Store, manipulate and analyze raster data within the PostgreSQL/PostGIS spatial database

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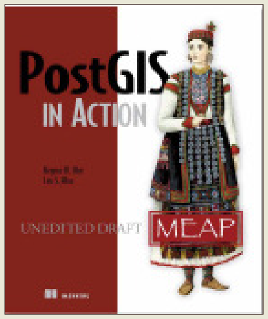
Introducing PostGIS Raster

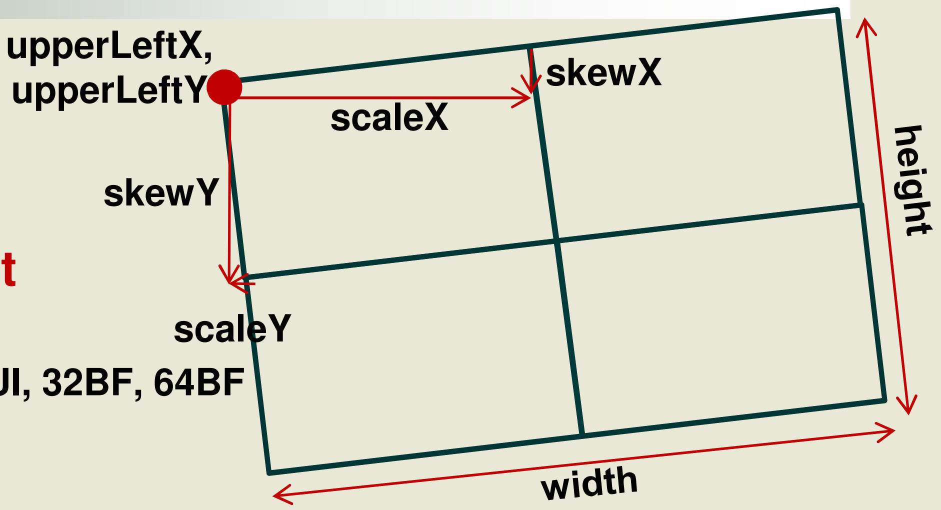
- Support for rasters in the PostGIS spatial database
  - RASTER is a new native base type like the PostGIS GEOMETRY type
  - Implemented very much like and is as easy to use as the PostGIS GEOMETRY type
    - One table row = one raster (or tile)
    - One table = one coverage
  - Integrated as much as possible with the GEOMETRY type
    - SQL API easy to learn for users already familiar with PostGIS
    - Full raster/vector analysis capacity taking nodata value into account
    - Operators & functions works seamlessly when possible
  - First release with PostGIS 2.0 (soon)
- Development Team
  - Current: Bborie Park, Jorge Arevalo, Pierre Racine, David Zwarg, Regina & Leo Obe
  - Past: Sandro Santilli, Mateusz Loskot
- Founding
  - Steve Cumming through a Canada Foundation for Innovation grant
  - Deimos Space, Davis University, Cadcorp, Azavea, OSGeo



Chapter 13 on PostGIS Raster

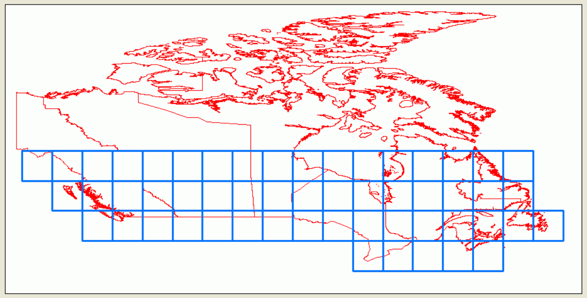
Georeferenced, Multiband, Multiresolution and Tiled Coverages

- Each raster/tile is georeferenced
  - Supports rotation (or skew)



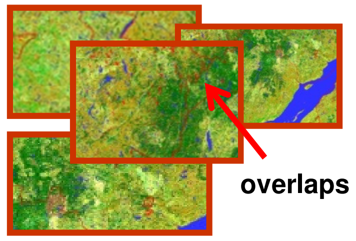
- Supports multiple bands with different pixeltypes in the same raster
  - 1BB, 8BSI, 8BUI, 16BSI, 16BUI, 32BSI, 32BUI, 32BF, 64BF
  - One nodata value per band
- Tiled & indexed
  - No real limit on size
    - 1 GB per tile, 32 TB per coverage (table)
    - Rasters are compressed (by PostgreSQL)
  - Supports irregularly tiled & overlapping coverages

e.g. SRTM Coverage for Canada

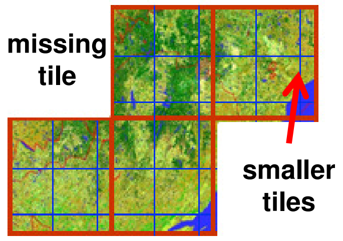


- Other resolutions (or overviews) are stored in sister tables
- List of raster columns available in a raster_columns table similar to the geometry_columns table

