From Mars to Earth through Cloud Computing

Dr. José Luis Vázquez-Poletti

dsa-research.org

Distributed Systems Architecture Research Group
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About me

José Luis Vázquez-Poletti

M.E. in Computer Science (2004) from Universidad Pontificia de Comillas and Ph.D. in Computer Science (2008) from Universidad Complutense de Madrid

Assistant Professor (Tenure Track) at Universidad Complutense de Madrid and Cloud Researcher at Distributed Systems Architecture Group

Directly involved in EU funded projects, such as EGEE and 4CaaSt

- 2005 – 2009: Application porting onto Grid Infrastructures (i.e. Fusion Physics and Bioinformatics) and training events
- Since 2010: Different aspects of Cloud Computing but always with applications in mind

@jlvazpol
http://dsa-research.org/jlvazquez/

KIT and about expanding Humanity's limits

Ferdinand Redtenbacher (1809-1863)

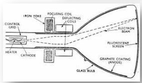
Initiated the mechanical engineering in Germany.

Karl Benz (1844-1929)

Invented the automobile.

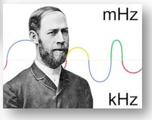
Karl Ferdinand Braun (1850-1918)

Developed the cathode ray tube.



Heinrich Rudolf Hertz (1857-1894)

Discovered the electromagnetic waves.



Wolfgang Gaede (1878-1945)

Founded the vacuum technology.

…

GridKa School (since 2003)

Leading summer schools for distributed computing and e-Science.

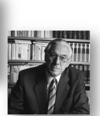
Computing as Humanity's tool

Konrad Zuse (1910-1995)

First working computer ever (Z3).

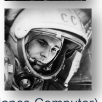
Karl Steinbuch (1917-2005)

Term "Informatic" is coined.



Yuri Gagarin (1934-1968)

First man in Space (thanks to a computer).

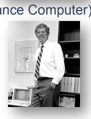


Neil Armstrong (1930-2012)

First man on the Moon (thanks to the Apollo Guidance Computer).

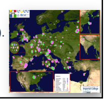
Don Estridge (1937-1985)

First PC (IBM).



European Union (since 1951)

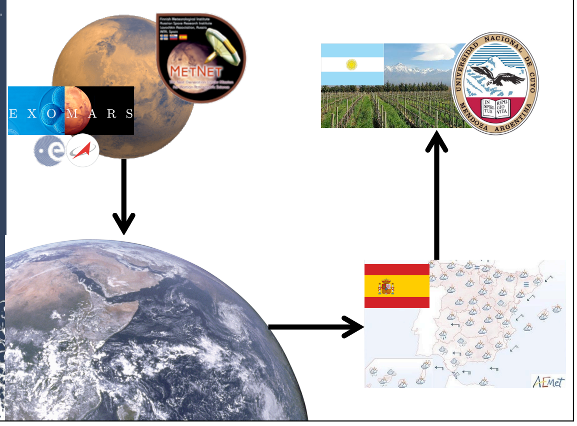
First reference multinational grid computing infrastructure (LCG, EGEE, EGI).



Various (since ???)

Cloud computing.

Today's Journey



Some Martian facts

4th planet from the Sun in Solar System

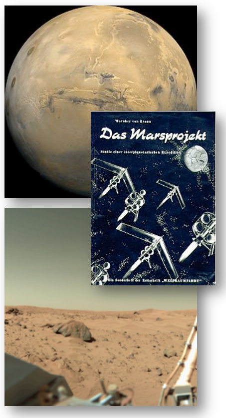
Iron oxide prevalent on surface gives red color

Rotational period: 24h40' hours

Half the radius of Earth
- 38% Earth's gravity

Thin atmosphere
- 95% carbon dioxide, 3% nitrogen, 1.5% argon, traces of oxygen and water
- Methane detected (volcanic, cometary impacts and/or microbial?)
- No magnetosphere

