



Centre for Credible
Artificial Intelligence

AutoML, Benchmarking and Open Science
Infrastructure for Earth Observation Workshop

ATLAS: Auditing the Geometry of Geophysical Knowledge in EO Foundation Models

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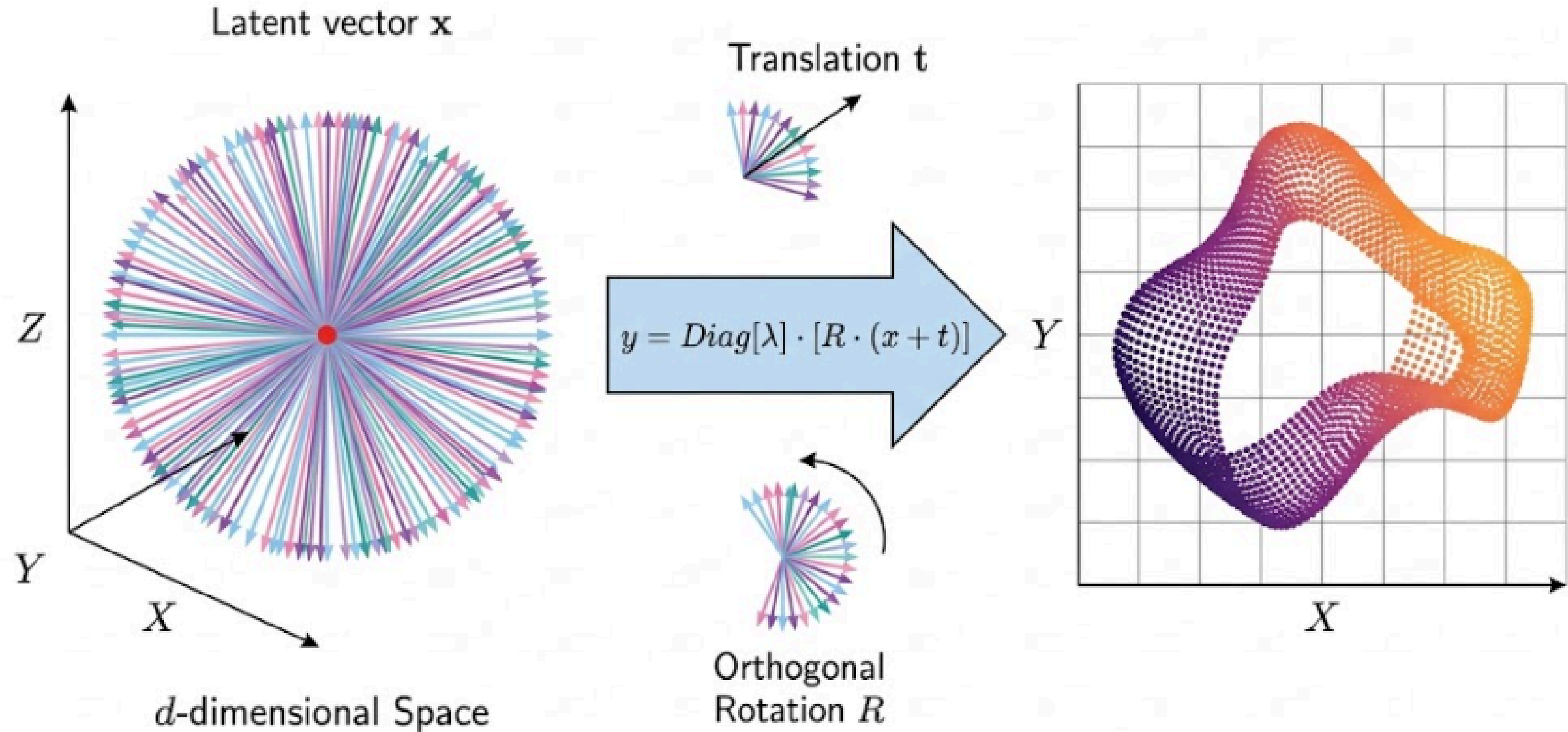
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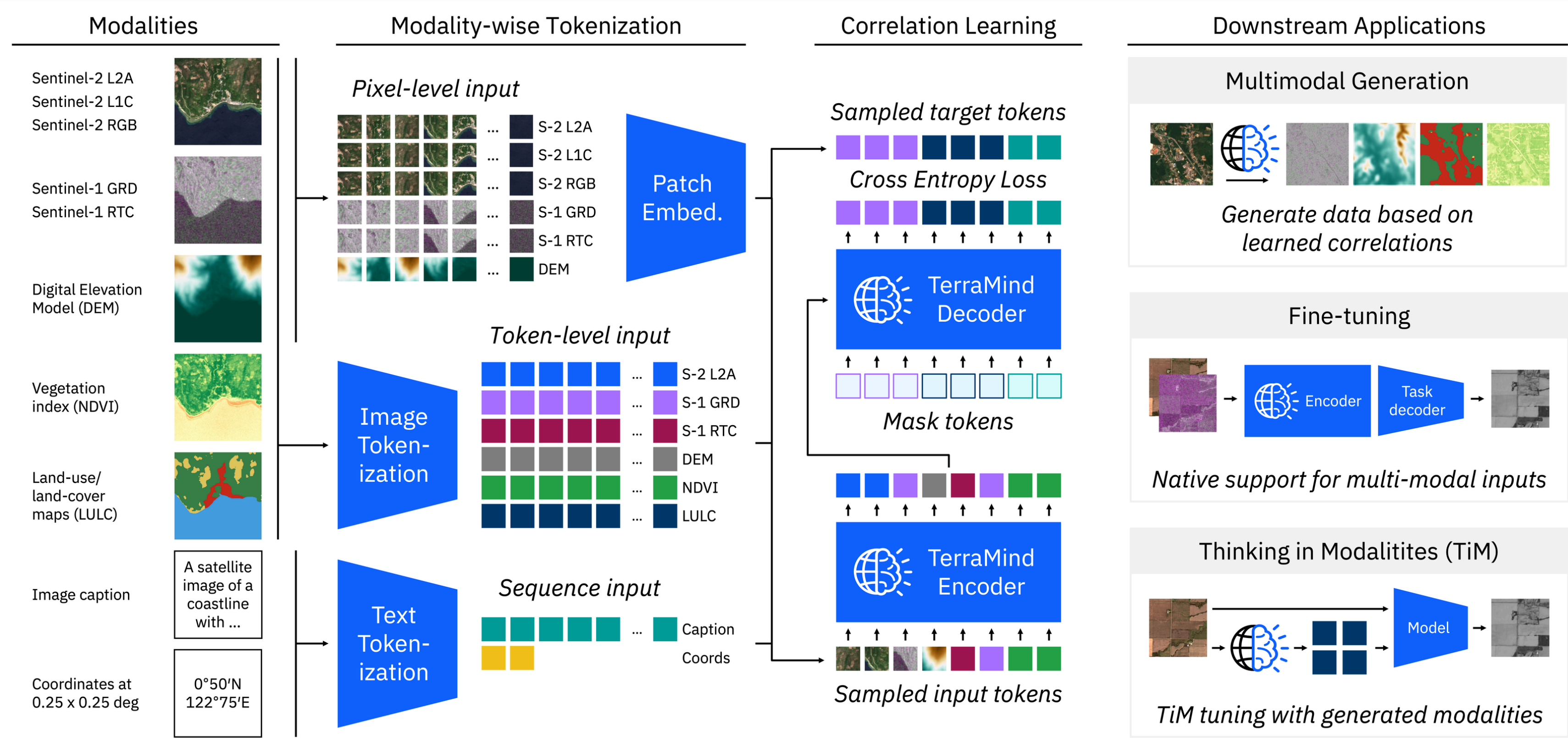
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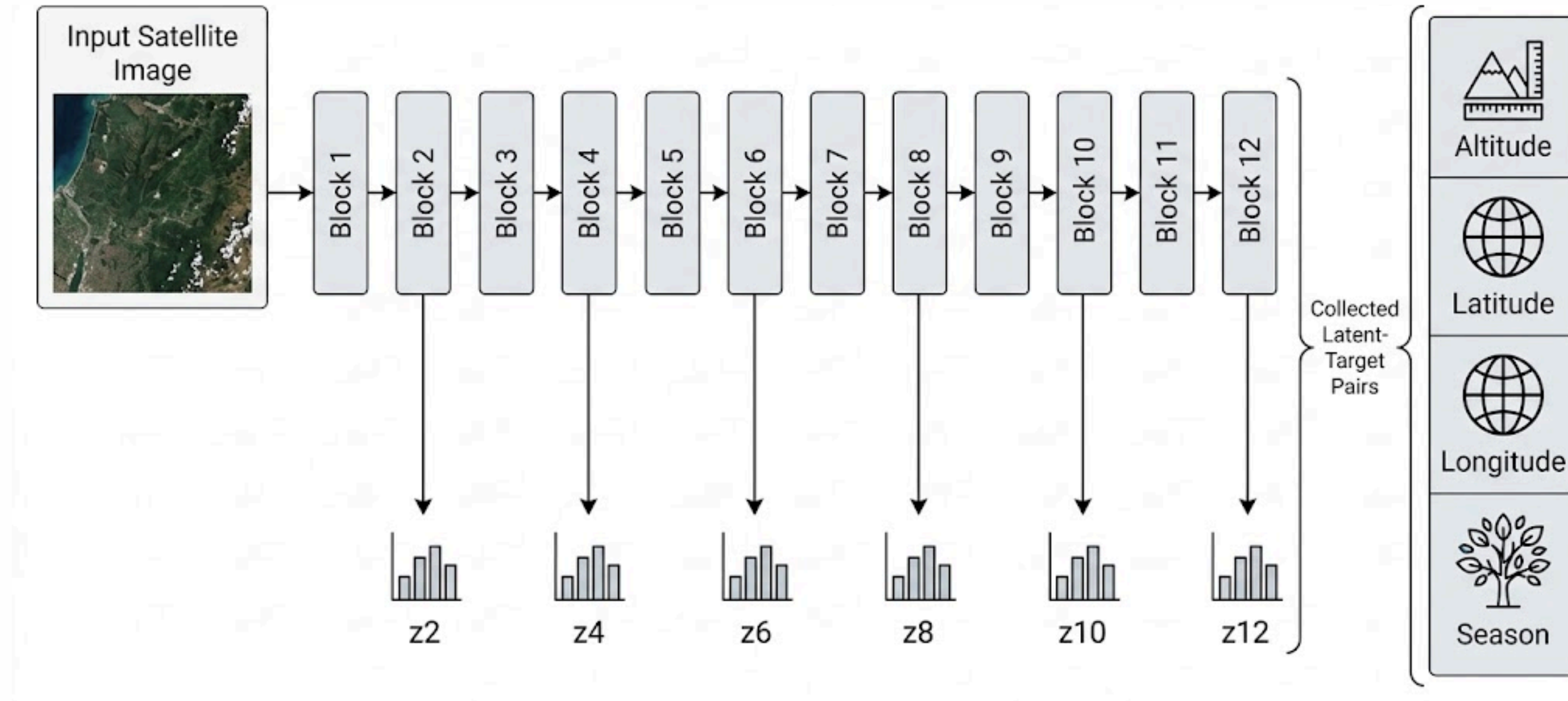
TerraMind Model



