



Moving Objects Database Technology for Ad-Hoc Querying and Satellite Data Retrieval of Dynamic Atmospheric Events

Markus Schneider (PI), Shen-Shyang Ho (co-I), Tao
Chen, Arif Khan, Ganesh

V

iswanathan, [Wenqing Tang](#), [W. Timothy Liu](#) (co-I)

University of Florida, Gainesville

[Jet Propulsion Laboratory](#)

University of Maryland, College Park

ESTF 2010, June 22, 2010

This work was carried out at the University of Florida, Gainesville, and at the Jet Propulsion Laboratory, California Institute of Technology. It was funded by the National Aeronautics and Space Administration (NASA) Advanced Information Systems Technology (AIST) Program under grant number AIST-08-0081.



Presentation Outline

- Motivations and Objectives
 - Application
 - System
- Review: Moving Objects Database Concepts
- System Overview and Status
 - Software Architecture
 - Demo I – Web-based Trajectory Query
 - Demo II – Matlab-based Satellite Data Retrieval
- Future Work



Motivations and Objectives

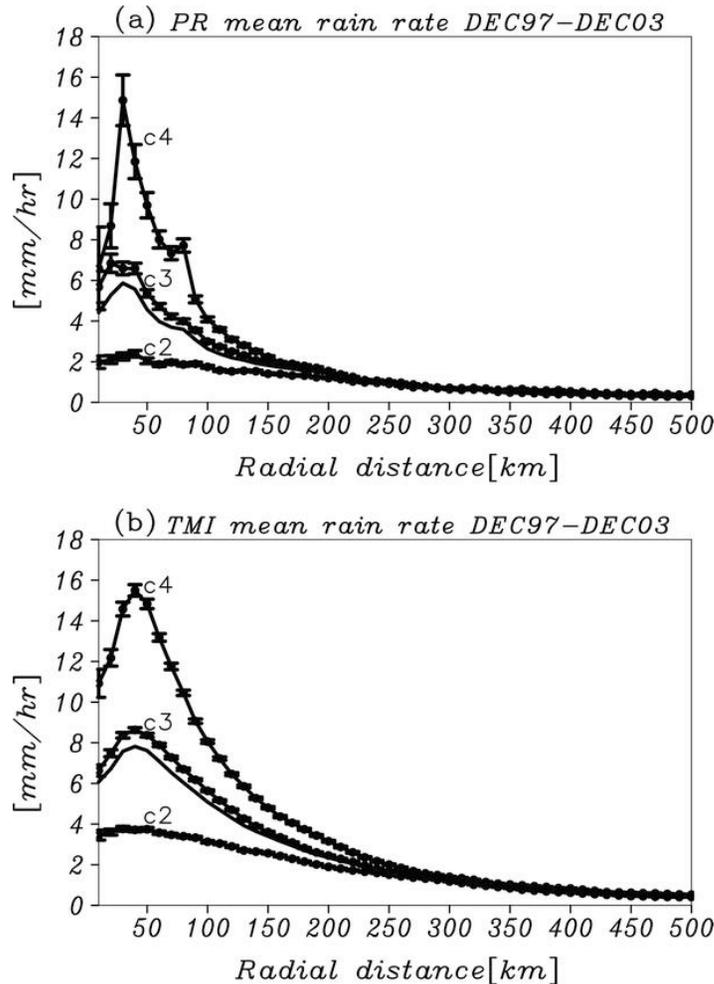


Application Objectives (I)

- Provide the NASA workforce with previously unavailable data(base) management, analysis, and query capabilities that will advance the research and understanding of dynamic weather events based on data derived from the NASA mission sensor measurements
- Focus on **tropical cyclone** events
- Our technology will provide both Earth Science researchers and non-scientist decision makers with the capability to
 - **ad-hoc query for dynamic atmospheric events and their related information, and**
 - **easily retrieve satellite data for scientific analysis.**



Application Objectives (III)



1-D Composite Data Analysis

“List all tropical cyclones from December 1997 to December 2003. Retrieve related TRMM 2A25 and 2A12.” and 563 tropical cyclones retrieved with 3703 TRMM satellite data snapshots.

Radial distributions of mean rain rates (derived from (a) PR and (b) TMI) at the “mature” stage. (Chie Yokoyama and Yukari N. Takayabu, “A Statistical Study on Rain Characteristics of Tropical Cyclones using TRMM Satellite Data”, Monthly Weather Review, vol. 136, pp. 3848--3862, Oct. 2008.



Application Objectives (IV)

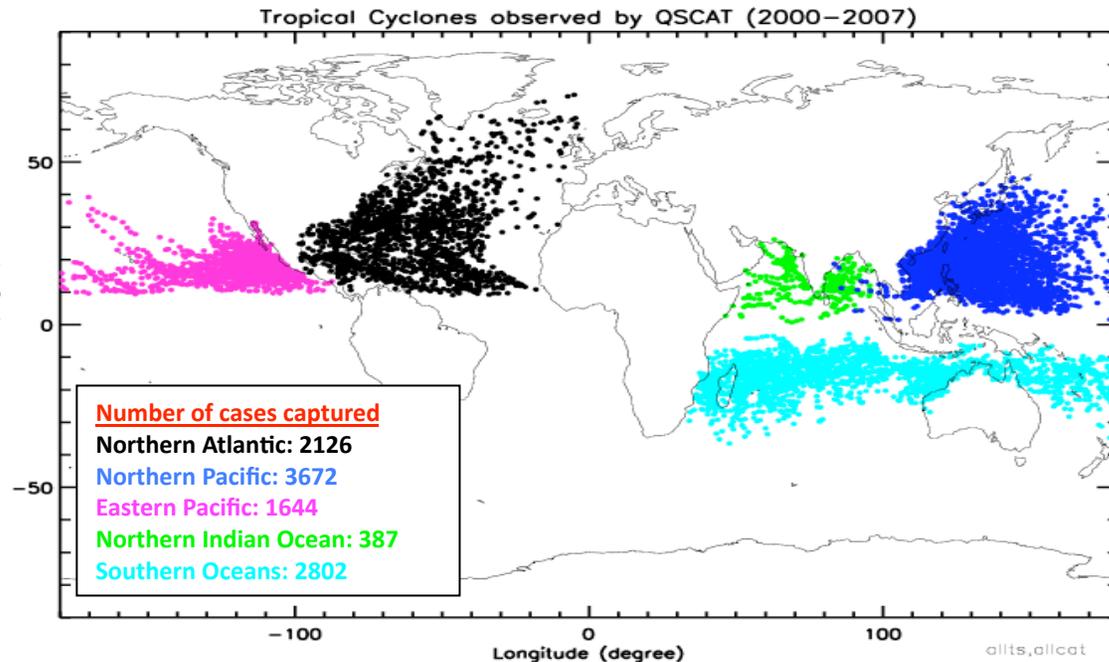
Tang, W. and W. T. Liu, 2010: Effect of Wind Stress Asymmetry in Typhoon Intensity Changes. *2010 Ocean Science Meeting*, February 19-24, 2010, Portland, Oregon.

