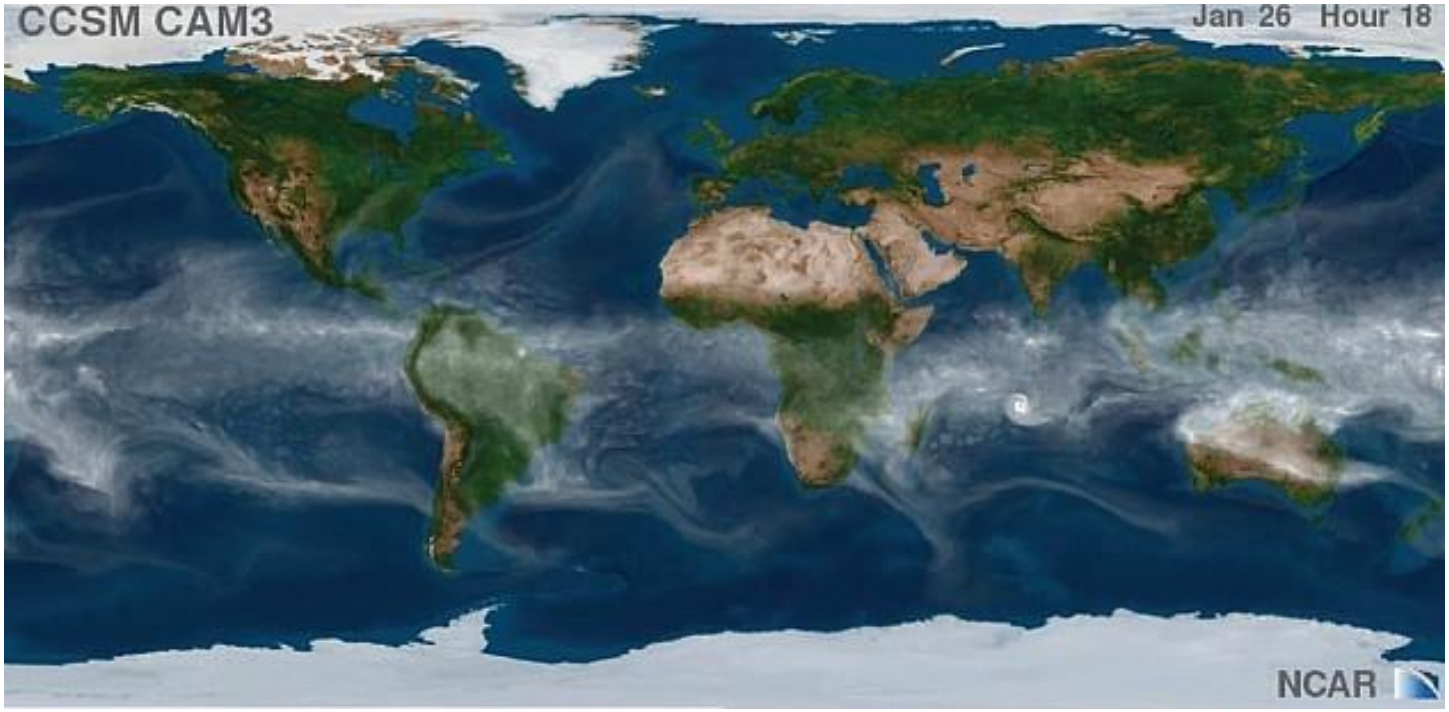
Scientific Data Model

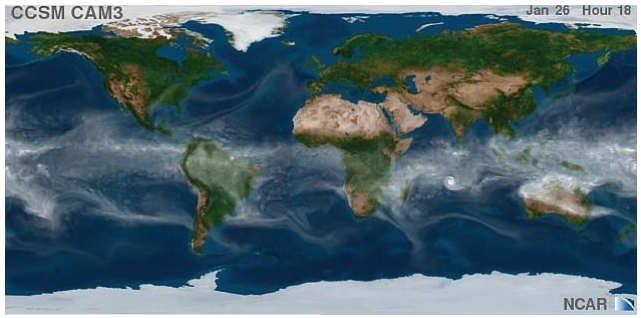
Courtesy of Prof. Han-Wei Shen
(CSE 5544, The Ohio State University)

What is a Data Model?



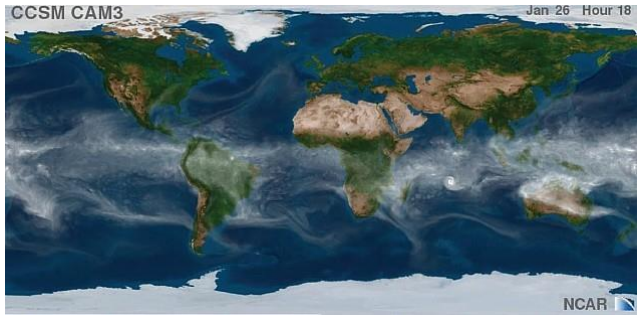
How do you describe the data represented by this image?

