INTERNATIONAL PRECIPITATION WORKING GROUP (IPWG): INTER-COMPARISON OF REGIONAL PRECIPITATION PRODUCTS

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Abstract

The International Precipitation Working Group (IPWG) supports the inter-comparison of precipitation products, with the verification/validation of products over selected regions against quality controlled surface radar and gauge networks. Results of comparisons between satellite, model and surface data sets are provided at daily time scales and spatial scales of 0.25 degrees. These results aim to provide both the algorithm/product developers and the user community with information on the performance of the techniques and their suitability for certain applications, such as hydrological modelling.

This paper will present the results of inter-comparisons between different satellite and model rainfall estimates, particularly focusing on the region covered by the Meteosat satellite sensors. A range of techniques, ranging from single sensor infrared or microwave algorithms through to multi-sensor/multi-satellite algorithms will be compared. In particular, the usefulness of the infrared/microwave blended techniques will be evaluated: these include the NOAA/CPC CMORPH technique, the EUEMESAT Multi-sensor Precipitation Estimate (MPE) and the NRL IR-Microwave blended technique.

1. INTRODUCTION

The International Precipitation Working Group (IPWG) was endorsed during the 52nd session of the WMO Executive Council in 2000, who encouraged the Coordination Group for Meteorological Satellites (CGMS) to participate in the formation of the IPWG. The foundation meeting of the IPWG was held at Colorado State University in June 2001, and was subsequently endorsed by the CGMS in July 2001. The IPWG is the precipitation equivalent of the longstanding International TOVS Working Group (ITWG) and the International Winds Working Group (IWWG) (see Levizzani and Gruber, 2007)

Main function of the IPWG is to provide a focus for the international scientific community for operational and research satellite-based quantitative precipitation measurement, with an emphasis on the derivation of improved precipitation products through greater scientific understanding. The objectives of the IPWG include the promotion of standards for satellite precipitation measurements and subsequent validation and verification of their products; procedures for data exchange; stimulate international research and development for precipitation retrievals and encourage education and training activities.

The exchange of scientific results is facilitated through the organisation of a number of international workshops at which issues relating to the observation, measurement and validation of precipitation have been discussed. The first workshop was held in Madrid, Spain, in September 2003 and focused upon operational rainfall estimates, missions and instruments, research activities and validation studies (Levizzani and Gruber, 2003). In October 2004 a second workshop was held in Monterey, California, building upon the initial workshop: data sets, error analysis, precipitation characterisation, retrievals and microphysics being he main themes (Turk and Bauer, 2005). The Bureau of Meteorology in Melbourne, Australia, hosted the third IPWG meeting in October 2006, alongside the Asia Pacific Satellite Applications

Training Seminar (APSATS). The most recent meeting of the IPWG was held in Beijing in October 2008 with topics ranged from data sets and applications through to the use of satellite retrievals with numerical models.

2. INTER-COMPARISON ACTIVITIES

One of the primary objectives of the IPWG is the validation/verification of precipitation products to aid both the algorithm/product developers and the users to gain better insights into the operation and usability of satellite observations for quantitative precipitation estimation. A number of baseline algorithms, NWP models, quasi-operational and 'experimental' satellite algorithms (both geostationary and polar-orbiting, infrared and/or passive microwave) are available in near real time and are compared against surface reference data sets derived from gauge and/or radar observations. The near real time inter-comparisons are focused on a number of regional sites that provide at daily/0.25° inter-comparisons: Australia (co-ordinated by Beth Ebert); USA (John Janowiak); Europe (Chris Kidd) and; South America (Daniel Vila). Satellite-surface data comparisons are generated in near real-time and the results made available on the internet: links to other validation regions are provided from these main sites. Figure 1 shows the global distribution of the near real time inter-comparison regions, together with regions with limited-period comparisons: web site addresses are shown in Table 1. A common template is used for the display of the comparison, comprising of images of the product and the validation source, scatterplot, descriptive statistics and quantitative statistics.

