# Remote Sensing of Critical Hydrologic Paramters: Soil Moisture, Topography and Vegetation

**Klaus Scipal & Wolfgang Wagner**

**Vienna University of Technology**
**Institute of Photogrammetry and Remote Sensing**

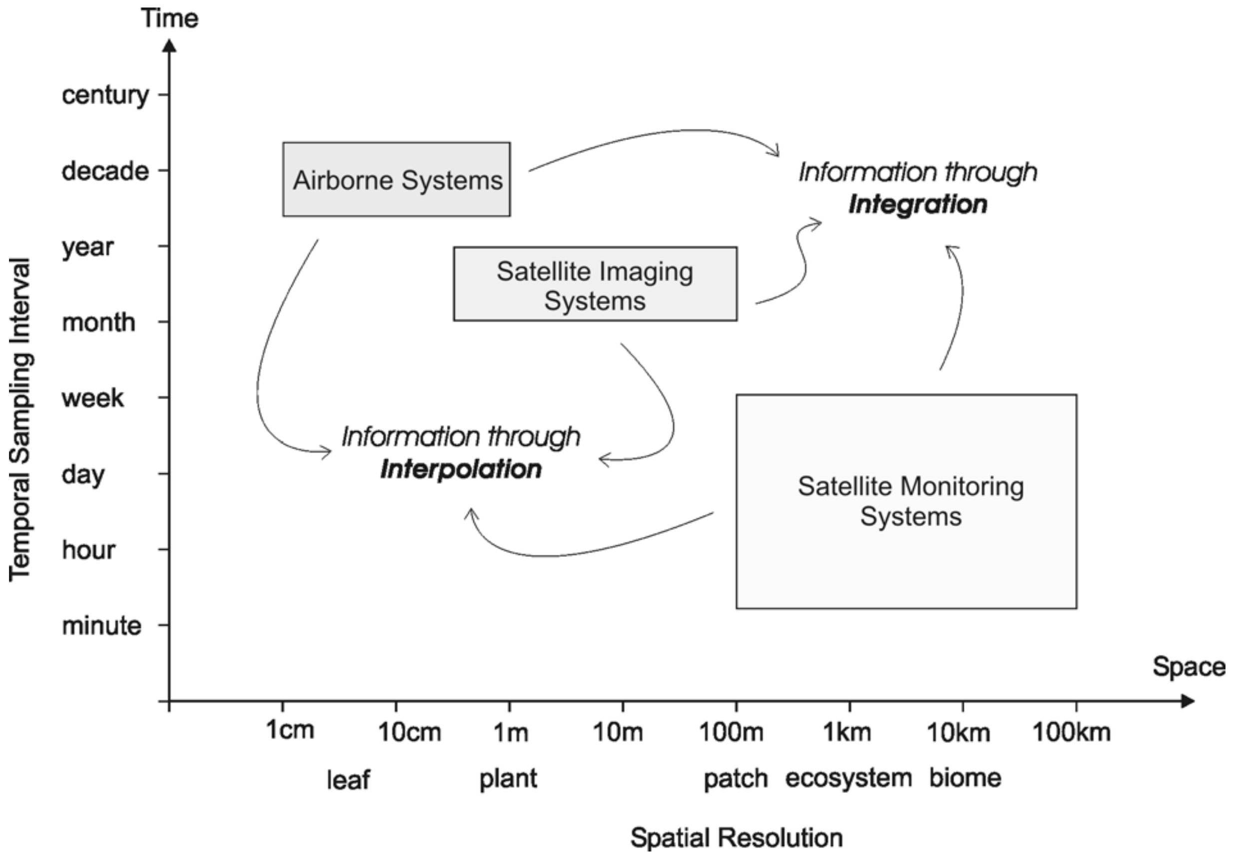
# Introduction

- **Content**
  - No „edge cutting“ technologies, but realistic
  - Operational products, proven in pilot applications
  - Compare competing technologies
- **Remote Sensing (as understood here)**
  - is not just about land cover classification using statistical image processing approaches
  - should be better regarded as a suite of techniques that aim to make physical measurements of geophysical parameters/processes
- **Active Remote Sensing Products**
  - Topography
  - Vegetation
  - Soil Moisture

