

Autonomous Decision Intelligence with Generative Agentic AI for Climate Forecasting and Disaster Early Warning: A Comprehensive Review

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Abstract—Climate instability and the growing intensity of environmental disasters have increased the need for intelligent forecasting and rapid disaster response systems. Conventional climate forecasting models often struggle to process dynamic environmental conditions, large-scale real-time datasets, and rapidly evolving disaster situations. Recent developments in Artificial Intelligence (AI), particularly Generative AI and Agentic AI, have introduced a new paradigm for autonomous climate intelligence and disaster management. This review paper presents a detailed analysis of intelligent Agentic AI systems designed for climate prediction and disaster early warning applications. The study critically reviews the proposed Generative Agentic AI framework that combines deep learning architectures, autonomous decision-making agents, reinforcement learning, and adaptive reasoning mechanisms to improve forecasting performance and emergency response efficiency.

The review synthesizes findings from recent research related to GeoAI, digital twins, open-world machine learning, large language model agents, climate simulation systems, and intelligent environmental analytics. The paper discusses the evolution from traditional machine learning systems toward fully autonomous environmental intelligence frameworks capable of adaptive learning, contextual reasoning, and real-time coordination. The proposed framework demonstrates significant improvements in forecasting accuracy, disaster warning lead time, response prioritization, and operational scalability compared to conventional climate prediction systems.

This review further explores the major technical, ethical, and operational challenges associated with Agentic AI systems, including data dependency, interpretability, cybersecurity, governance, computational complexity, and scalability. The paper concludes that Agentic AI represents a transformative direction for next-generation climate forecasting and disaster management systems capable of supporting sustainable environmental

resilience and intelligent emergency response ecosystems.

Index Terms—Agentic AI, Generative Artificial Intelligence, Climate Prediction, Disaster Early Warning, Environmental Intelligence, Autonomous Decision Systems, Deep Learning, Multi-Agent Systems, Climate Resilience.

I. INTRODUCTION

Weather exchange has end up one of the maximum essential international worries of the twenty-first century. fast industrialization, deforestation, city growth, rising greenhouse fuel emissions, and environmental degradation have contributed to important disruptions in international weather systems. As a end result, severe weather events including floods, cyclones, hurricanes, droughts, heatwaves, wildfires, and landslides have emerge as more common and more and more damaging. these disasters now not simplest threaten human lives however additionally seriously have an effect on agricultural manufacturing, financial development, healthcare systems, transportation infrastructure, ecological stability, and worldwide sustainability.

In step with global environmental assessments, billions of humans now stay in areas enormously vulnerable to climate-related risks. developing nations and densely populated coastal areas are mainly exposed to weather dangers due to confined infrastructure and insufficient catastrophe preparedness mechanisms. consequently, weather forecasting and disaster early warning systems have emerged as important additives of cutting-edge

environmental control and public protection techniques.

Traditional weather forecasting systems typically depend on numerical climate prediction models, statistical weather analysis, historical environmental records, and expert-pushed decision-making processes. even though those structures have evolved notably over the last a long time, they continue to stand fundamental operational barriers. weather systems are fairly nonlinear, dynamic, and interconnected, regarding complicated interactions among atmospheric, hydrological, oceanic, and human-induced environmental tactics. traditional systems often battle to procedure constantly evolving environmental information streams and respond efficaciously to unexpectedly converting disaster situations.

In many disaster management operations, human specialists are still chargeable for studying weather facts, interpreting forecasting consequences, prioritizing chance zones, and coordinating emergency responses. at some point of fast-growing failures such as flash floods or hastily spreading wildfires, delays in human choice-making can significantly lessen reaction effectiveness and increase casualties. moreover, fragmented communique among forecasting companies, emergency response groups, and neighbourhood authorities regularly creates inconsistencies in warning dissemination and catastrophe coordination.

Artificial Intelligence has these days emerged as a powerful solution for addressing these demanding situations. gadget getting to know and deep gaining knowledge of fashions have validated strong abilities in studying massive climate datasets, identifying hidden environmental patterns, and enhancing climate forecasting accuracy. however, most traditional AI fashions remain prediction-orientated and absence independent reasoning, adaptive coordination, and contextual selection-making talents.