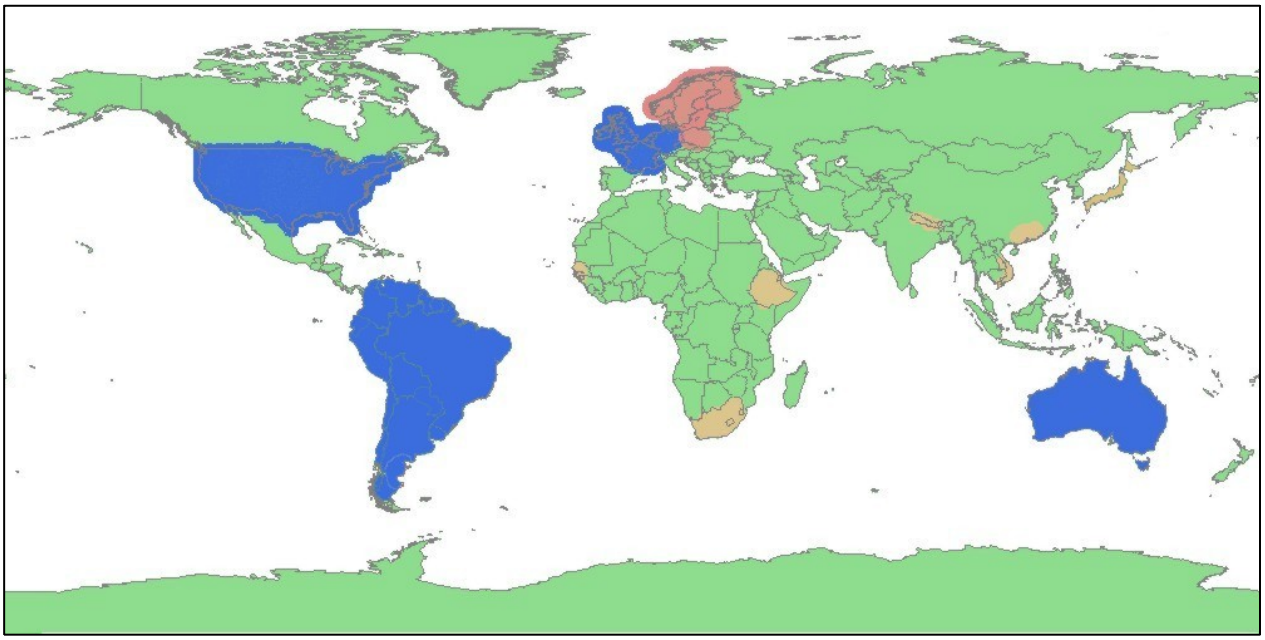

Figure 1: **IPWG validation regions. Blue regions indicate near real time inter-comparisons, red areas are currently being developed as validation regions, while beige are regions where fixed-period validation work has been undertaken.**

IPWG home page	http://www.isac.cnr.it/~ipwg/IPWG.html
Australian validation	http://www.bom.gov.au/bmrc/SatRainVal/sat_val_aus.html
European validation	http://kermit.bham.ac.uk/~ipwgeu/
US validation	http://www.cpc.ncep.noaa.gov/products/janowiak/us_web.shtml
S. America validation	http://cics.umd.edu/~dvila/web/SatRainVal/dailyval.html

***Table 1*: List of IPWG home page and inter-comparison web site links**

3. MULTI-SENSOR PRECIPITATION ESTIMATE COMPARISONS

3.1 The EUMETSAT MPE product

The Multi-sensor Precipitation Estimate (MPE) is a real-time instantaneous rain-rate product which is derived for each repeat cycle (15/30 minutes) of EUMETSAT's geo-stationary satellites (METEOSAT-7, METEOSAT-8 and METEOSAT-9) at the full pixel resolution (nominally 4 km) of the IR-channels. The MPE is generated over the regions up to 60° in longitude and latitude from the nominal sub-satellite points of the three satellites. The product is intended for users who require real-time information on precipitation fields, but have no ground-based precipitation radar data available. The special focus is on meteorological and short-range hydrological applications in Africa and Asia (e.g. flash-flood forecasting).

