

# **FIRE DISTURBANCE: THE TEN YEARS TIME SERIES OF THE ATSR WORLD FIRE ATLAS**

**Olivier Arino<sup>1</sup>, Stephen Plummer<sup>2</sup> and Diane Defrenne<sup>3</sup>.**

**<sup>1</sup>ESA-ESRIN, Via Galileo Galilei, 00044 Frascati, Italy. Email: Olivier.Arino@esa.int  
, <sup>2</sup>IGBP-ESA, <sup>3</sup>SERCO**

## **ABSTRACT**

To predict future climate change accurately and find ways to manage the concentration of atmospheric carbon dioxide, the processes and feedbacks that drive the carbon cycle must first be understood. In addition our current knowledge of the spatial and temporal patterns of carbon fluxes and other trace gases is uncertain, particularly over land and particularly for what regard disturbance phenomena such as fire. The European Space Agency has been generating a unique record of night time fire occurrence for the past ten years. This archive, the World Fire Atlas (WFA) generated using data from the second Along-Track Scanning Radiometer (ATSR-2) is now being extended using the advanced ATSR (AATSR) sensor on board ENVISAT. It is anticipated that this will continue the archive at least the next 5 years.

This paper presents the current status of the WFA, underlines the type of products and their limitation and recaps the validation of these products. It then demonstrates the consistency of data collected from ATSR-2 on board ERS-2 with those of AATSR. It provides a first analysis of a significant time series of 10 years of data and makes the first attempt to link these global and regional trends with climate variables such as El Nino. Finally the paper presents a non-exhaustive list of applications and users of the ATSR World fire Atlas.

## **1 INTRODUCTION**

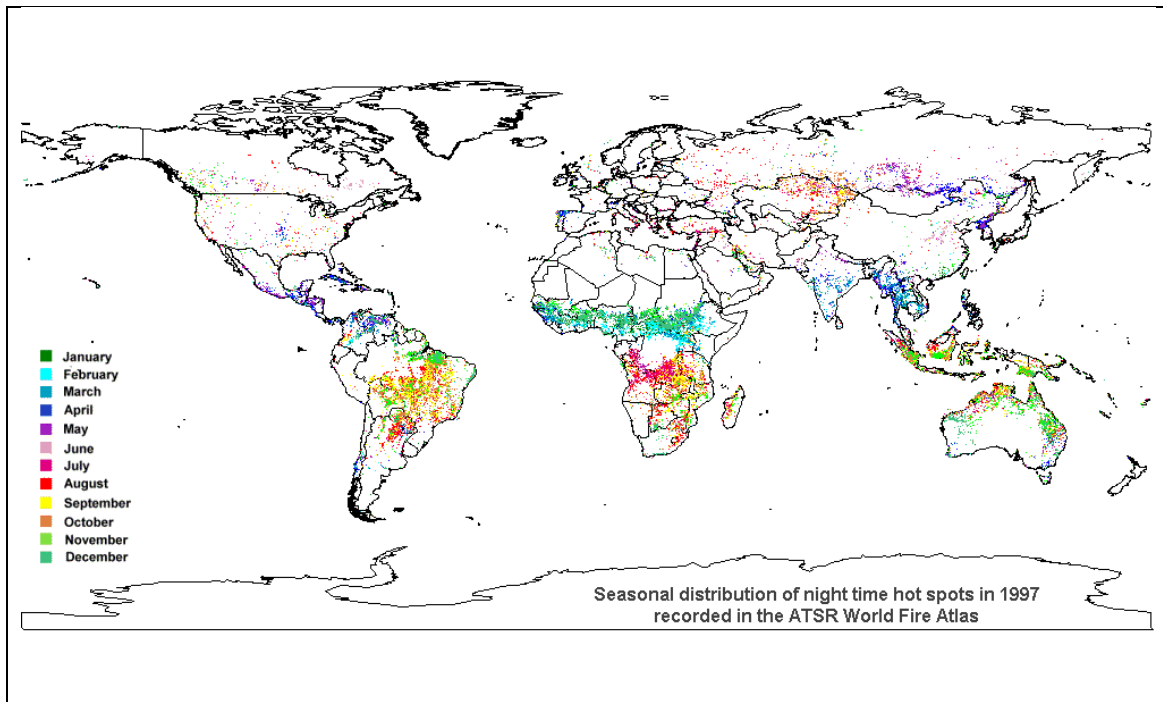
Worldwide information about disturbance is necessary to calculate the net carbon sink, and it may be a major cause of the large observed inter-annual variations in carbon emissions from ecosystems [1]. However, there is a need to recognise that there is a complex interplay between climate, the likelihood of disturbance, the phenological status, the severity of the disturbance, and disturbance return since these control emissions and recovery trajectories and hence the likelihood of change [2]. Disturbance has direct and indirect effects on patterns of tree establishment, future vegetation composition and structure, hydrology and carbon cycling [3]. Disturbance is also temporally variable. For example, there are tremendous fluctuations in global

