FACTORS IMPACT SAR BACKSCATTER

LECTURE 11

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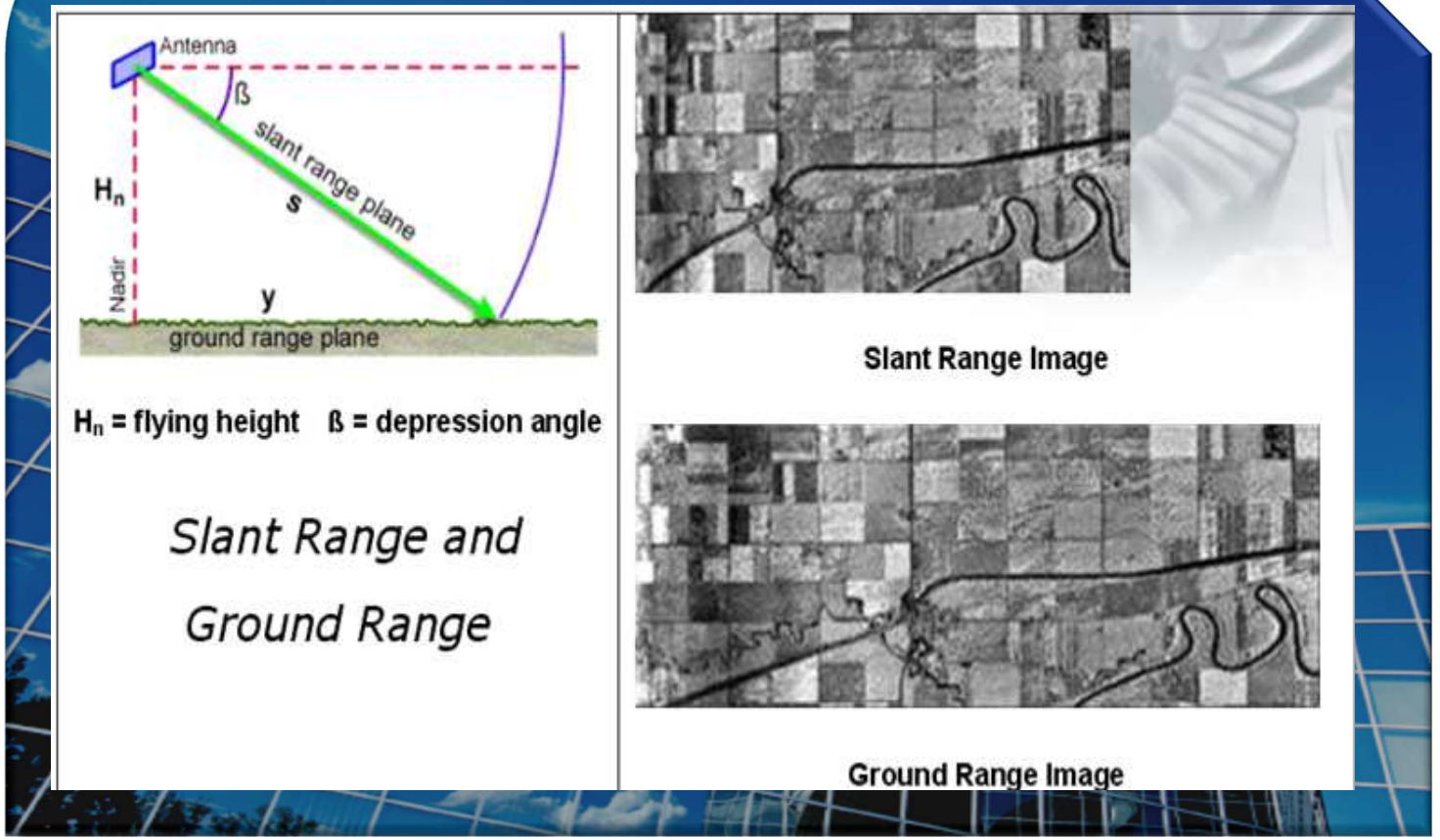
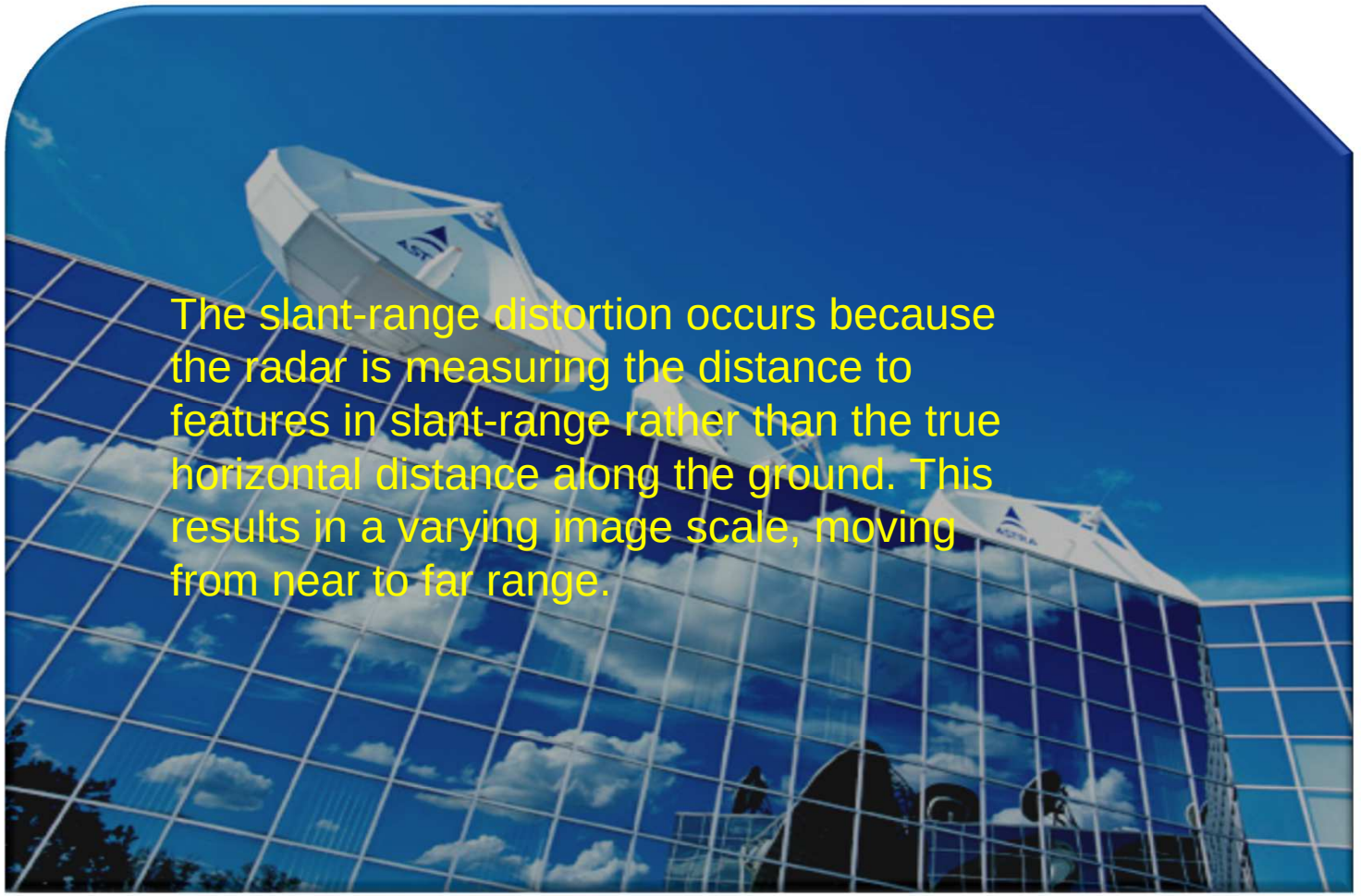
- Unlike optical sensors, radar looks not straight down but to one side of orbital plane. This is necessary for transmitted pulse to interact with terrain at increasing distances from radar antenna to provide range dimension of the image.

- Most users require images to represent distance on the ground (ground range) rather than slant range. SAR processor converts slant range to ground range.

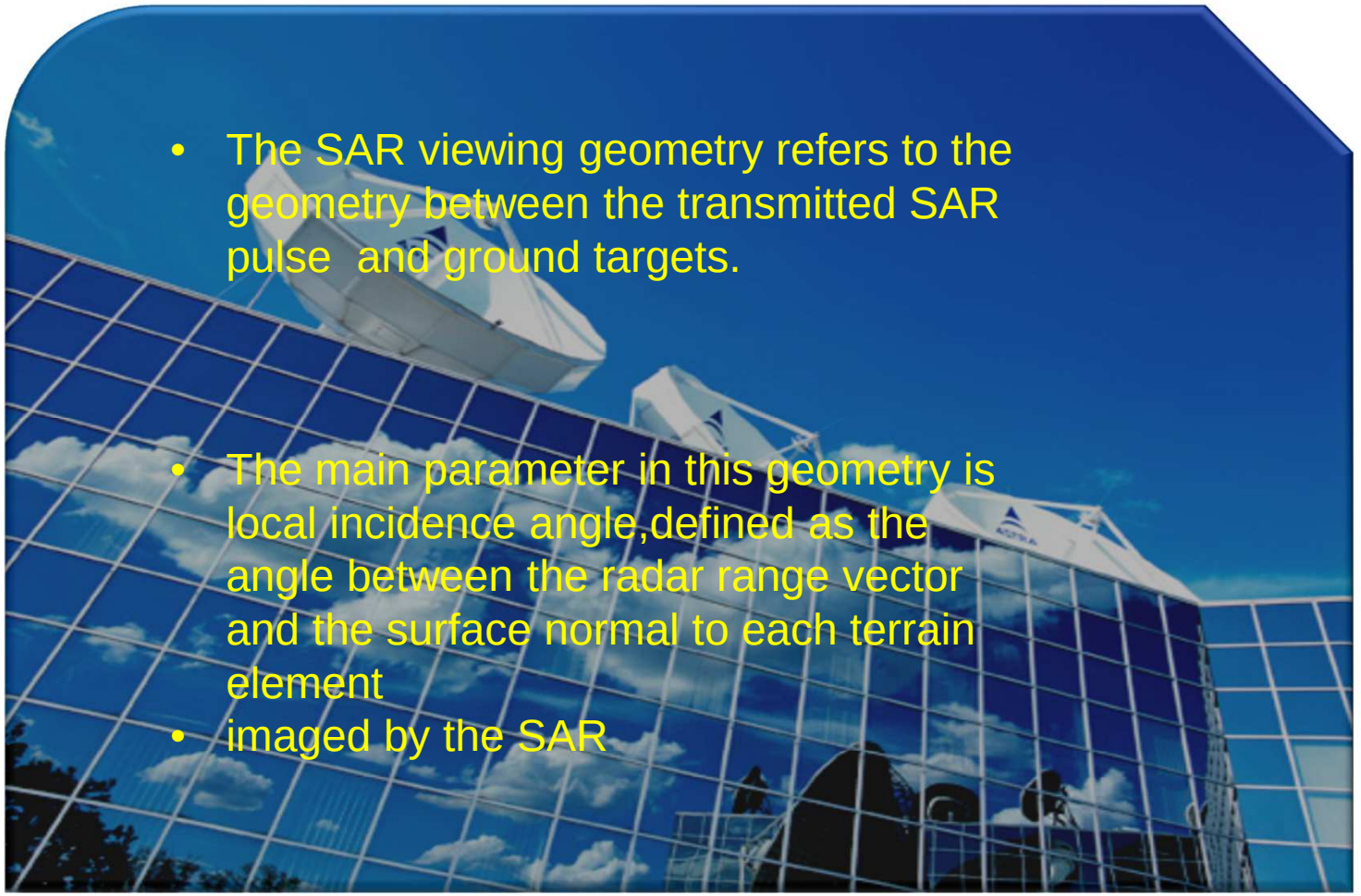
Slant Range vs. Ground Range





The slant-range distortion occurs because the radar is measuring the distance to features in slant-range rather than the true horizontal distance along the ground. This results in a varying image scale, moving from near to far range.