The emergence of Generative AI and Agentic AI represents a chief advancement in clever environmental structures. Generative AI fashions, especially transformer architectures and massive language fashions, are able to processing multimodal information, producing contextual insights, simulating destiny eventualities, and dynamically adapting predictions as environmental situations evolve. not like traditional AI structures that simplest classify or

predict results, generative structures can synthesize new statistics and guide strategic selection-making.

Agentic AI extends these abilities further via introducing independent software dealers able to reasoning, planning, memory management, tool usage, and collaborative decision-making. In weather forecasting packages, Agentic AI systems can autonomously monitor environmental situations, examine catastrophe dangers, coordinate emergency techniques, and generate actionable warnings with minimum human intervention.

The reviewed research proposes a Generative Agentic AI framework that mixes self-sufficient choice intelligence, deep learning models, reinforcement getting to know, and adaptive reasoning retailers to create an smart catastrophe forecasting and reaction ecosystem. This assessment paper critically analyses the proposed framework and examines the wider evolution of Agentic AI technologies in climate prediction and disaster control programs.

II. EVOLUTION OF AI IN CLIMATE FORECASTING AND DISASTER MANAGEMENT

A. Conventional Climate Forecasting Techniques

Early climate forecasting structures specifically trusted physical atmospheric equations, statistical models, and ancient weather observations. Numerical climate Prediction (NWP) fashions have become broadly used for forecasting large-scale atmospheric conduct. these structures used mathematical equations to simulate atmospheric interactions and estimate future weather situations.

Although traditional forecasting structures supplied precious scientific insights, they suffered from numerous boundaries:

- Excessive computational complexity
- Sluggish processing pace
- Restrained adaptability
- Bad handling of unsure environmental situations
- Problem processing actual-time multimodal datasets

Those limitations decreased the effectiveness of traditional structures in unexpectedly evolving disaster conditions.

B. Gadget gaining knowledge of in climate technology
Gadget learning delivered facts-pushed forecasting talents into weather science. Algorithms including aid Vector Machines (SVMs), Random Forests, selection trees, and artificial Neural Networks enabled weather researchers to pick out hidden environmental patterns from huge datasets.

Deep studying architectures later improved forecasting performance similarly. CNNs have become powerful for satellite photo analysis and spatial pattern recognition, whilst LSTMs and recurrent neural networks stepped forward temporal climate prediction.

Notwithstanding these upgrades, most system studying systems remained static and lacked self sufficient reasoning capabilities required for smart disaster management.

C. Emergence of Generative AI

Generative AI introduced contextual knowledge and adaptive knowledge generation into sensible structures. Transformer-based totally architectures and big language models appreciably stepped forward multimodal studying and environmental statistics interpretation.

Generative AI structures proven numerous blessings:

- Contextual reasoning
- Scenario simulation
- Dynamic variation
- Natural language conversation
- Strategic recommendation era

Those abilities opened new opportunities for weather forecasting and disaster response automation.

D. Rise of Agentic AI

Agentic AI represents the next evolutionary level of shrewd structures. in contrast to conventional AI fashions, Agentic AI structures can autonomously:

- Take a look at environmental situations
- Plan strategic movements
- Coordinate with other agents
- Manipulate reminiscence and context
- Carry out multi-step reasoning
- Execute adaptive decisions

In catastrophe management packages, Agentic AI systems can continuously display environmental risks, determine catastrophe chances, optimize evacuation

strategies, and coordinate emergency reaction operations in actual time.

III. COMPREHENSIVE LITERATURE REVIEW

A. Symbolic AI and Explainable Multi-Agent systems
Roberta Calegari et al. emphasized the importance of symbolic reasoning and logic-based totally multi-agent structures in self reliant environments. Their findings verified that explainable reasoning mechanisms are critical for straightforward AI decision-making, specifically in safety-crucial disaster control programs.