Once had large-scale water coverage
- Now only in poles and mid-latitudes



Missions to Mars

Mission	Country	Launch	Results
Marsnik-1	USSR	10/10/1960	Exploded before reach terrestrial orbit
Marsnik-2	USSR	10/14/1960	Exploded before reach terrestrial orbit
Sputnik 29	USSR	10/24/1962	Exploded in terrestrial orbit
Mars 1	**USSR**	**11/01/1962**	**Passed by Mars 200,000 Km.**
Sputnik 31	USSR	11/04/1962	Failure in terrestrial orbit
Zond 1	USSR	06/04/1964	Failure before reach terrestrial orbit
Mariner 3	USA	11/05/1964	Entered in Sun orbit
Mariner 4	**USA**	**11/28/1964**	**First Mars photos (21)**
Zond 2	USSR	11/30/1964	Communications failure
Zond 3	USSR	07/18/1965	Destroyed in terrestrial orbit
Mariner 6	USA	02/24/1969	Photograhies. Passed by Mars 3,215 Km.
Mariner 7	USA	03/27/1969	Photograhies. Passed by Mars 3,516 Km.
Mars 1969 A	USSR	03/27/1969	Launch failure
Mars 1969 B	USSR	04/02/1969	Launch failure
Mariner 8	USA	05/08/1971	Launch failure
Cosmos 419	USSR	05/10/1971	Launch failure
Mars 2	USSR	05/19/1971	Second artificial satellite of Mars. Surface module destroyed
Mars 3	USSR	05/28/1971	Third artificial satellite of Mars. Surface module sent signals for 20 seconds

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Missions to Mars

Mission	Country	Launch	Results
Mariner 9	**USA**	**05/30/1971**	**First artificial satellite of Mars (7,329 Photos)**
Mars 4	USSR	07/21/1973	Passed by Mars 9846 Km.
Mars 5	USSR	07/25/1973	Operative 9 days in Martian orbit (60 Photos)
Mars 6	USSR	08/05/1973	Surface module sent data during the descent but crashed.
Mars 7	USSR	08/09/1973	Surface module passed by Mars 1,500 Km.
Viking 1	**USA**	**08/20/1975**	**First surface data. Operative during several years**
Viking 2	USA	09/09/1975	Second successful module. Operative during several years
Phobos 1	USSR	07/07/1988	Communications failure approaching Mars
Phobos 2	USSR	07/12/1988	Contact lost during obtaining Phobos photos
Mars Observer	USA	09/25/1992	Contact lost approaching Mars
Mars Global Surveyor	USA	11/07/1996	Operative until November 2006
Mars-96	Russia	11/16/1996	Failure leaving terrestrial orbit
Mars Pathfinder	**USA**	**12/04/1996**	**First robotic vehicle. More than 160,000 photos**
Nozomi	**Japan**	**07/04/1998**	**Failure before entering in Martian orbit**
Mars Climate Orbiter	USA	12/11/1998	Lost before entering in Martian orbit (1999 September 23th)
Mars Polar Lander	USA	01/03/1999	Lost landing

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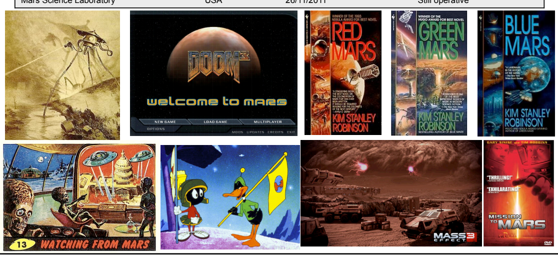
Missions to Mars

Mission	Country	Launch	Results
Mars Odyssey	USA	04/07/2001	Still operative
Mars Express	**ESA**	**06/02/2003**	**Orbital module operative. Surface module lost (Beagle 2)**
Mars Exploration Rover: Spirit	USA	06/10/2003	Operative for 7 years
Mars Exploration Rover: Opportunity	USA	07/07/2003	Still operative
Mars Reconnaissance Orbiter	USA	08/12/2005	Still operative
Phoenix	USA	08/04/2007	Operative for 5 months
Mars Science Laboratory	USA	26/11/2011	Still operative



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NASA

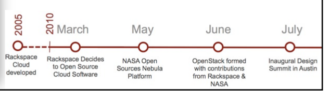
Nebula: NASA's Private Cloud (2008)

Emerged at NASA Ames Research Center and now supported by staff and infrastructure at Ames and at NASA Goddard Space Flight Center

"Computing Container as a Service"

- Open-source cloud computing project and service developed to provide an alternative to the costly construction of additional data centers whenever NASA scientist or engineers require additional data processing.
- Each shipping container data center can hold up to 15,000 CPU cores or 15 petabytes of storage while proving 50% more energy efficient than traditional data centers.