Liu, W.T. and W. Tang, 2009: Hurricane Asymmetry Revealed by a Decade of Spacebased Measurements. *2nd International Summit on Hurricanes and Climate Change*. Corfu, Greece, May 31 - June 5, 2009.

Tang, W., and W. T. Liu, 2009: Dependence of Hurricane Asymmetry and Intensification on Translation Speed Revealed by a Decade of QuikSCAT Measurements. *NASA Ocean Vector Wind Science Team Meeting*, Boulder, Colorado, May 18-20, 2009.

Tang, W. and W. T. Liu, 2008: Surface Wind/Stress Structure under Hurricanes, *SeaWinds Science Working Team meeting*, Seattle, Washington, November 2008.

“Retrieve QuikSCAT wind vectors and TRMM precipitation data for all tropical cyclones with translation speed faster than 15 meter/second”.

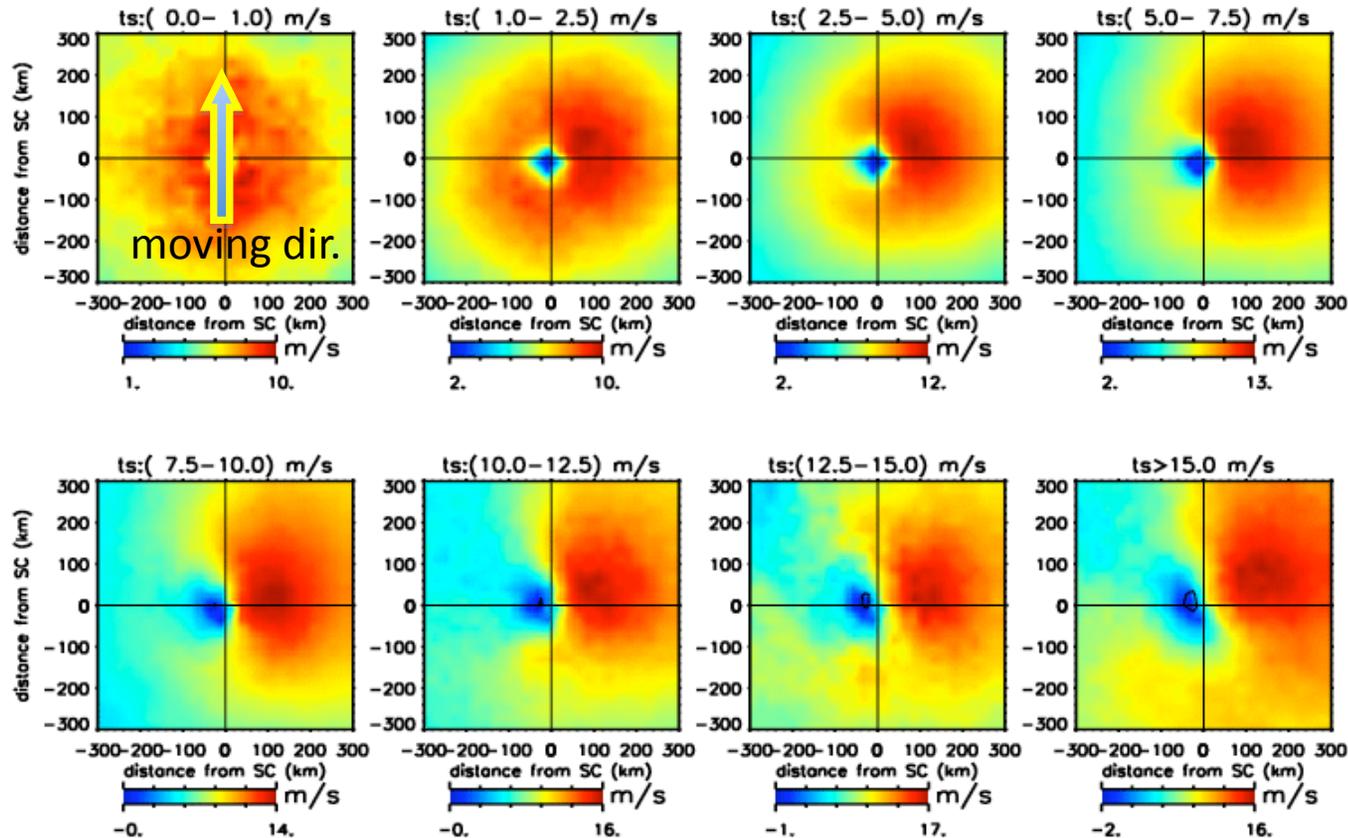




Application Objectives (V)

2-D Composite Data Analysis

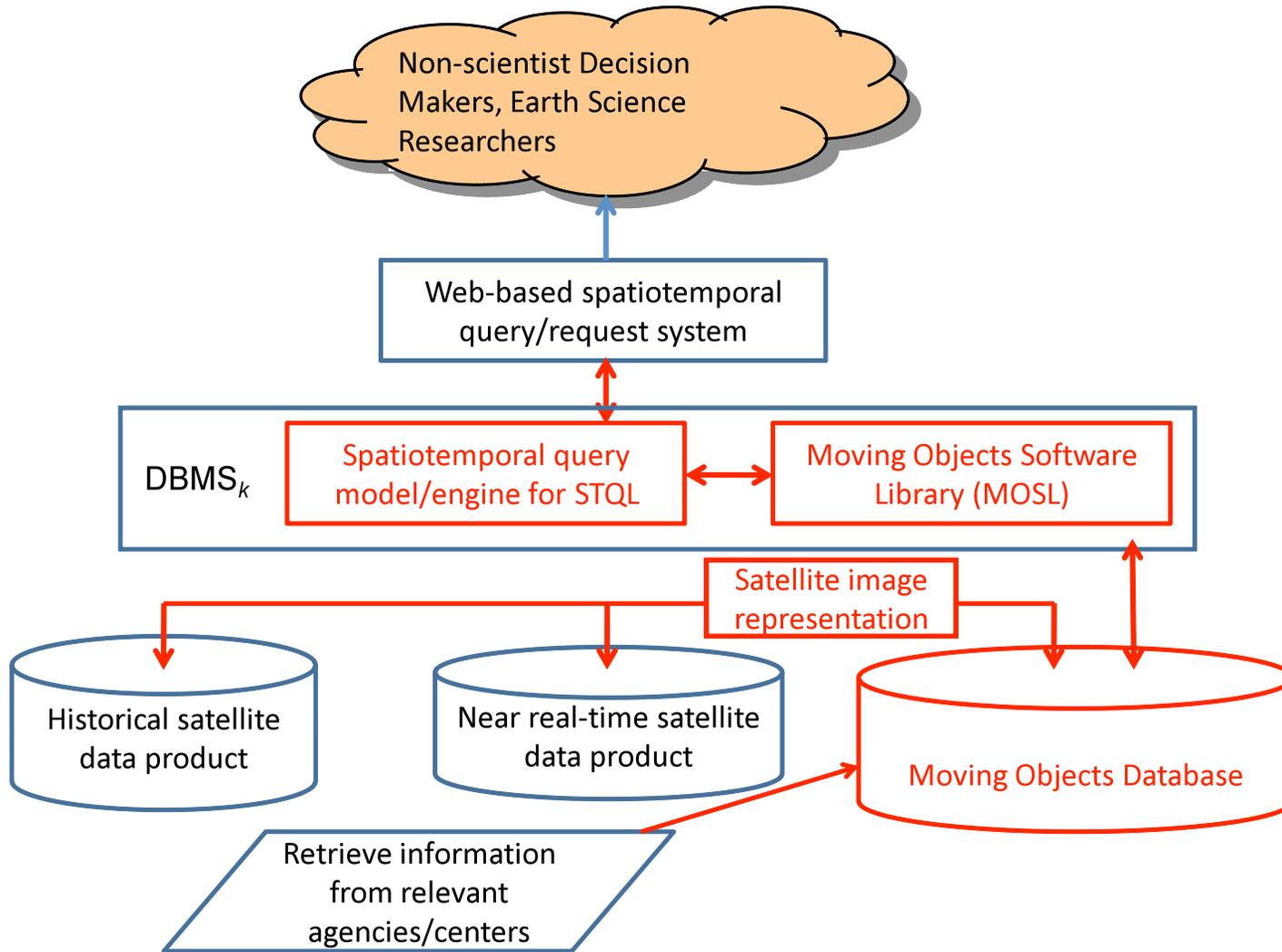
Composite QSCAT wind relative to storm center (2000_2007):nhemis,ton,allcat



