Development of web-based services for a novel ensemble flood forecasting & risk assessment system

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"The latest HPC technology combined with detailed terrain data achieves better understanding of flood risk for specific end-users"

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Introduction and Network Layout

Abstract – We present a case study using the TIGGE database for flood warning in the Upper Huai catchment (ca. 30672 km2). TIGGE ensemble forecasts from 6 meteorological centres with 10-day lead time were extracted and disaggregated to drive the Xinanjiang model to forecast discharges for flood events in July-September 2008. A web-based platform based on Grid middleware and GOOGLE's API is used to solve problems related spatial and temporal distribution of data and algorithms. An attempt is made to produce end-user specific forecasts. Results showed satisfactory flood forecasting skills with clear signals of floods up to 10 days in advance. Forecasts occasionally show discrepancies both in time and space. Forecasting quality could potentially be improved by using temporal and spatial corrections of the forecasted precipitation.

Introduction

Single deterministic weather forecasts from numerical weather prediction (NWP) systems do not take uncertainties and systematic biases into consideration and hence often fail to replicate weather events correctly. Ensemble Prediction Systems (EPS) have evolved over the last decade to simulate the effect on weather forecasts of observation uncertainties, model uncertainties, imperfect boundary conditions and data assimilation assumptions (Park et al., 2007). An EPS is interpreted by Buizza (2008) as a system based on a finite number of deterministic integrations and regarded as the only feasible method in meteorology to predict probability a density function beyond the range of linear error growth. EPS forecasts from a single weather centre only account for part of the uncertainties originating from initial conditions and sto-chastic physics (Roulin, 2006). Other sources of uncertainties, including numerical implementations and/or data assimilation, can only be assessed if a grand en-semble (GE) of EPS from different weather centres are combined (Goswami et al., 2007). This ensemble of weather forecasts can be coupled to catchment hydrology and provide improved early flood warning as some of the uncertainties can be quantified (Cloke and Pappenberger, 2008). The availability of twelve global EPSs through the 'THORPEX Interactive Grand Global Ensemble' (TIGGE) (Shapiro and Thorpe, 2004; Park et al., 2007) offers a new opportunity for the design of a probabilistic flood fore-casting framework. A prototype of such a framework was successfully demonstrated by Pappenberger et al. (2008) using 7 weather centres in the European Flood Alert System (EFAS) to hindcast the October 2007 flood event in the Danube basin in Romania. A study carried out for a meso-scale catchment (4062 km2) in the Midlands region of England set up a coupled atmospheric-hydrologic-hydraulic cascade system driven by TIGGE ensemble forecasts to produce a probabilistic discharge and flood inundation forecast (He et al., 2009). Both studies showed the TIGGE database in-frastructure is a promising tool for producing early flood warning within a probabilistic framework.

The need to test TIGGE ensemble forecasts with other flood events in catchments with different hydrological and climatic regimes before giving TIGGE the benefit of the doubt is stressed in He et al. (2009) and Cloke and Pappenberger (2009). To this end, a case study was carried out using six TIGGE forecast centres in the Huai River basin in China coupled with the Xinanjiang hydrological model. Single deterministic weather forecasts from numerical weather prediction (NWP) systems do not take uncertainties and systematic biases into consideration and hence often fail to replicate weather events correctly.

中文背景概述

集合预报系统从其实质上讲又可称之为概率预报系统，其最终目的是提供大气变量的完全概率预报。近几年集合预报技术经历了不断的发展完善，从以前仅考虑初值的不确定性发展为同时考虑模式的不确定性，进而发展到多模式和多分析集合预报技术。TIGGE集合预报是世界气象组织的“观测系统研究和预报实验”项目的重要组成部分，在全球范围组织各气象业务中心的集合预报开发与合作，并计划发展成为未来的“全球交互式预报系统”。该技术在世界范围被认同，并逐渐成为天气预报的主流发展趋势。NEWS‘中小尺度集合洪水预报系统’：(1) 引入尺度转化方法，加强该项技术用于到小尺度流域的可行性；(2) 完整的气象，水文和水力模型耦合，一套系统可以连续运行提供流域范围内降雨量，洪水过程线和洪水淹没区域及水深预报；(3) 对统计预报的后续处理和预报矫正；(4) 预报洪水统计风险区域图。NEWS已经在英国中部塞文河 (Severn river) 流域上游子流域进行了试验洪水预报(水文预报为1公里网格精度，水力预报为50米网格精度)。与传统预报技术相比，其预报准确性和命中率显著提高，虚警率降低。从时间上讲，洪水过程预报可以提前至3到10天，从而为疏散居民和转移物资提供了宝贵的时间。

