Comment

The submitted manuscript „The value of visualization in improving compound flood hazard communication: A new perspective through a Euclidean Geometry lens" proposes as stated in the title: a new visualization method that aims at better representation of bivariate relationships between variables relevant for flood hazard. Unfortunately, I don't feel that this goal was achieved.

As already noted by the other reviewer, the copula approach has been used for years in visualizing compound hazards. As literature on copulas shows, e.g. https://npg.copernicus.org/articles/15/761/2008/npg-15-761-2008.pdf , probability density function plotted on a graph where marginal distributions transformed to standard normal clearly shows the strength of the correlation (Fig. 3 therein). Further, it can show the structure of the dependency (Fig. 4 therein), which enables visually to detect tail dependence, which can be more relevant to compound hazard probability of occurrence that overall correlation. The authors' approach focuses only one dimension of the compound problem – not necessary the most important.

Even if one would not like to use the copula approach due to higher complexity (though simply showing data transformed to ranks or standard normal can already be very revealing), I don't see how presenting the correlations in Fig. 4 as angles improves this compared to e.g. showing three correlations as a bar graph. At least for me, it is not intuitive right away that a large angle with represent a low correlation. In the authors' survey results, there is clearly lower understanding of correlation in the angles method compared to simply having the numerical value. The authors only compare their approach with a raw scatterplot of particular composure of points. Scatterplots can be enhanced, as noted above, to improve the visibility of correlation.

I will skip any detailed comments, as I am not convinced at all by the authors' whole approach, which doesn't contribute to any improvement in visualization of compound hazards.

***Answer*:** Thank you for taking the time to review our manuscript. We appreciate your feedback, though we respectfully think that some aspects of our work may have been misinterpreted. We would like to address your concerns and clarify the purpose and contributions of our manuscript.

A) Purpose and Contribution of the Paper

Our manuscript focuses primarily on compound hazard communication and visualization rather than proposing a statistically superior method to existing approaches like copulas. The Angles method is introduced as a complementary visualization tool specifically designed to communicate evolving dependencies in compound flood hazards, particularly to diverse stakeholder groups including *non-technical audiences*.

It is important to emphasize that the Angles method is not a technique to model the bivariate distribution of the two flood drivers, as copulas do, but merely an alternative visualization tool of the bivariate dependence. Therefore, it is not meant to replace copula modeling, but rather to serve as an extra first visual check of the dependence before modeling the bivariate probability (with copulas or other techniques).

B) Key Distinctions from Copula Approaches

While we acknowledge the value of copulas in modeling compound hazards (as referenced in the works you cited, such as Scholzel and Friederichs (2008), our approach serves a different purpose:

1. **Accessibility for Non-Technical Audiences**: Copulas, while powerful, are mathematically complex and can be challenging for non-specialists to interpret. The Angles method provides a more intuitive visual representation that can be more accessible to diverse stakeholders.

2. **Temporal Evolution Visualization**: A key contribution of our work (particularly evident in Figures 4 and 5) is the ability to visualize how dependencies between flood drivers evolve over time. This aspect is crucial for communicating non-stationarity, which is an increasingly important concept in the context of climate change impacts on flood hazards.

3. **Survey-Based Empirical Evaluation**: Unlike most methodological papers, we empirically evaluated the effectiveness of our visualization approach through a survey with 91 respondents from diverse backgrounds and locations, providing evidence-based assessment of its utility in compound hazard communication.

C) Clarification Regarding Survey Results

You mentioned: "In the authors' survey results, there is clearly lower understanding of correlation in the angles method compared to simply having the numerical value." We would like to clarify this interpretation.

Our survey shows that for academic respondents, the overall understanding levels (those who at least slightly agreed) were identical for both numerical values and the Angles method, with 68.2% at least slightly agreeing with the understandability of each approach. For non-academics, the results do show lower immediate understanding, which is expected with the introduction of any new method.

However, when specifically examining the communication of non-stationarity (evolving dependencies), the Angles method showed significant improvements:

- For communicating to a potential audience, the Angles method enhanced the level of "agreeing or strongly agreeing" from 11.3% to 34.1% for academics, and from 4.3% to 23.4% for non-academics, compared to scatterplots.

These results indicate that while there is an initial learning curve, the Angles method offers substantial benefits for communicating the specific concept of evolving dependencies.

D) Methodological Considerations

D.1) Benchmark Comparison and Methodology Justification

Our methodological approach involved carefully designed sequential comparisons to evaluate different aspects of visualization effectiveness:

1. ***Benchmark with Numerical Values***: We first compared the Angles method with numerical correlation values as a baseline benchmark. This was necessary to establish whether the new visual representation maintained the interpretability of the underlying mathematical concept. While numerical values showed higher immediate understanding among experts, they fundamentally cannot represent temporal evolution or non-stationarity without additional visualization.

2. ***Comparison with Scatterplots for Non-Stationarity***: For communicating evolving dependencies (non-stationarity), numerical values alone are completely inadequate, as they can only represent static relationships at discrete time points. This limitation necessitated our comparison with scatterplots, which are the current standard in the field for visualizing bivariate relationships.

3. ***Comprehensive Evaluation Framework***: Our approach follows established evaluation frameworks in visualization science that recognize different visualization methods serve different communication purposes (Munzner, 2014; Borgo et al., 2013). While numerical representations excel at precision, geometric visualizations like the Angles method excel at communicating patterns and trends, particularly temporal evolution.

It's critical to understand that simply retaining numerical methods would fundamentally fail to address the central communication challenge our paper tackles: representing evolving dependencies over time. Numerical correlation values cannot intrinsically reflect on temporal patterns without being embedded in some visual representation (e.g., time series of correlations). The Angles method specifically addresses this limitation by providing an intuitive visual framework for representing changing relationships.

