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FOREST TYPE DISCRIMINATION USING SAR POLARIZATION INFORMATION

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ABSTRACT

In order to promote the unique polarimetric capability of RADARSAT-2, CCRS has investigated the potential of fully polarimetric C-band SAR for forest type discrimination. Six forest types in Eastern Ontario (Mer Bleu) were considered in this study: mixed forest, poplar, red pine, white pine, a mixed forest of red and white pines, and white spruce. In addition to the conventional linear polarizations HH, HV, and VV, various polarimetric discriminators, which were synthesized from the scattering matrix measurements, were investigated. It is shown that the radiometric of the conventional C-band SAR polarizations HH, HV and VV can only perform a limited discrimination of various trees, and cannot separate deciduous from coniferous trees in spring and summer conditions. The polarimetric information provided by the polarimetric (co- and cross-polarized) signatures, the circular polarizations, and the Cloude's parameters $H/A/\alpha/\beta$, did not improve significantly forest type discrimination. The best results were obtained with the extrema of the completely polarized component of the scattered wave. These parameters permit even the separation of deciduous from coniferous under leafy conditions, in the spring and summer seasons, and improve clearly forest types discrimination under no leaves conditions.

1.0 Introduction

Previous research using RADARSAT of HH polarization, and ERS-1 of VV polarization, has shown that radiometric information provided by C-band SARs can only perform very limited discrimination of various forests, mainly in spring-summer seasons [Proisy et al. 00]. The C-band radiometric information cannot even discriminate deciduous from coniferous trees, during these seasons under leafy conditions. In order to promote the unique polarimetric capability of RADARSAT 2, CCRS has investigated the potential of fully polarimetric C-band SAR for forest target discrimination. Six forest targets in Eastern Ontario (Mer Bleu), were considered in this study: mixed forest, poplar, red pine, white pine, a mixed forest of red and white pines, and white spruce (Figure 1).

A total of six C-band polarimetric SAR-580 data sets was acquired over the study area, in December of 1997 and March, June, and July of 1998. During each flight corner reflectors and polarimetric ARCs were deployed for calibration purposes. The antenna bore-sight angle was at 58º, and the study site was illuminated at about 60º. Data within 20º from the bore-sight angle were calibrated with an accuracy of ± 1.5 dB and 5º for each of the four linear channels HH, HV, VH, and VV. [Touzi 99, Hawkins et al. 99]. The results which will be presented in the following were obtained using two data sets: December (under no leaves conditions) and July (under leafy conditions).

