Analyzing Proximal Volcanic Ash Emissions Using High Spatial Resolution Thermal Infrared Imagery

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Introduction

Data on ash cloud composition, particle size and vesicularity are all essential in characterizing a volcanic plume and give a perspective on the volcanic processes occurring at depth (Turner et al., 2011). However, active sampling of a volcanic plume is both a difficult and highly dangerous task (Bluth and Rose, 2004), and because many eruptions take place in remote regions of the world, analysis of eruptive products can be a challenge. Ash detection using thermal infrared (TIR) data has become routine. However, what is lacking is a quantitative, high spatial resolution approach to obtain the characteristics of a volcanic plume. Using the unique spectral emissivity profiles of different compositions and particle sizes, it may possible to map these plumes using data from the Advanced Spacebourne Thermal Emissions Radiometer (ASTER).

Methods

- Initial proof of concept has been tested, using emissivity end members extracted from an ASTER TIR image of the 1 July 2007 eruption of Kliuchevskoi, Russia (Figure 2).
- Lab emissivity spectra were obtained. Ash was separated into individual size fractions through a series of sieving/Stoke's settling techniques.
- The spectral deconvolution approach of Ramsey and Christiansen (1998) was then used to determine the presence of ash in the image.
- ASTER images of the 2008/09 eruption of Chaitén, Chile, and the two 2011 eruptions of the Sakura-Jima volcano, Japan, were used.

