Space Geodesy: applications to New Orleans and the Gulf Coast

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Space Geodesy: What is it?

- **Measurement of position or displacement of the Earth's surface using space based techniques**
- **Contrasts with conventional, ground-based geodesy such as leveling, trilateration, and EDM**

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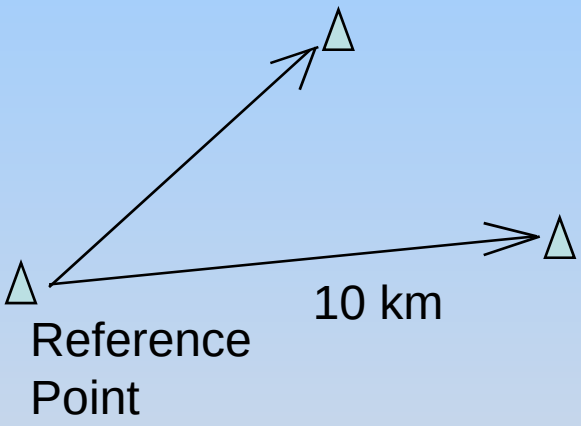

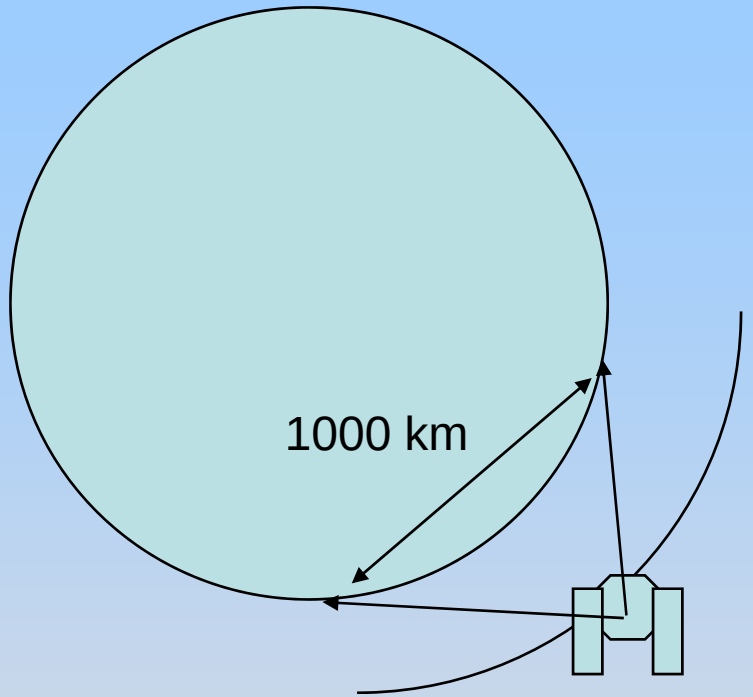

Ground Geodesy

Limited to terrestrial line of site; longer baselines involve summation of measurements & errors

Space Geodesy

Allows long baseline (beyond terrestrial line of site) by exploiting external reference frame (satellites, quasars)

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Space Geodesy:

GPS
VLBI
SLR
DORIS
InSAR

Satellite Microwave Techniques for Space Geodesy

- GPS (high time resolution) & InSAR (high spatial resolution)
- Both techniques use ranging via phase measurement on a carrier signal in the microwave portion of the electro-magnetic spectrum (wavelength 1 - 100 cm)
- Common Themes:
  - Range measurement (time measurement)
  - Phase measurement (’’)
  - Importance of accurate satellite orbit information
  - Earth Orientation, global reference frame (4-D!)

