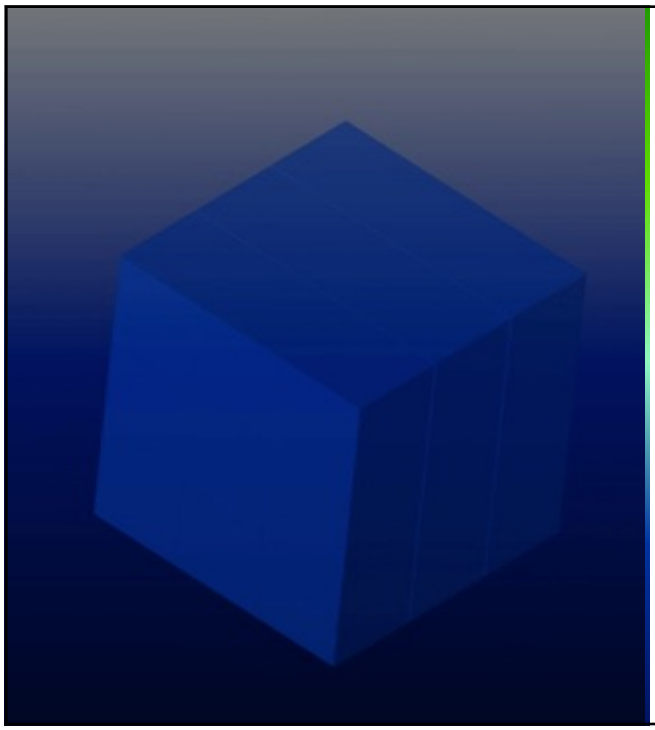


Leveraging Multi-Dimensional Data

Advancing Stormwater Analyses

Luke Villanueva, PE

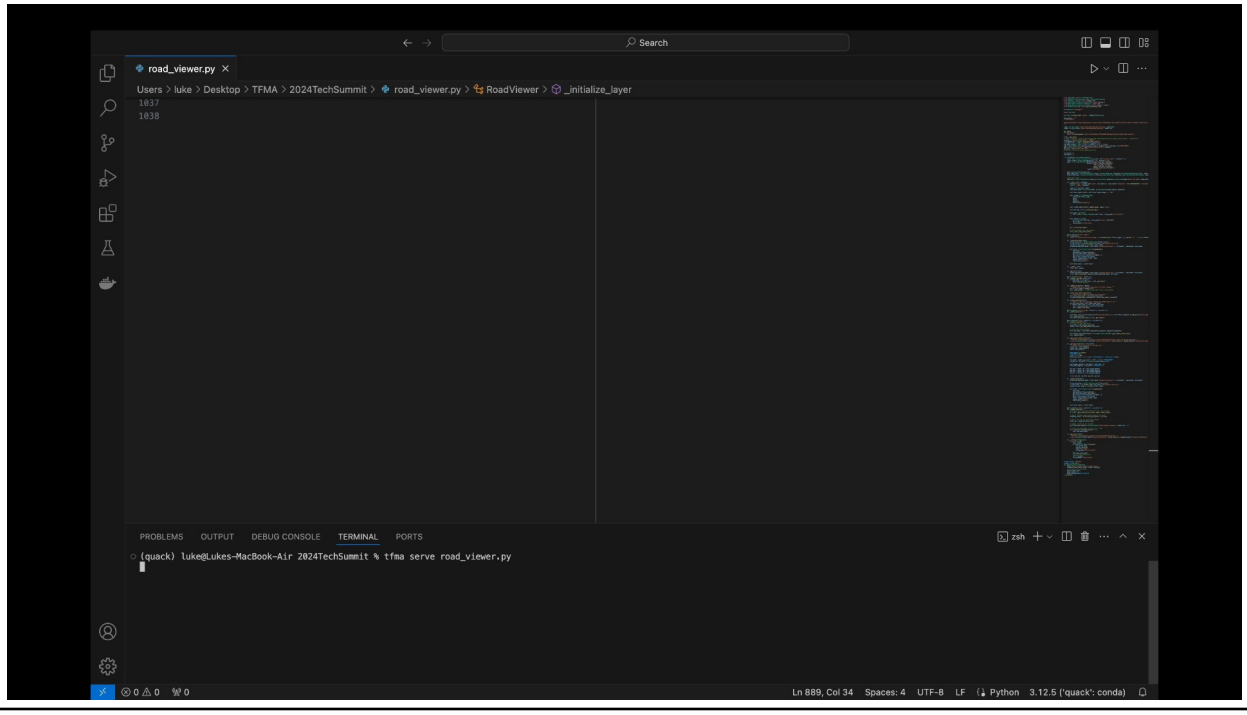
Outline

+ Motivation
+ Tech Summit Recap
+ Multi-Dimensional Thinking
+ Applications
+ What's Next
+ Questions

Motivation

+ Industry awareness
+ Advances in architecture and ecosystem
+ Larger models

2024 Tech Summit Recap



HEC-RAS HDF Output Frequency Analysis

Client

Client-66a0eb95-2afc-11ee-b5e5-00155d22ee78

Connection method: Cluster object **Cluster type:** distributed.LocalCluster

Dashboard: http://127.0.0.1:45217/status

▸ Cluster Info