The algorithm uses data from polar-orbiting passive microwave sensors, currently SSM/I, to continuously re-calibrate the retrieval function for the geo-stationary IR-data. In this way the higher accuracy of the rain-rate retrieval by microwave sensors is combined with the higher spatial and temporal resolution, as well as the better timeliness, of the geo-stationary IR-imagery. This classical blending approach was first introduced by Turk et al. (1999) and is applied in a similar way in the algorithm of the U.S. Naval Research Laboratory (NRL). The basic assumption of this algorithm type is that there is a monotonic relationship whereby colder clouds produce more rain than warmer clouds. As a result of the approach the algorithm is mostly suitable for convective weather situations. The actual functions which relate the brightness temperature of an IR window-channel to the apparent rain rates depend strongly on the weather situation. Therefore, rain-rates derived from passive MW are used to update these functions regularly. A detailed description of the algorithm can be found in Heinemann et al. (2002).

The MPE product is derived on an operational basis in the Meteorological product Extraction Facility (MPEF) which is an integral part of the MTP and MSG ground segments at EUMETSAT's central facility in Darmstadt. It is encoded in the GRIB-2 data format and is made available to the user community on the LRIT data stream of the satellite distribution system EUMETCAST and on the EUMETSAT web-page. For the PEHRPP comparison the current METEOSAT-9 product is sampled on a 0.25°x0.25° grid over the region from 57.5°N-57.5°S and 57.5°W-57.5°E.

3.2 European Validation

An initial validation study was carried out over the IPWG European validation region. Data from the MPE techniques was obtained for the period from 01 January through 31 August 2008, covering both cold and warm seasonal rainfall regimes. Satellite products for the European region are remapped to a polar-stereographic projection, the same as the radar data, to ensure an equal area analysis across the range of latitudes from 35°N to 65°N. Radar data from the U.K. Meteorological Office NIMROD radar composite was used as the surface reference data set and although, in common with other radar data sets, it is prone to some inaccuracy, it does provide a spatial representation of surface rainfall across much of western Europe. Comparisons were made at daily/0.25 degree resolution. The results for the comparison on 4 July 2008 are shown in Figure 2: the main images show that the spatial extent and intensities of the rainfall derived from the MPE match that of the radar, which is also confirmed by the bar plots in the top right showing the daily fraction of rainfall by accumulation and occurrence. Also on the right of Figure 2 is shown the statistical performance of the MPE.

The MPE was also evaluated against other satellite rainfall products. These included the CMORPH product (a morphed IR/PM product; Joyce et al, 2004), the NRL-GEO product (Turk et al. 1999), the NOGAPS model precipitation product (Hogan and Rosmond, 1991), PERSIANN (a neural network PM/IR product; Sorooshian et al. 2000) and the University of Birmingham PMIR (PM/IR blended product; Kidd et al. 2003). Figure 3 shows the correlations of each of these precipitation products for the period form 01/01/08 through 31/08/08. Although all the products show significant variations, in common with other analyses, the model precipitation product performs better than the satellite estimates during the cold season, while the satellite products perform generally better during the warm season. While the CMORPH technique outperforms the other satellite products, the MPE technique is comparable with the other satellite products. The MPE product is however available at time and spatial scales down to 4 km/15 minutes.