The tangential component is near symmetric for slow-moving storms. The left-right asymmetry induced by and becomes stronger for fast-moving storms. Asymmetry increases with translation speed and is associated with the weakening of tropical cyclones



System Objectives (I)





System Objectives (II)

Moving Objects Database (MOD)

- keeps tropical cyclone and hurricane data provided by public sources and web sites in a centralized repository.
- is a full-fledged database with **additional support for spatial and spatiotemporal data in its data model and query language**
- requires an extensible database system

Moving Objects Software Library (MOSL)

- provides the functionality (in terms of types, operations, predicates) that can be deployed by users/scientists in ad hoc queries and in database applications
- provides a spatiotemporal data type system together with a large number of operations (e.g., *Intersection, Union, Difference*) and predicates (*Inside, Meet, Disjoint, Overlaps; Enters, Leaves, Crosses, Bypasses*)
- provides **historical spatiotemporal data types** like *hmpoint, hmline, and hmregion*
- can be integrated into *extensible databases*
- is *database-independent* and *application-neutral*



System Objectives (III)

Spatiotemporal Query Language (STQL)

- provides the communication interface between the moving objects database for tropical cyclone data and the user/scientist
- enables users to pose *ad hoc spatiotemporal queries on moving objects* in general and tropical cyclone data in particular
- allows users to obtain immediate response

Satellite Data Retrieval (SDR)

- take output trajectory information from user queries as input for satellite data retrieval
- Enable users to manipulate satellite data for future data analysis



Review: Moving Objects Database Concepts



Review: Moving Objects Database Concepts (I)

A **moving object** represents the *continuous* evolution of a spatial object over time.

Classification of moving objects

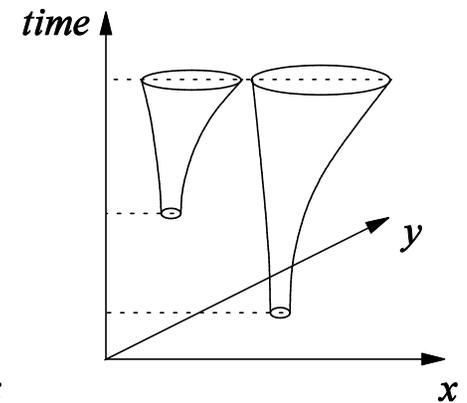
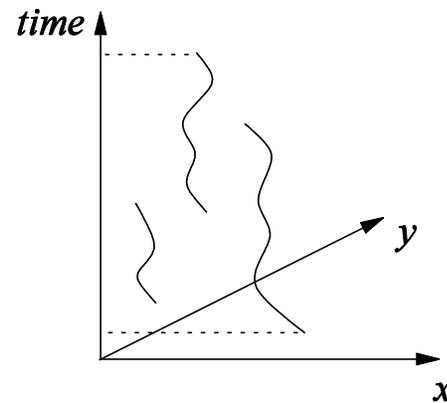
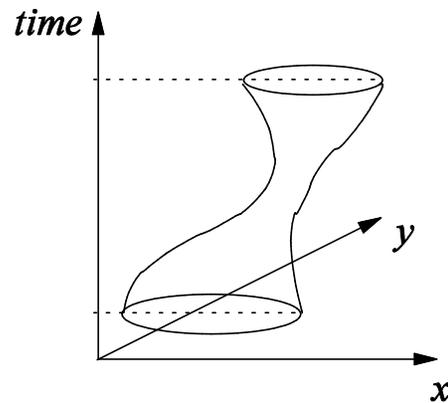
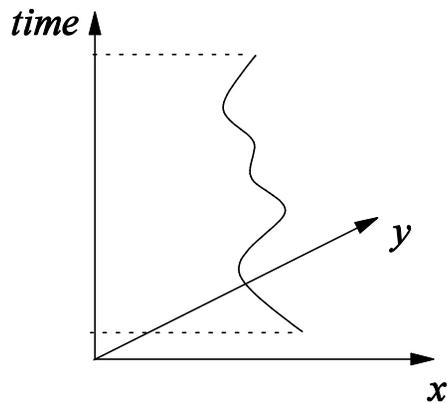
- Category 1: **Moving points**
 - Only time-dependent location is of interest
 - Examples: cell phone users, cars, terrorists, whales
- Category 2: **Moving region**
 - Also the time-dependent shape and/or areal extent is of interest
 - Examples: hurricanes, forest fires, oil spills, diseases, glaciers
- Category 3: **Moving line**
 - the time-dependent shape and/or linear extent is of interest
 - Examples: traffic jam, front of an army; boundary of any moving region



R

review: Moving Objects Database Concepts (II)

- Formally: Let $\mathbb{W} \subseteq \{point, line, region\}$. Then a moving object m is a function of a **spatiotemporal data type** $\mathbb{W}(\mathbb{W}) = time \times \mathbb{W}$.
 - $m_{point} = \mathbb{W}(point) = time \times point$
 - $m_{line} = \mathbb{W}(line) = time \times line$
 - $m_{region} = \mathbb{W}(region) = time \times region$





Review: Moving Objects Database Concepts (III)

- Spatiotemporal operations and spatiotemporal predicates embedded into a Spatiotemporal Query Language called STQL
- Query 1: “Determine the total size of the forest areas destroyed by the fire called “The Big Fire”.
- `forest(forestname:string, Territory:hmregion)`
`forest_fire(firename:string, Extent:hmregion)`
- ```
SELECT sum(size) FROM
 (SELECT size AS area(traversed(
 Intersection(Territory, Extent)))
 FROM forest fire, forest
 WHERE firename = "The Big Fire" AND
 Ever(Intersects(Territory, Extent)))
```

- In database terms: spatiotemporal<sup>15</sup> join



## R

### Review: Moving Objects Database Concepts (IV)

- Query 2: “Find all planes that ran into a hurricane.”
- `flights(id:string, Route:hmpoint)`  
`weather(kind:string, Extent:hmregion)`
- ```
SELECT id
FROM   flights, weather
WHERE  kind = "hurricane" AND
      Route Disjoint>>meet>>Inside Extent
```



Review: Moving Objects Database Concepts (V)

Why Moving Objects Database?