- Virtualization technologies
  - XEN and KVM hypervisors
  - Eucalyptus and then OpenStack virtual infrastructure manager



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NASA

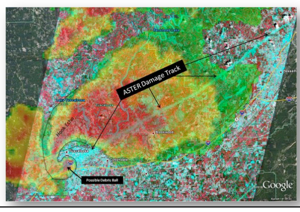
Some recent applications

SERVIR

- Integrates satellite observations, ground-based data and forecast models
- Monitors environmental changes and improves response to natural disasters

SPoRT Center

- Transitions unique NASA satellite observations and modeling capabilities to NOAA's National Weather Service
- Improves the analysis and prediction of weather events occurring within a 0-48 hour time-frame.



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NASA

NASA uses Amazon EC2 (December 2010)

ATHLETE (All-Terrain Hex-Limbed Extra-Terrestrial Explorer)

- High resolution satellite images
- Process needed for guidance

Application: Polyphony

- Evaluates cloud capabilities
- Delivered to the Mars Science Laboratory

"AWS's resources completed the work in less than two hours on a cluster of 30 Cluster Compute Instances. This demonstrates a significant improvement over previous implementations."

"(Polyphony) allowed us to process nearly 200,000 Cassini images within a few hours under $200 on AWS."

amazon web services™

Mars MetNet Mission

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Atmospheric Science Mission to Mars initiated and defined by the Finnish Meteorological Institute (FMI)

Put together by FMI, Lavochkin Association (LA), the Russian Space Research Institute (IKI) and Instituto Nacional de Técnica Aeroespacial (INTA)

The MetNet mission to Mars is based on a new type of semi-hard landing vehicle called MetNet Lander (MNL)

The scope of the MetNet Mission is eventually to deploy several tens of MNLs on the Martian surface

J.L. Vázquez-Poletti, G. Barderas, I.M. Llorente and P. Romero: *A Model for Efficient Onboard Actualization of an Instrumental Cyclogram for the Mars MetNet Mission on a Public Cloud Infrastructure*. **PARA2010: State of the Art in Scientific and Parallel Computing**, Reykjavík (Iceland), June 2010. Proceedings published in Lecture Notes in Computer Science (LNCS). Volume 7133, pp. 33-42, 2012. Springer Verlag.

P. Romero, G. Barderas, J.L. Vázquez-Poletti and I.M. Llorente: *Chronogram to detect Phobos Eclipses on Mars with the MetNet Precursor Lander*. **Planetary and Space Science**, vol. 59, n. 13, 2011, pp. 1542-1550.

G. Barderas, P. Romero, L. Vázquez, J.L. Vázquez-Poletti and I.M. Llorente: *Opportunities to observe solar eclipses by Phobos with the Mars Science Laboratory*. **Monthly Notices of the Royal Astronomical Society**, Volume 426, Number 4, pp. 3195–3200, 2012. Wiley.

A.-M. Harri, W. Schmidt, P. Romero, L. Vázquez, G. Barderas, O. Kemppinen, C. Aguirre, J.L. Vázquez-Poletti, I.M. Llorente and H. Haukka: *Phobos Eclipse Detection on Mars, Theory and Practice*. **Finnish Meteorological Institute Research Report 2012:2**, Finland, 2012.

Mars MetNet

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Application #1

Starting issues

- Probe landing location is needed for onboard instrument Calibration.
- Exact landing coordinates are unknown.
- Landing area (wide set of coordinates) is only determined 1h30' before entry procedure.
- Compass is useless and GPS is not offering service (yet) on Mars.

Approach

- Orientate through well known celestial objects

Mars MetNet: Phobos

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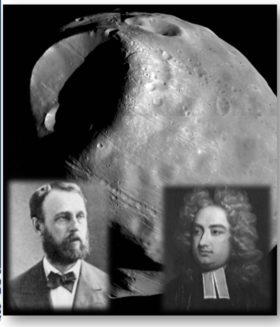

Phobos: The biggest Martian moon.

Discovered in 1877 by Asaph Hall or… by Jonathan Swift in his book "Gulliver's Travels" (1726).