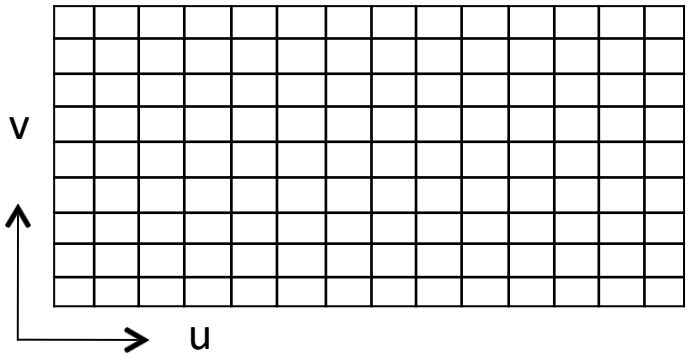
Data Model



- Describe the objects represented by the data

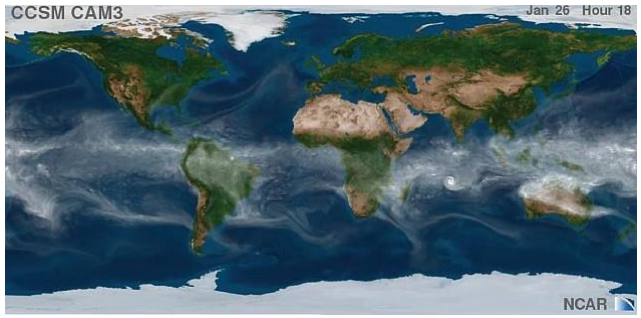
Data Model

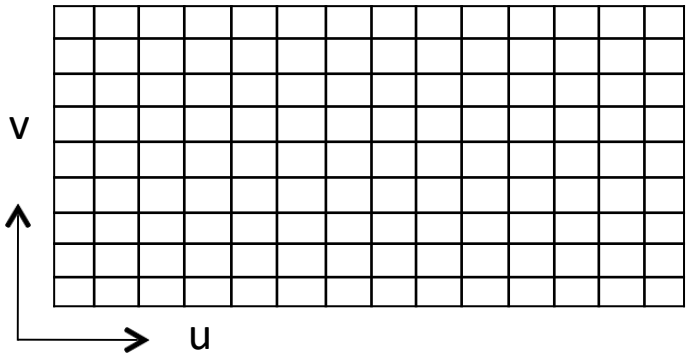




- Describe the objects represented by the data
  - Structures of the objects

Data Model



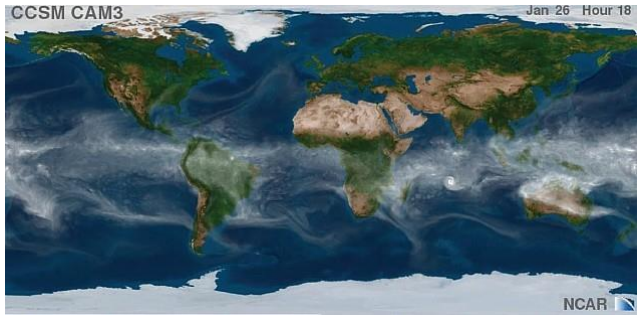


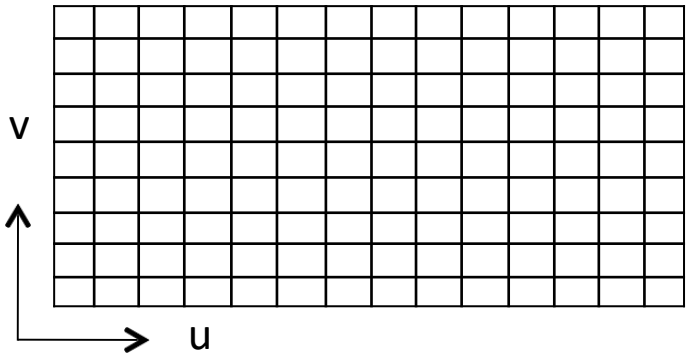
(u,v)

Temperature
Pressure
Cloud density
…

- Describe the objects represented by the data
  - Structures of the objects
  - Properties of the objects

Data Model



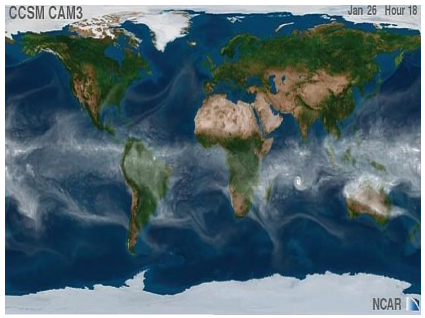


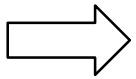
(u,v)

Temperature
Pressure
Cloud density
…

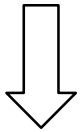
- Describe the objects represented by the data
  - Structures of the objects
  - Properties of the objects
  - Relationships between the objects

Scientific Data Model





Data Model



- Data set – a single or multiple valued function

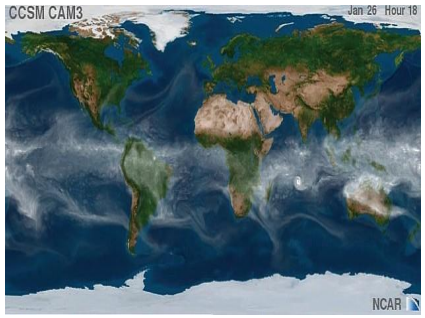
m dependent variables x_i (i=1..m)
n independent variable v_j (j = 1..n)

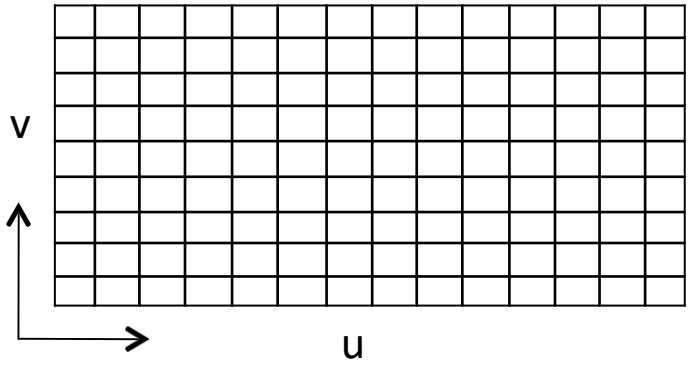
Temperature
Pressure
Cloud density
…

$$\mathbf{y}_1 = f_1(x_1, x_2, x_3, \ldots, x_n)$$
$$\mathbf{y}_2 = f_2(x_1, x_2, x_3, \ldots, x_n)$$
$$\cdots$$
$$\mathbf{y}_m = f_m(x_1, x_2, x_3, \ldots, x_n)$$

Each dependent variable y_i can have a tensor rank k
- k = 0 : scalar; k = 1: vector; k = 2; 2D matrix, etc.