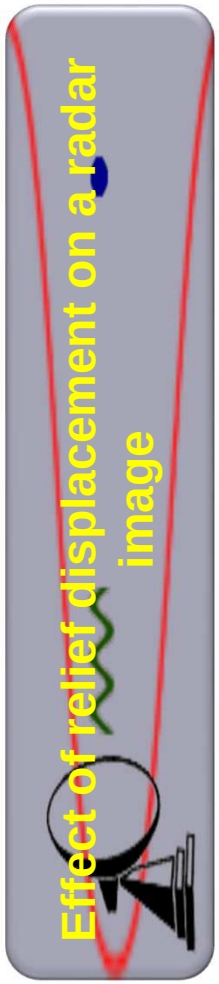
GEOMETRIC DISTORTIONS

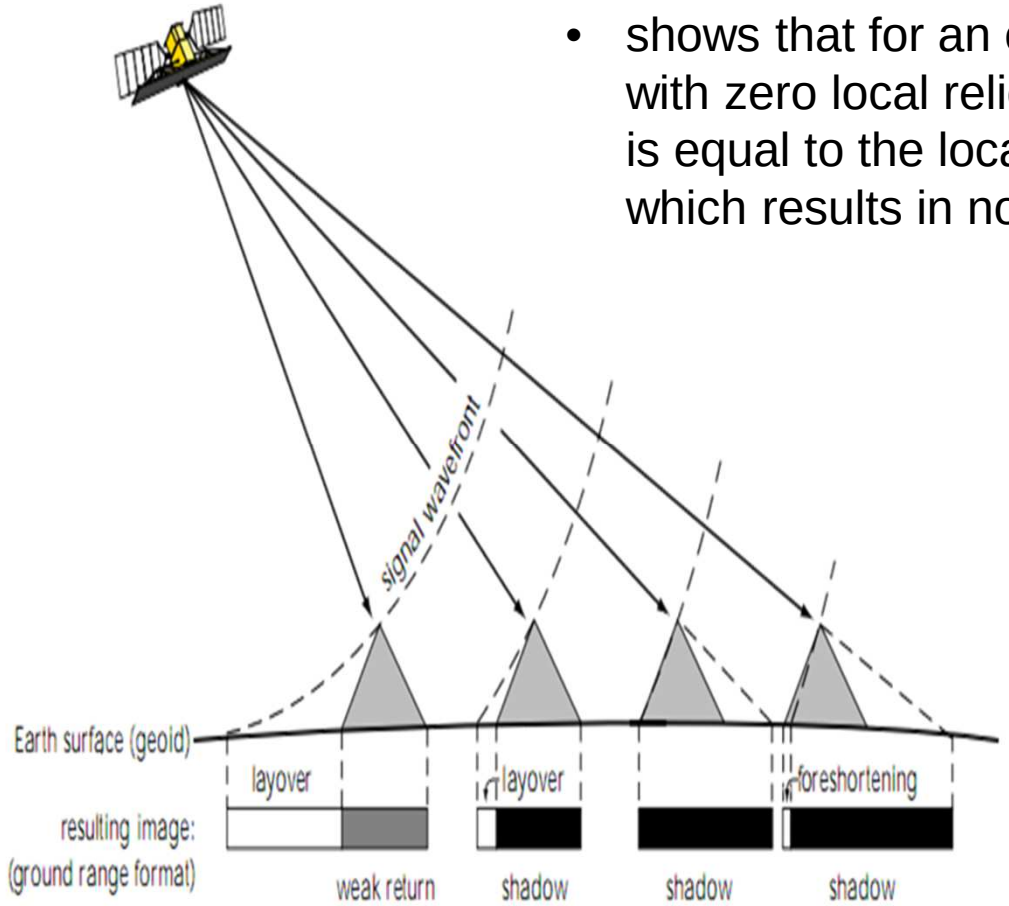


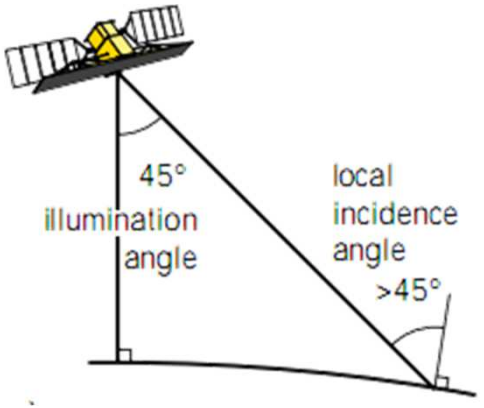
- The SAR viewing geometry refers to the geometry between the transmitted SAR pulse and ground targets.
- The main parameter in this geometry is local incidence angle,defined as the angle between the radar range vector and the surface normal to each terrain element
- imaged by the SAR

- The smaller the local incidence angle,the greater the relief displacement.

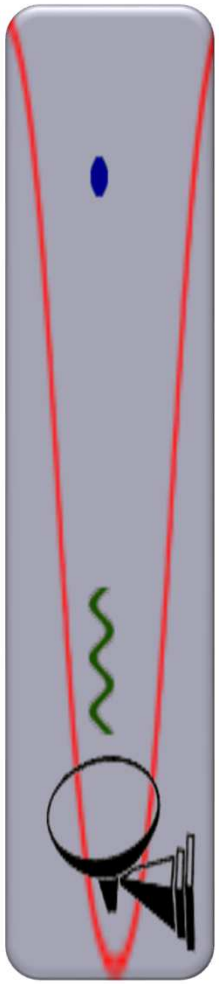
- shows that for an earth surface (geoid) with zero local relief, the incidence angle is equal to the local incidence angle which results in no relief displacement.

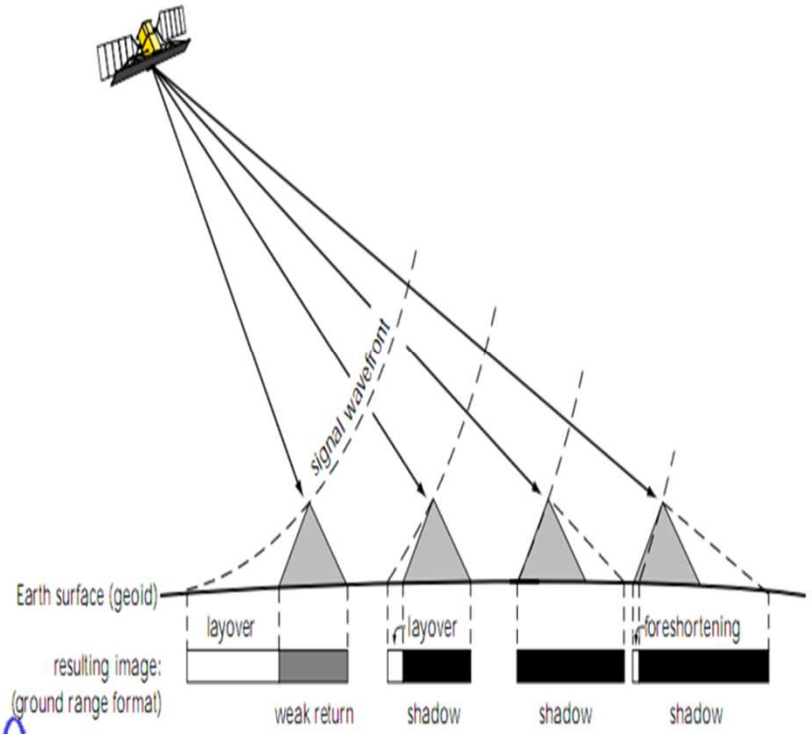


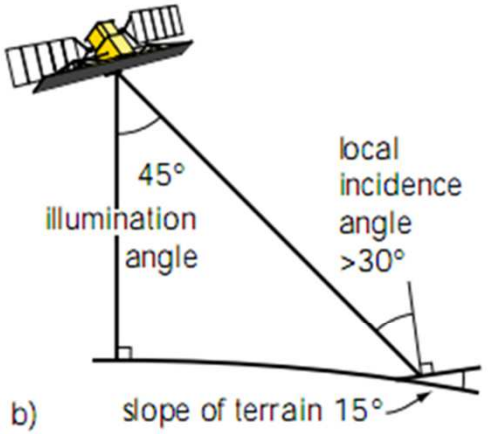


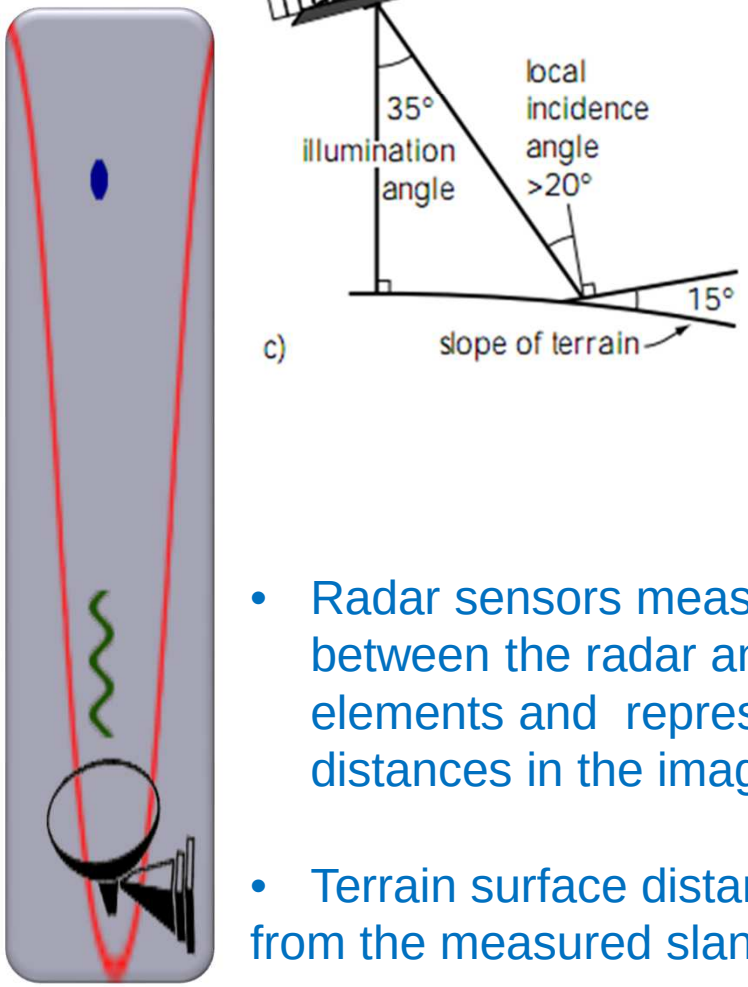


shows that a change in the local slope of the terrain with the illumination angle constant results in a change in the local incidence angle,which would result in relief displacement.





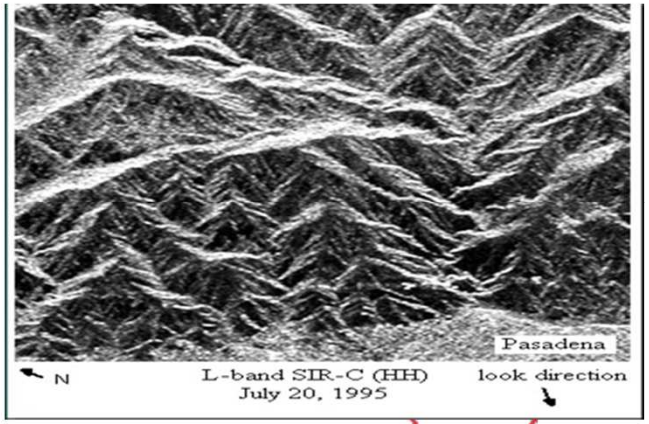


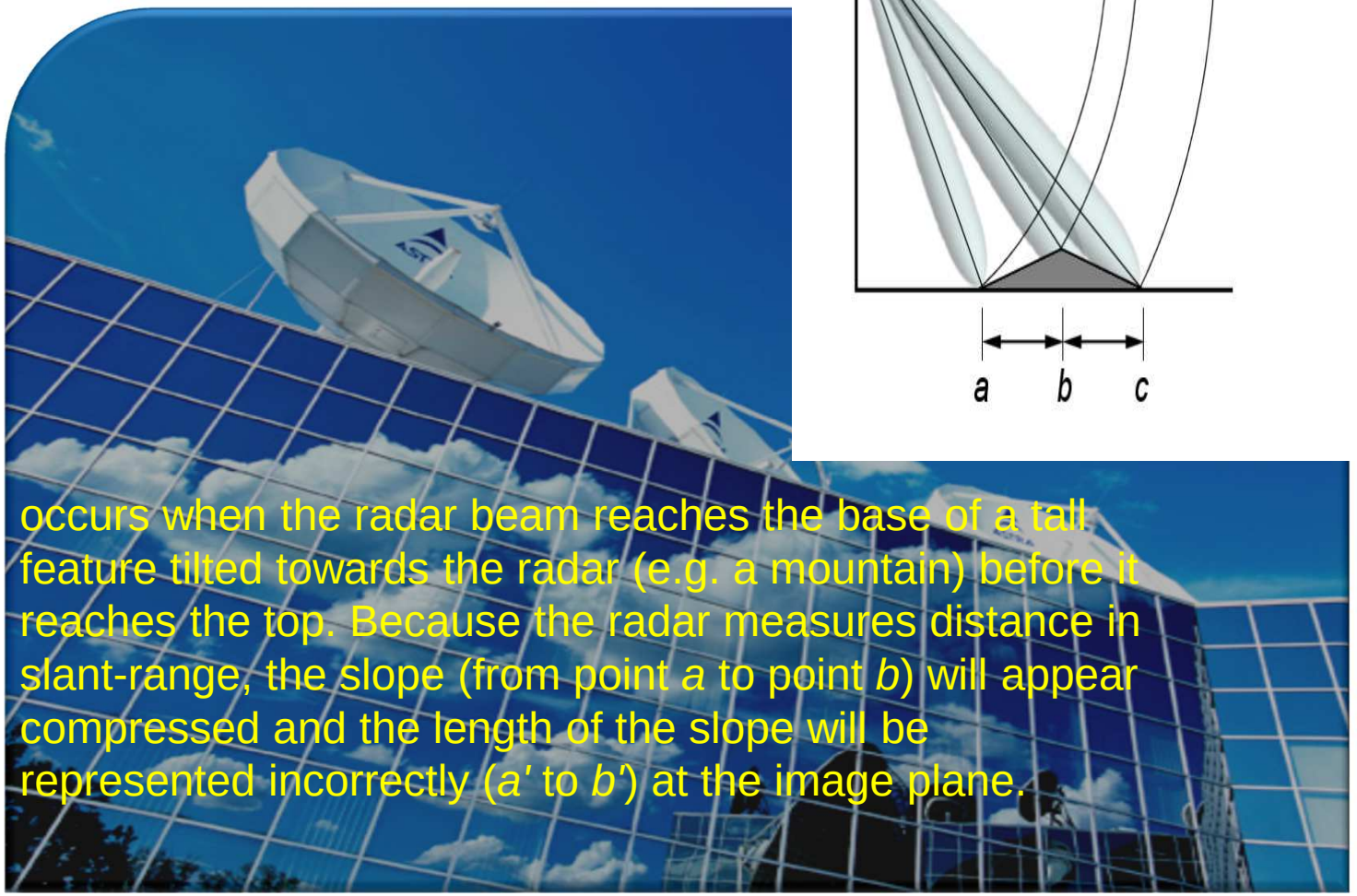


When the incidence angle decreases and terrain slope remains constant,as shown in following figure,there will be a corresponding decrease in local incidence angle,which will result in severe relief displacement.