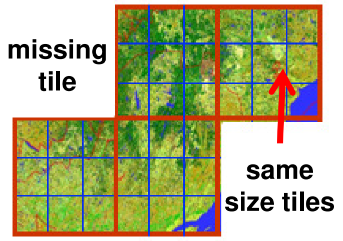
Supports Many Raster Arrangements



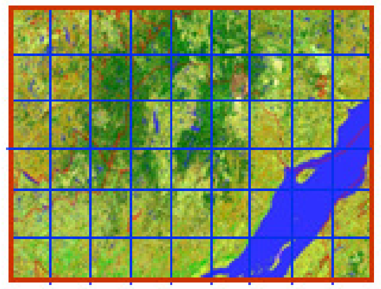
a) warehouse of untiled and unrelated images (4 images)



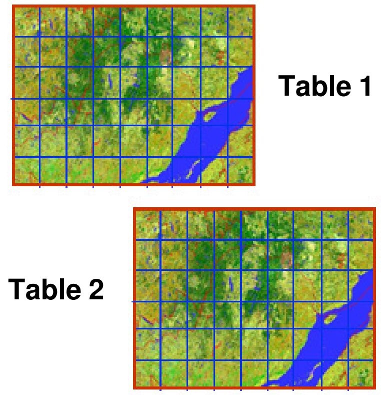
b) irregularly tiled raster coverage (36 tiles)



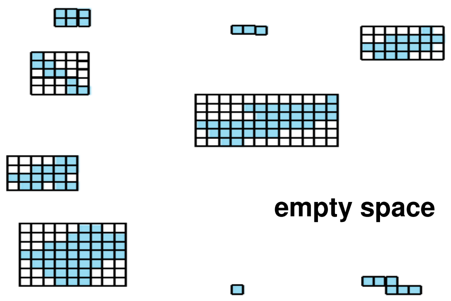
c) regularly tiled raster coverage (36 tiles)



d) rectangular regularly tiled raster coverage (54 tiles)



e) tiled images (2 tables of 54 tiles)



f) rasterized geometries coverage (9 lines in the table)

What You Can Do Now?

Store and manage rasters in the database…

- Batch import rasters
  - raster2pgsql.py -r “c:/temp/mytiffolder/*.tif” -t mytable -s 4326 -k 50x50 -l | psql -d testdb
- Get and set the raster properties
  - Upper left corner coordinates & transformation parameters
  - SRID & number of bands
- Get and set band properties
  - Pixel type & nodata value
- Reproject raster (ST_Transform)
- ST_Resample(raster), ST_Rescale(), ST_SnapToGrid()
- Convert a geometry to a raster (ST_AsRaster)
- Convert a raster to a set of geometries-values (ST_DumpAsPolygons)

What You Can Do Now?
Dump rasters from the database…

- With the 'PostGISRaster' GDAL driver
  - Developed and maintained by Jorge Arévalo
- Read only, optimization in progress
- The write part is still to do (by you?)
- Two modes
  1. ONE_RASTER_PER_ROW
  2. ONE_RASTER_PER_TABLE

What You Can Do Now? Get raster statistics…

- ST_SummaryStats(raster)
  - Return a set of (min, max, sum, mean, stddev, count (of withdata pixels)) records
  - 10 seconds for one SRTM tile of 3600 x 3600 pixels, 70MB
- ST_Histogram(raster, bin, width[ ])
  - Return a set of (min, max, count, percent) records for an array of bins
- ST_Quantile(raster, quantiles[ ])
  - Return a set of values for an array of quantile
- ST_ValueCount(raster, values[ ])
  - Return the frequency for an array of value

What You Can Do Now? Display rasters…

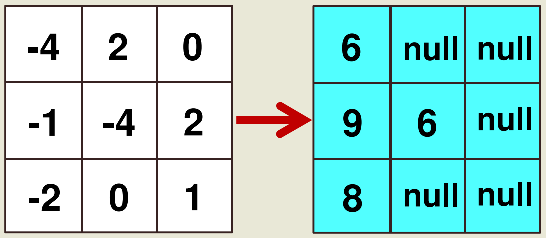
- **QGIS** plugin by Maurício de Paulo *(mauricio.dev@gmail.com)*
- **gvSIG** plugin by Nacho Brodin *(ibrodin@prodevelop.es)*
- **MapServer** through GDAL
  - Normally any software using GDAL to read raster and allowing passing database connection parameters to GDAL

