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# Cloud Computing in Atmospheric Science Education

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## Introduction

Cloud computing (the use of external computing networks and services instead of local resources) is the new frontier of teaching, learning and research (Sultan 2010). Nearly half of universities report that their Learning Management Systems (LMSs) are hosted in the cloud (campuscomputing.net), but only about 8% utilize the cloud for research or high-end computing (Green 2012). There are several types of cloud computing available:

- Software as a Service (SaaS)—Externally hosted & maintained software (e.g. most Learning Management Systems)
- Platform as a Service (PaaS)—Externally hosted platform for software development (e.g. Google App Engine)
- Infrastructure as a Service (IaaS)—Most fundamental and versatile, where user specifies the operating system, installs and maintains all software.

Table 1 lists the benefits and challenges associated with cloud computing.

## Benefits and Challenges

Table 1. Benefits and Challenges of Using Cloud Computing in Education (Source: James and Weber 2016).

| Benefits of Cloud Computing | Challenges of Cloud Computing |
|---|---|
| • Cloud computing is reasonably priced compared to the costs of hardware, system support and maintenance. | • The dynamic cost structure of cloud computing requires consistent oversight and monitoring. |
| • IaaS provides computing resources that can be expanded or adapted to meet the changing needs of the users. | • Massively parallel processing can be slowed due to lack of physical proximity within cloud networks. |
| • IaaS does not require hardware maintenance. | • It is still necessary to manage the OS and software in the cloud. |
| • Software can be containerized in the cloud, allowing sets of applications can be executed on practically any operating system. | • Cloud resources still require effort to configure the needed hardware and maintain the OS and software. |
| • Software and data stored in the cloud are triplicated, and this data redundancy eliminates the need for costly and time-consuming data backups. | • Users may have a sense of insecurity when storing data remotely in the cloud. |
| • Access to the cloud is easy and convenient, from any location where Internet connectivity is available. | • Computing in a distributed cloud computing environment is subject to latencies when/ where Internet connectivity is unreliable. |

## Sample Cloud Instance

Through assistance and expertise provided by Unidata, Embry-Riddle Aeronautical University (ERAU) is the first university to host an instance of Advanced Weather Interactive Processing System II (AWIPS II) in the cloud (James et al. 2015). AWIPS II is a Java application that consists of a back-end data server (Environmental Data Exchange [EDEX]) and front-end graphical rendering client (Common AWIPS Visualization Environment [CAVE]). IaaS was selected as the computing solution for this project due to the following requirements:

- Faculty and students needed to gain experience using AWIPS II and other Linux-based forecasting tools.
- Users required access to AWIPS II from virtually anywhere in support of ERAU's new Emergency Response Meteorologist (ERMet) certificate program (Woodall et al. 2015).
- ERAU desired a collaborative computing environment where users from multiple agencies, locations and operating systems could share AWIPS II visualization capability and other forecasting tools.
- Limited funding was available for hardware acquisition, maintenance and system administration.
- Low-cost transfers of meteorological data from Unidata servers to ERAU.

Fig. 1 illustrates the data flow and display configuration that has been created through an IaaS provider. Unidata servers upload meteorological data into the cloud IaaS via the Local Data Manager (LDM) software. The data are then transferred to ERAU's EDEX server at no additional cost. The CAVE client may then be used to access and render visualization graphics from any location where Internet connectivity is available. The total cost for ERAU's EDEX server and data transfers in/out of the cloud is about $200 - $250/month. Fig. 2 shows a sample AWIPS II display.

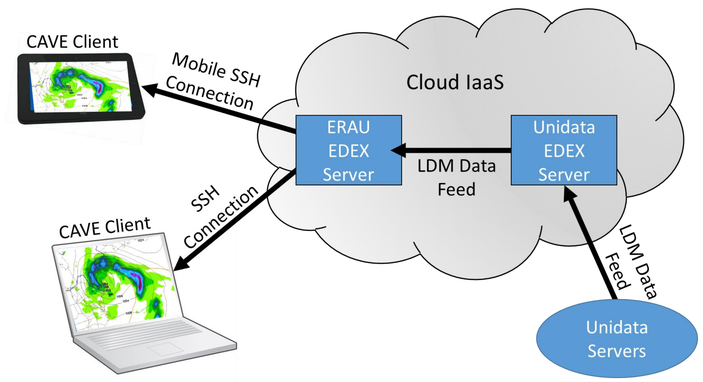


Figure 1. Data flow schematic for ERAU's instance of AWIPS II in the cloud (Source: James and Weber 2016).

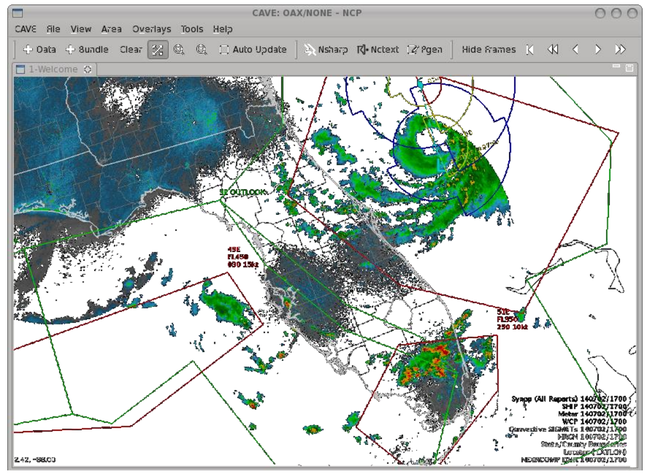


Figure 2. Sample AWIPS II display depicting Convective SIGMET outlines and radar reflectivity imagery around Tropical Storm Arthur off the coast of Florida on 2 July 2014 (Source: Unidata).

## Summary

As shown above, there are a number of benefits to hosting software and data in the cloud. Many universities are skeptical about cloud computing due to valid security concerns over migrating mission-critical data or processes to the cloud. Nevertheless, for hosting educational software, managing data, or providing a collaborative computing environment for scientific research, cloud computing should not be underestimated. ERAU has created a successful instance of AWIPS II currently being tested in the cloud. Despite latencies encountered when rendering AWIPS displays when Internet speeds are slow, student feedback indicates that students consider it a worthwhile endeavor to provide this "unique access to software used in the industry" and "useful training that can be placed on a resume." With practice, the students are become proficient with the use of AWIPS II and preparing for operational careers as forecasters or ERMets.

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