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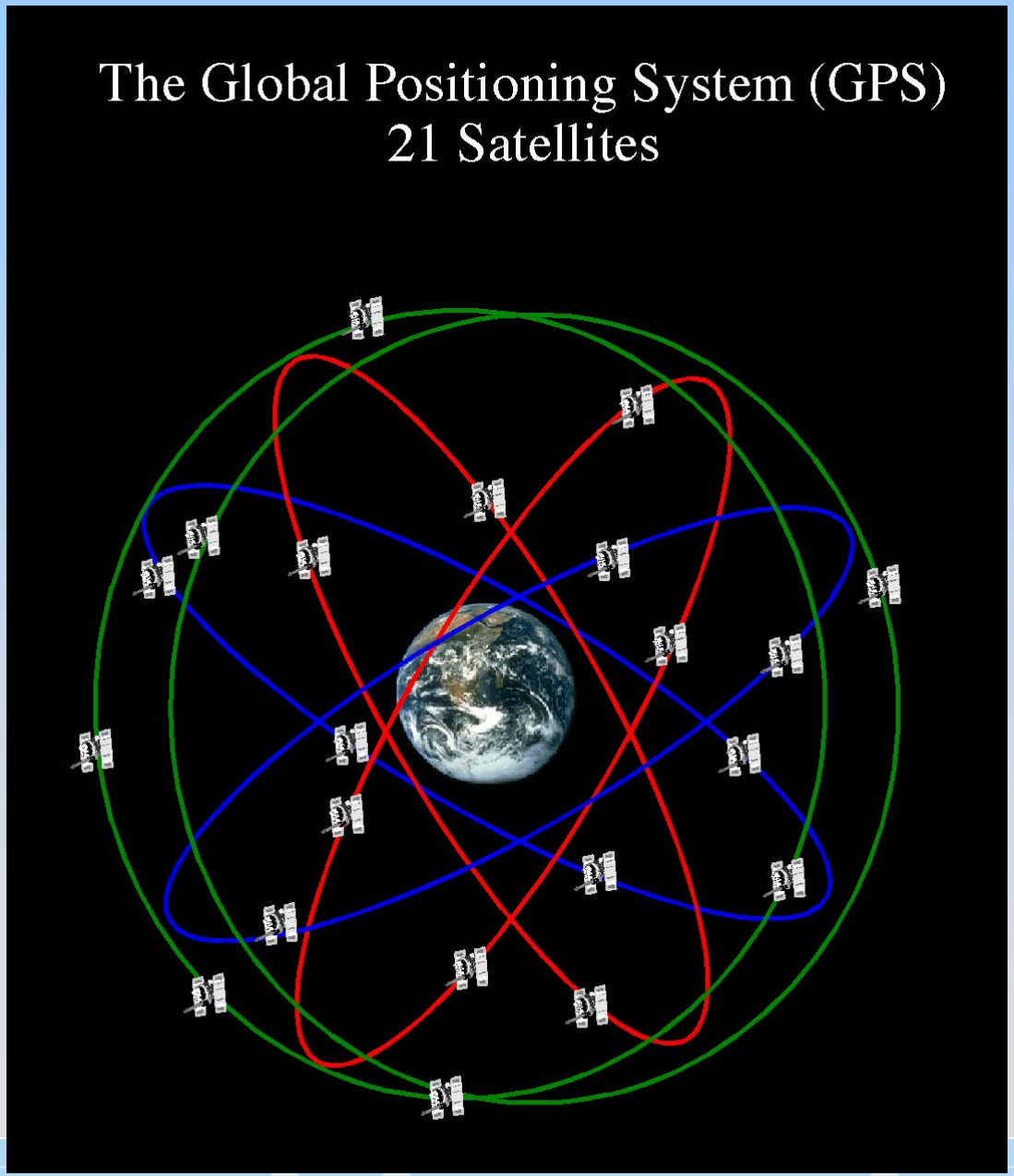
High Precision Geodesy with GPS



- Range to four or more satellites specifies 3D position + clock error
- Use dual frequency to make first order ionosphere correction
- Use precise phase and pseudo-range data to estimate range between satellite and ground point
- Use geophysical models to estimate and correct major error sources (orbits, troposphere, tides)
- Use global network to define global reference frame

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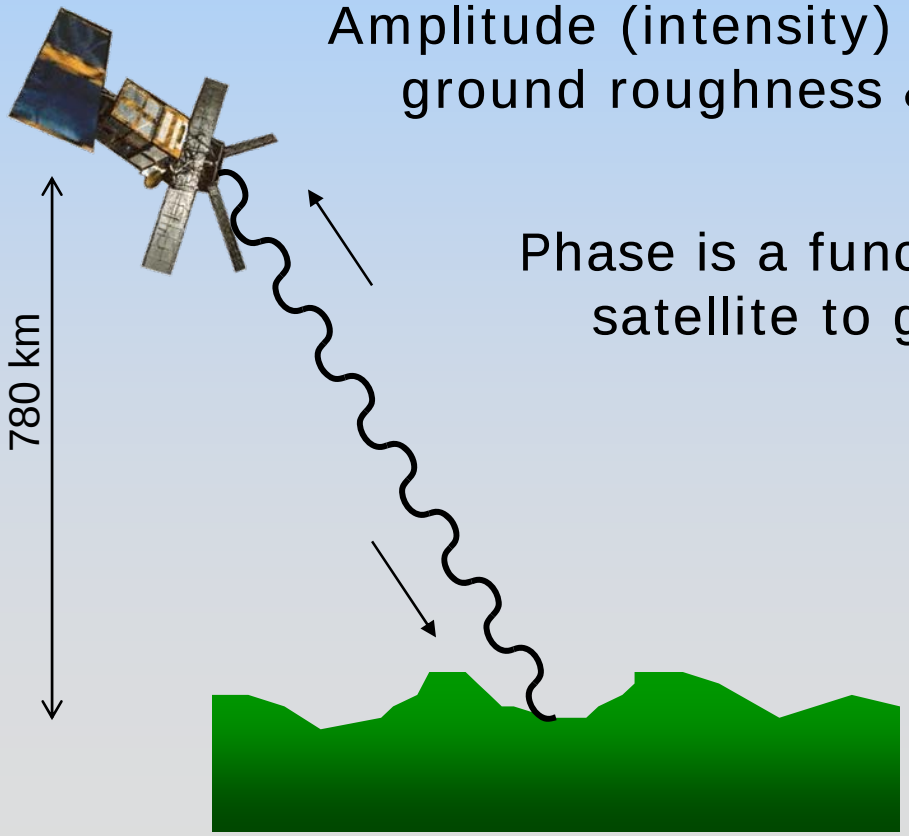
Ground Work
(the need to build a reference mark)

