



The method  
of  
soil moisture sensing  
by  
cosmic-ray neutrons

Knowledge|Sensor|Technology





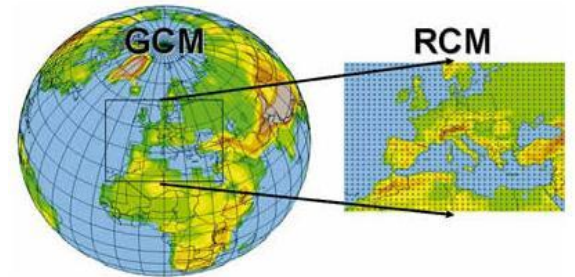
[1]



[3]



[2]



[1]

[1] <http://www.wmo.int/pages/themes/climate/images/figures/ClimateModelnesting.jpg>

[2] <http://www.livetradingnews.com/wp-content/uploads/2014/04/precisionag.jpg>

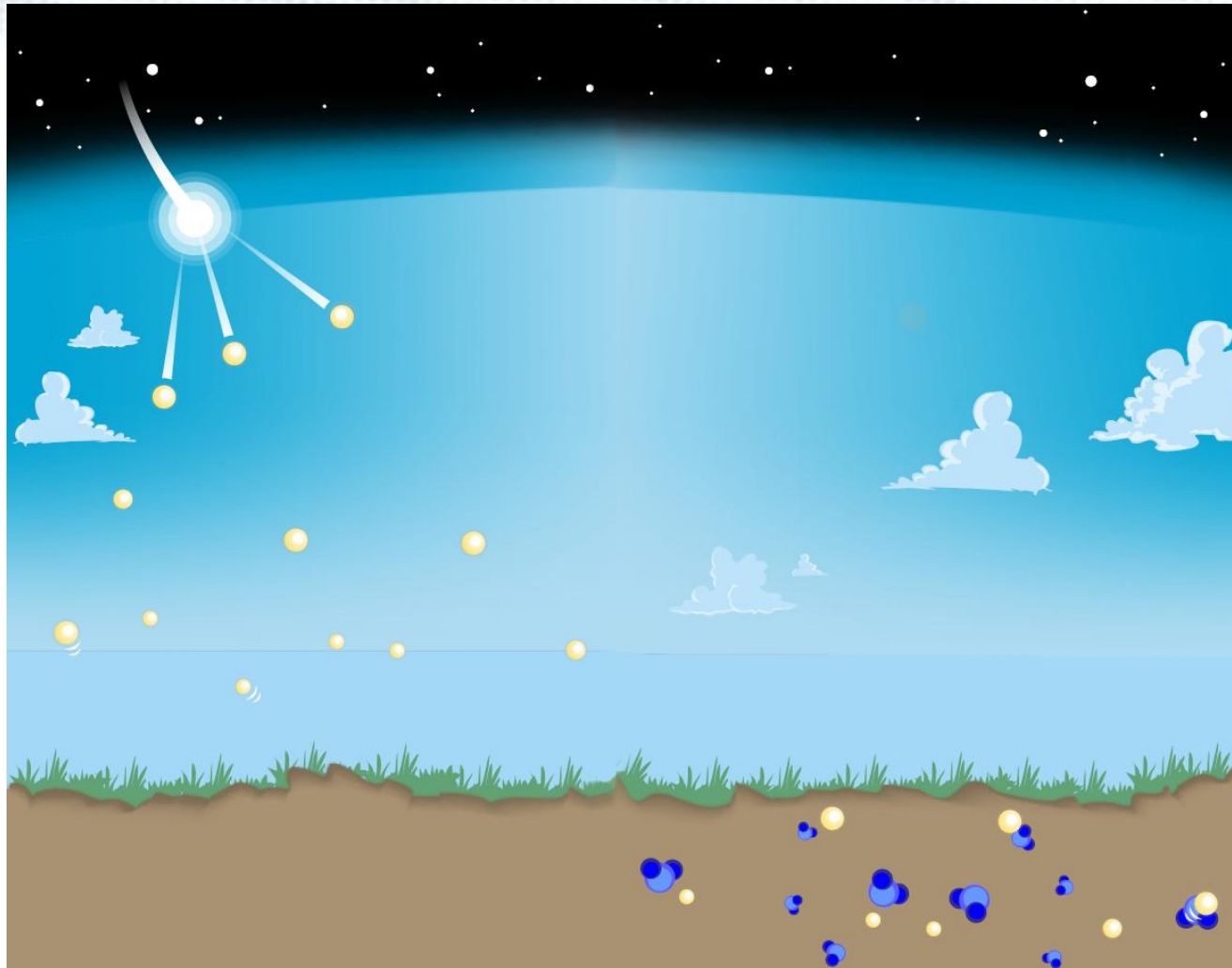
[3] [http://upload.wikimedia.org/wikipedia/commons/3/37/Nam\\_steppe.jpg](http://upload.wikimedia.org/wikipedia/commons/3/37/Nam_steppe.jpg)