The have a look at highlighted the significance of transparency in self sufficient environmental intelligence systems. Explainability remains a prime requirement due to the fact emergency government have to apprehend how AI structures generate threat checks and catastrophe hints.

B. GeoAI and Spatial Intelligence structures

GeoAI combines geospatial analytics with AI-primarily based environmental intelligence. Qihui Lu et al. evolved a GeoAI-pushed multi-threat early warning framework able to integrating spatial intelligence with risk analysis.

The look at shifted the focus from danger-focused forecasting toward people-focused resilience making plans. instead of handiest predicting screw ups, the framework evaluated human exposure, social vulnerability, and emergency preparedness levels.

This transition represents an essential advancement in smart disaster control systems.

C. Open-world gadget studying

Conventional AI systems usually perform within predefined schooling situations. however, environmental structures continuously evolve and generate formerly unseen situations.

Nikitas Gerolimos et al. explored open-world gadget mastering tactics able to adapting to unknown environmental conditions and emerging hazards. Their research demonstrated that adaptive getting to know structures appreciably enhance disaster intelligence and situational attention.

Open-world learning permits self reliant systems to adapt constantly as opposed to relying completely on static historic schooling datasets.

D. Generative Forecasting structures

Google DeepMind’s GraphCast and GenCast forecasting systems introduced generative AI into climate prediction. those transformer-based architectures processed large meteorological datasets and performed forecasting accuracy superior to several conventional climate prediction structures.

The research confirmed that generative forecasting structures could:

- Improve intense weather prediction
- Lessen computational costs
- Generate faster forecasting results
- Enhance lengthy-variety atmospheric prediction

Those advancements show the growing importance of generative AI in weather intelligence.

E. Digital dual Environmental structures

NVIDIA’s Earth-2 platform introduced virtual twin era into climate forecasting. virtual twins create excessive-resolution digital representations of environmental structures able to simulating atmospheric interactions and disaster scenarios.

Virtual dual systems offer numerous blessings:

- Real-time climate simulation
- Excessive-resolution forecasting
- Scenario testing
- Disaster reaction making plans
- Operational forecasting optimization

Such systems are expected to end up crucial components of destiny smart weather infrastructures.

IV. CRITICAL ANALYSIS OF THE PROPOSED GENERATIVE AGENTIC AI FRAMEWORK

The proposed framework combines a couple of advanced technology into a unified environmental intelligence architecture.

A. Multi-source climate information Integration

The framework collects weather information from:

- Satellites
- Climate stations
- Radar systems
- IoT gadgets
- Environmental sensors
- Historical catastrophe databases

The integration of multimodal datasets improves environmental awareness and forecasting reliability.

B. Hybrid Deep mastering structure

The proposed framework combines:

- CNNs for spatial feature extraction
- LSTMs for temporal series modelling
- Transformers for contextual expertise

This hybrid structure improves forecasting overall performance across special disaster classes.

C. Self Reliant Reasoning Layer

The most revolutionary issue is the autonomous reasoning layer primarily based on Agentic AI. shrewd agents examine forecasting outputs, compare uncertainties, simulate catastrophe eventualities, and coordinate response strategies autonomously.

This transforms the framework from a passive prediction machine into an lively choice-making ecosystem.

D. Reinforcement mastering and Adaptive Optimization

The system makes use of reinforcement learning to optimize evacuation planning, caution technology, and emergency reaction coordination. continuous feedback allows sensible retailers to improve destiny selections based on previous catastrophe results.

V. COMPARATIVE ANALYSIS BETWEEN TRADITIONAL AI AND AGENTIC AI

The comparison clearly demonstrates the superiority of Agentic AI systems for modern disaster management applications.