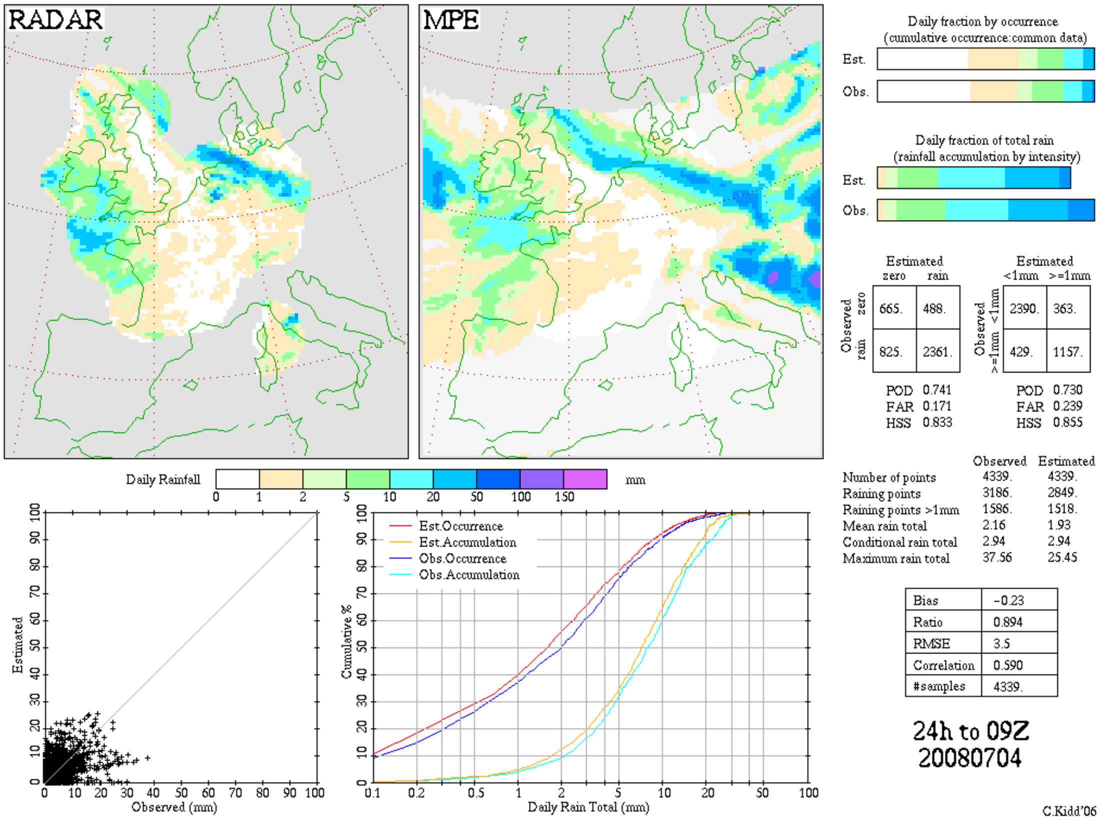

Figure 2: **Comparison of the MPE satellite precipitation product with surface radar data over Western Europe for 4 July 2008.**

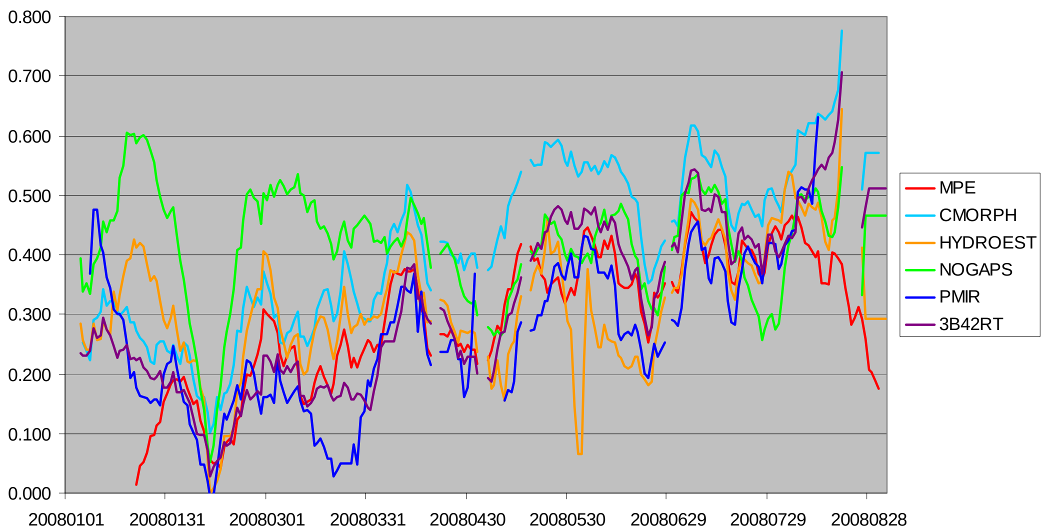

Figure 3: **Correlation performance of several satellite precipitation products from 01/01/08 through to 31/08/08. Products are MPE (red); CMORPH (light blue); Hydro-estimator (Orange), NoGAPS numerical model (green); Passive Microwave-Infrared technique (dark blue) and the NASA/GSFC 3B42RT technique (brown).**