# Scaling Issues

- **The term “scale” refers to a**
  - characteristic length
  - characteristic time
- **The concept of scale can be applied to**
  - Process = typical time and length scales at which a process takes place
  - Measurement = spatial and temporal sampling characteristics of the sensor system
  - Model = Mathematical/physical description of a process
- **Ideally: Process = Measurement = Model Scale**
- **Remote sensing offers a large suit of sensors**
  - Scaling issues must be understood in order to make appropriate use of sensors

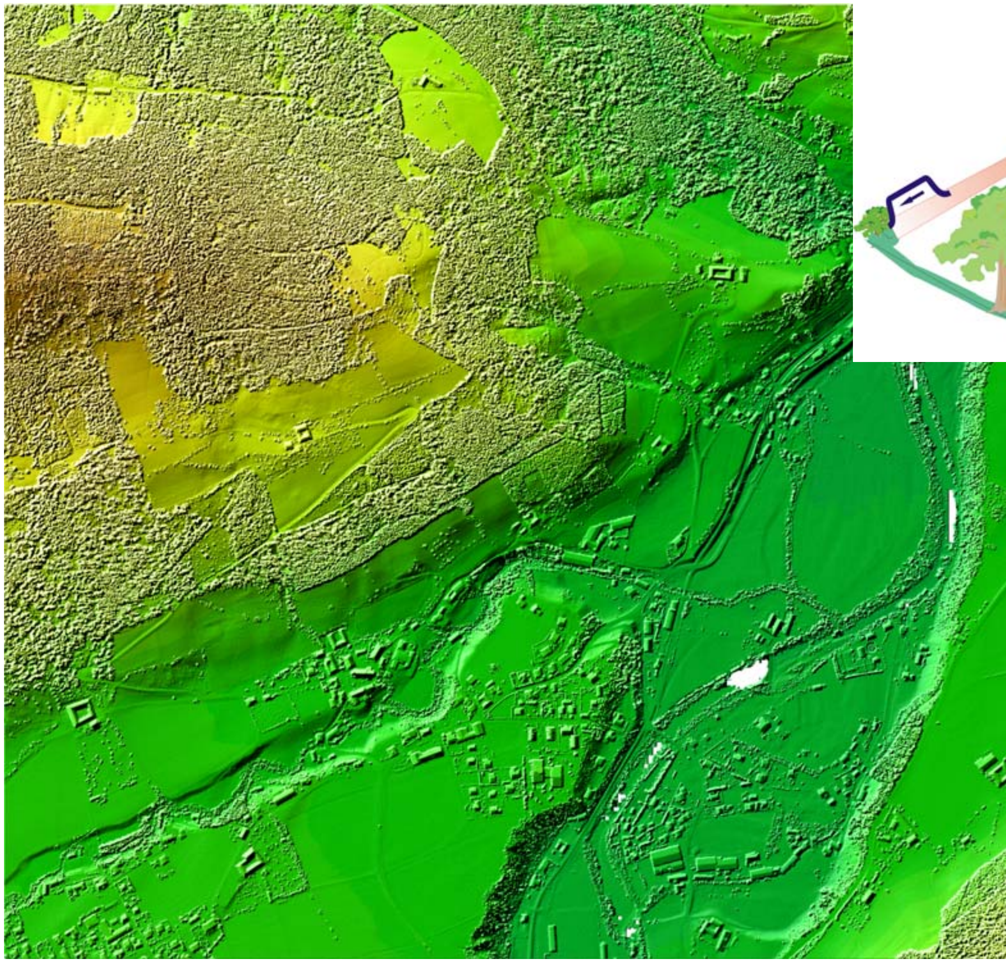
# Measurement Scales

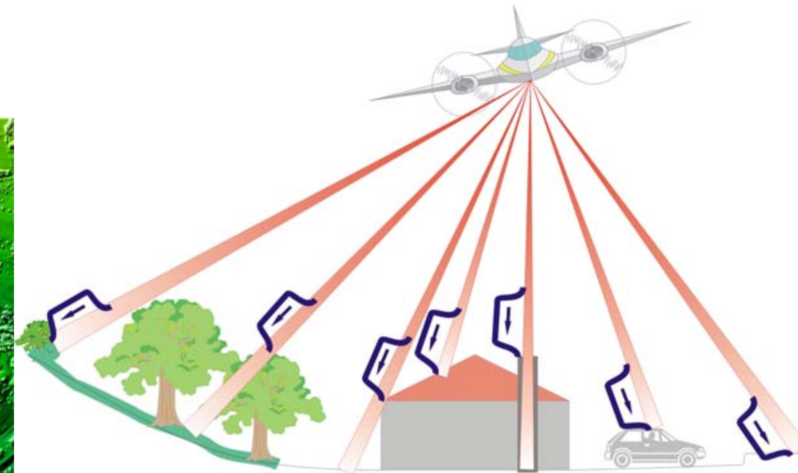


# Topography

- **Lidar (Airborne Laser Scanning)**
  - Highly accurate 1 m DEMs
  - High-costs
  - Special software and expertise needed
- **ERS-1/2 tandem interferometry**
  - 30-100 m DEM
  - Data from years 1995-1998 available for most parts of the world
  - Data costs moderate, but special software and expertise needed
  - Accuracy highly variable depending on land cover and topography
    - reasonable accuracy (< 10m) for non-vegetated, flat terrain
- **Shuttle Radar Topography Mission (SRTM)**
  - 100 m DEM with almost global coverage
  - Data are free