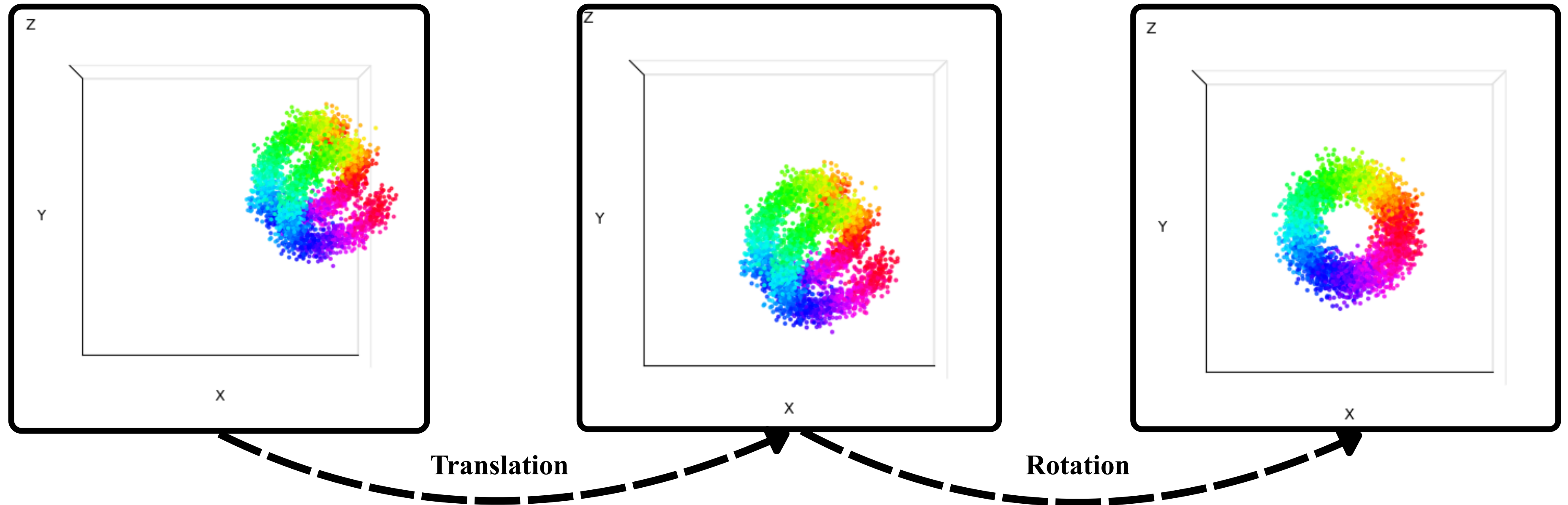
Source: *TerraMind: Large-Scale Generative Multimodality for Earth Observation, Jakubik et. al. 2025*

Experiments on TerraMind model

- We conducted experiments on the smallest available TerraMind model.
- We passed 96000 images from TerraMesh dataset through the model and collected the mean latent representations after even number of encoder blocks (2, 4, 6, 8, 10, 12).
- For each latent vector we saved the information about latitude, longitude, time of the year and altitude.



ATLAS: The Idea



- Interpretable subspace of the latent space
- There is no stretching or warping of the latent space
- We control the dimensionality of our affine chart

ATLAS: Affine Charts of Latent Space

We have a latent vector $\vec{x}$ from the latent space and a feature y f.e. altitude.

Then we train a probe:

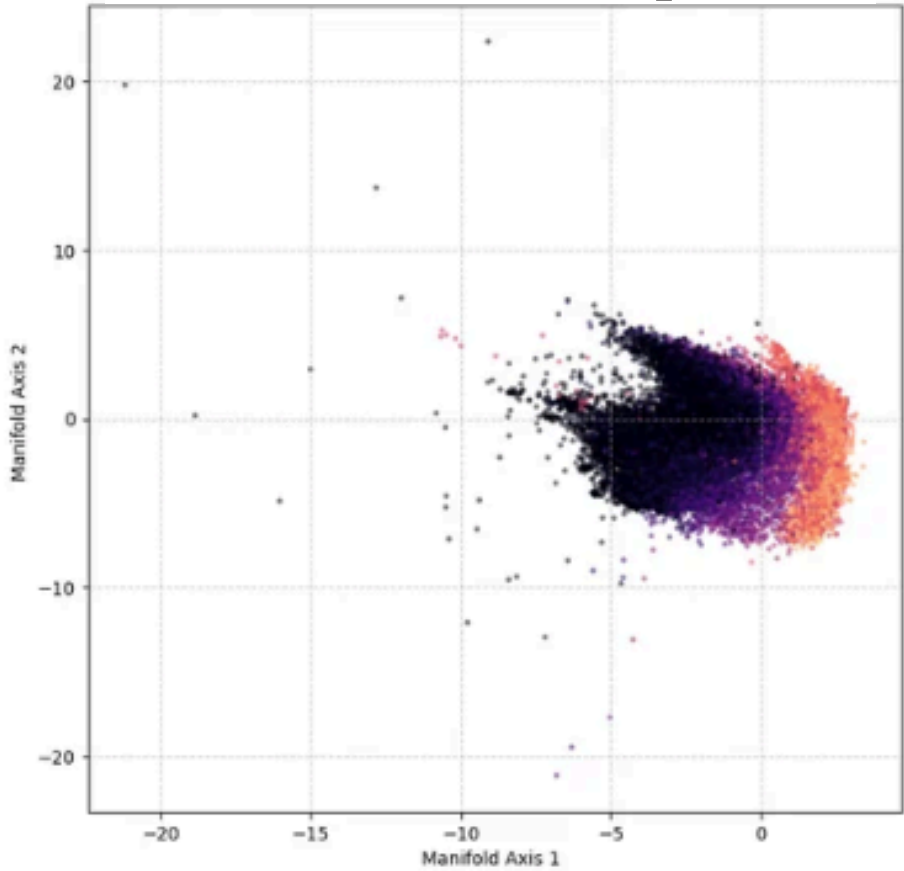
$$\begin{aligned} \text{Translation + Rotation + Projection} \\ \text{ATLAS}(x) = \text{MLP}(\text{Diag}[\vec{\lambda}] \cdot [R \cdot (\vec{x} + \vec{t})]), \quad \vec{\lambda}, \vec{t} \in \mathbb{R}^n, R \in \mathbb{R}^{n \times n} \\ \mathcal{L}(y, \hat{y}, x) = |y - \hat{y}| + \underbrace{\alpha \mathcal{L}_{1,m}(\vec{\lambda})}_{\text{Forces sparsity}} + \underbrace{\beta \|RR^T - I\|_2^2}_{\text{Forces R to be orthogonal}}, \end{aligned}$$

$\mathcal{L}_{1,m}(\vec{\lambda})$ applies L1 regularization on $n - m$ dimensions with currently smallest values.

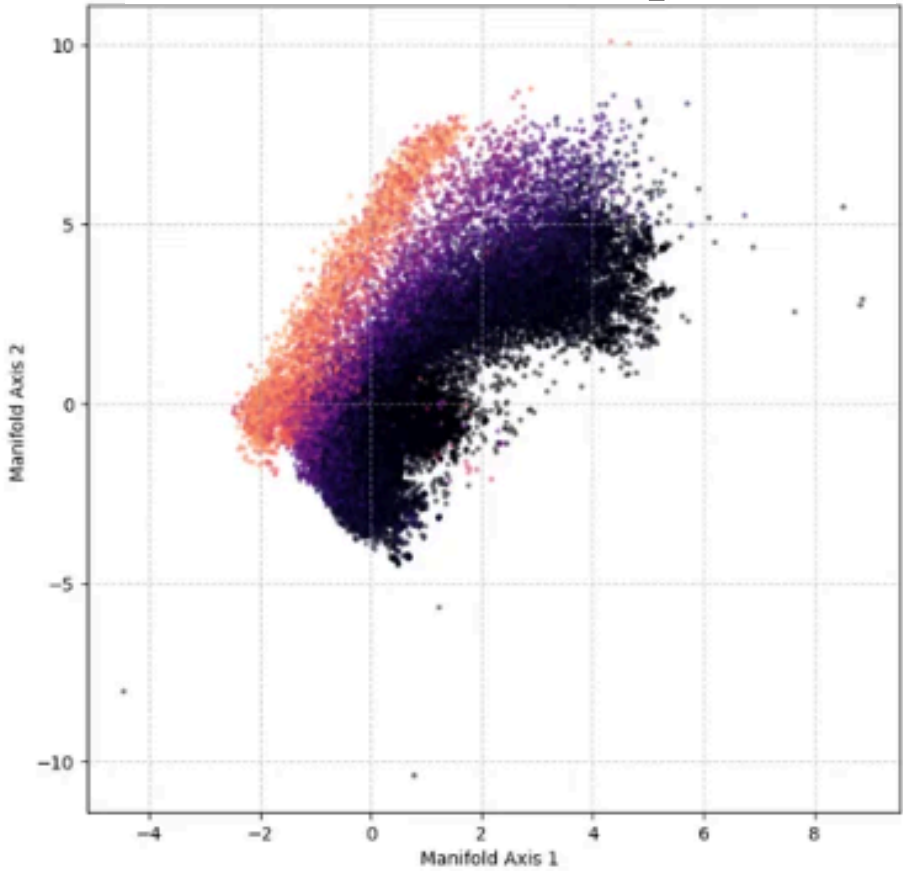
The tuple $(\vec{t}, R, \vec{\lambda})$ defines a projections of latent space into a hyperplane. We can change the dimensionality of that hyperplane with the design of the training.