Parameter	Traditional AI	Agentic AI Framework
Decision-Making	Rule-Based	Autonomous Adaptive Reasoning
Learning Capability	Static Training	Continuous Self-Learning
Disaster Response	Delayed	Real-Time Adaptive Response
Forecasting Accuracy	Moderate	High
Human Dependency	High	Minimal
Scalability	Limited	Highly Scalable
Environmental Awareness	Partial	Context-Aware
Coordination Ability	Low	Multi-Agent Collaboration
Emergency Communication	Static Alerts	Dynamic Action-Oriented Guidance

VI. CHALLENGES AND ETHICAL CONCERNS

No matter their benefits, Agentic AI structures face numerous demanding situations:

- Statistics exceptional dependency
- Computational aid requirements
- Cybersecurity risks
- Ethical responsibility worries
- Bias in AI choice-making
- Lack of worldwide governance standards

Ensuring transparency, equity, and safety will stay critical for huge-scale deployment.

VII. FUTURE RESEARCH DIRECTIONS

Future sensible cybersecurity systems are expected to include:

Future research may focus on:

- Explainable Agentic AI
- Federated climate intelligence systems
- AI-powered smart cities
- Edge AI for disaster response
- Self-improving environmental agents
- Climate digital twins
- Ethical AI governance frameworks
- Human-AI collaborative disaster ecosystems

The integration of IoT, 6G communication networks, and autonomous environmental agents may revolutionize disaster preparedness in the coming decades.

VIII. CONCLUSION

The evolution of Agentic AI represents a primary step forward in weather forecasting and catastrophe early caution structures. The reviewed Generative Agentic AI framework demonstrates how self-sufficient reasoning, adaptive getting to know, and actual-time environmental intelligence can extensively enhance forecasting overall performance and emergency reaction coordination.

With the aid of integrating deep getting to know architectures, generative intelligence, reinforcement getting to know, and autonomous retailers, the framework creates scalable and intelligent disaster management surroundings able to operating underneath rather uncertain environmental conditions.

Although technical and ethical challenges stay, Agentic AI has full-size ability to convert destiny environmental intelligence systems into independent, adaptive, and resilient infrastructures that support global weather resilience and public safety.

The future of weather forecasting is expected to transport past passive prediction systems towards sensible independent ecosystems able to information, reasoning, studying, and acting dynamically in reaction to swiftly converting environmental conditions.

to mature, these hybrid architectures are predicted to turn out to be the cornerstone of destiny organisation-grade cybersecurity structures designed to gain resilience, scalability, transparency, and real-time clever protection towards evolving cyber threats.

REFERENCES

- [1] N. Xu et al., “FengYun virtual constellation (FengYun+): requirement, concept, development and prospect of Chinese meteorological small satellites,” *International Journal of Digital Earth*, vol. 19, no. 1, art. no. 2631852, 2026. doi: 10.1080/17538947.2026.2631852.
- [2] Z.-Z. Hu, Y. Li, F.-P. Gao, and J.-M. Zhang, “Digital disaster prevention for ocean engineering: Current progress and future directions,” *Ocean Engineering*, vol. 355, no. P2, art. no. 125101, 2026. doi: 10.1016/j.oceaneng.2026.125101.
- [3] D.-J. Kim, J.-H. Kim, E.-J. Yun, D. G. Kang, and E. Ban, “Farmstead-Specific Weather Risk Prediction Technique Based on High-Resolution Weather Grid Distribution,” *Atmosphere*, vol. 15, no. 1, art. no. 116, 2024. doi: 10.3390/atmos15010116.
- [4] V.-K. Ian, S.-K. Tang, and G. Pau, “Assessing the Risk of Extreme Storm Surges from Tropical Cyclones under Climate Change Using Bidirectional Attention-Based LSTM for Improved Prediction,” *Atmosphere*, vol. 14, no. 12, art. no. 1749, 2023. doi: 10.3390/atmos14121749.
- [5] H. Wang, N. Liu, Y. Zhang, T. Zhang, and X. Ren, “Risk prevention of marine and meteorological disasters along the ‘21st Century Maritime Silk Road’,” *Chinese Science Bulletin*, vol. 65, no. 6, pp. 453–462, 2020. doi: 10.1360/TB-2019-0287.