Scientific Data Model





(u,v)

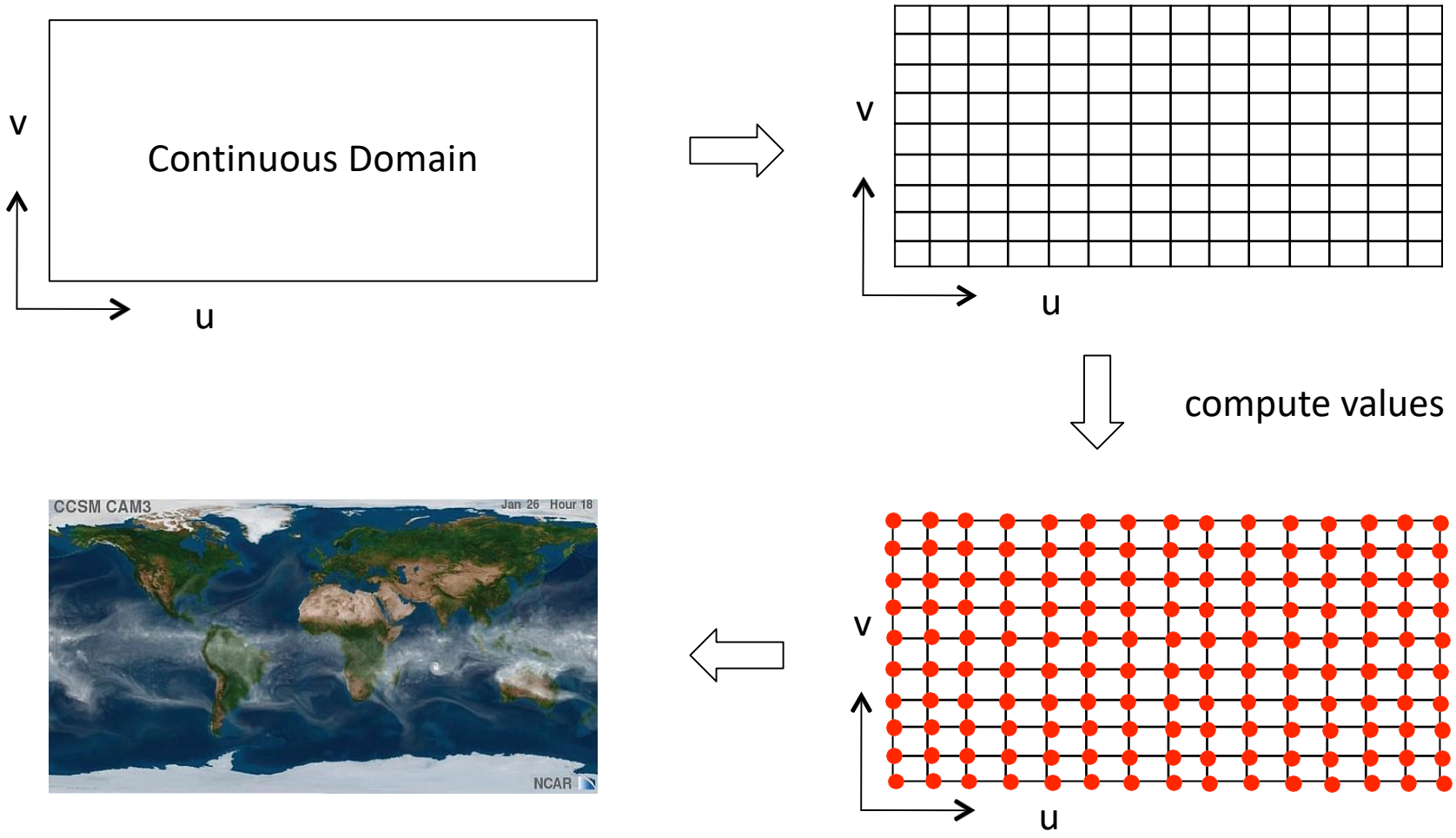
Temperature
Pressure
Cloud density
…

- Data set – a single or multiple valued function

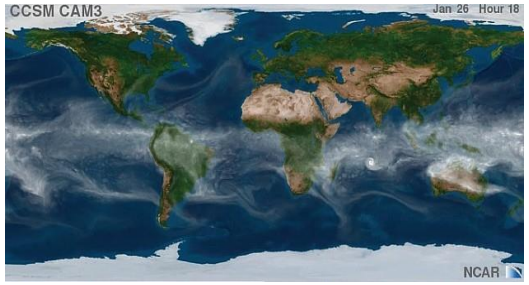
- **Independent variables** (dimensions)
  - Spatial coordinates (longitude, latitude, height)
  - Time
  - Zone ID
  - …
- Dimensionality - number of independent variables

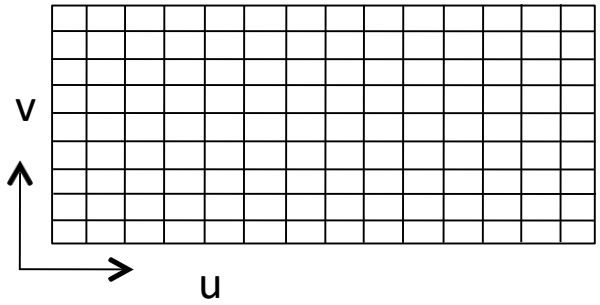
- **Dependent variables**
  - The function values of independent variables
  - The number of values associated with each dependent variable can be described by its *tensor rank*
    - 0: scalar
    - 1: vector
    - 2: n x n matrix …

