales of PLG/ Halite unit deposition (eg: PLG stage during 5.97-5.60 Myr, Halite deposition during 5.60 5.55 Myr), no information has been provided regarding the timescales considered for model experiments. For instance, it has not been shown how long it will take to reach halite saturation in the extra box in A1 scenario. Provided that, the extra box should precipitate gypsum before reaching halite saturation. What are the periods required to reach gypsum and halite saturation points? How do they compare to the suggested insolation-paced alternations for marginal basins? How would the strait efficiency parameter impact these timescales? Unless I'm mistaken, such information does not exist in the present manuscript. Because the authors are aiming to relate their experiments with existing hypotheses, I suggest that these comparisons would be important. Is it possible to add a brief explanation of these to the manuscript?

We have added a detailed description and discussion of the time component to address this.

Rev 2

1. While the authors suggest that the model could be applied to other basins (e.g., the Red Sea), it is not clear how the specific model configurations (A1, A2, B) would translate to different geochemical settings. Could the model be adapted to explore other evaporite-forming basins more explicitly?

   Since our focus is on the Mediterranean Sea and the MSC we have decided to not add an extra example.
2. Regarding the title, you should mention the "Mediterranean Sea" because the MSC occurred in the Med Sea, and your study focused on the Med Sea.

   We chose not to mention the Mediterranean Sea explicitly, since the title is already on the verge of being too bulky. We do not think adding this information would increase the information density of the title as the term 'Messinian Salinity Crisis' is indeed already strongly connected to the Mediterranean Sea.
3. The paper mentions that constant evaporation rates were used. How might a variable evaporation rate, could impact the model results? Could this change the timing or locations of gypsum and halite precipitation? Were there any sensitivity tests performed to explore this?

   We now refer to another paper that explored the influence of a varying net evaporation rate
4. The manuscript does not provide sufficient discussion on the role of the Strait of Gibraltar in influencing Mediterranean circulation and salinity. A more detailed analysis of how restricted or variable water exchange through the Strait affects gypsum and halite precipitation patterns would add depth to the study.

   We avoided labelling the connection to the Atlantic as Strait of Gibraltar, as the exact location of the connection between the Mediterranean Sea and the Atlantic is not entirely clear, with the Betic and Riffean corridor being two likely candidates.

   The influence of restricted exchange is already explore in the manuscript and we address the influence of a changing restriction (L450)
5. Have you conducted sensitivity tests on key parameters such as evaporation rates, river water composition, or Strait of Gibraltar exchange? If not, how might these factors impact your

results?

We have added the compositions of the rivers we used and extended the description of the results. The influence of the other parameters was already explored in the manuscript

6. Missing punctuation occurs in multiple sentences where commas or periods could help separate clauses or clarify meaning (references style, the caption of the figure in bold, the table legends …).

   Several changes have been made to improve this.

7. The abstract could benefit from a clearer articulation of the novelty of the study. It touches on known issues but doesn't strongly emphasize how the modeling results diverge from or contribute to existing theories.

   We improved the way the methods are introduced in the abstract to highlight the novelty of our approach.

8. The comparison with Simon & Meijer (2017) is helpful, but the contributions of the present study (e.g., density driven dynamic overturning) could be more explicitly emphasized early on. For instance, the detailed breakdown of different studies (e.g., Meilijson et al., 2019 vs. Manzi et al., 2018) could be summarized more concisely to avoid overloading the reader with too many specific comparisons at the outset.

   We have added an extra figure to the introduction to visualise the premise of out research question.

9. Citations are included in parentheses, but in some cases, they interrupt the flow of the text. For better readability, consider rephrasing sentences to integrate citations more naturally. Example: Instead of "5.97 to 5.33 Ma, (Roveri et al., 2008)," you could say "According to Roveri et al. (2008), the event occurred between 5.97 and 5.33 Ma." This would make the text smoother.

   We have rephrased that sentence.

10. Consistency in citation formatting is needed. For example, in some instances, authors' names are written in all caps, which should be corrected., e.g. (Decima & WEZEL, 1971; Decima & Wezel, 1973)

    We have fixed this problem

11. The flow between ideas could be improved with clearer transitions between sections. For example, when moving from the discussion of modeling to the thermo-haline circulation section, adding transitional sentences can help guide the reader more smoothly from the background after the modeling approach.

    we have not added transitional sentences

12. The conversion from Atlantic water to more saline Mediterranean overflow water happens via an overturning cell in the Mediterranean Sea." Not clear, this sentence could be rephrased.

    We have rephrased the sentence.

13. The abbreviation "MSC" for Messinian Salinity Crisis is introduced but not consistently used throughout the text. It would help to use the abbreviation after it's introduced to avoid repeating the full term, e.g. line 342.

    We are now only using MSC after it has been introduced.

