A Digital Twin for Climate Extremes using Artificial Intelligence

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I Climate Extremes

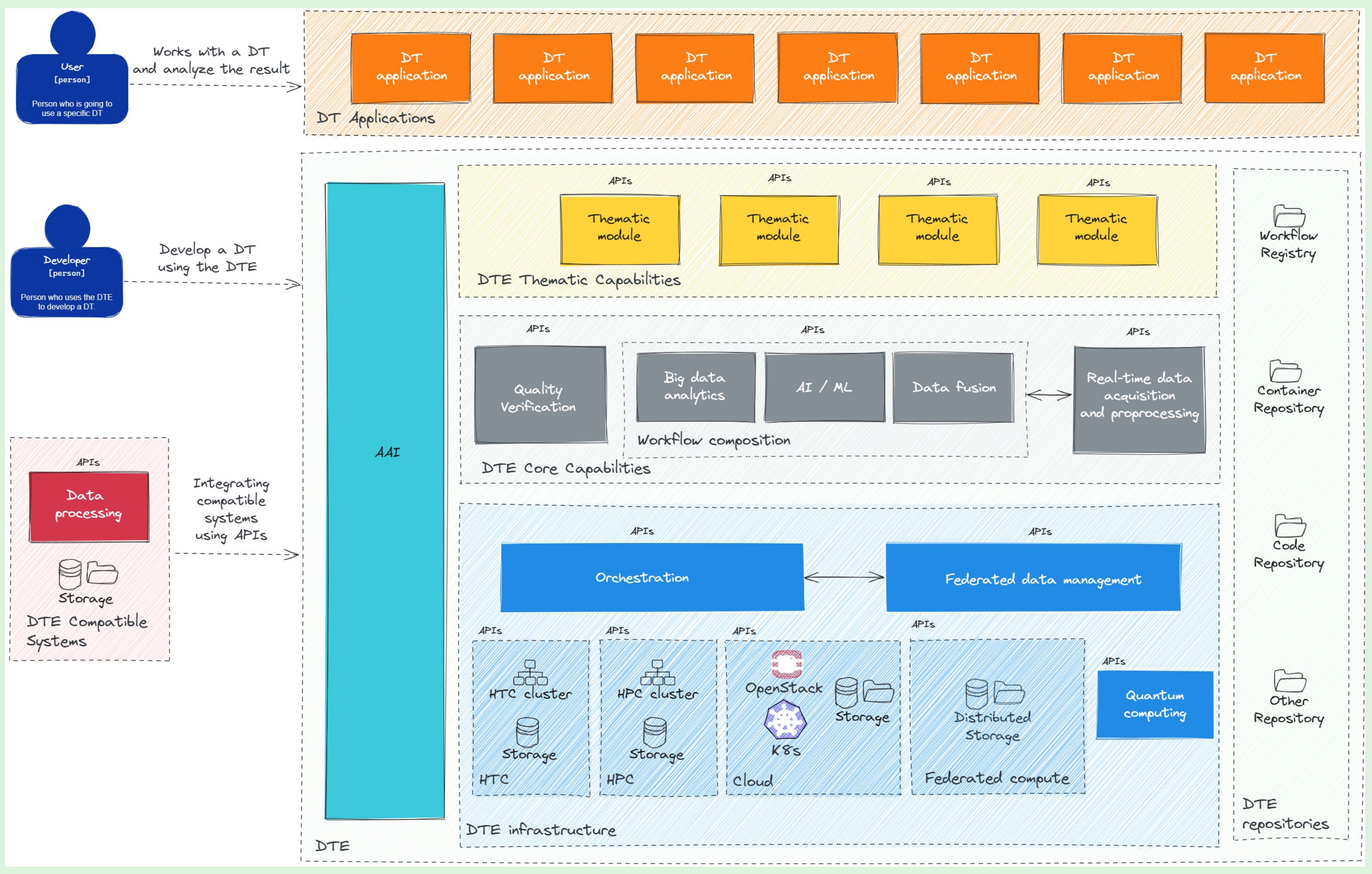
2021 Germany Erftstadt, southwest of Cologne

2020 Hurricane Delta causes damage to Louisiana's Gulf Coast

- Urgent needs of impact assessments
- Characterize changes of climate extremes
- Multiple domains: infrastructures, urban, agriculture, transportation, etc.
- Compound Events