# Cosmic Ray Neutron Sensing .CRNS.

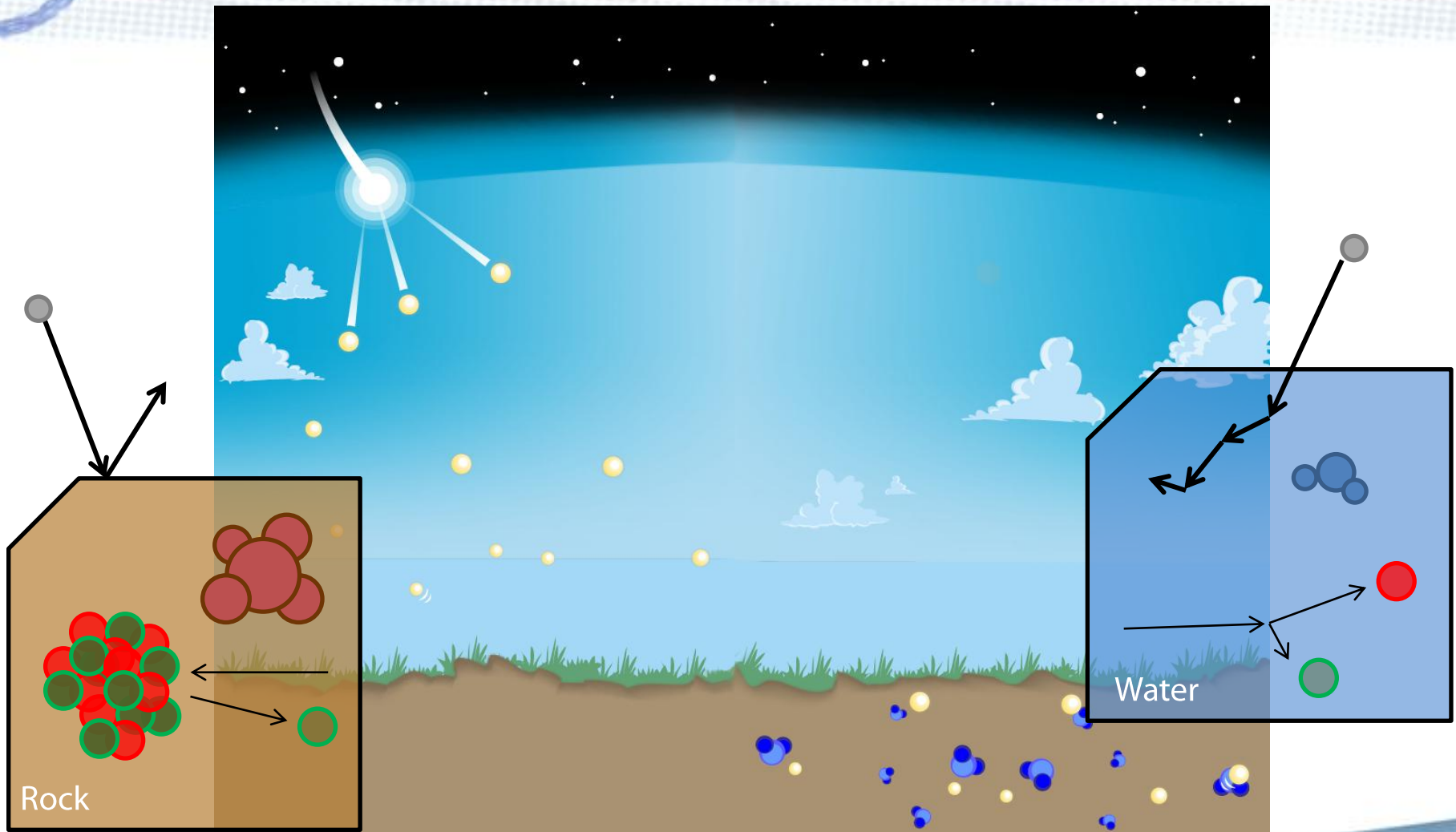




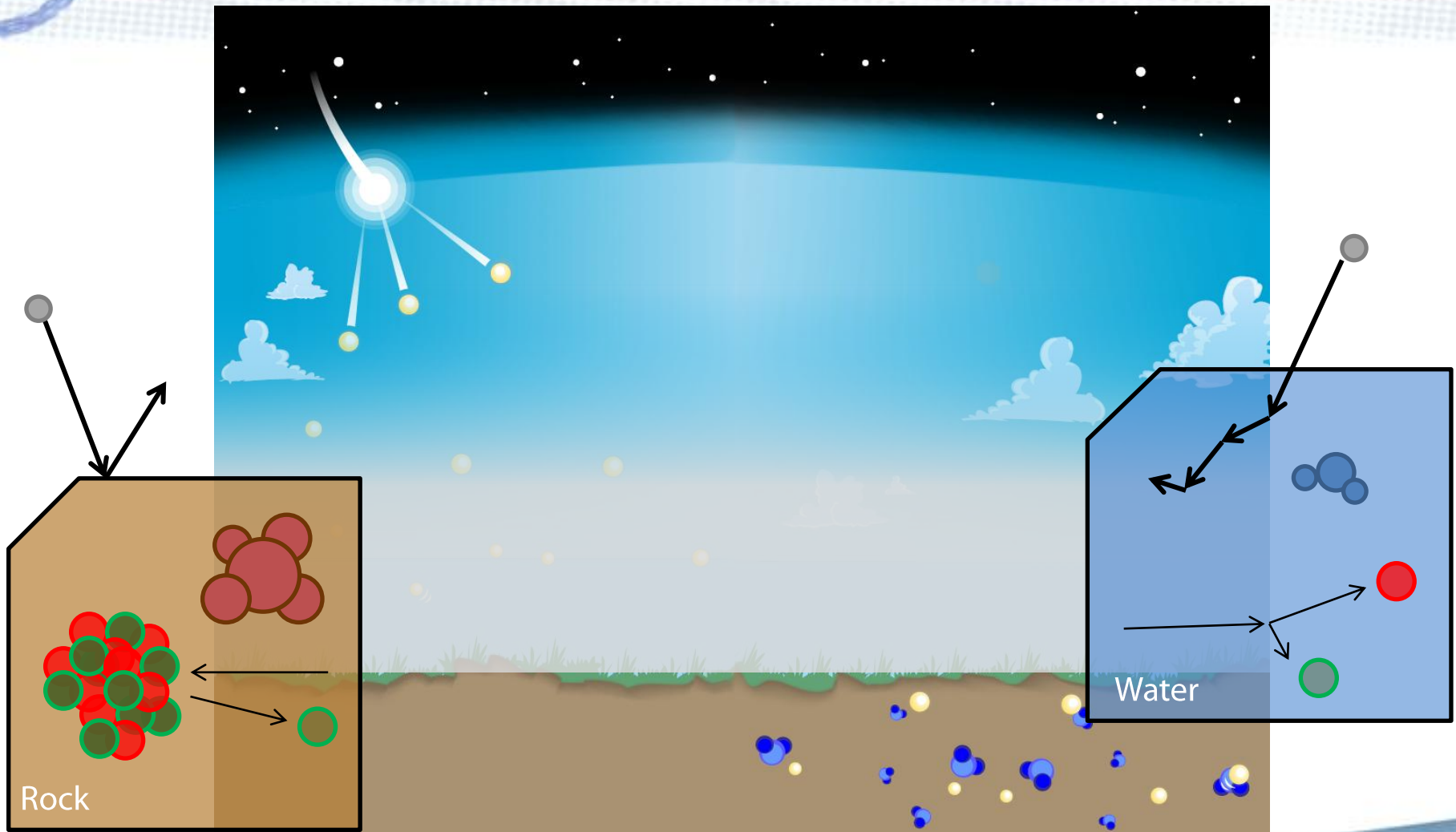
# The Cosmic Neutron Basics



# The Cosmic Neutron Basics



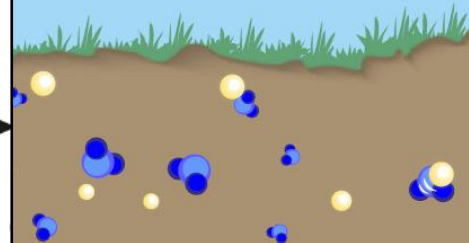
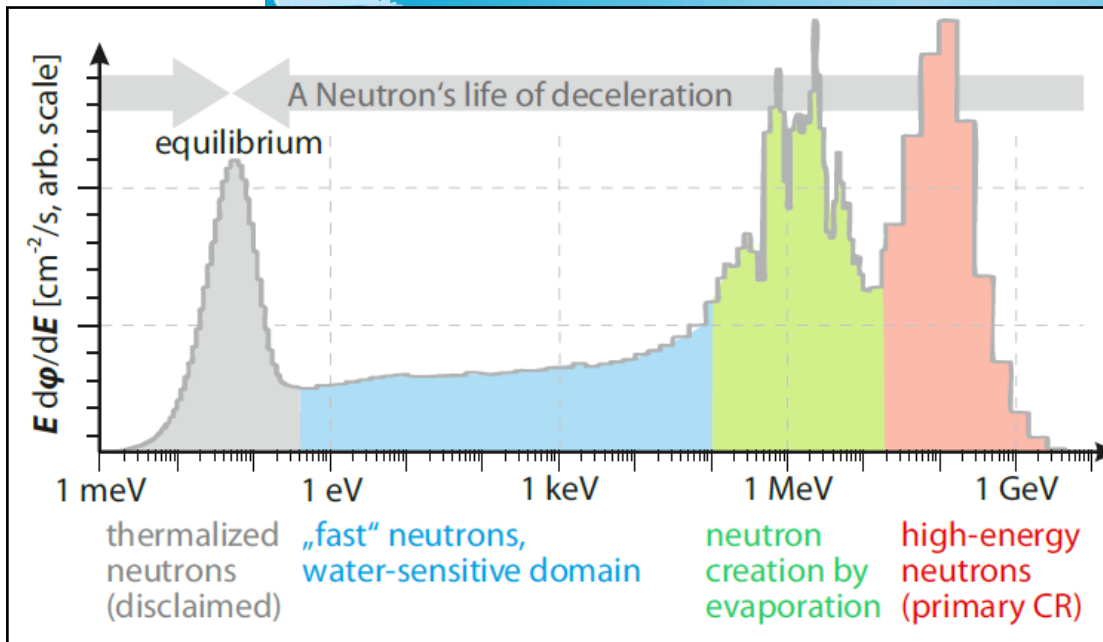
# The Cosmic Neutron Basics



Rock

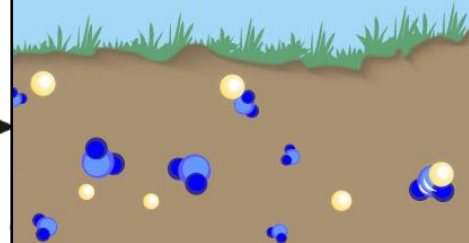
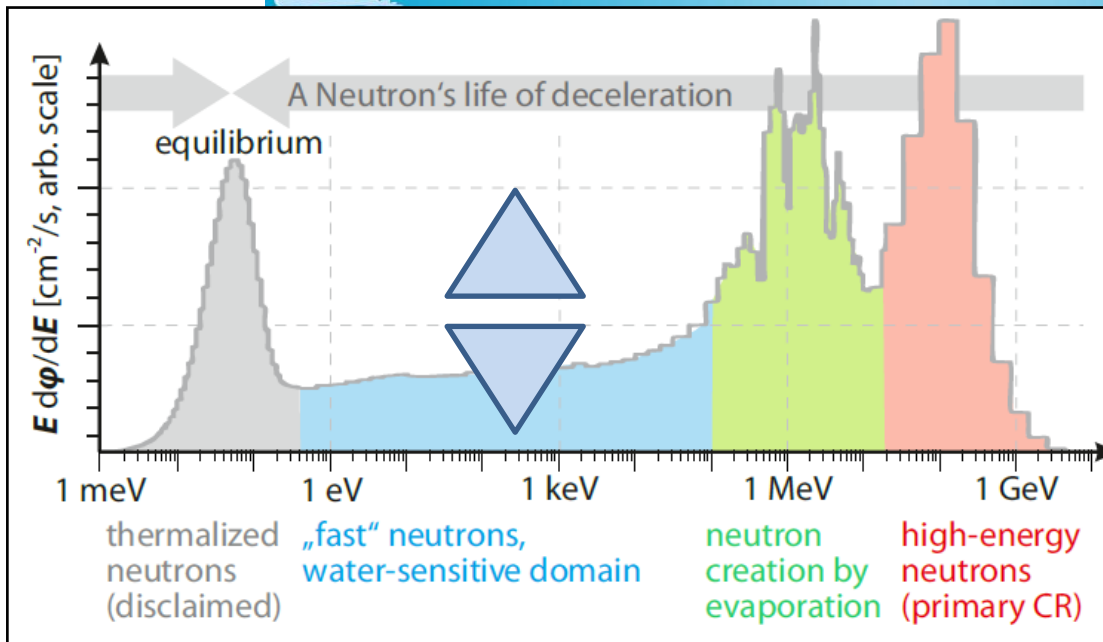
Water