# Digital Surface Model from Lidar

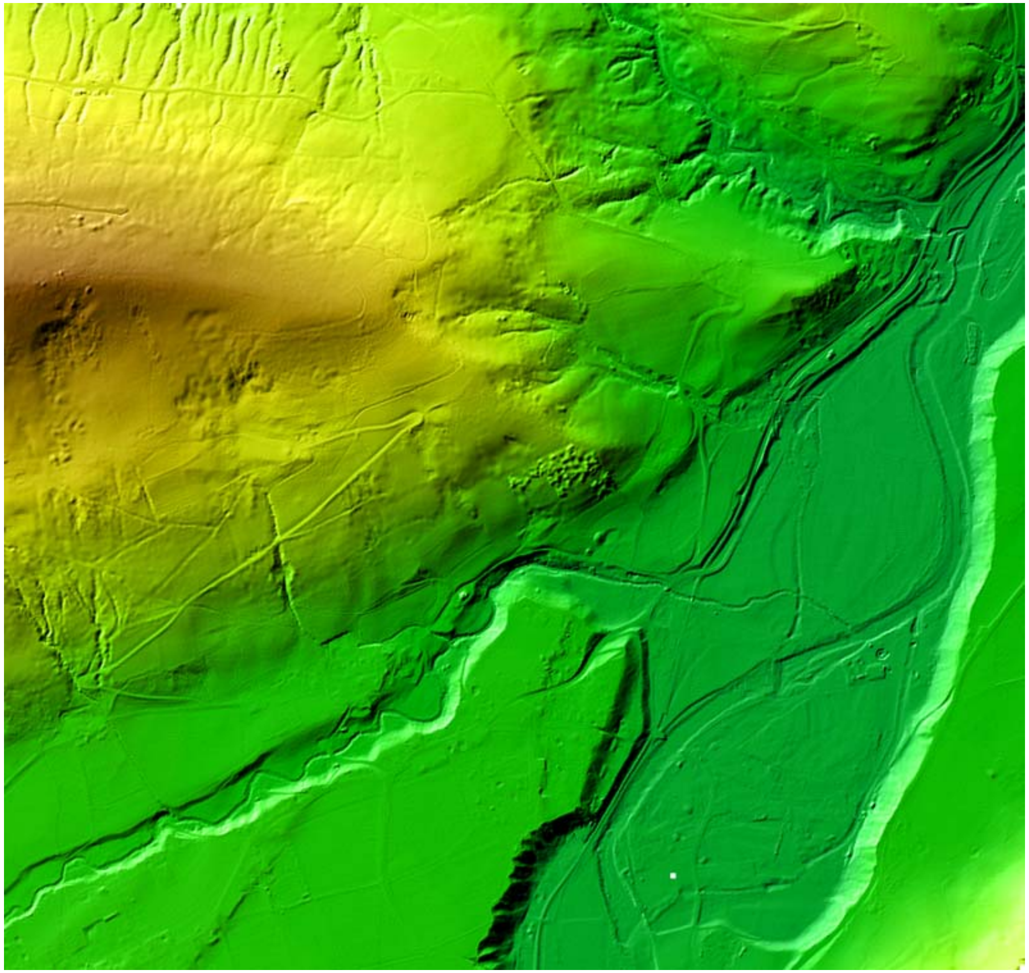




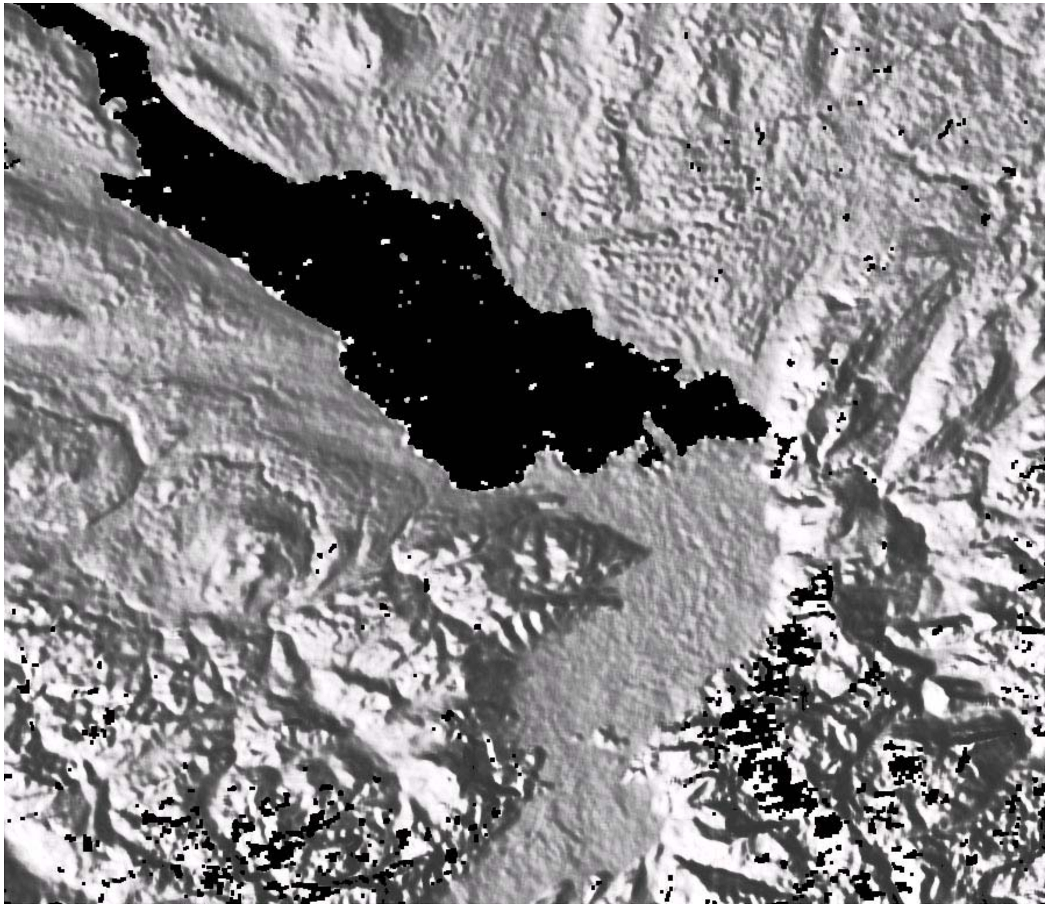
Laser scanner mounted on an airplane