SAR (Synthetic Aperture Radar)

Transmit a pulse of microwave-energy, measure amplitude and phase of reflected signal



Amplitude (intensity) is a mainly a function of ground roughness & incidence angle

Phase is a function of distance from satellite to ground (‘range’)

Satellites: ERS-1,2; JERS
Radarsat; Envisat; ALOS

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InSAR (Interferometric SAR)

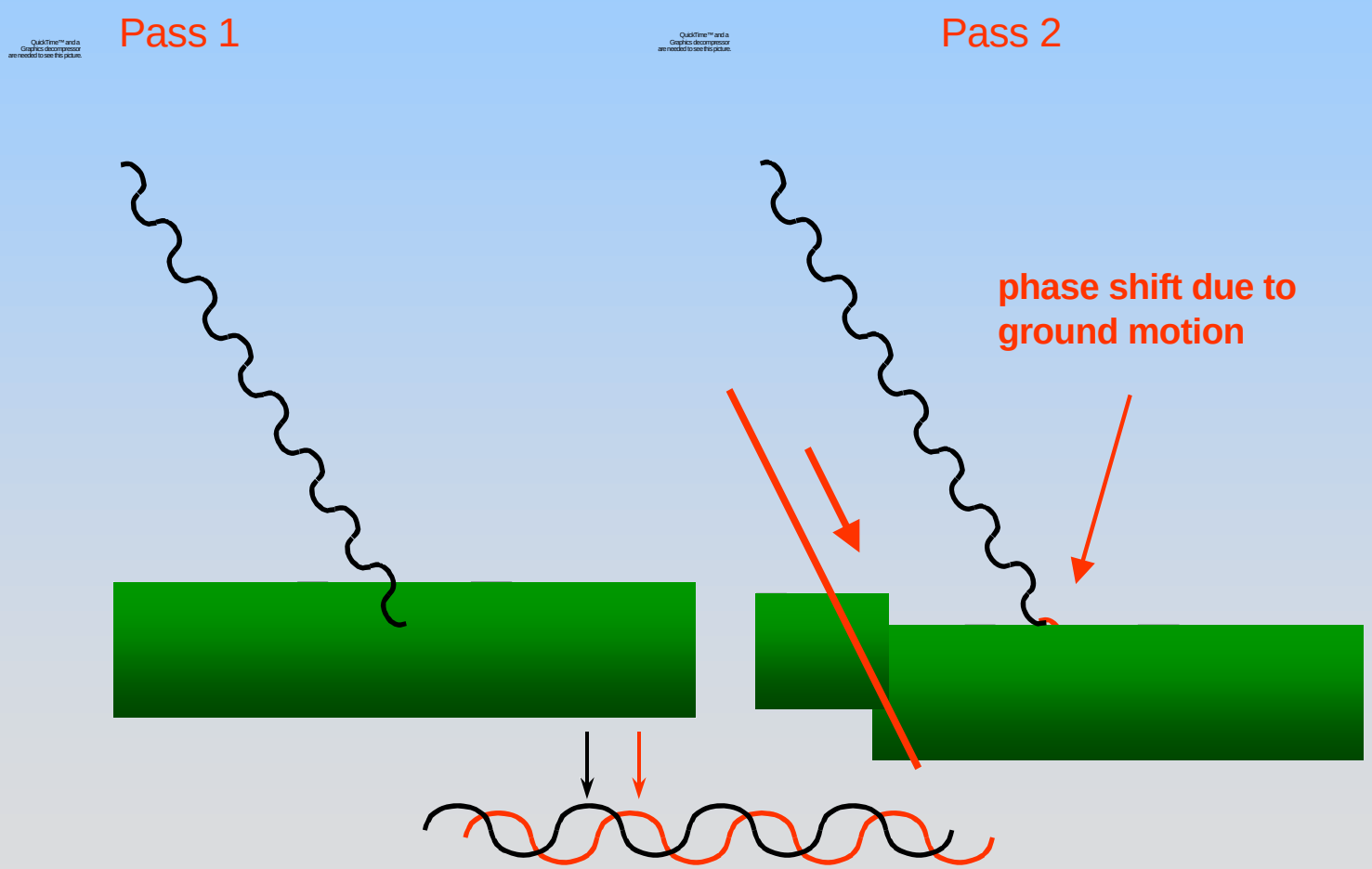

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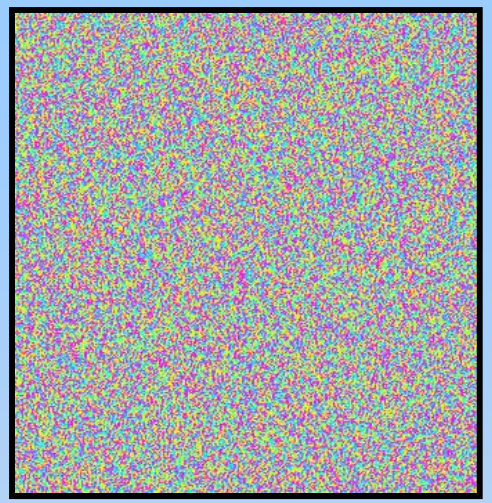
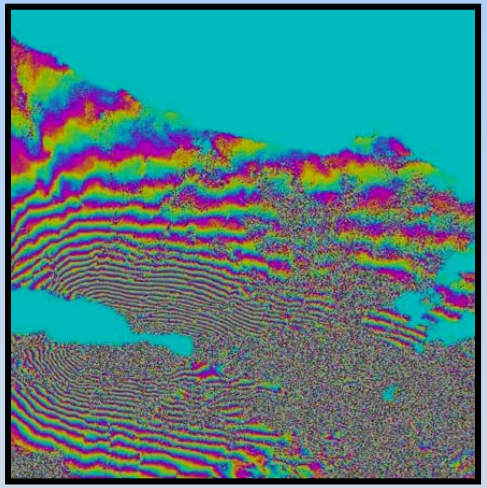
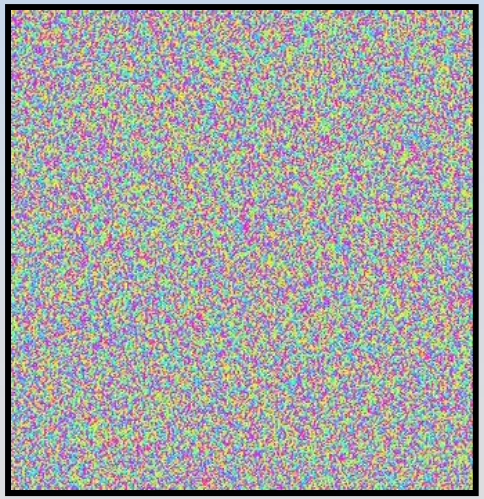
Image A - 12 August 1999



Interferogram =
Phase A - Phase B





Remove phase due to: **topography**
satellite positions
earth curvature

Image B - 16 September 1999

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Applications

- **Subsidence & uplift: Space geodesy is the only reliable way to measure vertical changes of the land surface over large regions**
- **Measures surface change relative to Earth Center of Mass, sea level, or some other useful reference**
- **In contrast, terrestrial techniques like leveling are relative indicators (subsidence with respect to a specific reference benchmark, which may actually be moving) and also suffer from error propagation**
- **MRGO levee example**
- **Can be used to monitor bridges and other transportation infrastructure for long term stability**

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Example: causes of low elevation and flooding in New Orleans?