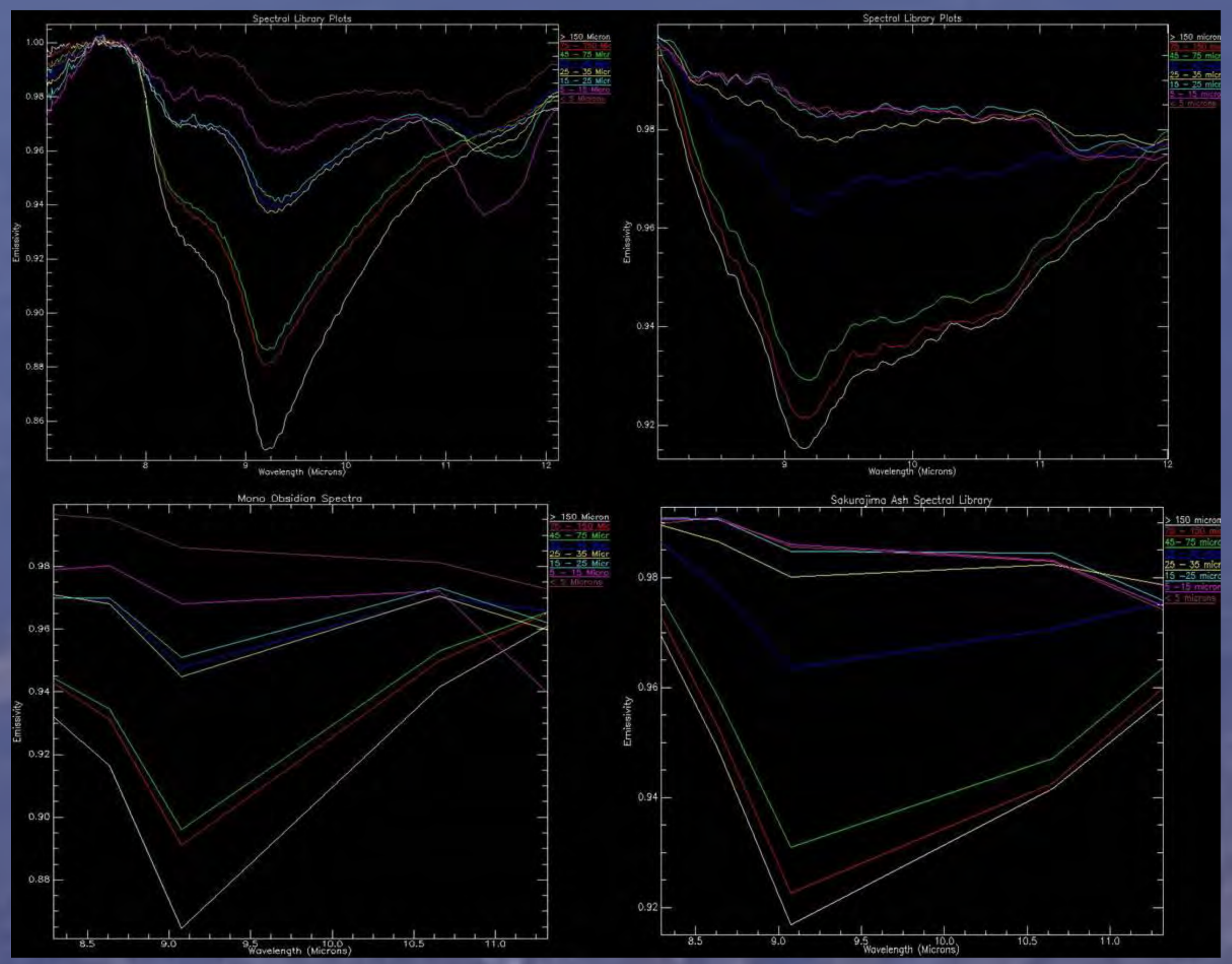

Figure 1. - Emissivity spectra A) laboratory measurements of crushed obsidian and B) Sakura-Jima ash. Same sample suite degraded to the ASTER 5-point TIR resolution. C) obsidian and D) Sakura-Jima spectra. Note that the major ash absorption feature between 8 and 9 µm is still discernable.

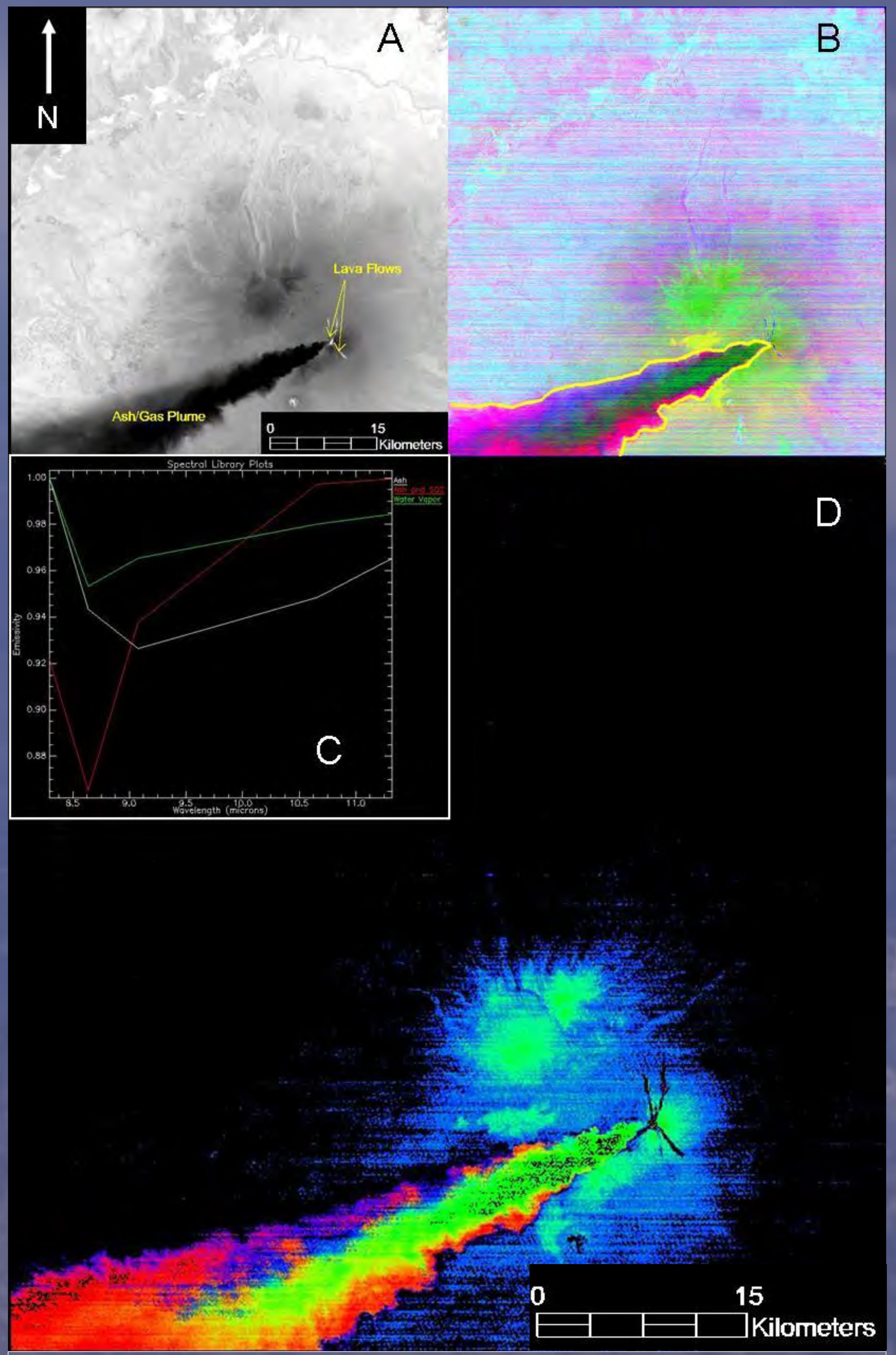

Figure 2. – A) Level 1B ASTER band 14 (11.31 µm) image of the July 1 2007 eruption of Kliuchevskoi volcano, Russia. B) Decorrelation stretch of ASTER TIR channels 14,13 and 11 (plume is highlighted by the yellow line). Ash rich portions of the plume are red, ash and SO_2 present together are green/yellow and water vapor is blue (Rose and Ramsey, 2009). C) Emissivity spectra obtained from pixels within the different portions of the cloud (as determined from B). D) Spectral deconvolution result (Red – Ash; Green – Ash and SO_2; Blue – Water Vapor).