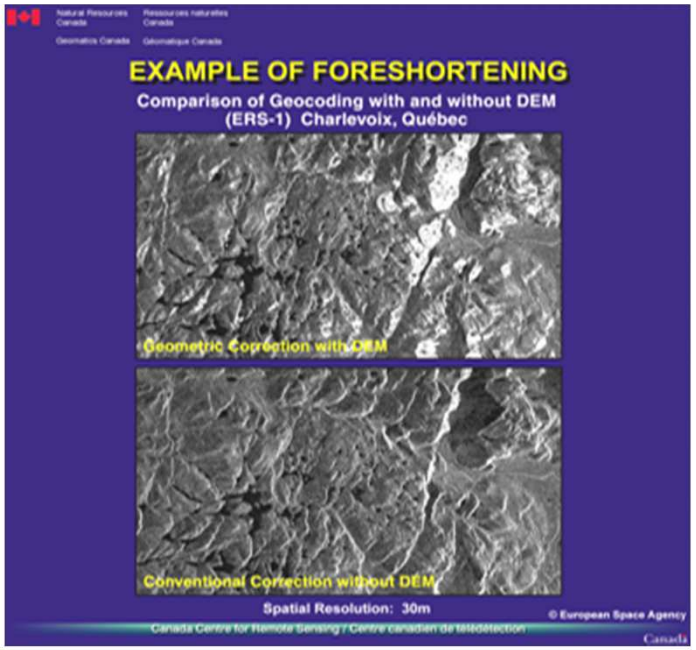
- Radar sensors measure distances between the radar and the terrain elements and represent these as distances in the image.

- Terrain surface distances are inferred from the measured slant range distances



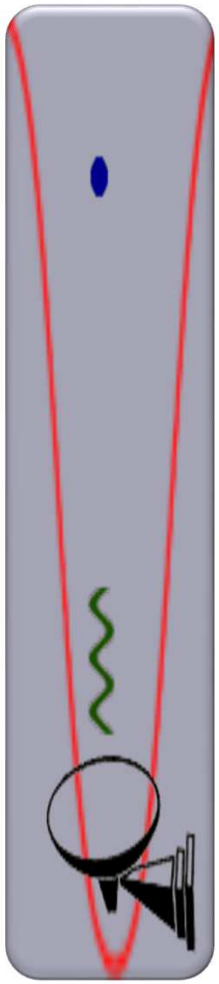


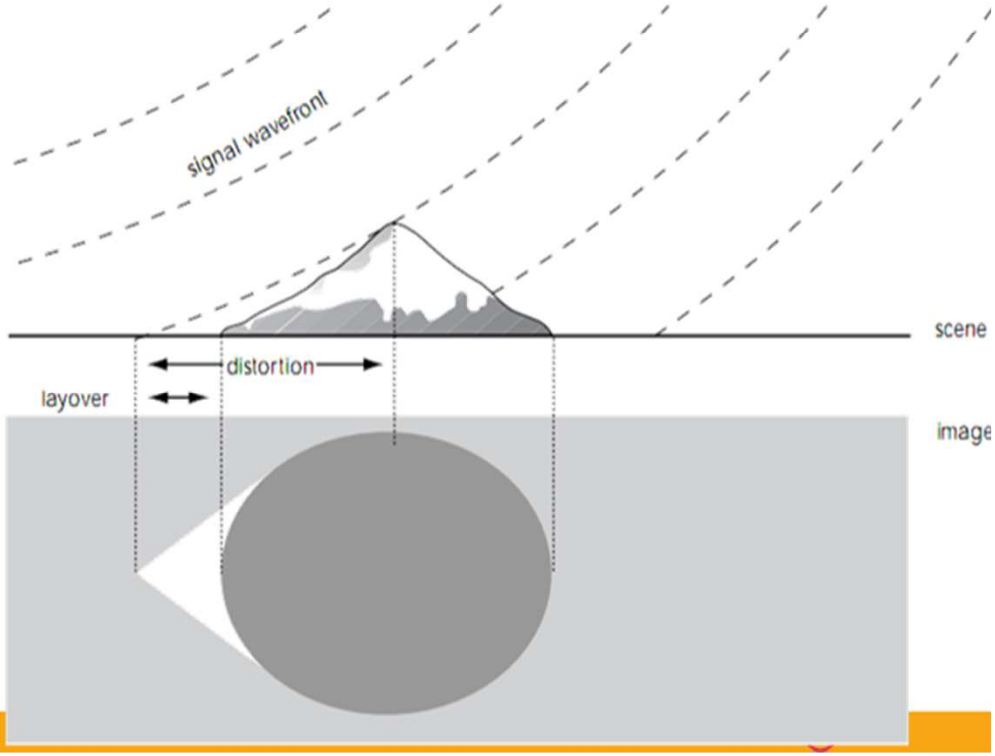
occurs when the radar beam reaches the base of a tall feature tilted towards the radar (e.g. a mountain) before it reaches the top. Because the radar measures distance in slant-range, the slope (from point *a* to point *b*) will appear compressed and the length of the slope will be represented incorrectly (*a'* to *b'*) at the image plane.

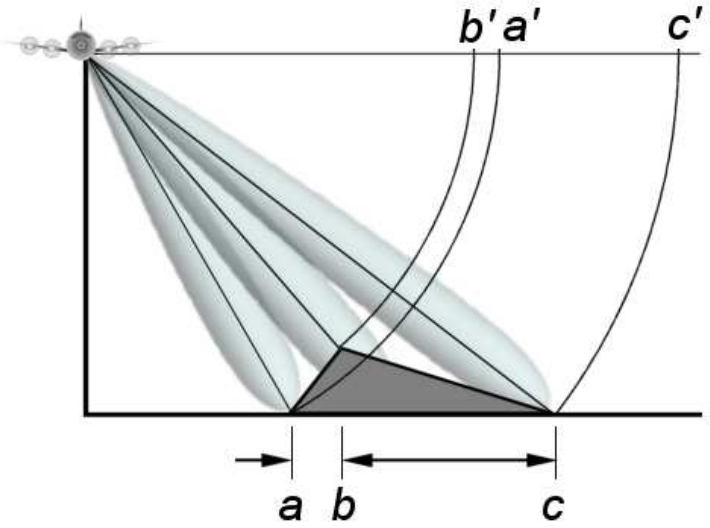


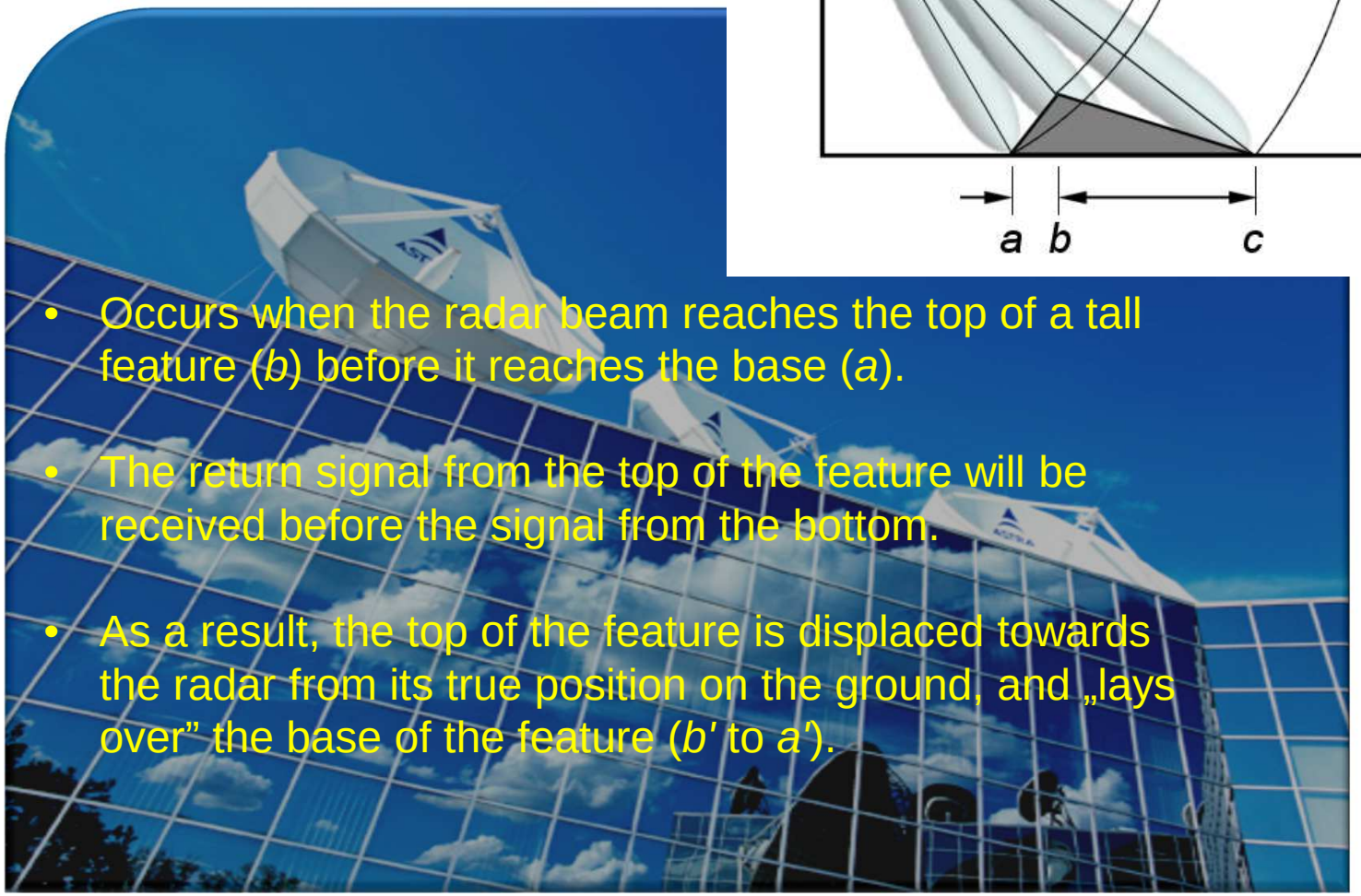
Foreshortening occurs when the local incidence angle is smaller than the incidence angle,but larger than 0°.

This type of distortion appears on an image as if the sensor-facing slope is shortened and the feature is leaning towards the sensor (hence the term foreshortening)

