Discover floods

Background science and suggestions to teach young about flood protection

Giorgio Boni
Introducing myself....

<table>
<thead>
<tr>
<th>Giorgio Boni, Ph.D., assistant professor, University of Genova, Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGU Natural Hazard Division President</td>
</tr>
<tr>
<td>CIMA Research Foundation, remote sensing applications to hydrology</td>
</tr>
<tr>
<td>In cooperation with World Meteorological Organization, APFM-WET Project</td>
</tr>
</tbody>
</table>
WMO Associated Programme for Flood Management

Mission
To support countries in the implementation of Integrated Flood Management (IFM) within the overall framework of Integrated Water Resources Management (IWRM) to maximize net benefits from the use of their floodplains and minimize loss of life and impacts.

APFM’s **Key Strategic Areas** can be seen in the image on the left while the goals stemmed from those areas are:

- Assisting countries, regions and communities in the implementation of IFM
- Collecting and disseminate knowledge on IFM
- Advocating for IFM
- Growing and reinforcing a network of partners for cooperation on IFM
- Strengthening partnerships to increase technical, institutional, and financial contributions to IFM
- Efficiently and effectively manage APFM

http://www.apfm.info
Course format

• The target of the course is to provide the science background on relevant physical and social processes that produces floods and damages

• For each topic first the science background is provided, then some examples on how to teach the topics involving actively students

• Teaching material provided by APFM Helpdesk, WET project will be used
Course target

The target of the course is to learn how to know our own "water address"

• The natural features of a specific location, such as topography/landscape, geology, hydrology (atmospheric, surface and ground water), soils and vegetation; weather and climate;
• the human environment, including structures and utilities (e.g., roads, buildings, power lines, dams, dikes, levees).

The features of a specific site may change over time.

Individuals should determine their water address to assess the likelihood of their location becoming inundated during a flood.

A person’s water address changes if she or he is on vacation, at school/work, in a car, camping or on a hike. If flood waters approach an individual’s water address, it is important to be prepared.
Course outline

• What is a flood:
  – The incredible journey: the hydrological cycle
  – Thunderstorm!

• Color me a watershed
  – what is a watershed
  – some principles of hydrology of the extremes
  – role of land use in flood formation

• Where we can expect a flood
  – my hazard map: how to identify risk prone areas?

• During and after a flood
  – flood forecast
  – Take action! What to do to reduce the impact of a flood
The hydrologic cycle: the way our planet circulates water and energy and then defines its climate
Water distribution on Earth


http://ga.water.usgs.gov/edu/earthwherewater.html
Water distribution on Earth

- Atmosphere: 0.001%
- Glaciers, ice caps: 2.04%
- Oceans: 97.31%
- Ground Water: 0.615%
- Soil Moisture: 0.009%
- Biomass: 0.009%
Water cycle time scale
## Water cycle time scale

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume ($10^6$ km$^3$)</th>
<th>%</th>
<th>Turn-over time (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans</td>
<td>1320</td>
<td>97.22</td>
<td>3000</td>
</tr>
<tr>
<td>Groundwater</td>
<td>8.25</td>
<td>0.61</td>
<td>5000</td>
</tr>
<tr>
<td>Ice caps and glaciers</td>
<td>29.2</td>
<td>2.15</td>
<td>8000</td>
</tr>
<tr>
<td>Saline lakes and inland seas</td>
<td>0.105</td>
<td>0.008</td>
<td>7</td>
</tr>
<tr>
<td>Fresh water lakes</td>
<td>0.125</td>
<td>0.009</td>
<td>7</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>0.06</td>
<td>0.005</td>
<td>1</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>0.013</td>
<td>0.001</td>
<td>10 days</td>
</tr>
<tr>
<td>Rivers</td>
<td>0.001</td>
<td>0.0001</td>
<td>11 days</td>
</tr>
</tbody>
</table>
The engine is powered by..

Solar Energy
Play the hydrological cycle

• Target:
  – describe the movement of water within the water cycle.
  – identify the states of water as it moves through the water cycle.

• Students play the role of “water molecules”

• they often think the hydrological cycle as a linear path. This game is specifically designed to understand the complexity underlying the hydrological cycle
Play the hydrological cycle
Thunderstorm!

Thunderstorms are one of nature’s most spectacular phenomena. They occur throughout the world. What distinguishes a thunderstorm from other types of storms? Thunder and lightning.

They also can generate **Flash Floods**, which are very dangerous to humans, wildlife and human-made structures. Flash Floods form when too much precipitation falls in a relatively short time.
Background: air mass uplift

To have rainfall moist air masses must be uplifted.