Extract data from HDF files to Parquet

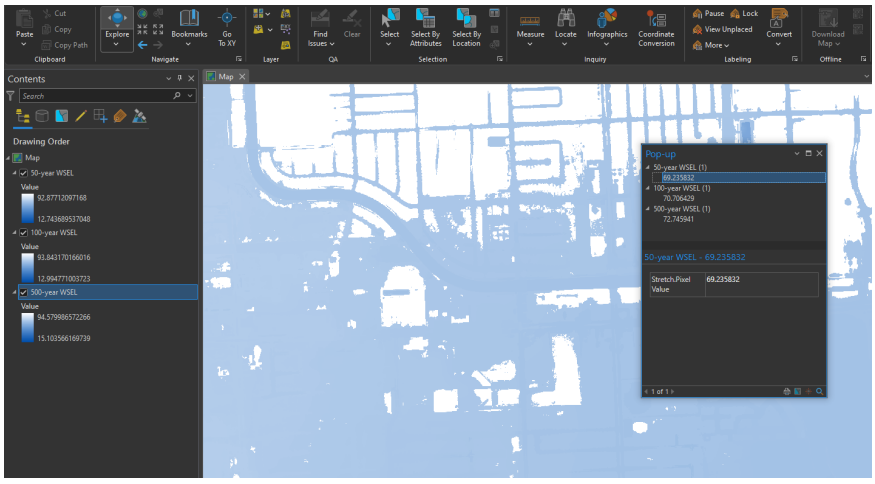
100%|| 96/96 [00:25<00:00, 3.79it/s]

Extracted data

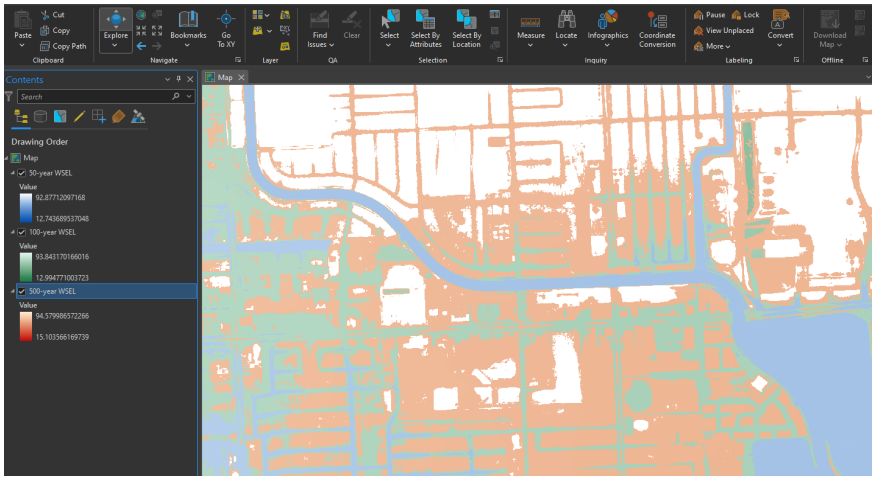
	x	y	wsel_max	wsel_min
0	1.085386e+06	1.928431e+06	87.012085	87.012085
1	1.085486e+06	1.928431e+06	85.290344	85.290344
2	1.085586e+06	1.928431e+06	84.875061	84.875061
3	1.085186e+06	1.928331e+06	87.055847	87.055847
4	1.085286e+06	1.928331e+06	86.137634	86.137634
...	...	...	...	...
85192	1.106179e+06	1.913128e+06	67.521000	67.521000
85193	1.084537e+06	1.908434e+06	73.996460	73.996460
85194	1.084885e+06	1.905620e+06	69.905029	69.905029