# The Cosmic Neutron Basics

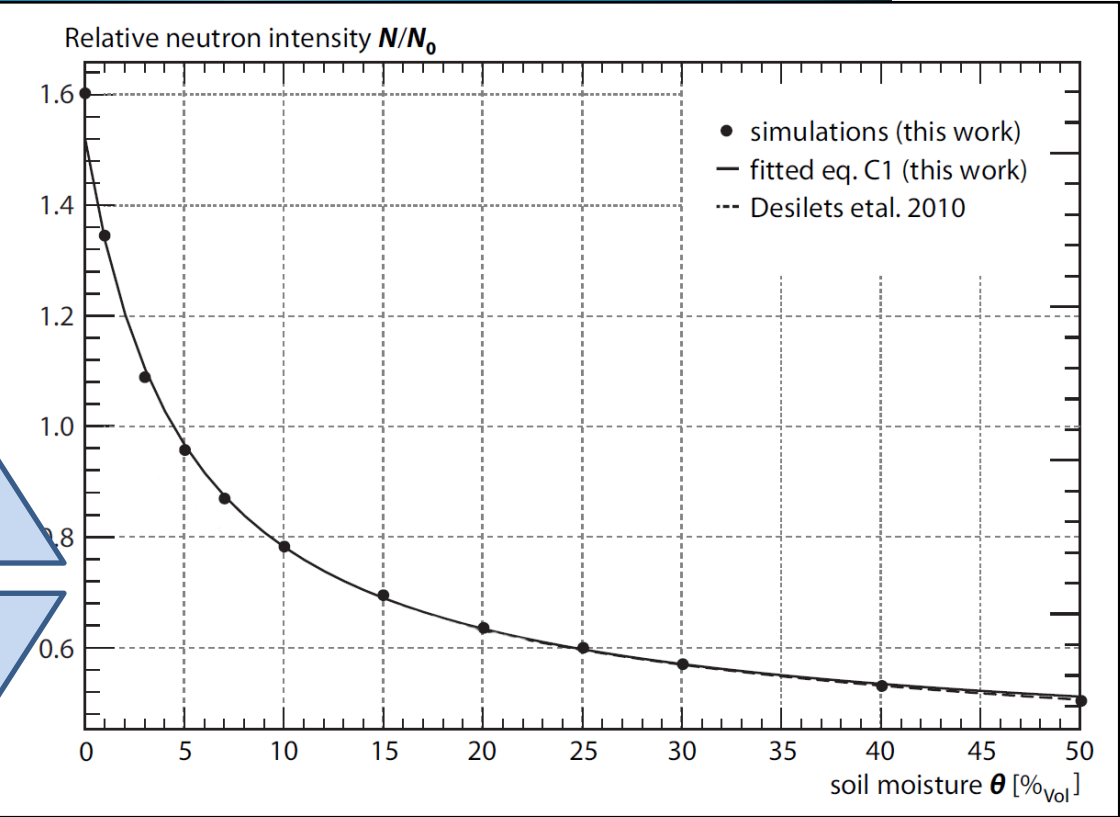
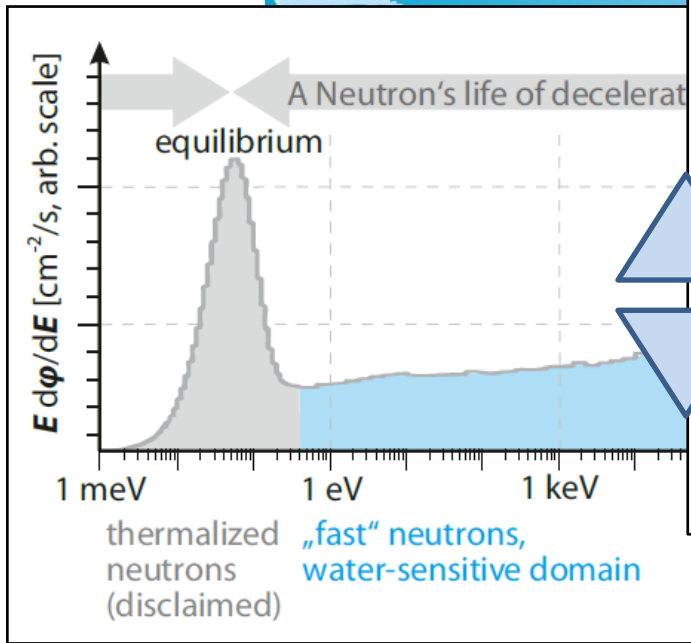
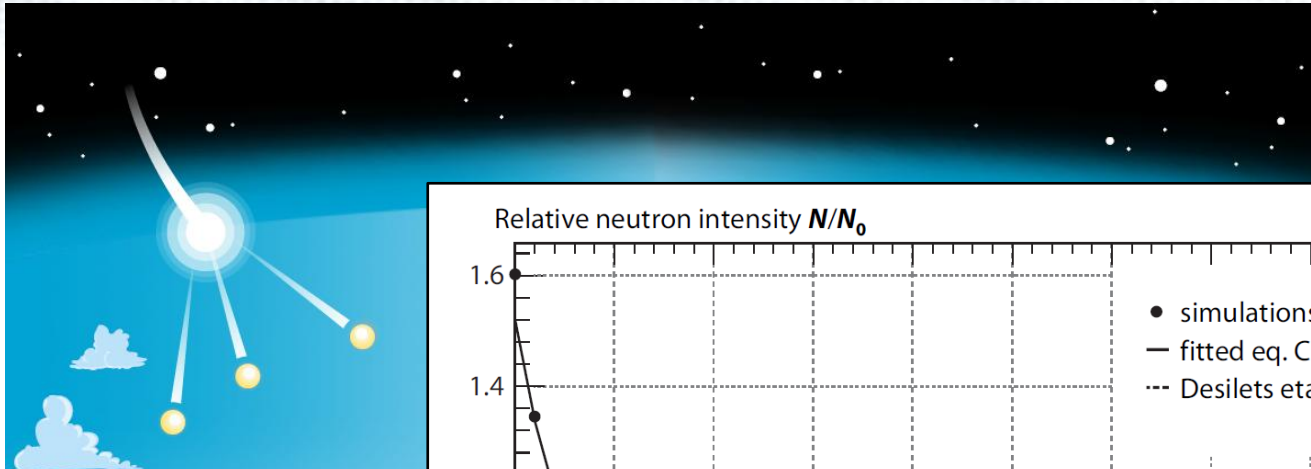




# The Cosmic Neutron Basics



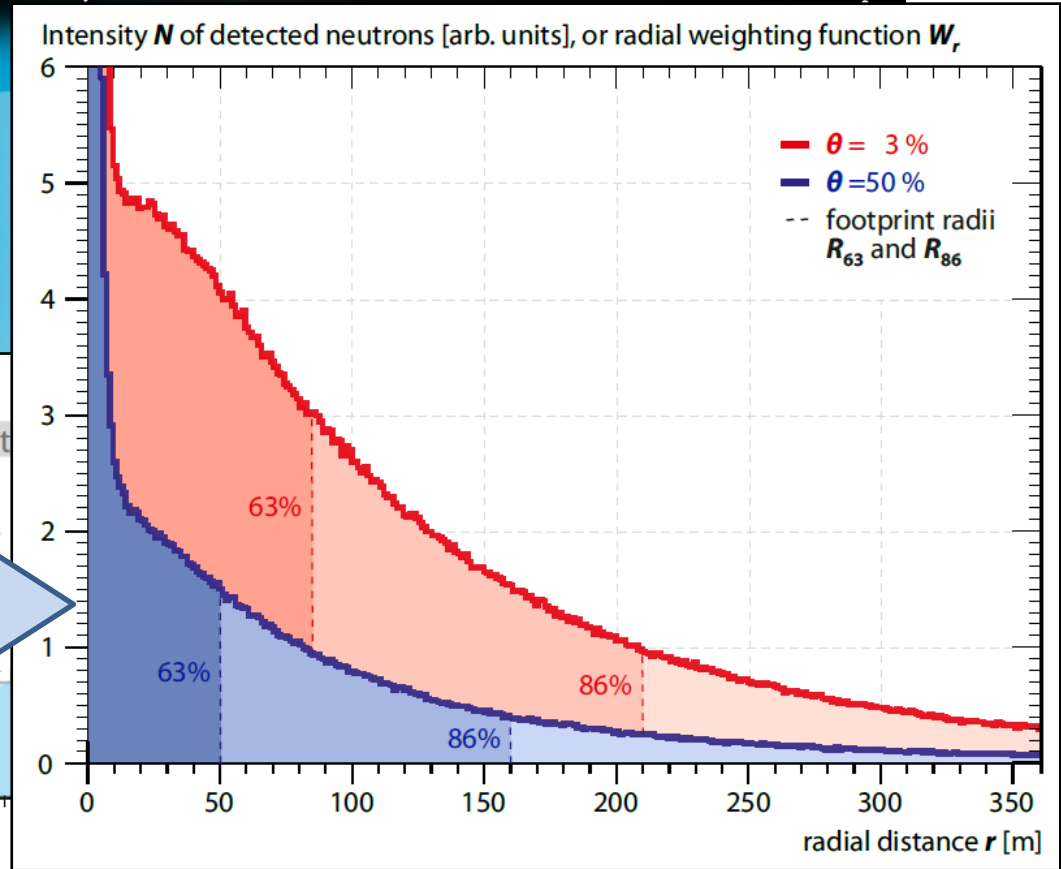
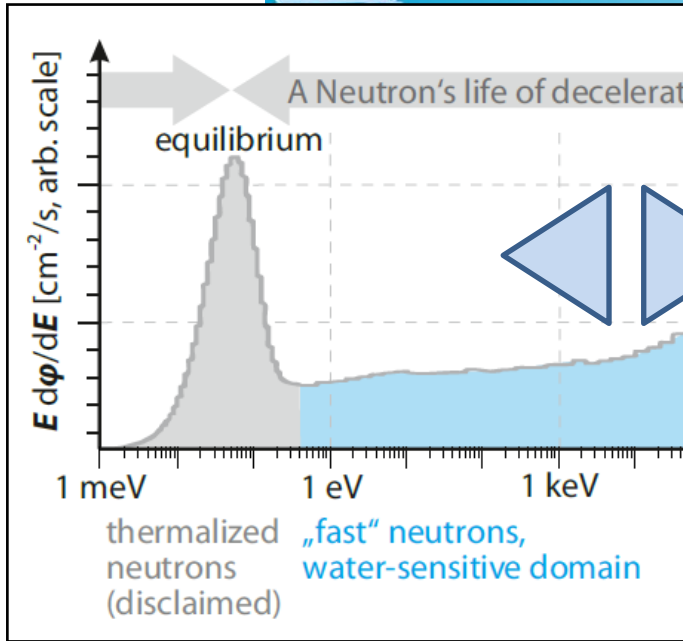
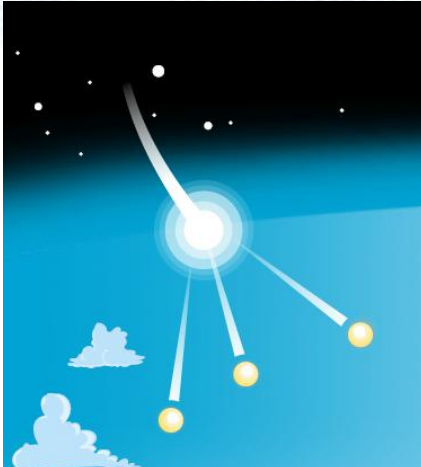
# The Cosmic Neutron Basics



neutron creation by evaporation

high-energy neutrons (primary CR)