Extracted Affine Charts for altitude

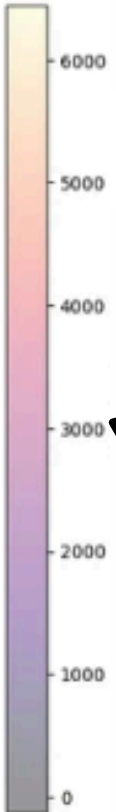
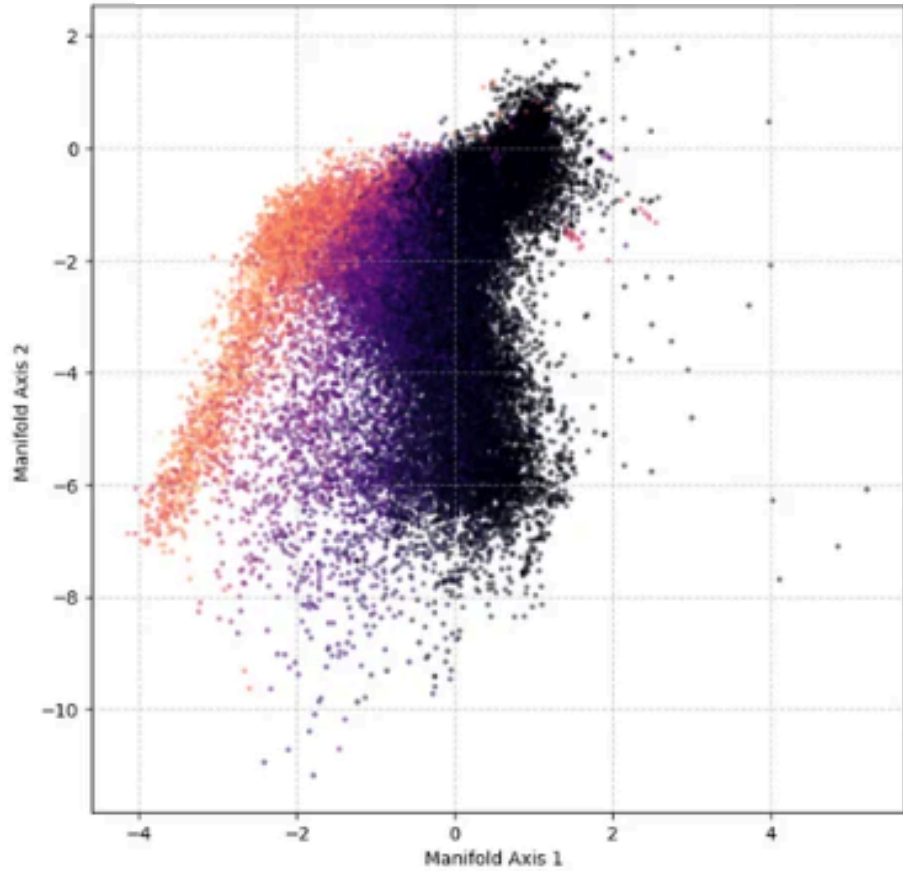
Affine chart at depth 2



