The ERS Interferometric Quick Look Processor: a Powerful System to Assess and Exploit the ERS Tandem Archive for Land-Use Information Retrieval

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ABSTRACT

The ERS Interferometric Quick Look processor developed by ESA has made it possible to examine the interferometric coherence of ERS data for land-use applications on a world wide scale. Many successful interferometric studies have been focussed on relatively small regions of terrain. This is partly because of the localised nature of some of the areas of interest but also because of the relatively high processing load required by interferometry. The Interferometric Quick Look system has been designed to rapidly process complete strips of ERS SAR data and many examples, covering a wide range of land surfaces, have been processed at ESRIN. Some of these can be viewed at:

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In this paper we describe the Interferometric Quick Look system, show examples of how its output is relevant to land classification, and discuss the use of the system to assess ERS Tandem data for land-use exploitation.

IQL BACKGROUND

What is the IQL?

The Interferometric Quick Look (IQL) system produces 'interferometric images' from very large volumes of ERS SAR data. The IQL requires complete passes of raw SAR data as input and generates continuous output images. The system is completely automatic and has been designed with many features to ensure a fast throughput.

What is the Aim of the IQL?

The IQL processor was built with the aim of trying to assess the quality of selected samples of ERS tandem data. Usually this involves checking that there is sufficient coherence to facilitate the various interferometric applications for a particular set of images or terrain type.

The ERS tandem mission, during which both the ERS-1 and ERS-2 satellites were observing the same part of the ground with a 1-day time interval, has produced a unique archive of data which covers the vast majority of the Earth's surface. Although there have been many interferometric studies that have made use of ERS tandem data, this only represents a very small fraction of the available archive. There is therefore still much to learn from this data and the large scale production capability of the IQL provides a powerful tool for helping to reveal the full potential of ERS tandem data.

How is the IQL Currently Being Used?

The IQL system is currently being run at ESRIN on a daily basis. Data from many regions around the world are being selected for processing, with the aim of covering a wide range of representative land-use types.

Where can I see IQL images?

ESRIN has developed a web site to host examples of the IQL output images. The address for the web site is:

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The data shown on this site are in a browse format; the pixel size is 200m x 200m and the images are jpeg compressed. This means that they are not usually appropriate for conducting quantitative scientific studies but that they provide very clear information about the quality of the data. In particular the coherence of the data can readily be assessed and hence the suitability of interferometric techniques for the particular region of the world covered by the image.

To date, the "INSI" web site contains data from the following countries: Angola, Argentina, Australia, Austria, Bolivia, Borneo, Brazil, Cambodia, Canada, Central African Republic, China, Congo (Zaire), Ecuador, Egypt, Eritrea, Ethiopia, France, Guatemala, Guyana, Haiti, Indonesia, Iran, Iraq, Israel, Italy, Jordan, Kazakhstan, Kenya, Kuwait, Laos, Mexico, Netherlands, Norway, Paraguay, Portugal, Saudi Arabia, Spain, Sudan, Suriname, Tanzania, Thailand, Turkmenistan, USA, Uganda, Uzbekistan, Vietnam and Zambia.

The web site also contains facilities for users to provide feedback about any features they consider to be of interest.

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Who is interested in IQL output?

Traditionally the main application of interferometric techniques has been the measuring and monitoring of the Earth's topography. However, the use of interferometric coherence is increasingly being used in applications related to the retrieval of bio- and geo-physical parameters for land applications. This fact has been reflected by a corresponding increase in interest in the ILU (Interferometric Land-Use) image produced by the IQL system.

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The ILU (Interferometric Land-Use) image is an RGB image where the separate channels have been coded such that:

Red = Interferometric coherence.
Green = The minimum intensity, at any given pixel, from the two acquisitions.
Blue = Intensity change between the two acquisitions.

More commonly, for this type of image, the average intensity between the two intensity acquisitions is used as the green channel. However, under certain wind conditions, this combination often leads to water bodies being green in colour. This can cause confusion with forest regions. By using the minimum intensity it is often possible to help give the water bodies a blue colour.

The resulting ILU image is useful for quickly assessing the suitability of an interferometric pair for discrimination between different land use types.

In addition, this particular RGB combination has been chosen so that the land-use types are coloured in a manner which might be found in a photographic image. In this way the ILU images can be thought of as a form of "colour SAR image". This can often be an important consideration when presenting SAR data to audiences who are not SAR experts.

A simplified understanding of the relationship between the ILU image colours and the land surface type is as follows:

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The other type of image which can be found on the 'INSI' web page is what we have called the Interferometric Browse Product or IBP. The IBP image shows

the interferometric phase projected on a colour wheel in those regions where the coherence is higher than 0.2 and the average intensity image on a grey-scale elsewhere. This image is useful to quickly assess the quality of the interferometric fringes, which might, for example, be used to make digital elevation models (DEMs). Each cycle of the colours (for example, going from yellow to purple to turquoise and back to yellow again) represents a change in the ground height which is dependent on the satellite geometry.

Are there any Specific Applications where the IQL System has Provided Input Data?

A project conducted at ESRIN [1] has made use of the IQL output to investigate the extent of deforestation caused by the fire events that occurred in the forests of Indonesia in 1997. In general, one of the main advantages of using interferometric techniques for land classification tasks is that the coherence provides an extra valuable feature, which can help to separate regions of forest from agricultural land cover. These are classes which are difficult to separate using SAR intensity alone. Therefore, the Indonesia project provides a good example of a large scale project where the IQL system has provided valuable information.

In figure 1 another example of deforestation is shown. This is an ILU image from a region in Paraguay made with tandem data acquired on 29-30 March 1996. The orbit numbers are ERS-1: 24604 and ERS-2: 4931 and the frame number is approximately 4041. It can be seen that the predominant colour in this image is green, indicating forested areas. However, cut into the forest are many rectangular shaped regions which contain colours which include a greater degree of red, principally orange. This higher level of coherence indicates areas where the forest has been cleared in order to allow agricultural activity.