annual area burned, typically varying in boreal forest between 5-10M Ha [4]. Disturbance also occurs in temporal clumps, both across years and within the active fire season, rather than having a consistent average. This clumping is associated with weather patterns such as low precipitation and high temperature and closely coupled with anthropogenic activities.

Thus, disturbance, especially fire, represents a major source of uncertainty and a major challenge to represent in models of both global vegetation and atmospheric chemistry. While efforts are being dedicated towards incorporating disturbance in such models e.g. [5] [6] there remains the difficulty in having sufficiently long time series of observations to adequate testing. This paper reports on the longest time series of global fire data currently available, the ATSR World Fire Atlas, the initiative to maintain and extend it and then examines the record as a source of information to interrogate other global products and also provide independent evidence of global change.

## **2 CURRENT STATUS**

The World Fire Atlas forms a unique long time series of global fire location and timing. Data exist since 1995 and the processing is ongoing, with the first full year of data available for 1997. The data used in constructing the record are those recorded at night-time by the second Along Track Scanning Radiometer (ATSR-2) and since 2003 the follow-on Advanced Along Track Scanning Radiometer (AATSR). Each record is comprised of the date, latitude and longitude of a 1 km by 1 km pixel when the brightness temperature in the 3.7 $\mu$ m channel superseded either 312 (algorithm 1) or 308 (algorithm 2) degrees K with pixels being revisited on average every 3 days. These records are available as monthly ASCII files direct from the World Fire Atlas website (<http://dup.esrin.esa.it/ionia/wfa/index.asp>). It should be noted that the records represent all pixels superseding the thresholds above with no subsequent elimination of pixels, thus the interpretation of these records as vegetation fires is for the user to perform. Figure 1 shows the seasonal distribution of fires recorded in WFA for 1997.



**Figure 1: Seasonal distribution of night time fires in 1997 recorded in the ATSR World Fire Atlas**

### 3 VALIDATION

#### 3.1 Original IGBP Initiative

A validation exercise was carried out for the period 1997-98, under the auspices of the International Geosphere Biosphere Data Information System (IGBP-DIS), involving contributions from researchers in Turkey, Italy, Spain, Portugal, Russia, Mongolia, China, Indonesia, South East Asia, Australia, Canada, Alaska and South America. The main positive results of this exercise were:

- the low level of commission errors;
- the good spatial distribution of the hot spots;
- the accurate geo-location of the hot spots.

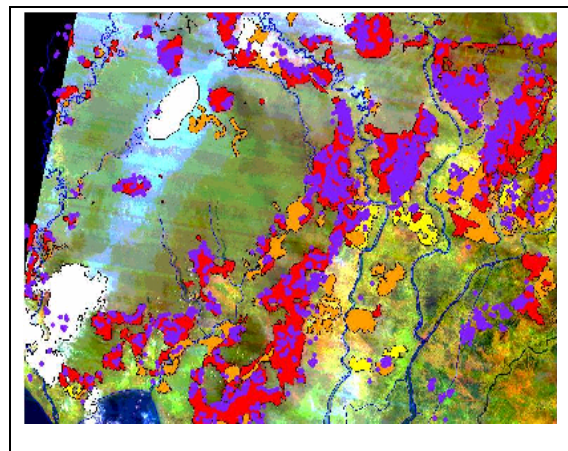
The principal limitation identified in comparison with other fire observations were:

- the high level of omission due to cloud coverage, satellite coverage and threshold value.