NEWS中小尺度集合洪水预报系统现由河海大学和伦敦国王学院在淮河上游共同试验开发，英国合乐集团 (Halcrow) 受聘进行市场调研。NEWS项目同时得到了安徽省水文局和欧洲中期天气预报中心(ECMWF)的大力支持。

尽管集合概率预报结果与传统方法比较有显著提高，但其发布还需要做大量的普及推广和培训工作。目前伦敦国王学院在塞文河流域的试点项目是世界范围内第一次将TIGGE多模式集合气象预报与分布式水文水力模型耦合应用，其推广前景还需要在不同流域范围内，不同气候条件的区域进行试验，以便确定其应用技术的普遍性。中国在面向TIGGE的集合预报关键应用技术已经做了大量工作，为水文水力领域中应用该技术做好了准备工作。

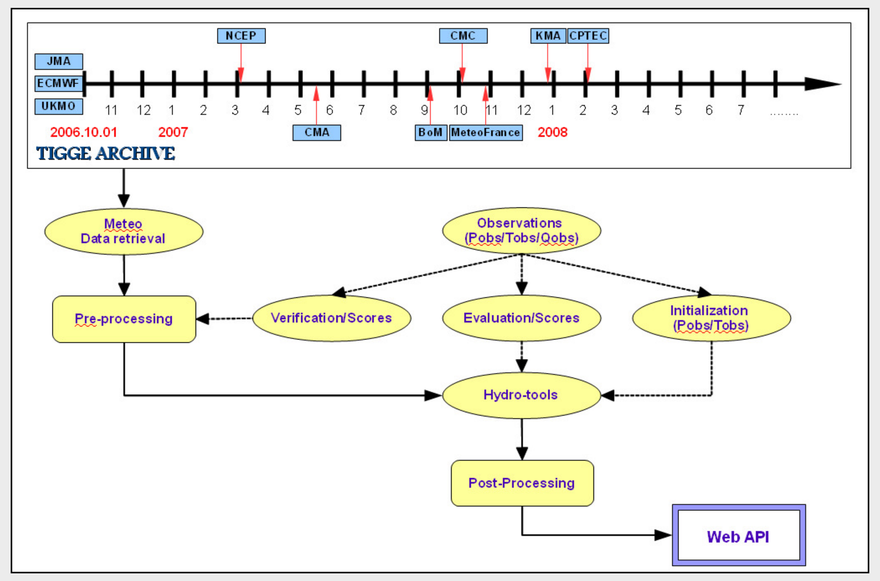


Figure 1a. TIGGE Archive in **NEWS** Algorithm Workflow Diagram

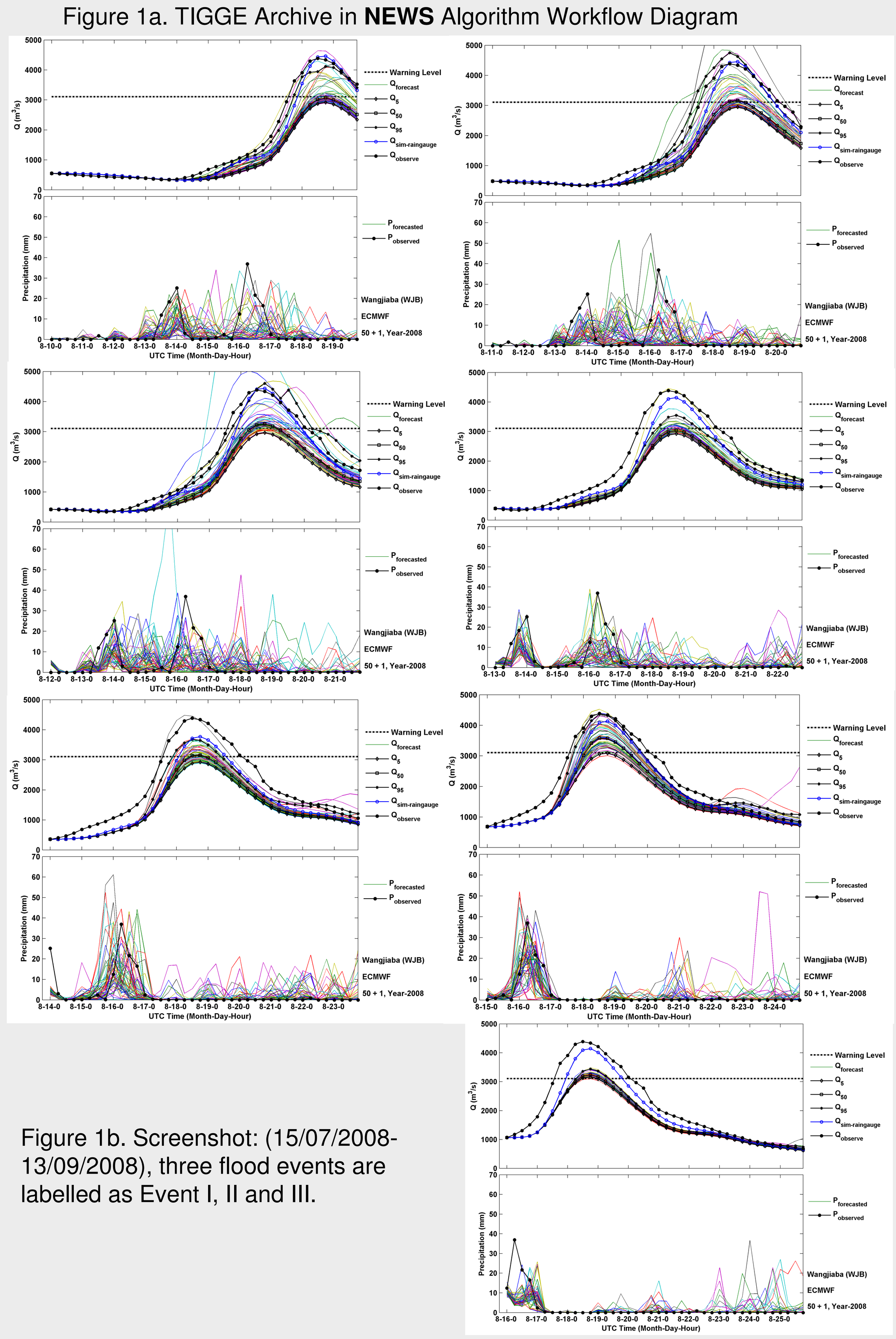


Figure 1b. Screenshot: (15/07/2008-13/09/2008), three flood events are labelled as Event I, II and III.