IQL DESIGN

Various techniques are used in the IQL system to allow efficient processing. The five most important features are described here.

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Raw data is band-pass filtered and re-sampled in both range and azimuth before it is focused. This greatly reduces the amount of input data and the size of the necessary filters thus improving the efficiency. A sub-sampling factor of 2 is used in range and 8 in azimuth. Out of the 8 possible azimuth spectral bands (looks), 3 are discarded and 5 are processed separately and then combined as independent spectral looks to reduce speckle noise. The bands are chosen so as to include, firstly, the look centered on the average Doppler centroid of the 2 passes and then the 4 looks which are the nearest neighbours to this one.

In range, the different look angle between the 2 passes creates a spectral shift between their spectra. The non-overlapping part of the spectrum is filtered out and a look is taken so that it is centred on the overlapping part. The other look, which usually does not contain much information, is discarded.

(2) Co-registration

The IQL is basically processed in independent slices which cover the full 100 km swath in range and are 30 km long in azimuth. After the sub-sampling stage the raw data slices are focussed. The co-registration parameters between the 2 passes are calculated by finding 2 pairs of corresponding tie-points in the images made from the central look of the 2 passes. These tie-points are found by looking at the cross correlation function of many small patches (~8x8 pixels) in the 2 images and stopping as soon as soon as there is reasonable confidence that good tie-points have been found. Two pairs of tie-points are used to give the co-registration process both a shift and a stretch capability. Various rules are employed to try and ensure that reliable tie-points are chosen. However, there are still situations when errors can occur in the co-registration process, for example in situations where the processing strips correspond to water (or forest and thus with no reasonable coherence patches) or where the terrain is unstable such when there is moving ice.

Once the co-registration parameters have been established, each complex focussed look of the first pass is re-sampled on to the corresponding look of the second pass using small (~7 pixel) time domain filters. From these co-registered complex images 3 basic outputs are produced: a coherently averaged 5 look complex interferogram and two incoherently averaged 5 look inten-

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where the sums are over L=5 looks in frequency and N spatially adjacent pixels. In general, large values of N will give poor spatial resolution but will help to reduce the zero coherence bias and the speckle noise. A value of N=3x3 is the compromise used in the IQL, which gives a zero coherence bias of approximately 0.21. It should be noted that values of N greater than 1 also introduce a negative bias for high phase slopes. This leads to an under-estimate of the coherence in regions of high slope.

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After the processing strips have been joined together, taking account of the changes in SWST (sampling window start time) and after the coherence has been calculated, the phase of the interferogram is computed. The phase image is corrected for fringes due to the Earth's ellipsoid by accurately propagating the input state-vectors and calculating the induced phase. It has been found that using precise rather than restituted state vectors gives a clear improvement in the ellipsoid correction.

At this stage the first output from the IQL processor is saved on disk. This is the basic, lowest level, output from the IQL system and comprises four slant range images; the coherence, phase, intensity 1 and intensity 2. These images have 1 byte per pixel and have a resolution of 32 m in azimuth and 38 m in ground range. The ILU and IBP browse images, discussed earlier, are produced from these basic slant-range images. As well as the browse images, the IQL offers the possibility to produce the coherence, phase and two intensity images in ground range with a chosen pixel size. The colour browse images can also be produced at higher resolutions than those shown on the "INSI" web page.

(5) Parallel Processing

An important part in the design of the IQL was the use of parallel processing to increase efficiency. This consisted mainly of the implementation of the IQL as many small programs, each with its own specific task. These sub-programs are launched by a main program (when required) and communicate with each other using shared memory and semaphores. The decision exactly when to run which program on which CPU is decided during run-time by the computer's operating system.

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Who Built the IQL system?

The IQL system has been developed by Advanced Computer Systems based on an initial prototype designed at the Dipartimento di Elettronica, Politecnico di Milano.

CONCLUSION

The ERS Interferometric Quick Look system developed at ERSIN has provided a powerful tool for assessing the quality of the ERS tandem archive over large areas of the world's surface. It has been found that the mode of the coherence over non-forested areas is typically 0.7 for tandem data. This confirms the value of this dataset for DEM generation and is also usually sufficient to allow forested surfaces to be separated from other land classes with a high degree of confidence.

REFERENCES

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Figure 1: An ILU image over Paraguay.

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The ERS Interferometric Quick Look system developed at ERSIN has provided a powerful tool for assessing the quality of the ERS tandem archive over large areas of the world's surface. It has been found that the mode of the coherence over non-forested areas is typically 0.7 for tandem data. This confirms the value of this dataset for DEM generation and is also usually sufficient to allow forested surfaces to be separated from other land classes with a high degree of confidence.

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Figure 1: An ILU image over Paraguay.

The ERS Interferometric Quick Look Processor: a Powerful System to Assess and Exploit the ERS Tandem Archive for Land-Use Information Retrieval

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ABSTRACT

The ERS Interferometric Quick Look processor developed by ESA has made it possible to examine the interferometric coherence of ERS data for land-use applications on a world wide scale. Many successful interferometric studies have been focussed on relatively small regions of terrain. This is partly because of the localised nature of some of the areas of interest but also because of the relatively high processing load required by interferometry. The Interferometric Quick Look system has been designed to rapidly process complete strips of ERS SAR data and many examples, covering a wide range of land surfaces, have been processed at ESRIN. Some of these can be viewed at:

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In this paper we describe the Interferometric Quick Look system, show examples of how its output is relevant to land classification, and discuss the use of the system to assess ERS Tandem data for land-use exploitation.

IQL BACKGROUND

What is the IQL?

The Interferometric Quick Look (IQL) system produces 'interferometric images' from very large volumes of ERS SAR data. The IQL requires complete passes of raw SAR data as input and generates continuous output images. The system is completely automatic and has been designed with many features to ensure a fast throughput.

What is the Aim of the IQL?