- Representing and storing moving entities in (standard) database system using spatiotemporal data types
- A collection of comprehensive spatiotemporal operations and predicates to query moving entities.
- Efficient ad-hoc query on moving entities.



System Overview and Status



Sys tem Overview and Status (I) - Software Architecture

- Exploration of database systems

W

with extensibility features appropriate and needed for implementing MOSL

- Needed features

- B
LO
B

(Binary Large Object) data type for representing values/objects of arbitrary length

- UDTs and UDFs for the
specificatio
n

and external binding of user-defined data types and functions implemented in MOSL

- Appropriate DBS: Oracle, Informix; PostgreSQL

- BLOB data type

- is
a
bu

uilt-in data type in SQL and represents arbitrarily long, finite *byte strings* (4GB)

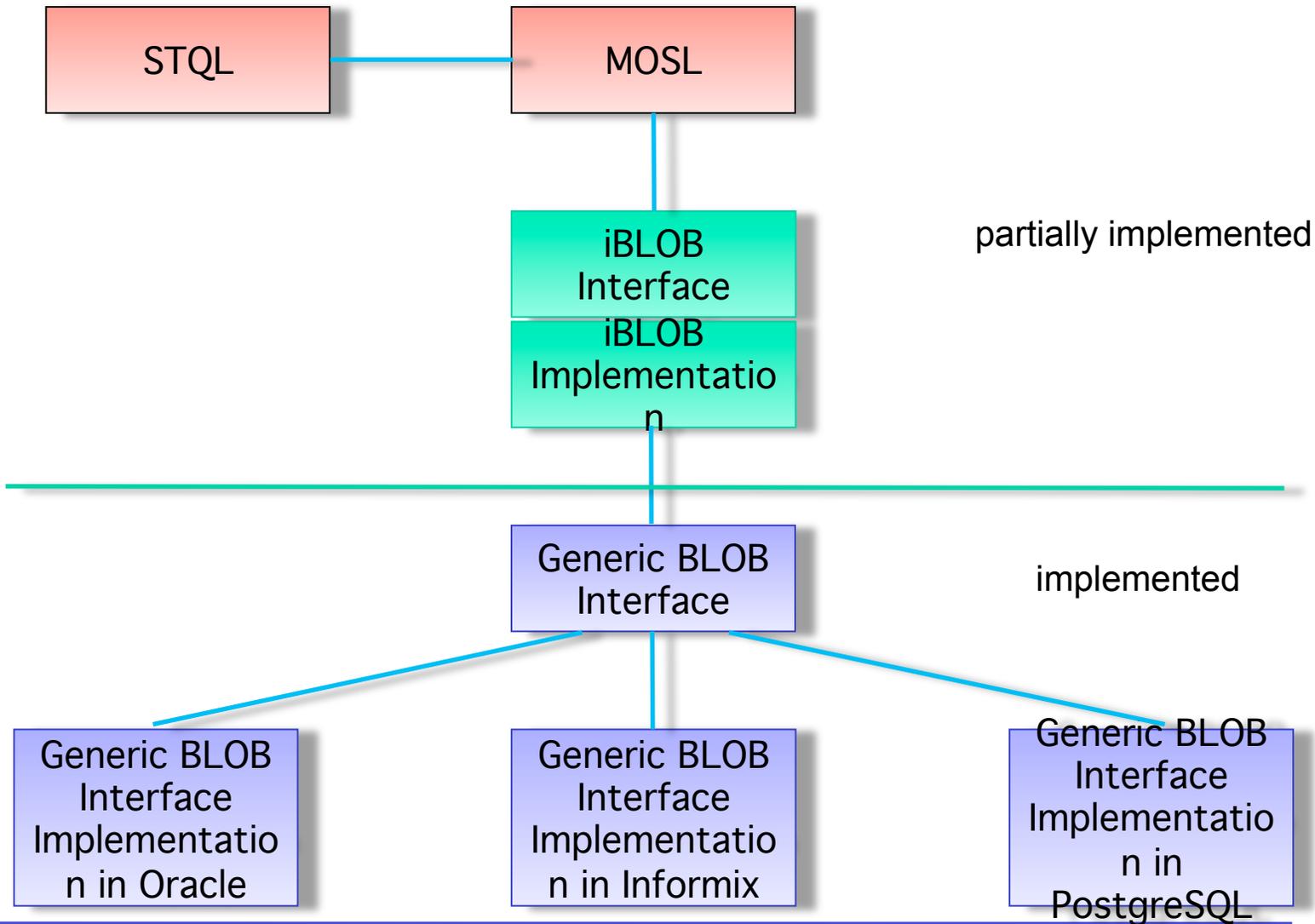
- is used for representing complex application objects

of
lar
g

e and/or varying length (e.g. spatial image, DNA, video, multimedia objects)



Sys tem Overview and Status (II) - Software Architecture





System Overview and Status (III) - Software Architecture

- Generic BLOB Interface
 - is database system independent
 - makes all components built on top of it database system independent
- User-defined data type iBLOB
 - **iBLOB = Intelligent Binary Large Object**
 - implemented on top of the generic BLOB interface
 - enables *random read access* to the conceptual components of a *complex application object* without understanding their meaning
 - enables *random updates* of application objects
 - Not necessary to load a complex application object completely into main memory
 - Two main parts
 - **Structure index** represents the hierarchical structure of the application object
 - **Sequence index** maintains the logical sequential order of components stored in the structure index and supports updates



System Overview and Status (IV) - Demo I

- **Moving Objects Software Library (MOSL)**
 - provides a first implementation of the data type **hmpoint** for historical moving point objects
 - offers a few spatiotemporal operations on historical moving point objects
- **Spatiotemporal Query Language (STQL)**
 - enables the embedding of spatiotemporal operations and predicates into an extension of SQL
 - allows the execution of spatiotemporal queries
- **Simple Query Tool and Visualization Tool**
 - Query tool for posing STQL queries
 - Web-based and Google Map-based visualization tool
 - ❖ for showing the results of STQL queries (trajectories) with Google maps as background
 - ❖ providing the full functionality of Google maps like zooming, tagging, etc.