Multi-Dimensional Thinking

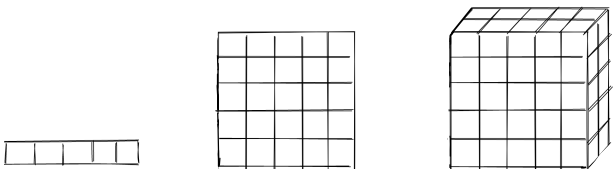
Common Practice



Common Practice



Array/Tensor Review



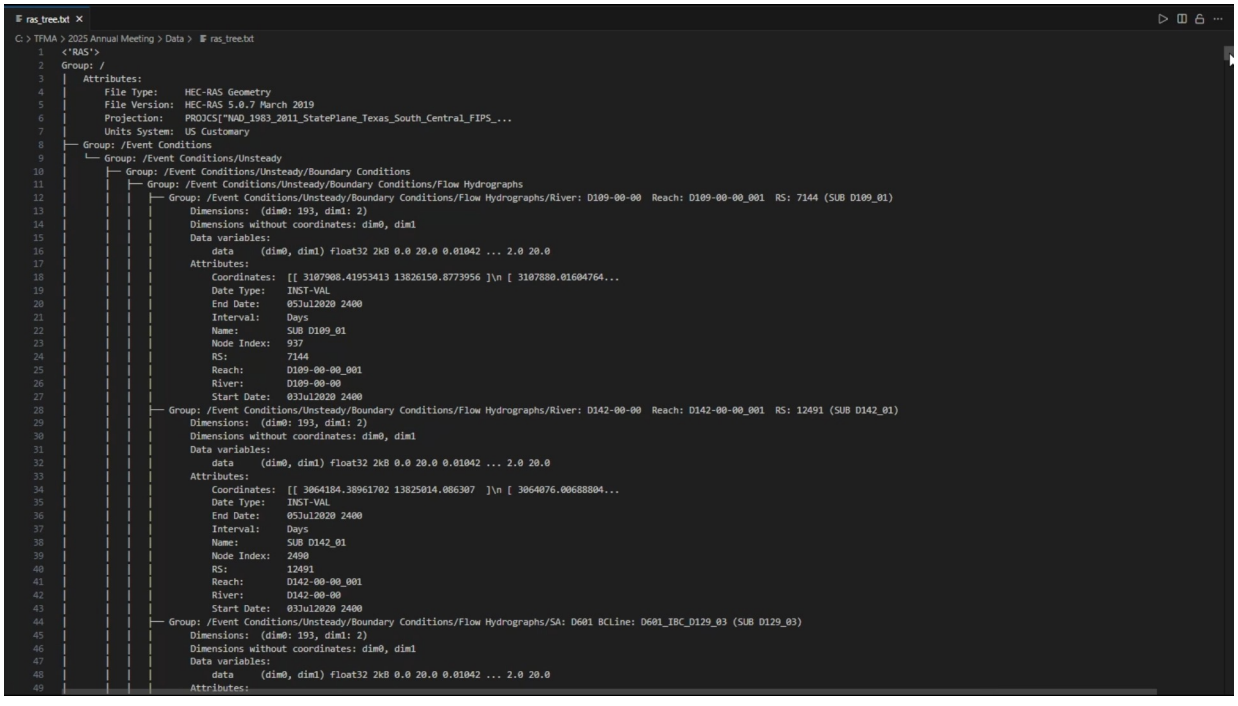
1D
5 elements

2D
5x5 elements

3D
5x5x2 elements

Common Multi-Dimensional Formats

+ GRIB
+ HDF
+ NetCDF
+ Zarr



```
ras_tree.txt
C: > TFMA > 2025 Annual Meeting > Data > ras_tree.txt
<'RAS'>
Group: /
|   Attributes:
|       File Type:     HEC-RAS Geometry
|       File Version:  HEC-RAS 5.0.7 March 2019
|       Projection:    PROJCS["NAD_1983_2011_StatePlane_Texas_South_Central_FIPS_...
|       Units System:  US Customary
├── Group: /Event Conditions
|   └── Group: /Event Conditions/Unsteady
|       ├── Group: /Event Conditions/Unsteady/Boundary Conditions
|       |   ├── Group: /Event Conditions/Unsteady/Boundary Conditions/Flow Hydrographs
|       |   |   ├── Group: /Event Conditions/Unsteady/Boundary Conditions/Flow Hydrographs/River: D109-00-00  Reach: D109-00-00_001  RS: 7144 (SUB D109_01)
|       |   |   |       Dimensions:  (dim0: 193, dim1: 2)
|       |   |   |       Dimensions without coordinates: dim0, dim1
|       |   |   |       Data variables:
|       |   |   |           data     (dim0, dim1) float32 2kB 0.0 20.0 0.01042 ... 2.0 20.0
|       |   |   |       Attributes:
|       |   |   |           Coordinates:  [[ 3107908.41953413 13826150.8773956 ]\n [ 3107880.01604764...
|       |   |   |           Date Type:    INST-VAL
|       |   |   |           End Date:     05Jul2020 2400
|       |   |   |           Interval:     Days
|       |   |   |           Name:         SUB D109_01