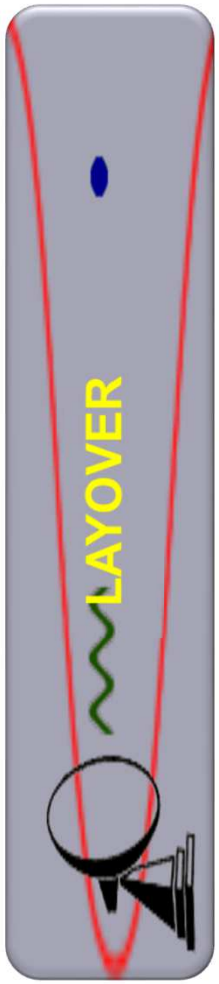




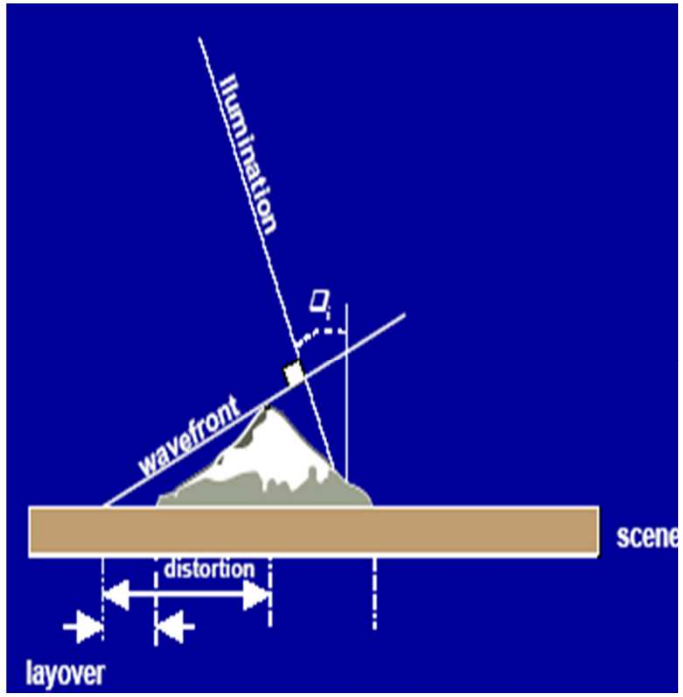


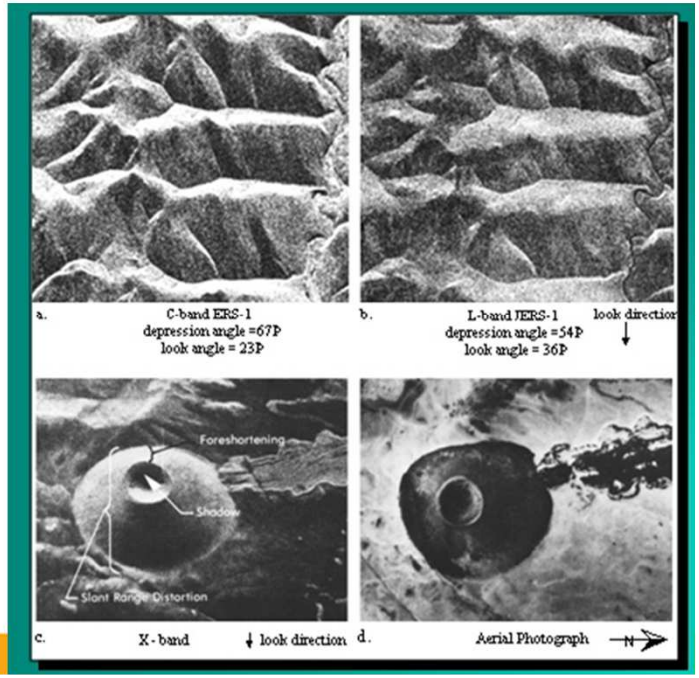


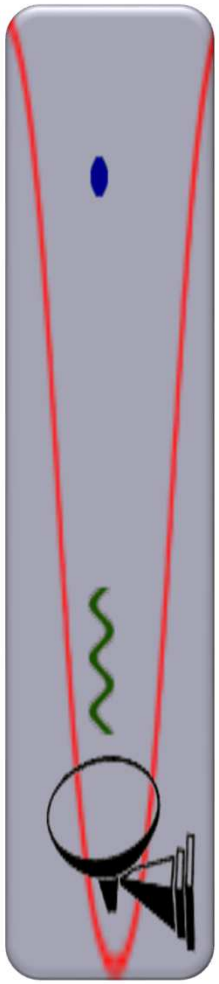
- Occurs when the radar beam reaches the top of a tall feature (*b*) before it reaches the base (*a*).
- The return signal from the top of the feature will be received before the signal from the bottom.
- As a result, the top of the feature is displaced towards the radar from its true position on the ground, and „lays over" the base of the feature (*b'* to *a'*).



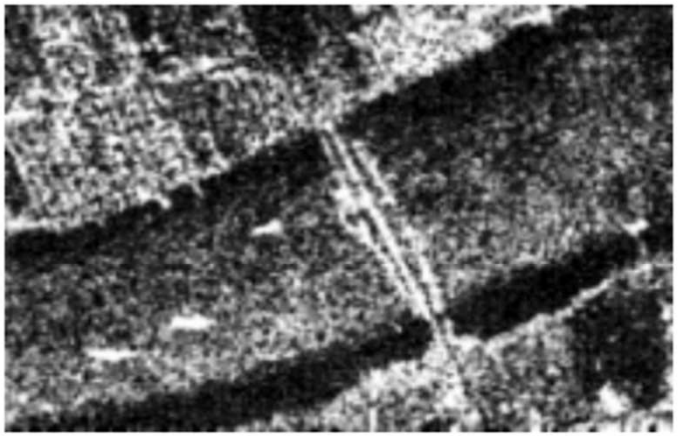
- For small incidence angles or very steep ground relief features, the backscatter often returns from the top of the feature before the base .
- This occurs where the local incidence angle is greater than incidence angle.
- On the SAR image,this appears as if the highest point of the vertical feature is laid over top of its base in the direction of the sensor.







Radar Layover Example



Seasat SAR image of the bridge crossing the
St. Lawrence Seaway at Trois Rivieres, Quebec, Canada

Foreshortening and Layover,Cont.,

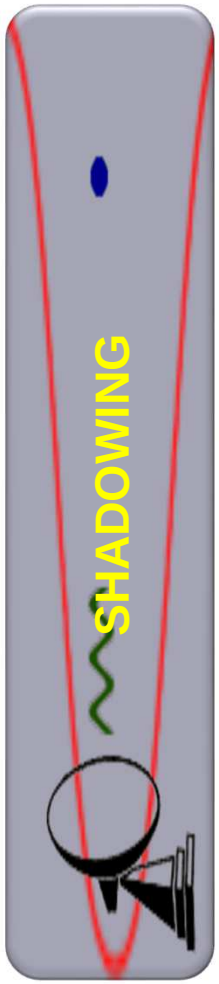
All terrain that has a slope inclined toward the radar will appear compressed or foreshortened relative to slopes inclined away from the radar. The foreshortening factor, Ff , is approximately:

$$Ff = \sin(\theta - \alpha^{+})$$

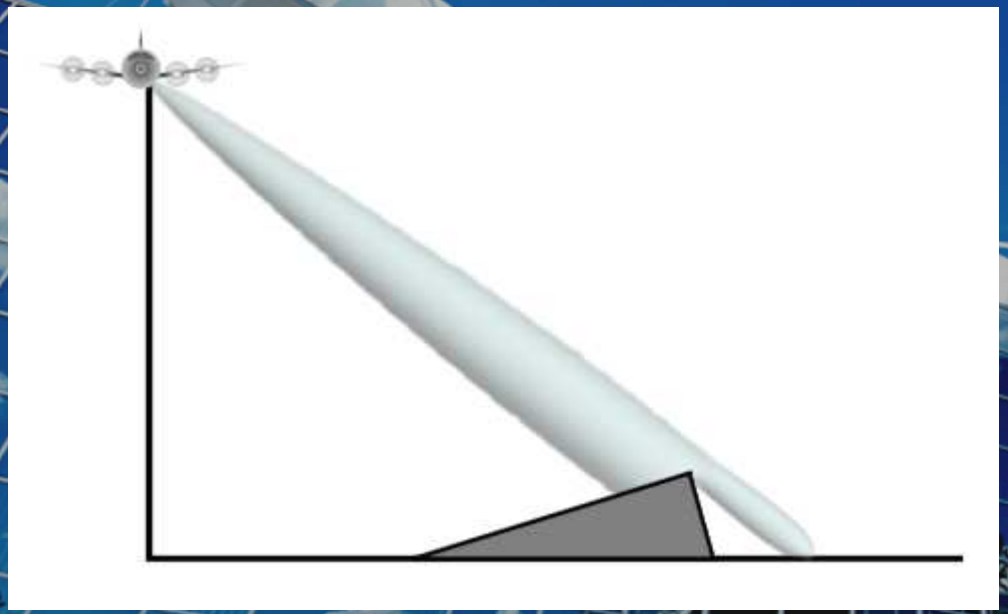
where the incident angle θ is the angle between the vertical plane at nadir and a line that links the imaging radar antenna to a feature on the ground, and α is the slope angle of the surface.

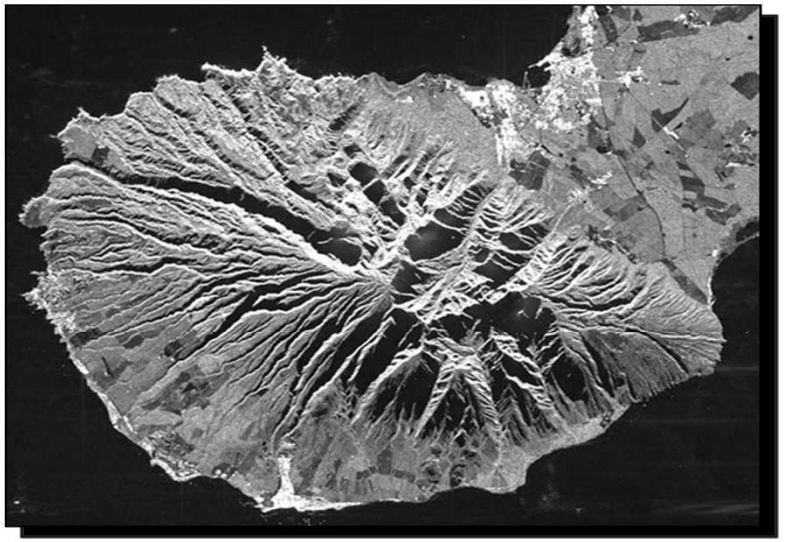
Alpha is positive (α^{+}) where the slope is inclined toward the radar (foreslope),

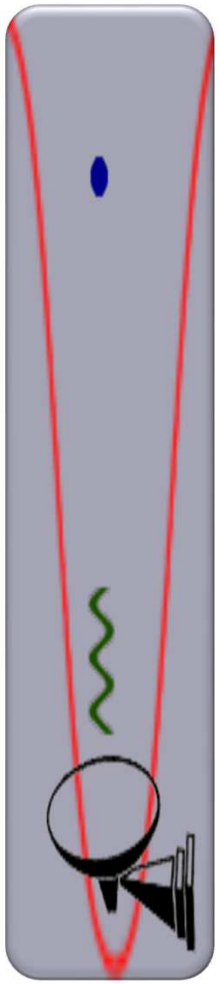
and negative (α^{-}) where the slope is inclined away from it (backslope).

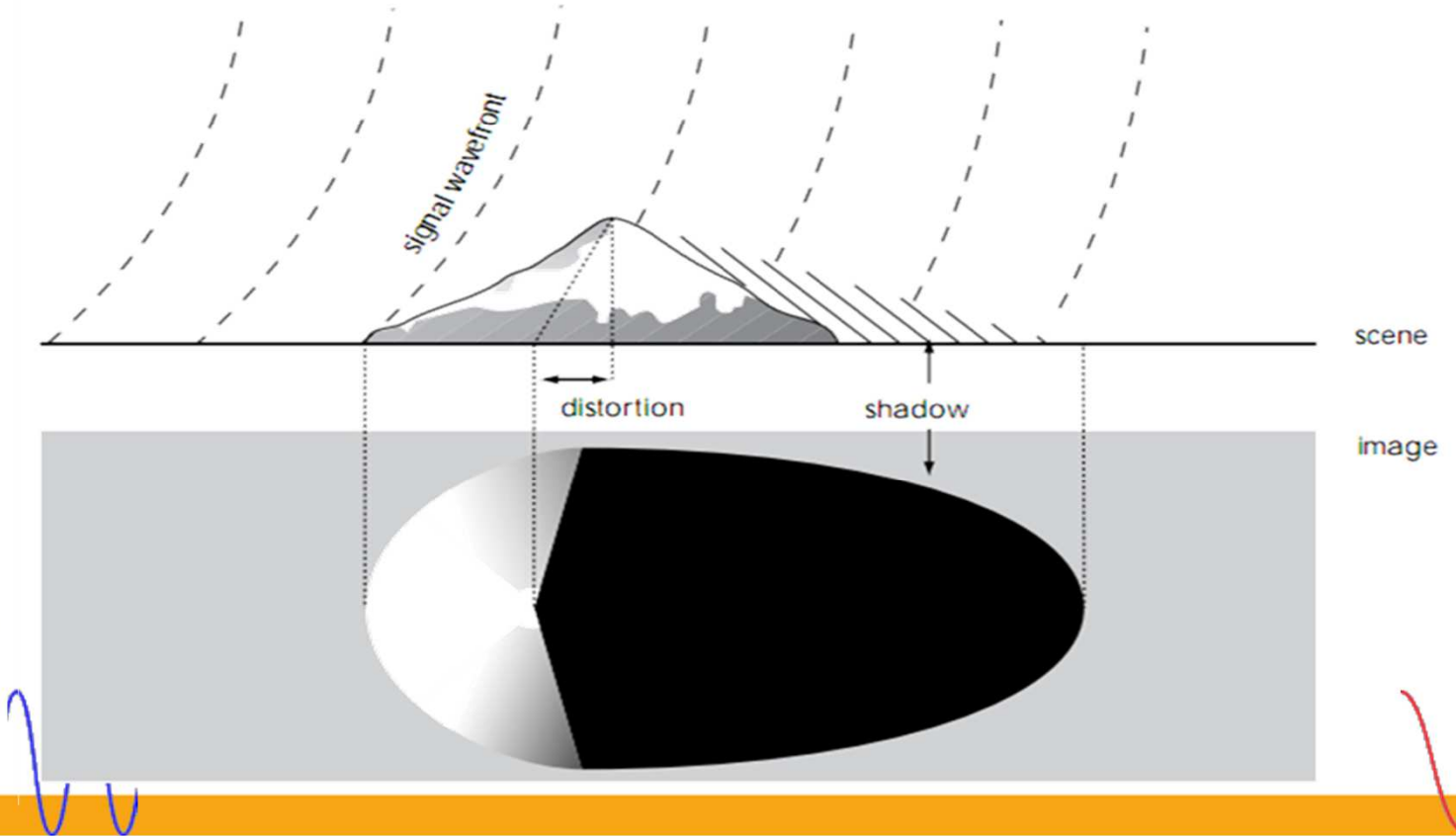


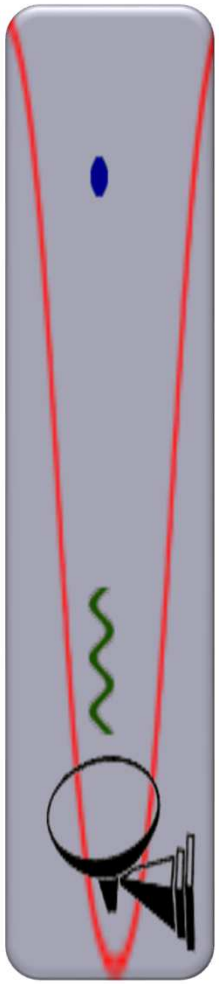
increases with greater incident angle θ, just as our shadows lengthen as the sun sets.