Laser Scanner
Flight of Almtal,
Upper Austria

# Digital Terrain Model after Filtering

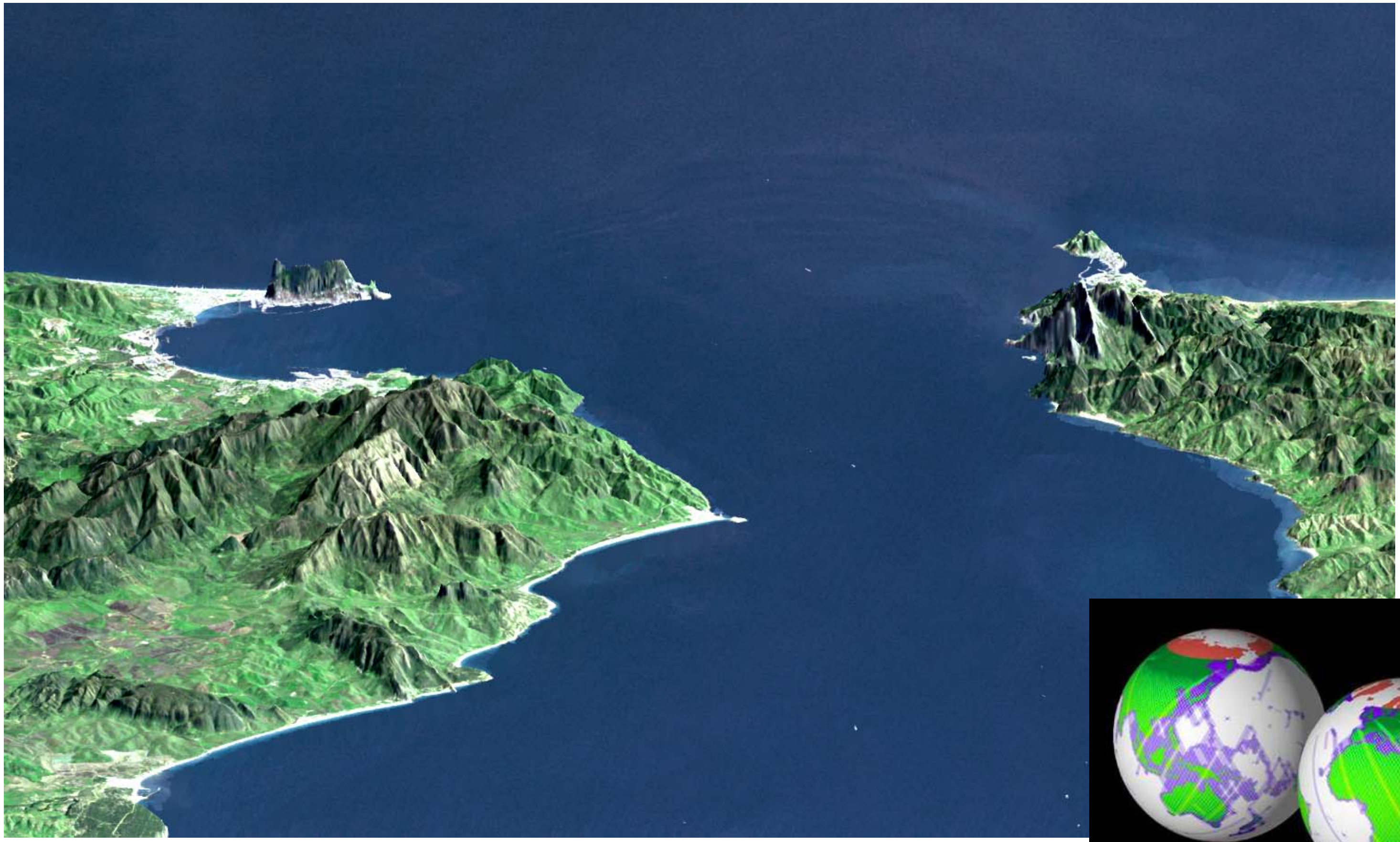


# DEM from ERS-1/2 Tandem Interferometry

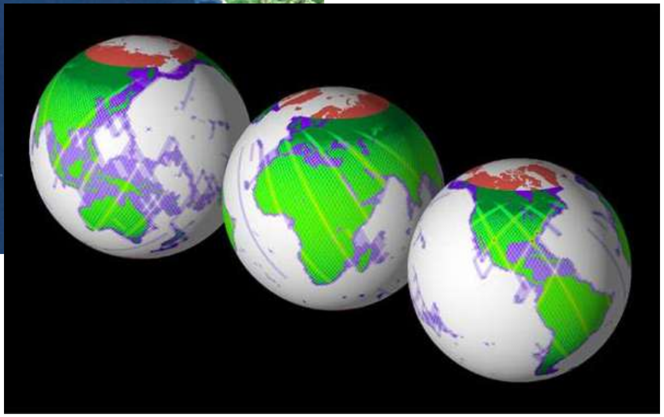


DEM from ERS-1/2 tandem data produced with commercially available software, Bregenzer See, Vorarlberg