Affine chart at depth 4

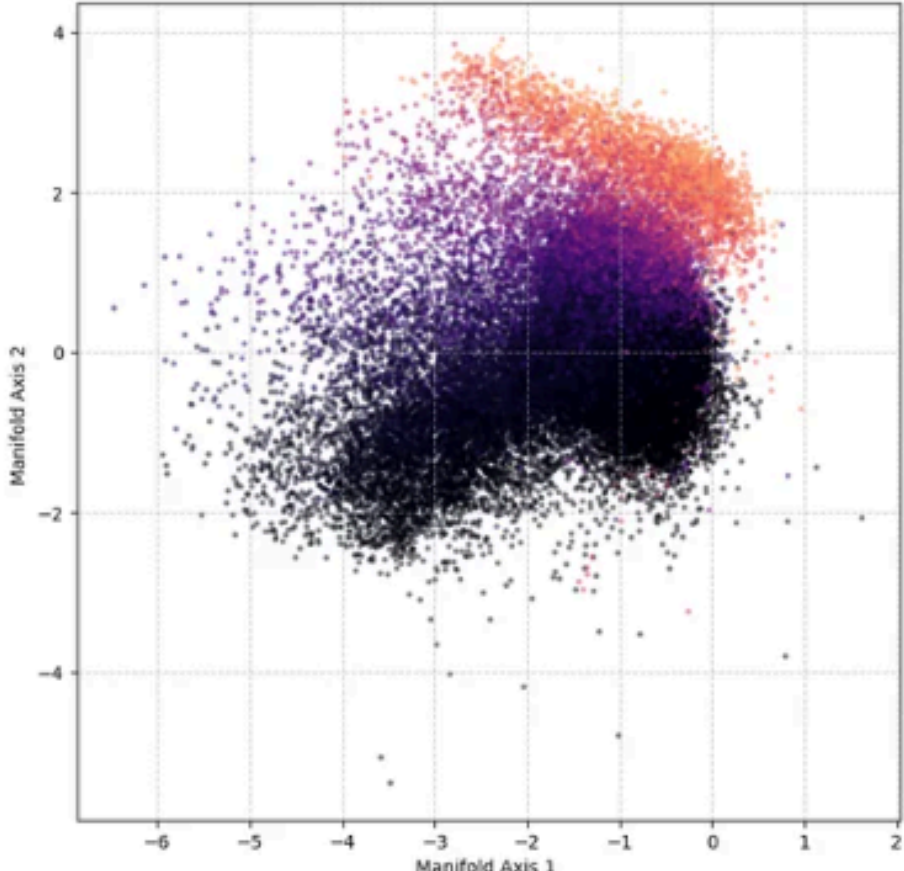


Affine chart at depth 6

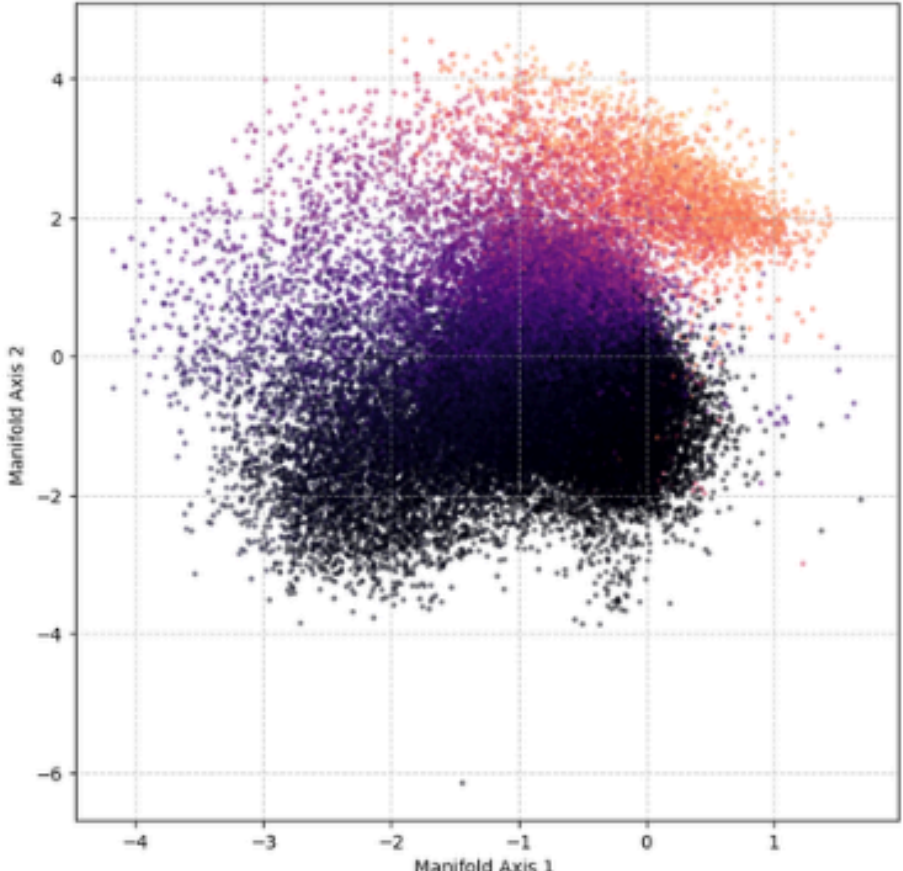


Color represents the average altitude of the satellite photo

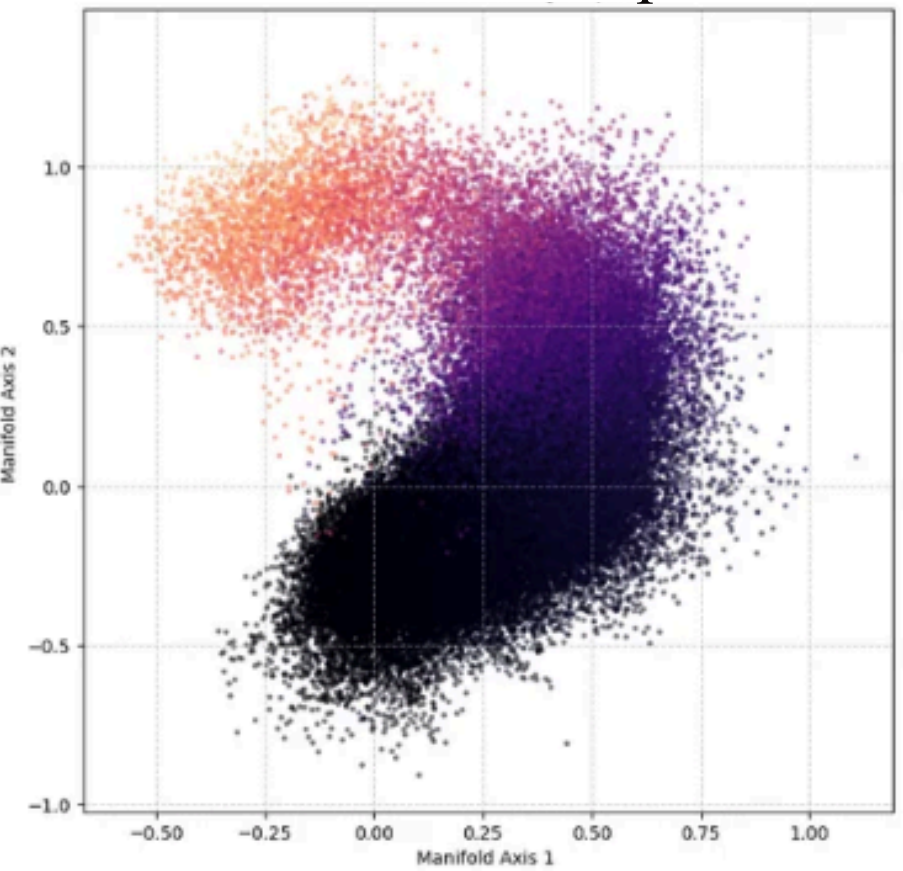
Affine chart at depth 8



Affine chart at depth 10



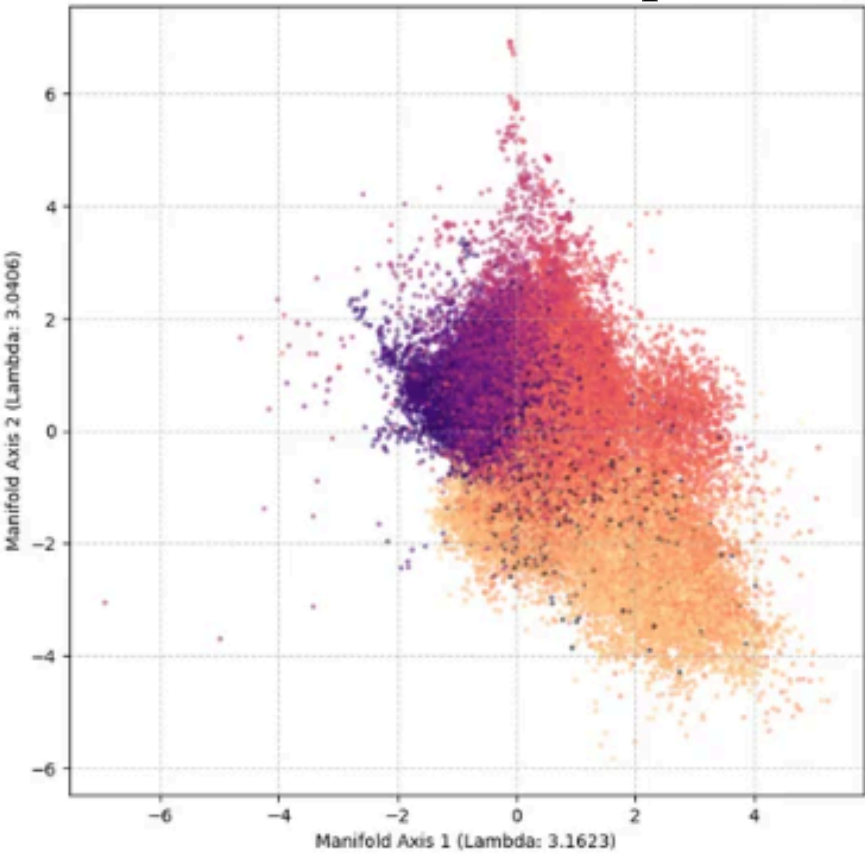
Affine chart at depth 12



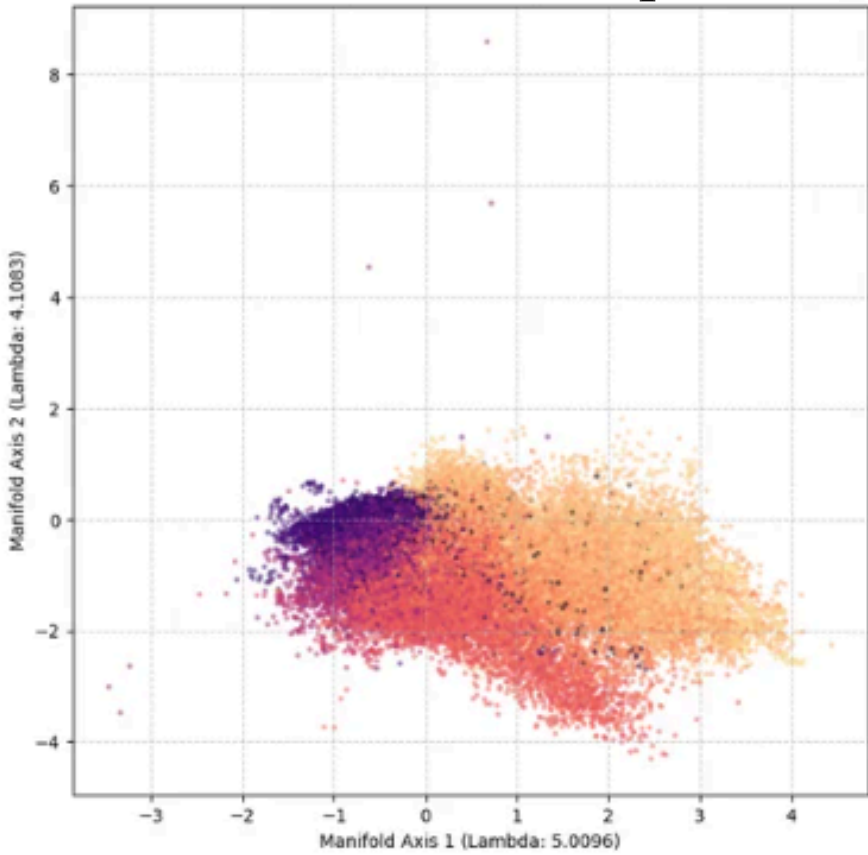
We see the emergent structure of geophysical information