Visualization has proven to be a key tool for enhancing understanding, engagement, and decision-making (Atasoy et al., 2022; Colle et al., 2023). Our survey results demonstrate that when specifically evaluating non-stationarity communication, the Angles method substantially outperformed scatterplots, with improvements in audience clarity of 22.8 percentage points for academics and 19.1 percentage points for non-academics. This provides empirical evidence that the Angles method serves its intended purpose more effectively than current standard visualization approaches for this specific communication challenge.

D.2) Selection of Scatterplots for Comparison

We specifically chose scatterplots for comparison because:

1. They represent the current standard practice in the compound flood hazard literature

2. They enable a direct, one-to-one comparison with the Angles method

3. They allow for assessment of both methods' capabilities in communicating the same underlying information
4. Copula-based visualizations (i.e. the joint PDF) is too complicated for non-experts to digest and connect to.

E) Response to Other Reviewers

We note your reference to another reviewer's comments. That reviewer suggested using Spearman's correlation coefficient instead of Pearson's correlation for the geometric interpretation, which we have addressed in our revision by:

1. Acknowledging the limitations of Pearson's correlation
2. Adding a complete derivation of the geometric interpretation using Spearman's rank correlation in a new Appendix A
3. Explaining how this alternative approach addresses issues of non-linearity and invariance under monotonic transformations

Summary

In summary, we believe our manuscript makes several valuable contributions:

1. Introduces a complementary visualization approach specifically designed for communicating evolving dependencies in compound flood hazards
2. Provides empirical evidence of its effectiveness through a diverse international survey
3. Addresses a critical need in compound hazard communication for tools that can bridge the gap between technical analysis and stakeholder understanding
4. Supports the broader goals of enhancing community resilience to increasing compound flood hazards

We hope this response clarifies the purpose and contributions of our manuscript. We would be happy to incorporate further improvements or clarifications in a revised version to address any remaining concerns.

In order to address your comments and to make the objectives and the contribution of this document clearer, the following amendments have been made to the text:

1. Abstract enhancement (**P1, L22-23**):

   "This paper introduces the Angles method, based on Euclidean geometry of the so-called "subject space," as a complementary visualization approach specifically designed for

communicating the dependence structure of compound flooding drivers to diverse end users."

2. Clarify communication focus (**P2&3, L60-68**):

"Our approach aligns with established principles in visualization science that recognize different visualization methods serve distinct communication purposes (Munzner, 2014; Borgo et al., 2013). Current approaches for visualizing compound flood dependencies, including scatterplots and statistical measures, while mathematically sound, often struggle to effectively communicate evolving patterns to diverse end users. Copula-based approaches (Schoelzel and Friederichs, 2008) provide powerful statistical frameworks but can be mathematically complex for non-specialists. The Angles method complements these approaches by offering a more intuitive visual representation specifically designed for communicating temporal evolution of dependencies. This perspective is especially important for compound flood hazard communication, where conveying evolving dependencies to non-technical audiences remains challenging."

and **P3, L84-89**:

"It should be emphasized that while statistical approaches like copulas provide sophisticated analytical frameworks for modeling compound flood hazards (Schoelzel and Friederichs, 2008), our focus is specifically on developing intuitive visualization techniques for effective risk communication across diverse stakeholder groups. The Angles method is not meant to replace statistical methods like copula modeling, but rather to complement them by serving as an accessible first visual check of dependency relationships for broader audiences, including non-technical end users, before proceeding with more complex bivariate probability modeling."

3. Clarify purpose of angles method (**P4, L108-111**):
"While the Angles method does not capture the full complexity of dependence structures (such as tail dependencies) that copula approaches can model, its primary strength lies in its visual intuitiveness for communicating evolving dependencies. Therefore, the method presented here is primarily designed as a communication tool rather than a statistical modeling technique."

4. Add a new subsection, "**2.2. Survey Design and Implementation**" to draw attention of the authors to one of main contributions of the paper, as per Editor's comment. Updated text in this section (**P7, L155-168**):
"Our evaluation framework follows established principles in visualization science (Munzner, 2014) that recognize the importance of assessing visualization techniques based on their intended purpose and audience. We designed a sequential comparative evaluation to assess both immediate understanding and effectiveness for communicating

specific concepts like non-stationarity. This approach allows for a comprehensive assessment of the method's strengths and limitations across different stakeholder groups. The survey consisted of questions designed to gauge the respondents' familiarity with CCF dependencies, the clarity of non-stationarity concepts, and the effectiveness of the Angles method in communicating compound hazard. Likert scale questions were used to capture the degree of agreement or disagreement on various aspects of the Angles method, including its understandability, applicability, and perceived usefulness in CCF hazard communication. The responses are subsequently grouped into two categories: academic and non-academic respondents. This classification is used to evaluate the differing perceptions of the proposed Angles method between these two groups. Academic respondents primarily included researchers, faculty, and students from various universities, while non-academic respondents comprised professionals from the industry, government agencies, and NGOs. This segmentation allows us to explore how familiarity, relevance, and clarity of the Angles method differed across these distinct sectors."

5. Introducing this method as a complementary approach (**P17, 368-371**):
"This study evaluated the Angles method as a complementary visualization approach specifically designed for communicating evolving dependencies in CF hazards. Rather than replacing sophisticated statistical methods like copulas, the Angles method serves a distinct purpose in making temporal patterns of dependence more accessible to diverse stakeholder groups, particularly those without technical backgrounds."

References:

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