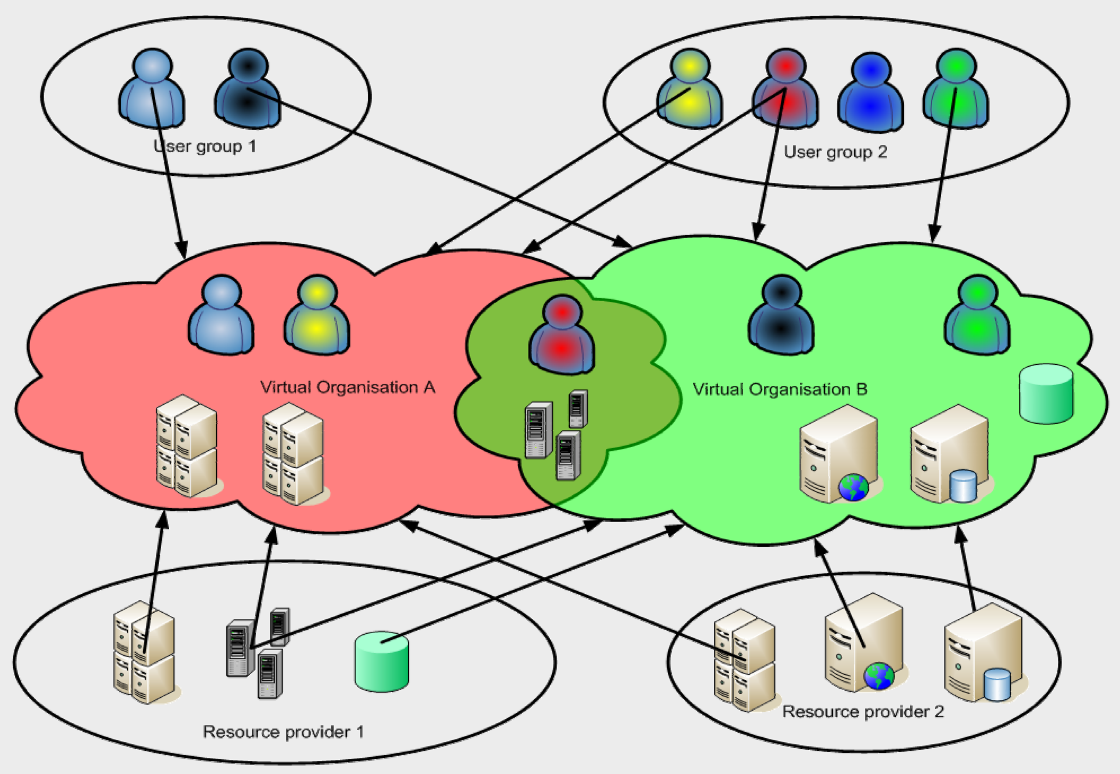


Figure 1c. Relational illustration of UNICORE Grid middleware platform as applied to NEWS forecasting system