The nearest moon to its planet in all the Solar System (6000 Km)

Orbit: 3 times/day aprox.

Diameter: 28x20 Km

Gravity: 0.00067g

Escape velocity: 25 Km/h

Very interesting effects on the Martian surface, **specially eclipses**.

Mars MetNet: Phobos

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Phobos tracing application developed within the MEIGA project.

Phobos tracing will help in:

1. Obtaining probe landing coordinates
2. Data analysis

   (Eclipses = low radiation)

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Mars MetNet: Phobos

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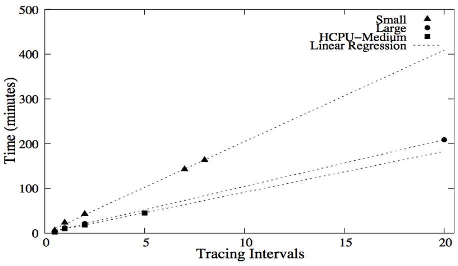
Simulation in 1 area = 800 years in 1 coordinate

11 days 8 hours (without parallelism)

Using VMs from **Amazon EC2**

¿Which Interval/Task? ¿Which type/number of VMs?



A Public Cloud Example: Amazon

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Machine Type	Cores	C.U.	Memory	Storage	Platform
Standard On-Demand Instances					
Small (Default)	1	1	1.7GB	160GB	32bit
Large	2	2	7.5GB	850GB	64bit
Extra Large	4	2	15GB	1,690GB	64bit
High CPU On-Demand Instances					
Medium	2	2.5	1.7GB	350GB	32bit
Extra Large	8	2.5	7GB	1,690GB	64bit

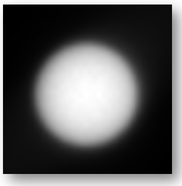
amazon webservices™

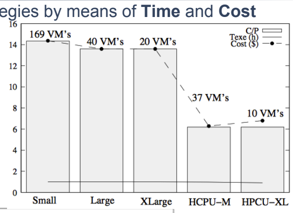
Execution

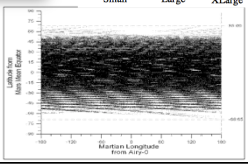
Machine Type	Price in USA
Standard On-Demand Instances	
Small (Default)	\$0.10/hour
Large	\$0.40/hour
Extra Large	\$0.80/hour
High CPU On-Demand Instances	
Medium	\$0.20/hour
Extra Large	\$0.80/hour

Mars MetNet: Phobos

Model for best strategies by means of **Time** and **Cost**







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Mars MetNet: Phobos

More in detail…

Possible solution: 37 HighCPU Medium Machines (**1h** ~ **$7.50**)

What is the price of a similar cluster for the chosen solution?

Example:

HP ProLiant DL170h G6 Server - **$4,909** x **37 nodes** = **$181,633**

What about administration? Electricity? Physical Security?

How many times will it be used at full power? Amortization?

Viking Landers

Application #2

Starting issues

- 2 landers (1976-1980) with different sensors (temperature, pressure).
- Data taken in different intervals and some got corrupted.
- Measurements will help MetNet.

Approach

- Some of the “inconsistent” data could be provoked by Phobos (or Deimos) eclipses.
- Other may indicate a temporal malfunction of sensors.

A.-M. Harri, W. Schmidt, P. Romero, L. Vazquez, G. Barderas, O. Kemppinen, C. Aguirre, J.L. Vazquez-Poletti, I.M. Llorente and H. Haukka: *Phobos Eclipse Detection on Mars, Theory and Practice*. **Finnish Meteorological Institute Research Report 2012:2**, Finland, 2012.