- **Subsidence: due to combination of effects, exacerbated by anthropogenic intervention in natural system**
- **All deltas subside, but natural sedimentation patterns replenish topmost layer, maintaining height near sea level**
- **Levees restrict natural sedimentation**
- **Can GPS and InSAR identify regions of rapid subsidence, and contribute to better understanding of the Mississippi Delta system?**
- **Can these studies be extended over the entire low-lying Gulf Coast region?**

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InSAR Application: the Advantage of Spatial Resolution

- **Use InSAR to look in detail at pattern of subsidence**

- **Pre-Katrina study: 33 Radarsat scenes, acquired between 2002 and 2005**

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Problem

- **InSAR is sensitive to tropospheric water**

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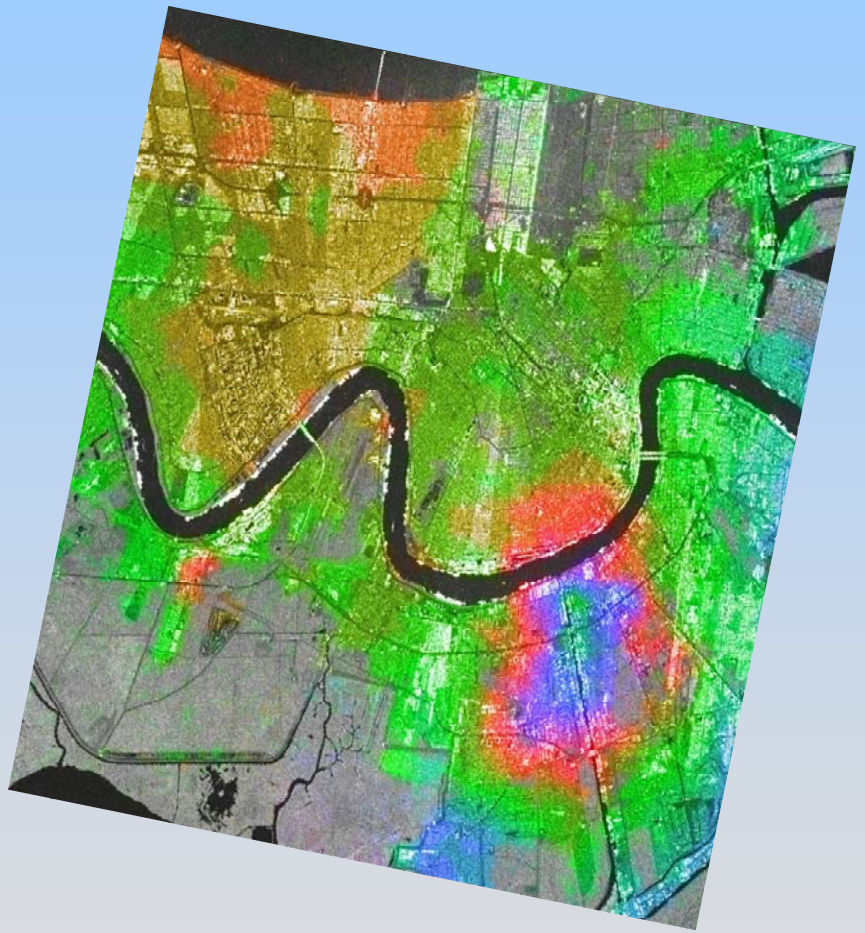
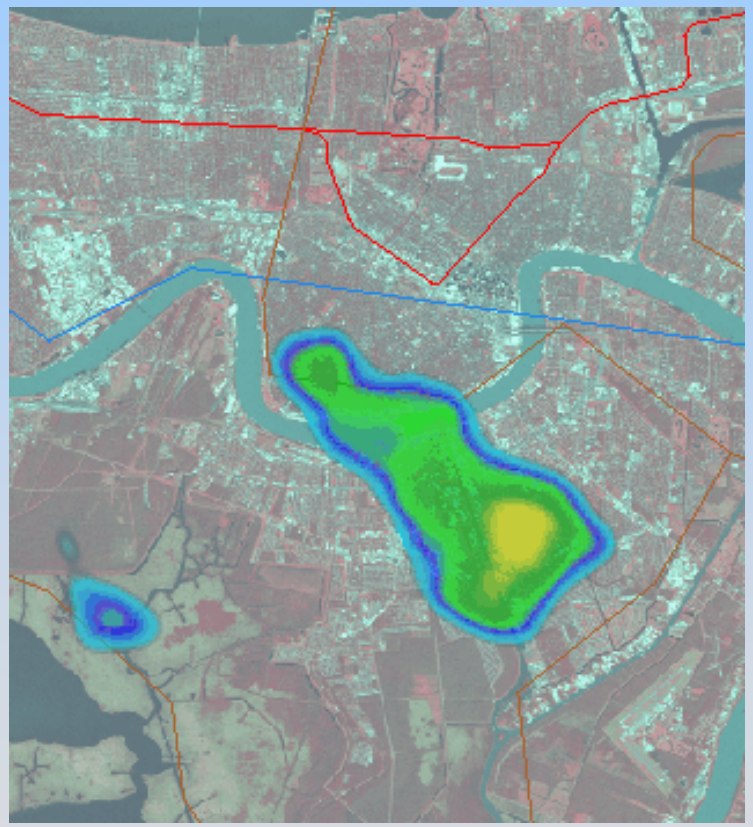
Comparison of InSAR and Nexrad Water Vapor