Extracted Affine Charts for latitude

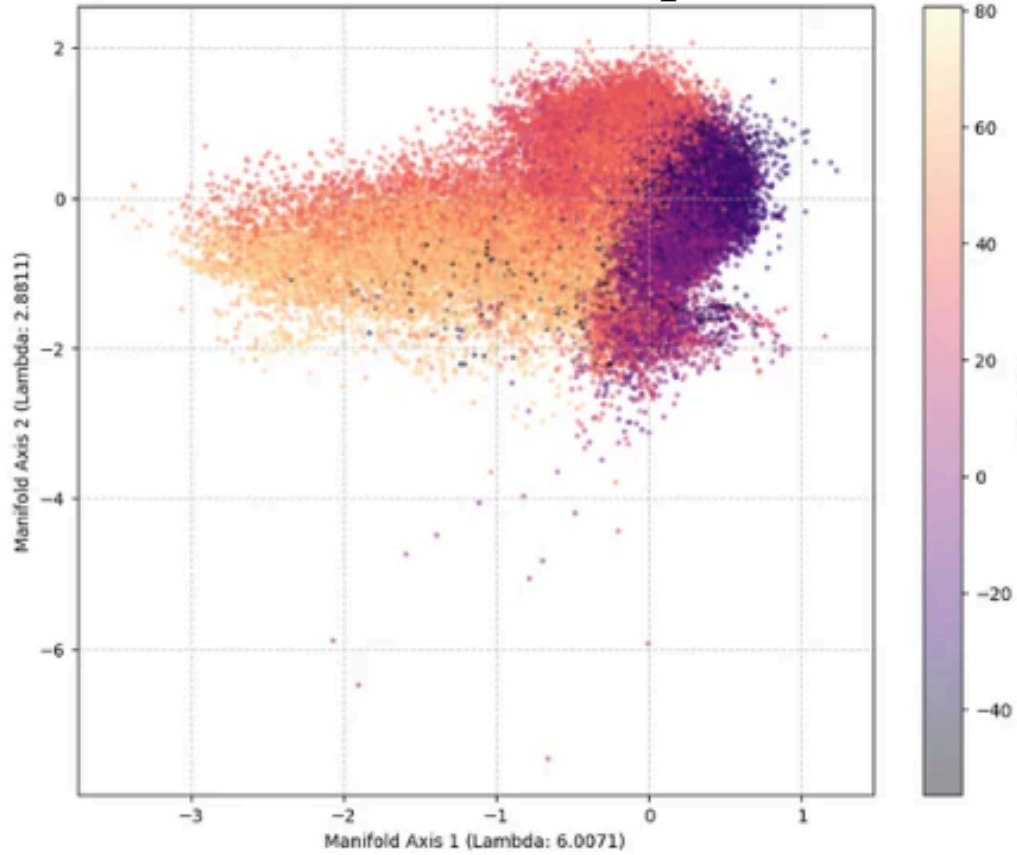
Affine chart at depth 2



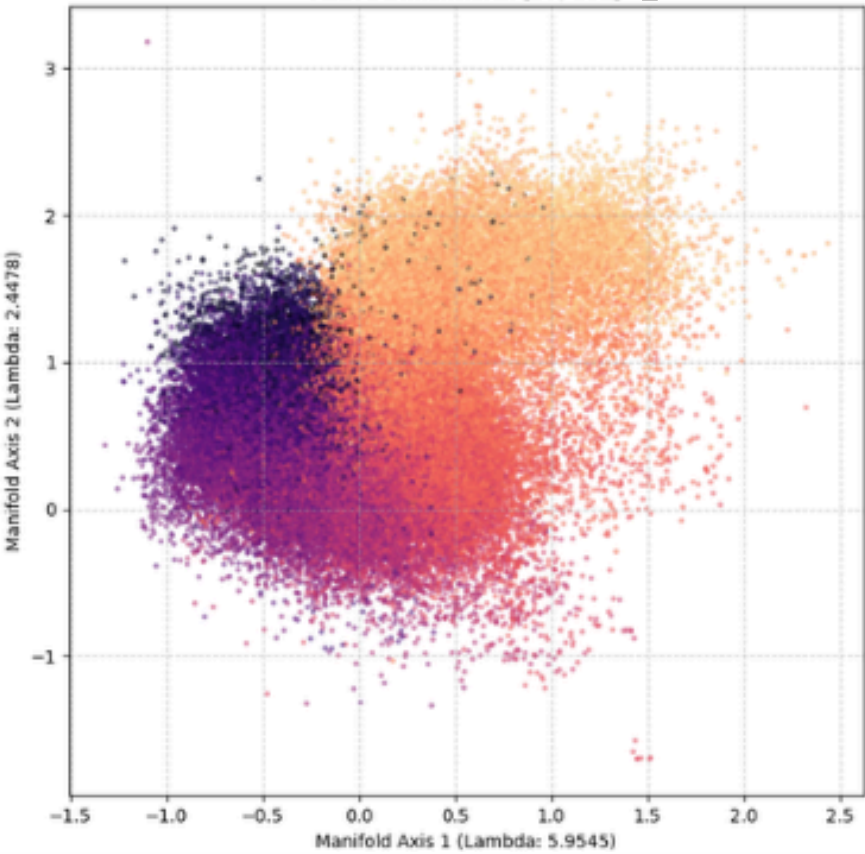
Affine chart at depth 4



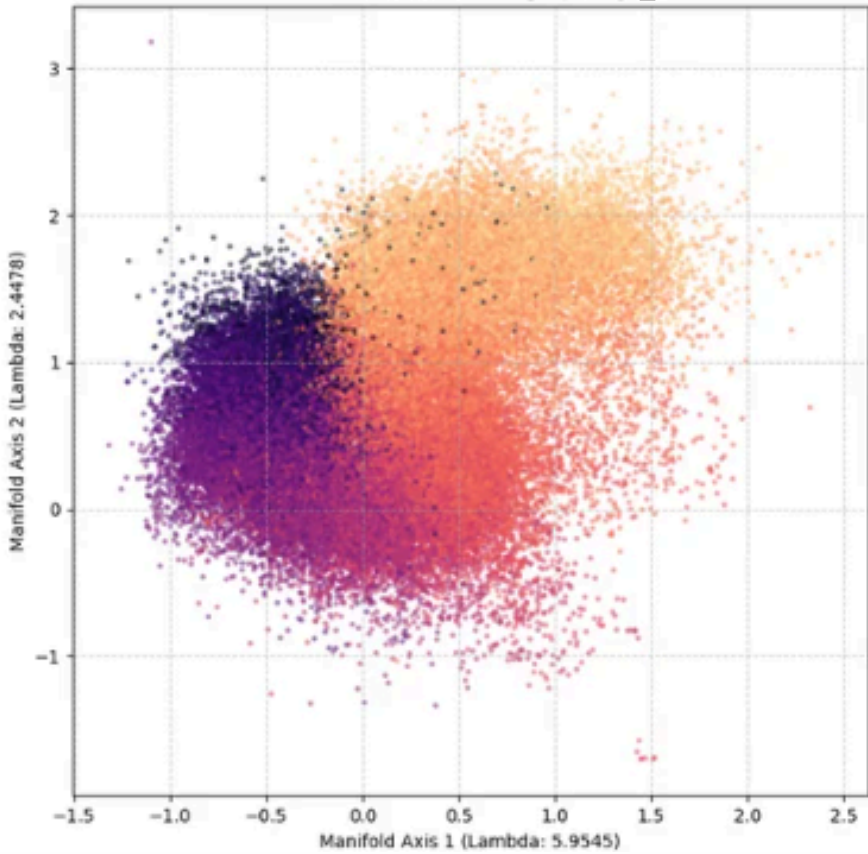
Affine chart at depth 6



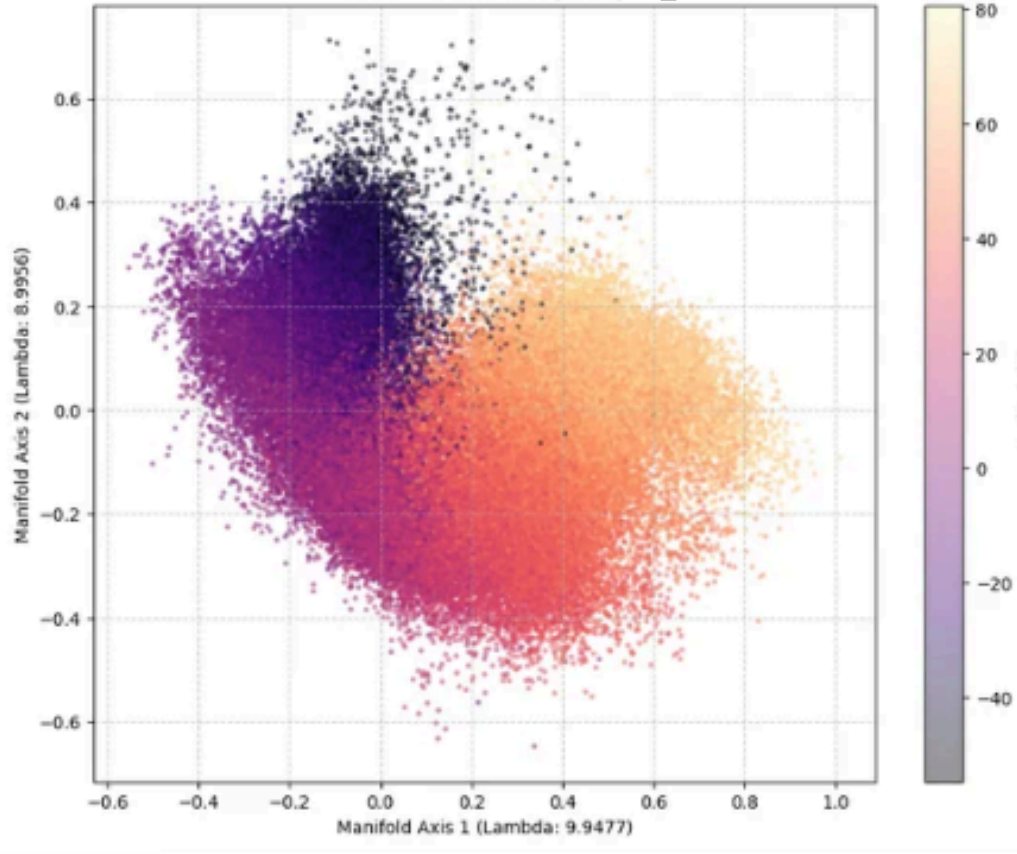
Affine chart at depth 8



Affine chart at depth 10



Affine chart at depth 12

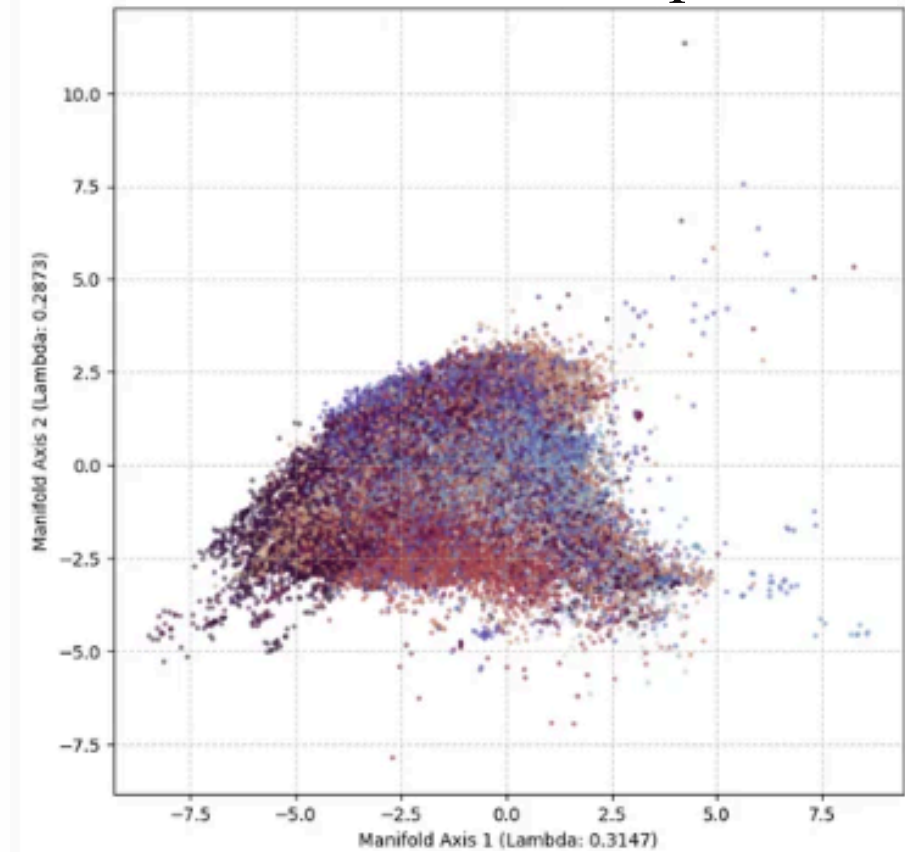


Color represents the
latitude of the satellite
photo

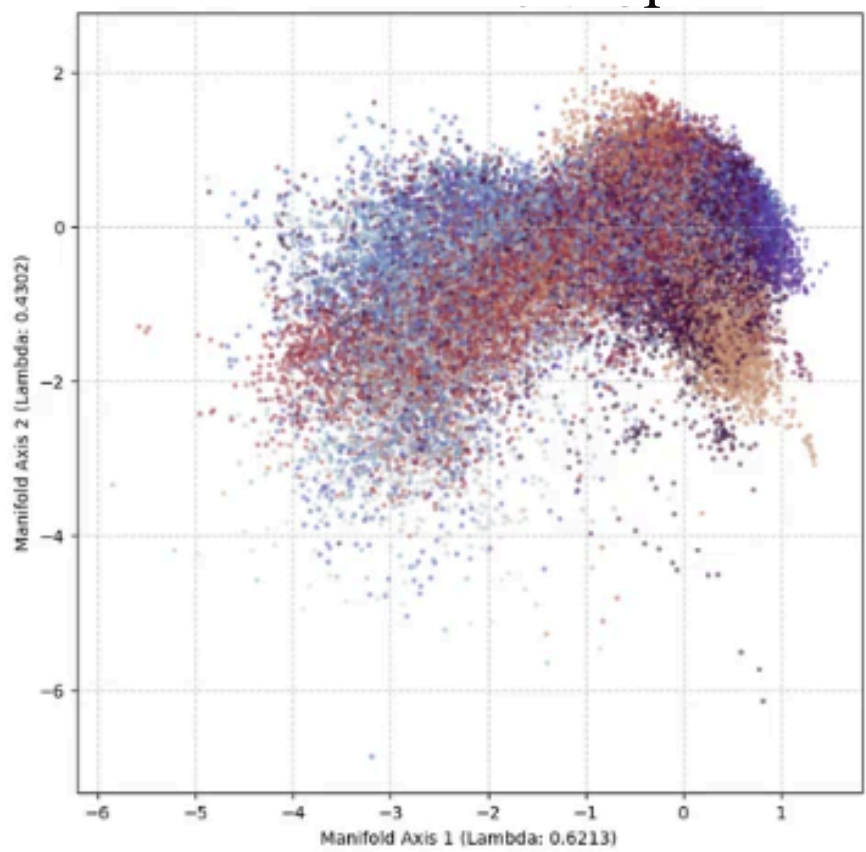
The model separates
southern and
northern subpolar
regions

