We thank the reviewer and the editor for the thorough evaluation of our revised manuscript and the helpful comments. We respond to these comments as follows:

Reviewer #3:

The manuscript explores how enhancing interoperability across data, models, communication, and governance through knowledge co-production can strengthen disaster risk management and climate change adaptation, but it requires clearer contextual framing to reflect its predominantly European practical perspective and limitations in broader applicability. Apart from that, I'll focus my assessment on evaluating the authors' responses to the existing reviewers' comments.
The authors have made considerable efforts to respond to the reviewers' comments using a constructive approach. In their responses, they show a good understanding of the points raised by the reviewers.

Thank you for the overall positive assessment of our implemented changes. Even though we do not have a particular focus on Europe per se, as clarified in our response to the previous review #2, we recognize that this should be better explained in the paper. We would like to stress, that in the previous revision we have added application examples of underlying concepts and methods (e.g Tandem and Real-World-Lab approaches) from different geographies globally (ll 69 to 86), demonstrating that the proposed approach is not limited to Europe.
In addition we suggest to further expand on this in the introduction and perspective summary as follows:

Introduction, ll 128 (suggested additions to the text in bold):

"In this perspective paper, we discuss interoperability challenges for DRM and CCA by taking a detailed look at data and models, information and communication, and governance systems (Chapter 2). On this basis, we propose recommendations for overcoming these challenges (Chapter 3) based on research and development work carried out in the inter- and transdisciplinary EU innovation project DIRECTED which aims to reduce vulnerability to extreme weather events and foster disaster-resilient societies by promoting interoperability between DRM and CCA. **While the learning from real-world-labs within the DIRECTED project is based on the specific conditions given in these European settings, the methods proposed will be applicable in other geographical and cultural contexts.** We summarise our perspectives on interoperability for disaster resilience through transdisciplinary knowledge co-production (Chapter 4)."

Perspective summary, ll 541 (suggested additions to the text in bold)

"However, the combined focus on enabling governance, information and communication, and data and model interoperability aims to strengthen stakeholders' collective capacity to continuously adapt and respond to the changing context and associated needs/-gaps for DRM and CCA. **The Risk-Tandem framework and the Data Fabric are applicable in different contexts, sustained by the overarching international policy context, such as the Sendai Framework for disaster risk reduction, the UN Sustainable Development Goals, and the Paris Agreement. The core premise of the underlying co-production approach is the need to be tailored to the application context. It is thus valid in various geographies and decision domains requiring transdisciplinary participation between a wide range of actors across the science-society interface. For example, the Tandem approach has been applied in both European contexts and beyond, in Africa, Asia, and Latin America.** Through the DIRECTED project we intend to advance the required methods and tools and provide novel outputs for the DRM and CCA community to implement and fruitfully replicate the recommended co-creation process in RWL settings **globally**.

[1] That said, a few important points remain only partially addressed, in my opinion. For example, reviewer #1 raised concerns about the lack of depth regarding implementation practicalities and stakeholder motivation in transdisciplinary approaches (point [1]). While the authors acknowledge that this manuscript is not meant to provide comprehensive implementation details and refer to other publications under review, which is a vague argument in terms of scientific evidence, the rebuttal leans too heavily on deferral. This, in my opinion, leaves a noticeable gap in the manuscript, especially given the emphasis of this perspective piece on real-world application.

We understand the concern of the reviewer regarding practicalities of implementation and stakeholder motivation, which is indeed a critical issue for applying transdisciplinary approaches. We propose to elaborate on our experience in implementing the Risk-Tandem framework within the real world labs. We will draw on new insights gained within the recently published studies of Parviainen et al (2025) and Cumiskey et al (2025) which details the practicalities of capacity development for locally-led knowledge co-production in RWLs within the framework of Risk-Tandem
We suggest to include this additional contents in section 3.2 Innovations for interoperability (ll 496, suggested additions to the text in bold):