14. While you define many variables, key terms could be better explained to ensure the reader fully understands. For example, explaining "net evaporation rate" in more detail would help if a reader is not familiar with the exact context. Similarly, more context around κ and why it's used differently from its traditional sense could be provided upfront to avoid confusion. Some

terms such as "anti-estuarine circulation," "driver flux," and "marginal basin" are used without sufficient context for non-expert readers.

net evaporation rate: we chose to not introduce that term as we assume that our readers are familiar with that term.

Anti-estuarine circulation is now introduced

driver flux is now introduced with the model sketch

15. After describing each configuration (A1, A2, and B), it might be helpful to summarize their key differences in a table. This would help the reader quickly differentiate between them.
    We found it to be not beneficial to add a table for that and trust that the introduction and sketches are sufficient.
16. What is the temporal resolution of your model, and how does influence the results, particularly regarding the timing of halite and gypsum precipitation?
    The temporal resolution is given in the table displaying the parameters and has no influence on the timing. However we have added a detailed discussion of the timing of precipitation.
17. The use of the strait restriction parameter (q) and its bulky unit [$(m^3/s)/(\sqrt{kg/m^3})$] is well justified, but simplifying its interpretation would help make the section more accessible.
    We did not know how to simplify this.
18. The model uses generic assumptions about river water composition to assess gypsum precipitation in the extra box. How significant are variations in river chemistry (e.g., calcium and sulfate concentrations) for altering the results, and were sensitivity tests performed with different river compositions?
    We have added an overview of the compositions used, as well as a description of their influence on the outcome.
19. The section compares the model results with the Mediterranean and Red Seas, I think that the appearance of the part about the Black Sea is very abrupt, and there is very little information about the Black Sea in the paper.
    The Red Sea is just to add another example, next to present day Mediterranean Sea, to help the reader get a feeling for the scale of the metric we are using and to show how extreme the restriction during the MSC must have been.
20. The discussion is rich in technical detail but sometimes lacks a clear "so what?" moment that emphasizes why these results are significant in the context of the Messinian Salinity Crisis or other studies on evaporite formation.
    We hope to have strengthened that point by adding the discussion of the time component.
21. It would be helpful to suggest what future studies could address based on these results. How could the model be improved? What future work is needed to fill the gaps identified in your study?
    We now address this in the conclusion.
22. The conclusion, while summarizing the key findings, could be strengthened by tying the results more explicitly to potential future research directions or practical implications. It currently ends somewhat abruptly and could benefit from a more definitive closing statement on the significance of the study. For example, what does this timeline and model tell us about the general understanding of evaporite formation in restricted basins? How might these findings inform future models or field studies in similar settings?
    We have extended our conclusion to address this comment.

Rev 3

1. The box model construction illustrated in Figure 1 shows two-way Mediterranean Atlantic exchange. It is widely accepted that this configuration probably only applies to Stage 1 of the MSC, when gypsum was precipitated in the marginal basins of the Mediterranean requiring a high sea-level. Stage 2 and 3 are more likely to have occurred with Atlantic inflow but negligible outflow from the Med, consistent with a base level that was below the level of the gateway. Consequently, the main application of this model configuration is Stage 1. This is mentioned in the abstract but is not made clear in the introduction where a description of all three phases of the MSC (L31-39) is followed by a statement about the challenges of shallow-deep water correlation as a justification for looking at synchronous gypsum-halite precipitation (L50-50).
   We have added a figure to make this clearer.
2. The paper concludes that synchronous precipitation of gypsum and halite can only happen in Scenario A when the system as a whole is close to halite saturation. While I accept the statement in the first paragraph of the discussion (L334-339) that the model is not meant to represent "the complexity of the Mediterranean Sea", none the less, it is possible at least to point out the episodes within the MSC that are closet to the model configuration used and consider the implications. For example, some discussion about when within Stage 1 reaching near halite saturation is most likely would enhance the applicability of the results. The strait efficiency required to generate synchronous gypsum-halite precipitation could be evaluated against the Sr isotope ratio data for Stage 1 which progressively diverges from the ocean water curve. This might then enable them to evaluate the duration of the potential overlap between Stage 1 and 2 mentioned in L417-20.
   Comparing model results to strontium values is indeed an interesting idea, that we are addressing by developing a model that accounts for spatial differences (east vs. west, central vs. marginal), the influence of a non-constant freshwater balance (FWB), river chemistry, and the role of the Paratethys in the evolution of strontium isotopic ratios and the formation of evaporite deposits. Without a more detailed analysis of these factors, any comparison to strontium values appears futile, as their average remains relatively stable throughout stage 1.
   To give a better indication of the timespan we have added the times we can deduct from the model to the results and discussion.
3. Section 3.2.3 (Scenario B) – this section needs a little more explanation of the chemistry and particularly some more information about the chemistry of the rivers that are modelled in Fig. 4 so that the reader can see how their different compositions result in different consequences.
   We have added the compositions and extended the explanation of the results to address this.