Three kinds of uplift mechanisms are usually observed:

1. Air masses convergence

2. Convection

3. Orographic uplift
• Extra tropical cyclones- frontal convergence: vertical uplift, cooling and condensation generated by convergence of cold and warm and moist air masses
Convergence uplift

Sezione A-A'

Fronti occlusi
Convergence uplift

Non frontal convergence: tropical storms, hurricanes
Un secondo meccanismo, molto più efficiente e in grado di produrre precipitazioni molto intense, è il sollevamento orografico: un flusso di aria umida e calda, incontrando una catena montuosa, è costretto a sollevarsi per superarla.
Rainfall observation

Area 0.1 m²

Tipping bucket
- Capacity: 0.020 kg
- Rainfall depth: 0.2 mm

spatial resolution: 0.1 m² (point observation)
Temporal resolution:
- variable (traditional sensors)
- few minutes (last generation sensors)

Problems: underestimation
- Obstacles close to the gauge
- Defective support of the bucket
- Bucket filling decreasing with rainfall intensity
Remote sensors: the meteorological radar
Example of radar rainfall map

Typical temporal resolution: 10 min
Typical spatial resolution: 1 km
Remote sensors: satellites

- Geosynchronous Earth Orbit (GEO) Satellites
- Low Earth Orbit (LEO) Satellites
Comparison satellite-radar
Color me a watershed

• understanding how floods form needs to know what a watershed is and how it works when rain comes
• size matters: floods in small and large basins have complete different characteristics
• population growth and settlement cause land-use changes.
• land-use variations in a watershed can affect surface-water runoff and flood frequency
Water cycle at catchment scale

Interception
Evapotranspiration
Infiltration
Surface runoff
Evapotranspiration

Sum of evaporation and plant transpiration from the earth's land surface to atmosphere.

**Evaporation** accounts for the movement of water to the air from sources such as the soil, canopy interception, and water bodies.

**Transpiration** accounts for the movement of water within a plant and the subsequent loss of water as vapor through stomata in its leaves.

Is a function of the availability of energy and water in soil.
Infiltration

Is the process by which water on the ground surface enters the soil. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. The rate decreases as the soil becomes “saturated”. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier.

Major factors affecting infiltration
Where are the boundaries of a watershed?

Credits: WATER Resources Mr. Manskopf, http://slideplayer.com/slide/6458761/
Evaluate runoff and land use changes effects
**Chart for Option 2  AREA OF LAND COVERAGE**

<table>
<thead>
<tr>
<th>Land coverage</th>
<th>MAP A 100 yrs. ago</th>
<th>MAP B 50 yrs. ago</th>
<th>MAP C Present</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km²</td>
<td>%</td>
<td>km²</td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasslands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetlands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stream</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Chart for Option 3  VOLUME OF RAIN AND VOLUME OF RUNOFF**

<table>
<thead>
<tr>
<th>Land coverage and % runoff</th>
<th>MAP A 100 years ago</th>
<th>MAP B 50 years ago</th>
<th>MAP C Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>volume m³</td>
<td>runoff m³</td>
<td>volume m³</td>
<td>runoff m³</td>
</tr>
<tr>
<td>Forest 20% runoff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasslands 10% runoff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetlands 5% runoff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential 90% runoff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural 30% runoff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total runoff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total runoff plus stream discharge (5,550,000 m³)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From runoff to floods

1. Precipitation
2. Catchment Runoff
3. Flood peak
4. Osservare per prevedere, prevedere per prevenire
Flash floods
Where we can expect a flood

- A floodplain offers enormous advantages for communities, although living in a floodplain exposes its occupants to flooding.
- History shows that absolute protection from flooding is neither technically feasible nor economically (or environmentally) viable.
- Any risk-reduction strategy—aimed at reducing flood damages through structural measures (such as flood embankments)—provides only partial protection for people inhabiting floodplains.
- Such measures, too often, offer a false sense of security.
- Everyone living in a floodplain must be aware of the risks and be prepared for flood.
- **Flood-hazard and risk maps** are one tool to help achieve this.
Effects of land use: not only runoff
**Flood risk**

**Flood risk depends on**

- **Magnitude** (flow speed, depth, extension, duration): **HAZARD** (H)
- **Location**, **numerosity** and value for different economic categories of exposed (E)
- **Vulnerability** (V) of the exposed elements (people, shops, roads, schools...)