"The Risk-Tandem framework **is** co-developed and tested in RWLs and refined based on the feedback and needs of RWLs. New insights generated from the process are expected to support RWL participants in their strategic (integrated) decision-making at long-term and immediate time scales and help break down silos between technical and political authorities at all levels, e.g. organisations, sectors and disciplines. **Experiences from the co-production process in the RWLs emphasize that the implementation of the Risk-Tandem framework is resource-intensive. Its implementation within a co-production approach requires continuous engagement of all stakeholders in discussions and continuous adjustments for balancing between a theoretical approach that requires practical implementation and risk governance practice. Instead of following a standard implementation approach, customizable and flexible application concepts are recommended to meet the case-specific stakeholder needs and shared challenges. Risk-Tandem facilitates a theory-informed approach for transdisciplinary co-production of risk reduction and climate change adaptation strategies (Parviainen et al. 2025). In practice, this refers to the co-development of creative methodologies to co-explore contextual risk issues (including via the use of tabletop exercises, serious games, and visioning exercises), supporting the phases of co-design during which fit-for-purpose interventions are developed alongside RWL stakeholders. Interventions will prioritize issues of risk governance such as stakeholder engagement and coordination, and risk communication, for instance, improving public risk communication and -awareness.**
Local leadership by RWL hosts based in different DRM and CCA agencies in combination with support from researchers/ scientists ensures that all Risk-Tandem activities and resulting solutions are rooted within local issues and priorities. To support this practical application of Risk-Tandem, RWL hosts are trained to build their collaborative, systems-thinking, creative and reflexive capacities and related facilitation, research and design skills to implement knowledge co-production in their RWLs (Cumiskey et al. 2025). For example, one host, the Civil Protection Agency of the Emilia-Romagna Region, benefited from training on systems-mapping exercises and serious games. This increased their capacity to design and facilitate interactive workshop activities to map governance gaps, perspectives, needs and priorities for their RWL stakeholders. This then led to designing and implementing an intervention in their RWL For example, a flood simulation exercise with multiple stakeholders including volunteers to test the flood mapping tools being co-designed in the Data Fabric for extreme climate events and to better understand communication needs and flows and

decision-making between agencies for different risk management actions, e.g. emergency response and urban planning. The increased effort of this interdisciplinary co-production approach thus also leads to further development of the local actors and stakeholders and a deeper understanding of the factors and interrelationships that are crucial for the successful implementation of effective measures."

[2] Another example is point [2] of reviewer #1, where the authors reacted by tweaking a few words in the text to address something that clearly demanded more depth. A more effective response and corresponding change in the manuscript would be to summarise actionable strategies briefly or include a short "snapshot" or box within the manuscript offering practical insights or motivational mechanisms drawn from experience. While the authors comment on balancing model complexity and stakeholder needs, the point would be more compelling if supported by a specific example, such as how different types of flood models may serve the needs of emergency responders versus urban planners (only an example).

We address this point in response to the previous comment [1] where we describe the practical details of the Risk-Tandem-Framework implementation. In the suggested additions to the text we describe how various stakeholder perspectives and preferences are taken into account during the implementation process in the RWL and we also provide an example for the co-design of the data fabric to provide tailored information which is useful for specific risk management actions.

[3] Another area that could be improved is the treatment of trust in modelling. The authors clarify the distinction between trust in models themselves and trust among stakeholders who use these models. While this is a relevant point, the explanation, though strong in the response letter, needs to be made more accessible and clearly articulated in the manuscript. This would help avoid misinterpretation, particularly by non-specialist readers, who often are key stakeholders in co-production frameworks.