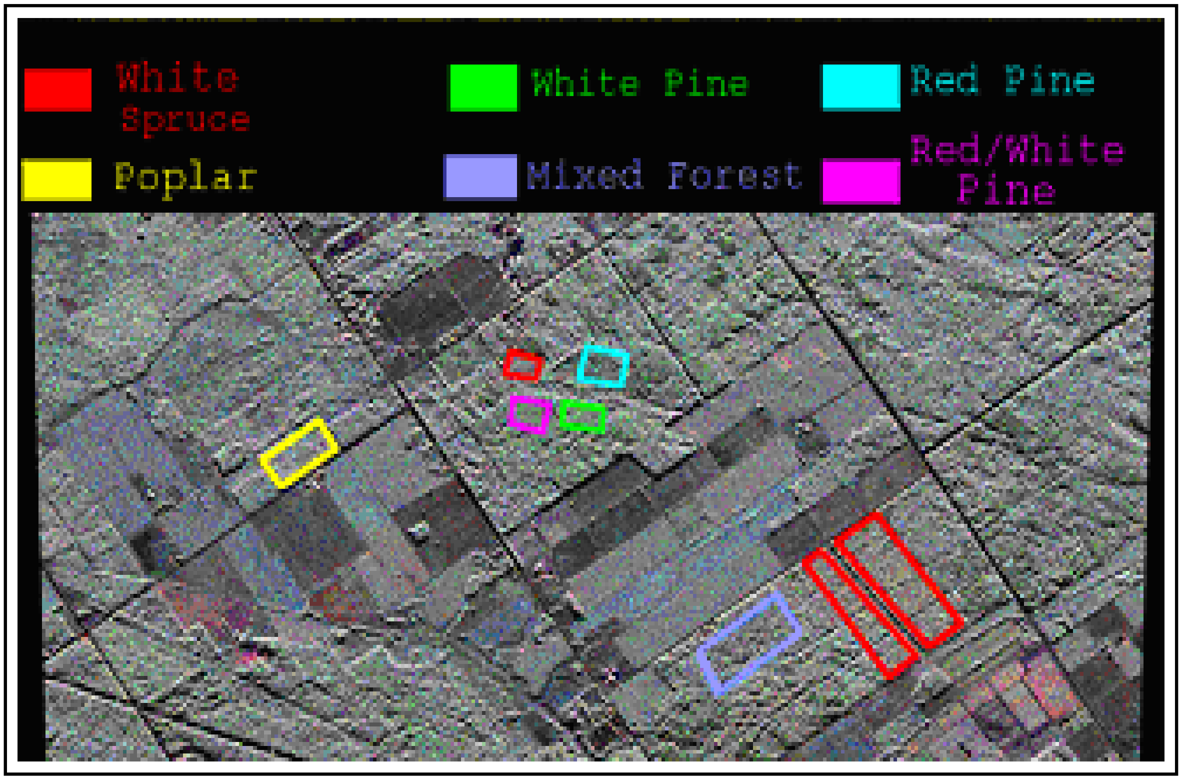

Figure 1 Forested areas under study. These airborne Convair-580 data were acquired in Eastern Ontario (Mer Bleu). This image is a composite of linear polarizations (Red: HH, Green: HV and Blue: VV).

2.0 Polarimetric tools investigated for forest type discrimination

In addition to the conventional linear polarizations HH, HV, and VV, the following polarimetric tools, which were synthesized from the scattering matrix measurements, were investigated:

- The Circular polarizations RR, LL, and RL (R= right circular polarization, L= left circular polarization). These measurements should characterize backscattering dominated by a single or double bounce scattering mechanism.
- The co-polarized and cross-polarized signatures.
- The extrema of the completely polarized and unpolarized components, which permit to characterize target scattering mechanisms type and heterogeneity [Touzi *et al*. 92].
- The Cloude's parameters $H/\ \alpha/\ \beta$ and anisotropy (A) [Cloude and Pottier, 96]. The Entropy (H) and the Anisotropy (A) parameters provides information on the randomness scattering process, while the angle α□ refers to the scattering mechanisms.

3.0 Results and discussion

3.1 HH, VV, and HV

Figure 2 presents various curves of $\sigma°$ obtained with the 29-July, 98 acquisition for HH, HV, and VV for different forest types. The dynamic range of σ^o is within 2 dB, and hence the forest types can hardly be discriminated. Notice that backscatter levels in the HH and VV polarizations are almost identical. Under leafy conditions, backscatter measurements in the three linear polarizations cannot even be used to distinguish between poplar (broad leave species) and coniferous species. The radiometric information of the three polarizations which is mainly due to the crown layer cannot discriminate clearly the various forests targets, and cannot even discriminate the poplar (broad-leaved family) from the coniferous trees. Under leafless conditions, poplar can clearly be discriminated from the coniferous trees, as can be seen in Figure 3 with the data set of December. However, the dynamic range still remains small and the other forest types can hardly be discriminated.

3.2 Circular polarizations RR, RL, and LL

The Figures 2 and 3 illustrate that the RR, RL and LL polarized radar return signals are also of little value for forest type discrimination. This can be explained from the fact that, in C-band, the backscatter of closed forests mainly results from volume scattering in the upper canopy and lacks significant single or double bounce components. Hence, the circular polarizations do not add to the information available in the linear polarizations. Notice the similarities in the curves for the like-circular (RR and LL) and cross-circular (RL) polarizations. This confirms the insignificance of the simple (single and double) scattering mechanisms.