Mars MetNet

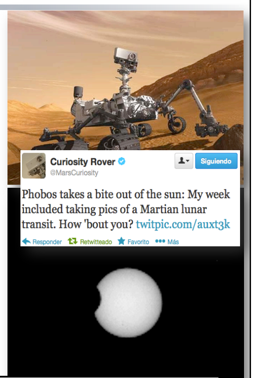
Application #3

Starting point

- Mars Science Laboratory (Curiosity)
- Phobos eclipses prediction
  - Sol 37 (13/09/2012)
  - Sol 41 (17/09/2012)

Results

- On-site validation
  - <1 second precision!!!
- The application is ready for its use on the Mars MetNet probes



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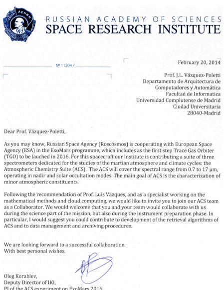
ExoMars 2016 Mission

Large Mars mission to search for biosignatures of Martian life, past or present, currently under development by the European Space Agency (ESA) in collaboration with the Russian Federal Space Agency (Roscosmos)

Two spacecraft elements to be launched in 2016: Trace Gas Orbiter (TGO) and “Schiaparelli” EDM lander

TGO analyzes the Martian atmospheric gas through instruments such as the Atmospheric Chemistry Suite



RUSSIAN ACADEMY OF SCIENCES
SPACE RESEARCH INSTITUTE

№ 11204 /

February 20, 2014

Prof. J.L. Vázquez-Poletti
Departamento de Arquitectura de
Computadores y Automática
Facultad de Informatica
Universidad Complutense de Madrid
Ciudad Universitaria
28040-Madrid

Dear Prof. Vázquez-Poletti,

As you may know, Russian Space Agency (Roscosmos) is cooperating with European Space Agency (ESA) in the ExoMars programme, which includes as the first step Trace Gas Orbiter (TGO) to be lauched in 2016. For this spacecraft our Institute is contributing a suite of three spectrometers dedicated for the studies of the martian atmosphere and climate cycles: the Atmospheric Chemistry Suite (ACS). The ACS will cover the spectral range from 0.7 to 17 μm, operating in nadir and solar occultation modes. The main goal of ACS is the characterization of minor atmospheric constituents.

Following the recommendation of Prof. Luis Vazques, and as a specialist working on the mathematical methods and cloud computing, we would like to invite you to join our ACS team as a Collaborator. We would welcome that you and your team would collaborate with us during the science part of the mission, but also during the instrument preparation phase. In particular, I would suggest you could contribute to development of the retrieval algorithms of ACS and to data management and archiving procedures.

We are looking forward to a successful collaboration.
With best personal wishes,

Oleg Korablev,
Deputy Director of IKI,
PI of the ACS experiment on ExoMars 2016

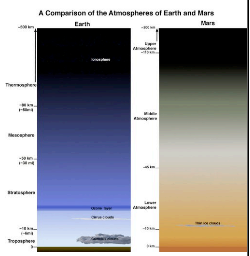
Martian Meteorology

Starting point

- Need of a Martian meteorological model

Computational workplan

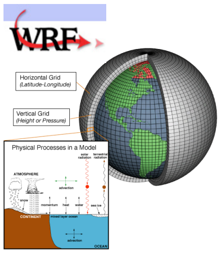
- Cost optimization of terrestrial meteorological models
  - Will apply to Martian models later
- Validation of proposed Martian models
  - Huge amount of data process



WRF

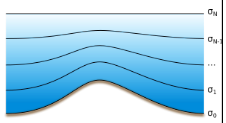
Weather Research & Forecasting Model

- portable, flexible, and state-of-the-art code, especially efficient when executed in a massively parallel computing environment
- various physics options and can be used in a broad spectrum of applications across scales, ranging from meters to thousands of kilometers
- currently used in many worldwide meteorological agencies and adopted by a huge community of users (over 20,000 in over 130 countries)



Numeric mesoscale:

- uses mathematical models to predict the weather on current conditions
- divides the atmosphere vertically



Chosen compiling options:

- Distributed Memory
- Message Passing Interface (MPI)

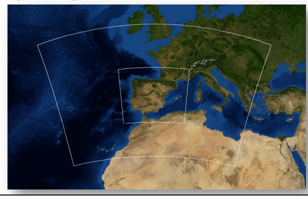
WRF

Target area for study:

- Iberian Peninsula
- resolution: 5x5 km (horizontal) and 28 levels (vertical)
- 301x250 grid mesh
- 48-hour forecast horizon

Data models:

- **GFS**-NCEP**:** free data, sometimes imprecise, 2 level computation
- IFS-**ECMWF:** restricted access data, 1 level computation
  - **$207,002.19/year** (for target area)