- Display a vectorization of the raster
  - OpenJump

    -
      ```
      SELECT ST_AsBinary((ST_DumpAsPolygons(rast)).geom),
                                      (ST_DumpAsPolygons(rast)).val
      FROM srtm_tiled WHERE rid=1869;
      ```
  - ArcGIS 10
    - Add Query Layer (same as OpenJump but without ST_AsBinary())
  - Any software displaying vector PostGIS queries

What You Can Do Now?
Edit and compute new rasters…

- **ST_SetValue()** of a pixel
- **ST_Reclass()** a raster
- **ST_MapAlgebra**(raster, band,
  expression,
  nodatavalueexpr,
  pixeltype)



-4	2	0
-1	-4	2
-2	0	1

6	null	null
9	6	null
8	null	null

  - Expressions are evaluated by the PostgreSQL parser
  - You can use any complex SQL expression
  - e.g. 'CASE WHEN rast < 0 THEN rast+10 ELSE NULL END'
  - You can provide a **nodatavalueexpr** to handle source nodata values

What You Can Do Now?

Convert rasters to any GDAL format in SQL…

- Get the list of GDAL drivers available (ST_GDALDrivers)

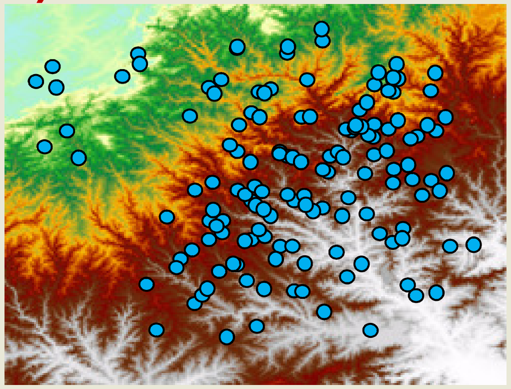
- Convert to any of the available format (ST_AsGDALRaster)
  - SELECT ST_AsGDALRaster(rast, 'USGSDEM')
    FROM srtm_22_03

- ST_AsTIFF(), ST_AsJPEG(), ST_AsPNG()

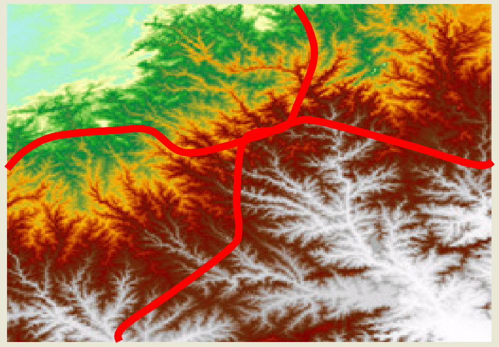
What You Can Do Now?

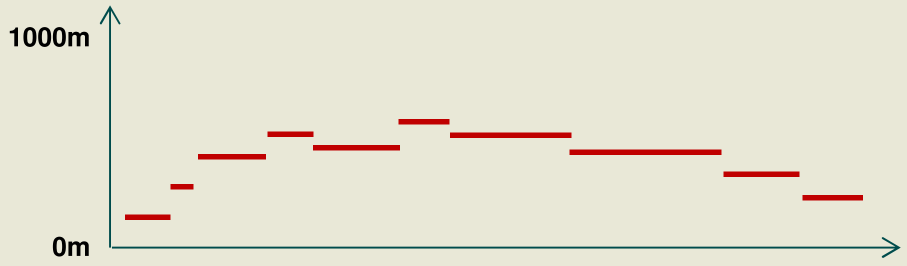
Intersects rasters with points and lines…

- Extract ground elevation values for lidar points…
  - SELECT pointID, ST_Value(rast, geom) elevation
    FROM lidar, srtm WHERE ST_Intersects(geom, rast)



- Intersect a road network to extract elevation values for each road segment
  - SELECT roadID,
    (ST_Intersection(geom, rast)).geom road,
    (ST_Intersection(geom, rast)).val elevation
    FROM roadNetwork, srtm WHERE ST_Intersects(geom, rast)



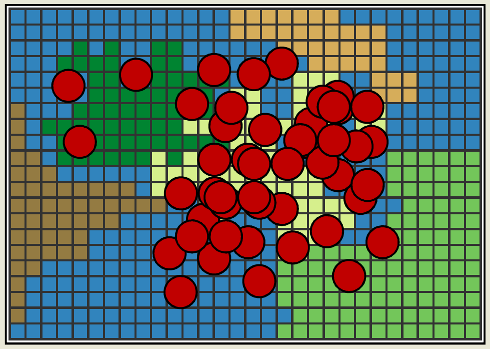


What You Can Do Now?

Intersects rasters with polygons...