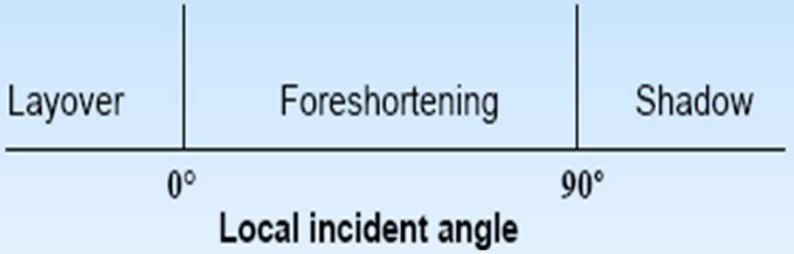



signal wavefront
scene
distortion
shadow
image

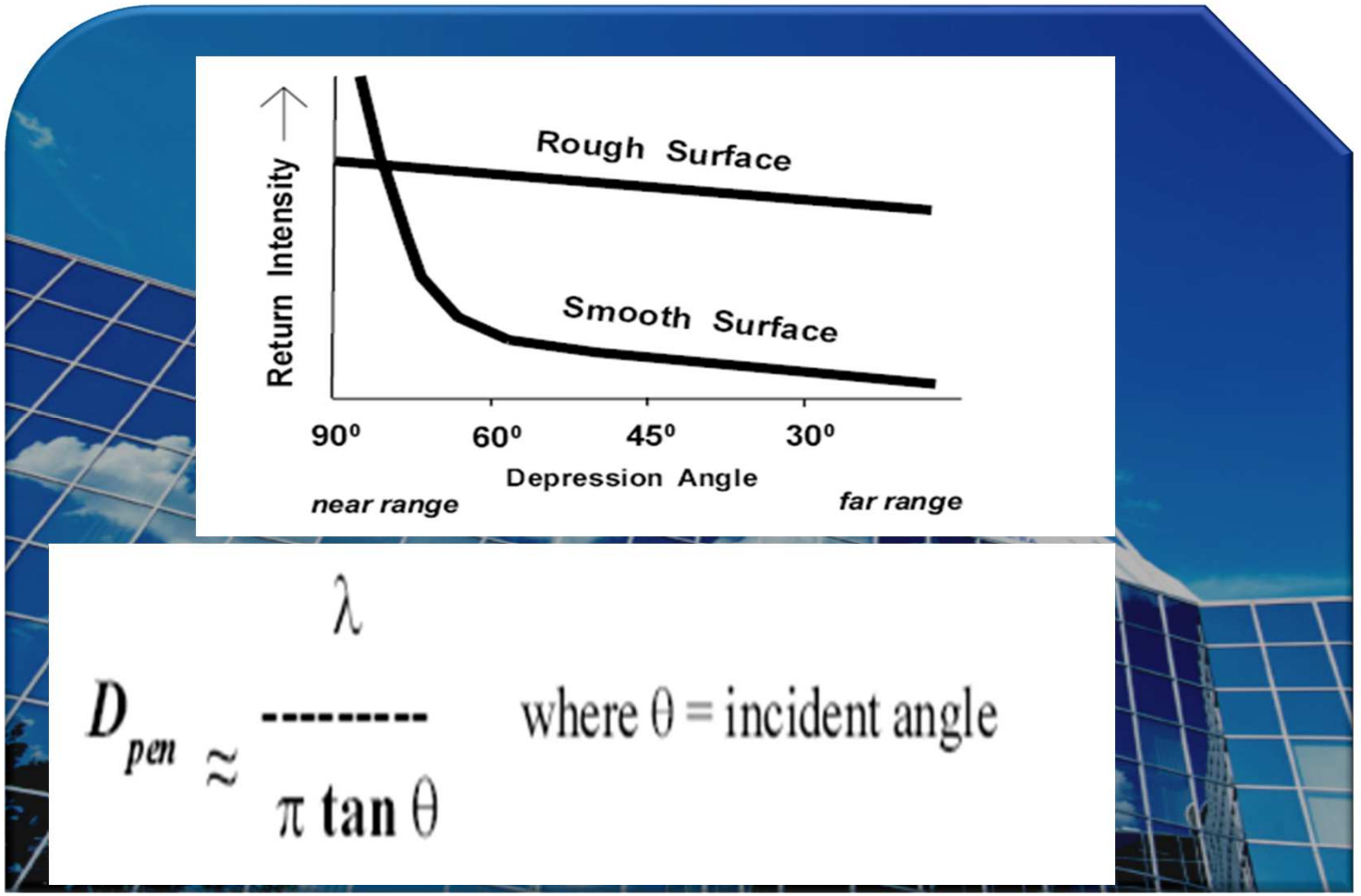


Relief Displacement (Radar Sensor)

The type and degree of relief displacement in the radar image is a function of the angle at which the radar beam hits the ground, *i.e.* it depends upon the local slope of the ground.



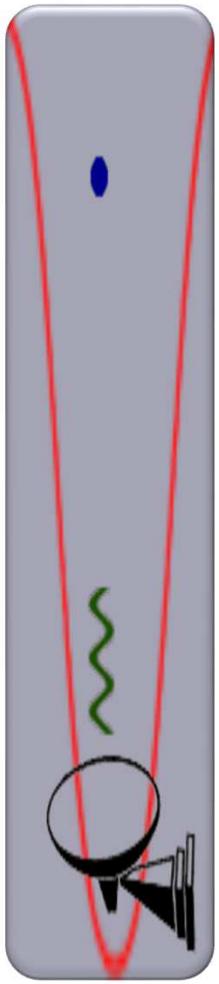
DETERMINE SURFACE CHARACTERISTICS



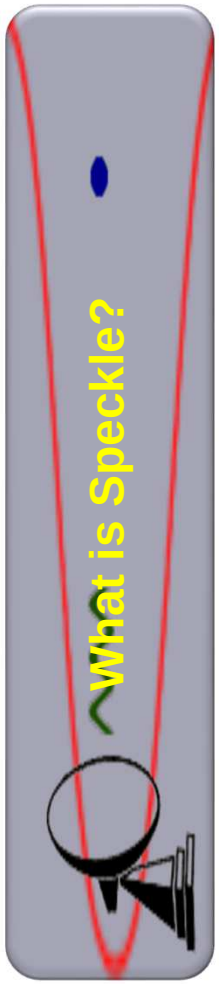
$$D_{pen} \approx \frac{\lambda}{\pi \tan \theta}$$

where θ = incident angle

Geometric Correction

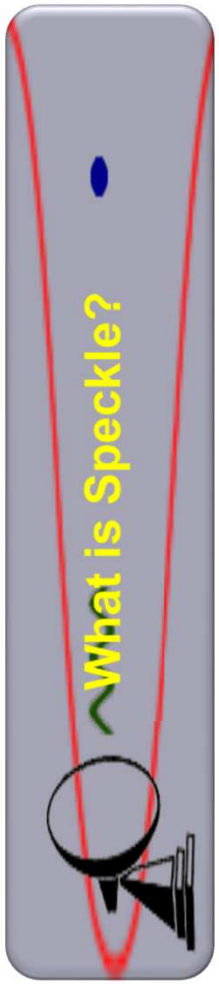


- Geometric correction includes slant to ground range, registration, and local incident angle corrections (if topographic information is available).
- Allows a correspondence between the position of points on the final image and their location in a given cartographic projection.
- Consists of introducing spatial shifts on the original image .

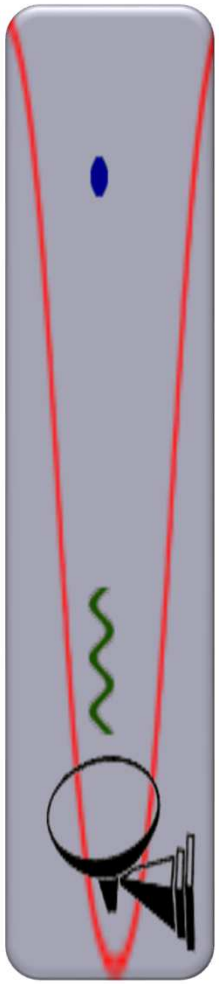

What is Speckle?

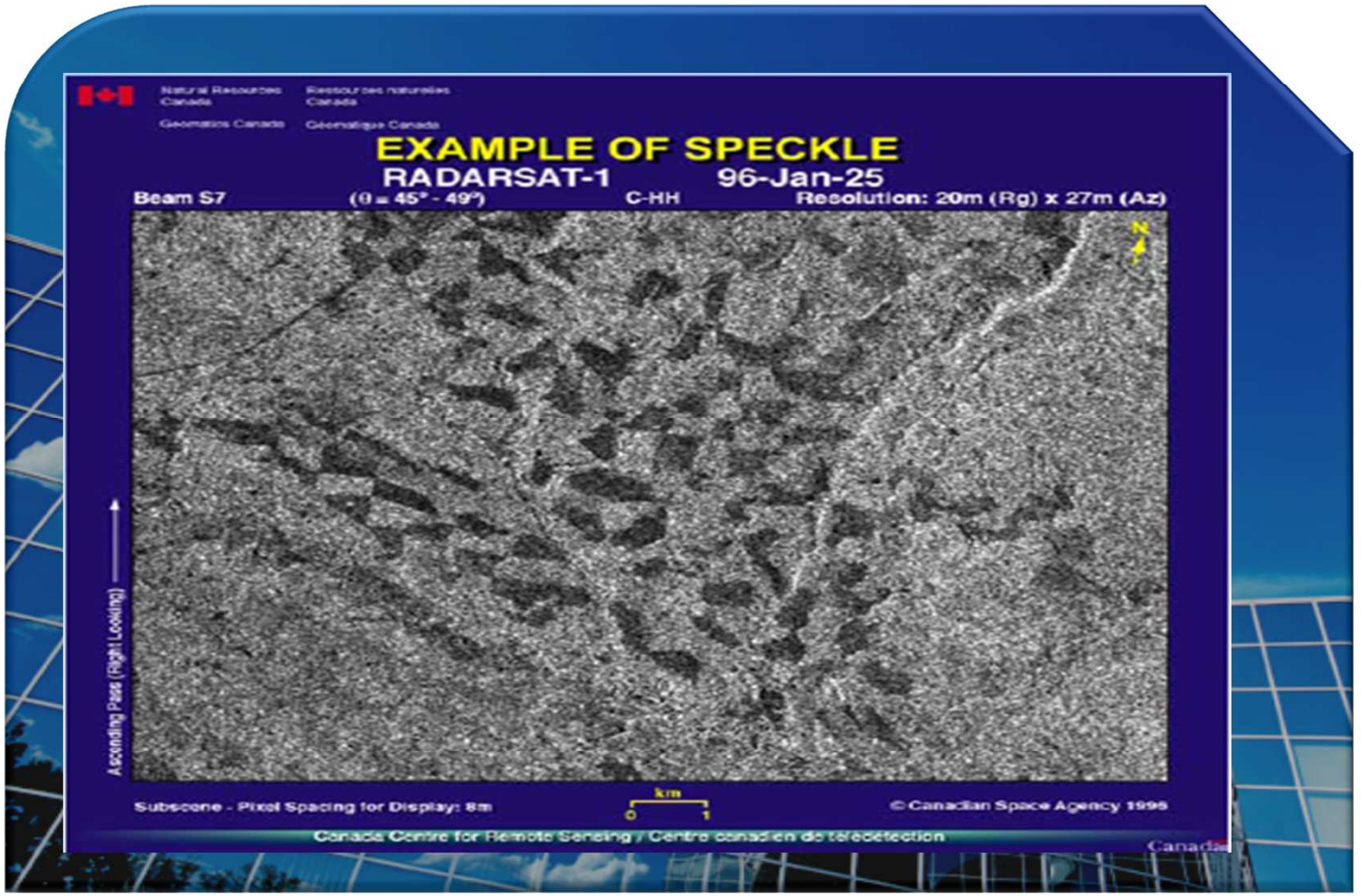

Speckle is coherent interference of waves
scattered from terrain elements observed
in each resolution cell.

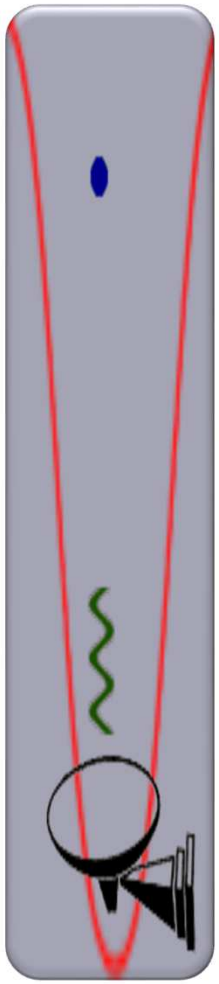
What is Speckle?

