Integrating Sentinel-1 and Sentinel-2 with AI for Enhanced Flood Monitoring and Disaster Response

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Flood Facts (1990–2022)

Floods are the most frequent natural disaster, affecting over 3.2 billion & 250 million people annually

Damage exceeded US$ 1.3 trillion globally (1990–2022), with annual losses of US$ 50–66 billion

218,000 lives are lost due to floods

Flood events are increasing in frequency and severity due to climate change, making early detection and monitoring even more critical

Why Early Flood Detection?

Provides timely warnings for evacuation and resource allocation

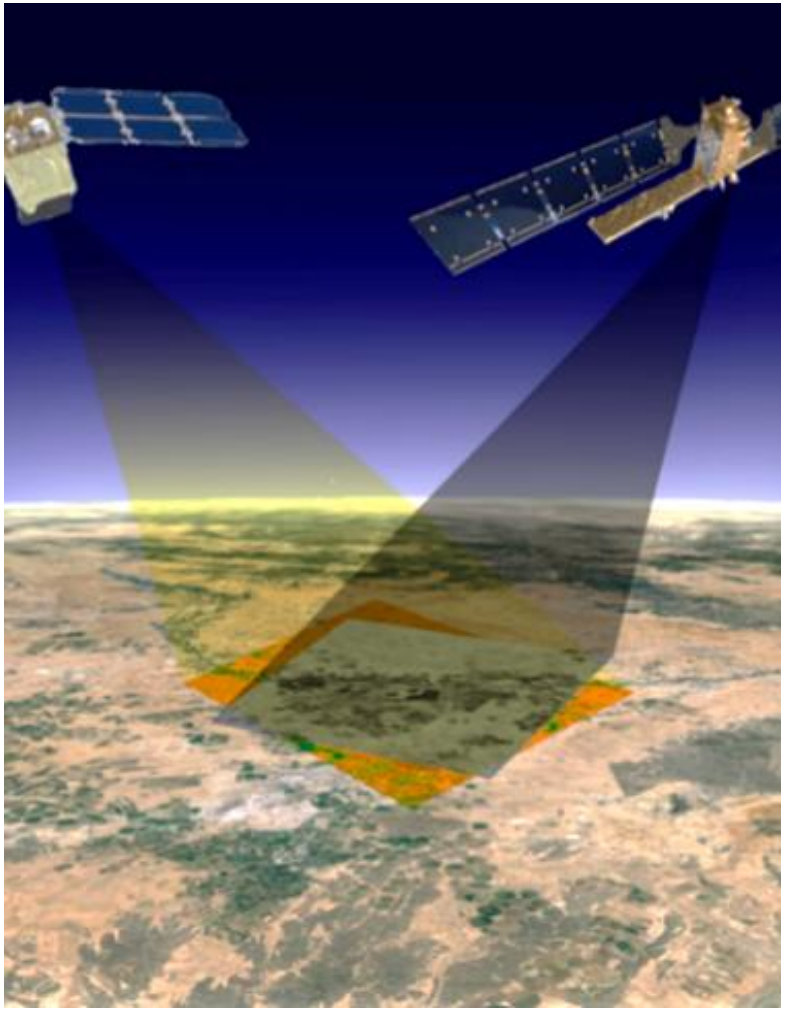
Helps disaster response agencies plan rescue and relief operations