Extracted Affine Charts for angle-encoded longitude

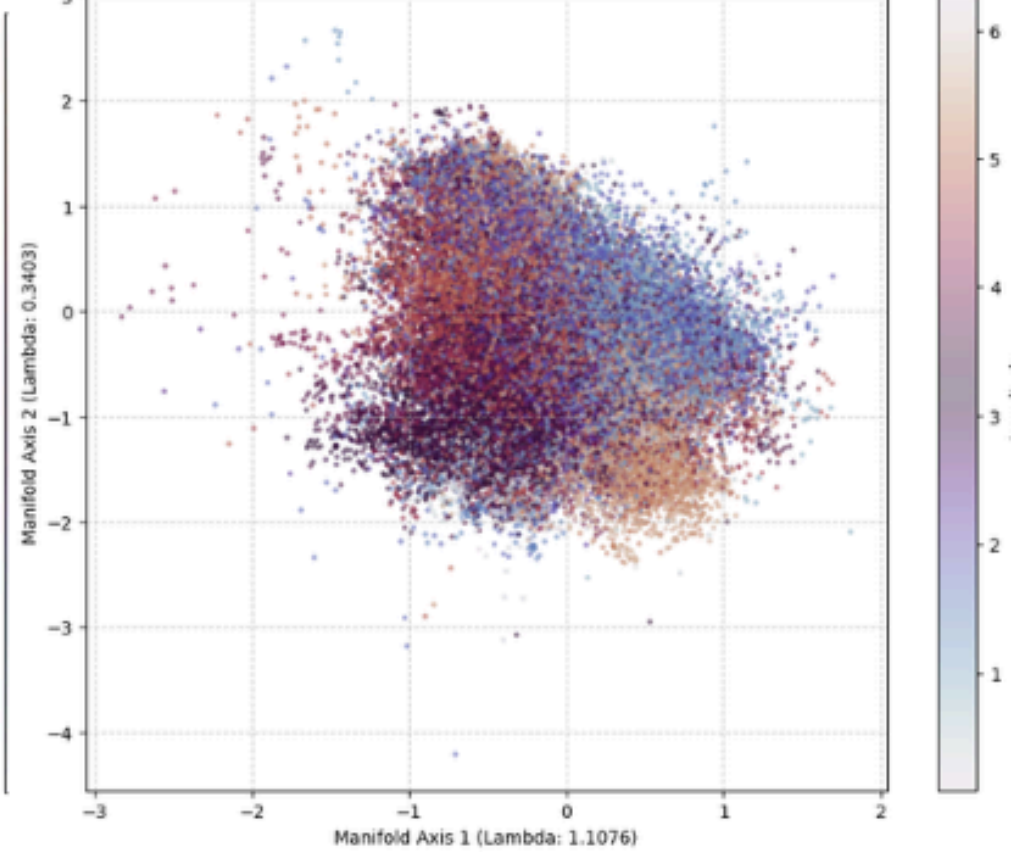
Affine chart at depth 2



Affine chart at depth 4



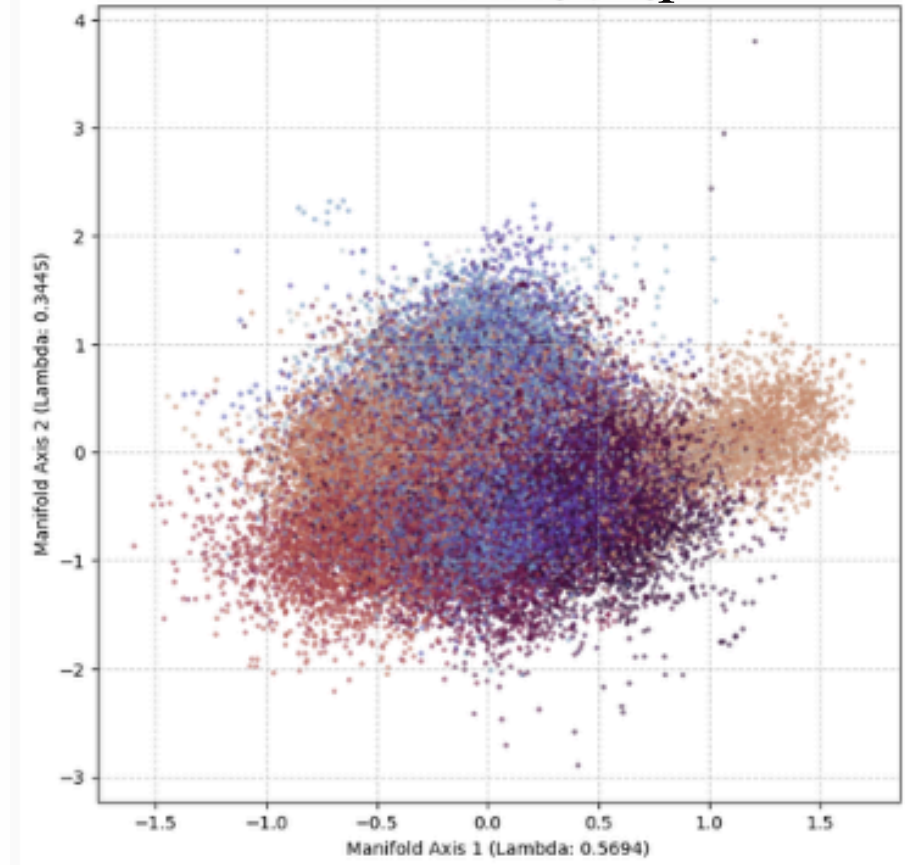
Affine chart at depth 6



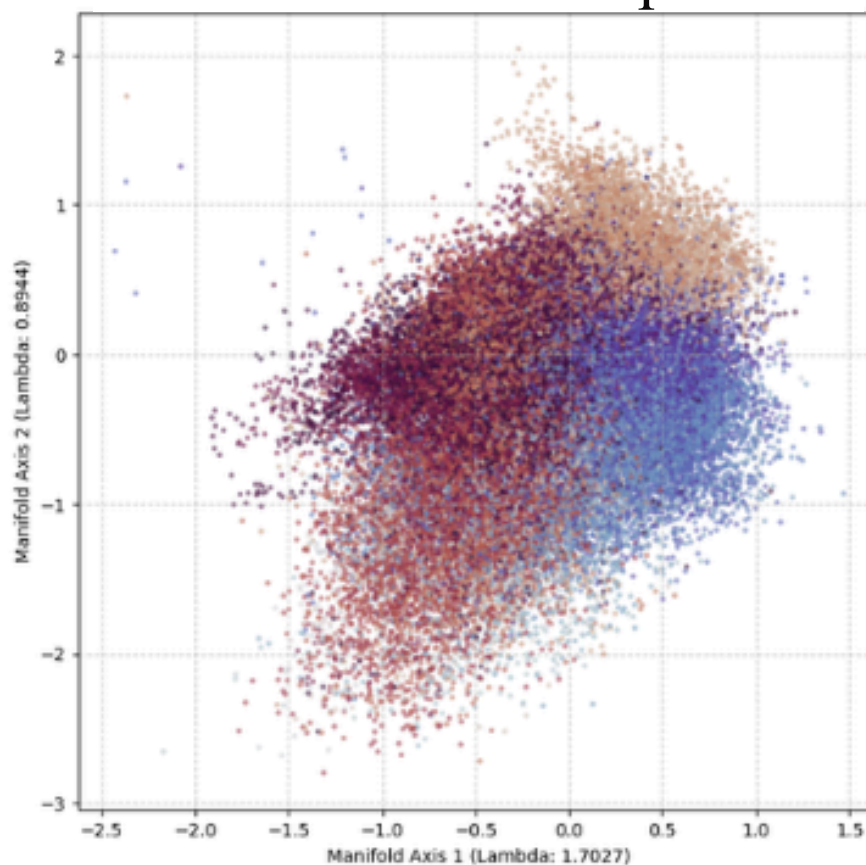
Color represents the longitude of the satellite photo