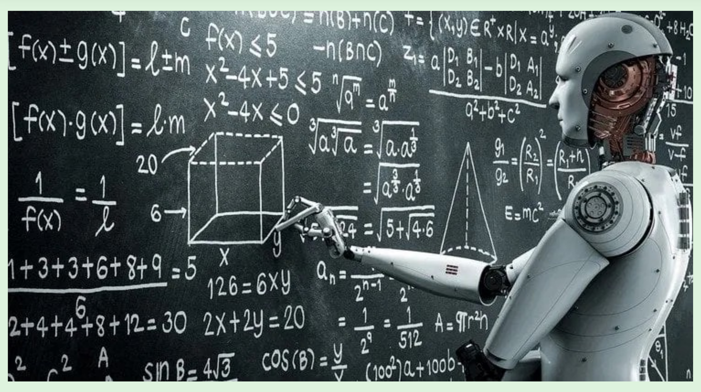
II interTwin Digital Twin Engine (DTE)

- interTwin DTE conceptual model
- Open-source integrated platform based on open standards, APIs and protocols that offers the capability to integrate with application-specific Digital Twins (DTs).



Blueprint Architecture

III Why use AI?



- Possible huge gain of performance
- Efficient parallel execution
- Use of GPU architectures
- More generic approach
- Novel techniques in climate data analysis

Take Home 🏠 Messages ☑

1. **Generic and unsupervised anomaly detection and characterization**
2. **Coherent results**
3. **Handles high amounts of data**
4. **First CVAE for climate projection analyses**

V Perspectives

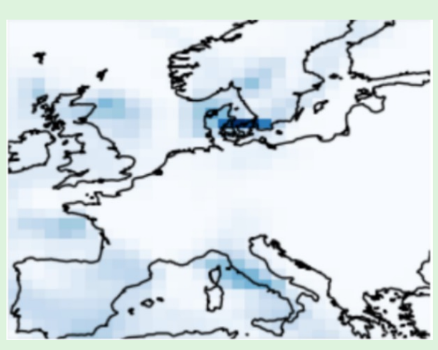
- 1D model (interpretability)
- Robustness with more members
- Validation with icclim
- n-day input (“video”)
- Integration with interTwin architecture

IV Using Machine Learning to Detect and Characterize Climate Extremes

Generic detection algorithm	Characterization
◦ Intense rainfall ◦ Drought ◦ Heatwave ◦ Cold spell ◦ High wind	◦ Frequency of occurrence ◦ Spatial extent ◦ Intensity (if relevant) ◦ Duration