Reduces economic impact by protecting infrastructure and agriculture

Enables climate resilience planning and long-term risk assessment

Why Sentinel-1 and Sentinel-2 Are Widely Used

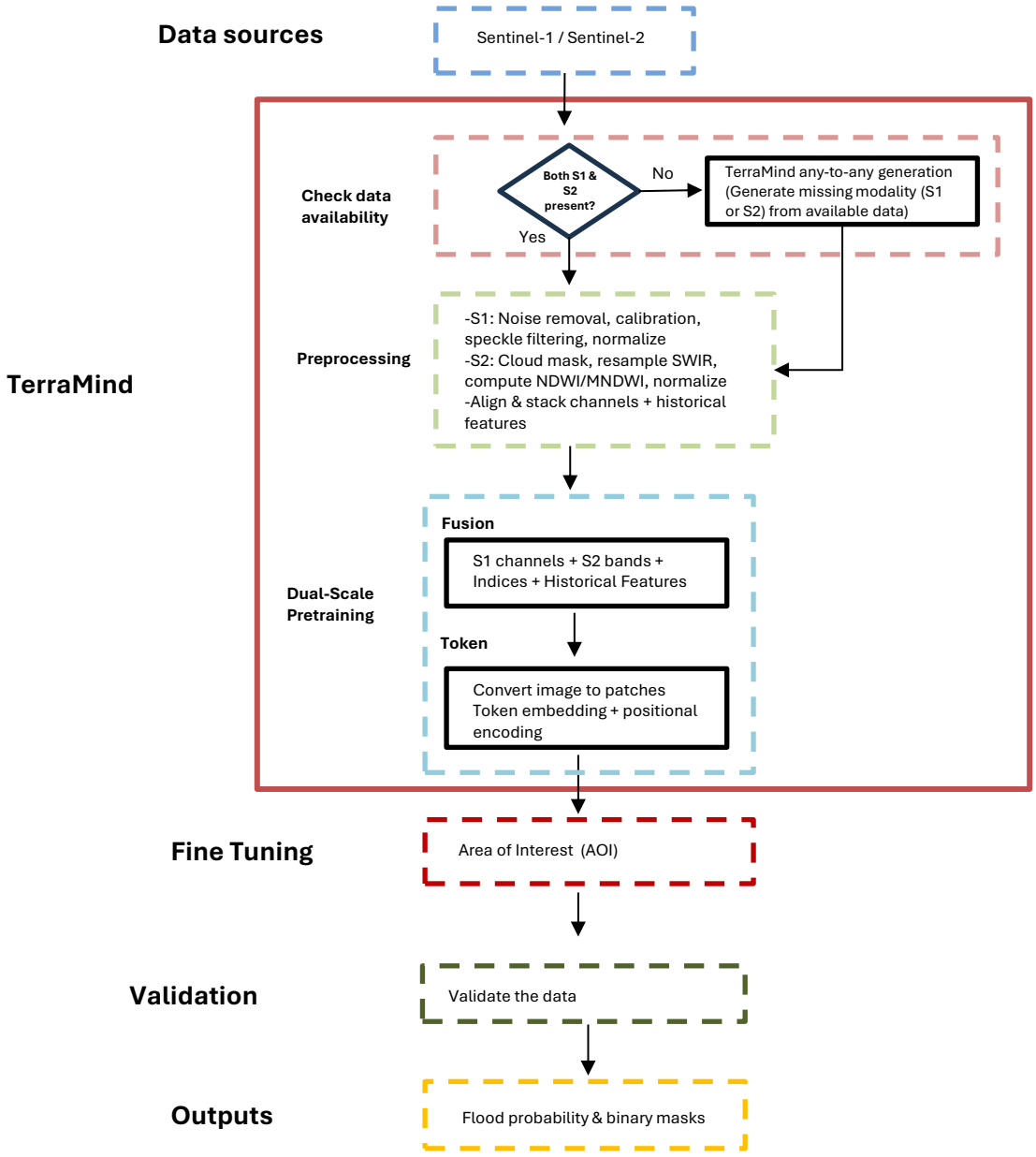
- Sentinel-1 (SAR): Works day/night, penetrates clouds, ideal for flood detection during storms
- Sentinel-2 (Optical): High-resolution multispectral imagery, good for visual validation & water detection
- Together: Complementary – S1 ensures continuous monitoring, S2 provides spectral information
- Free & global coverage crucial for operational use worldwide
- Frequent revisit (6–12 days), enabling near-real-time flood mapping