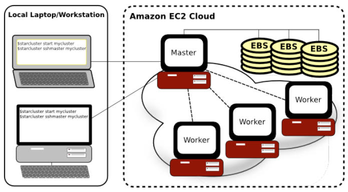
WRF on Cloud

Execution of WRF is a typical HPC problem

- Different technologies have been used (multi-core to GPU)
- (Public) cloud computing infrastructures have not been studied before

Cloud Infrastructure

- **IaaS:** Amazon EC2
  - great instance type offering
- **PaaS:** StarCluster
  - allows the automation and simplification of the building, configuration and management of computing clusters deployed on Amazon EC2



WRF on Cloud

Amazon EC2 Machines:

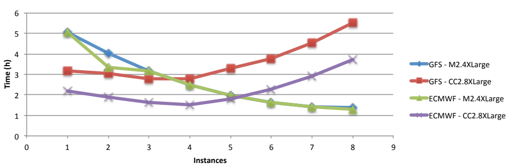
Type	Family	vCPU	ECU	Memory (GB)	Storage (GB)	Network Performance	Cost ($)
m1.small	General	1	1	1.7	1 x 160	Low	0.60
cc2.8xlarge	Compute Optimized	32	88	60.5	4 x 840	10 Gigabit	2.40
m2.4xlarge	Memory Optimized	8	26	68.4	2 x 840	High	3.50

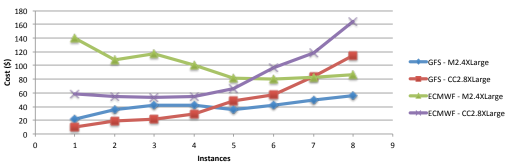
WRF on Cloud

Experimental results

GFS: free data, sometimes imprecise, 2 level computation

ECMWF: restricted access data ($23.61/h), 1 level computation



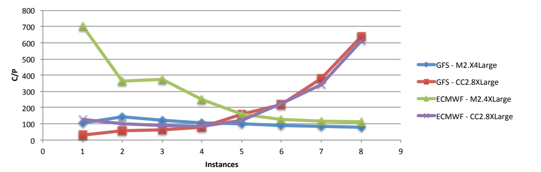


WRF on Cloud

C/P Metric

GFS: free data, sometimes imprecise, 2 level computation

ECMWF: restricted access data ($23.61/h), 1 level computation



Strategy:

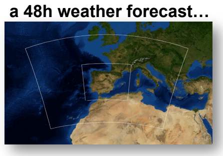
GFS

- cc2.8xlarge (1 to 4 nodes)
- m2.4xlarge (5 to 8 nodes)

ECMWF

- m2.4xlarge (no less than 6 nodes)

a 48h weather forecast…



… is obtained in 1,5h and costs $60-$80

Agricultural weather monitoring

Province of Mendoza (Argentina)

- 160,704 ha of vineyards
- 70.31% of national production

Frosts

- Temperature falls below 0ºC under 1.5 meters
  - Even below 3ºC depending depending the stage
- Two phase damage: cellular burst and dehydration
- Damage 5% to 15% of World agricultural production (Mendoza: 9%)
- September 2013: many districts of Mendoza lost up to 80% of crops

Agricultural weather monitoring

Passive defense

- Choose zone and species wisely
- Not always possible

Active defense

- Detect/predict frost and apply countermeasures
- Most used: kerosene/diesel heaters and water sprinklers
- Other: fans/turbines, helicopters (expensive), greenhouses (small areas), smokescreens (no wind), infrared heaters (bad results)

Detection/Prediction

- April to October
- Need of a wide and cheap weather sensor network
- Need of an on-demand computing infrastructure (HPC/HTC)

Calorías aportadas por distintos combustibles

Madera	3.990 - 4.420 Kcal por Kg
Carbón Vegetal	8.080 - 8.100 Kcal por Kg
Carbón Mineral	3.335 - 8.115 Kcal por Kg
Fuel oil	10.454 Kcal por Kg
Gas oil	entre 10.188 y 10.852 Kcal por Kg
Kerosén	10.995 Kcal por Kg
Petróleo crudo	10.496 Kcal por Kg
Biodiesel	entre 10.094 y 10.732 Kcal por Kg