System Overview and Status (V) - Demo I

Step 1: User Input STQL query

Search | STQL

STQL is a spatial-temporal query language, which enables users to pose ad hoc queries.

```
SELECT r.id, r.sname, r.geoshape, m.name, m.track
from usmap r, test_moving m
where m.name='KATRINA' and
is_cross(m.track, r.geoshape)=1
```

plot on map

Submit Query

Step 2: Push "Submit Query" button and result plotted.

Moving Object Database GUI
for weather event analysis and tracking

Map Visualization

Map | Satellite | Hybrid

8 rows retrieved.



System Overview and Status (VI) - Demo I

Applications Places System 10:30 AM

AIST Maps GUI - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://berlin.dbcenter.cise.ufl.edu/AIST_WEB/ Google

Most Visited Red Hat Red Hat Magazine Red Hat Network Red Hat Support

Moving Object Database GUI

for weather event analysis and tracking

Search STQL

[Back](#)

Below is a list of prepared queries

- [Find all hurricanes that have crossed Louisiana state](#) [STQL]
- [Find all US states that have been affected by the hurricane KATRINA](#) [STQL]
- [Find all states that have been crossed by all hurricanes that last longer than 10 days](#) [STQL]
- [Find US states that have never been affected by any hurricanes in 2005](#) [STQL]
- [Find all hurricanes with life time longer than 7 days](#) [STQL]
- [Find the average life time of all hurricanes](#) [STQL]
- [Find all hurricanes that have their life time overlap with hurricane OPHELIA](#) [STQL]
- [Find all hurricanes that exist during the life time of hurricane OPHELIA](#) [STQL]

Map Visualization

Map Satellite Hybrid

m.name: CINDY
r.id: 18

Map data ©2010 AND, Europa Technologies, INEGI, MapLink, Tele Atlas - Terms of Use

Data Table

3 rows retrieved.

Done

[sho@lmc-0069...] [MATLAB 7.8.0 (...)] [Command Win...] [Workspace] [Editor - /usr/loc...] AIST Maps GUI - ... Starting Take Scr...



System Overview and Status (VII) - Demo I

Applications Places System 10:36 AM

AIST Maps GUI - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://berlin.dbcenter.cise.ufl.edu/AIST_WEB/ Google

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- [Find all hurricanes that have their life time overlap with hurricane OPHELIA](#) [STOLI]
- [Find all hurricanes that exist during the life time of hurricane OPHELIA](#) [STOLI]
- [Find all hurricanes that exist prior to hurricane OPHELIA](#) [STOLI]

Map data ©2010 AND, Geocentre Consulting, MapData Sciences Pty Ltd, PSMA, MapLink, Tele Atlas, Terms of Use

Data Table

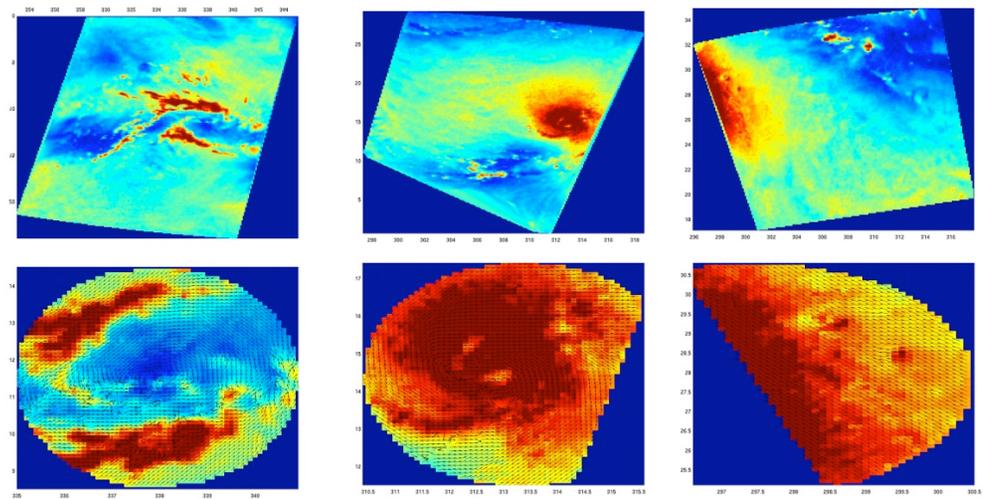
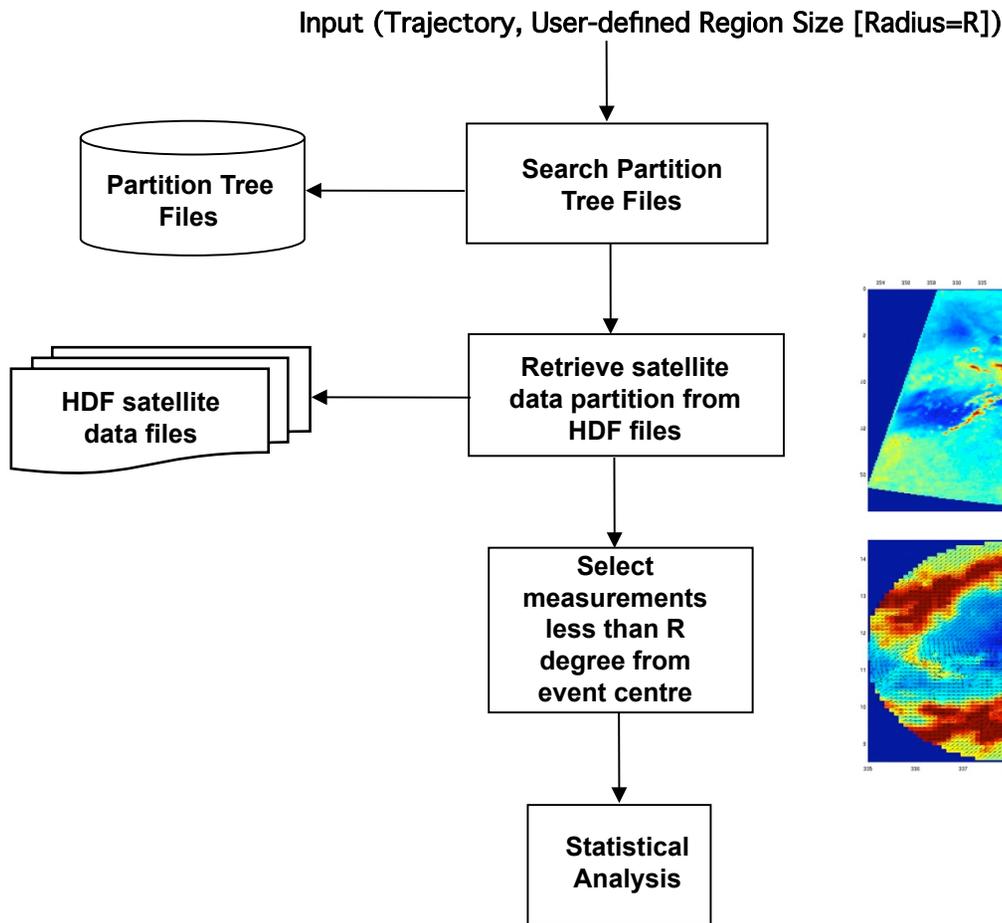
m2.name : VARCHAR2	m1.name : VARCHAR2	m2.track : MPOINT	m1.track : MPOINT
OPHELIA	MARIA	MPOINT0	MPOINT0
OPHELIA	NATE	MPOINT0	MPOINT0
OPHELIA	PHILIPPE	MPOINT0	MPOINT0
OPHELIA	RITA	MPOINT0	MPOINT0

Done

[sho@lmc-0069...] [MATLAB 7.8.0 (...)] [Command Win...] [Workspace] [Editor - /usr/loc...]