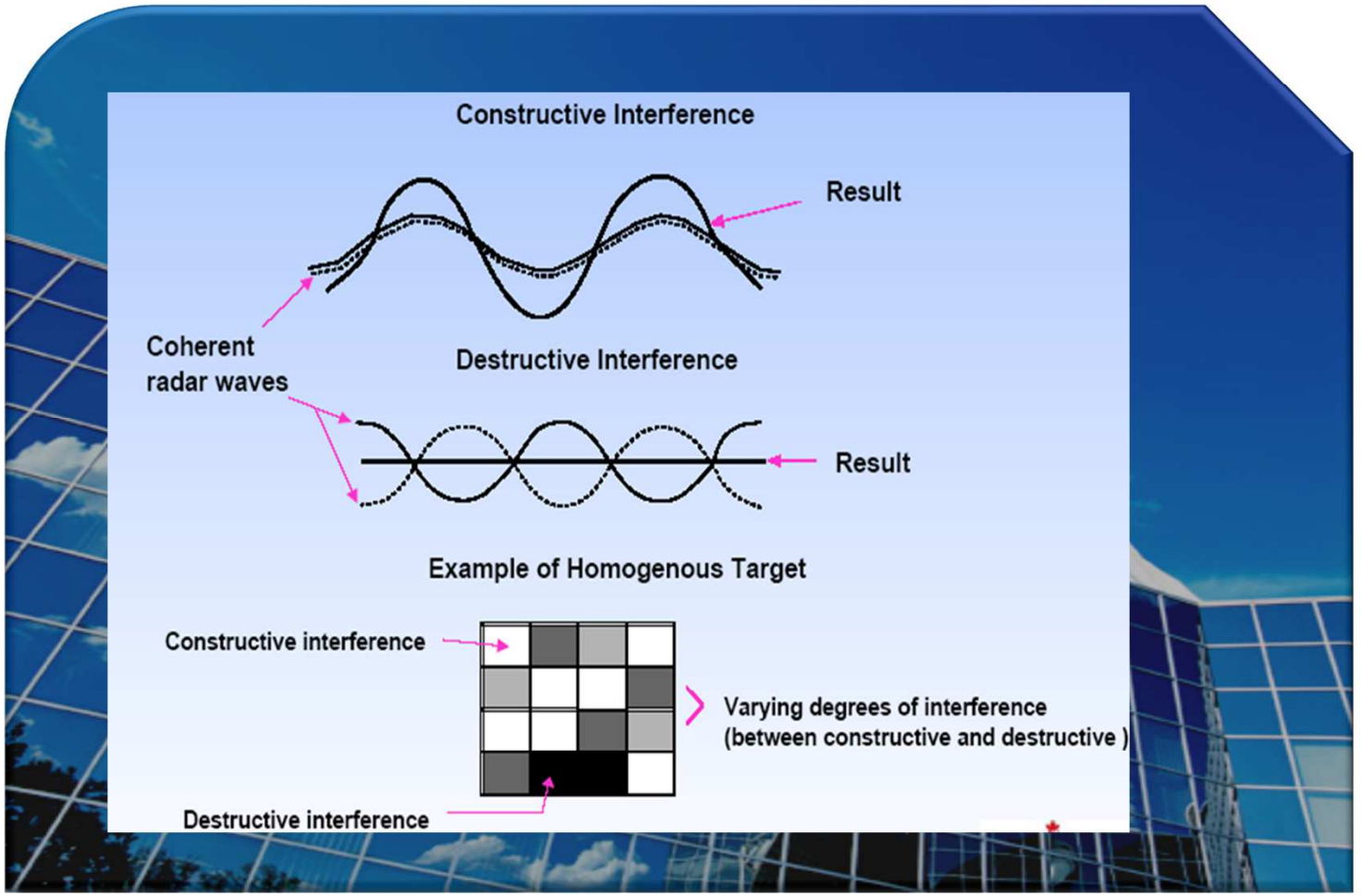


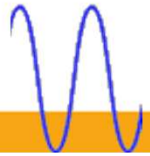
- An incident radar wave interacts with each element of the surface and surface cover to generate scattered waves propagating in all directions.
- Those scattered waves that reach the receiving antenna are summed in direction and phase to make the received signal.
- The relative phase components contain the differential propagation paths.
- The SAR focusing operation coherently combines the received signals to form the image.
- The scattered wave phase addition results in both constructive and destructive interference of individual scattered returns and randomly modulates the strength of the signal in each resolution cell.

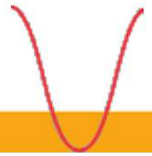


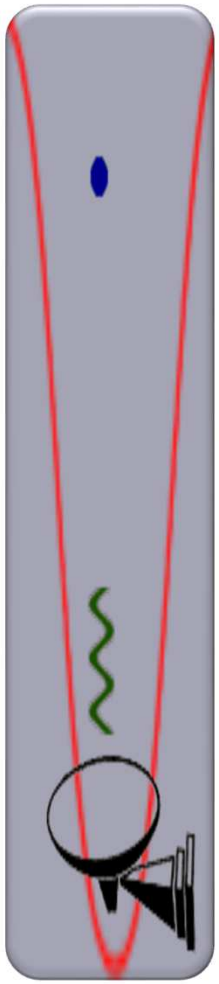

Natural Resources Canada
Ressources naturelles Canada
Geomatics Canada
Géomatique Canada
EXAMPLE OF SPECKLE
RADARSAT-1
96-Jan-25
Beam S7
(θ = 45° - 49°)
C-HH
Resolution: 20m (Rg) x 27m (Az)
N
Ascending Pass (Right Looking)
Subscene - Pixel Spacing for Display: 8m
km
0
1
© Canadian Space Agency 1996
Canada Centre for Remote Sensing / Centre canadien de télédétection
Canada

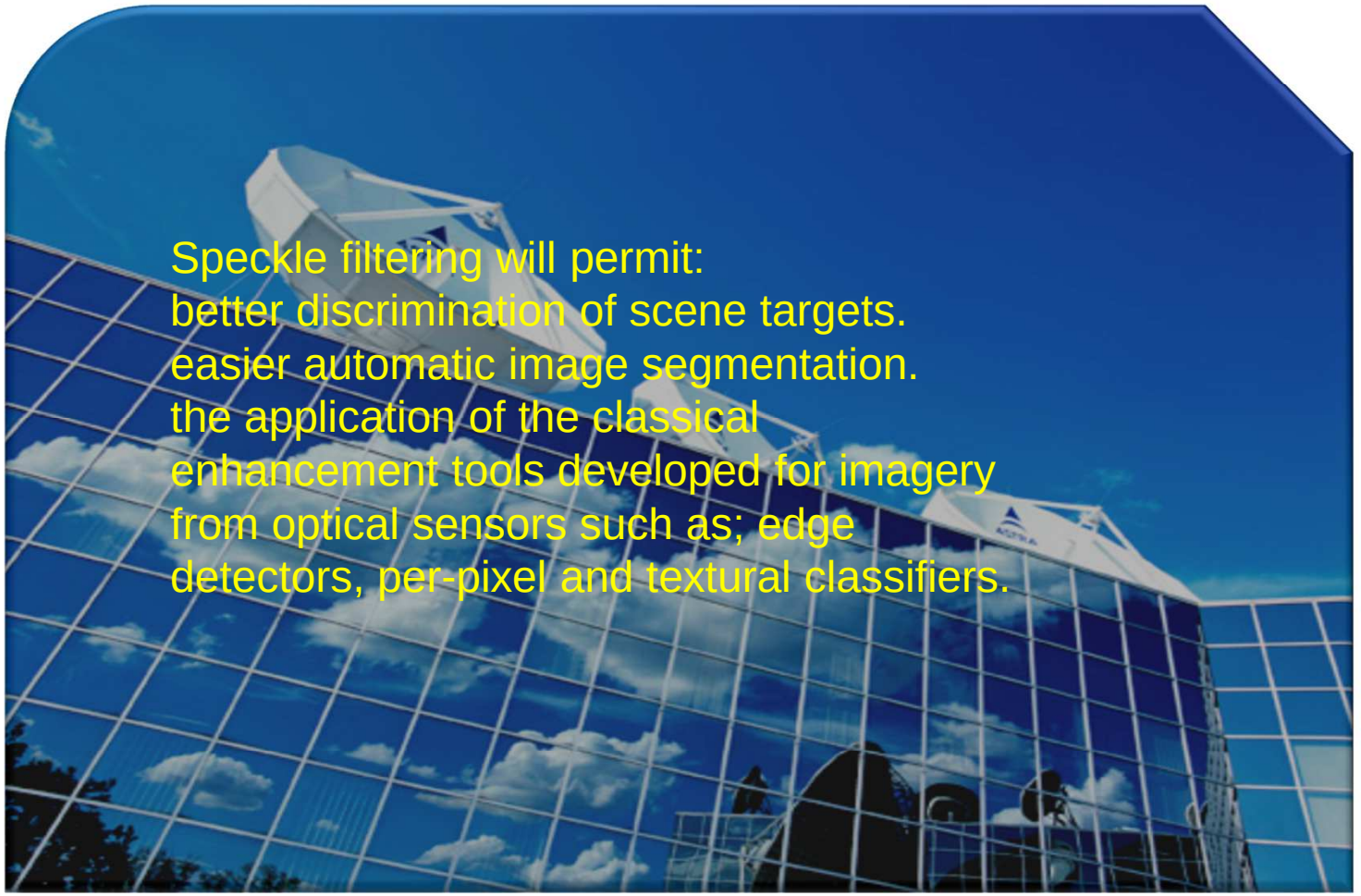



Constructive Interference
Result
Coherent
radar waves
Destructive Interference
Result
Example of Homogenous Target
Constructive interference
Varying degrees of interference
(between constructive and destructive)
Destructive interference



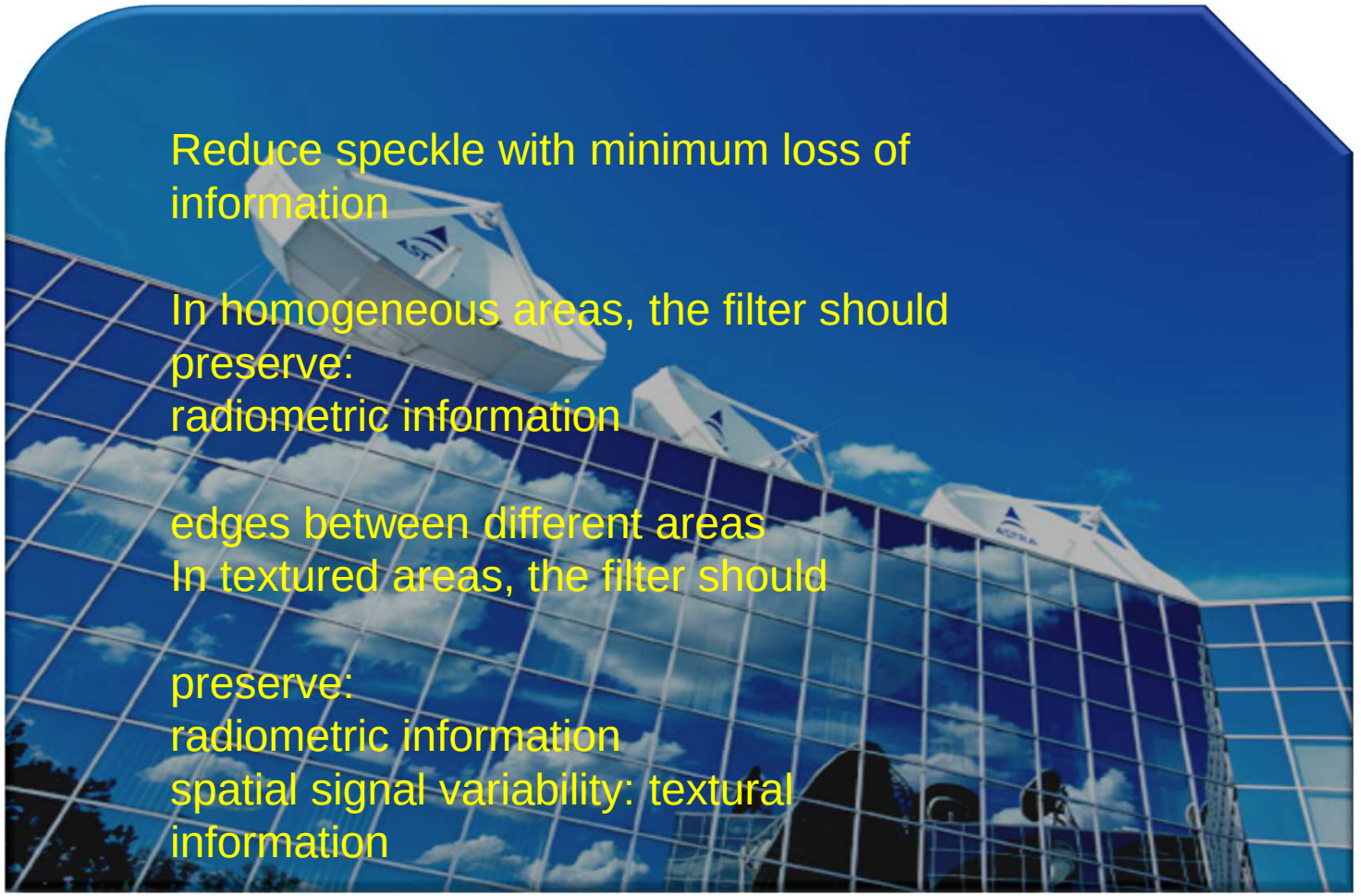






Speckle filtering will permit:
better discrimination of scene targets.
easier automatic image segmentation.
the application of the classical enhancement tools developed for imagery from optical sensors such as; edge detectors, per-pixel and textural classifiers.