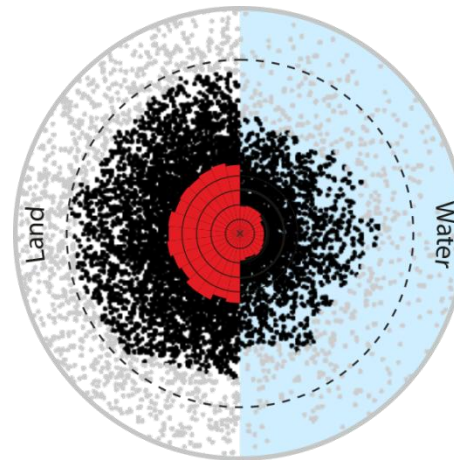
# The Cosmic Neutron Basics



neutron creation by evaporation (primary CR)  
high-energy neutrons (primary CR)

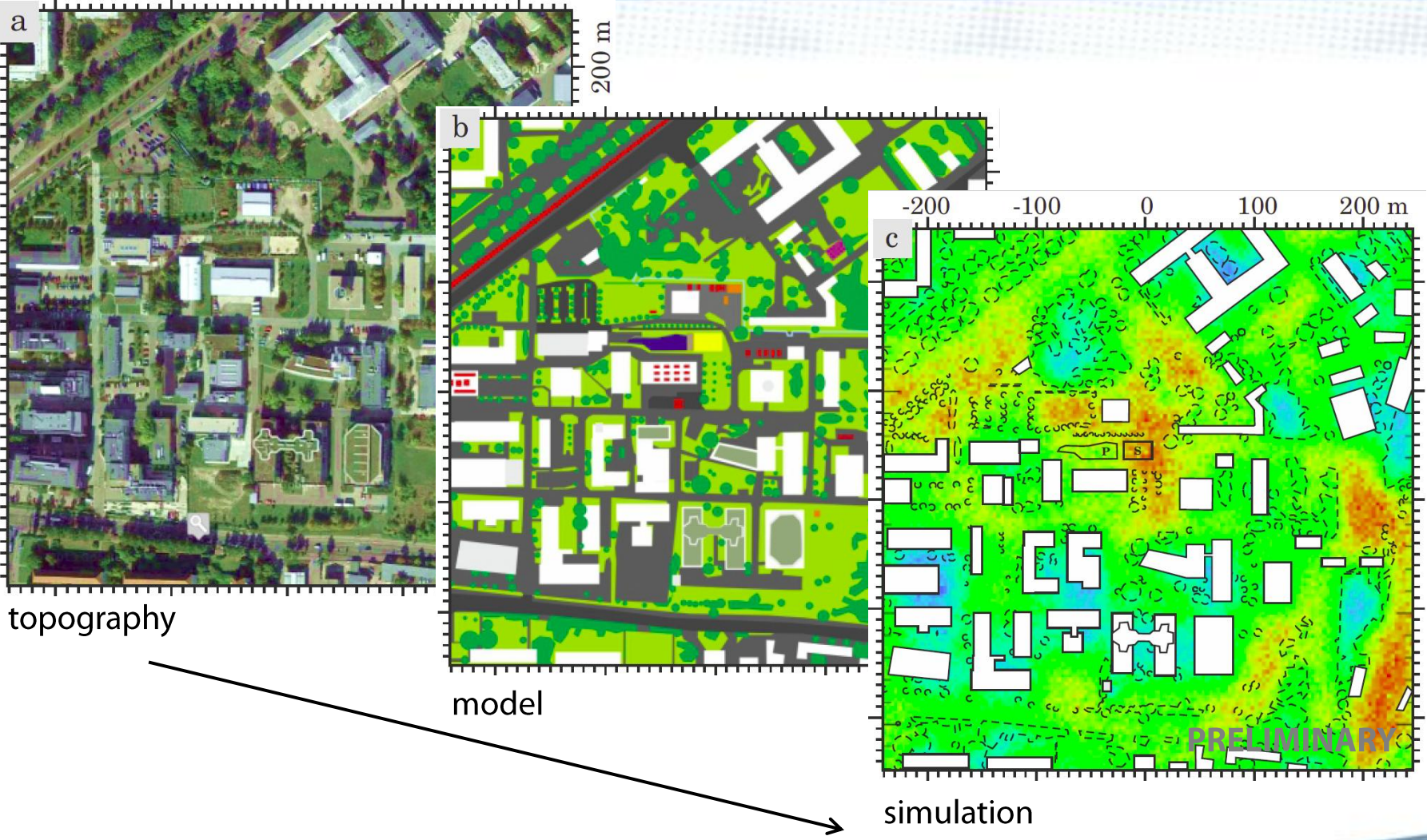
# Cosmic Neutron Propagation

dry land



water

# Cosmic Neutron Density

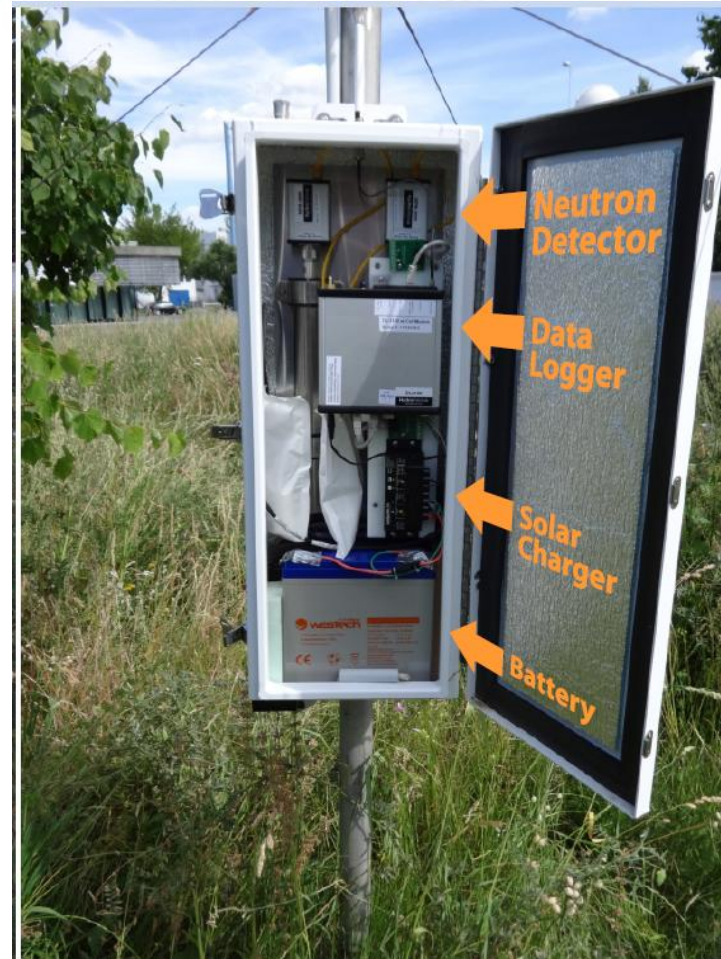
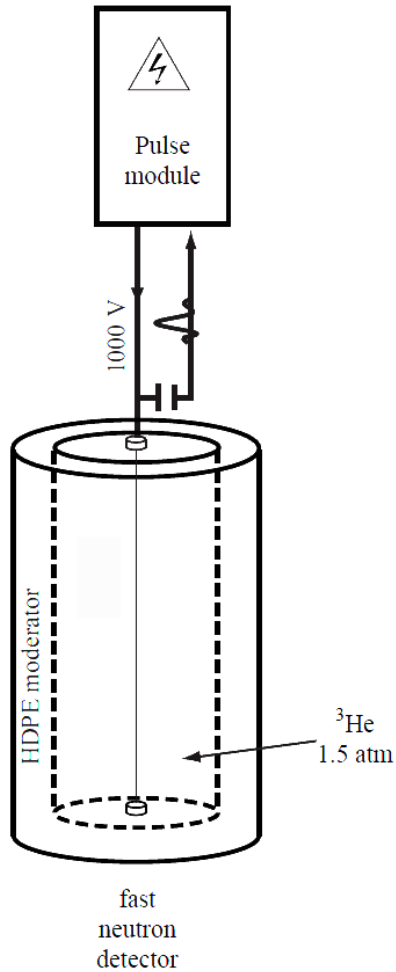