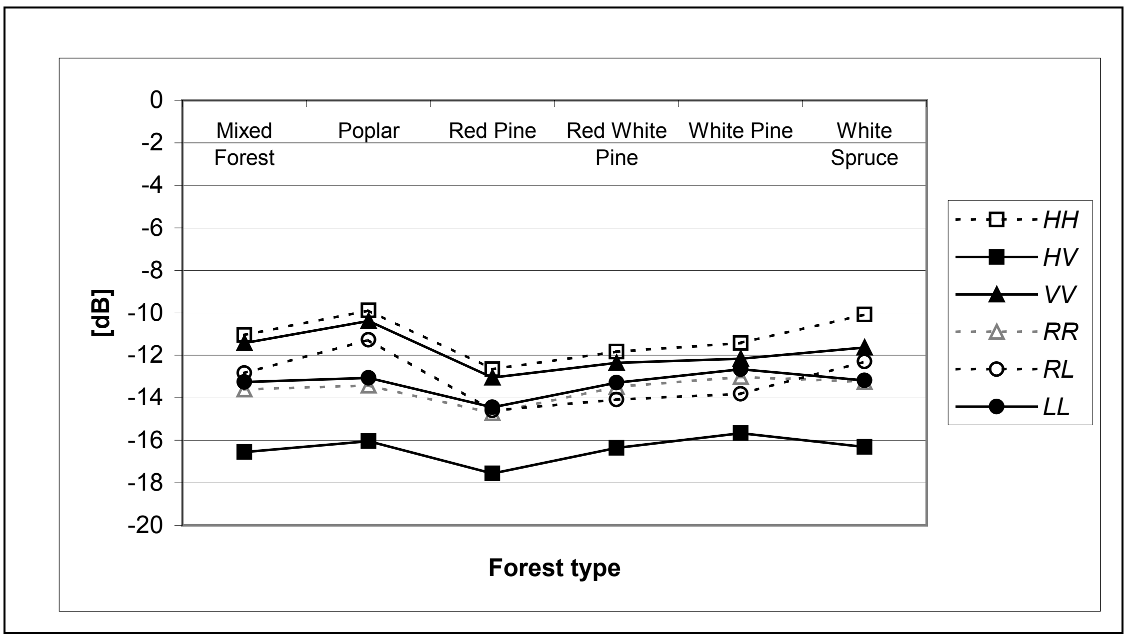

Figure 2 Backscattering coefficient σ^o, linear and circular polarizations, function of forest species. Convair-580 data acquired on July 29, 1998

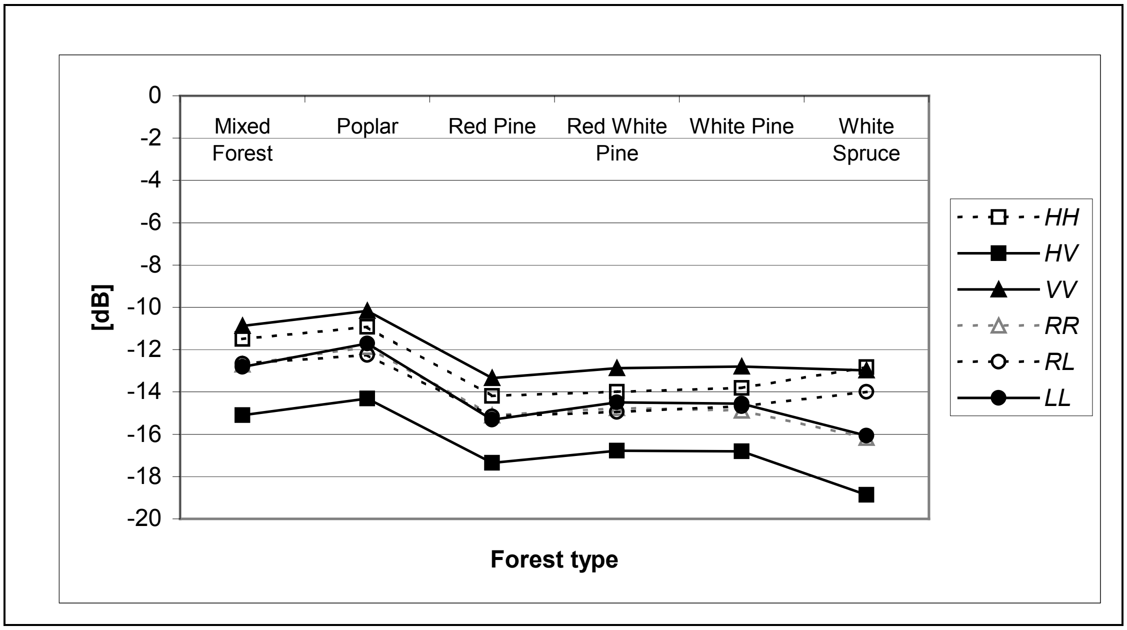

Figure 3 Backscattering coefficient σ°, linear and circular polarizations, function of forest species. Convair-580 data acquired on December 1, 1997.