- Compute the mean temperature for each polygons of a table

```
SELECT bufID, (gv).geom buffer, (gv).val temp
FROM (SELECT bufID, ST_Intersection(geom, rast) gv
          FROM buffers, temperature
          WHERE ST_Intersects(geom, rast)
```



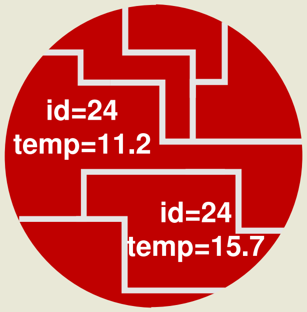
buffers	
geom	pointid
polygon	24
polygon	46
polygon	31
polygon	45
...	...

∩

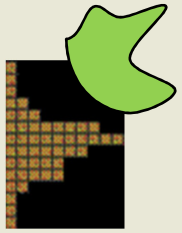
temperature
raster
raster
raster
raster
raster
...

=

result		
geom	pointID	temp
polygon	24	11.2
polygon	53	13.4
polygon	24	15.7
polygon	23	14.2
...	...	...



- Results must be summarized per buffer afterward
- All analysis functions take nodata values into account
- Have a look at the tutorial in the PostGIS Raster wiki page!



What You Can Do Now?

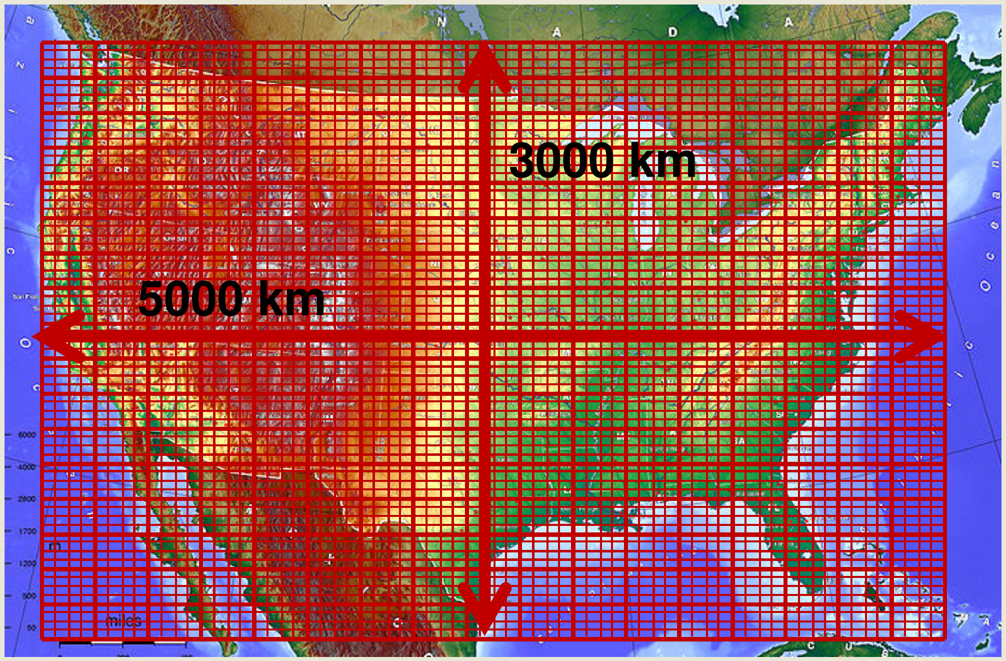
Create a high resolution analysis grid for a large area…

Compute values of many variables for each cell of a grid

- Road & river length, mean temperature, population, water surfaces, etc…
- Easy in vector mode (1 cell = 1 polygon) but

- What about all of USA at 10m?

500 000 x 300 000
=
Way too many polygons!



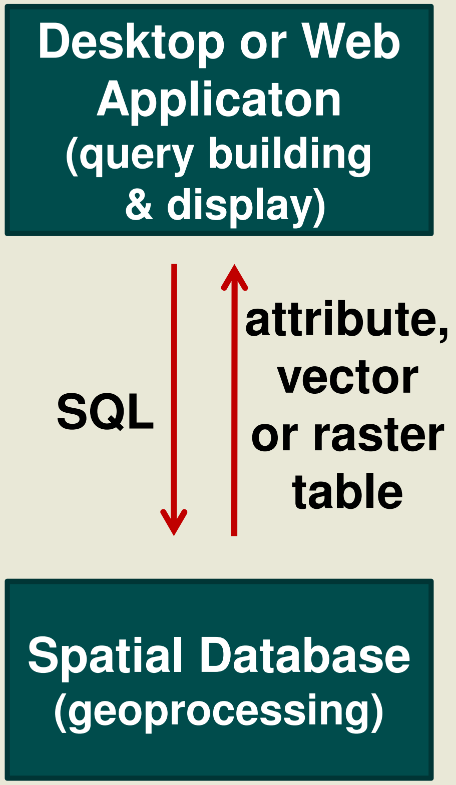
- Manageable in raster format!
- 15 000 000 tiles 100x100 pixels

1. Create a raster having a uid per pixel
2. Intersect your vector layers with your raster grid
3. Summarize per pixel uid
4. Create a new band for each variable and assign the values

What You Can Do Now?