3.3 Regional studies

A larger scale study was carried out to investigate the performance of the MPE relative to the precipitation products used above. All products have be averaged from their native 0.25°x0.25° resolution to match the GPCP 1 degree-daily product included here: this product uses a blend of gauge data sets over the land surface and satellite estimates over the ocean. The mean daily rainfall maps are shown in Figure 4 and cover the region 60°N-60°S and 60°W-60°E. The MPE product (top right) is generally in the centre of the range of values shown by the different products. Compare to the GPCP data set, the MPE produces slightly more rainfall over the land areas and less of the oceans, consistent across both the higher precipitation regions of the South Atlantic convergence zone and the sub-tropical high pressure regions. Both the CMORPH and the NRL-GEO products show less rainfall across the whole region compare with the GPCP and MPE products, as does the PMIR product, particularly over the ocean regions.

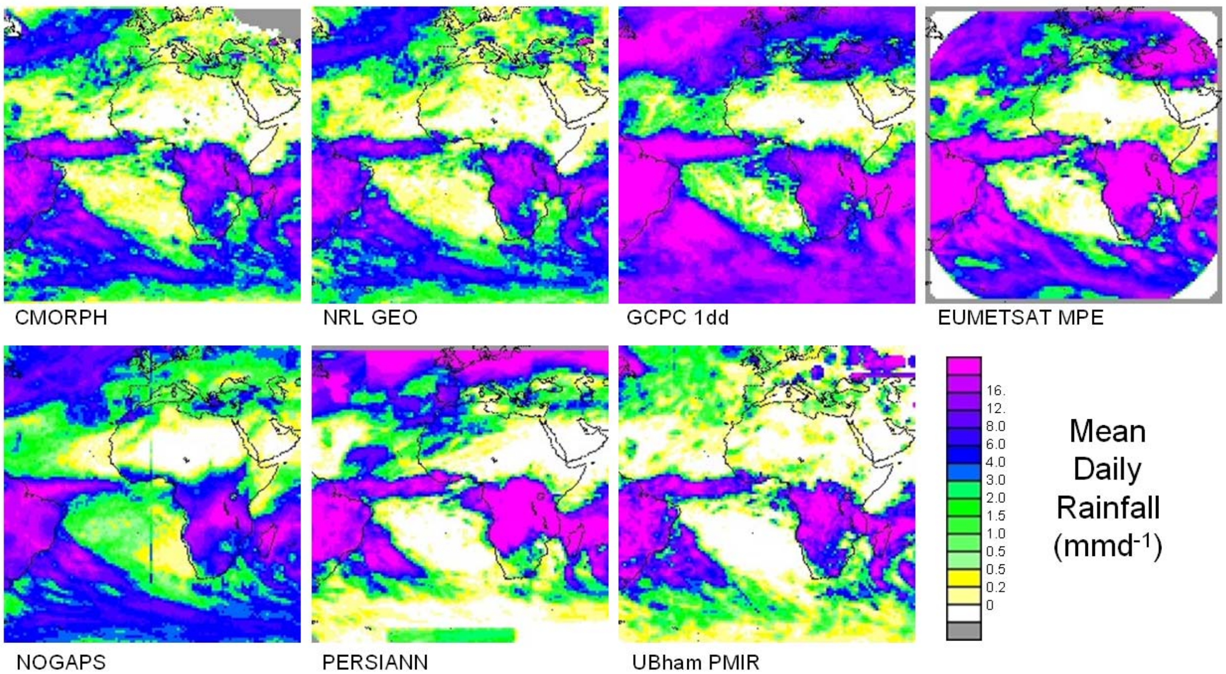

Figure 4: **Mean 1-degree/daily rainfall derived from 7 precipitation products.**

The occurrence of rainfall for each of these products is shown in Figure 5. The NOGAPS product shows a much greater occurrence of rainfall compared to the other precipitation products, with much of the region exceeding 50% occurrence. The satellite-derived and the GPCP 1dd products are generally similar, particularly over the land areas, although some differences do occur over the Sahel region of Africa. This is most noticeable in the CMORPH, NRL-GEO and PMIR algorithms that show some isolated regions of high occurrence of rainfall: this could be surface screening problems. Over the oceans the PERSIANN product shows much less rainfall occurrence than the other products, while the GPCP product shows some processing artefacts in the mid-latitudes.