# Shuttle Radar Topography Mission



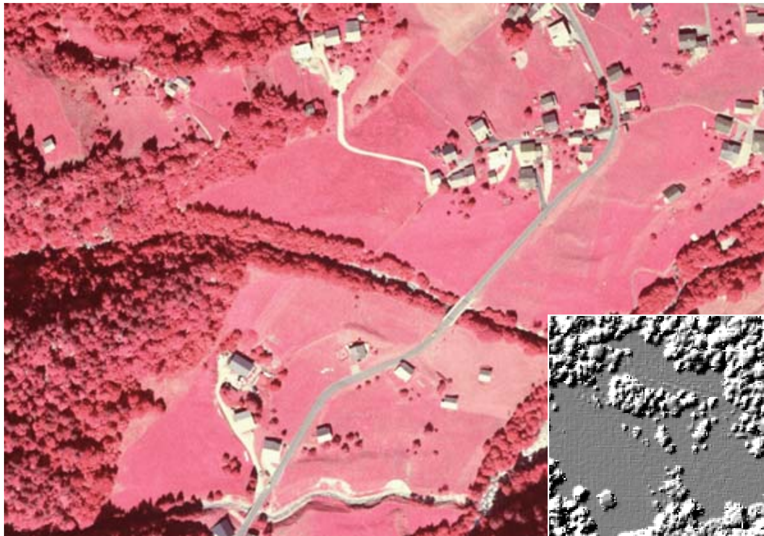
Street of Gibraltar (DEM with overlay of a Landsat image) © NASA



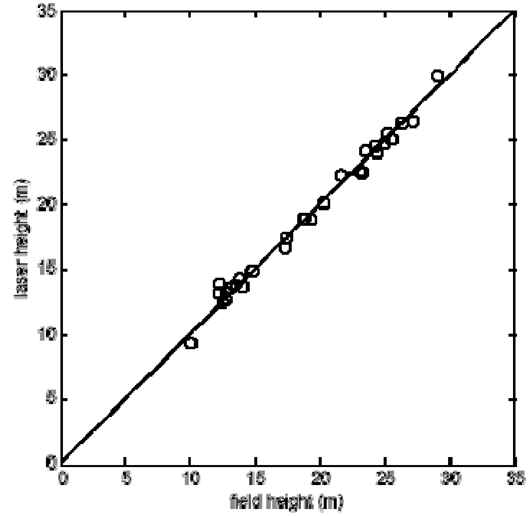
# Vegetation

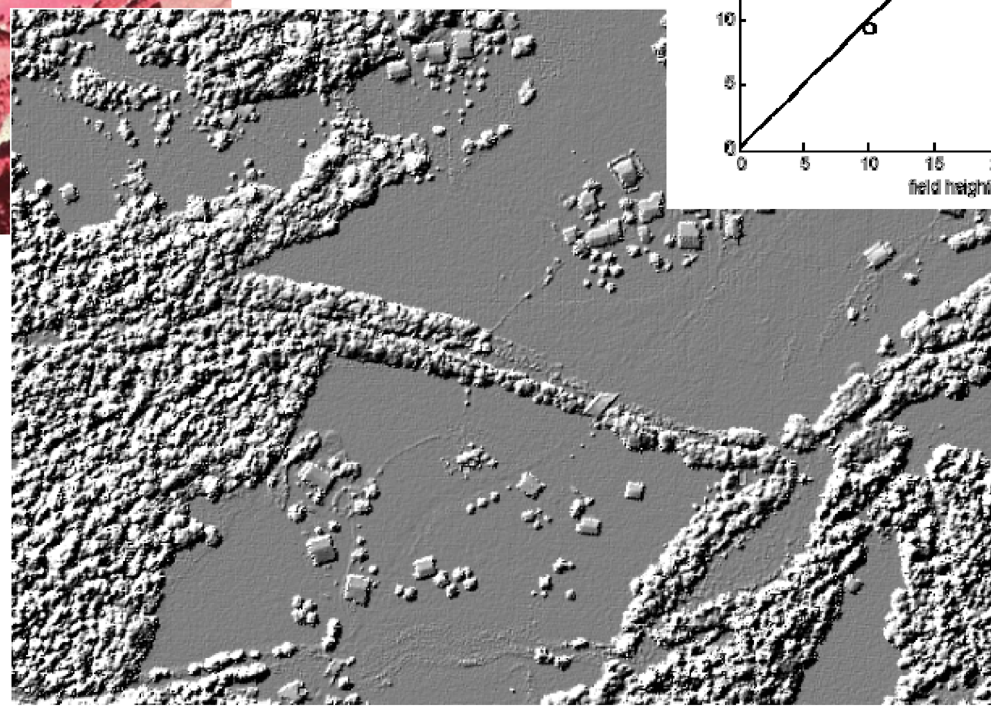
- **Lidar**
  - Airborne laser scanning
    - High-quality 1m vegetation height models, but expansive for large areas
    - Research is still in the beginning
  - Full-waveform satellite lidars for vegetation mapping have repeatedly been proposed, but so far not approved
- **SAR and SAR Interferomery**
  - Broad vegetation categories can be distinguished
  - Not suited at local scale (< 100 m)
  - Data costs moderate, but specialised software and high level of expertise needed