TerraMind

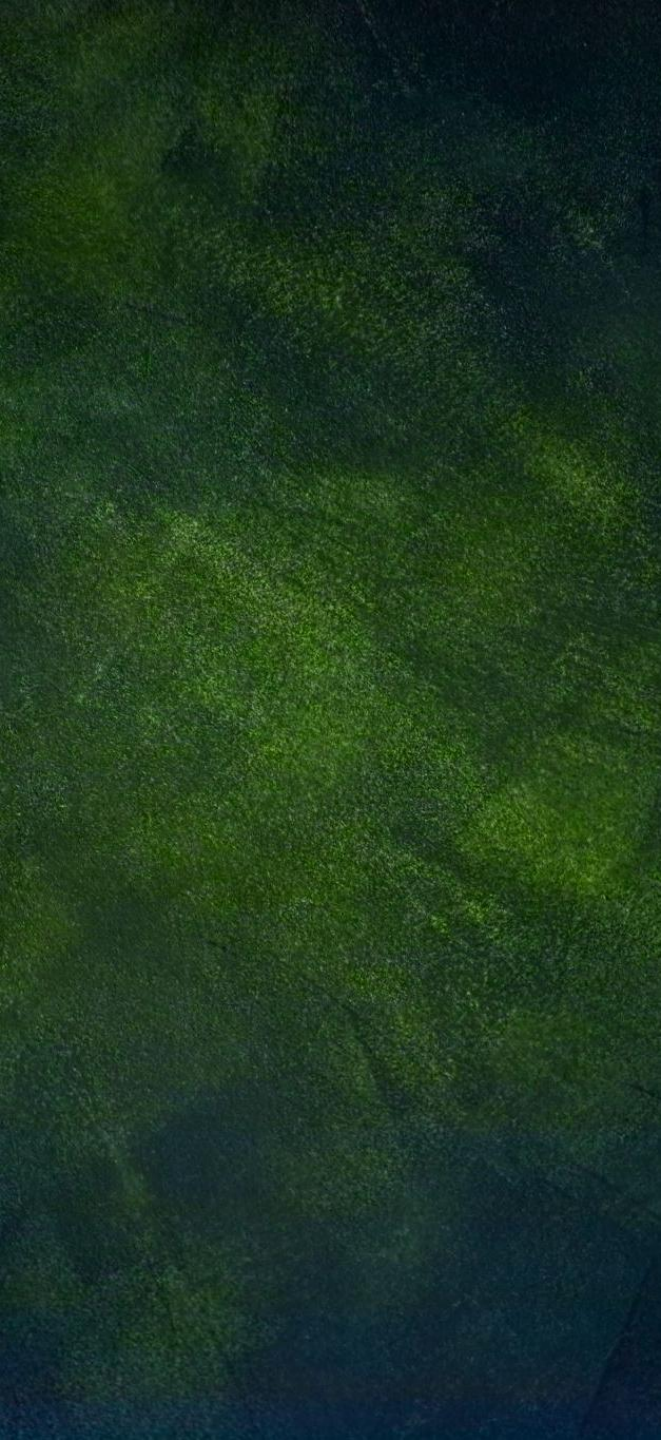
Functionality	Description	Example for Flood Detection
Any-to-Any Modality Generation	Generates one modality from another (SAR → Optical, Optical → NDVI)	Cloudy Sentinel-2 imagery can be replaced with synthetic S2-like data generated from Sentinel-1 radar, enabling clear flood mapping
Zero-Shot Capability	Performs flood detection without task-specific fine-tuning	Produces usable flood extent maps immediately for new flood events with no labeled data, reaching ~70% IoU
Few-Shot Learning	Adapts to local conditions with very few labeled examples (1-shot, 5-shot)	Fine-tunes quickly using a handful of labeled flood patches to improve accuracy for a specific region
Thinking-in-Modalities (TiM)	Generates synthetic modalities during training/inference and uses them as additional input	Generates LULC or NDVI maps during fine-tuning to enhance flood detection accuracy (+2% mIoU improvement reported)

Workflow


Data sources
Sentinel-1 / Sentinel-2
TerraMind
Check data availability
Both S1 & S2 present?
No
Yes
TerraMind any-to-any generation (Generate missing modality (S1 or S2) from available data)
Preprocessing
-S1: Noise removal, calibration, speckle filtering, normalize
-S2: Cloud mask, resample SWIR, compute NDWI/MNDWI, normalize
-Align & stack channels + historical features
Dual-Scale Pretraining
Fusion
S1 channels + S2 bands + Indices + Historical Features
Token
Convert image to patches Token embedding + positional encoding
Fine Tuning
Area of Interest (AOI)
Validation
Validate the data
Outputs
Flood probability & binary masks

Advantages & Applications

- Works even with missing or noisy data
- Combines radar + optical for all-weather monitoring
- Zero-shot inference reduces need for large labeled datasets
- Generalizes to other disasters: wildfires, drought, deforestation
- Scalable for global monitoring and early warning systems



References

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Thank you
For listening

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