INTOGENER: ARTES 20 Demonstration Study on Water Flow Forecast Service in Remote Mountainous Areas

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Introduction

Having an **accurate forecast of available water flow** is crucial for hydropower companies and water management authorities in order to **optimize operations and improve efficiency.**

In the frame of the ESA Integrated Applications Promotion (IAP) programme (ARTES element 20), Starlab is in the second phase of the INTOGENER project, aiming at the development and demonstration of a **new, operational, water-flow forecast concept, based on the assimilation of near real time measurements of geophysical parameters into a hydrological model**.

The system makes use of **measurements** derived both from **Earth Observation satellites** (SAR and Optical instruments for the retrieval of snow cover and temperature maps), and from **in-situ sensors** (for temperature, precipitations, soil moisture, solar radiation, water level). Satellite links are used to transfer information from the field (remote mountainous areas) to the processing centre.

During a first phase of the activity, one basin in the Chilean Andes has already been equipped, and sound predictions have been obtained. In 2013 and 2014, in partnership with Endesa and the Pontificia Universidad Católica de Chile (PUC) and with the support of Hispasat and Future Water, Starlab is demonstrating the real-time operational capabilities of the system, as the last step before potential commercialization of the service.

Target Users and Needs

INTOGENER Demo is targeting **water management applications**. The more accurate streamflow predictions are, the better water management and energy efficiency can be attained, with the derived economical benefit.

The user area is **renewable energy production** with a focus on hydroelectric production companies. Starlab has established along the years a strong **partnership with Endesa Chile,** which is a key player in the region, being the main producers of hydroelectricity in Chile.

An analysis of **User Needs** has been performed, leading to a set of statements concerning the current status of flow prediction:

- **The indicators and methodology** used to assess the hydrological uncertainty, i.e. flow prediction, through models are **key to obtain valuable results** to monitor the plants energy production.
- **Current operations models used in water management require hydrological information of water resource availability**, particularly during drought events. To monitor these events is also very important for risk management.
- The **current hydrological model inputs** are based on in situ measurements and statistical analysis **based on past events**.
- **In situ data might sometimes be of difficult retrieval** due to the extremely difficult access to the area to be monitored.
- There is a **clear need to include EO near real-time data** in the prediction methodology and to integrate it into the model.
- Flow prediction tasks are often subcontracted. **Statistical Tools are the most common prediction tool** in certain areas.
- Flow prediction models used by majors companies can have **between 40% and 80% of accuracy and need to be improved**

Key Issues

In areas like Chile, hydro **power companies have been using** forecasting solutions such as **statistical regressions** of flow observations, or **mathematical simulations** with a **minimum content of real-time physical** information.

Recently, **a succession of non-average climatic years** made an **impact on their energy efficiency planning**, as the models were **not able to predict the water availability**.

Moreover, **in remote locations** with large inflow reservoirs of difficult access and challenging forecasting points, **current solutions are limited by the scarce amount of in-situ data**, complex operational systems, extreme topographic conditions, and lack of communications systems.

Possible use of space assets to solve these issues

Communication satellites for **transmission of in situ data** from remote sites (not possible by terrestrial ways in remote areas)

GNSS Satellites for estimation of water level in remote lakes using GNSS-R instrument (Low maintenance, works in any weather, automated, allows large water lever excursion).

Earth Observation satellites to derive:

- **Snow cover from SAR** and optical sensors. Huge geographical coverage compared to in situ snow routes
- Space-based **Digital Elevation Models**. Very large coverage and availability compared to plane based or other methods.
- **Land Use Maps**. Large coverage and availability compared to other methods