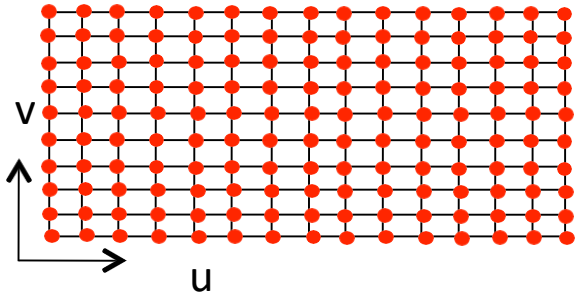
Domain Discretization



Scientific Data Set







Scientific Data Set =

Domain Structure +

Attributes

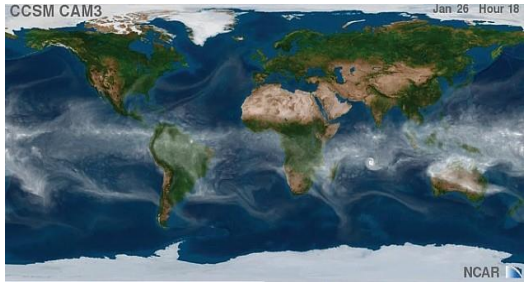
Domain Structure

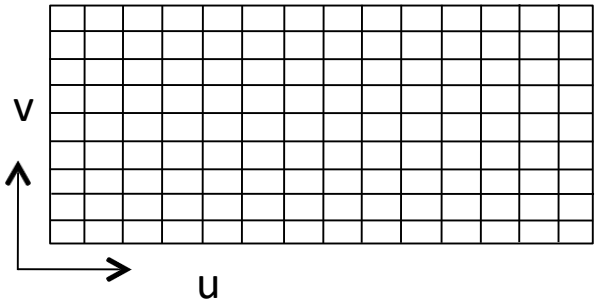
- Topology: property invariant under transformation
- Geometry: instantiation of topology with specific positions
- Consists of *Points* and *Cells*, which define the *Mesh*

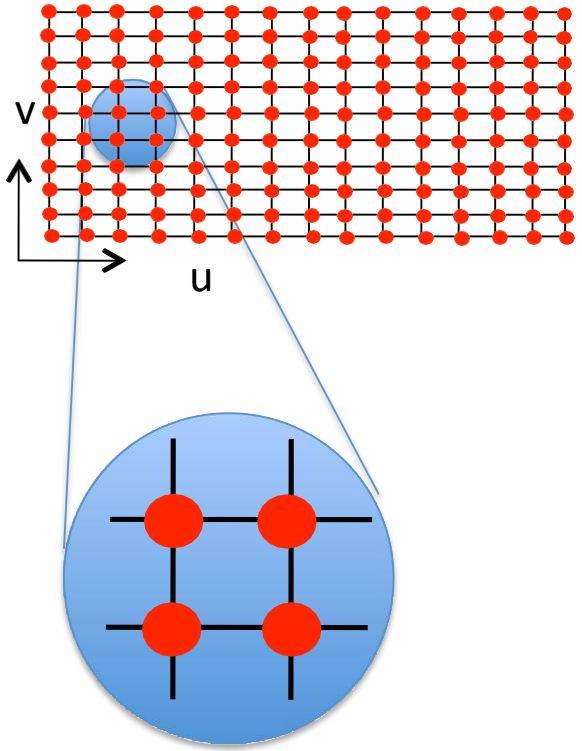
Attributes

One or multiple values (scalars, vectors, tensors) defined at points or cells

Domain Structure - Cell



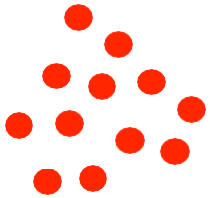




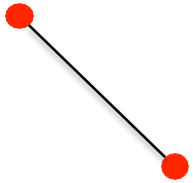
- Cells are the fundamental building blocks of scientific data sets
- Cells define how points are connected together to form the basis for interpolation
- Cells can be of different dimensionality
  - 0 D: Vertices
  - 1 D: Line; Polylines;
  - 2 D: Triangle; Quadrilateral; Polygon
  - 3 D: Tetrahedron; Hexahedron; Voxel;