WSN on Cloud

Weather Sensor Networks

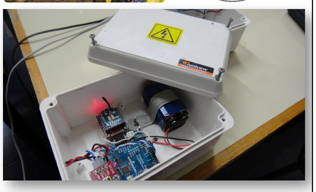
- Universidad Nacional de Cuyo (Argentina)

Node characteristics:

- humidity and temperature
- low power consumption
- low cost
- robustness
- reliability

Interconnection

- ZigBee (node to base station)
  - Based on IEEE 802.15
  - 250 kbit/s
- TCP/IP (uplink from base station)
  - Required bandwidth: 64 bytes/s
  - Process generates delay of 0,5 s

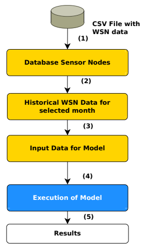


Lucas Iacono, Carlos García Garino, Osvaldo Marianetti and Cristina Párraga, *Wireless Sensor Networks: A Software as a Service Approach.* **HPCLatAm 2013**. Mendoza, Argentina.

WSN on Cloud

Frost prediction application

- Allows to predict **radiation (hoar) frost**
- Calculates minimum temperature in nights without clouds and cold fronts
  - with and without dew point
- Continuous comparison with historical data
  - temperature 2 hours after sunset
  - minimum temperature during previous night
  - dew point (if chosen, needs humidity sensor)



Sensor Cirrus
Wireless Sensor Cloud Platform
https://sites.google.com/site/sensorcirrus/

R. L. Snyder, J. P. Melo-Abreu, *Frost protection: Fundamentals, Practice and Economics*, Vol. 1, **Food and Agriculture Organization of the United Nations (FAO)**, 2005.

WSN on Cloud

WSN Initial problems:

1. Need to process large volume of data on technologies not prepared to scale
2. Users must have knowledge on WSN programming
3. Scaling is not economically feasible
4. No fault tolerance and high reliability mechanisms (data process)

Solutions:

1. On-demand provided resources
2. Process delegated to 3rd party applications running on 3rd party infrastructure
3. Pay-as-you-go infrastructure
4. Infrastructure with SLA and on-demand deployment of additional resources

amazon webservices™

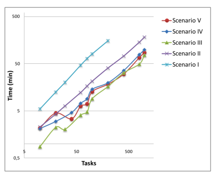
Test Scenario	Instance	vCPUs	ECU	Memory (GBytes)	Cost on demand (U$S)
I	t1.micro	1	variable	0.615	0.020
II	m1.small	1	1	1.7	0.047
III	m1.large	2	4	7.5	0.190
IV	m1.xlarge	4	8	15	0.379
V	c3.xlarge	4	14	7.5	0.239

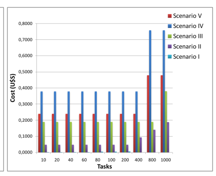
WSN on Cloud

Experiments

- execution of frost prediction application
- 4 experiments with different number of sensor nodes (10-1000) for each instance (1 node = 1 task)
- usage cost from average execution time and Amazon EC2 pricing

Test Scenario	Instance	vCPUs	ECU	Memory (GBytes)	Cost on demand (U$S)
I	t1.micro	1	variable	0.615	0.020
II	m1.small	1	1	1.7	0.047
III	m1.large	2	4	7.5	0.190
IV	m1.xlarge	4	8	15	0.379
V	c3.xlarge	4	14	7.5	0.239





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Execution model

Test Scenario	Instance	vCPUs	ECU	Memory (GBytes)	Cost on demand (U$S)
I	t1.micro	1	variable	0.615	0.020
II	m1.small	1	1	1.7	0.047
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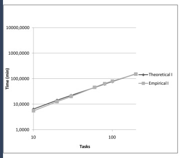
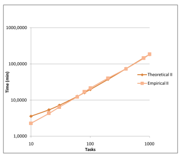
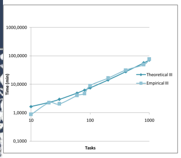

(a) Scenario I.

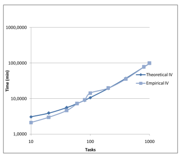

(b) Scenario II.

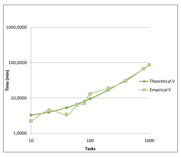
$$t = Ax^2 + Bx + C$$

Table 2: Coefficients of Each Scenario Theoretical Model.