Comments by line

location	comment	answer
title	suggested tweak "A model approach to the synchronous precipitation of gypsum…."	

	A question of time and space: A model approach to the synchronicity of gypsum and halite deposition during the Messinian Salinity Crisis. Suggestion to add 'deposition' to the title.	We have changed out title to *A question of time and space: A model approach to the synchronous precipitation of gypsum and halite during the Messinian Salinity Crisis*
L4	Earth Sciences – 2 words	corrected
L6	well studied….	Corrected
	"Saltgiants" => "Salt giants" ?	corrected
L7	Define Ma	Removed from line 7 and added to line 31
L9	"different configurations". A little more clarity about what those configurations are would help here	Changed to: different possible configurations of the basin and circulation
	"could be not yet been confirmed" => "could not yet be confirmed".	corrected
L11	…for different configurations… of what?	Now specified
L16	"salinifying". Suggested alternative "a timeline for an increasingly saline basin."	We chose to keep this term throughout the manuscript
L17	…a sufficiently restricted marginal basin….	Changed throughout the text
L18	remove 'the one of' and 'areas of the' → gives- …once the average salinity approaches halite saturation it can also form in the open basin…	changed
L19	same as for Line 17	Changed throughout the text
L20	Define kyr	Defined in line 31
L21	…within a one basin… rephrase	corrected
L27	change to …youngest salt giant formation…	Changed
L28-29	suggestion to reorganize for clarity	Changed
L32	"reaches up to three km" => "reaches up to three kilometers".	Changed

L40	“unambiguous, since we, for example, cannot follow” should be “unambiguous since, for example, we cannot follow”.	changed
L47-48	vague statement …a more recent study, however, reopened this question again…	Extended with content of study
L48	“re-opened” => “reopened”.	changed
L56	should you mention the Black Sea as well?	In this line we are referring to a paper that focused on the Mediterranean Sea, while there are box model studies that focus on the Black Sea, none of them would be as good of a comparison as (Simon & Meijer, 2017)
L80	“overturing” => “overturning”.	corrected
L95	add citations: From previous studies, we know…	Added 3 studies
L135	To arrange the diffusivity term in order → suggestion to rearrange the equation to $mix = Kmix .(Sopen - Sdeep).Aopen\ dmix$	changed
L140	Shouldn’t the salt flux be upward, therefore for equations 5a and 5c the jmix terms become opposite in sign (positive for 5a and negative for 5c)?	changed
L271	can you state the salinity difference?	added
L274	You have not stated to which figure you are referring to.	Added the reference
L283	perhaps move ‘also’ in front of ‘halite’?	We decided against that, because it would shift the meaning of the sentence
L300	Reads disorganized when you start the sentence with ‘which’.	changed
L334	"The models presented here not a representation of the complexity..." => "The models presented here are not a representation..."	corrected
L340	a space between "per" and "1°C" (per 1°C)	corrected

L362	the word “Dead” is missing before “Sea”	Removed ‘Sea’
	Should ‘Sea’ be removed?	
	Reads disorganized when you start the sentence with ‘those’.	rephrased
L363	…to be represented?	changed
L383	suggestion to add a figure explaining you time series of salinification.	Added a figure in line 422
L388	Into the deep basin?	Changed to ‘deep basin’
L391	Into the deep basin?	
L405	– the thickness of the lower Tripoli Unit in the Lorca basin is used to illustrate the likely sedimentation rates resulting from step 3, but that isn’t helpful if you don’t know how thick that unit is…. and I don’t!	Information is now added
L427	Majorly?	corrected
428	Explain why your results do not exclude this (vague statement).	We made this clearer by adding more information

Comments regarding figures and tables

Figure 1	Add labels of different parameters (eg: evaporation, convection, diffusion) to one of the configurations. Strait of Gibraltar is not properly visible as you have not shown the Atlantic side.	We have added the label ‘Atlantic’ to indicate the position of the connection. We have decided against labelling the parameters within the sketches as they would otherwise be too convoluted
Figure 2d	for clarity, label the y-axis “salinity difference”	
Figure 3	both the caption and the text in line 244 state that there should be an “x” showing the present-day Mediterranean on Fig 3a, but I can’t see it.	The x was indeed hard to spot, we have replaced it by a bigger, red x
Figure 3c	Suggestion to update the label ca to ca2 (correct?)	The labelling was confusing, we have corrected that.
Table 1	If the relative size of the extra box is f, shouldn’t Aopen be (1-f)Atot and Aextra be (f)Atot?	We have corrected that.
	For Vextra, you have not prescribed what 500 m is (which, I assume is the depth/ thickness of the water column)	We have added this information now to the text to make this clearer