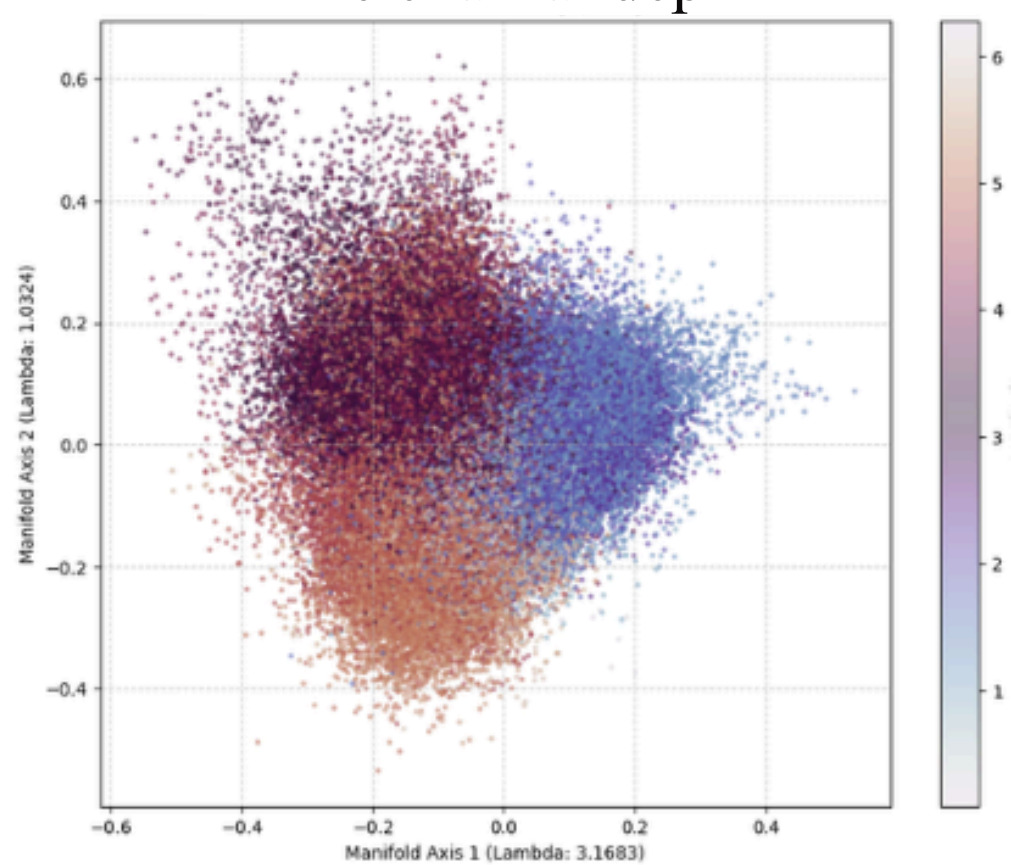
Affine chart at depth 8



Affine chart at depth 10



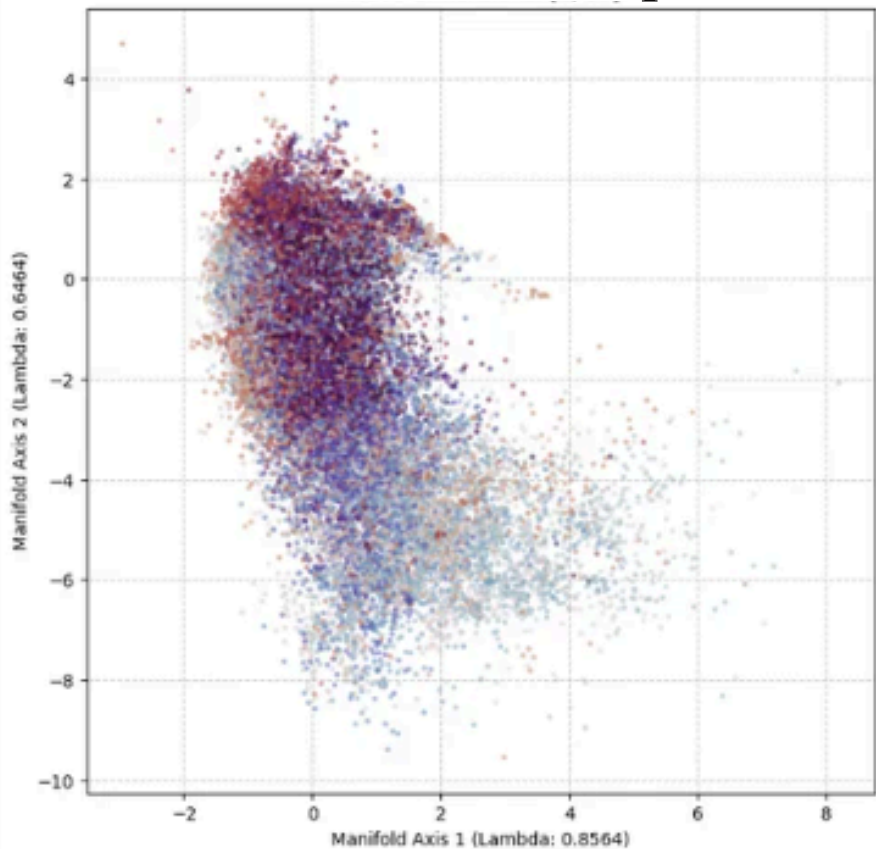
Affine chart at depth 12



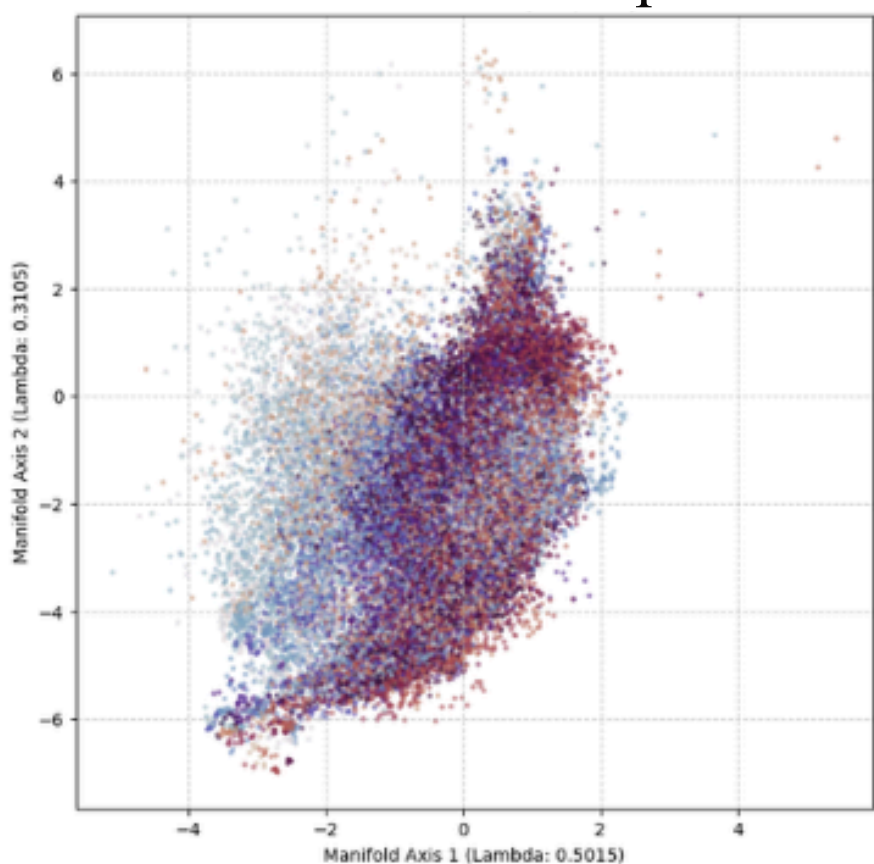
Model organizes the information about longitude into continental clusters

Extracted Affine Charts for angle-encoded season

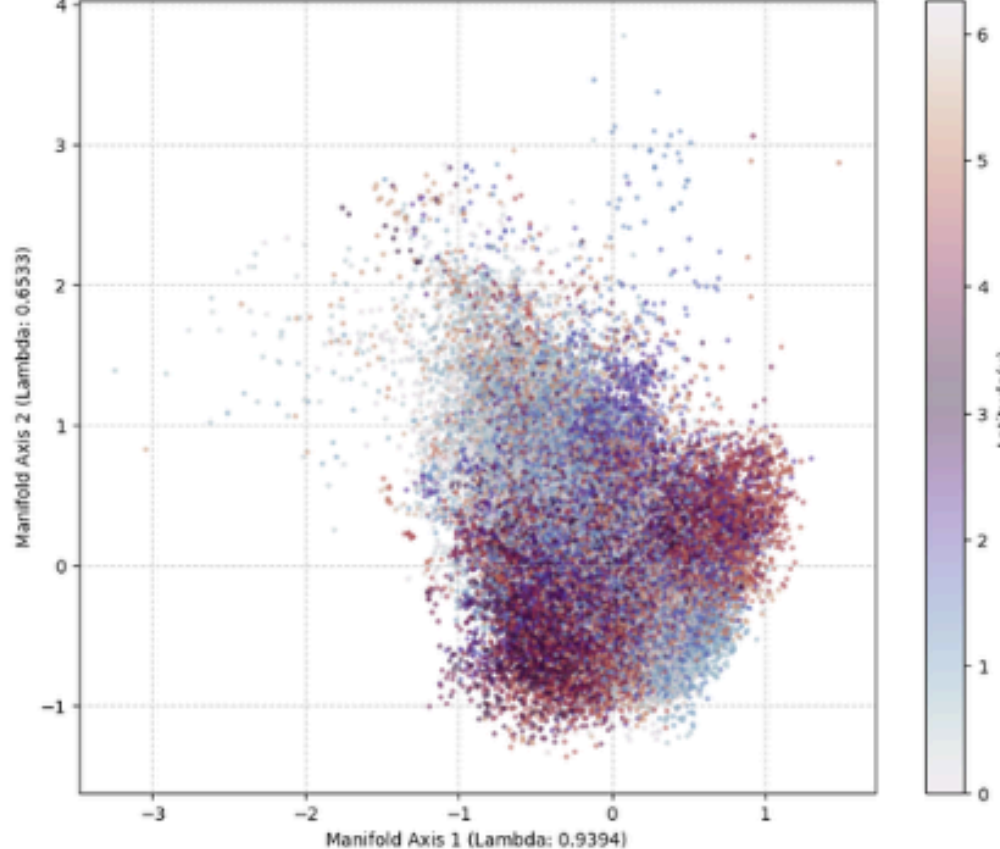
Affine chart at depth 2



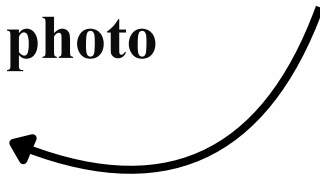
Affine chart at depth 4



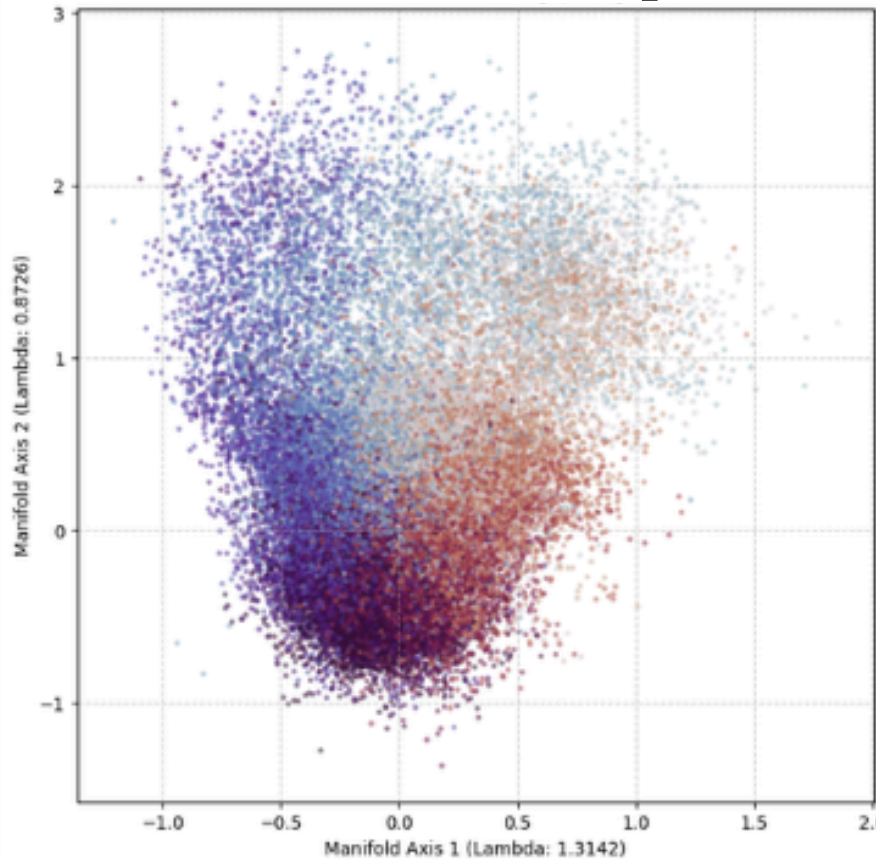
Affine chart at depth 6



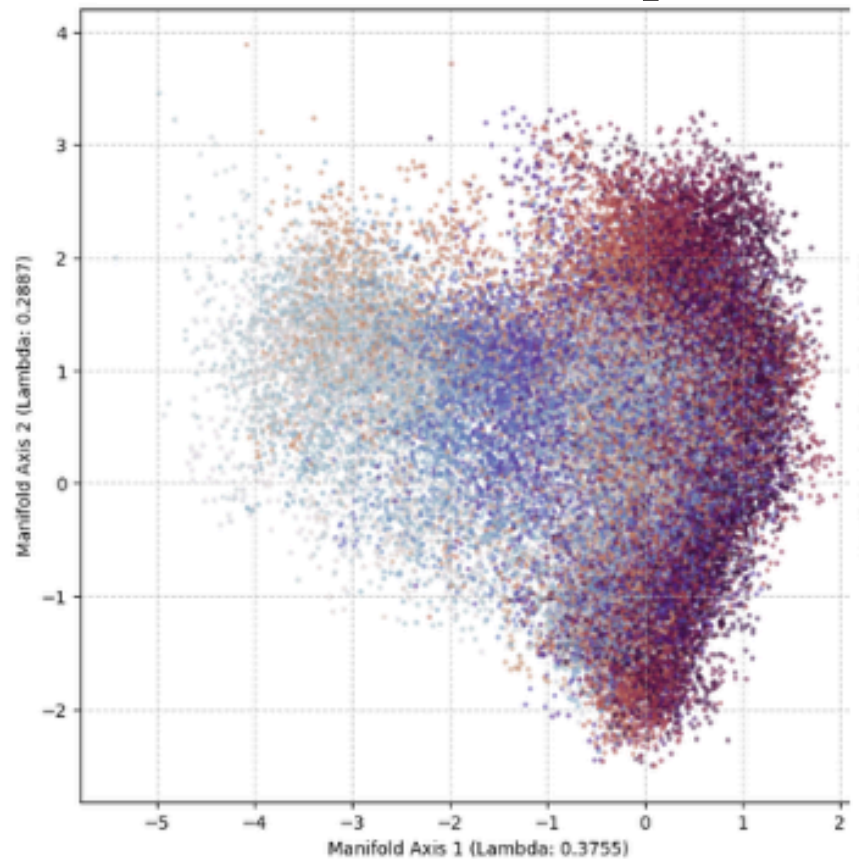
Color represents the
angle-encoded season
progression of the satellite
photo