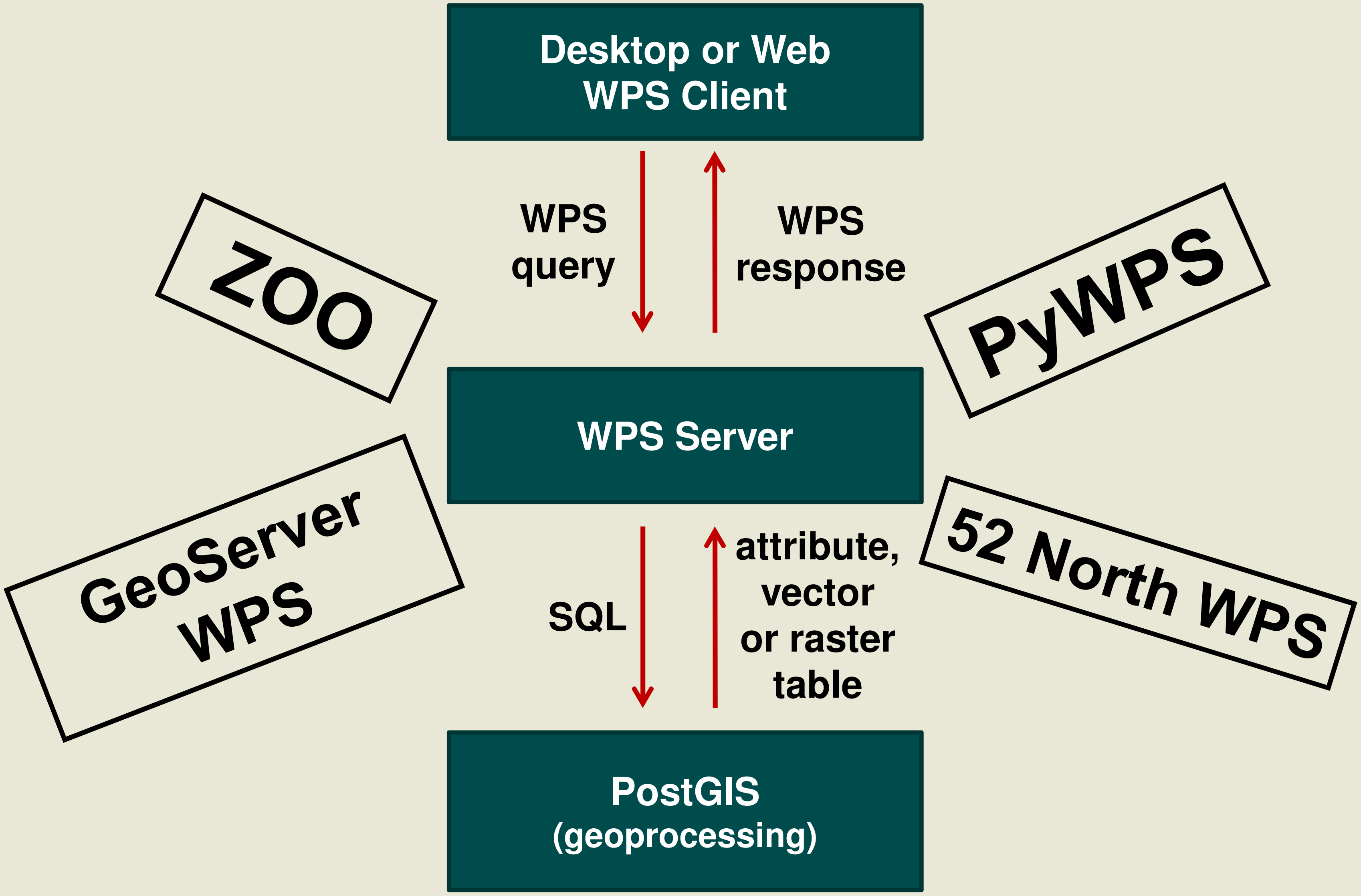
Create a specialised web or desktop GIS application…

- With the raster API, PostGIS is now a very complete SQL GIS
  - All data are implicitly **tiled** and **spatially indexed**
  - No need to write **complex** C,C++, Python or JAVA code to manipulate complex geographical datasets.
  - **Use SQL**: The most used, most easy and **most minimalist though complete** language to work with data in general. Easily **extensible** (PL/pgSQL)
  - Keep the **processes close to the data** where the data should be: in a database!
- Lightweight multi-users specialized desktop and web GIS applications
  - All the (geo)processing is done **in the database**
  - Applications become **simple SQL query builders** and **data** (results) **viewers**


Desktop or Web Applicaton (query building & display)
SQL
attribute, vector or raster table
Spatial Database (geoprocessing)

What You Can Do Now?