Thus the archive should be used with caution for the detection of:

- agricultural fires;
- savannah fires;
- small fires;
- boreal forest fires.

Further details and discussion of these observations can be found in [7]. Figure 2 shows an example of the validation result for Kalimantan, Indonesia produced by H. Böhm.



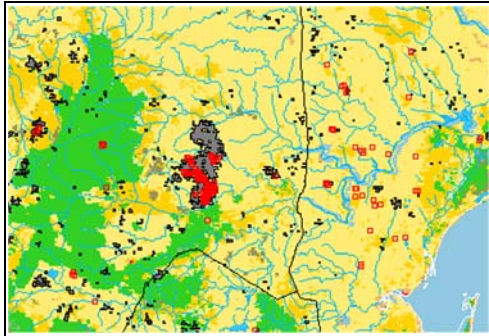
**Figure 2: Inter-comparison of detected hotspots from ATSR-2 against visually delineated burned areas from two dates (red and orange) as seen on a Landsat TM image from the 29 March 1998. A close correspondence exists between the red areas and the hotspots indicated in purple.**

Despite the limitations of the detection indicated above, the availability for a long period of time (1995 - present) along with the good spatial distribution of the detection

allows the use of this product for large-scale analysis or as a complement to AVHRR fire detection.

### 3.2 GLOBSCAR-WFA

A full inter-comparison between WFA and the GLOBSCAR burned area product has also been conducted and generally shows good agreement. The details are reported in [8] and an example is shown in Figure 3 of the correspondence between WFA hotspots in red and burned areas in grey for the region around the Kruger National Park, South Africa.



**Figure 3: Comparison of WFA fire detections with burned areas detected using GLOBSCAR for an area around Kruger National Park, South Africa in September 2000.**

## 4 Consistency

The original WFA corresponded to the acquisition of data with the ATSR-2 and lasted from 1995 through to 2002. From 2003 this system is being run with data from the AATSR sensor on board ENVISAT. To ensure there is consistency between the two records, given the fact that the two systems orbit on the same track but 30 minutes apart, the data from both ATSR-2 and AATSR were compared for the period 1-15 January 2003. While not a 1:1 match there is sufficient confidence in correlation to suggest that the record is both continuous and consistent. Full details of the inter-comparison are given in [9]. Figure 4 shows the match for the 8<sup>th</sup> January 2003.

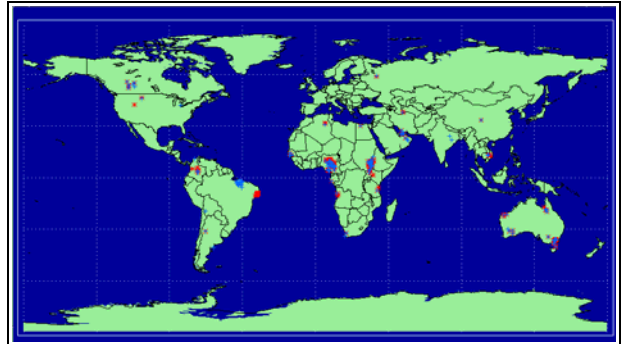
## 5 Time Series Analysis

The WFA now represents the longest time series of fire records. This can be data-mined to resolve variability observed in other environmental records and provides the opportunity to conduct the first analysis, based on quasi 10 years of fire records, in relation to global and regional trends of climate variables such as precipitation and temperature.

### 5.1 Data Mining

The quasi ten years of data allows us to start examining inter- and intra-annual variability in fire as a function of

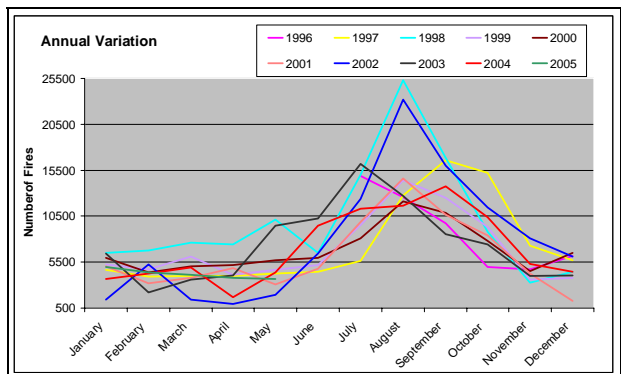
political distribution as well as natural environmental factors.