Scenario	A	B	C
I	0	$7.8526E-01$	-1.4436
II	$1.8465E-06$	$1.7883E-01$	1.8027
III	$6.0225E-06$	$6.5069E-02$	$9.9827E-01$
IV	$1.4014E-05$	$8.2443E-02$	2.2512
V	$1.6670E-05$	$6.7349E-02$	2.5970


(c) Scenario III.


(d) Scenario IV.


(e) Scenario V.

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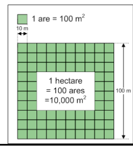
Execution model (small example)

- Optimal number of nodes per instance (by means of performance)
- Deadline: 1 hour

Test Scenario	Instance	Nodes	Execution Time (min)	Economic Cost (U$S)
I	t1.micro	78	59.806	0.020
II	m1.small	324	59.937	0.047
III	m1.large	841	59.980	0.190
IV	m1.xlarge	632	59.952	0.379
V	c3.xlarge	722	59.912	0.239

Remember: 160,704 ha of vineyards!



Short term improvements

- Model considering multiple instances
  - Performance, cost and cost/performance
- Placement based on WSN resolution
  - 100 nodes/ha, 10 nodes/ha…

L. Iacono, J.L. Vazquez-Poletti, C. Garcia Garino and Ignacio M. Llorente: *A Model to Calculate Amazon EC2 Instance Performance in Frost Prediction Applications*. **1st HPCLATAM-CLCAR Joint Conference (CARLA2014)**. Valparaiso (Chile), October 2014. Proceedings published in the series Communications in Computer and Information Science (CCIS). Vol. 485, pp. 68-82, 2014. Springer.

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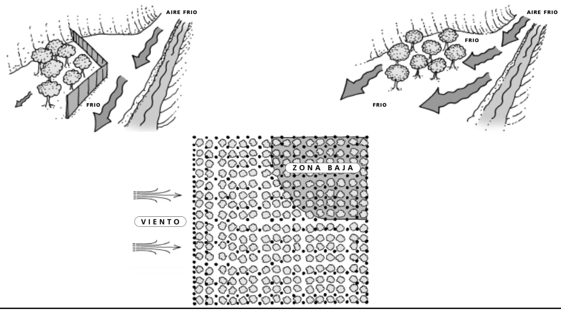
Mid-long term work

- Placement strategy to cover different fields and share costs
- Transfer optimization
- Optimal node deployment considering environmental elements



Another tool for expanding Humanity's limits

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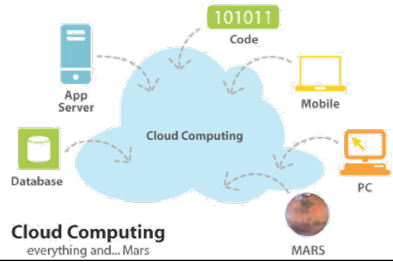
Cloud Computing is taking the role of ancient computing systems which brought Humanity to Space.

Mars represents the nearest frontier to be broken by Humanity.

As in the rest of scenarios, achievements will directly affect technology and general knowledge on Planet Earth. Cloud Computing is not an exception.



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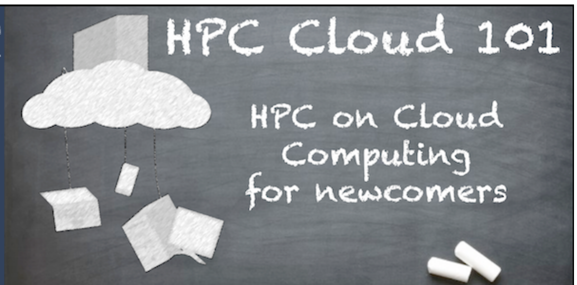

Room 229.3
Building 30.22

Tuesday
September 8th, 2015

Thank you very much!
Vielen Dank!
HaaS: House as a Service
deployment spotted at Karlsruhe Marktplatz
Research mentioned in this talk was funded by: MEDIANET (Comunidad de Madrid S2009/TIC-1468), ServiceCloud (MINECO TIN2012-31518) and MEIGA-METNET-PRECURSOR (AYA2009-14212-C05-05/ESP)