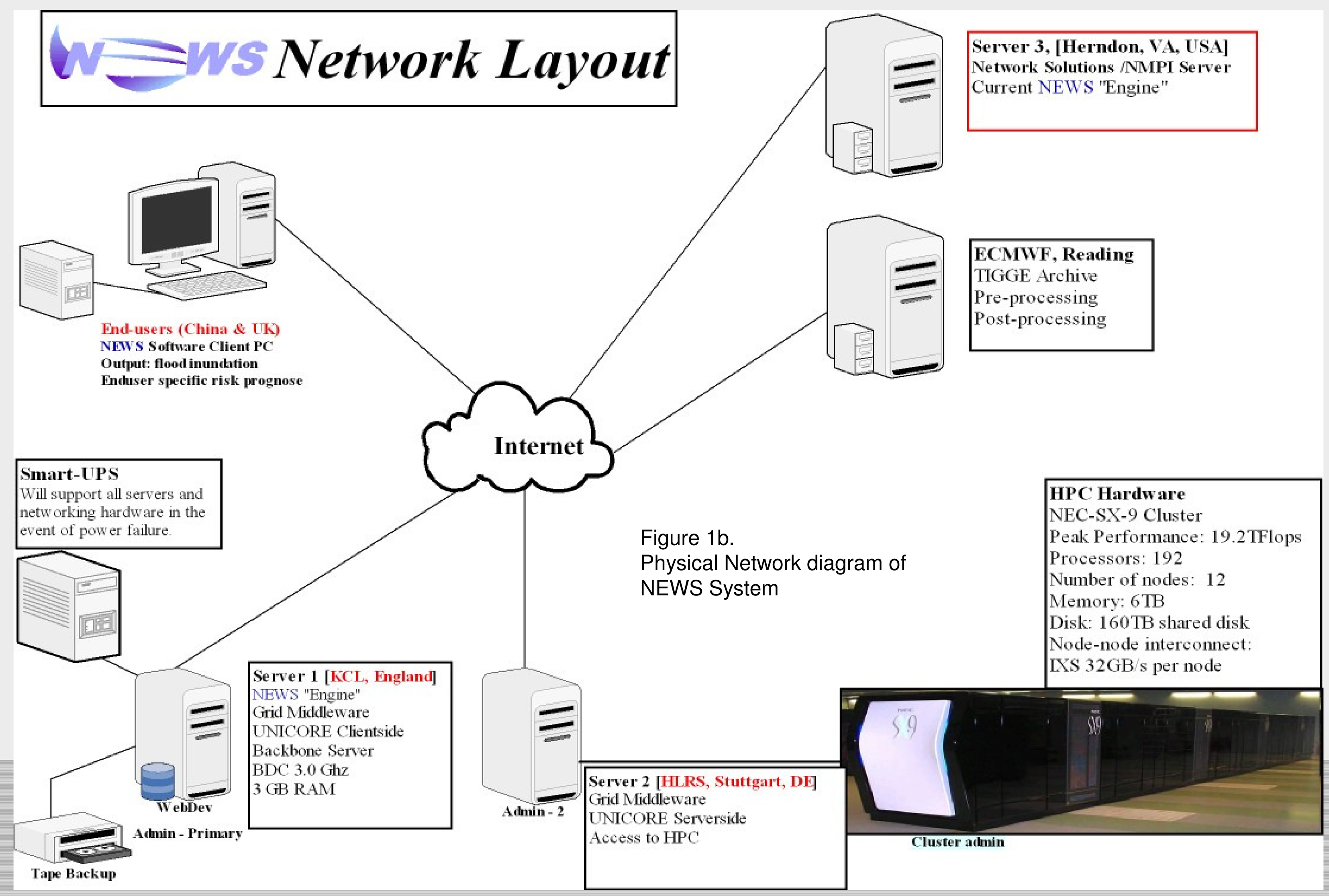
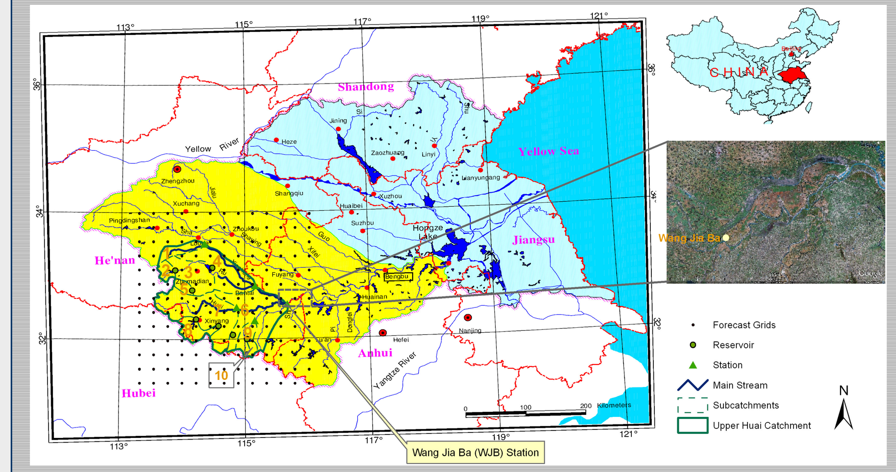


Figure 1b. Physical Network diagram of NEWS System

Results and Visualization



The Huai River has a length of 1,078 kilometres and a drainage area of ca. 174,000 km2 and located mid-way between the Yellow and Yangtze Rivers. Its mean annual precipitation is ca. 888 mm. The dynamics of precipitation including spatial and temporal distribution is very irregular and changes from year to year. This is attributed to its location in the transitional area between the southern monsoon and the northern continental climate (Huai River Commission, 1999). The basin is a very important economic region in China (Zhao, 1996). Its average population density is ca. 600inh/km2 (PCFCG 2001), more than four times the national average of 138 inh/km2. The basin is vulnerable to flooding. Major basin-wide floods are recorded every 5 years on the average and regional floods once every 2 or 3 years (Ningyuan, 1999).

The period between 1 May and 31 September is officially regarded as the Huai River flood season, although large spring floods have occurred in April a number of times in the past years. Snowfall is rare and thus large floods are mainly driven by heavy rainfall.