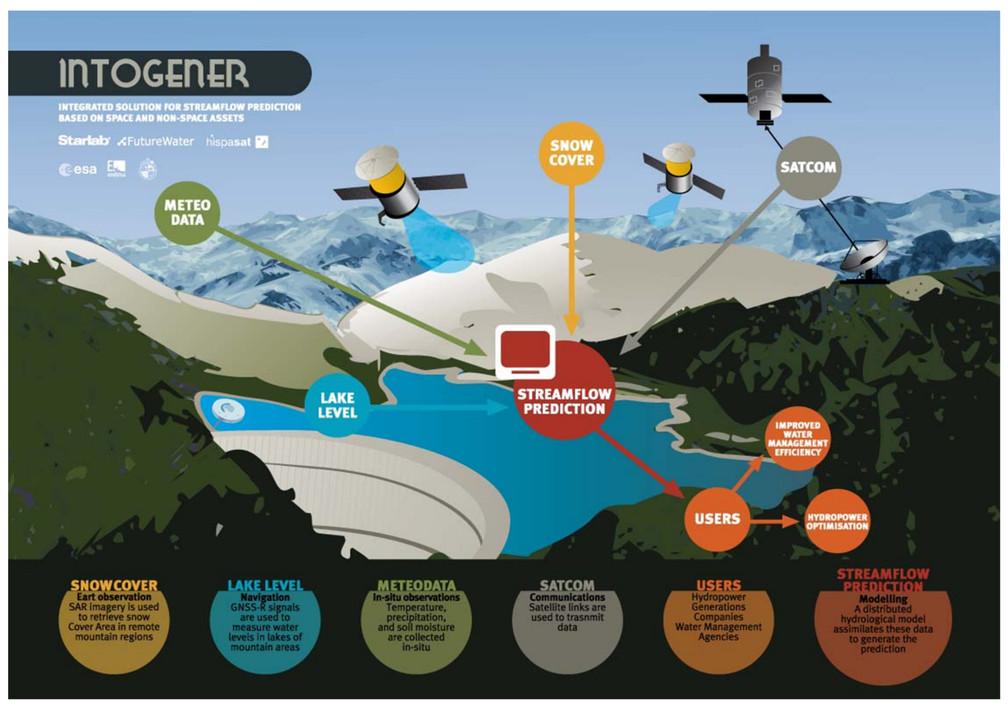
Intogener Service Concept

INTOGENER aims at **improving the water flow predictions in remote mountainous catchments** were most of the hydroelectric production is located. For this purpose **the service concept is based on near real-time geophysical information** from **in situ** and **remote sensing space based instruments** to feed a **hydrological model producing water flow forecast.**

The **in situ measurements** identified as relevant for flow prediction are:
temperature, precipitation, solar radiation, water level, soil moisture. Reservoir water level is estimated using a novel technology based on the measurements of Global Navigation Satellite System (such a s GPS and Galileo) signals reflected by the lake surface (GNSS-R). If required, in situ information can be sent by satellite communications, in order to provide real-time data to the model.

The **space based Earth Observations** identified as relevant for flow prediction are **temperature** and **snow cover** maps. **Snow cover and temperature maps are measured by optical sensors**, with the limitation of cloud cover that occurs regularly during the melting season, and coarse resolution.
Whereas temperature can be completed by in situ measurement, extrapolated and downscaled using a digital elevation model, **snow cover is more difficult to downscale and extrapolate**.
For this reason the service includes the acquisition of **SAR images** which are **cloud immune** and have a **better resolution**.
Using state of the art algorithms, **optical and SAR images are fused** in order to produce **high resolution maps of the snow cover with sufficient temporal resolution.**

The **hydrological model** is initialized with digital elevation model, land use and soil type maps, and calibrated using **historical meteorological and flow data**. It is then capable of producing short term (days) to long term (seasons) water flow forecasts at points of interest by taking as starting points an updated state of the basin (from updated geophysical information) and meteorological model outputs.



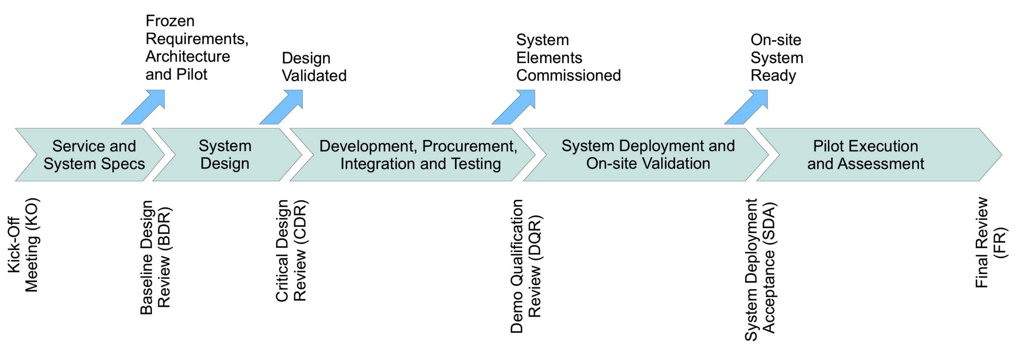
All the information (from in situ instruments, satellite observations, historical data, and model output) is centralized on a **secure server** running a database as well as services required for data flow and automation.

Routines on this server produce **water flow reports**, including **quality indicators**, as well as **system health indicators** available by the service team.

The **output of the service** is a complete **forecast of the water-flow** based on near real time physical observations **delivered automatically to the user on a weekly basis**. This forecast is computed at points of interest of the basin, that match input variables in the operational model, and therefore **usable directly in their management practices**.

Project current status

INTOGENER DEMO is following the management scheme proposed my the ESA and depicted on the figure below



The **BDR tasks** performed between May and August 2012 were the following:

- Consolidation of **user requirements**, **system requirements** and overall **system architecture**
- **Design activities planning** for every subsystems
- **Validation plan draft** for every subsystem
- **Description of the demonstration activities**
- **Campaign definition**
- Demonstration **performance assessment plan**
- **Service assessment plan**

The **CDR tasks** performed between September and October 2012 were the following:

- **Design Definition** and justification for every subsystem
- Consolidated **System Validation Document**

The **DQR tasks** performed between November 2012 and March 2013 were the following:

- **Development, Procurement and Integration of the subsystems**
- **Validation at subsystem level**
- **Validation of a End-to-end test system**

SDA Tasks: **On-site deployment** of the **satellite communication** terminals and **weather stations** has been performed successfully during the first week of May 2013. Operational valiation of the model has been done

The pre-operational system pilot is about to start on the 1st of october 2013, with weekly water flow forecast being deliverd to the user for 6 months.

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