3.3 Polarimetric signatures

In spring and summer seasons, the polarimetric signature shape is the same for all the forest targets at the exception of the white spruce.

Figure 4, and 5 present the co- and cross-polarized polarimetric signatures of the white spruce, and red pine that were obtained for the 9th of July 1998.

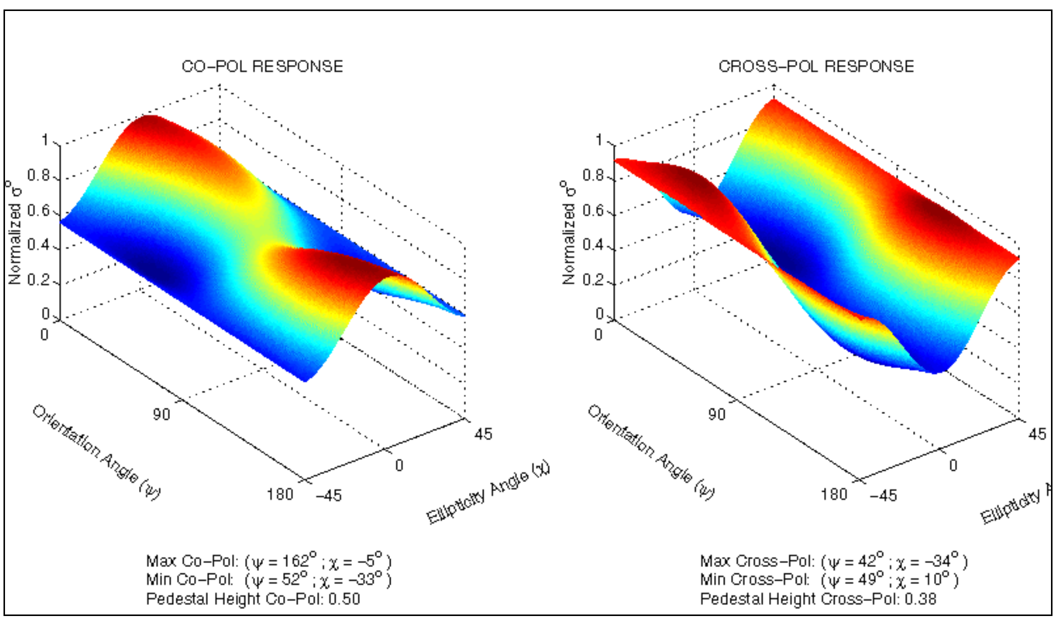

Figure 4 Co-polarization and cross-polarization signatures of white spruce forest. Convair-580 data acquired on July 9, 1998.