Cell Types

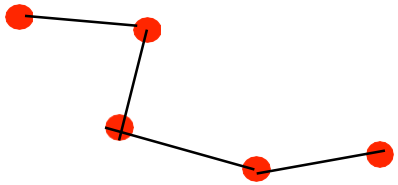
1D



Vertices

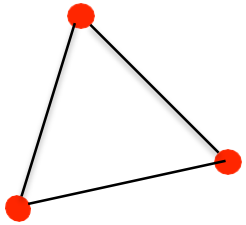


Line

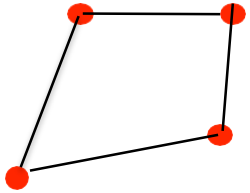


Polyline

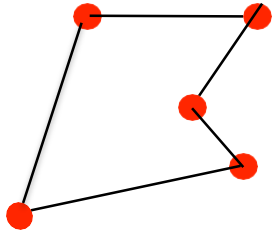
2D



Triangle

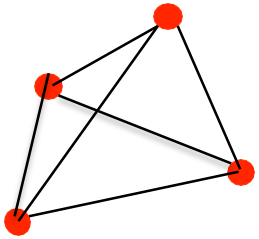


Quad

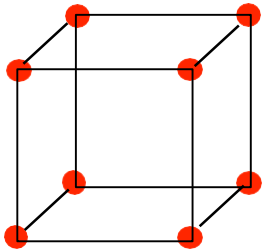


Polygon

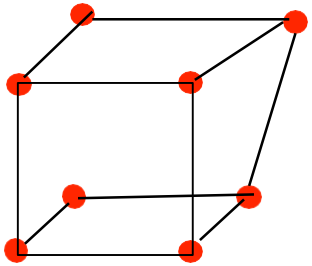
3D



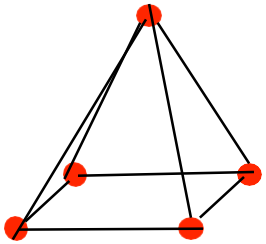
Tetrahedron



Cube



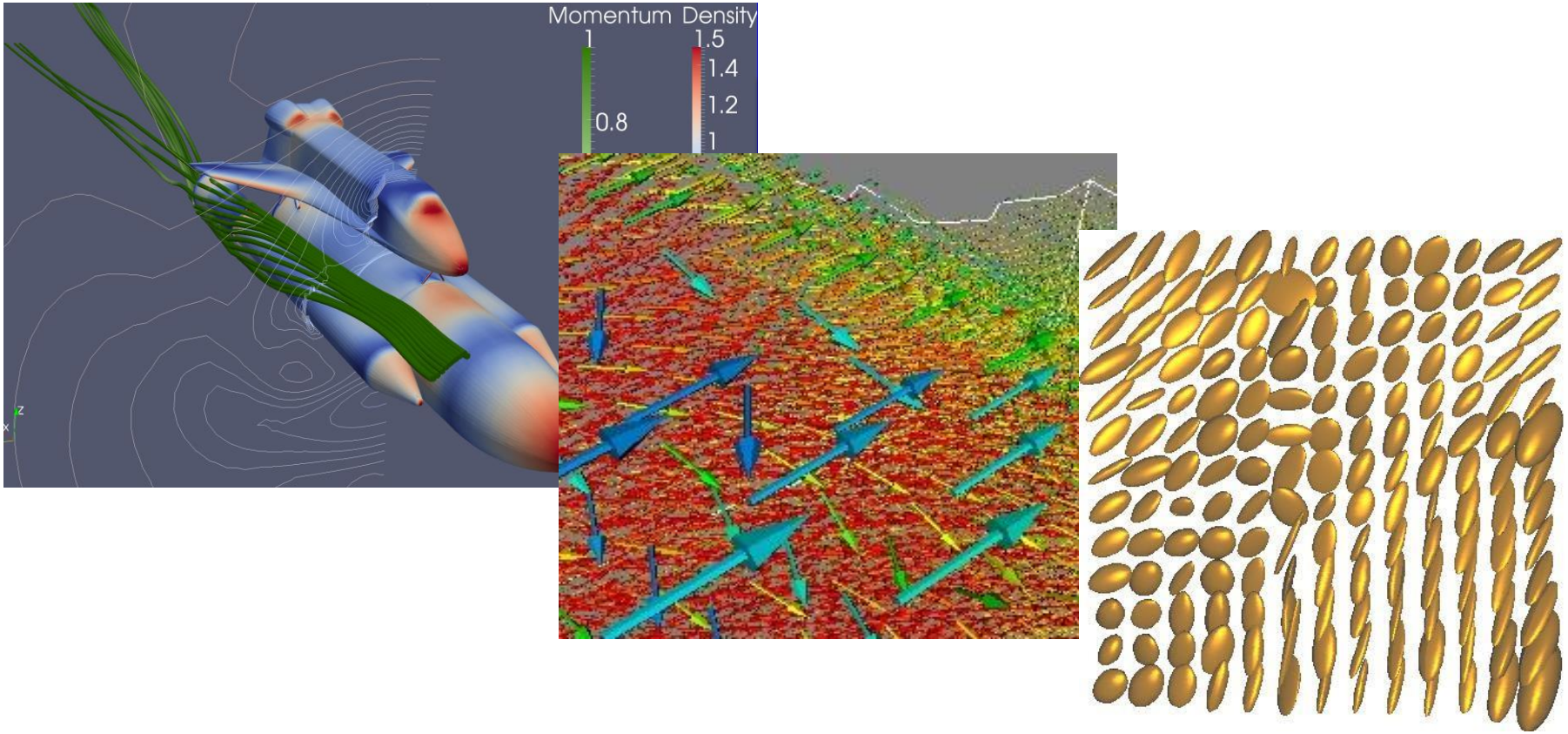
Hexahedron



Pyramid

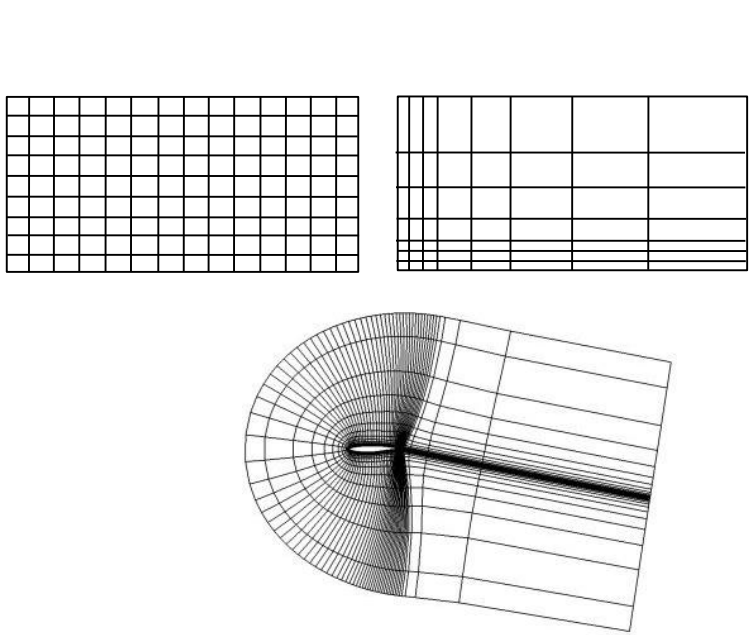
Attributes

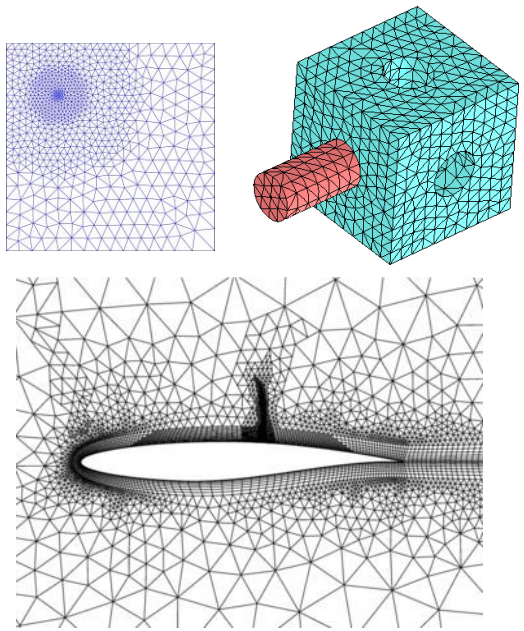
- Scalars (e.g. density), Vectors (e.g. momentum), Tensors (e.g. stress tensor)



Scientific Dataset Types

- Data sets are categorized into different types based on their underlying grid (domain structures)
  - Structured Grid
  - Unstructured Grid





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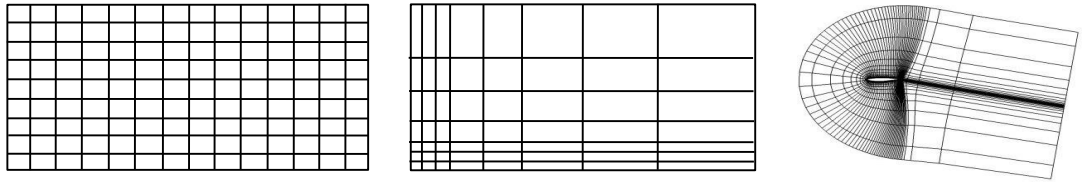

    - Consisting of a collection of points and cells arranged on a regular lattice

Scientific Dataset Types