# Cosmic Neutron Test Site

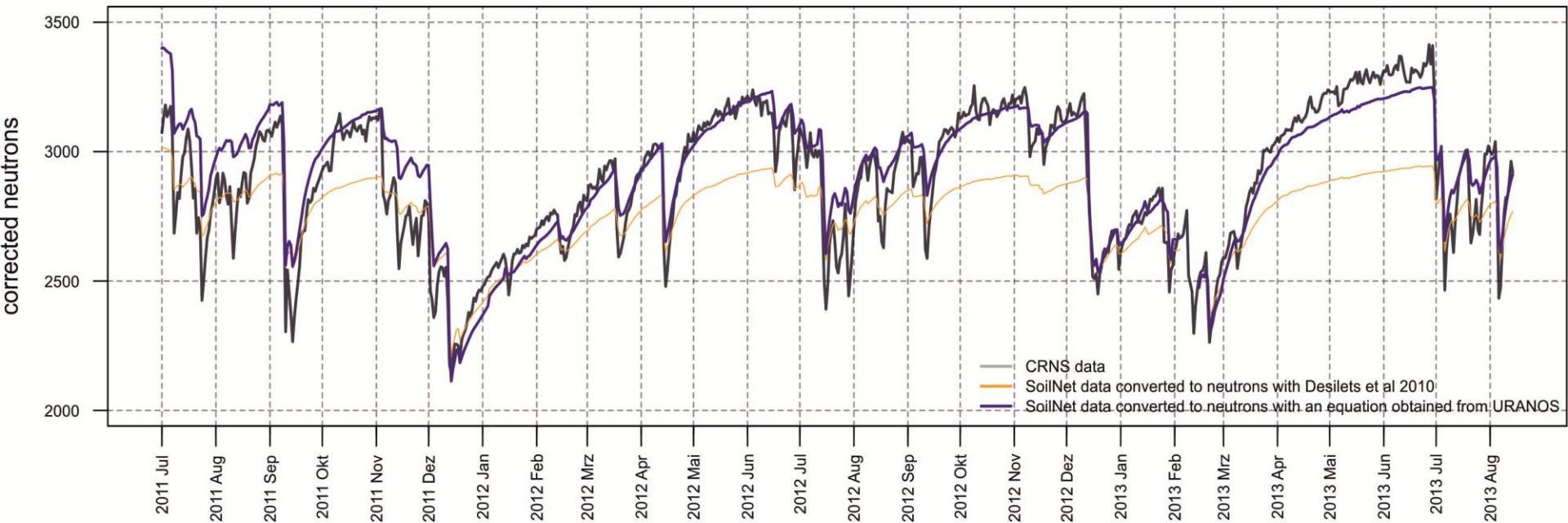


# The Measurement Device





# The Measurement Results

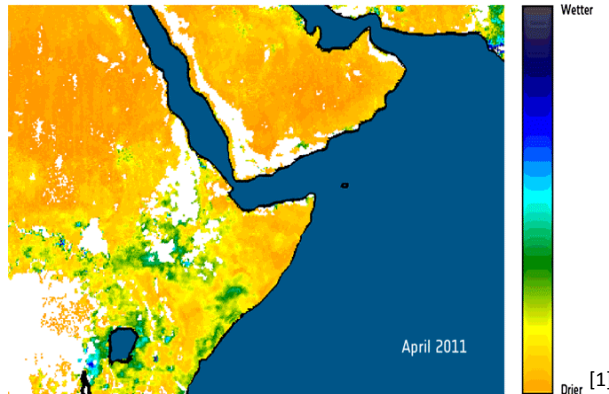


data from T. Franz, Santa Rita Site, refined by URANOS



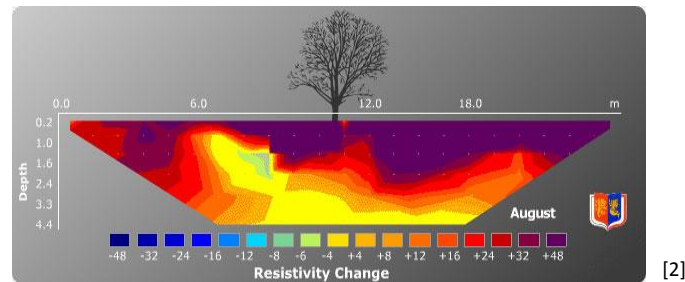
# > The Measurement Gap

> 1 km



via  
satellite remote sensing  
(optical, microwave)

< 10 m



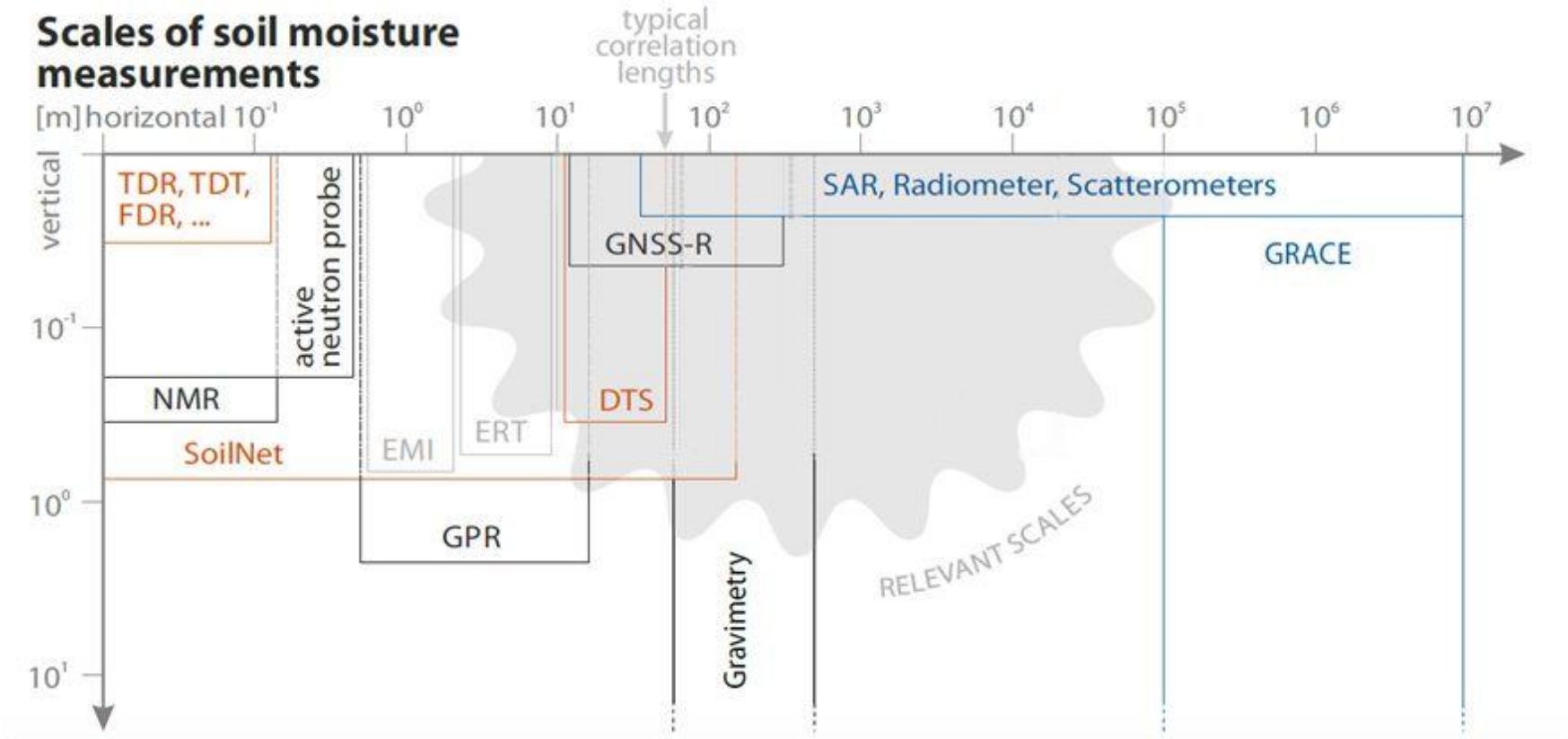
via  
local techniques  
(electrical resistivity, capacitance, etc)  
(even neutrons...)

[1] ESA SMOS ([http://www.esa.int/Our\\_Activities/Observing\\_the\\_Earth/SMOS/Horn\\_of\\_Africa\\_drought\\_seen\\_from\\_space](http://www.esa.int/Our_Activities/Observing_the_Earth/SMOS/Horn_of_Africa_drought_seen_from_space))

[2] The Clay Research Group (<http://www.theclayresearchgroup.org/images/ert.jpg>)