The Ideal Speckle Reduction Filter

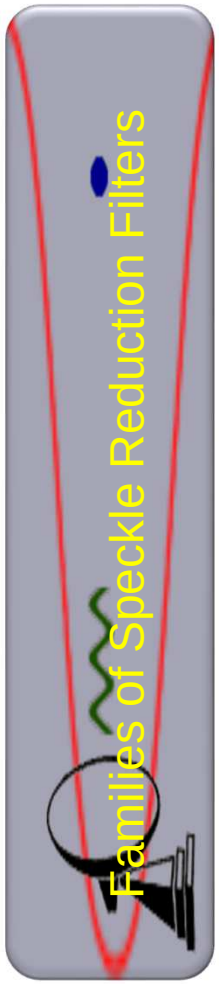


Reduce speckle with minimum loss of information

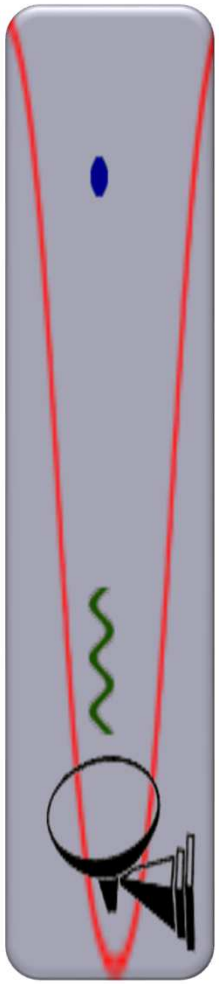
In homogeneous areas, the filter should preserve:
radiometric information

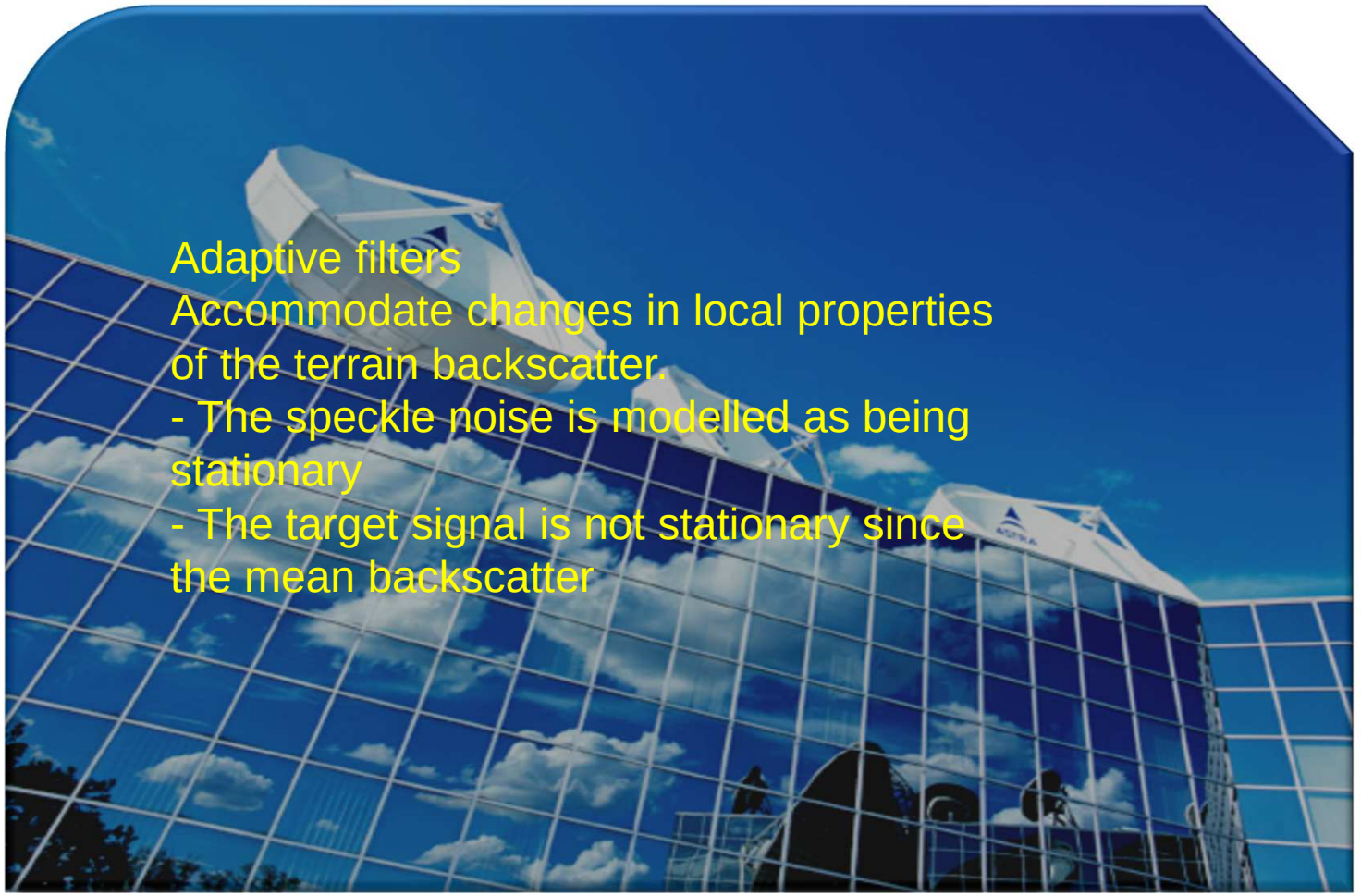
edges between different areas
In textured areas, the filter should

preserve:
radiometric information
spatial signal variability: textural information

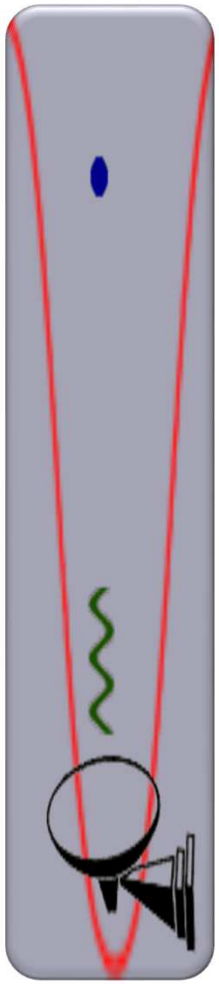


Non-adaptive filters
The parameters of the whole image signal are considered.
Do not take into consideration the local properties of the terrain backscatter or the nature of the sensor.
Not appropriate for filtering of non-stationary scene signal.
Examples are the FFT filters.



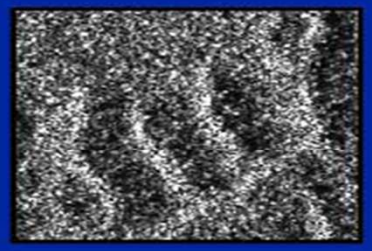


Adaptive filters
Accommodate changes in local properties of the terrain backscatter.
- The speckle noise is modelled as being stationary
- The target signal is not stationary since the mean backscatter

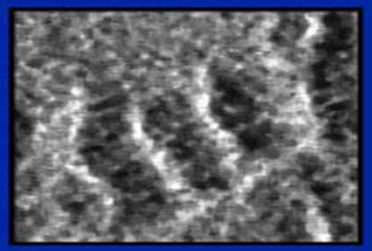


Gamma vs. Median Filter

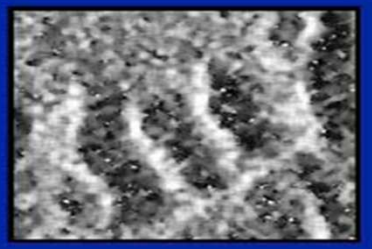
Tapajós, Brazil
May 20, 1996 Beam F2



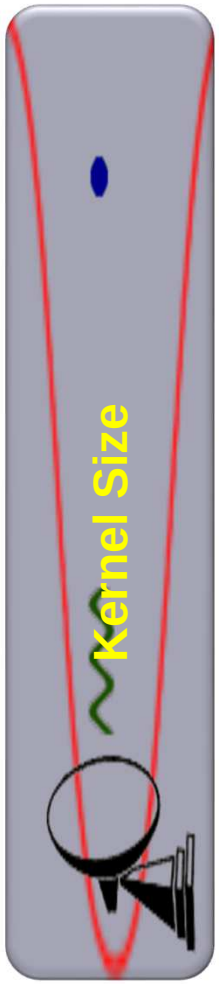
Original Image



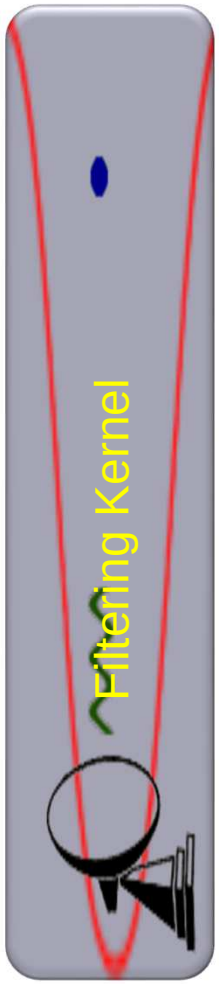
Median 5x5



Map Gamma
5x5



As filter kernel size increases, smoothing increases.



MEAN

5	7	4
9	8	6
5	5	8

5+7+4+9+8+6+5+5+8= 57
57÷ 9 =
MEAN = 6

MEDIAN

5	7	4
9	8	6
5	5	8

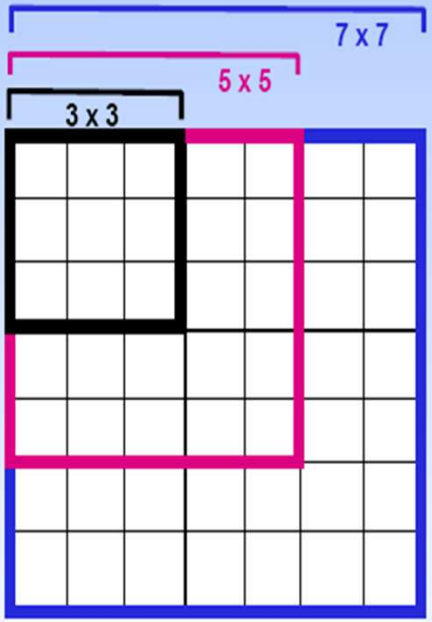
4,5,5,5,6,7,8,8,9
MEDIAN = 6

MODE

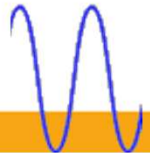
5	7	4
9	8	6
5	5	8

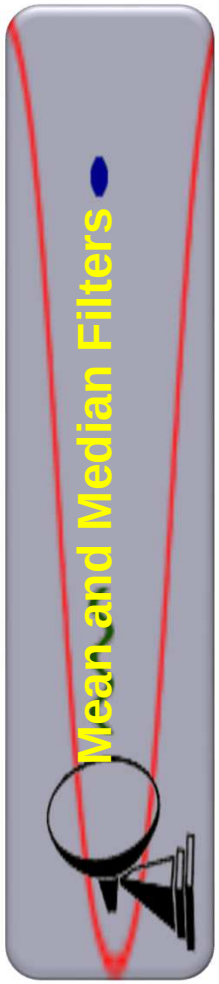
4
555
6
7
88
9

MODE = 5



Source: CCRS





Principle

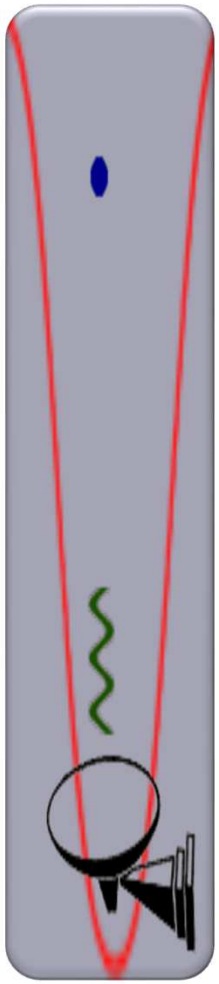
- Intensity at each sample interval in the image is replaced by the mean of pixel values in a moving window surrounding the sample.