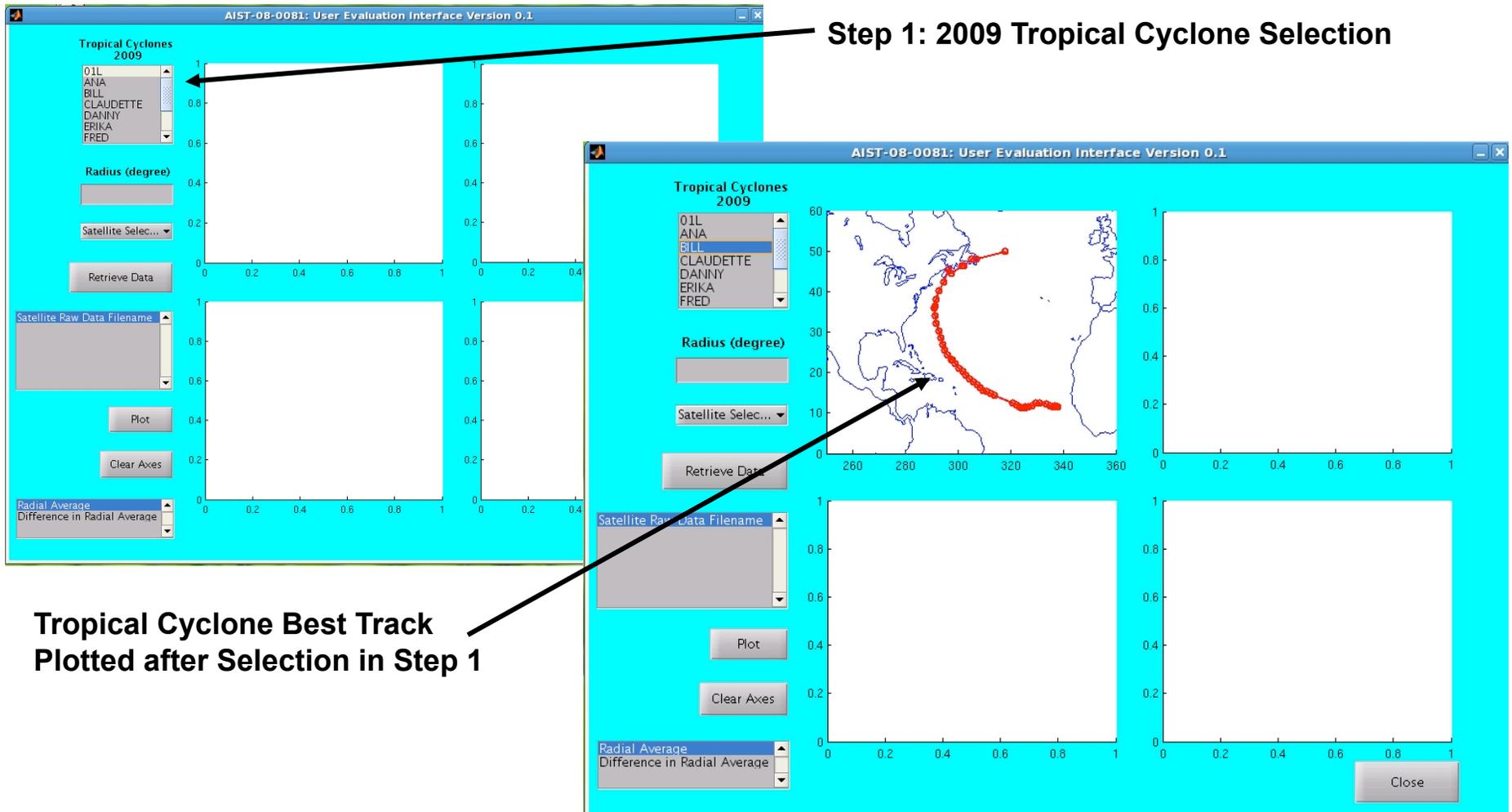
System Overview and Status (VIII) - Demo II





System Overview and Status (IX) - Demo II

GUI DEMO Snapshots



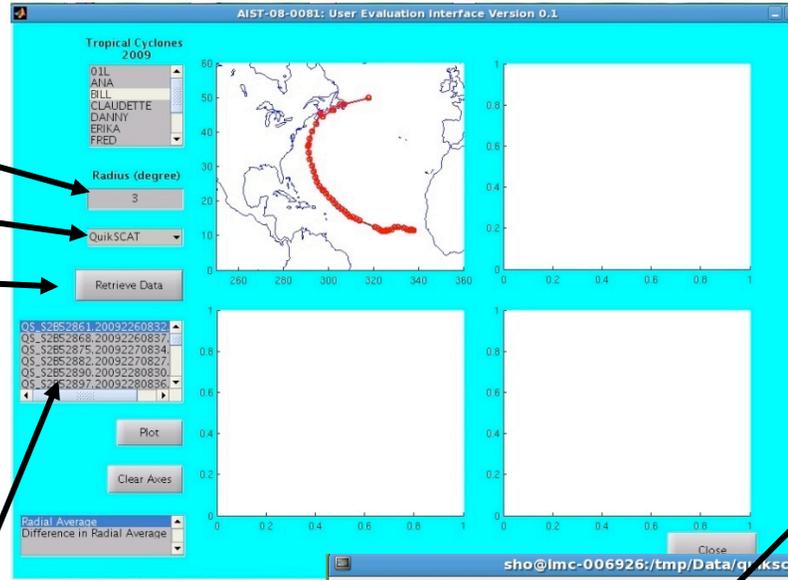


System Overview and Status (X) - Demo II

Step 2: User Specifies Radius in degree

Step 3: User Specifies Mission (Satellite)

Step 4: Push "Retrieve Data" Button to retrieve data based on user-defined tropical cyclone trajectory and radius parameter



Satellite Data (HDF format) stored in local file systems

```
Command Window
File Edit Debug Desktop Window Help
New to MATLAB? Watch this Video, see Demos, or read Getting Started.
updating.....
No data points in user-defined region
updating.....
updating.....
updating.....
updating.....
updating.....
fx >>
```