The IQL processor was built with the aim of trying to assess the quality of selected samples of ERS tandem data. Usually this involves checking that there is sufficient coherence to facilitate the various interferometric applications for a particular set of images or terrain type.

The ERS tandem mission, during which both the ERS-1 and ERS-2 satellites were observing the same part of the ground with a 1-day time interval, has produced a unique archive of data which covers the vast majority of the Earth's surface. Although there have been many interferometric studies that have made use of ERS tandem data, this only represents a very small fraction of the available archive. There is therefore still much to learn from this data and the large scale production capability of the IQL provides a powerful tool for helping to reveal the full potential of ERS tandem data.

How is the IQL Currently Being Used?

The IQL system is currently being run at ESRIN on a daily basis. Data from many regions around the world are being selected for processing, with the aim of covering a wide range of representative land-use types.

Where can I see IQL images?

ESRIN has developed a web site to host examples of the IQL output images. The address for the web site is:

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The data shown on this site are in a browse format; the pixel size is 200m x 200m and the images are jpeg compressed. This means that they are not usually appropriate for conducting quantitative scientific studies but that they provide very clear information about the quality of the data. In particular the coherence of the data can readily be assessed and hence the suitability of interferometric techniques for the particular region of the world covered by the image.

To date, the "INSI" web site contains data from the following countries: Angola, Argentina, Australia, Austria, Bolivia, Borneo, Brazil, Cambodia, Canada, Central African Republic, China, Congo (Zaire), Ecuador, Egypt, Eritrea, Ethiopia, France, Guatemala, Guyana, Haiti, Indonesia, Iran, Iraq, Israel, Italy, Jordan, Kazakhstan, Kenya, Kuwait, Laos, Mexico, Netherlands, Norway, Paraguay, Portugal, Saudi Arabia, Spain, Sudan, Suriname, Tanzania, Thailand, Turkmenistan, USA, Uganda, Uzbekistan, Vietnam and Zambia.

The web site also contains facilities for users to provide feedback about any features they consider to be of interest.

THE IQL AND LAND-USE

Who is interested in IQL output?

Traditionally the main application of interferometric techniques has been the measuring and monitoring of the Earth's topography. However, the use of interferometric coherence is increasingly being used in applications related to the retrieval of bio- and geo-physical parameters for land applications. This fact has been reflected by a corresponding increase in interest in the ILU (Interferometric Land-Use) image produced by the IQL system.

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Figure 1: An ILU image over Paraguay.

The ERS Interferometric Quick Look Processor: a Powerful System to Assess and Exploit the ERS Tandem Archive for Land-Use Information Retrieval

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ABSTRACT

The ERS Interferometric Quick Look processor developed by ESA has made it possible to examine the interferometric coherence of ERS data for land-use applications on a world wide scale. Many successful interferometric studies have been focussed on relatively small regions of terrain. This is partly because of the localised nature of some of the areas of interest but also because of the relatively high processing load required by interferometry. The Interferometric Quick Look system has been designed to rapidly process complete strips of ERS SAR data and many examples, covering a wide range of land surfaces, have been processed at ESRIN. Some of these can be viewed at:

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In this paper we describe the Interferometric Quick Look system, show examples of how its output is relevant to land classification, and discuss the use of the system to assess ERS Tandem data for land-use exploitation.

IQL BACKGROUND

What is the IQL?

The Interferometric Quick Look (IQL) system produces 'interferometric images' from very large volumes of ERS SAR data. The IQL requires complete passes of raw SAR data as input and generates continuous output images. The system is completely automatic and has been designed with many features to ensure a fast throughput.

What is the Aim of the IQL?

The IQL processor was built with the aim of trying to assess the quality of selected samples of ERS tandem data. Usually this involves checking that there is sufficient coherence to facilitate the various interferometric applications for a particular set of images or terrain type.

The ERS tandem mission, during which both the ERS-1 and ERS-2 satellites were observing the same part of the ground with a 1-day time interval, has produced a unique archive of data which covers the vast majority of the Earth's surface. Although there have been many interferometric studies that have made use of ERS tandem data, this only represents a very small fraction of the available archive. There is therefore still much to learn from this data and the large scale production capability of the IQL provides a powerful tool for helping to reveal the full potential of ERS tandem data.

How is the IQL Currently Being Used?

The IQL system is currently being run at ESRIN on a daily basis. Data from many regions around the world are being selected for processing, with the aim of covering a wide range of representative land-use types.

Where can I see IQL images?

ESRIN has developed a web site to host examples of the IQL output images. The address for the web site is:

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The data shown on this site are in a browse format; the pixel size is 200m x 200m and the images are jpeg compressed. This means that they are not usually appropriate for conducting quantitative scientific studies but that they provide very clear information about the quality of the data. In particular the coherence of the data can readily be assessed and hence the suitability of interferometric techniques for the particular region of the world covered by the image.

To date, the "INSI" web site contains data from the following countries: Angola, Argentina, Australia, Austria, Bolivia, Borneo, Brazil, Cambodia, Canada, Central African Republic, China, Congo (Zaire), Ecuador, Egypt, Eritrea, Ethiopia, France, Guatemala, Guyana, Haiti, Indonesia, Iran, Iraq, Israel, Italy, Jordan, Kazakhstan, Kenya, Kuwait, Laos, Mexico, Netherlands, Norway, Paraguay, Portugal, Saudi Arabia, Spain, Sudan, Suriname, Tanzania, Thailand, Turkmenistan, USA, Uganda, Uzbekistan, Vietnam and Zambia.

The web site also contains facilities for users to provide feedback about any features they consider to be of interest.

THE IQL AND LAND-USE

Who is interested in IQL output?

Traditionally the main application of interferometric techniques has been the measuring and monitoring of the Earth's topography. However, the use of interferometric coherence is increasingly being used in applications related to the retrieval of bio- and geo-physical parameters for land applications. This fact has been reflected by a corresponding increase in interest in the ILU (Interferometric Land-Use) image produced by the IQL system.

What is an ILU image?