Results

- Initial results have shown that the deconvolution algorithm can be used to view proximal volcanic ash plumes, using an appropriate ash end member spectral library.
- However, particle size variations across a plume are not currently visible in the imagery.
- Crushed obsidian has provided a good analogue for high SiO_2 ash, such as seen at Chaitén volcano.
- Larger size fractions than expected show the best results for Sakura-Jima, possibly due to the deeper absorption bands seen in the emissivity spectra from image pixels compared to that of the laboratory spectra.
- Furthermore, SO_2 within the volcanic cloud may have an affect on the absorption in the 8.6 µm region.

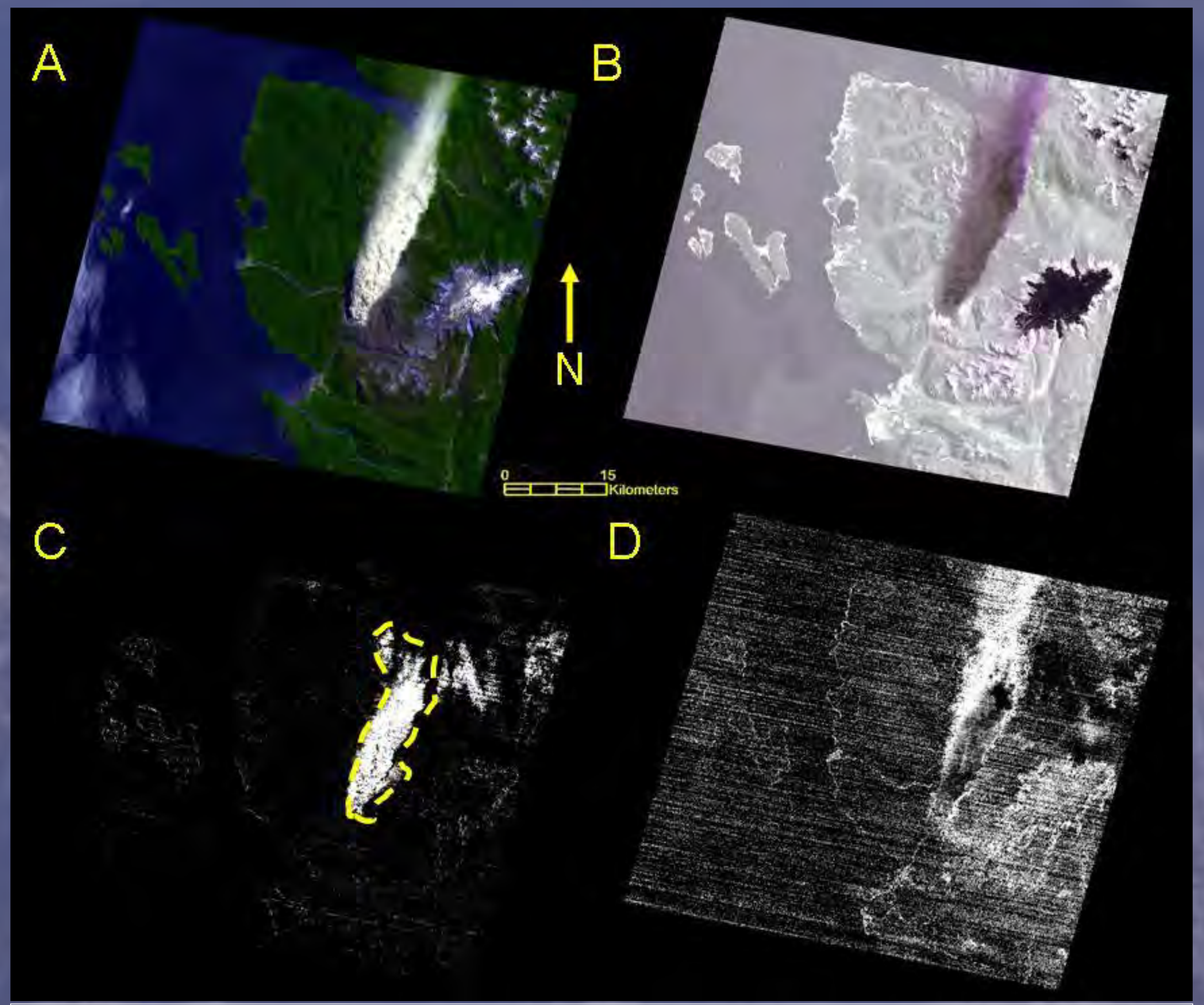

Figure 3. – Images of the Chaitén eruption, January 19th 2009. A) False color ASTER visible/near infrared (VNIR) image of the eruption. B) ASTER TIR image. C) Result for the 15 – 25 µm particle size end member. This produced the best result for this image, with the cloud (highlighted by the yellow line) clearly visible. D) Spectral deconvolution result for the 35 - 46 µm fraction. This result was positive for the region of the plume further north in the image. However, whilst the plume region is clearly defined, there are also regions that are not part of the plume that clearly give false positive results.