Implement a WPS server raster/vector geoprocessor…



Performance?

- Import of 1 GB SRTM DEM files
  - tiled to 48373 100x100 pixels tiles: 3 minutes
  - tiled to 525213 30x30 pixels tiles: 6 minutes
- ST_Intersection() of 814 buffers with the 30x30 SRTM
  - 4 minutes
- ST_Intersection() of 100 000 lines with a 300 MB landsat coverage
  - 8 minutes
- Recently selected by the main Canadian governmental provider of geospatial data (GeoBase)
  - online on-the-fly and internal elevation product generation
- PostGIS raster is still a baby, many optimizations are still possible

Summary

- PostGIS Raster is multiband, tiled, multiresolution
  - Each band supports one nodata value, one pixel type.
  - One row = one raster, one table = one coverage.
  - Supports many tile arrangement.
  - Very much like a vector coverage.
  - Import is done the same way as usual with PostGIS: raster2pgsql
- There are plenty of functions to…
  - manipulate,
  - edit,
  - do raster and raster/vector analysis,
  - get raster statistics,
  - create new rasters,
  - write web and desktop applications.

Summary

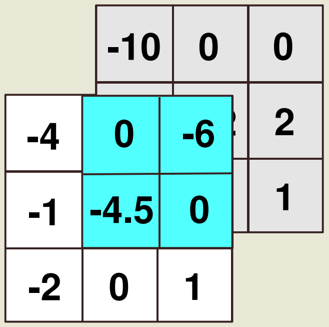
- **Roadmap…**
  - Two raster version of ST_Intersection()
  - Neighbor version of ST_MapAlgebra()
  - Two rasters version of ST_MapAlgebra()
  - Aggregate rasters with ST_Union()
  - Statistic functions as aggregates
  - ST_Interpolate() from irregular grid of point (lidar)
  - ST_AsDensity() to produce density maps
- **Third party developments…**
  - GDAL write driver
  - Support in GeoServer
  - Read/write in FME

What You Can Do Soon? More complex analyses…

- Two rasters ST_Intersection()
  - ST_Intersection(raster, raster) -> raster
  - Equivalent to ST_Clip(raster, ST_AsRaster(geometry))

- One raster neighbor version of ST_Mapalgebra()
  - or “ focal function ” or “moving window” computation
  - User function taking a 3x3, 5x5, 7x7, or more raster and optional parameters and returning a value

- Two rasters version of ST_MapAlgebra
  - Useful to implement most overlay functions and more
    - ST_Union(raster, raster) -> raster
    - ST_Intersection(raster, raster) - > raster
    - ST_BurnToRaster(raster, geometry, value)…
  - Resulting extent can be FIRST, SECOND, UNION or INTERSECTION.



What You Can Do Soon?

Aggregate many tiles into one raster… (or merge)

- **Use ST_Union() as an aggregate function**
  - Taking a state, a temporary and a final function specifying how to aggregate pixel values in a state, a temporary and a final raster
  - User can defines their own expressions or use predefined functions like FIRST, LAST, MIN, MAX, SUM, MEAN, COUNT

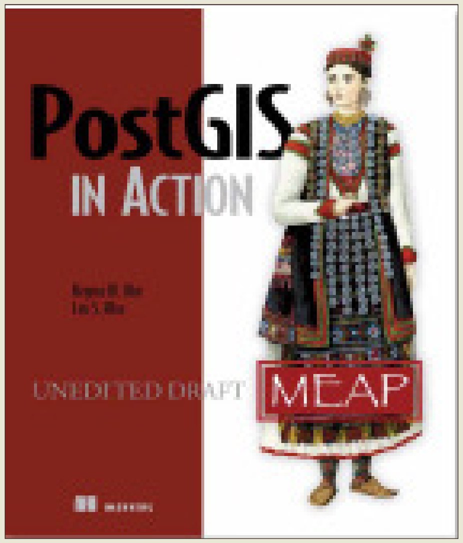
- **Ex. SELECT ST_Union(raster, 'MEAN')**
  - Compute the mean pixel value of many overlapping pixels
  - The state function 'SUM' accumulate pixel values
  - The temporary function 'COUNT' count the number of pixels
  - The final function 'state raster/temporary raster' divide the sum by the count
  - See pl/pgsql code in raster/script/plpgsql/st_union.sql