Results and discussion

The NEWS platform unlike current flood forecasting system is able to: (1) incorporate multiple weather forecasts and post-forecast data processing into one system to achieve reliable flood warning (2) assess uncertainty and risk of an ensemble forecasts (3) Provide API Web services with interactive flood risk mapping (4) make use of advances in HPC environments. NEWS provides web-based services to a broad spectrum of end-users in different geographical locations. This presents challenges including (1) databases and codes that reside in different locations and converge at different times and (2) security issues. To overcome this hurdle the Grid middleware product UNICORE is used. UNICORE is a ready-to-run system that makes distributed computing and data resources available seamlessly and provides robust interoperability through strong security and workflow. We examined the consistency between forecasts issued on consecutive days by visually comparing the forecasted area mean precipitation over 7 days. It is interesting to note the 14/08/2008 storm displayed the best agreement amongst all members on the forecast issued on 13/08/2008, and the second storm was best forecasted on 15/08/2008. Both were best forecasted with 1-day lead time, the 51 forecast members demonstrate a fairly consistent signal of a large precipitation event but one could not tell the exact day it was to occur as the forecast members are dispersed and display disagreement. The percentage of Hit accounting for the total number of forecasts obtained from each individual centre, the ensemble of the 6 centres and the ensemble of 2 centres is shown in Figure 6. All 6 centres and 2 ensembles correctly forecasted Event I/II/III as early as 10 days in advance.

Development challenges web-based services: (1) How far can we model & visualize flooding? - global, national, regional, local, microscale? (2) Uncertainty visualization in hazards maps (3) Visualizing uncertainty for sector specific risk managers (4) Uncertainty representation of point and linear data (4) Multimedia Atlas Information Systems (MAIS)

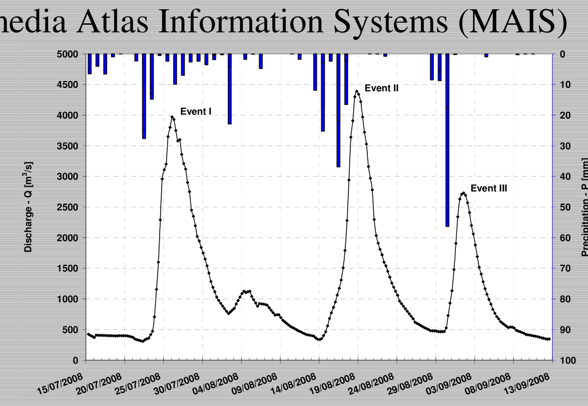
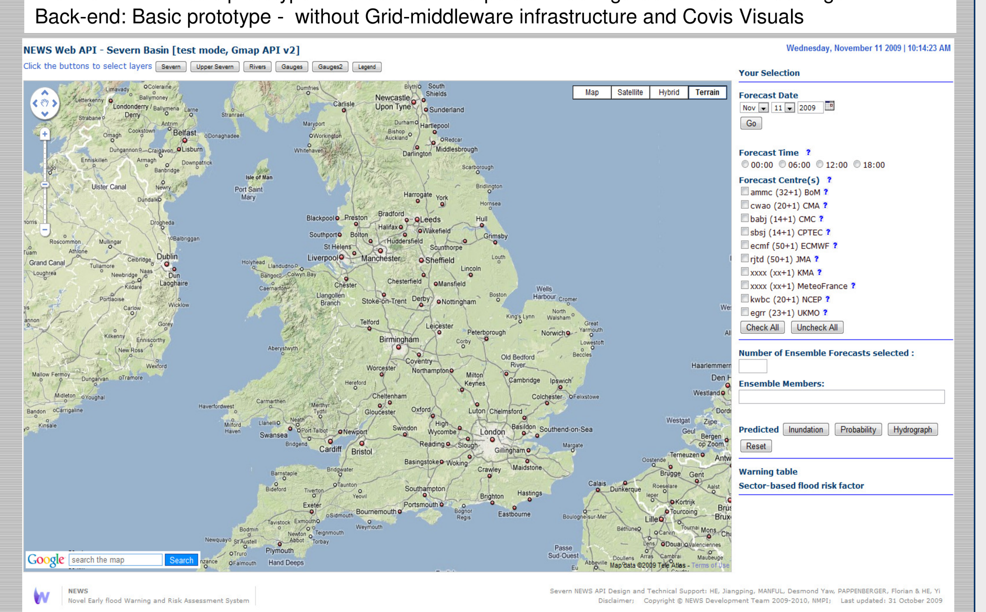


Figure 3. Observed daily precipitation and discharge at WJB (15/07/2008-13/09/2008), three flood events are labelled as Event I, II and III.