|       |   |   |           Node Index:   937
|       |   |   |           RS:           7144
|       |   |   |           Reach:        D109-00-00_001
|       |   |   |           River:        D109-00-00
|       |   |   |           Start Date:   03Jul2020 2400
|       |   |   ├── Group: /Event Conditions/Unsteady/Boundary Conditions/Flow Hydrographs/River: D142-00-00  Reach: D142-00-00_001  RS: 12491 (SUB D142_01)
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|       |   |   |       Dimensions without coordinates: dim0, dim1
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|       |   |   |       Attributes:
|       |   |   |           Coordinates:  [[ 3064184.38961702 13825014.086307  ]\n [ 3064076.00688804...
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|       |   |   |           End Date:     05Jul2020 2400
|       |   |   |           Interval:     Days
|       |   |   |           Name:         SUB D142_01
|       |   |   |           Node Index:   2490
|       |   |   |           RS:           12491
|       |   |   |           Reach:        D142-00-00_001
|       |   |   |           River:        D142-00-00
|       |   |   |           Start Date:   03Jul2020 2400
|       |   |   ├── Group: /Event Conditions/Unsteady/Boundary Conditions/Flow Hydrographs/SA: D601 BCLine: D601_IBC_D129_03 (SUB D129_03)
|       |   |   |       Dimensions:  (dim0: 193, dim1: 2)
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|       |   |   |       Attributes:
```
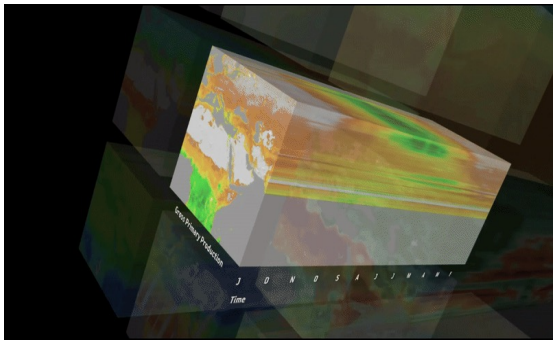