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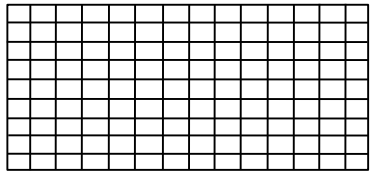
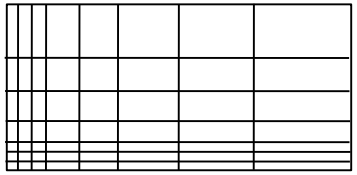
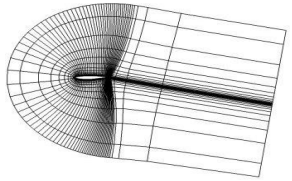
  - Structured Grid

    - Consisting of a collection of points and cells arranged on a regular lattice
    - Every point in the structured grid can be indexed by (i,j) in 2D, (i,j,k) in 3D, etc.

Scientific Dataset Types

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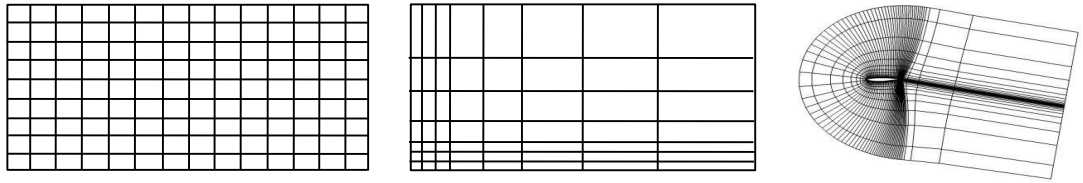
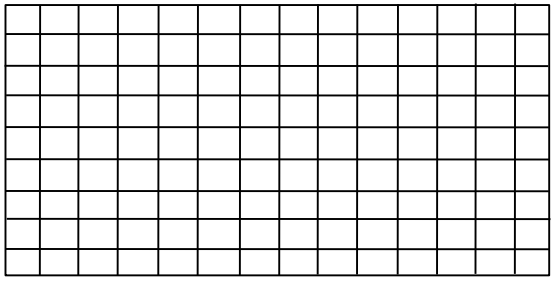
  - Structured Grid



    - Consisting of a collection of points and cells arranged on a regular lattice
    - Every point in the structured grid can be indexed by (i,j) in 2D, (i,j,k) in 3D, etc.
    - The position of the points, and hence the geometry of the cells, can be either implicitly defined (Cartesian gird), or explicitly specified (rectilinear or curvilinear grid)

Scientific Dataset Types

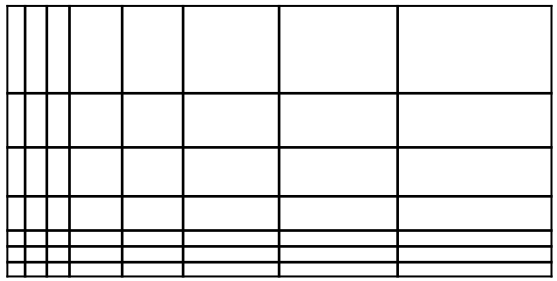
- Data sets are categorized into different types based on their underlying grid (domain structures)
  - Structured Grid
    - Cartesian mesh