The ILU (Interferometric Land-Use) image is an RGB image where the separate channels have been coded such that:

Red = Interferometric coherence.
Green = The minimum intensity, at any given pixel, from the two acquisitions.
Blue = Intensity change between the two acquisitions.

More commonly, for this type of image, the average intensity between the two intensity acquisitions is used as the green channel. However, under certain wind conditions, this combination often leads to water bodies being green in colour. This can cause confusion with forest regions. By using the minimum intensity it is often possible to help give the water bodies a blue colour.

The resulting ILU image is useful for quickly assessing the suitability of an interferometric pair for discrimination between different land use types.

In addition, this particular RGB combination has been chosen so that the land-use types are coloured in a manner which might be found in a photographic image. In this way the ILU images can be thought of as a form of "colour SAR image". This can often be an important consideration when presenting SAR data to audiences who are not SAR experts.

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The other type of image which can be found on the 'INSI' web page is what we have called the Interferometric Browse Product or IBP. The IBP image shows

the interferometric phase projected on a colour wheel in those regions where the coherence is higher than 0.2 and the average intensity image on a grey-scale elsewhere. This image is useful to quickly assess the quality of the interferometric fringes, which might, for example, be used to make digital elevation models (DEMs). Each cycle of the colours (for example, going from yellow to purple to turquoise and back to yellow again) represents a change in the ground height which is dependent on the satellite geometry.

Are there any Specific Applications where the IQL System has Provided Input Data?

A project conducted at ESRIN [1] has made use of the IQL output to investigate the extent of deforestation caused by the fire events that occurred in the forests of Indonesia in 1997. In general, one of the main advantages of using interferometric techniques for land classification tasks is that the coherence provides an extra valuable feature, which can help to separate regions of forest from agricultural land cover. These are classes which are difficult to separate using SAR intensity alone. Therefore, the Indonesia project provides a good example of a large scale project where the IQL system has provided valuable information.

In figure 1 another example of deforestation is shown. This is an ILU image from a region in Paraguay made with tandem data acquired on 29-30 March 1996. The orbit numbers are ERS-1: 24604 and ERS-2: 4931 and the frame number is approximately 4041. It can be seen that the predominant colour in this image is green, indicating forested areas. However, cut into the forest are many rectangular shaped regions which contain colours which include a greater degree of red, principally orange. This higher level of coherence indicates areas where the forest has been cleared in order to allow agricultural activity.

IQL DESIGN

Various techniques are used in the IQL system to allow efficient processing. The five most important features are described here.

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In range, the different look angle between the 2 passes creates a spectral shift between their spectra. The non-overlapping part of the spectrum is filtered out and a look is taken so that it is centred on the overlapping part. The other look, which usually does not contain much information, is discarded.

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The ERS Interferometric Quick Look system developed at ERSIN has provided a powerful tool for assessing the quality of the ERS tandem archive over large areas of the world's surface. It has been found that the mode of the coherence over non-forested areas is typically 0.7 for tandem data. This confirms the value of this dataset for DEM generation and is also usually sufficient to allow forested surfaces to be separated from other land classes with a high degree of confidence.

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Figure 1: An ILU image over Paraguay.

The ERS Interferometric Quick Look Processor: a Powerful System to Assess and Exploit the ERS Tandem Archive for Land-Use Information Retrieval

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ABSTRACT

The ERS Interferometric Quick Look processor developed by ESA has made it possible to examine the interferometric coherence of ERS data for land-use applications on a world wide scale. Many successful interferometric studies have been focussed on relatively small regions of terrain. This is partly because of the localised nature of some of the areas of interest but also because of the relatively high processing load required by interferometry. The Interferometric Quick Look system has been designed to rapidly process complete strips of ERS SAR data and many examples, covering a wide range of land surfaces, have been processed at ESRIN. Some of these can be viewed at:

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In this paper we describe the Interferometric Quick Look system, show examples of how its output is relevant to land classification, and discuss the use of the system to assess ERS Tandem data for land-use exploitation.

IQL BACKGROUND

What is the IQL?

The Interferometric Quick Look (IQL) system produces 'interferometric images' from very large volumes of ERS SAR data. The IQL requires complete passes of raw SAR data as input and generates continuous output images. The system is completely automatic and has been designed with many features to ensure a fast throughput.

What is the Aim of the IQL?

The IQL processor was built with the aim of trying to assess the quality of selected samples of ERS tandem data. Usually this involves checking that there is sufficient coherence to facilitate the various interferometric applications for a particular set of images or terrain type.

The ERS tandem mission, during which both the ERS-1 and ERS-2 satellites were observing the same part of the ground with a 1-day time interval, has produced a unique archive of data which covers the vast majority of the Earth's surface. Although there have been many interferometric studies that have made use of ERS tandem data, this only represents a very small fraction of the available archive. There is therefore still much to learn from this data and the large scale production capability of the IQL provides a powerful tool for helping to reveal the full potential of ERS tandem data.

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The IQL system is currently being run at ESRIN on a daily basis. Data from many regions around the world are being selected for processing, with the aim of covering a wide range of representative land-use types.

Where can I see IQL images?

ESRIN has developed a web site to host examples of the IQL output images. The address for the web site is:

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The data shown on this site are in a browse format; the pixel size is 200m x 200m and the images are jpeg compressed. This means that they are not usually appropriate for conducting quantitative scientific studies but that they provide very clear information about the quality of the data. In particular the coherence of the data can readily be assessed and hence the suitability of interferometric techniques for the particular region of the world covered by the image.

To date, the "INSI" web site contains data from the following countries: Angola, Argentina, Australia, Austria, Bolivia, Borneo, Brazil, Cambodia, Canada, Central African Republic, China, Congo (Zaire), Ecuador, Egypt, Eritrea, Ethiopia, France, Guatemala, Guyana, Haiti, Indonesia, Iran, Iraq, Israel, Italy, Jordan, Kazakhstan, Kenya, Kuwait, Laos, Mexico, Netherlands, Norway, Paraguay, Portugal, Saudi Arabia, Spain, Sudan, Suriname, Tanzania, Thailand, Turkmenistan, USA, Uganda, Uzbekistan, Vietnam and Zambia.