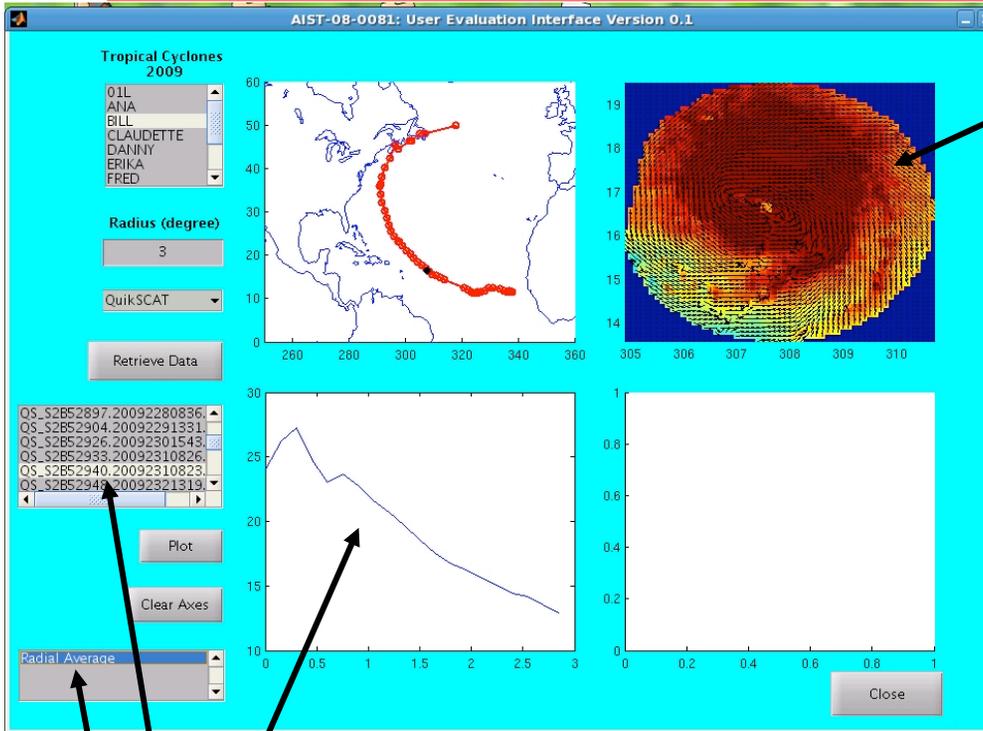
Filename corresponding to retrieved data.

Data based on user-defined trajectory and radius parameters retrieved on-demand from local file system

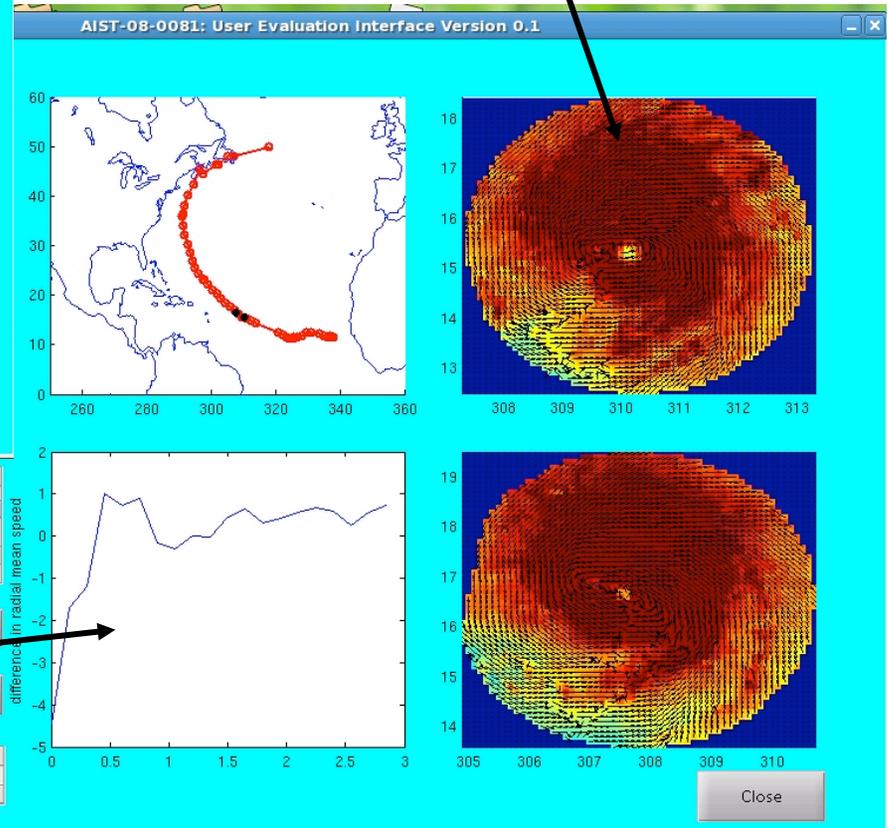
```
sho@lmc-006926:/tmp/Data/quikscat/225
File Edit View Terminal Tabs Help
[sho@lmc-006926 quikscat]$ ls
140 152 164 176 188 200 212 224 236 249 261 273 285 297 309 321
141 153 165 177 189 201 213 225 237 250 262 274 286 298 310 322
142 154 166 178 190 202 214 226 238 251 263 275 287 299 311 323
143 155 167 179 191 203 215 227 239 252 264 276 288 300 312 324
144 156 168 180 192 204 216 228 240 253 265 277 289 301 313 325
145 157 169 181 193 205 217 229 241 254 266 278 290 302 314
146 158 170 182 194 206 218 230 242 255 267 279 291 303 315
147 159 171 183 195 207 219 231 243 256 268 280 292 304 316
148 160 172 184 196 208 220 232 244 257 269 281 293 305 317
149 161 173 185 197 209 221 233 245 258 270 282 294 306 318
150 162 174 186 198 210 222 234 246 259 271 283 295 307 319
151 163 175 187 199 211 223 235 248 260 272 284 296 308 320
[sho@lmc-006926 quikscat]$ cd 225
[sho@lmc-006926 225]$ ls
QS_S2B52857.20092260832.CP12 QS_S2B52864.20092260832.CP12
QS_S2B52858.20092260831.CP12 QS_S2B52865.20092260836.CP12
QS_S2B52859.20092260827.CP12 QS_S2B52866.20092260836.CP12
QS_S2B52860.20092260831.CP12 QS_S2B52867.20092260847.CP12
QS_S2B52861.20092260832.CP12 QS_S2B52868.20092260837.CP12
QS_S2B52862.20092260833.CP12 QS_S2B52869.20092260837.CP12
QS_S2B52863.20092260823.CP12 QS_S2B52870.20092261026.CP12
[sho@lmc-006926 225]$
```



System Overview and Status (XI) - Demo II



Step 6: Push "Plot" button to plot retrieved measurements.