Common Multi-Dimensional Formats

+ GRIB
+ HDF
+ NetCDF
+ Zarr

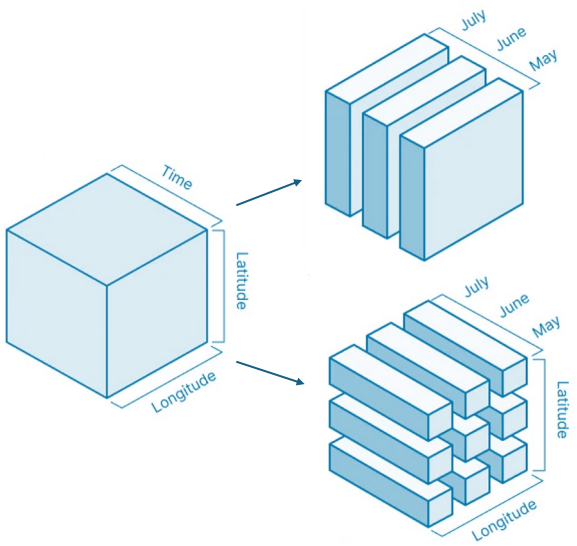
Data Cubes

+ Spatiotemporal Grid
+ Analysis-ready
+ Extremely Scalable



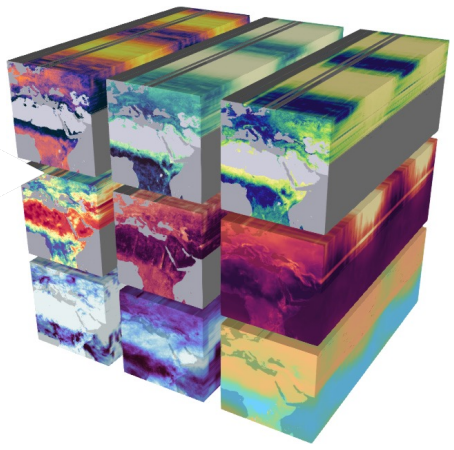
Data Cubes

+ Time Chunks
+ Space Chunks



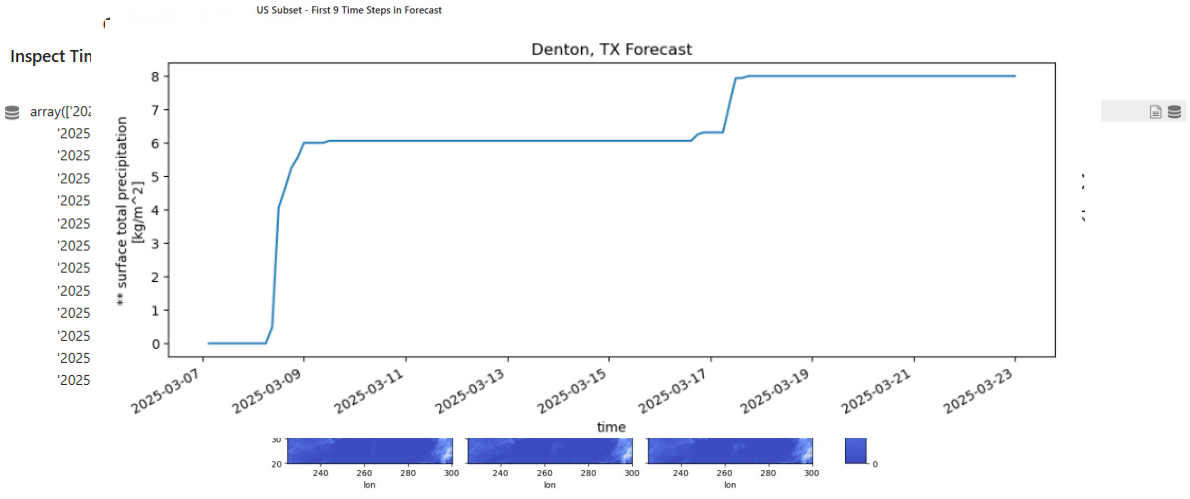
Data Cubes

+ Statistical Analysis
+ Machine Learning/AI