The web site also contains facilities for users to provide feedback about any features they consider to be of interest.

THE IQL AND LAND-USE

Who is interested in IQL output?

Traditionally the main application of interferometric techniques has been the measuring and monitoring of the Earth's topography. However, the use of interferometric coherence is increasingly being used in applications related to the retrieval of bio- and geo-physical parameters for land applications. This fact has been reflected by a corresponding increase in interest in the ILU (Interferometric Land-Use) image produced by the IQL system.

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Green = The minimum intensity, at any given pixel, from the two acquisitions.
Blue = Intensity change between the two acquisitions.

More commonly, for this type of image, the average intensity between the two intensity acquisitions is used as the green channel. However, under certain wind conditions, this combination often leads to water bodies being green in colour. This can cause confusion with forest regions. By using the minimum intensity it is often possible to help give the water bodies a blue colour.

The resulting ILU image is useful for quickly assessing the suitability of an interferometric pair for discrimination between different land use types.

In addition, this particular RGB combination has been chosen so that the land-use types are coloured in a manner which might be found in a photographic image. In this way the ILU images can be thought of as a form of "colour SAR image". This can often be an important consideration when presenting SAR data to audiences who are not SAR experts.

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The other type of image which can be found on the 'INSI' web page is what we have called the Interferometric Browse Product or IBP. The IBP image shows

the interferometric phase projected on a colour wheel in those regions where the coherence is higher than 0.2 and the average intensity image on a grey-scale elsewhere. This image is useful to quickly assess the quality of the interferometric fringes, which might, for example, be used to make digital elevation models (DEMs). Each cycle of the colours (for example, going from yellow to purple to turquoise and back to yellow again) represents a change in the ground height which is dependent on the satellite geometry.

Are there any Specific Applications where the IQL System has Provided Input Data?

A project conducted at ESRIN [1] has made use of the IQL output to investigate the extent of deforestation caused by the fire events that occurred in the forests of Indonesia in 1997. In general, one of the main advantages of using interferometric techniques for land classification tasks is that the coherence provides an extra valuable feature, which can help to separate regions of forest from agricultural land cover. These are classes which are difficult to separate using SAR intensity alone. Therefore, the Indonesia project provides a good example of a large scale project where the IQL system has provided valuable information.

In figure 1 another example of deforestation is shown. This is an ILU image from a region in Paraguay made with tandem data acquired on 29-30 March 1996. The orbit numbers are ERS-1: 24604 and ERS-2: 4931 and the frame number is approximately 4041. It can be seen that the predominant colour in this image is green, indicating forested areas. However, cut into the forest are many rectangular shaped regions which contain colours which include a greater degree of red, principally orange. This higher level of coherence indicates areas where the forest has been cleared in order to allow agricultural activity.

IQL DESIGN

Various techniques are used in the IQL system to allow efficient processing. The five most important features are described here.

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Raw data is band-pass filtered and re-sampled in both range and azimuth before it is focused. This greatly reduces the amount of input data and the size of the necessary filters thus improving the efficiency. A sub-sampling factor of 2 is used in range and 8 in azimuth. Out of the 8 possible azimuth spectral bands (looks), 3 are discarded and 5 are processed separately and then combined as independent spectral looks to reduce speckle noise. The bands are chosen so as to include, firstly, the look centered on the average Doppler centroid of the 2 passes and then the 4 looks which are the nearest neighbours to this one.

In range, the different look angle between the 2 passes creates a spectral shift between their spectra. The non-overlapping part of the spectrum is filtered out and a look is taken so that it is centred on the overlapping part. The other look, which usually does not contain much information, is discarded.

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The IQL is basically processed in independent slices which cover the full 100 km swath in range and are 30 km long in azimuth. After the sub-sampling stage the raw data slices are focussed. The co-registration parameters between the 2 passes are calculated by finding 2 pairs of corresponding tie-points in the images made from the central look of the 2 passes. These tie-points are found by looking at the cross correlation function of many small patches (~8x8 pixels) in the 2 images and stopping as soon as soon as there is reasonable confidence that good tie-points have been found. Two pairs of tie-points are used to give the co-registration process both a shift and a stretch capability. Various rules are employed to try and ensure that reliable tie-points are chosen. However, there are still situations when errors can occur in the co-registration process, for example in situations where the processing strips correspond to water (or forest and thus with no reasonable coherence patches) or where the terrain is unstable such when there is moving ice.

Once the co-registration parameters have been established, each complex focussed look of the first pass is re-sampled on to the corresponding look of the second pass using small (~7 pixel) time domain filters. From these co-registered complex images 3 basic outputs are produced: a coherently averaged 5 look complex interferogram and two incoherently averaged 5 look inten-

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THE IQL AND LAND-USE

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The resulting ILU image is useful for quickly assessing the suitability of an interferometric pair for discrimination between different land use types.

In addition, this particular RGB combination has been chosen so that the land-use types are coloured in a manner which might be found in a photographic image. In this way the ILU images can be thought of as a form of "colour SAR image". This can often be an important consideration when presenting SAR data to audiences who are not SAR experts.

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In figure 1 another example of deforestation is shown. This is an ILU image from a region in Paraguay made with tandem data acquired on 29-30 March 1996. The orbit numbers are ERS-1: 24604 and ERS-2: 4931 and the frame number is approximately 4041. It can be seen that the predominant colour in this image is green, indicating forested areas. However, cut into the forest are many rectangular shaped regions which contain colours which include a greater degree of red, principally orange. This higher level of coherence indicates areas where the forest has been cleared in order to allow agricultural activity.

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In range, the different look angle between the 2 passes creates a spectral shift between their spectra. The non-overlapping part of the spectrum is filtered out and a look is taken so that it is centred on the overlapping part. The other look, which usually does not contain much information, is discarded.