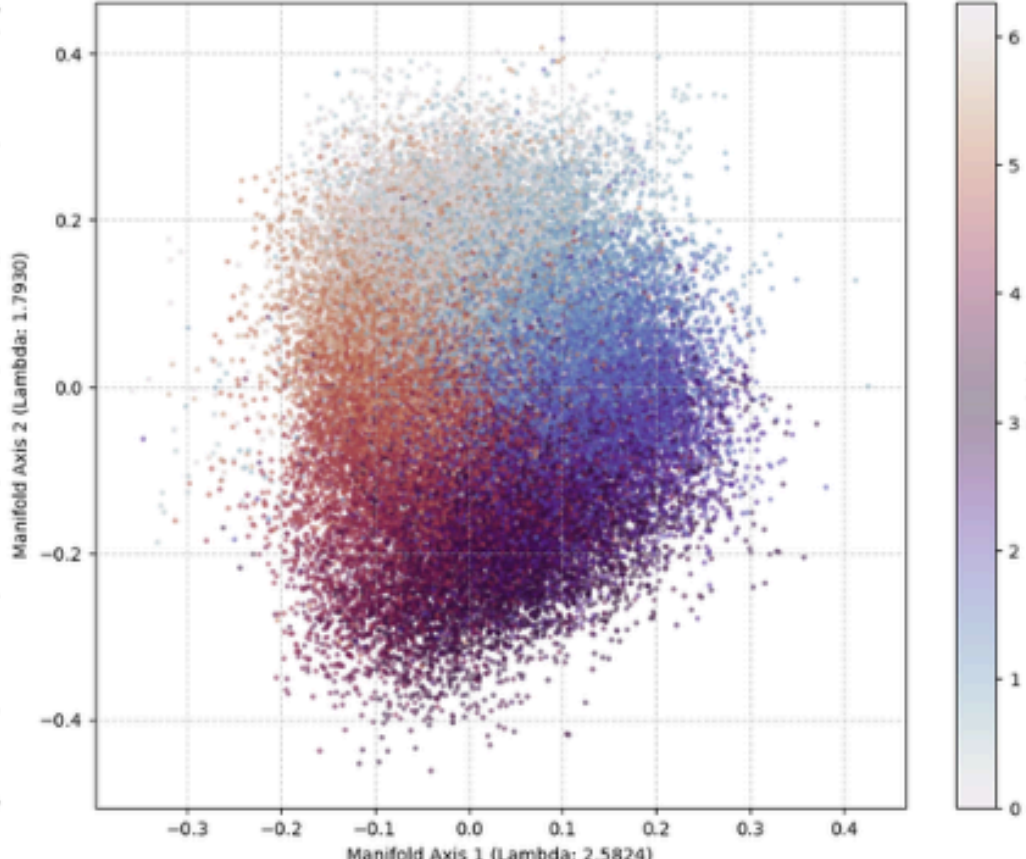
Affine chart at depth 8



Affine chart at depth 10



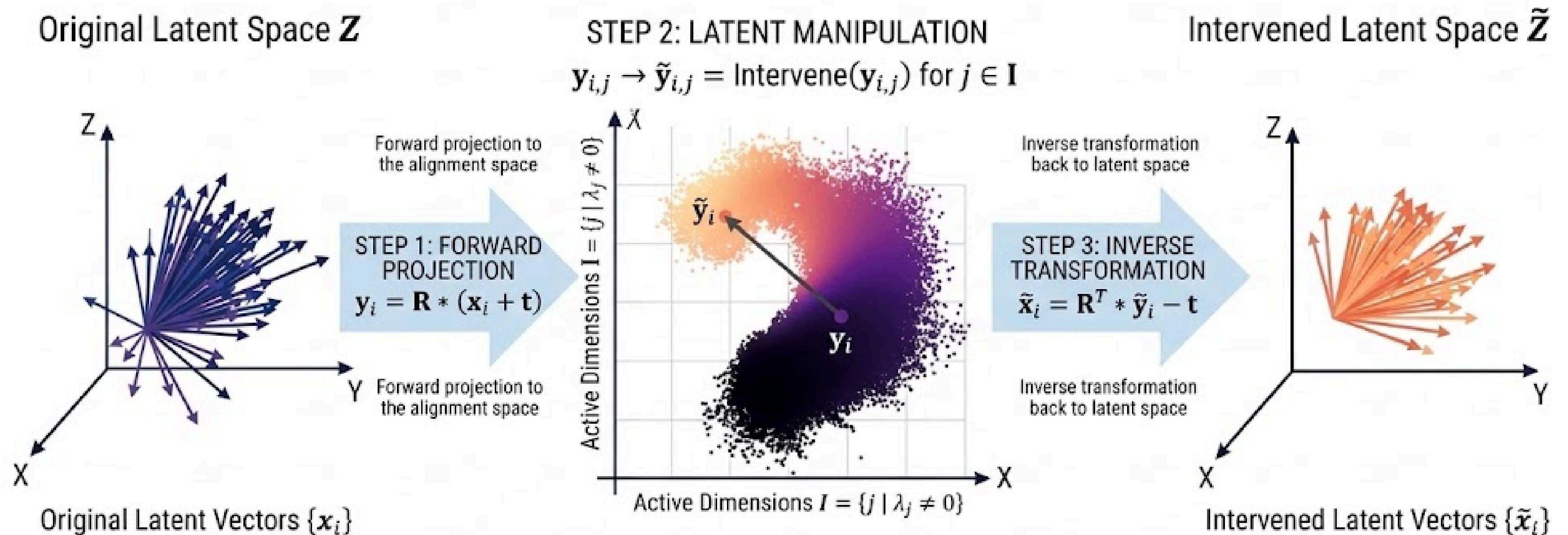
Affine chart at depth 12



Model learns to
represent information
about seasons in a
periodic fashion

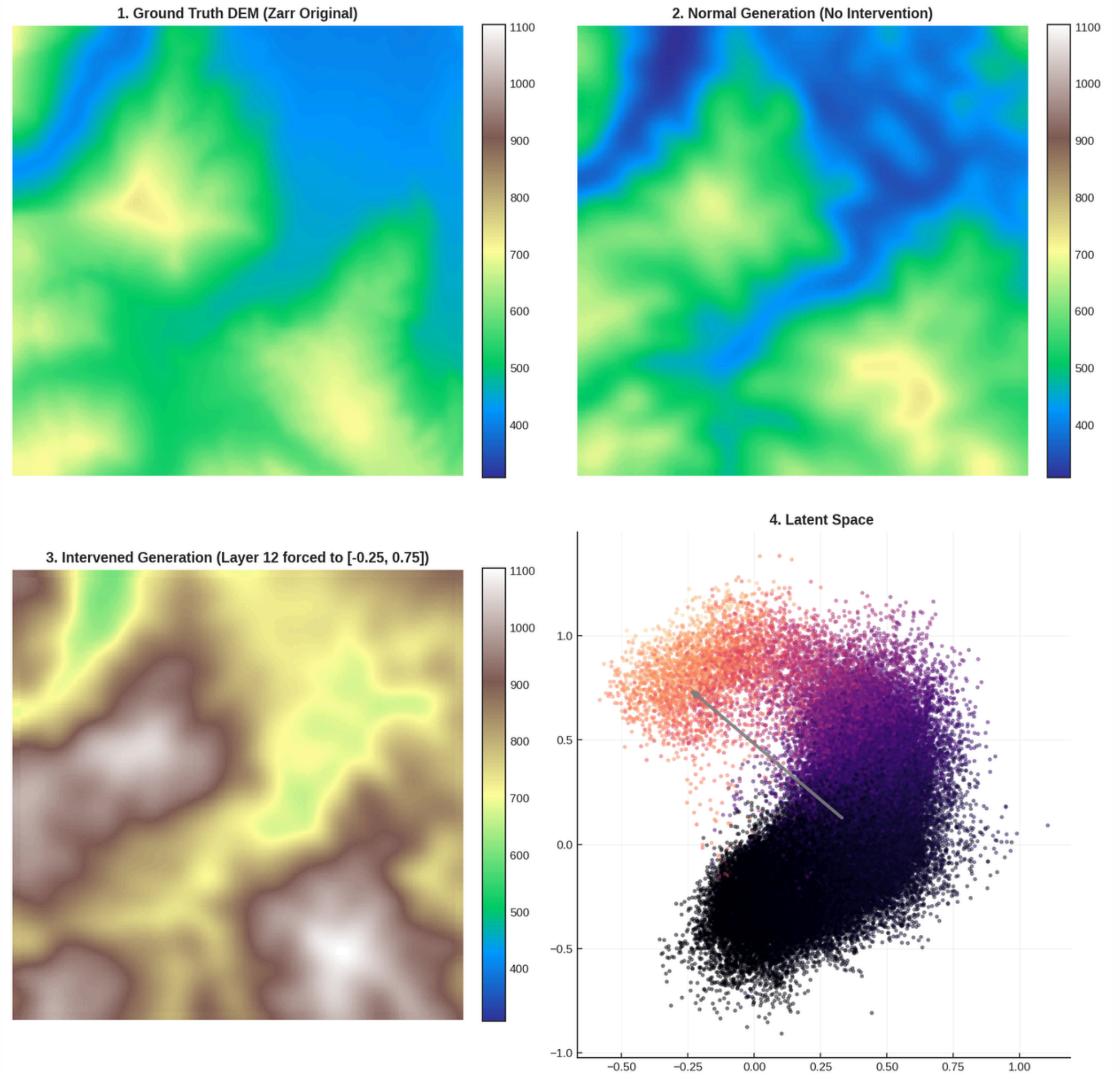
Intervention in latent space

Initial geometric transformation in ATLAS is invertible by design. This allow for a simple intervention procedure.



Intervention in latent space

- Human-guided intervention on the affine chart
- The resulted heightmap generated by the model is consistently higher
- The shape of the terrain remains similar





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QR to GitHub



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