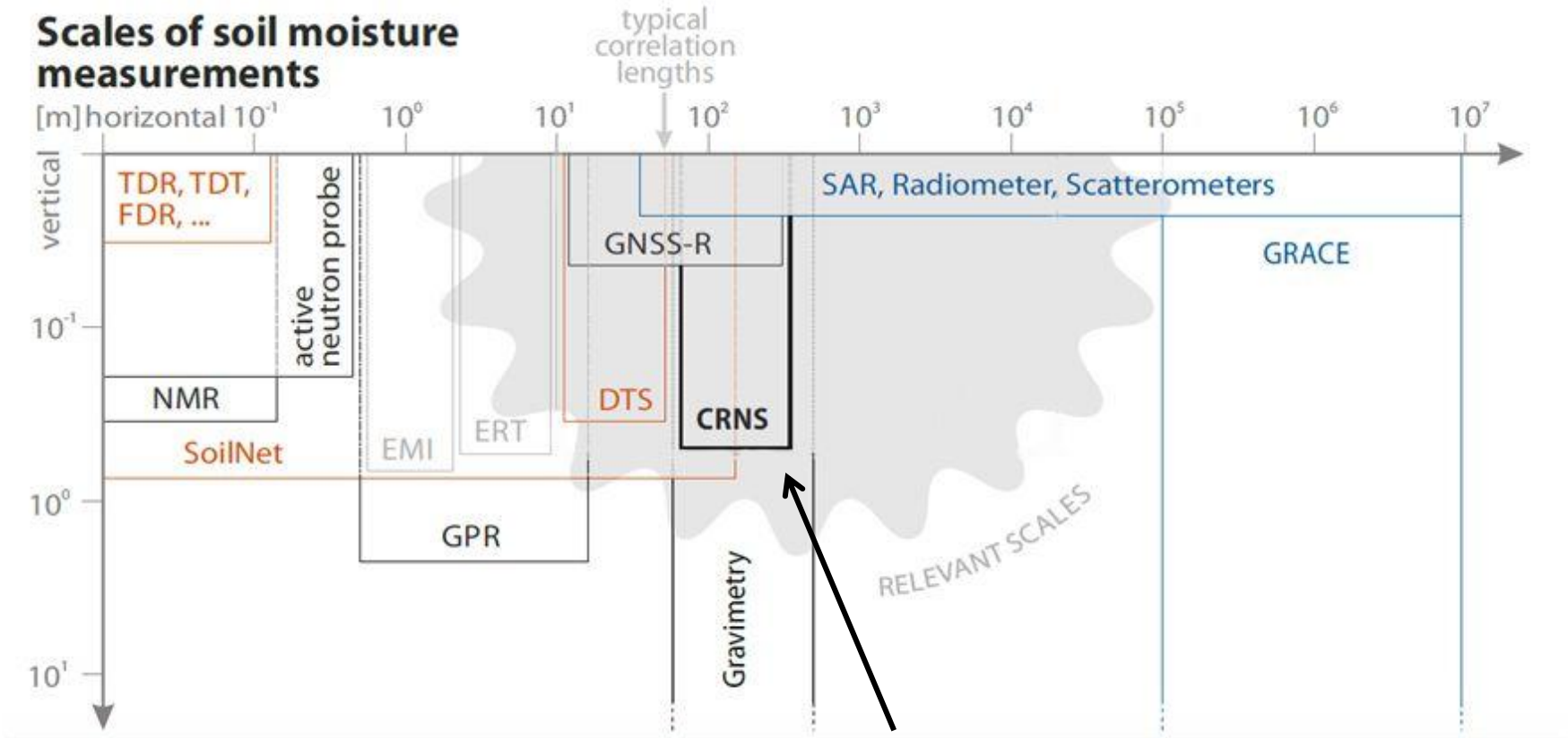
# The Measurement Gap

## Scales of soil moisture measurements



# The Measurement Gap

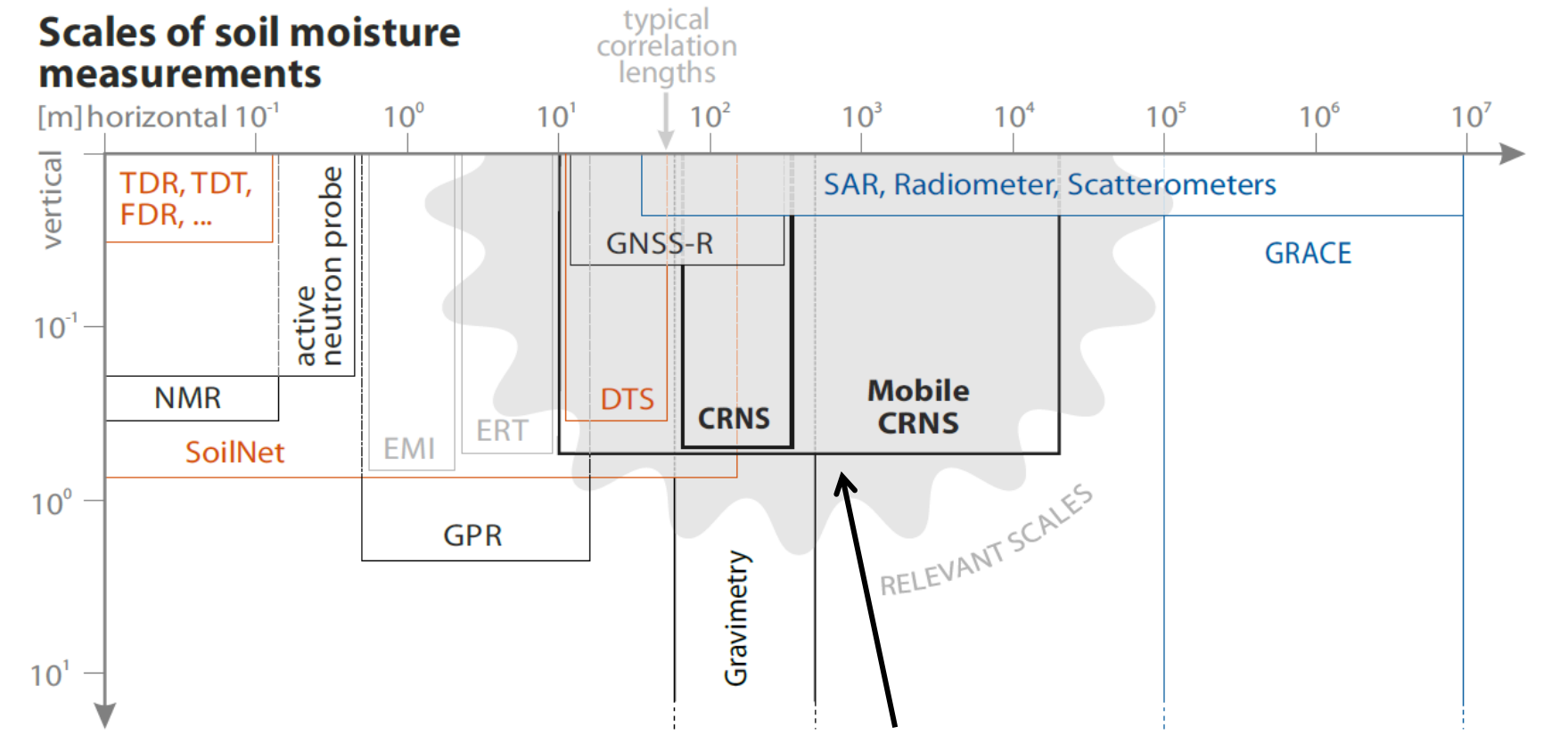
## Scales of soil moisture measurements



You are here

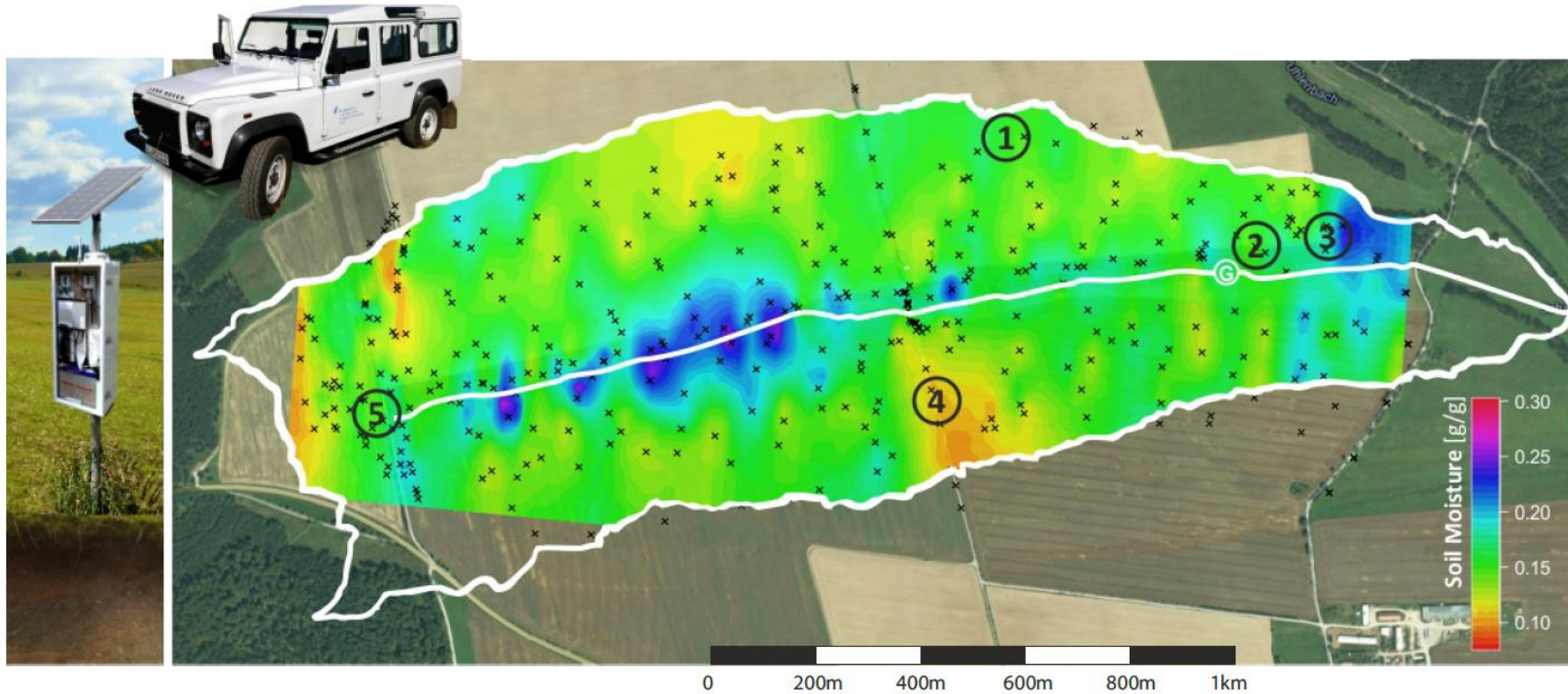
# The Measurement Gap

## Scales of soil moisture measurements



And now here

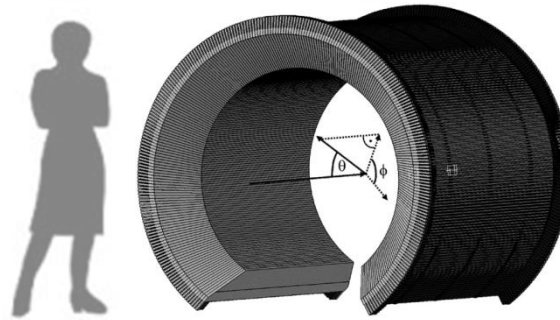
# Mobile Soil Moisture Mapping



# How going mobile?

By:  
large-scale Boron converter  
based detectors

The JALOUSIE system  
(Heidelberg)