Figure 6 shows the latitudinal profiles of the occurrence of precipitation across the 60°W-60°E region. The NOGAPS product shows a significantly higher occurrence of precipitation than the satellite and surface estimates. The satellite/surface products are in good agreement across the tropics with all these products being within ±5% across the region from 20°N to 20°S in all three months. With the exception of the PMIR product, these products agree to within ±5% over 40°N to 40°S for April 2008, although beyond 40°S they show progressively less precipitation than the GPCP product. Interestingly the divergence of the satellite estimates towards the high-latitudes compared with the GPCP product does not appear to be cold-season related since the greatest variations in the southern hemisphere in February.

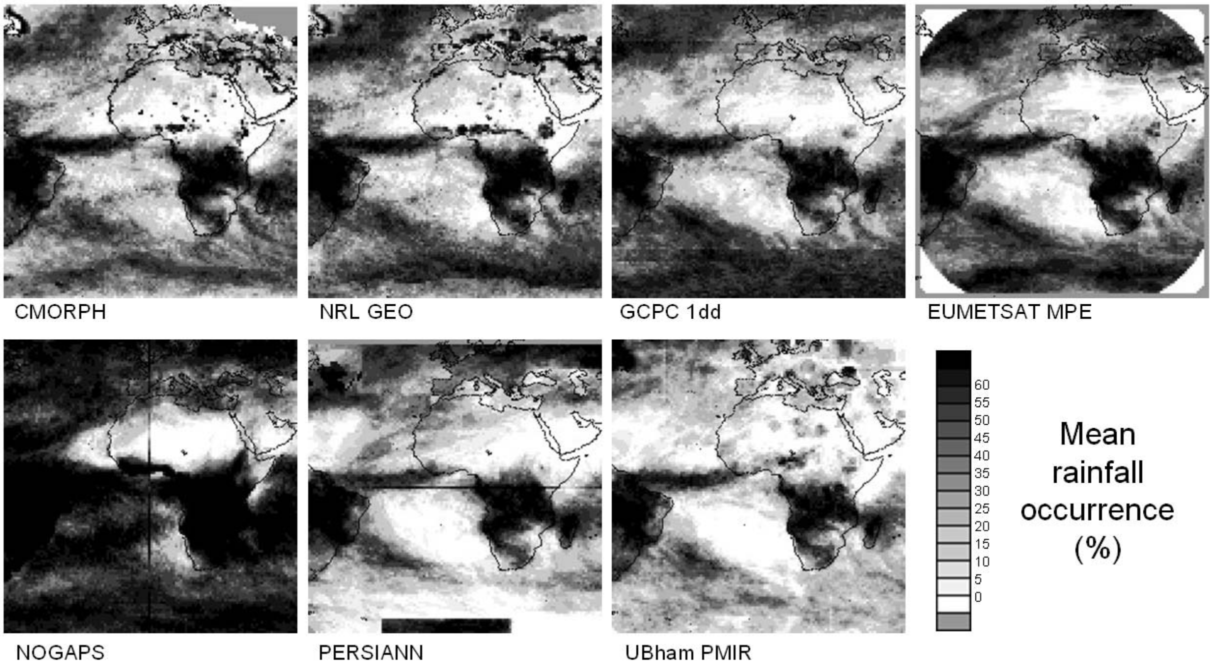

Figure 5: **Occurrence of rainfall at 1-degree/daily scales**

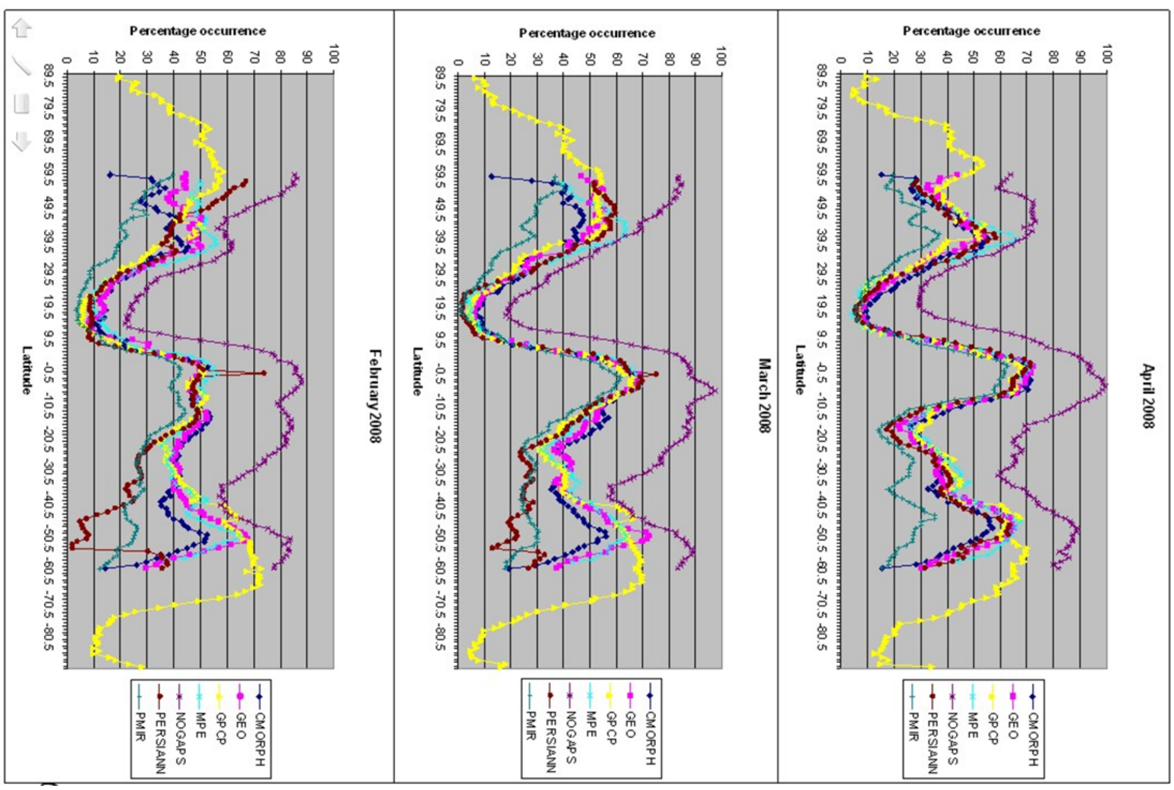

Figure 6: **Latitudinal profiles of precipitation occurrence for February, March and April 2008. The yellow line is the reference GPCP 1dd product. The high occurrence of rainfall identified by the NOGAPS model is clearly illustrated, as is the divergence of product-values at the higher latitudes.**

4 Conclusions

4. CONCLUSIONS

The IPWG provides a focus and support for precipitation research through and number of activities, including workshops, meetings and education. Through these it encourages the development, exploitation and testing of new techniques, together with the inter-comparison of techniques for operational applications. It also provides a means to represent the precipitation scientific community, and to make recommendations to the national and international agencies responsible for overseeing precipitation-related programmes.

A main focus of the IPWG activities is the inter-comparison of precipitation products. Here the EUMETSAT MPE product has been compared on a regional scale over Western Europe and on a larger scale over its retrieval domain. These studies reiterate earlier findings (e.g. Ebert et al, 2007) that models perform better in cold seasons, while satellite products perform better in warm seasons. This is generally attributed to the ability of satellite techniques to identify convective rainfall. The EUMETSAT MPE algorithm is generally comparable with current satellite techniques, particularly with the PM-IR genre of blended techniques. It should be noted that the generation of high-resolution data sets (i.e. 4 km/15 minutes), such as MPE, show significant benefits for hydrological modelling, enabling more representative retrievals to be made over small catchments.

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