**Figure 4: Inter-comparison of active hotspots detected with the ATSR-2 (blue crosses) and AATSR (red stars) for the 8<sup>th</sup> January 2003.**

### 5.1.1 Annual Normalised

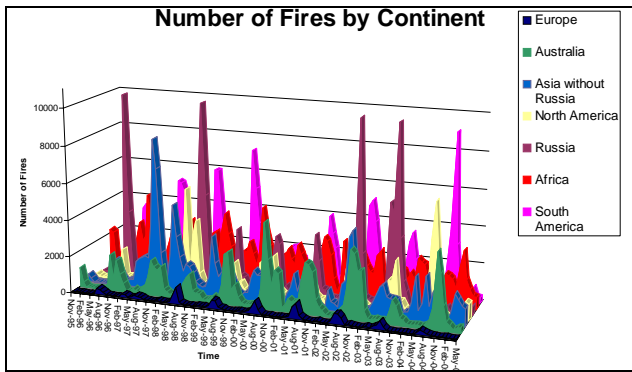
If we examine the annual variability, normalised by the average number of fires, it is clear that the number of fires does not vary considerably but their temporal and implicitly their geographical distribution is subject to significant variation which is correlated to the ENSO cycle (greater peak presence in strong El Niño years) (Figure 5).



**Figure 5: Variation of number of fires annually for the period 1997-2005. 1996 is shown but is not a complete year. The total number of fires is generally very similar but there are shifts in peaks and peak size with year.**

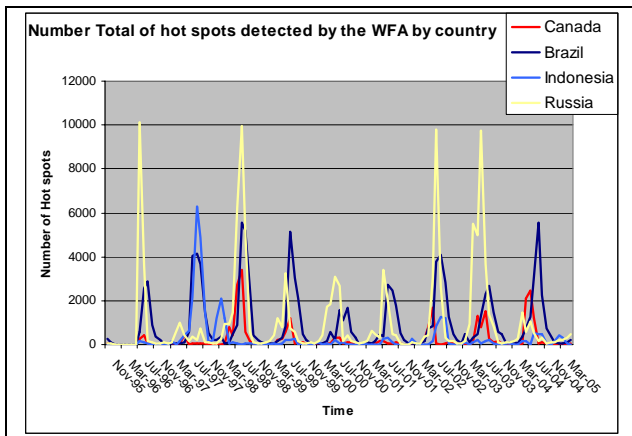
### 5.1.2 Continental and Country level partitioning

If these observations are further analysed it is clear that such variation is strongly geographically distributed with 'Asia' (including Siberia) a major contributor to the overall pattern (Figure 6).



**Figure 6: Distribution of observed night time fires on a continental basis**

Breaking this down to the country level confirms such observations with Russia being the dominant contributor in annual variation while other regions e.g. Brazil (1999), South East Asia (1997-8) exhibit peaks following exceptional events (Figure 7).



**Figure 7: Variation in night time fire recorded on a region/country basis.**

### 5.2 Long term trend analysis

A trend towards increasing sea surface temperature as a function of time after removing the mean has already been observed in data produced by the ATSR series of instruments [11]. However, missing data in the early years of operation of the sensor series (the 3.7 $\mu$ m channel on ATSR-1 failed shortly after launch and the first two years of ATSR-2 are characterised by missing data for the first part of both years) means such a similar analysis cannot yet be conducted on the night time fire record. It is however expected that as the AATSR record starts to accumulate such an analysis can be conducted.