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The IQL is basically processed in independent slices which cover the full 100 km swath in range and are 30 km long in azimuth. After the sub-sampling stage the raw data slices are focussed. The co-registration parameters between the 2 passes are calculated by finding 2 pairs of corresponding tie-points in the images made from the central look of the 2 passes. These tie-points are found by looking at the cross correlation function of many small patches (~8x8 pixels) in the 2 images and stopping as soon as soon as there is reasonable confidence that good tie-points have been found. Two pairs of tie-points are used to give the co-registration process both a shift and a stretch capability. Various rules are employed to try and ensure that reliable tie-points are chosen. However, there are still situations when errors can occur in the co-registration process, for example in situations where the processing strips correspond to water (or forest and thus with no reasonable coherence patches) or where the terrain is unstable such when there is moving ice.

Once the co-registration parameters have been established, each complex focussed look of the first pass is re-sampled on to the corresponding look of the second pass using small (~7 pixel) time domain filters. From these co-registered complex images 3 basic outputs are produced: a coherently averaged 5 look complex interferogram and two incoherently averaged 5 look inten-

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After the processing strips have been joined together, taking account of the changes in SWST (sampling window start time) and after the coherence has been calculated, the phase of the interferogram is computed. The phase image is corrected for fringes due to the Earth's ellipsoid by accurately propagating the input state-vectors and calculating the induced phase. It has been found that using precise rather than restituted state vectors gives a clear improvement in the ellipsoid correction.

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CONCLUSION

The ERS Interferometric Quick Look system developed at ERSIN has provided a powerful tool for assessing the quality of the ERS tandem archive over large areas of the world's surface. It has been found that the mode of the coherence over non-forested areas is typically 0.7 for tandem data. This confirms the value of this dataset for DEM generation and is also usually sufficient to allow forested surfaces to be separated from other land classes with a high degree of confidence.

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ABSTRACT

The ERS Interferometric Quick Look processor developed by ESA has made it possible to examine the interferometric coherence of ERS data for land-use applications on a world wide scale. Many successful interferometric studies have been focussed on relatively small regions of terrain. This is partly because of the localised nature of some of the areas of interest but also because of the relatively high processing load required by interferometry. The Interferometric Quick Look system has been designed to rapidly process complete strips of ERS SAR data and many examples, covering a wide range of land surfaces, have been processed at ESRIN. Some of these can be viewed at:

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In this paper we describe the Interferometric Quick Look system, show examples of how its output is relevant to land classification, and discuss the use of the system to assess ERS Tandem data for land-use exploitation.

IQL BACKGROUND

What is the IQL?

The Interferometric Quick Look (IQL) system produces 'interferometric images' from very large volumes of ERS SAR data. The IQL requires complete passes of raw SAR data as input and generates continuous output images. The system is completely automatic and has been designed with many features to ensure a fast throughput.

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The IQL processor was built with the aim of trying to assess the quality of selected samples of ERS tandem data. Usually this involves checking that there is sufficient coherence to facilitate the various interferometric applications for a particular set of images or terrain type.

The ERS tandem mission, during which both the ERS-1 and ERS-2 satellites were observing the same part of the ground with a 1-day time interval, has produced a unique archive of data which covers the vast majority of the Earth's surface. Although there have been many interferometric studies that have made use of ERS tandem data, this only represents a very small fraction of the available archive. There is therefore still much to learn from this data and the large scale production capability of the IQL provides a powerful tool for helping to reveal the full potential of ERS tandem data.

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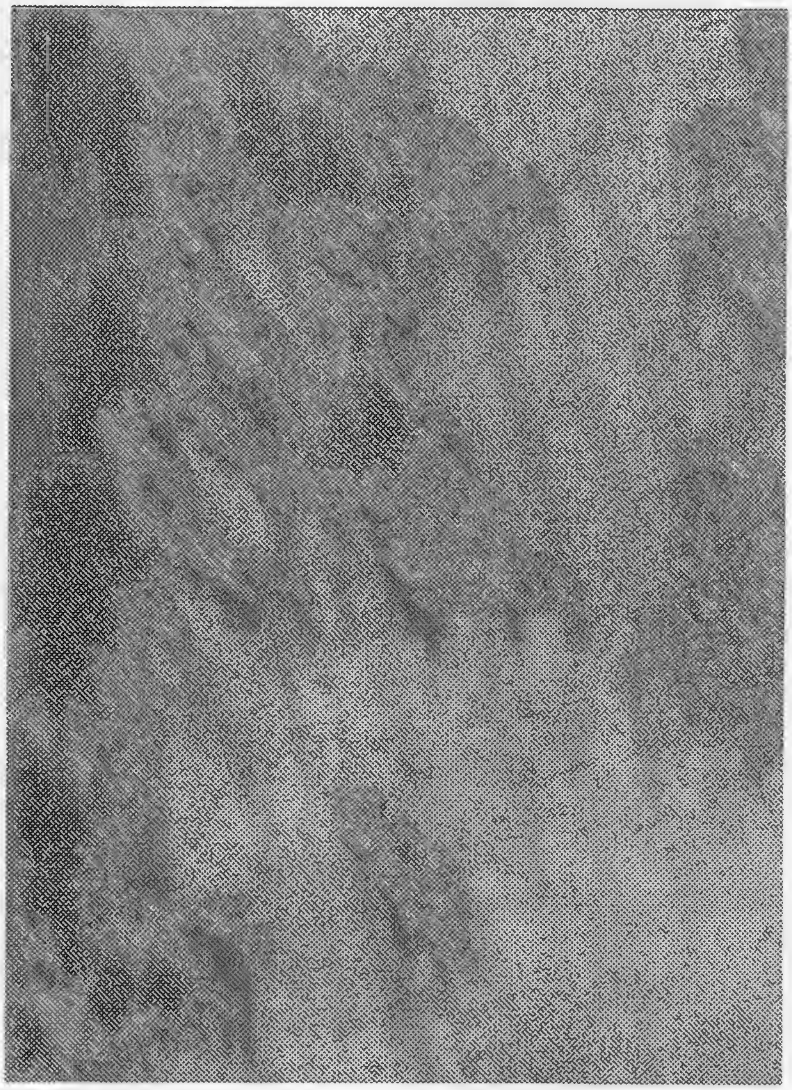

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Figure 1: An ILU image over Paraguay.