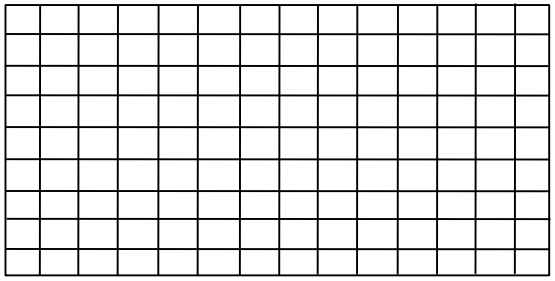
Cartesian Grid

Scientific Dataset Types

- Data sets are categorized into different types based on their underlying grid (domain structures)
  - Structured Grid
    - Cartesian mesh
    - Rectilinear mesh



Rectilinear Grid



Cartesian Grid

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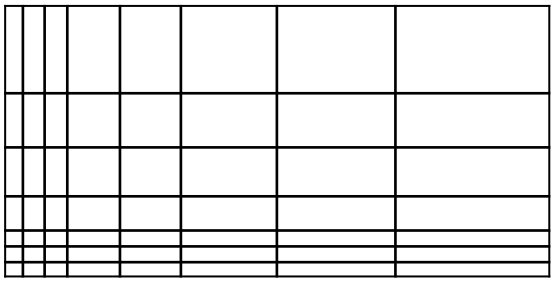
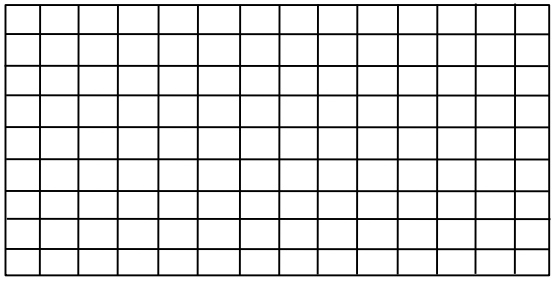
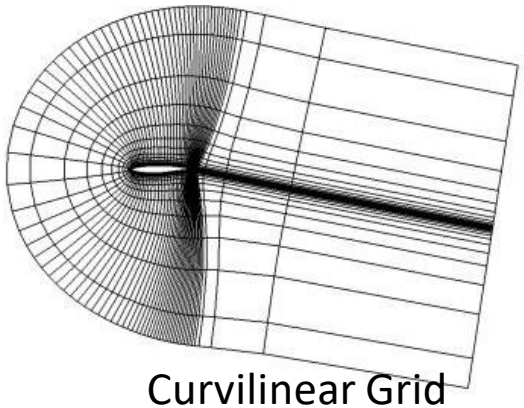
  - Structured Grid
    - Cartesian mesh
    - Rectilinear mesh
    - Curvilinear mesh



Rectilinear Grid



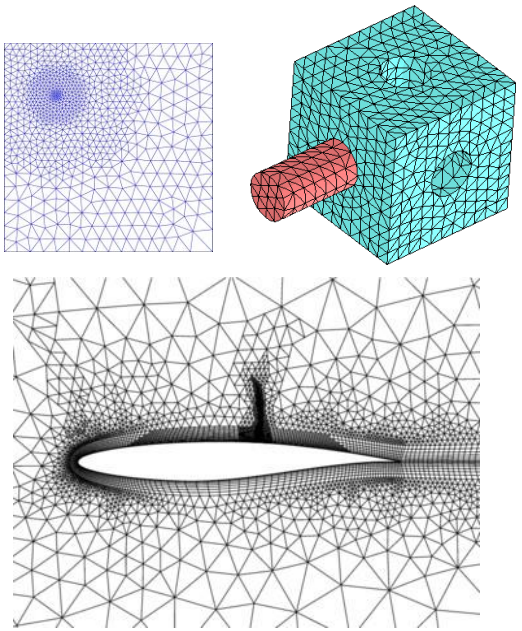
Cartesian Grid



Curvilinear Grid

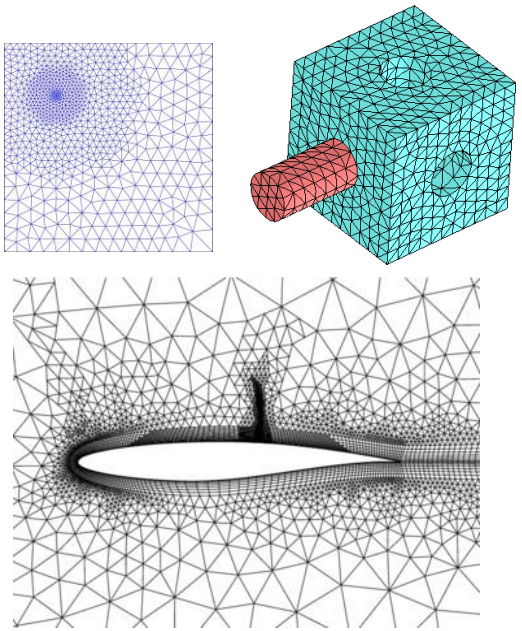
Scientific Dataset Types

- Data sets are categorized into different types based on their underlying grid (domain structure)
  - Unstructured Grid
    - Also called irregular grid data