## 6 User Access

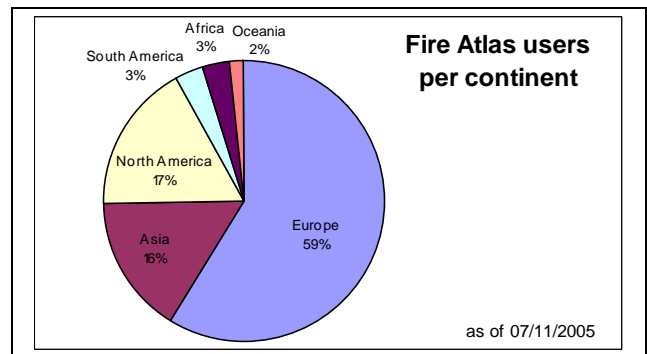
A critical test of the value of a given database and therefore the need for continuity is in its use by the external scientific community. Information on use is extremely important for three reasons:

- (i) as a means of ensuring the continuity of the product based on existing sensors
- (ii) as a reason for investing resources in improving the product and re-processing and
- (iii) as a mechanism for ensuring continuity of, and potentially improvement in, satellite sensors, in this case the ATSR sensor series.

Users have always been requested to feedback on and acknowledge use of the products in scientific articles and research reports and analysis of the publications. 74 published scientific articles that have either been identified by ESA or have been notified to ESA by the authors. Of these 80% can be classed as from the atmospheric chemistry research field. For the reasons above and to try to further encourage feedback a very simple registration interface has now been established. Without changing the ease of access a user is now requested to register on the site prior to obtaining access to the data.

### 6.1 User Distribution

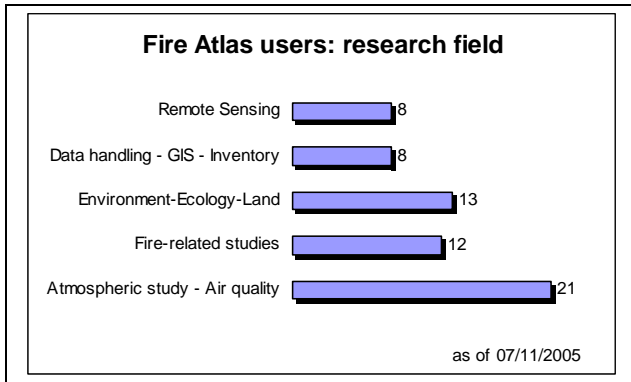
Examination of the returns from the first two months of registration reveals that the majority of users are located in Europe (Figure 8). This naturally reflects the visibility of the service in Europe but is also probably a function of the availability of regional alternatives elsewhere and, for global change research, reflects the tendency of the global change community to visit the site infrequently and download all products in one go.



**Figure 8: Spatial distribution of users of the ATSR World Fire Atlas**

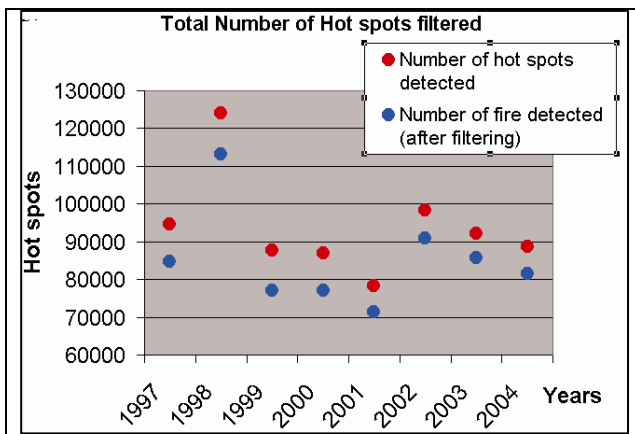
### 6.2 Application type

While gross figures such as those in Figure 8 are useful it is extremely important to respond to the needs of the principal users of the database. Examination of the specific research areas for the 62 users so far registered, reveals that, contrary to the common assumption, the users of the product are primarily non-remote sensing scientists with the majority involved in studies of atmospheric transport of gases emitted by fires e.g [5] (Figure 9). It is these users who will have the greatest attention when new developments are being planned.