We thank the reviewer for his critical reassessment of this point. We will follow his advice and expand on the issue of trust in modelling in the text. We propose to rephrase the text (ll 343) as follows (suggested additions to the text in bold):

"A possible way to embed this in existing workflows is to build standardized and simplified data and model pipelines, which encapsulate some of the complexity and allow for the easy running of separate models addressing the same question. This allows comparing model outputs of different approaches, which can support building trust in the models to be fit for **the intended** purpose. **While it should be acknowledged that running different models does not inherently enhance trust in the models, in particular when outputs are highly uncertain and variable, using several distinct modelling approaches building up to shared evidence and a common understanding of the phenomenon of interest is one of the main ways for scientists to build trust in models that are only hardly verifiable (Taylor et al. 2012; Merz et al. 2024). For instance, climate models may yield very large variances in global temperature outputs for the same emission trajectories. Confidence in the climate models is established by pooling the information from several, distinct models. This confidence was built thanks to a large-scale interoperability effort led by the CMIP team. This type of multi-model angle is not only required on the physical modelling side, where it is already common throughout the entire chain of information, but ideally for all models to best characterize uncertainties. However, this often shows how large they are, and is often difficult for stakeholders to fully understand. More importantly, disclosure of uncertainties does not inherently increase trust and credibility in risk analyses (Doyle et al., 2019), and thus information about uncertainty should be embedded in the co-production process and tailored to the specific audience, considering their perspectives, technical knowledge and concerns (Merz et al. 2024).**

Crucially, to bridge this gap, there arises a need to build trust among modelers, stakeholders and decision-makers. Effective communication plays a pivotal role in establishing trust in DRM and CCA decisions. The proposed knowledge co-production process, i.e. connecting modellers, data providers and end users, promotes discussions regarding different modelling approaches and explores user needs vis-à-vis available information in a non-hierarchical manner (see Daniels et al., 2020). This is expected to increase the usability and accessibility of information by clarifying potential errors, uncertainties and underpinning assumptions embedded in each model for users, to align available information with the needs of planners and decision-makers. In other words, the co-production process is an ongoing negotiation between needs and what models can provide, which, insofar as uncertainty is accounted for, also generates trust in data through continuous and transdisciplinary engagement with it (Daniels et al., 2020).
~~Importantly, t~~**~~T~~**~~he co-production process connects modellers, data providers and end users, promotes discussions regarding different modelling approaches, and explores user needs in contrast to available information (Daniels et al., 2020). In this process, effective communication is essential in establishing trust in DRM and CCA decisions. Uncertainties embedded in underlying data and models can be considerable. For stakeholders, uncertainties are often difficult to understand. Therefore, information about uncertainty should be embedded in the co-production process and tailored to the specific audience and consider their perspectives, e.g. Merz et al. (2024) for the example of flood hazard and risk modelling."~~

[4] Another example is the authors' response to reviewer #1's concern about vague terms such as "creative and interdisciplinary approaches". Although they now offer concrete examples such as games and participatory methods, I'd suggest reviewing them to ensure they are seamlessly integrated into the manuscript text.

We have carefully checked the manuscript for the terms "creative approaches", "interdisciplinary approaches", "specific roles and capacities". These terms are only used in section 3.1 Sub-system interoperability (ll 360) where, in response to the previous review, we provide the additional examples for clarification. We therefore think, that they are smoothly integrated to the text.
The additional reference now included (Cumiskey et al. 2025) gives more context on the importance of building creative capacity for knowledge co-production,

References:

Cumiskey, L., Parviainen, J., Bharwani, S., Ng, N., Bagli, S., Drews, M., ... & Håkansson, V. W. (2025). Capacity development for locally-led knowledge co-production processes in Real World Labs for managing climate and disaster risk. International Journal of Disaster Risk Reduction, 125, 105398. https://doi.org/10.1016/j.ijdrr.2025.105398

Doyle, E. E. H., Johnston, D. M., Smith, R., and Paton, D.: Communicating model uncertainty for natural hazards: A qualitative systematic thematic review, International Journal of Disaster Risk Reduction, 33, 449–476, https://doi.org/10.1016/j.ijdrr.2018.10.023, 2019.

Parviainen, J., Hochrainer-Stigler, S., Cumiskey, L., Bharwani, S., Schweizer, P.-J., Hofbauer, B., and Cubie, D.: The Risk-Tandem Framework: An iterative framework for combining risk governance and knowledge co-production toward integrated disaster risk management and climate change adaptation, International Journal of Disaster Risk Reduction, 116, 105070, https://doi.org/10.1016/j.ijdrr.2024.105070, 2025.

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