Thanks!

http://trac.osgeo.org/postgis/wiki/WKTRaster

Géomatique Expert
N° 81 - Juillet-Août 2011
Modélisation 2D du bâti 3D
PostGIS 2.0 arrive
Télédétection des toitures végétalisées

Géomatique Expert July 2011



Chapter 13 on PostGIS Raster April 2011

BRASIL FOSSGIS
Georreferenciando o Conhecimento
WKT RASTER solução OpenSource para arquivos matriciais
A ponta do ICEBERG do projeto KOSMO
BD espaciais desastres naturais e eventos extremos
SOFTWARES LIVRES no Ensino
Capacitação com TERRAVIEW
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O uso de softwares livres no meio acadêmico
TUTORIAL WebGIS GeoExt
Mapa da Vez Instituições de Ensino no Brasil
Um Planeta Brasileiro sobre Geotecnologias Livres

Brazil FOSSGIS June 2011

Some extra slides…

Comparison with Oracle GeoRaster

Oracle GeoRaster

- Stored as a one to many relation between two types, in two different tables
  - SDO_GEORASTER (raster)
  - SDO_RASTER (tile)
  - Only SDO_RASTER is georeferenced
- Supports (too) many raster features for any kind of raster application
  - bitmap mask, two compression schemes, three interleaving types, multiple dimensions, embedded metadata (colour table, statistics, etc…), lots of unimplemented features
- Hard to load data
- Designed for raster storage

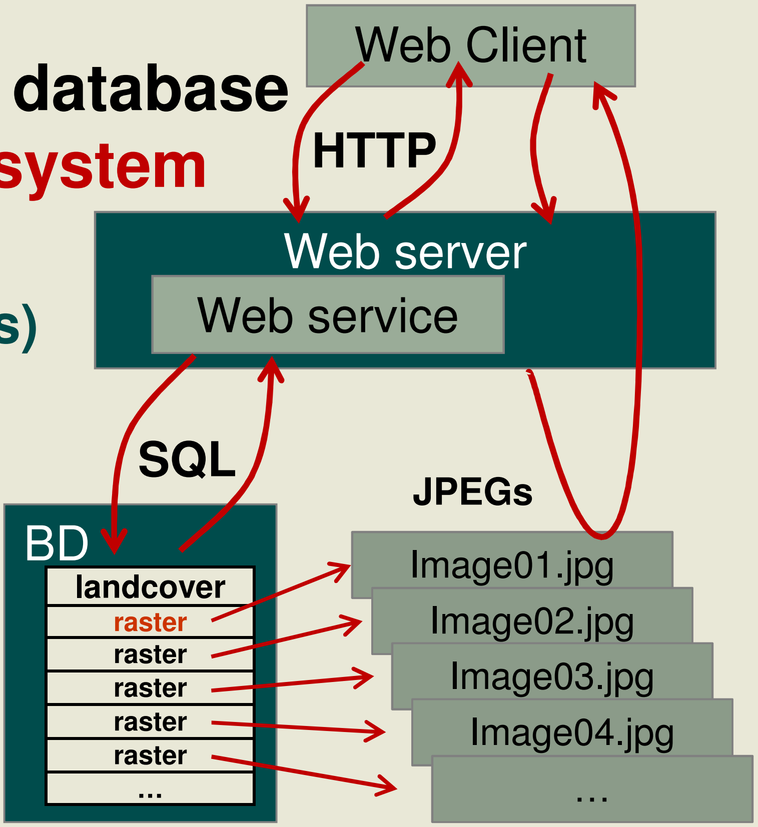
PostGIS Raster

- Stored as a unique type, in one table
  - RASTER (or tile)
  - Each raster is geoferenced
- Supports the minimal set of characteristics for the geospatial industry
  - georeference, multiband, tiling, pyramids, nodata values
- Easy to load data
- Designed for raster/vector analysis

What You Can Do Now?

Store and manage rasters stored outside the database…

- By default raster are stored **INSIDE the database** in the PostGIS raster format
- It is also possible to **register** in the database rasters stored **OUTSIDE in the file system**
  - Stored in any **GDAL format**
  - **Faster direct access** for web apps (JPEGs)
  - Avoid **useless database backup** of large datasets not requiring edition
  - Avoid **importation** (copy) of large datasets into the database
  - Provides an **easy SQL API** to manipulate/analyse raster files
  - Use the **–R** raster2pgsql.py option
  - All functions should eventually works **seamlessly** with out-db raster. Now only a few.



What You Can Do Now?