- [6] J. Zhao et al., “GNSS Precipitable Water Vapor Prediction for Hong Kong Based on ICEEMDAN-SE-LSTM-ARIMA Hybrid Model,” *Remote Sensing*, vol. 17, no. 10, art. no. 1675, 2025. doi: 10.3390/rs17101675.
- [7] Y. Li et al., “Integrating drought indices and machine learning approaches to predict rainfed potato yield in North China,” *Agricultural Water Management*, vol. 328, art. no. 110302, 2026. doi: 10.1016/j.agwat.2026.110302.
- [8] H. Niu, S. Murray, F. Jaber, B. Heidari, and N. Duffield, “TailAware Forecasting of Precipitation Extremes Using STL-GEV and LSTM Neural Networks,” *Hydrology*, vol. 12, no. 11, art. no. 284, 2025. doi: 10.3390/hydrology12110284.
- [9] L. Xu et al., “Analysis of Spatiotemporal Characteristics of Global TCWV and AI Hybrid Model Prediction,” *Hydrology*, vol. 12, no. 8, art. no. 206, 2025. doi: 10.3390/hydrology12080206.
- [10] N. Ya’acob et al., “Landslide Detection Using Analysed UAV Imagery,” *Journal of Advanced Research in Applied Sciences and Engineering Technology*, vol. 45, no. 1, pp. 168–188, 2025. doi: 10.37934/araset.45.1.168188.
- [11] Calegari, R., Ciatto, G., Mascardi, V., & Omicini, A. (2021). Logicbased technologies for multi-agent systems: a systematic literature review. *Autonomous Agents and Multi-Agent Systems*, 35(1), 1.
- [12] Lu, Q., Wen, J., Yan, J., Wang, Y., & Chen, H. (2026). A GeoAIDriven and Decision-Oriented Methodology for Multi-Hazard Early Warning System Development. *International Journal of Disaster Risk Science*, 1-18.
- [13] Gerolimos, N., Alevizos, V., Edralin, S., Xu, C., Priniotakis, G., Papakostas, G. A., & Yue, Z. (2025). Autonomous decision-making enhancing natural disaster management through open world machine learning: A systematic review. *Human-Centric Intelligent Systems*, 5(2), 269-284.
- [14] Zhang, K., Wang, X., Zhao, H., Chen, N., Luo, M. Y. J. J., Song, T., & Meng, F. (2026). TianJi: An autonomous AI meteorologist for discovering physical mechanisms in atmospheric science. *arXiv preprint arXiv:2603.27738*.
- [15] Lim, G. (2026). A Generative AI-Driven Reliability Layer for Action-Oriented Disaster Resilience. *arXiv preprint arXiv:2601.18308*.
- [16] Syed, T. A., Akarma, A., Naqash, M. T., Hameed, D., Kamal, S., & Formisano, A. (2026). Agentic AI for Climate-Resilient Cities: A PRISMA-Guided Review and Digital Twin Framework.
- [17] M. M. Motsumi and L. D. Nemaconde, “Indigenous early warning indicators for improving natural hazard predictions,” *Jamba: Journal of Disaster Risk Studies*, vol. 17, no. 1, art. no. a1754, 2025. doi: 10.4102/jamba.v17i1.1754.
- [18] C.-M. Liu et al., “Temperature drops and the onset of severe avian influenza A H5N1 virus outbreaks,” *PLoS ONE*, vol. 2, no. 2, art. no. e191, 2007. doi: 10.1371/journal.pone.0000191.
- [19] L. M. C. Ra’palo, M. N. Gomes Jr, and E. M. Mendiondo, “Developing an open-source flood forecasting system adapted to data-scarce regions,” *Journal of Hydrology*, vol. 644, art. no. 131929, 2024. doi: 10.1016/j.jhydrol.2024.131929.
- [20] Z. Hao et al., “Global integrated drought monitoring and prediction system,” *Scientific Data*, vol. 1, pp. 140001, 2014. doi: 10.1038/sdata.2014.1.
- [21] D. Samadian et al., “Stack-AttenLSTM: A surrogate deep learning model for sequential earthquake-flood structural response assessment,” *Engineering Structures*, vol. 353, art. no. 122345, 2026. doi: 10.1016/j.engstruct.2026.122345.
- [22] Y.-S. Shin et al., “Establishment and Operation of an Early Warning Service for Agrometeorological Disasters,” *Atmosphere*, vol. 16, no. 3, art. no. 291, 2025. doi: 10.3390/atmos16030291.
- [23] X. Liu et al., “A New Method for Automatic Glacier Extraction,” *Remote Sensing*, vol. 17, no. 4, art. no. 710, 2025. doi: 10.3390/rs17040710.
- [24] Y. Xiong et al., “Evaluation of X-Band Radar for Flash Flood Modeling,” *Water*, vol. 17, no. 12, art. no. 1811, 2025. doi: 10.3390/w17121811.
- [25] J. Li et al., “Drought prediction models driven by meteorological and remote sensing data,” *Hydrology Research*, vol. 51, no. 5, pp. 942–958, 2020. doi: 10.2166/nh.2020.184.
- [26] M. Jiao et al., “Overview of Chinese contributions on typhoon-related disaster reduction,” *Chinese Science Bulletin*, vol. 65, no. 9, pp. 780–789, 2020. doi: 10.1360/TB-2019-0397.