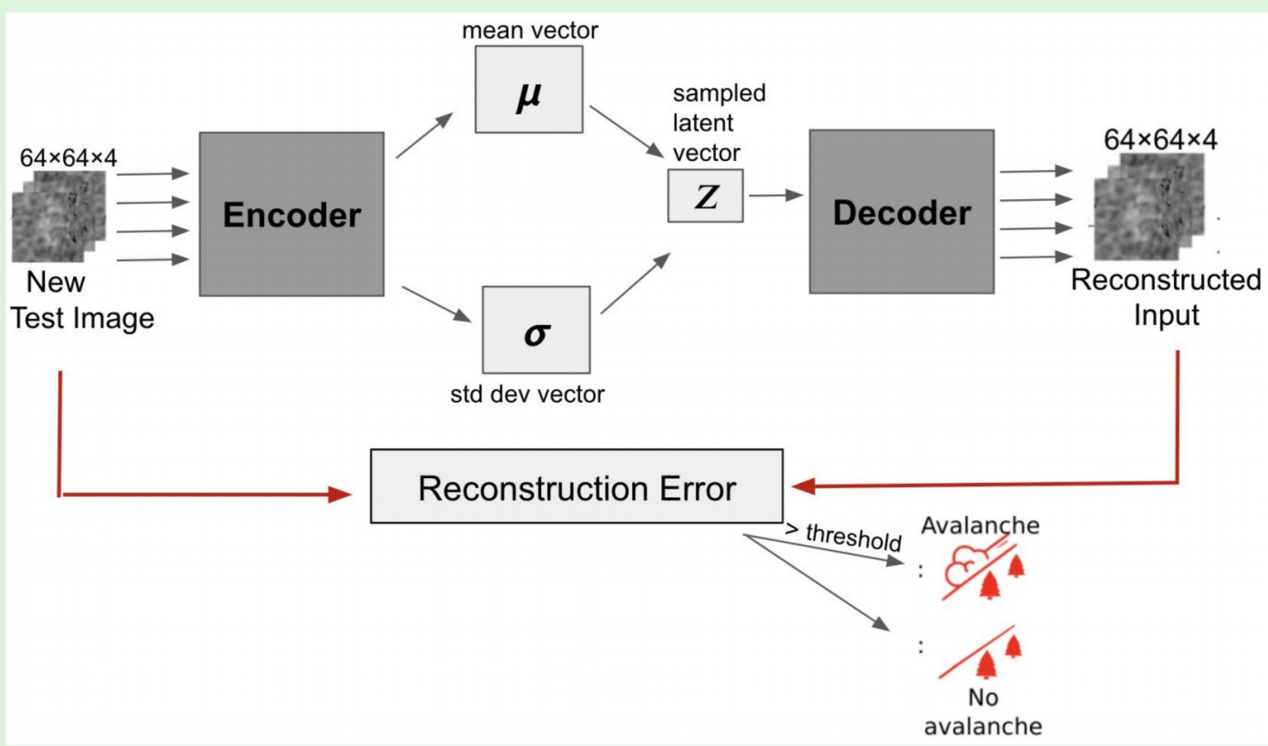
Data

- Climate variables
  - 1950-2100 (historical and projected)
  - ~125*125km grid
  - SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5
  - Daily maximum temperature, precipitations, wind
  - Climate model: CMCC-ESM2
- NetCDF files preprocessed to ndarrays
  - 32*32 square of Western Europe
  - Season split
  - Normalization
  - Climate indices (icclim) for validation