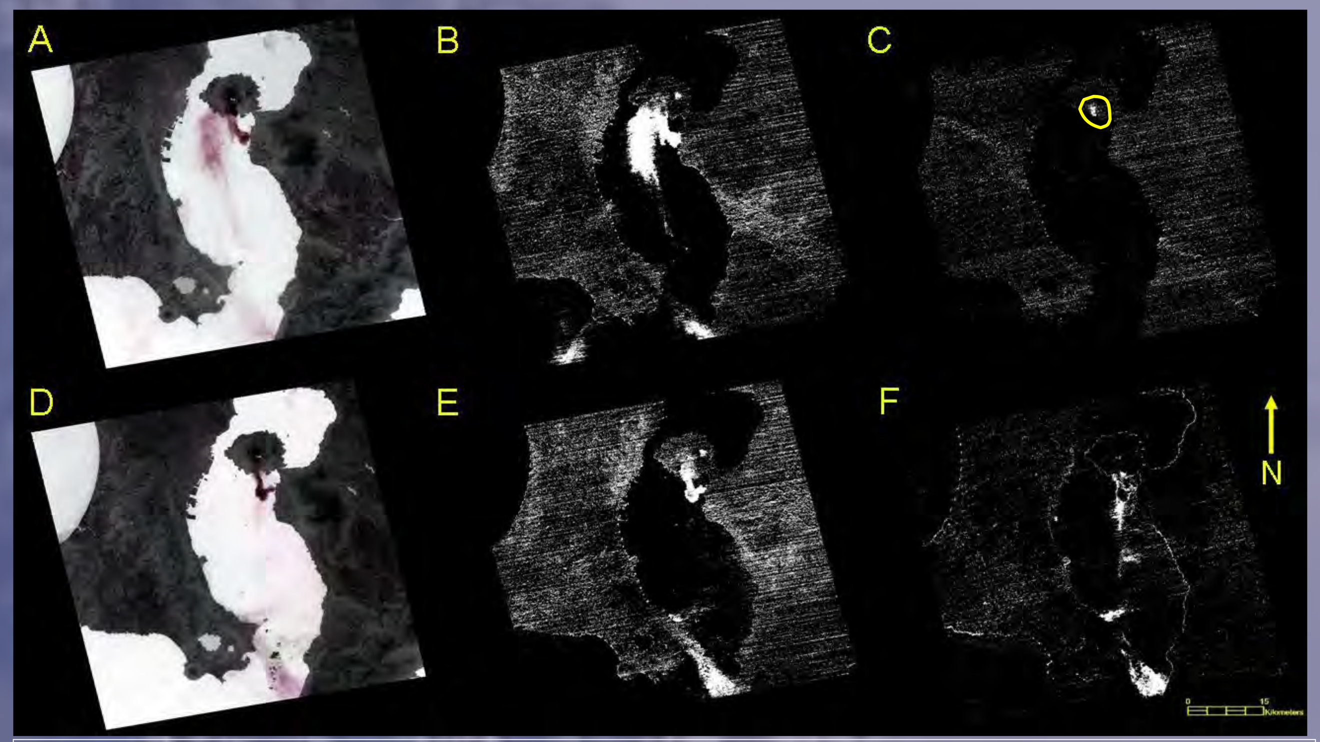

Figure 4. – Night–time images of Sakura-Jima eruptions, and spectral deconvolution results, from March 4 2011 (A – C), and December 17 2011 (D – F). A) ASTER TIR image. B) 35 – 45 µm end-member result. C) 5 µm end member result, with a small portion of the cloud (outlined in yellow) giving the only positive result for this size fraction. D) ASTER TIR image. E) 35 – 45 µm end-member once again produced the best result for this image. F) >150 µm end member result giving the only positive result for this size fraction.

Conclusions

This initial test of the deconvolution approach to proximal ash cloud composition/size fraction has shown it could enable mapping of opaque portions of volcanic plumes. It is hoped that by increasing the amount of samples present in the current volcanic ash spectral library, more rigorous testing of this approach can be achieved. It is also expected that, with better modelling of the effects of SO_2, water vapor and ground upwelling, these effects can be corrected.

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