... All these variables defines the risk in the most classical way....

\[ R = H \times E \times V \]
Ask students which environment is more exposed to risk.
The Residual Risk is the result of planning and permanent risk mitigation actions. It must be faced, if it realizes, with real time intervention by Civil Protection.
A simple example of Residual Risk

High vulnerability to Very frequent inundation (T=5-10 years)

Very low probabilities of rare events remain – Civil Protection warnings, insurance

Local defense measure against flooding to reduce the inundation frequency
Drawing a risk map

• interview people about past floods
• look for past floodmarks
• go to the field with a map and try to draw areas where flood can occur
• identify other risks (landslides on hillslopes)
• identify infrastructures (hospital, schools, shops, ...)
• identify possible escape roads and safe places
During and after a flood

• we have seen as floods are “produced” and where they can hit
• it is important that everyone knows her/his “water address”
  – The likelihood their location (home but also school, workplace...) can be flooded. A person water address can change during the day!
  – timing: floods may come quickly on small creeks (flash floods) or take days (riverine floods)
• flash floods are hard to predict while riverine floods can be predicted days in advance
• once the water address is known, emergency plans must be drawn
  – for cities and neighbourhoods usually this is made by authorities -> be informed!
  – for your family is good to prepare a family emergency plan
Flood forecast

Precipitation

Catchment runoff

Flood

STREAM HYDROGRAPH FOR A HYPOTHETICAL RIVER

- Flooding crest (highest level of water)
- Flood waters overflow river bank and enter floodplain

Alert!!!
How to protect yourself if a flash flood comes

• know your “water address”
• monitor water level in rivers
• monitor water level and water speed on the roads
• have ready or know the action plan depending on where you are
Rivers

- Low risk
- Medium risk
- High risk

- Not critical
- About 1/3 of the riverbed
- About 1/2 of the riverbed
- About 2/3 of the riverbed
Examples

Low flow

Low risk
Examples

Medium risk
2/3 of the riverbed and bridges

DANGER!!!

A nearby river is flowing out the sewer system
Water on the road

cars start to float!

water covering tires, flowing rapidly

20 ÷ 25 cm
8 ÷ 10 cm
Some ponding with water level covering ankles and reaching the car body.

Medium risk

Examples
DANGER!!

HIGH risk conditions
Modesta presenza di acque di ruscellamento

Copiosa presenza di acque di ruscellamento e segni di erosione e movimento

Movimento di terreno, distacchi o interessamento della sede stradale

Osservare per prevedere, prevedere per prevenire
Family action plan

An Action Pack could include:
- Containers of water—drinking water may be polluted.
- Flashlight with batteries—electrical power may be out.
- Battery-powered or hand-crank radio to hear flood warnings and updates.
- Batteries—to power the radio and flashlight.
- First Aid kit—for minor scratches/injuries.
- Rain gear—protection in a storm.
- Canned food—fresh food may be contaminated by flood waters.
- Can opener—to open canned food.
- Emergency cooking supplies—power to cook may be unavailable.
- Pet food, water—pets need basic essentials, too.
- Medicine/prescriptions—anything you need to stay healthy.
- Emergency phone numbers—to call for help if you become separated from your family.

A Family Action Plan could include the following points:

- Prepare an Action Pack (or emergency supply kit).
- Put special treasures and memorabilia in a waterproof container.
- Plan how you will secure your home; moving furniture and appliances to the second floor, also any chemical agents, paints, etc. You must shut off electricity, gas and water, and if possible hermetically seal sewage installations.
- Know where to go and where your family will meet.
- Know evacuation routes to safety, either to higher, stable ground or away from the flood area.
- Know how to stay in contact with family if separated.
- Have pets and personal items ready, so you can evacuate immediately.
- Know where you will store farm machinery, cars, etc. and where you will keep livestock.

Listen to flood watches and warnings on the radio, television and Internet. Follow instructions.
Make those around you aware of a possible flood.
When you are away on vacation, be aware of your surroundings.
Pay attention to the weather and think about how a flood could affect you and your activities.
Stay away from rushing water, storm drains and rising rivers.
Stay out of flood water.
Never drive through flood water in a vehicle.
Understand weather patterns in your area.
Course material and references

Discover FLOODS – Kids in Discover Series - Joint development of WMO and “Project WET: Water Education for Teachers”. In English
http://www.apfm.info/education/kids/WET_Discover_Floods_KIDs.pdf

Discover FLOODS – Educators Guide - Joint development of WMO and “Project WET: Water Education for Teachers”

READY FLOODS – Kids in Discover Series - Developed by U.S. FEMA – In Spanish
http://www.ready.gov/kids/know-the-facts/floods