The ERS Interferometric Quick Look Processor: a Powerful System to Assess and Exploit the ERS Tandem Archive for Land-Use Information Retrieval

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ABSTRACT

The ERS Interferometric Quick Look processor developed by ESA has made it possible to examine the interferometric coherence of ERS data for land-use applications on a world wide scale. Many successful interferometric studies have been focussed on relatively small regions of terrain. This is partly because of the localised nature of some of the areas of interest but also because of the relatively high processing load required by interferometry. The Interferometric Quick Look system has been designed to rapidly process complete strips of ERS SAR data and many examples, covering a wide range of land surfaces, have been processed at ESRIN. Some of these can be viewed at:

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In this paper we describe the Interferometric Quick Look system, show examples of how its output is relevant to land classification, and discuss the use of the system to assess ERS Tandem data for land-use exploitation.

IQL BACKGROUND

What is the IQL?

The Interferometric Quick Look (IQL) system produces 'interferometric images' from very large volumes of ERS SAR data. The IQL requires complete passes of raw SAR data as input and generates continuous output images. The system is completely automatic and has been designed with many features to ensure a fast throughput.

What is the Aim of the IQL?

The IQL processor was built with the aim of trying to assess the quality of selected samples of ERS tandem data. Usually this involves checking that there is sufficient coherence to facilitate the various interferometric applications for a particular set of images or terrain type.

The ERS tandem mission, during which both the ERS-1 and ERS-2 satellites were observing the same part of the ground with a 1-day time interval, has produced a unique archive of data which covers the vast majority of the Earth's surface. Although there have been many interferometric studies that have made use of ERS tandem data, this only represents a very small fraction of the available archive. There is therefore still much to learn from this data and the large scale production capability of the IQL provides a powerful tool for helping to reveal the full potential of ERS tandem data.

How is the IQL Currently Being Used?

The IQL system is currently being run at ESRIN on a daily basis. Data from many regions around the world are being selected for processing, with the aim of covering a wide range of representative land-use types.

Where can I see IQL images?

ESRIN has developed a web site to host examples of the IQL output images. The address for the web site is:

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The data shown on this site are in a browse format; the pixel size is 200m x 200m and the images are jpeg compressed. This means that they are not usually appropriate for conducting quantitative scientific studies but that they provide very clear information about the quality of the data. In particular the coherence of the data can readily be assessed and hence the suitability of interferometric techniques for the particular region of the world covered by the image.

To date, the "INSI" web site contains data from the following countries: Angola, Argentina, Australia, Austria, Bolivia, Borneo, Brazil, Cambodia, Canada, Central African Republic, China, Congo (Zaire), Ecuador, Egypt, Eritrea, Ethiopia, France, Guatemala, Guyana, Haiti, Indonesia, Iran, Iraq, Israel, Italy, Jordan, Kazakhstan, Kenya, Kuwait, Laos, Mexico, Netherlands, Norway, Paraguay, Portugal, Saudi Arabia, Spain, Sudan, Suriname, Tanzania, Thailand, Turkmenistan, USA, Uganda, Uzbekistan, Vietnam and Zambia.

The web site also contains facilities for users to provide feedback about any features they consider to be of interest.

THE IQL AND LAND-USE

Who is interested in IQL output?

Traditionally the main application of interferometric techniques has been the measuring and monitoring of the Earth's topography. However, the use of interferometric coherence is increasingly being used in applications related to the retrieval of bio- and geo-physical parameters for land applications. This fact has been reflected by a corresponding increase in interest in the ILU (Interferometric Land-Use) image produced by the IQL system.

What is an ILU image?

The ILU (Interferometric Land-Use) image is an RGB image where the separate channels have been coded such that:

Red = Interferometric coherence.
Green = The minimum intensity, at any given pixel, from the two acquisitions.
Blue = Intensity change between the two acquisitions.

More commonly, for this type of image, the average intensity between the two intensity acquisitions is used as the green channel. However, under certain wind conditions, this combination often leads to water bodies being green in colour. This can cause confusion with forest regions. By using the minimum intensity it is often possible to help give the water bodies a blue colour.

The resulting ILU image is useful for quickly assessing the suitability of an interferometric pair for discrimination between different land use types.

In addition, this particular RGB combination has been chosen so that the land-use types are coloured in a manner which might be found in a photographic image. In this way the ILU images can be thought of as a form of "colour SAR image". This can often be an important consideration when presenting SAR data to audiences who are not SAR experts.

A simplified understanding of the relationship between the ILU image colours and the land surface type is as follows:

Green areas correspond to heavily vegetated (forests) or layover areas.
Blue areas correspond to water surfaces (sea & inland water).
Red areas correspond to bare rock and stable agricultural fields.
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The other type of image which can be found on the 'INSI' web page is what we have called the Interferometric Browse Product or IBP. The IBP image shows

the interferometric phase projected on a colour wheel in those regions where the coherence is higher than 0.2 and the average intensity image on a grey-scale elsewhere. This image is useful to quickly assess the quality of the interferometric fringes, which might, for example, be used to make digital elevation models (DEMs). Each cycle of the colours (for example, going from yellow to purple to turquoise and back to yellow again) represents a change in the ground height which is dependent on the satellite geometry.

Are there any Specific Applications where the IQL System has Provided Input Data?

A project conducted at ESRIN [1] has made use of the IQL output to investigate the extent of deforestation caused by the fire events that occurred in the forests of Indonesia in 1997. In general, one of the main advantages of using interferometric techniques for land classification tasks is that the coherence provides an extra valuable feature, which can help to separate regions of forest from agricultural land cover. These are classes which are difficult to separate using SAR intensity alone. Therefore, the Indonesia project provides a good example of a large scale project where the IQL system has provided valuable information.