SAR Image T=0



NEXRAD reflectivity T=+2min

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Solutions

- **Edit the data: only use interferograms from dry season (implies some knowledge of signal)**
- **Stack the interferograms: assume tropospheric noise is random, signal is systematic (random noise is reduced or cancelled in the stack, while signal is additive)**
- **Permanent (or persistent) scatterer interferometry: focus on strong (radar-bright) scatterers**
- **Use only short time span interferograms (1 month or less)**

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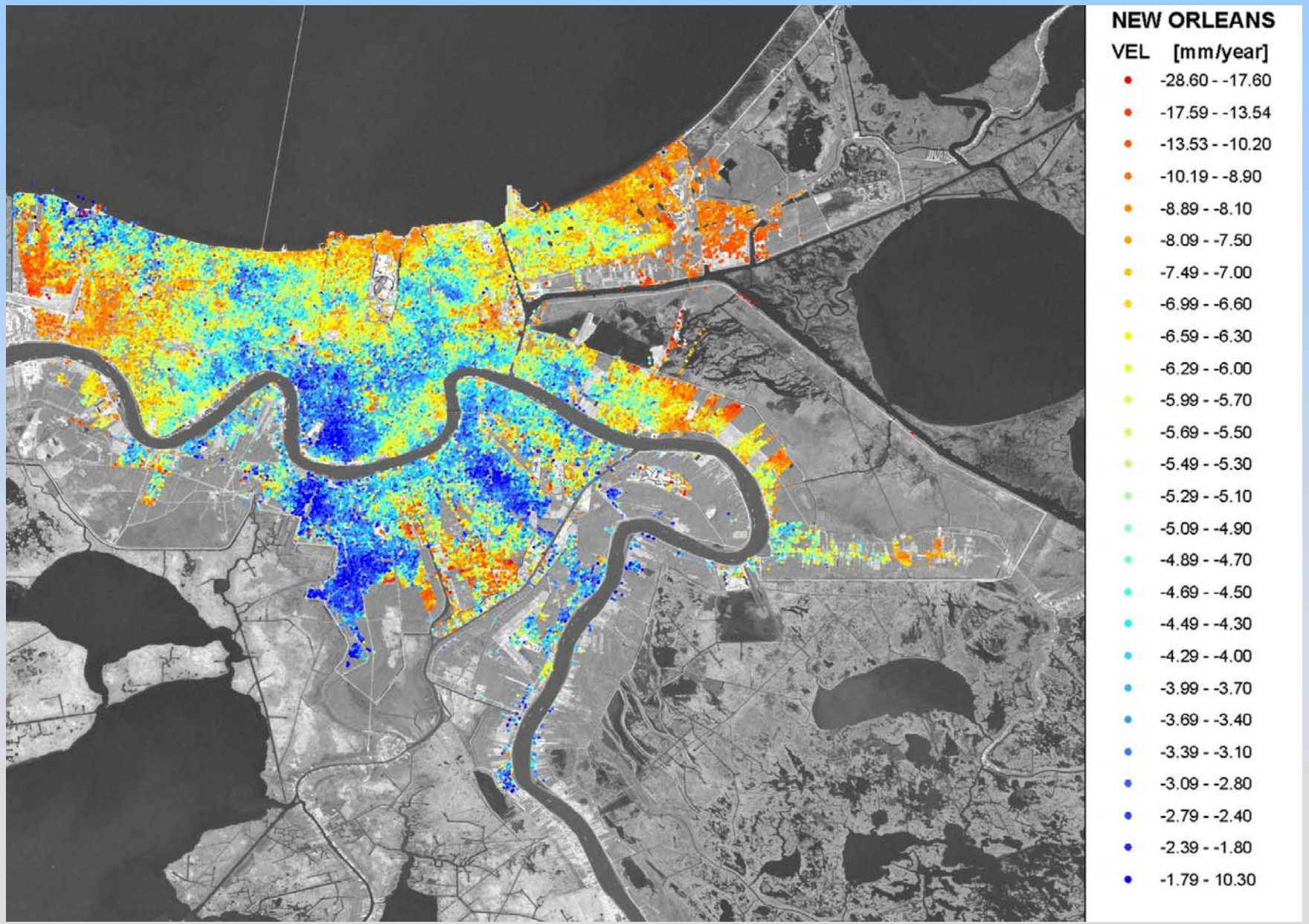
First Space-Based Image of Subsidence in New Orleans (Dixon et al., 2006)



