## Mojette day

Retrieval of rainfall fields over urban areas using tomographic processing from microwave communication links.

**Bahtiyor ZOHIDOV** 

PolyTech Nantes, February 5, 2015







ARCHITECTURALES ET URBAINES



### Little about me...





## Accurate rainfall measurement is always problematic... The reason: It is highly variable in space and time.













MetOp Series

OAA)

Arthur Hou 1 July 2011

(JAXA)

Author: Jade, August 23, 2014

## Why cellular network antennas...?

- ✓ Antennas are very close to the ground
- ✓ Dense in cities (covers ~90 % of worlds population)
- Operating at high frequencies where rain is a major source of signal loss

Transmitter	Receiver
transmission Attenuation of the signal	
Path length	
	-

### Motivation...





Author: Jade, August 23, 2014



## **Our simulation framework**



### Cellular companies antennas in Nantes



b. Commercial microwave links at 18, 23 and 38 GHz over the urban area of Nantes, 2014.



page. 12

3. SOCIÉTÉ FRANÇAISE DU RADIOTÉLÉPHONE (SRF)

## Our simulation framework



## Our simulation framework

1. Approach 2. Study area Mobile Nantes **Network Antennas** Rainfall estimation 4. Algorithm 3. Data 1) Mojette Transform Signal attenuation due to rainfall 2) Statistical inverse

### Electromagnetic scattering theory is the key point...!







## Our simulation framework





### 1<sup>st</sup> Algorithm: Mojette Transform

- The sampling rate on each projection, which is no longer constant but depends on the chosen angle as  $\frac{1}{\sqrt{p_i^2+q_i^2}}$ .
- The number of bins, B(i), for each projection depends on the chosen direction vector (pi, qi), and for a P × Q image :

$$B(i) = (Q - 1)|p_i| + (P - 1)q_i + 1$$



### Mojette Transform for rainfall...?



### **Challenges in Mojette case**

Ill-posedness, N>M, where, N – number of pixels, M – number of data;

page. 21

• Non-uniform shape of links geometry (more challenging for Mojette);



### **Challenges in Mojette case**

bn bn+1 =? q (p2, q2) bn Receiver (p1, q1) r5 / r1 r2 r3 **r**9 r6 r7 r8 r10 Oops.. How can we continue the r11 r12 r13 blue ray travelling in the green pixels? r7 r8 r18 r19 r16 r17 r13 р Rainmap **Transmitter** 

- Not enough projection "rays";
- Not enough bins for projection (p,q);
- Improper geometry of ray (non-uniform);

page. 23

Rays dont cross the entire area

# So, what to do ?

## Solution: Why not to reconstruct partially? page. 24



Quality map at 2.0 km resolution



### **1. Create subgrids**

2. Get Projection

3. Interpolate

4. Reconstruct

# Choose projections and min number of bins page. 25



qf



### Angular interpolation





### **Apply Mojette Filtered Back Projection**

**1. Create subgrids** 

**2. Get Projection** 

3. Interpolate

4. Reconstruct

### Apply Mojette Filtered Back Project

### Initial results are encouraging from Mojette FBP



### page. 29

### Initial results are encouraging from Mojette FBP



### Evaluation of the model capability/limitations

Root Mean Square Error (RMSE): RMSE = 
$$\sqrt{\frac{1}{n}\sum_{i=1}^{n} (r_i - r_i')^2}$$

	Lightrain	Shower	Organisedstorm	Unorganisedstorm
T1	40	38.84	26.71	35.6
T2	41.76	38.98	40.25	33.93
T3	40.13	39.91	34.45	33.27
T4	39.32	37.78	31.10	33.75
T5	31.81	38.49	41.45	34.01

## 2<sup>nd</sup> Algorithm: Statistical inverse method

Based on: Generalized Nonlinear Least Square method



# 2<sup>nd</sup> Algorithm: Statistical inverse method page. 32

### **Grid Nesting method**



Discretization of microwave link for one pixel at 2, 1, 0.5 km.





### **Results by Statistical Inverse model**

page. 33

#### Estimation at different resolutions: 1, 0.5 km



### **Further work**

page

#### Mojette case:

- To improve subgrid choice procedure
- To improve the way of taking projection using interpolation.
- To apply Spline 0 and compare Angular interpolation
- To apply Iterative Mojette Reconstruction

#### Statistical inverse case

- Has been applied to ~200 rainfall events
- Consistent with radar data.
- Should applied to another cities in France
- Should be compared to Mojette performance

page. 35

# THANKS FOR YOUR ATTENTION

# Do not be angry with the rain; it simply does not know how to fall upwards

### Vladimir Nabokov