In figure 1 another example of deforestation is shown. This is an ILU image from a region in Paraguay made with tandem data acquired on 29-30 March 1996. The orbit numbers are ERS-1: 24604 and ERS-2: 4931 and the frame number is approximately 4041. It can be seen that the predominant colour in this image is green, indicating forested areas. However, cut into the forest are many rectangular shaped regions which contain colours which include a greater degree of red, principally orange. This higher level of coherence indicates areas where the forest has been cleared in order to allow agricultural activity.

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At this stage the first output from the IQL processor is saved on disk. This is the basic, lowest level, output from the IQL system and comprises four slant range images; the coherence, phase, intensity 1 and intensity 2. These images have 1 byte per pixel and have a resolution of 32 m in azimuth and 38 m in ground range. The ILU and IBP browse images, discussed earlier, are produced from these basic slant-range images. As well as the browse images, the IQL offers the possibility to produce the coherence, phase and two intensity images in ground range with a chosen pixel size. The colour browse images can also be produced at higher resolutions than those shown on the "INSI" web page.

(5) Parallel Processing

An important part in the design of the IQL was the use of parallel processing to increase efficiency. This consisted mainly of the implementation of the IQL as many small programs, each with its own specific task. These sub-programs are launched by a main program (when required) and communicate with each other using shared memory and semaphores. The decision exactly when to run which program on which CPU is decided during run-time by the computer's operating system.

What Machines does the IQL Run on and How Fast is it?

The IQL is currently running on various Silicon Graphics machines. Specifically:

An 8-CPU (R8000/R8010 70/90 MHz), 1792 MB ram, 30 GB disk, IRIX v.6.2 Power Onyx. This can process raw data from 2 3000km long passes on disk at a rate of ~ 1.5 minutes per 30km slice.

A 2-CPU R10000 Origin 200 with 768MB. This can process raw data from 2 3000km long passes on disk at a rate of ~ 2.5 minutes per 30km slice.

Data ingestion is from SONY D1, DLT or Exabyte in various formats and can be run independently from the processing.

Who Built the IQL system?

The IQL system has been developed by Advanced Computer Systems based on an initial prototype designed at the Dipartimento di Elettronica, Politecnico di Milano.

CONCLUSION

The ERS Interferometric Quick Look system developed at ERSIN has provided a powerful tool for assessing the quality of the ERS tandem archive over large areas of the world's surface. It has been found that the mode of the coherence over non-forested areas is typically 0.7 for tandem data. This confirms the value of this dataset for DEM generation and is also usually sufficient to allow forested surfaces to be separated from other land classes with a high degree of confidence.

REFERENCES

[1] Antikidis E., O Arino, H Laur, A Arnaud, "ERS SAR Coherence and ATSR Hot Spots: a Synergy for Mapping Deforested Areas. The Special Case of the 1997 Fire Event in Indonesia. Second International Workshop on "Retrieval of Bio- and Geo-Physical Parameters from SAR Data for Land Applications", ESTEC 1998.

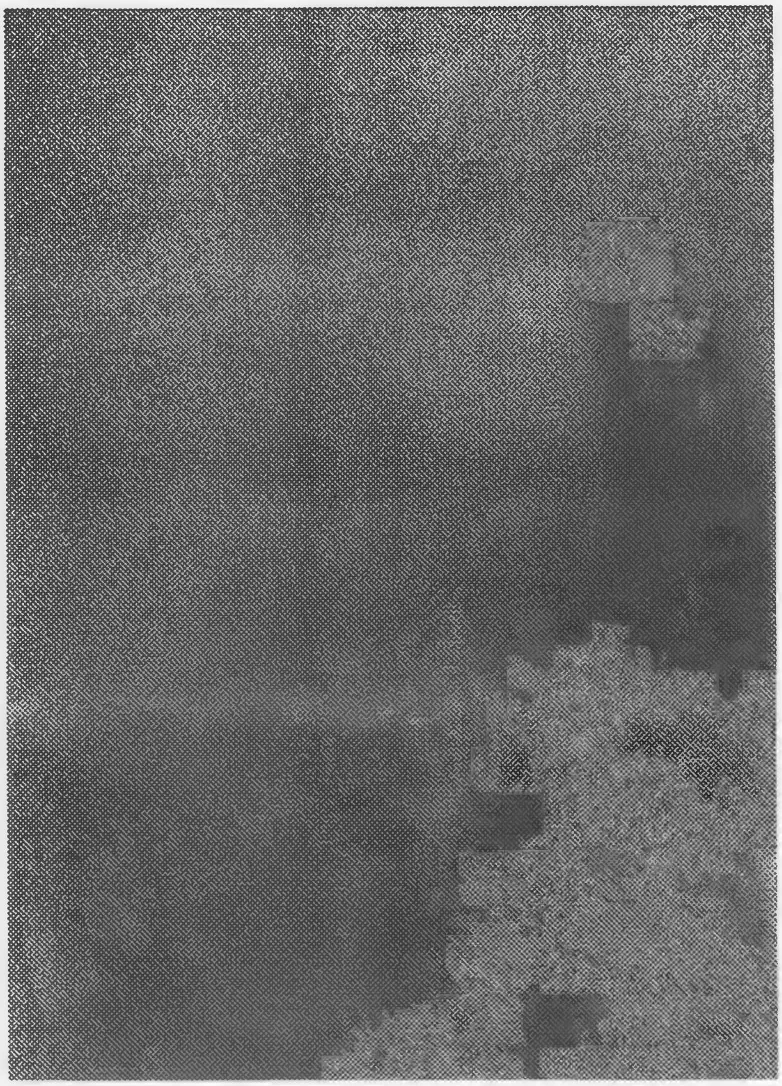

Figure 1: An ILU image over Paraguay.