Distribution of Subsidence

- **Mean subsidence rate ~ 6±2 mm/yr**
- **Extremely high subsidence rates (20-30 mm/yr) in a few locations**
- **These are located in recently drained marshes (eg Kenner)**
- **Suggests soil compaction & oxidation is cause of highest subsidence rates**

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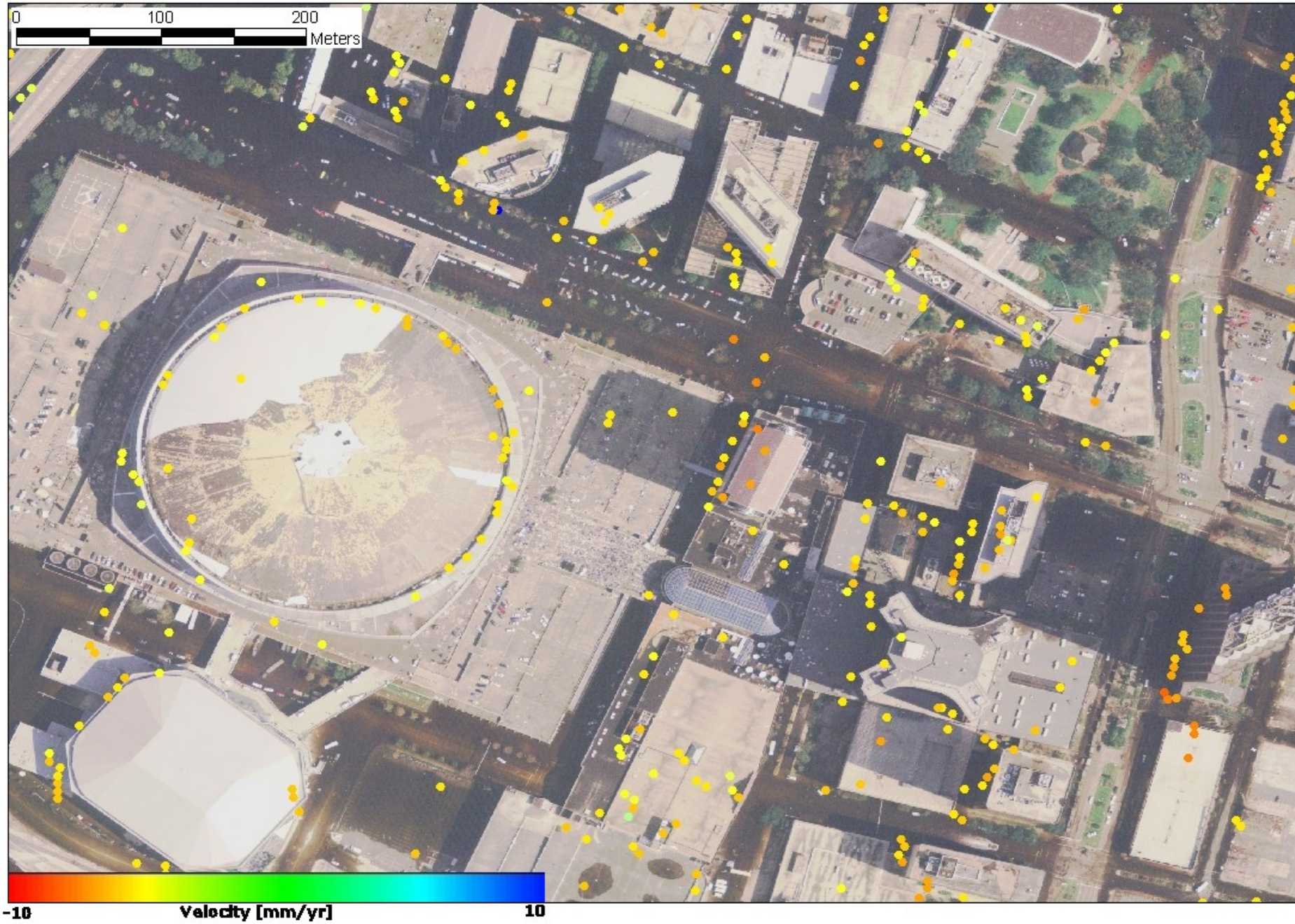
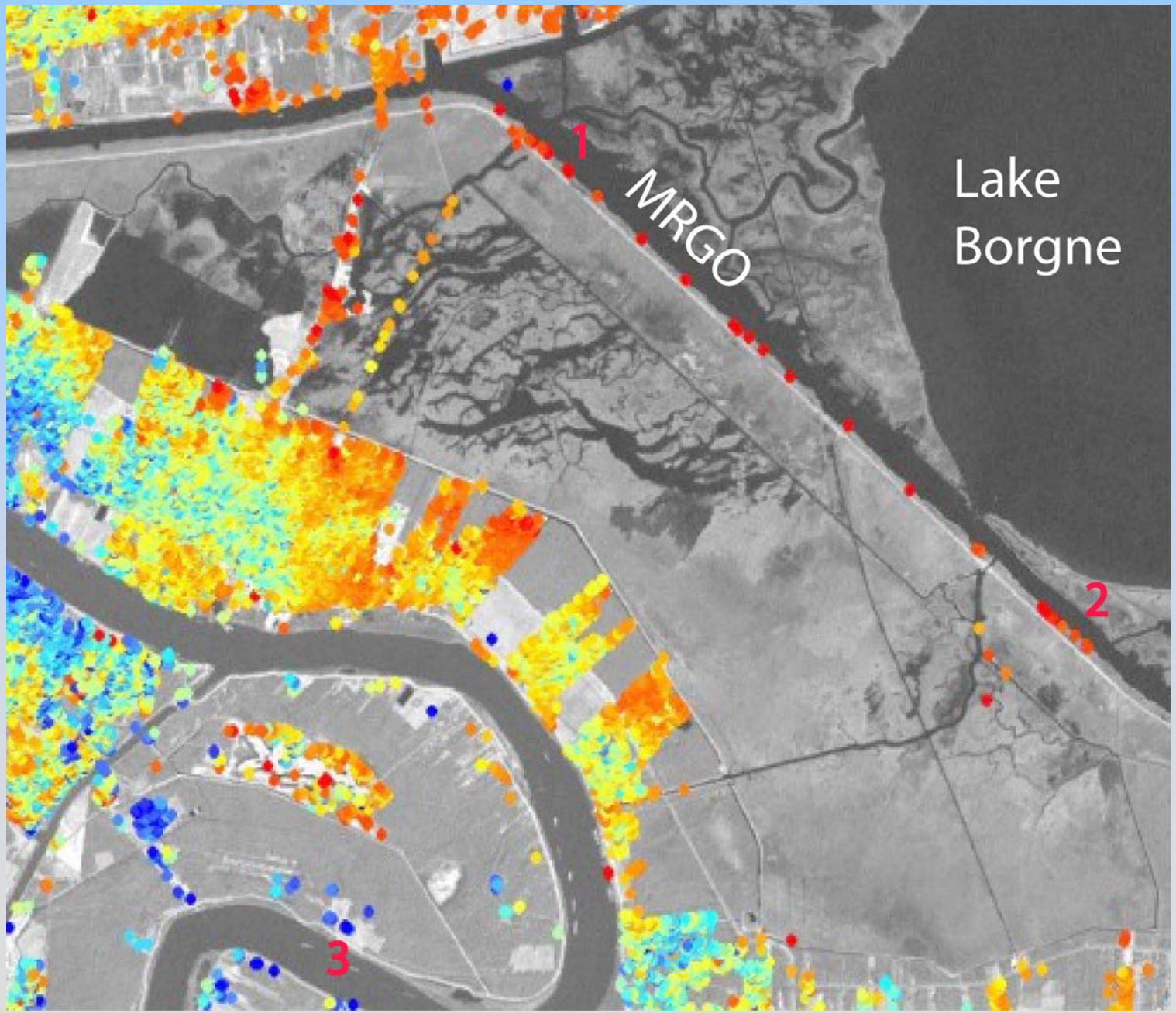

0
100
200
Meters
-10
Velocity [mm/yr]
10

St. Bernards Parish:
Levee system post Katrina damage assessment

Source: http://www.freerepublic.com/focus/f-news/1489838/posts

St. Bernards Parish: PS on levees



What's Next?

- **Post-Katrina changes?**
- **Role of annual variation (eg loading from Mississippi flooding, changes due to seasonal rainfall)**
- **Do new high resolution SAR's provide new opportunities to monitor specific structures (eg bridges)?**
- **Role for near-real time observations (Emergency management)?**

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TSX 2008

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

TSX Interferogram 2/11 - 3/15, 2008

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