**Figure 9: Distribution by scientific field of the users of the World Fire Atlas**

For example efforts to filter the product for non-vegetation fires are currently being considered both within and outside ESA [12][13] (Figure 10).



**Figure 10: Filtering of the ATSR WFA to remove non-vegetation fires (after [13]).**

## 7 Conclusions and Perspectives

The ATSR World Fire Atlas is the longest most consistent fire event time series existing in the world. This is due to recurrent sensor flown on board ERS and ENVISAT satellite and to systematic acquisition and processing of all world data. This time series has been validated and its consistency carefully analysed. This time series is only meaning full statistically as both omissions and commissions are obvious. The ATSR World Fire Atlas is therefore being used as input to atmospheric models with sufficient reliability by more than 70 users. Preliminary analysis of the time series indicates some trends that seem to correspond with climate and vegetation variability but these need to be confirmed. The extension of the WFA up to the end of the ENVISAT lifetime is planned at ESA.

## 8 References

- [1] Cihlar, J. et al, 2001, IGOS-P Carbon Cycle Observation Theme Report: Terrestrial and Atmospheric Components, A Report to The Integrated Global Observing System Partnership, February 2001, 41pp. <http://www.fao.org/gtos/doc/pub25.pdf>.
- [2] Goldammer, J.G., 1993, Feuer in Waldökosystemen der Tropen und Subtropen, Birkhäuser Verlag, Basel-Boston-Berlin.
- [3] Fosberg et al. 1999, Strategy for a fire module in Dynamic Global Vegetation Models, Int J. Wildland Fire, 9, 79-84.
- [4] Cofer, W.R., E.L. Winstead, B.J. Stocks, L.W. Overbay, J.G. Goldammer, D.R. Cahoon, and J.S. Levine, 1996, Emissions from boreal forest fires: Are the atmospheric chemical impacts underestimated?, In Biomass Burning and Global Change, Vol. II, (ed. J.S. Levine, ed.), MIT Press, Cambridge, MA, 834-839.
- [5] Hoelzemann, J.J., Brasseur, G.P., Diehl, T., Granier, C., Niemeier, U. and Schultz, M.G., 2002, A global biomass burning inventory for tropospheric chemistry transport modelling, EGS02-A-01652, EGS XXVII General Assembly, Nice, France, April 2002.
- [6] Schultz, M., 2002, On the use of ATSR fire count data to estimate the seasonal and inter-annual variability of biomass burning emissions, Atmos. Chem. Phys. (ACP), 2, 387-395.
- [7] Arino, O. and Plummer, S. eds. 2001, Along Track Scanning Radiometer World Fire Atlas: Validation of the 1997-98 Active Fire Product, IGBP-DIS Working Paper 23, IGBP, Sweden, 66pp.
- [8] Simon, M., Plummer, S., Fierens, F., Hoelzemann, J., Arino, O., 2004, Burnt area detection at global scale using ATSR-2: the GLOBSCAR products and their qualification, Journal of Geophysical Research, Vol. 109, No. D14, D14S02, 10.1029/2003JD003622.
- [9] Plummer, S., Arino, O. and Defrenne, D., in prep, Extending the ATSR Active Fire Count Data with AATSR – a Test of Continuity, Atmos. Chem. Physics, 2005.

- [10] Lieth, H., 1972. "Modelling the primary productivity of the earth. Nature and resources", UNESCO, VIII, 2:5-10.
  
- [11] Lawrence, S.P., Llewellyn-Jones, D. and Smith, S.J., 2004, The measurement of climate change using data from the Advanced Very High Resolution and Along Track Scanning Radiometers, *Journal of Geophysical Research*, Vol. 109, C08017, Doi:10.1029/2003jc002104.
  
- [12] Mota, B. W., Pereira, J. M. C., Oom, D. Vasconcelos, M. J. P., Schultz, M., 2005, Screening the ESA ATSR-2 World Fire Atlas (1997–2002), *Atmospheric Chemistry and Physics Discussions*, 5, 4641-4677.
  
- [13] Defrenne, D., Arino, O. and Plummer, S.E., 2005, Calibration and Filtering of ATSR-2 and AATSR World Fire Atlas data, this proceedings.