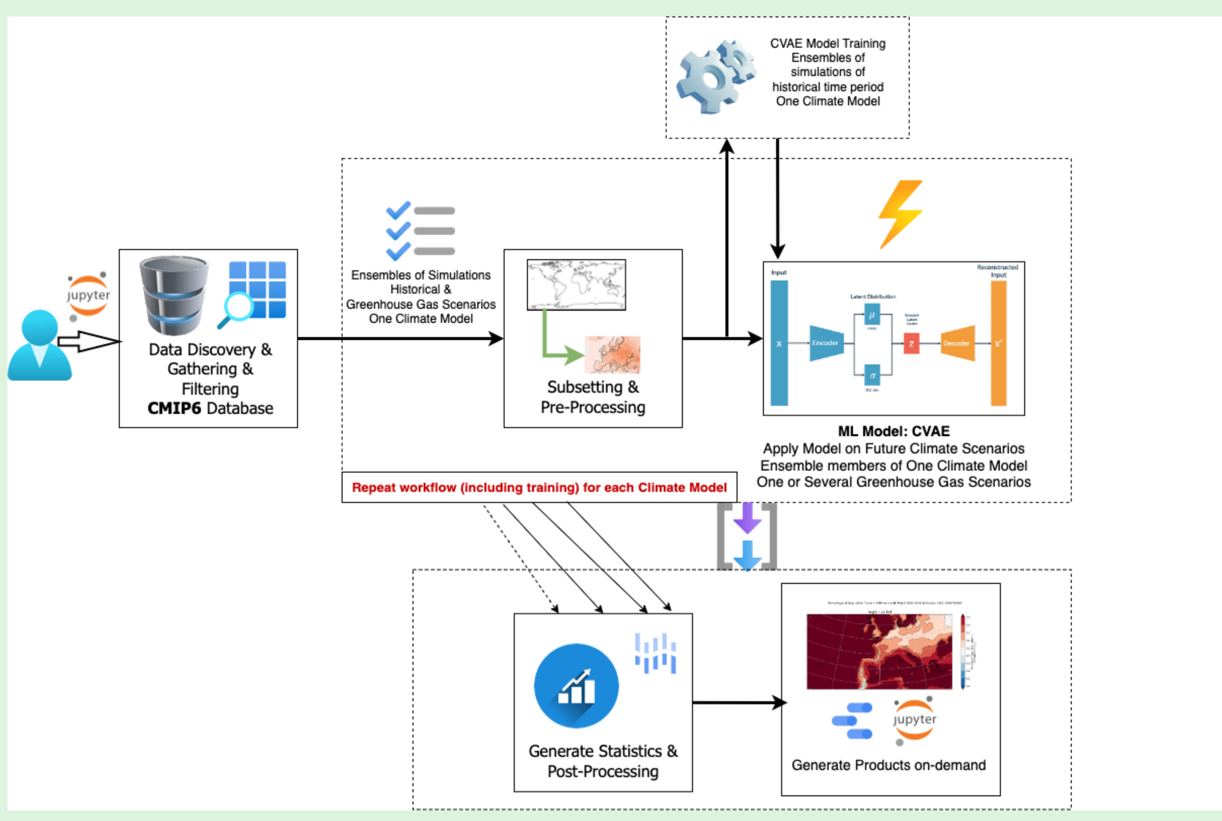
Input Example after Preprocessing

Method: Variational Auto Encoder



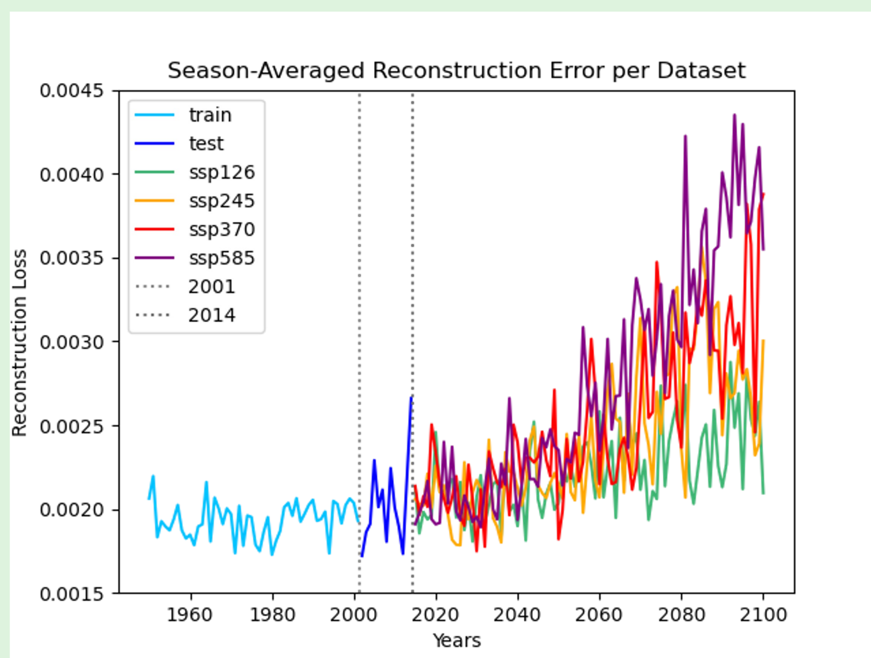
Variational autoencoder anomaly-detection of avalanche deposits in satellite SAR imagery, Sinha et al., 2020

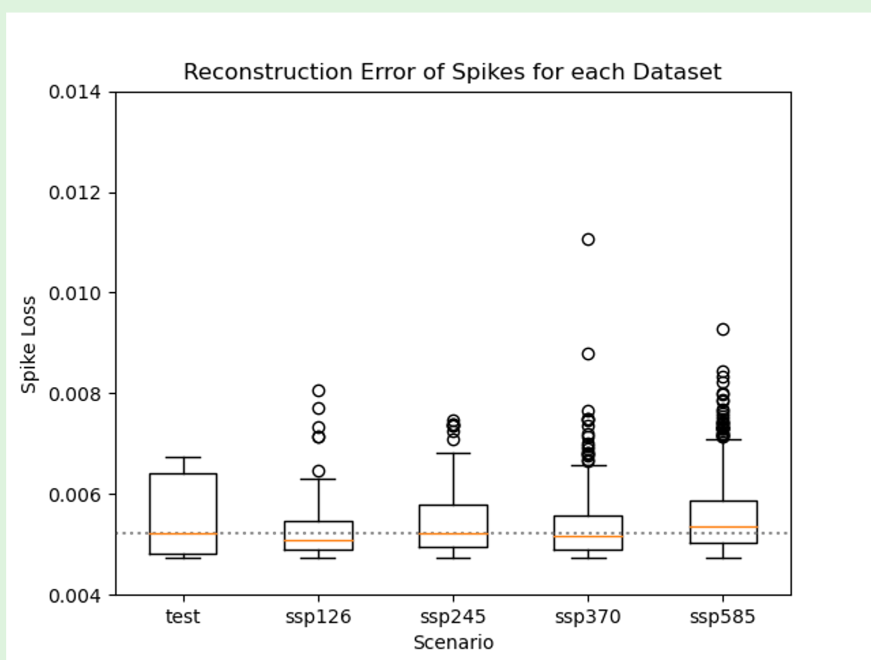
Method: High-Level Workflow



Results: Summer Statistics

	2001-2014	2015-2100			
Scenario	Test data	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
Number of spikes	9	48	99	120	145
Proportion of unusual days	1,00%	0,87%	2,78%	3,70%	7,56%
Maximum spike	0,00675	0,00807	0,00746	0,0111	0,00928
Average maximum	0,00549	0,00545	0,00551	0,00543	0,00571
Maximum duration (days)	2	3	14	17	25
Average duration (days)	1,33	1,44	2,22	2,44	4,12





interTwin: https://www.intertwin.eu xtclim: https://github.com/cerfacs-globc/xtclim

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https://rebrand.ly/xtclim-escience