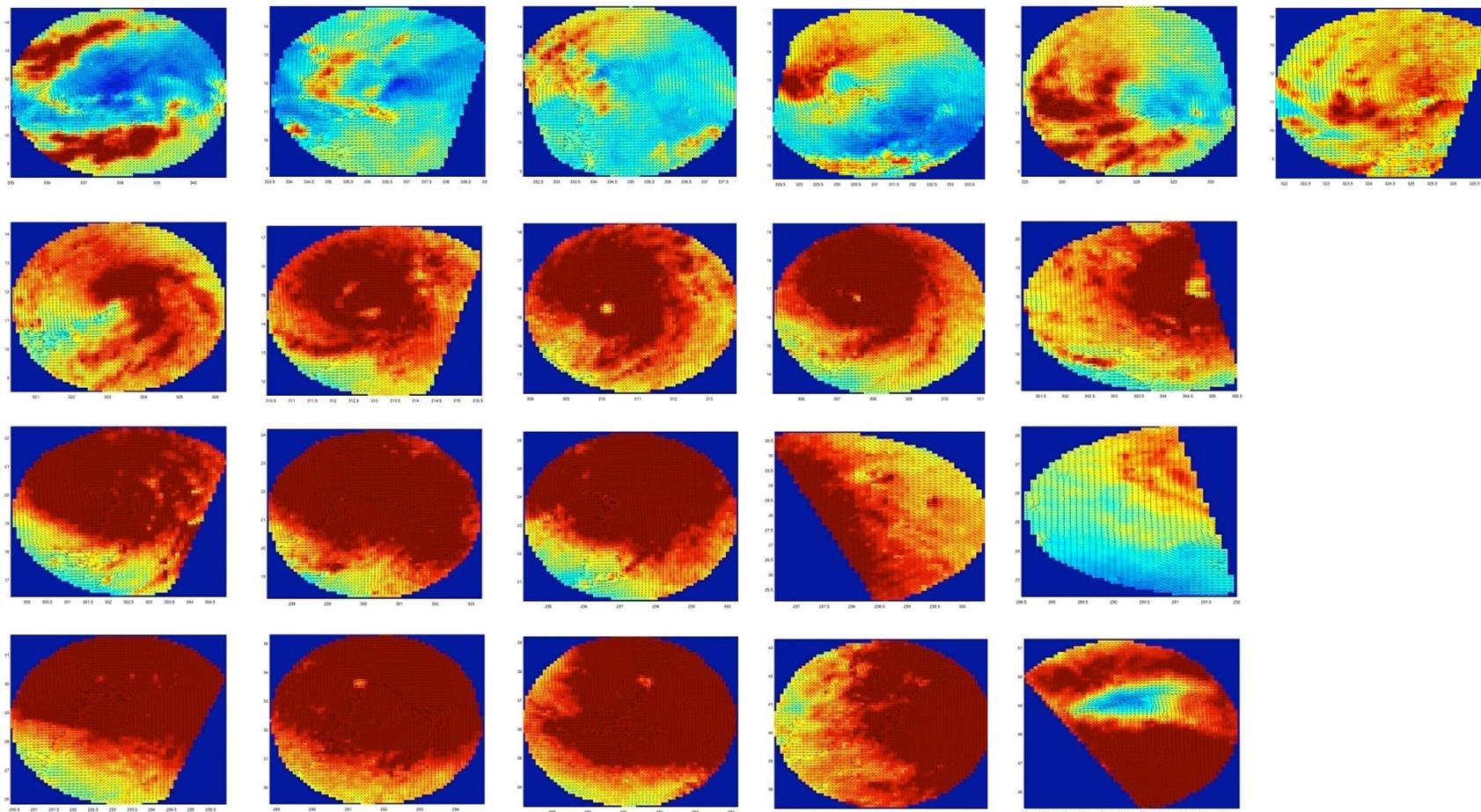
Step 5: User selects filename(s)

Step 7: Select Statistical Analysis Options of measurements and Plot Results



System Overview and Status (XII) - Demo II

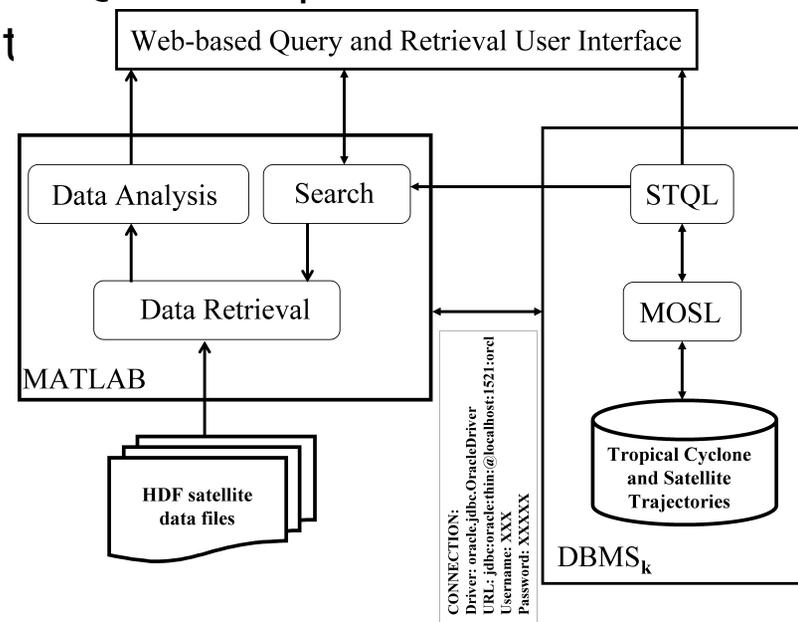
QuikSCAT Data Retrieved for Hurricane Bill 2009 and R = 3





Future Work

- Populating the Moving Objects Database with global tropical cyclone trajectories from 2000-2009, QuikSCAT and TRMM trajectory data
- Integrating/Connecting Satellite Data Retrieval on Matlab to Oracle-based moving objects database.
- Exploration of other integration alternatives
- Continuation of MOSL and STQL development
- Implementation of a protot





Publications

- Shen-Shyang Ho, Wenqing Tang, W. Timothy Liu, and Markus Schneider. A Framework for Moving Sensor Data Query and Retrieval of Dynamic Atmospheric Events. *22nd Int. Conf. on Scientific and Statistical Database Management (SSDBM)*, Heidelberg, Germany, June 30-July 2, 2010.
- Shen-Shyang Ho, Wenqing Tang, and W. Timothy Liu. Tropical Cyclone Event Sequence Similarity Search via Dimensionality Reduction and Metric Learning, *16th ACM SIGKDD Int. Conf. on Knowledge Discovery and Data Mining (KDD)*, Washington, DC, July 25-28, 2010.
- **Reference:** R. Guting and M. Schneider, *Moving Objects Databases*. Morgan Kaufmann Publications, 2005.