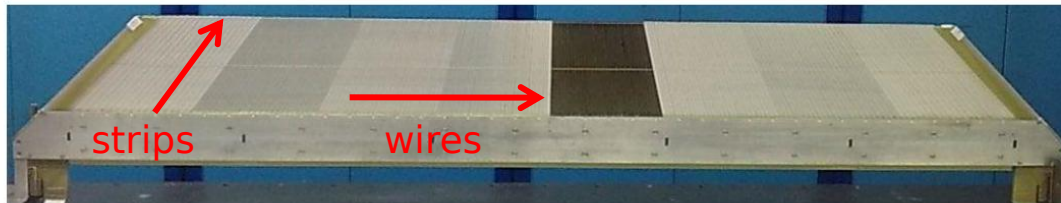
1600 mm

218 mm

With  
Cover

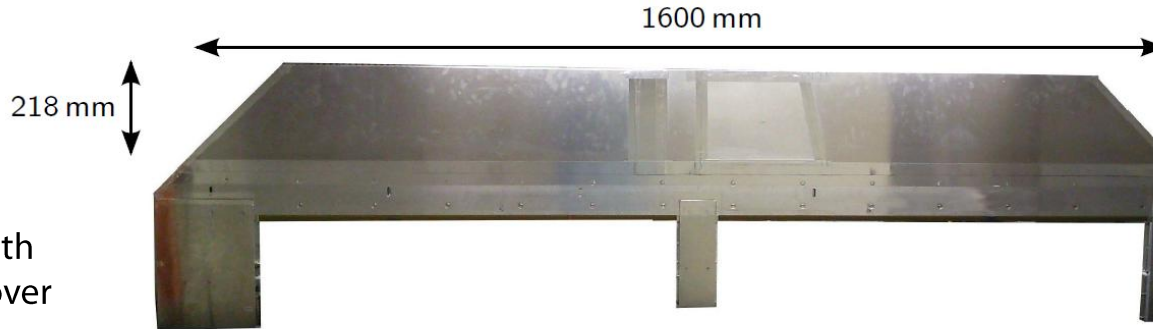
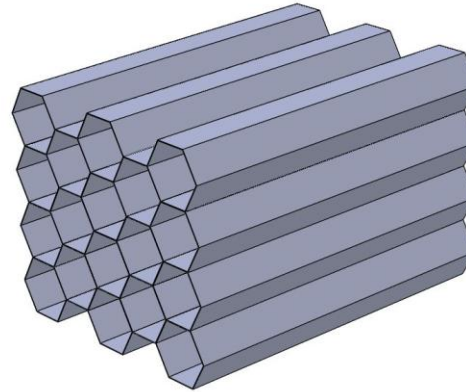


Without  
Cover



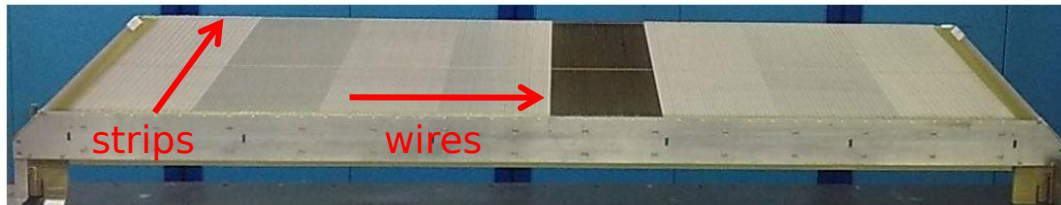
# How going mobile?

By:  
large-scale Boron converter  
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With  
Cover