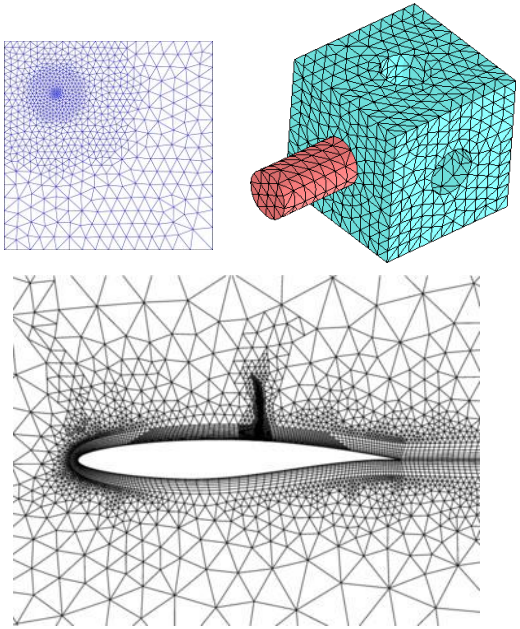
Scientific Dataset Types

- Data sets are categorized into different types based on their underlying grid (domain structure)
  - Unstructured Grid
    - Also called irregular grid data
    - Unstructured grid points are irregularly distributed in space



Scientific Dataset Types

- Data sets are categorized into different types based on their underlying grid (domain structure)
  - Unstructured Grid
    - Also called irregular grid data
    - Unstructured grid points are irregular located in space
    - It is ocen a result of space tessellation with simple shapes



Scientific Dataset Types

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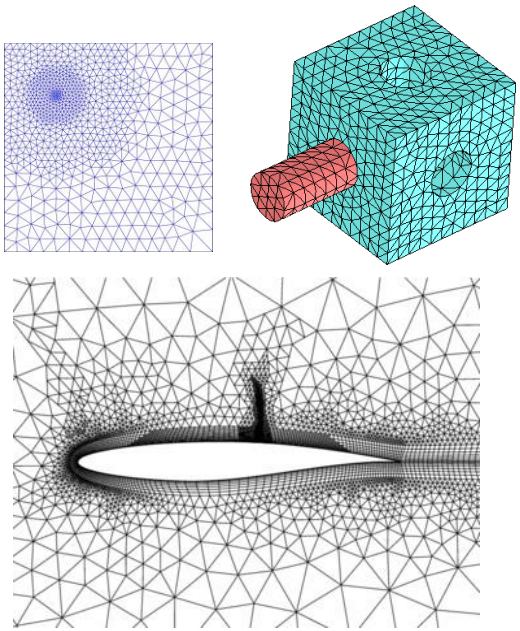
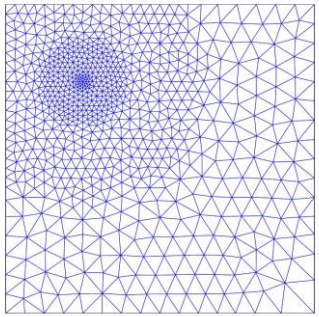
  - Unstructured Grid
    - Also called irregular grid data
    - Unstructured grid points are irregular located in space
    - It is ocen a result of space tessellation with simple shapes
    - Explicit connectivity information to form cells is necessary



Scientific Dataset Types

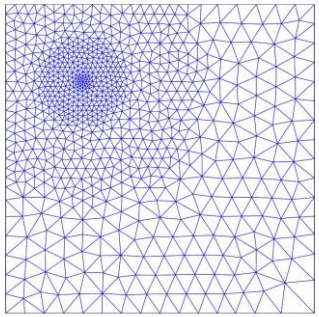
- Data sets are categorized into different types based on their underlying grid (domain structure)
  - Unstructured Grid
    - Polygonal mesh



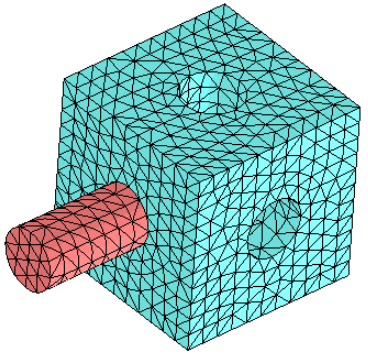
Polygonal mesh

Scientific Dataset Types

- Data sets are categorized into different types based on their underlying grid (domain structure)
  - Unstructured Grid
    - Polygonal mesh
    - Tetrahedral mesh



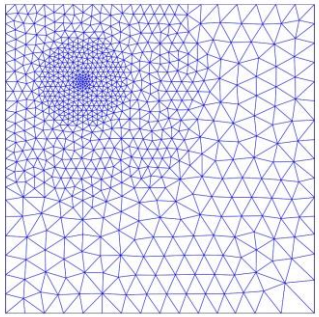
Polygonal mesh



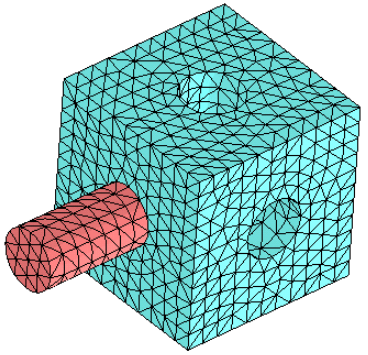
Tetrahedral mesh

Scientific Dataset Types

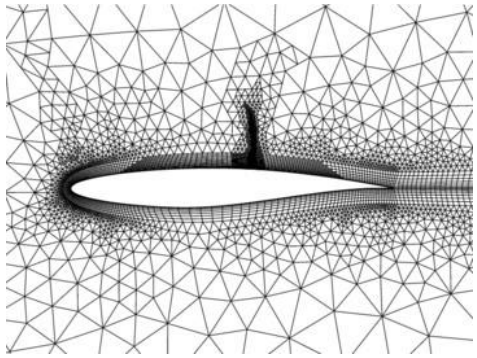
- Data sets are categorized into different types based on their underlying grid (domain structure)
  - Unstructured Grid
    - Polygonal mesh
    - Tetrahedral mesh
    - Hybrid Mesh



Polygonal mesh



Tetrahedral mesh



Hybrid mesh