Figure 2. Screenshot: (15/07/2008-13/09/2008), three flood events are labelled as Event I, II and III.

Screenshot: 2nd Gen. NEWS Software – Web-based Service Platform

Front-end API: Basic prototype - without Risk interpolator \ Configurable End-user Settings
Back-end: Basic prototype - without Grid-middleware infrastructure and Covis Visuals



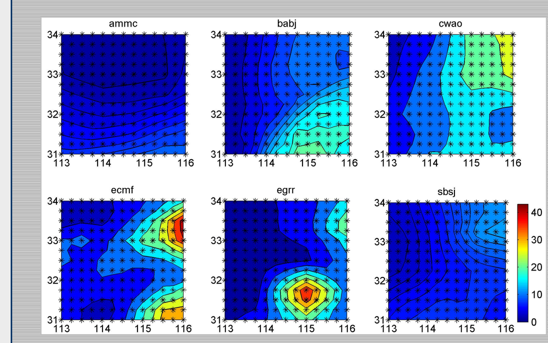


Figure 4. Maximum forecasted precipitation (30 Aug 2008) from 6 centres over the upper Huai catchment domain.

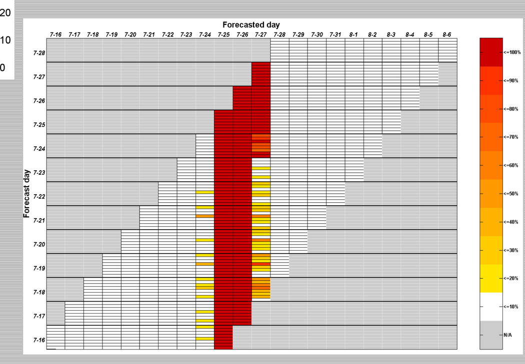


Figure 6. The hit table of the three flood events. The horisontal bars from top to bottom represent the 6 centres (BOM, CMC, CMA, ECMWF, UKMO, CPTEC), the ensemble of the 6 centres and the ensemble of ECMWF/UKMO.

Screenshot: 2nd Gen. NEWS Software – Web-based Service Platform

Prototype: Event Simulation 1 /Severn River near Monkmoor Wastewater Treatment Works

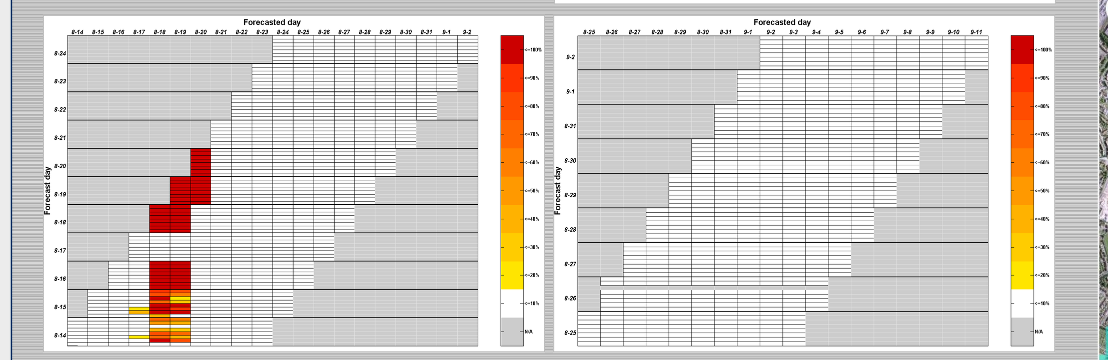


Figure 5. Forecasted precipitation and discharge for Event II from 10/8/2008 to 16/8/2008. The horizontal dashed line is the warning level. Lines marked with diamonds, squares and stars represent the 5th, 50th and 95th percentile of the forecasted discharges respectively. The lines marked with circles and the solid lines represent the observed and the forecasted values respectively.

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