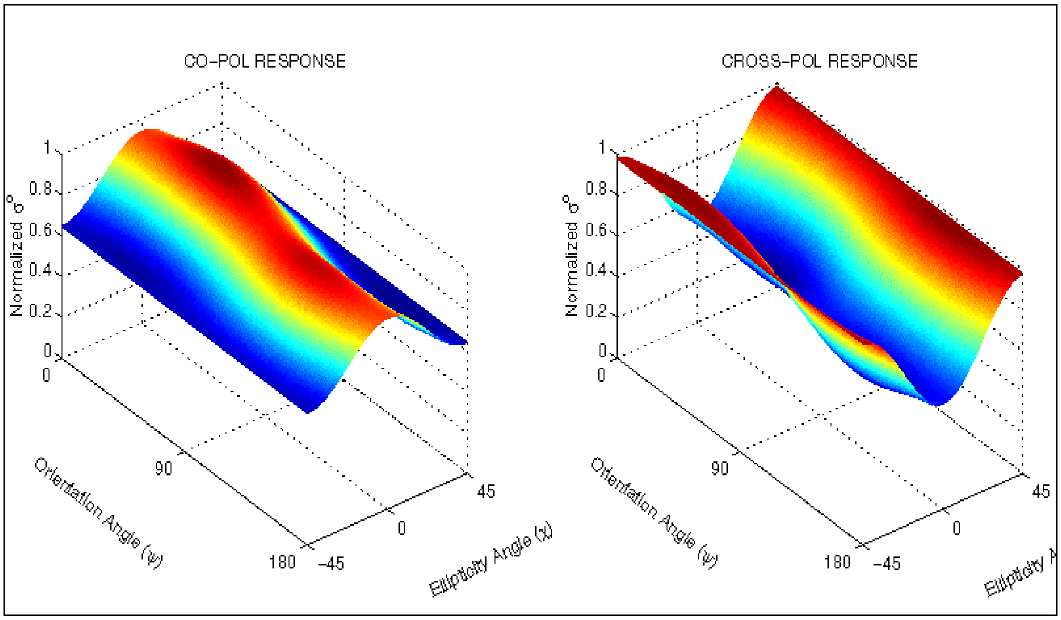

Figure 5 Co-polarization and cross-polarization signatures of red pine forest. Convair-580 data acquired on July 9, 1998.

Polarimetric signatures can only be used to discriminate white spruce from the other forest targets. For all the other forest targets, the polarimetric signatures are almost identical (in shape and pedestal), and cannot even separate poplar from the coniferous trees (June and July) seasons.

3.4 Extrema of the completely polarized and unpolarized components

- The information provided by the maximum of the completely polarized component of the scattered wave is very similar to the one provided by the minimum of the completely unpolarized component. This might be expected, as the two tools are quite correlated [Touzi et al. 92].

- Idem for the minimum of the completely polarized component, which is quite correlated with the inverse of the maximum of the completely unpolarized component.

- The minimum of the completely polarized component for each of the stands studied ranges by about 15 dB for the data acquired in July of 1998 (see Figure 6). Thanks to the large dynamic range, this variable offers good potential for forest type discrimination. The broad-leaved poplar is now well separated from the red pine, under leafy conditions in the spring and summer seasons (June and July data sets). Notice that this polarimetric tools improves a lot the tree type discrimination under no leaves conditions, in comparison of the linear and circular polarizations of figure 3.

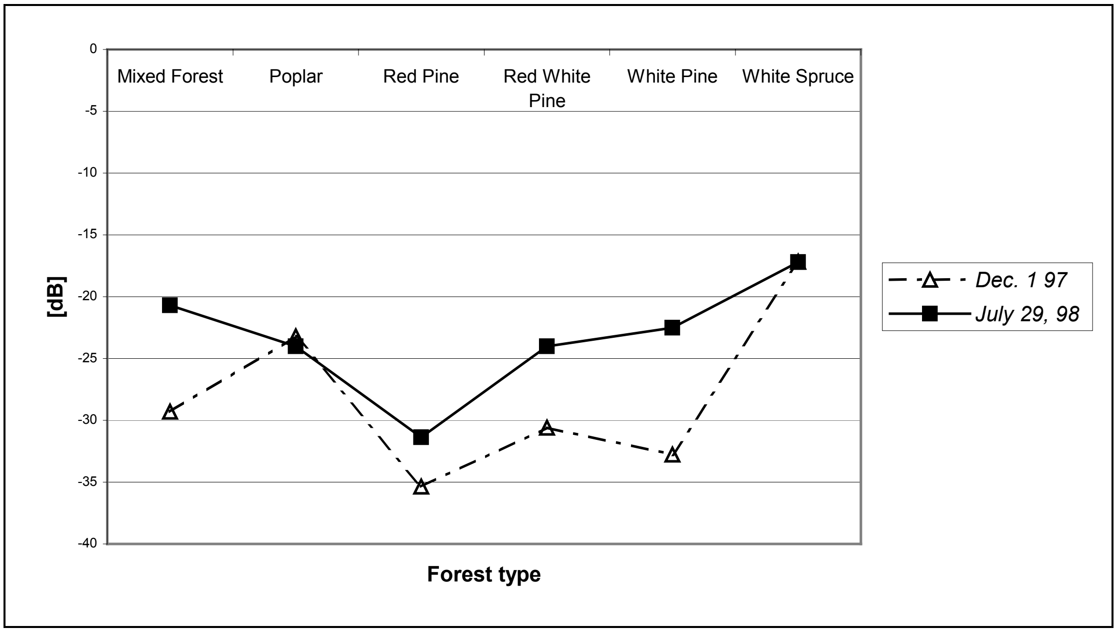

Figure 6 Minimum of the completely polarized scattered component function of the forest species. Convair-580 data acquired on December 1, 1997 and July 29, 1998

