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Physical and Mathematical Constraints in Artificial Intelligence-Based Methods for Monitoring Floods and Droughts

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Disasters, including floods and droughts, are a pressing issue for many countries, particularly Brazil, due to the significant loss of life and economic damage they cause. The effects of climate change are expected to aggravate this issue by increasing the frequency and intensity of extreme weather events. Therefore, developing accurate and reliable disaster forecasting models is critical to reducing the impact of these events.

Machine Learning (ML)-based methods, such as Neural Networks, have been used extensively in developing flood and drought forecasting predictive models. However, these models often lack transparency and interpretability, making understanding the reasoning behind their predictions challenging. This lack of explainability limits the usefulness of these models in real-world scenarios where stakeholders require clear and understandable information to make decisions [1, 2].

Incorporating physical and mathematical constraints into ML models can enhance accuracy and interpretability. Physical laws, such as mass conservation or energy conservation, can constrain ML models' output to ensure they adhere to known physical principles. Mathematical constraints, such as incorporating domain-specific knowledge into the models, can also improve their accuracy and interpretability.

This multidisciplinary work presents an overview of the literature on physical and mathematical constraints for ML applications in flood and drought forecasting. The approaches covered range from simple strategies for mass conservation to more complex methods, such as Lagrangean

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relaxation for incorporating physical laws into the objective/loss function. The presented examples demonstrate how these constraints can improve the accuracy and interpretability of ML-based models.

Recommendations are also provided to guide future research in this field. One such recommendation is the use of interdisciplinary teams in developing ML-based models. These teams should include experts in the domain-specific knowledge, ML, and mathematical sciences to ensure the constraints are properly implemented and understood.

In conclusion, incorporating physical and mathematical constraints into ML models is a promising avenue for improving the accuracy and interpretability of predictive models for flood and drought forecasting. This multidisciplinary work provides an overview of the current state-of-the-art approaches and offers recommendations for future research.

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