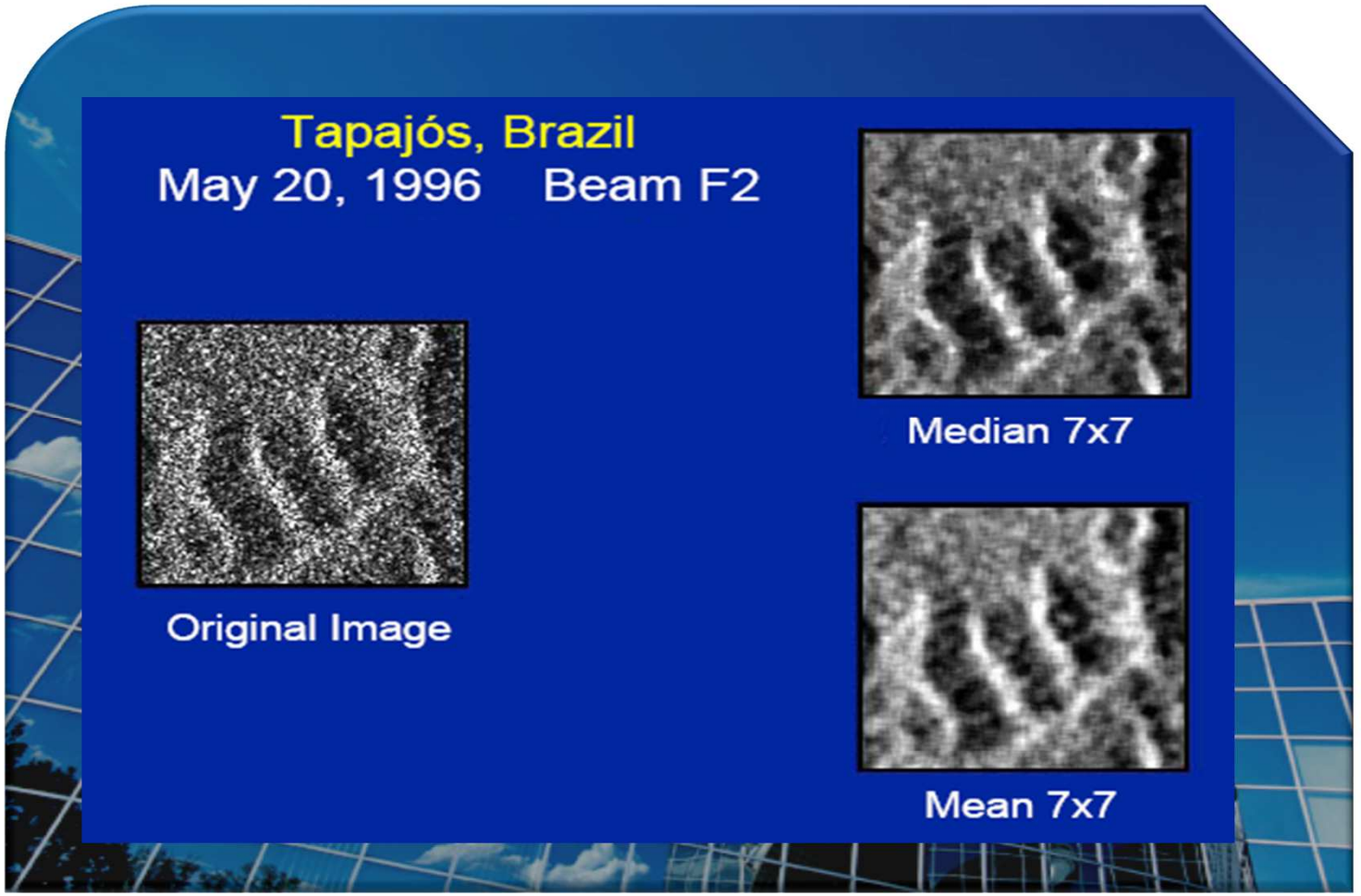
The box or mean filter preserves well the radiometry but blurs textured areas.

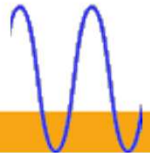
The median filter assigns the window median value to each sample.

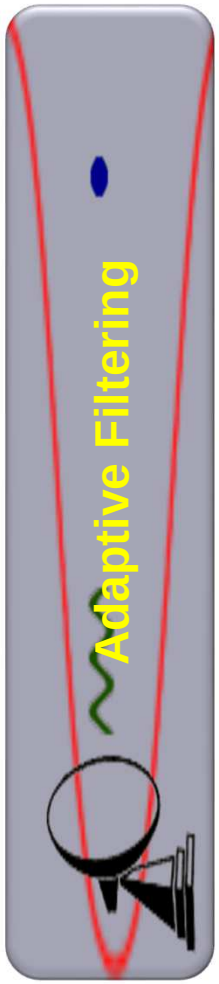
- Preserves texture information better
- Modifies the radiometric information of homogeneous areas, and does not preserve point target signature

Not recommended for radar imagery.

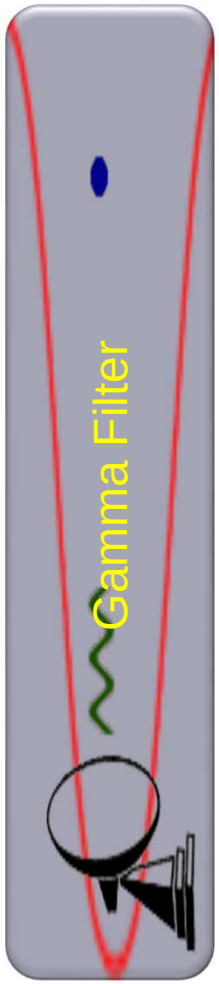



Tapajós, Brazil
May 20, 1996 Beam F2
Original Image
Median 7x7
Mean 7x7



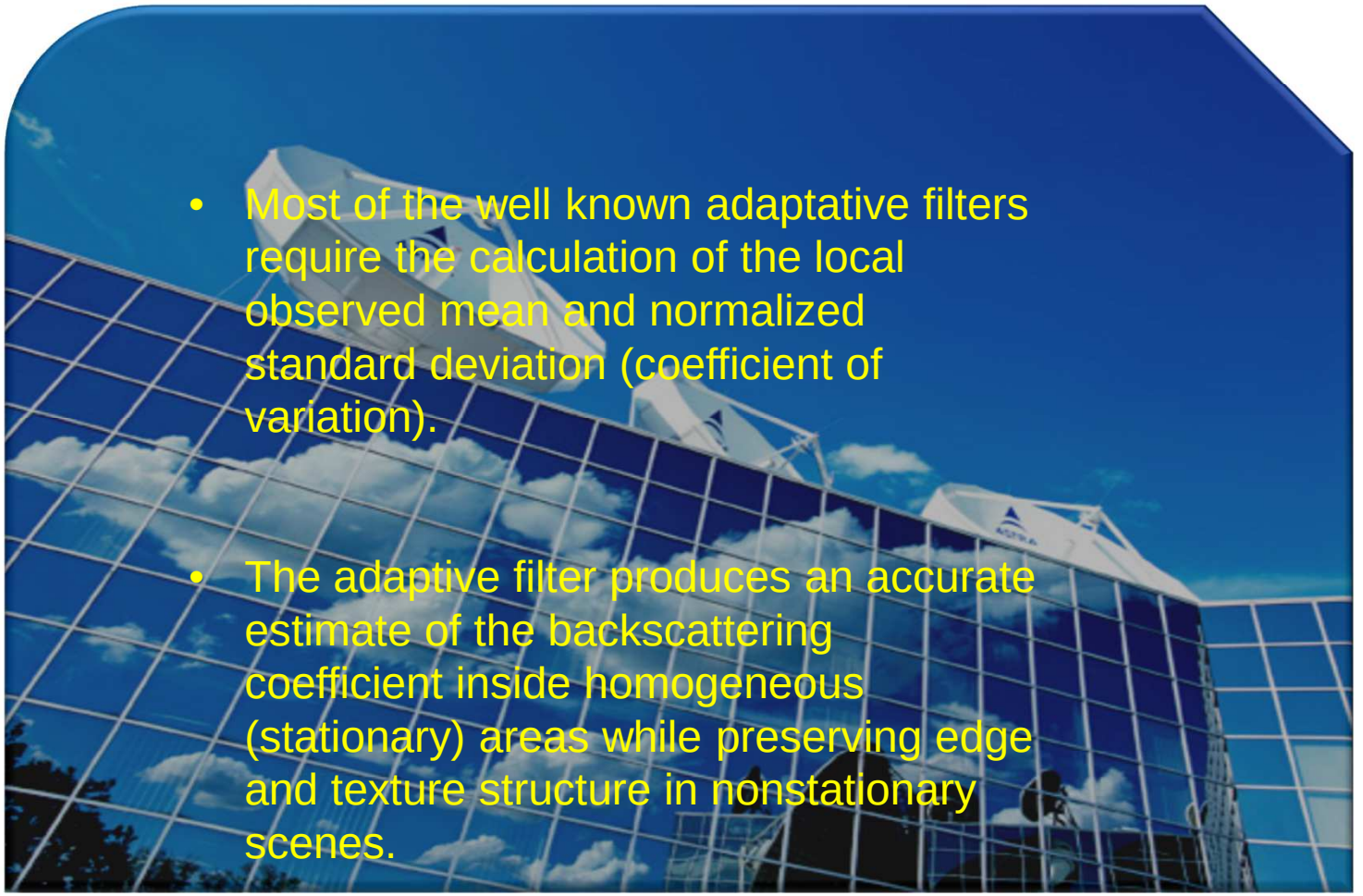


- Adaptive filters (e.g. Map Gamma) reduce speckle while preserving the edges (sharp contrast variation).
- Adaptive filters modify the image based on statistics extracted from the local environment of each pixel.
- Larger kernel size (e.g. 11x11) result in an important increased smoothing effect on the resulting image


Gamma Filter

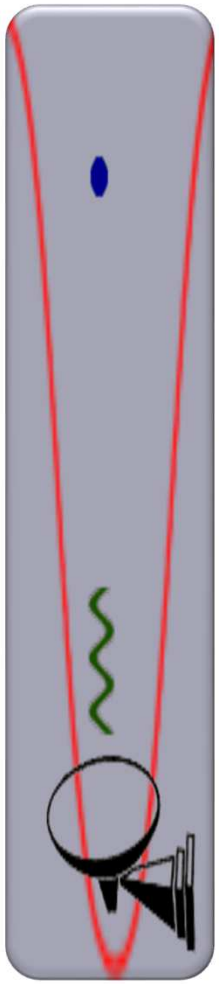

Tapajós, Brazil
May 20, 1996 Beam F2
Original Image
Map Gamma
7x7
Map Gamma
11x11

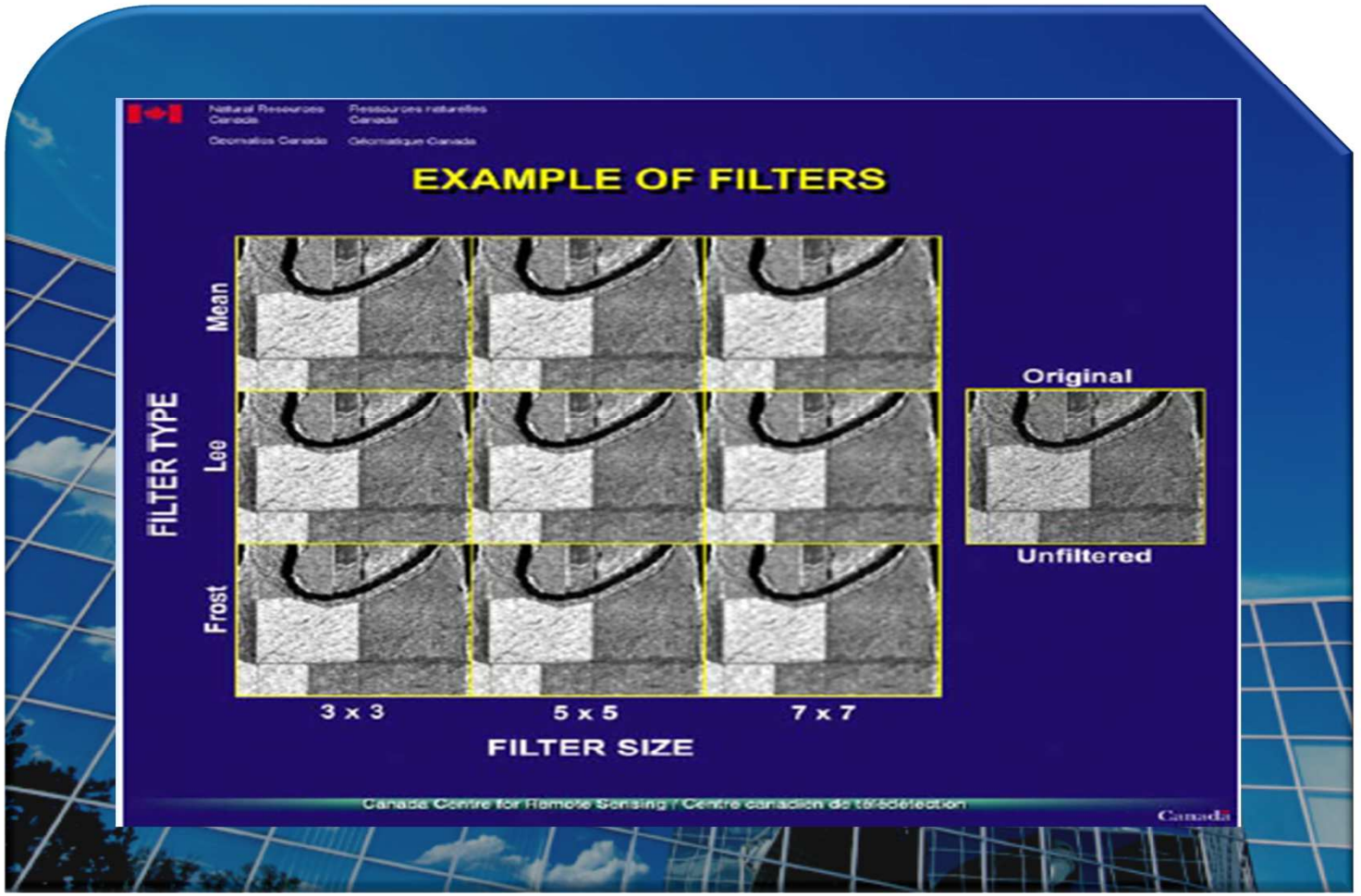
Advantages of Adaptive Filters



- Most of the well known adaptative filters require the calculation of the local observed mean and normalized standard deviation (coefficient of variation).

- The adaptive filter produces an accurate estimate of the backscattering coefficient inside homogeneous (stationary) areas while preserving edge and texture structure in nonstationary scenes.




Natural Resources Canada
Ressources naturelles Canada
Géomatique Canada
EXAMPLE OF FILTERS
FILTER TYPE
Mean
Lee
Frost
3 x 3
5 x 5
7 x 7
FILTER SIZE
Original
Unfiltered
Canada Centre for Remote Sensing / Centre canadien de télédétection
Canada