+ Changes and Trends

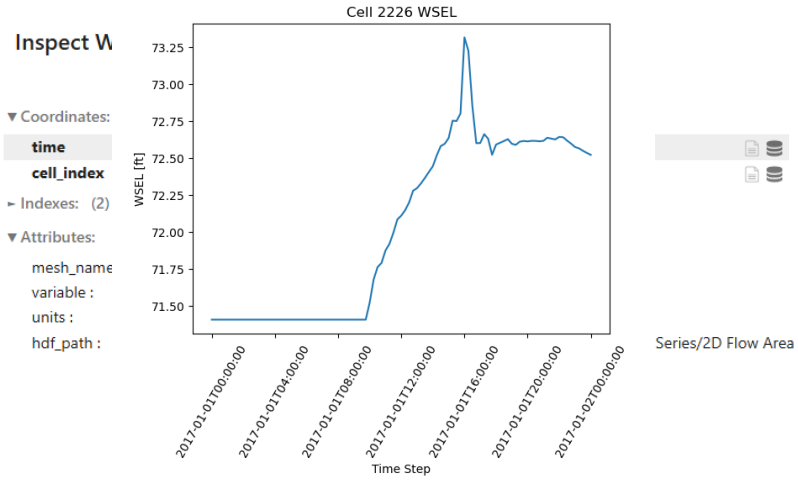


Real World Applications

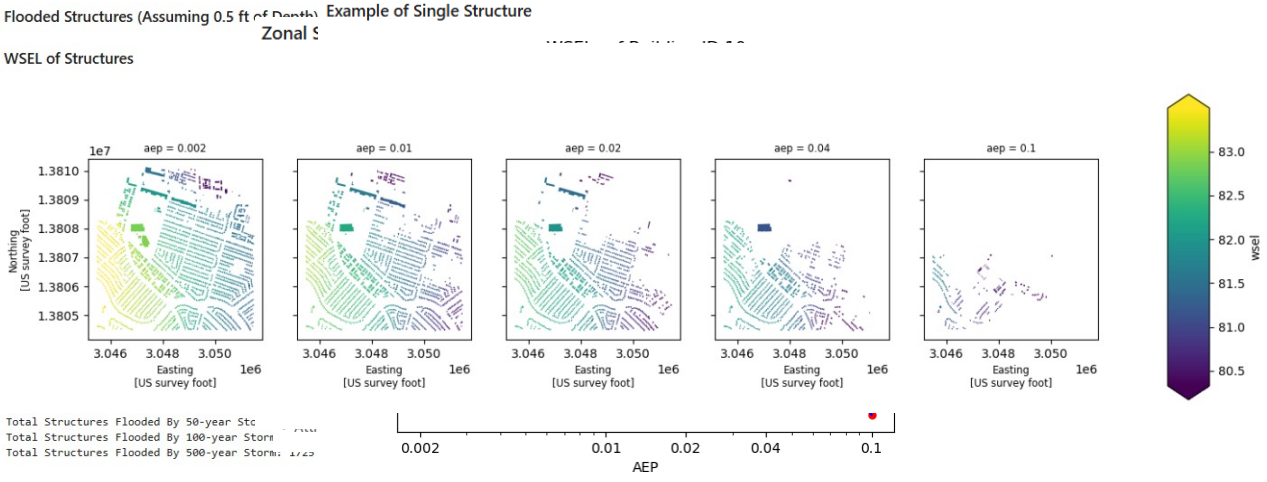
NOAA Global Forecast System (GFS) Preview



HEC-RAS Cell Analysis



Vector Data – Zonal Stats



What's Next

Questions?

Thank you for attending today!

Luke Villanueva, PE
Project Engineer
LAVillanueva@lan-inc.com