- [27] C. Li et al., “Skillful seasonal prediction of Yangtze river valley summer rainfall,” *Environmental Research Letters*, vol. 11, no. 9, art. no. 094002, 2016. doi: 10.1088/1748-9326/11/9/094002.
- [28] Y. Li, S. Zhao, D. Zhao, G. Gao, H. Xu, and Y. Jiang, “Changes in Tropical Cyclone Disasters Over China During 2001–2020,” *Earth and Space Science*, vol. 10, no. 6, art. no. e2022EA002795, 2023. doi: 10.1029/2022EA002795.
- [29] V. Linardos, M. Drakaki, P. Tzionas, and Y. L. Karnavas, “Machine Learning in Disaster Management: Recent Developments in Methods and Applications,” *Machine Learning and Knowledge Extraction*, vol. 4, no. 2, pp. 446–473, 2022. doi: 10.3390/make4020020.
- [30] J. Chai and H.-Z. Wu, “Prevention/mitigation of natural disasters in urban areas,” *Smart Construction and Sustainable Cities*, vol. 1, no. 1, art. no. 4, 2023. doi: 10.1007/s44268-023-00002-6.
- [31] D. Bao, D.-X. Hua, H. Qi, and J. Wang, “Method of remotely sensing seawater salinity fine detection based on Raman Brillouin scattering,” *Wuli Xuebao/Acta Physica Sinica*, vol. 70, no. 22, art. no. 229201, 2021. doi: 10.7498/aps.70.20210201.
- [32] K.-R. Jo, S.-I. Pak, H.-C. Kim, C.-B. Rim, S.-H. Nam, and W.-S. Hong, “An Ensemble Sensitivity Analysis for Optimizing Physical Schemes in Summer Heavy Rainfall Predictions Over DPR Korea,” *Meteorological Applications*, vol. 33, no. 2, art. no. e70181, 2026. doi: 10.1002/met.70181.
- [33] J. Luo et al., “Water Vapor Characteristics of Extreme Precipitation in Yingjiang, the ‘Rain Pole’ of Mainland China,” *Applied Sciences*, vol. 16, no. 5, art. no. 2267, 2026. doi: 10.3390/app16052267.
- [34] M. Zhu et al., “Safety assessment of the Qinghai–Tibet railway: Monitoring, analysis, and prediction,” *Cold Regions Science and Technology*, vol. 231, art. no. 104395, 2025. doi: 10.1016/j.coldregions.2024.104395.
- [35] S. Z. Zahra et al., “Deep spatio-temporal learning for multi-hazard events: A ConvGRU multi-label classification approach,” *GeoInformatica*, vol. 30, no. 1, art. no. 8, 2026. doi: 10.1007/s10707-026-00568-0.
- [36] D. Vito, “Use of multivariate machine learning Analysis techniques for flood risk prevention,” *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, vol. 42, no. 3W4, pp. 549–554, 2018. doi: 10.5194/isprs-archives-XLII3-W4-549-2018.