Without  
Cover





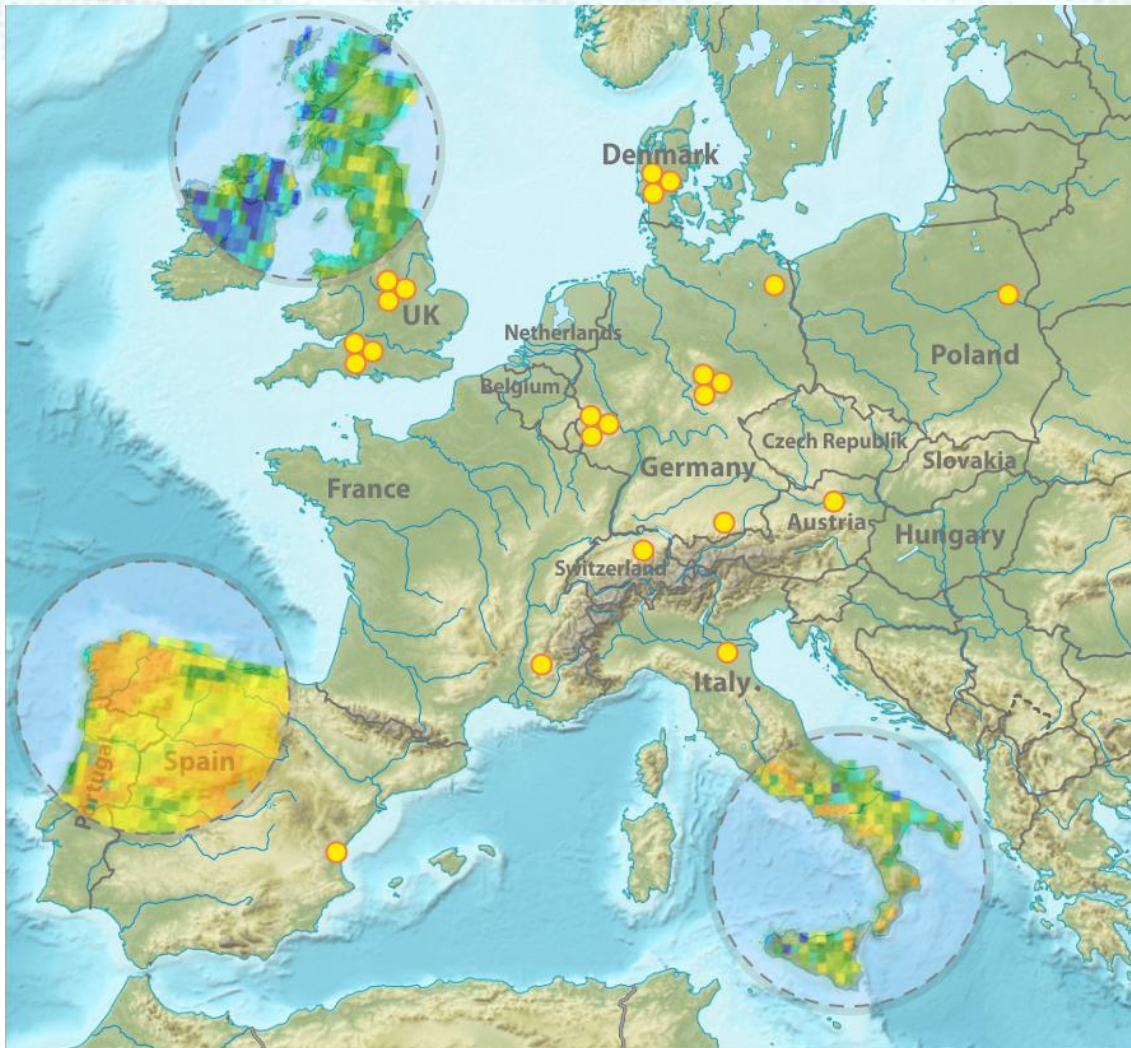
# Trends

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# ► Trends - Europe



**COSMOS probes:** ● existing single, ●● existing clusters, ○ SMOS

# Trends - World



M. Zreda et al. (2008)

## Experts Network

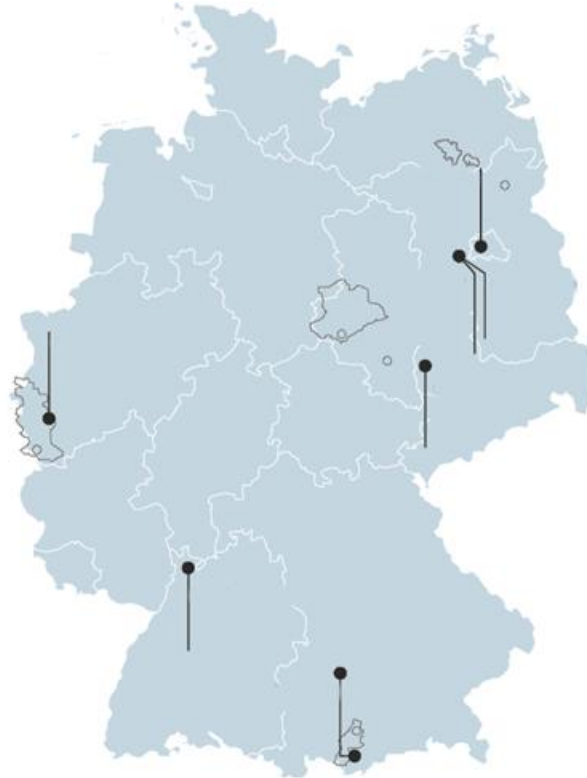
Hydrogeodesy

Hydrology

Groundwater Management

Remote Sensing

Soil Physics





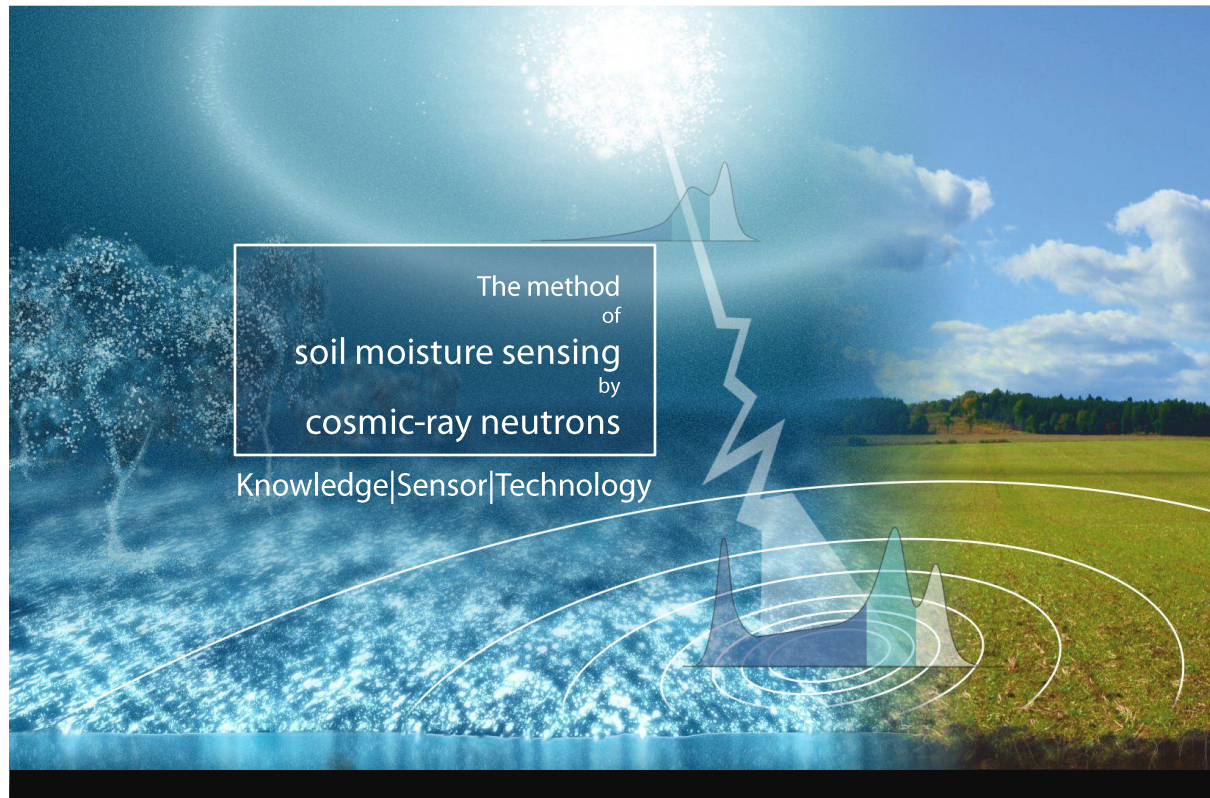
# Wishes & Dreams

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# Wishes

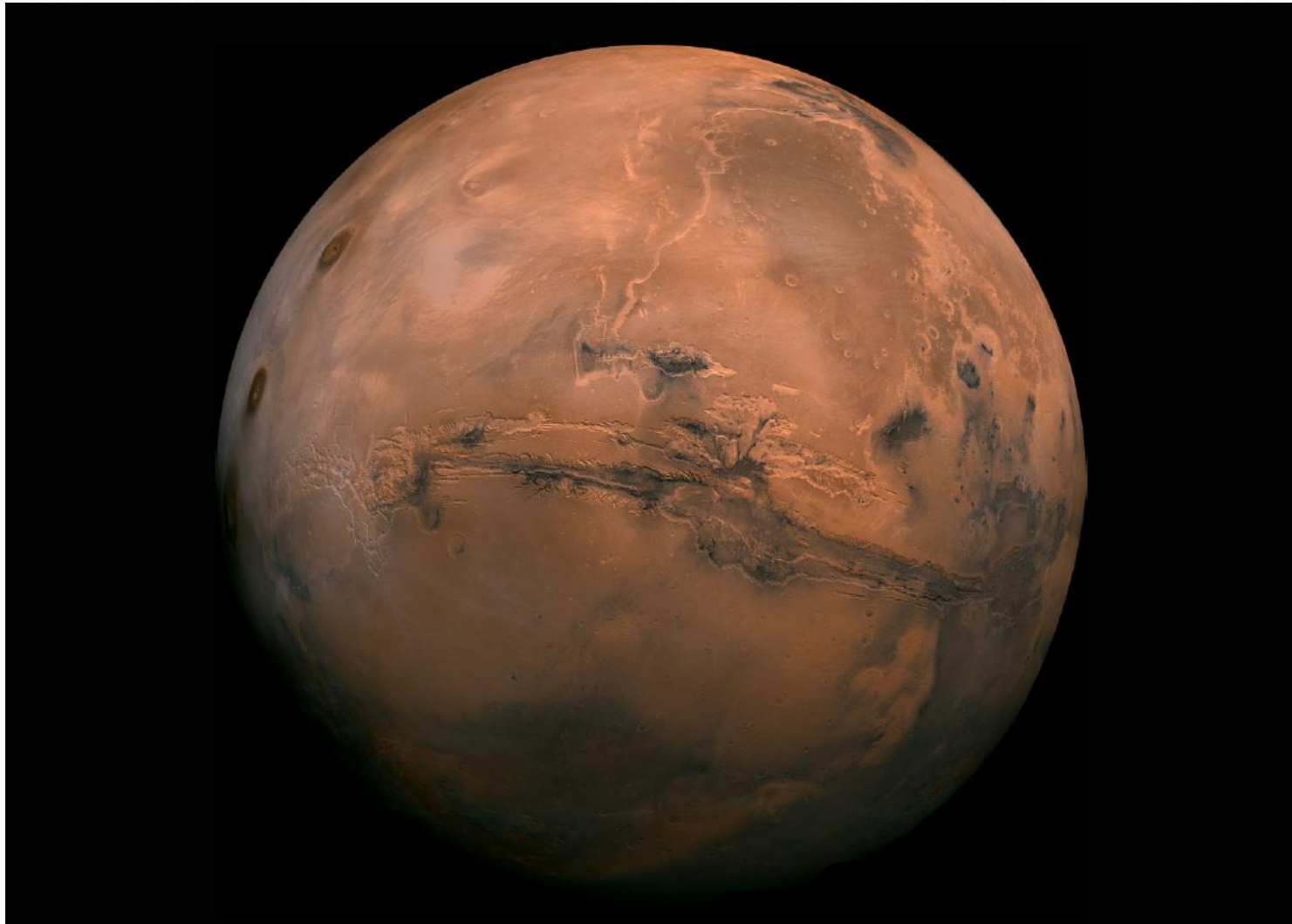
□ Change the title of this talk



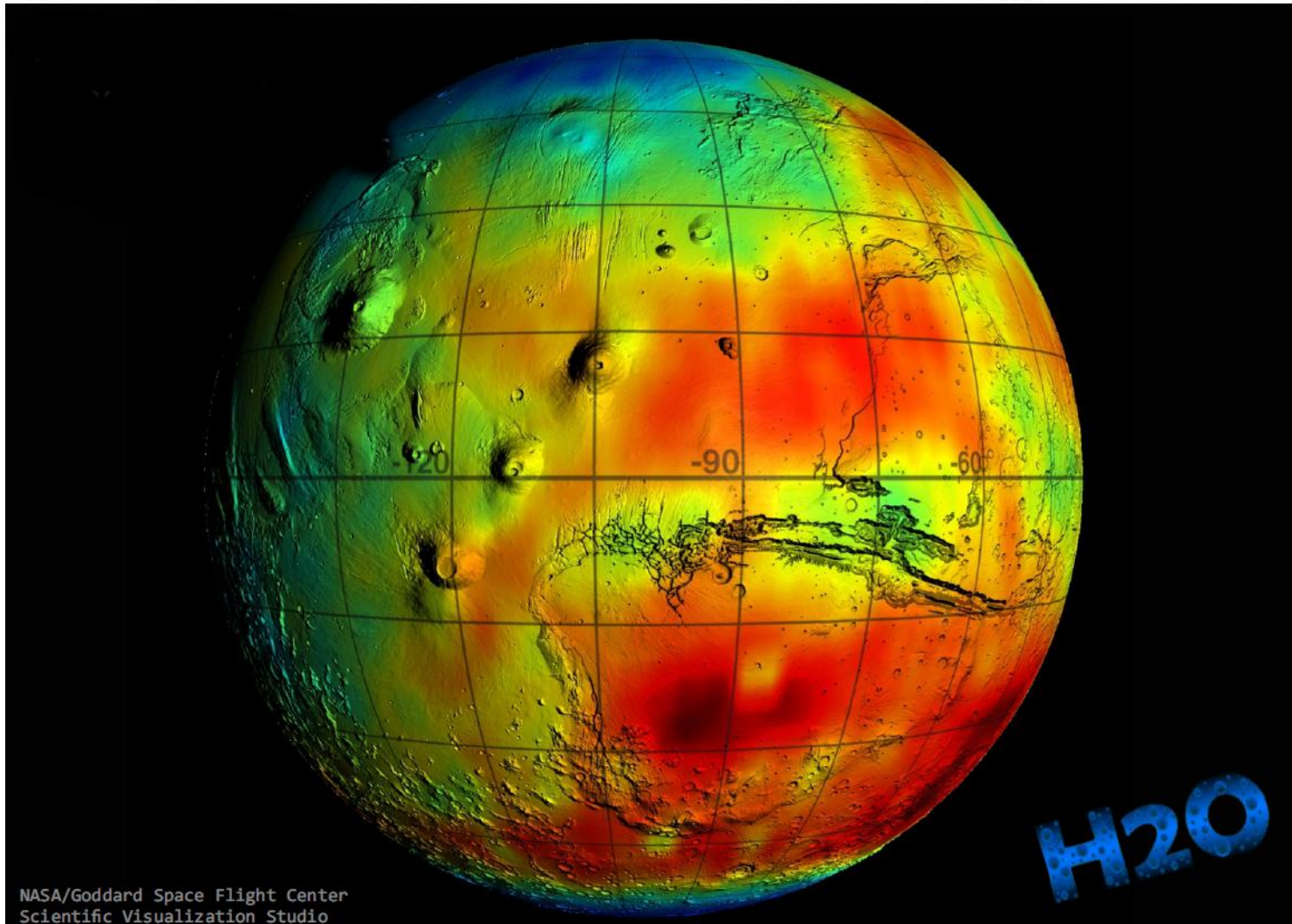
# Google Maps for Water Resources

Knowledge|Sensor|Technology

# ▶ Extraterrestrial Water Resources



# ▶ Extraterrestrial Water Resources







# Dreams

■ Realize Water Resources Mapping for

# ▶ Dreams

## □ Realize Water Resources Mapping for



Drought Monitoring

## □ Realize Water Resources Mapping for



Drought Monitoring



Precision Farming

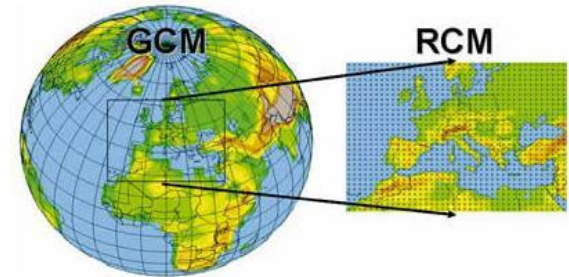
## Realize Water Resources Mapping for



Drought Monitoring



Precision Farming



Climate Modelling

# Knowledge|Sensor|Technology

The method  
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