3.5 The Cloude's H / A / α□/ β parameters

The curves obtained with the Cloude's H/α/β parameters and the anisotropy [Cloude and Pottier, 97] are presented in Figure 7. The narrow (2 dB) dynamic range of H/α/β parameters does not permit clear discrimination of the various forest types. The anisotropy (A) is also of little value for discrimination of "homogeneous" forest type, with a dynamic range of about 2 dB. Non homogeneous forests (mixed forest and mixed red & white pine) are well discriminated with a spreader dynamic range (about 6 dB), as can be seen in Figure 7.

4.0 Conclusion

In summary, the radiometric information provided by the polarizations HH, HV and VV of conventional C-band SARs, and the future European Satellite Envisat, can only perform a limited discrimination of various trees, and cannot even separate broad-leaved trees from coniferous trees in spring and summer conditions. The circular polarizations do not bring additional information, as the backscattered signal which is mainly due to the crown layer at C-band, does not contain a significant double or simple bounce component. The H/ A/ α/ β parameters and the polarimetric co- and cross-polarized signatures were also of little value for forest type discrimination. The best forest target characterization is obtained with the extrema of the completely polarized components. These polarimetric tools permit even the separation of deciduous from coniferous trees under leafy conditions, in the spring and summer seasons, and improve clearly forest types discrimination under no leaves conditions. The data set used in this study was collected at large incidence angle (about 60^o). Further studies will be conducted at lower incidence angles, with various forest types, and new polarimetric discriminators (such as the Touzi anisotropy [Touzi 00]) in order to optimize the use of the polarimetric information for forest type discrimination.

Acknowdlegments

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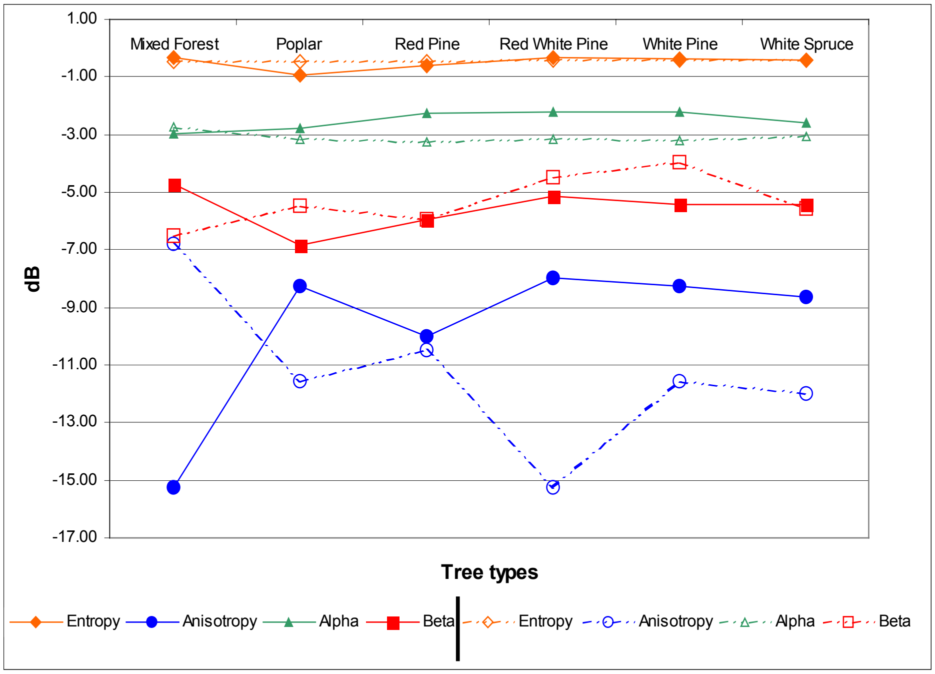

Figure 7 Cloude decomposition parameters function of the forest species. Convair-580 data acquired on December 1, 1997 and July 29, 1998

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