Develop new raster processing functions…

- ST_MakeEmptyRaster()
- ST_AddBand()
  - Empty band or copy a band from another raster
- All georeference setters
  - ST_SetScale (), ST_SetSkew(), ST_SetUpperLeft(), ST_SetGeoReference()
- ST_SetBandNodataValue
- ST_SetValue()
- Coordinates transformation helpers
  - ST_World2RasterCoordX(), ST_World2RasterCoordY(), ST_Raster2WorldCoordX(), ST_Raster2WorldCoordY()
- ST_Intersection() & ST_intersects()
  - To interact with vector data
- Many more…

What You Can Do Now?

Develop new raster processing functions…

- PL/pgSQL example for ST_DeleteBand

```
CREATE OR REPLACE FUNCTION ST_DeleteBand(rast raster, band int)
  RETURNS raster AS $$
  DECLARE
      numband int := ST_NumBands(rast);
      newrast raster := ST_MakeEmptyRaster(rast);
  BEGIN
      FOR b IN 1..numband LOOP
               IF b != band THEN
                        newrast := ST_AddBand(newrast, rast, b, NULL);
               END IF;
      END LOOP;
      RETURN newrast;
  END;
  $$ LANGUAGE 'plpgsql';
```

What You Can Do Soon?

Write to PostGIS raster with GDAL…

- A write GDAL driver does not exist yet.
- It should allows
  - loading raster in the database using gdal_translate
  - loading many raster at the same time
  - any application writing to GDAL to write to PostGIS raster
  - tiling a raster to any tile size
  - to create overviews

What You Can Do Soon? Complex MapAlgebra analyses…

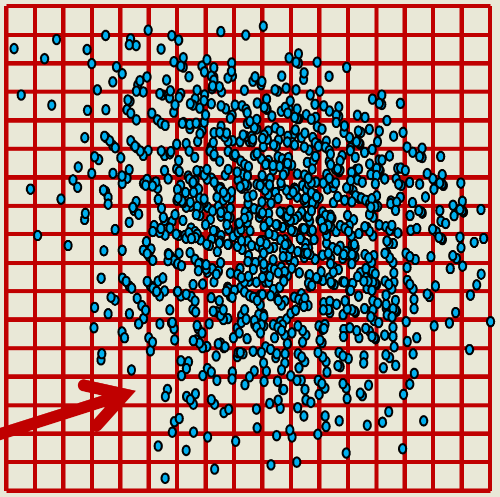
- Already available: One raster version of ST_MapAlgebra()
- Soon: Faster user-defined function version
  - Function taking a pixel value and some parameters and returning a computed value

    -
      ```
      CREATE FUNCTION polynomial(x float,
                                 VARIADIC args TEXT[])
      RETURNS FLOAT AS $$
      DECLARE
          m FLOAT;
          b FLOAT;
      BEGIN
          m := args[1]::FLOAT;
          b := args[2]::FLOAT;
          return m * x + b;
      END; $$ LANGUAGE 'plpgsql';
      ```
    - `SELECT ST_MapAlgebra(raster, 'polynomial', ARRAY['1.34', '5.2'])`

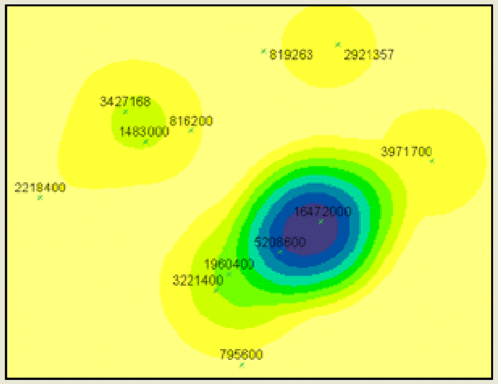
What You Can Do (maybe not too) Soon?

Interpolate a raster coverage from a point coverage…

- **ST_Interpolate**(pts geometry)
  - Should be an **aggregate** returning one raster (or a set of tiles)
  - Implementing many different interpolation algorythms
    - Nearest neighbor, linear, polynomial
  - Very useful to convert **lidar** data to raster



- **ST_AsDensity**(geometry)
  - **Count** the number of features touching each pixel and then **smooth** the surface using a moving window (neighbor map algebra)



What You Can Do (maybe not too) Soon?

Create a clean raster coverage… from a messy one…

1. Load a bunch of unaligned overlapping rasters (e.g. landsat)

2. ST_SetBrightness() & ST_SetContrast()
   - or ST_NormalizeColor('table', 'rasterColumn')

3. ST_MakeEmptyRasterCoverage()
   - Create a vector grid or an empty raster coverage based on a set of parameters

4. ST_MapAlgebra(emptyRaster, messyRaster, 'MEAN', 'FIRST') -> raster