# Vegetation Height from Lidar



Infrared Orthophoto



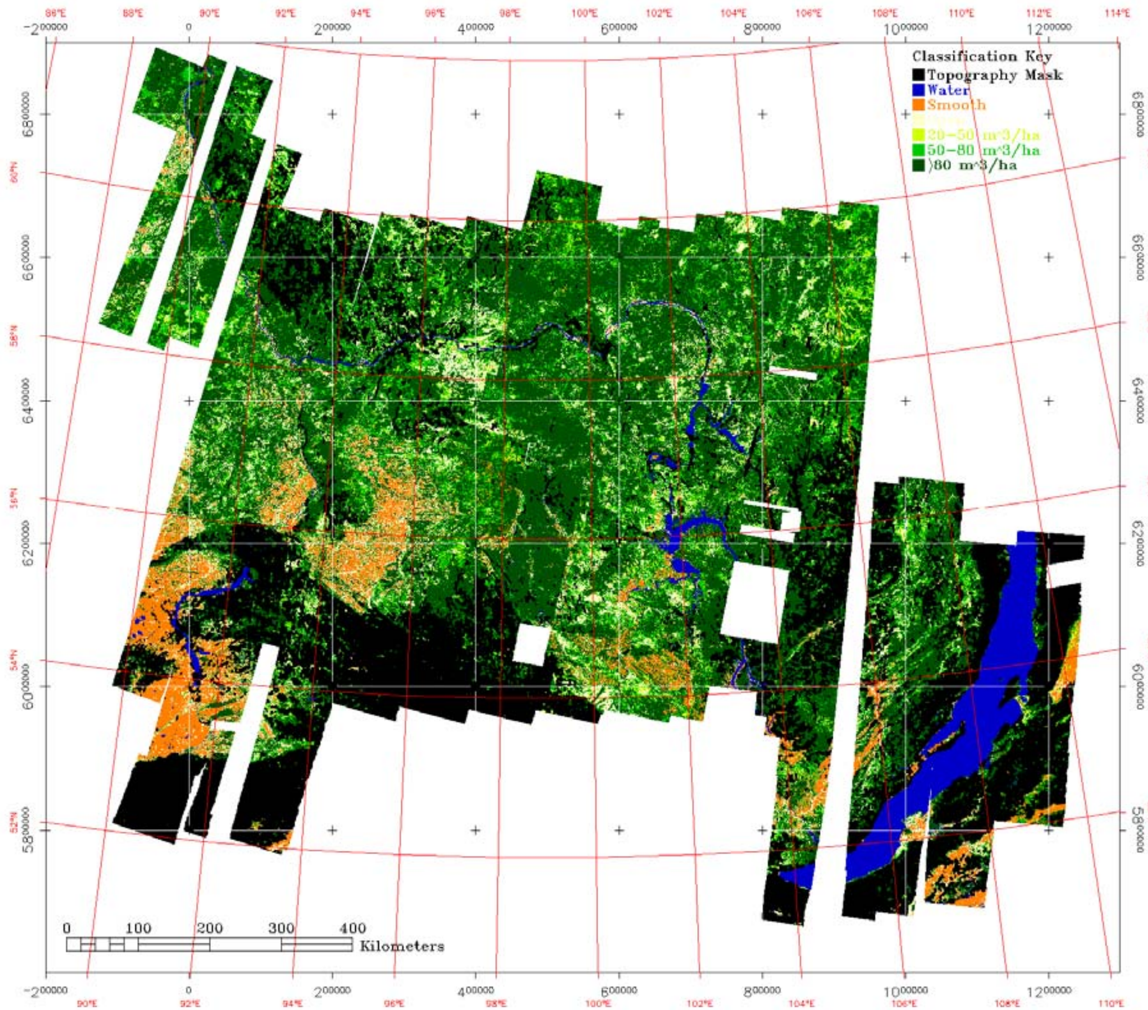



Normalised surface model
from airborne lidar data
© Landesvermessungsamt
Feldkirch

# Vegetation Parameters from SAR Interferometry

ERS-1/2 Tandem
Coherence,
Bregenzer See,
Vorarlberg

# Biomass Mapping using SAR Interferometry




**Legend:**

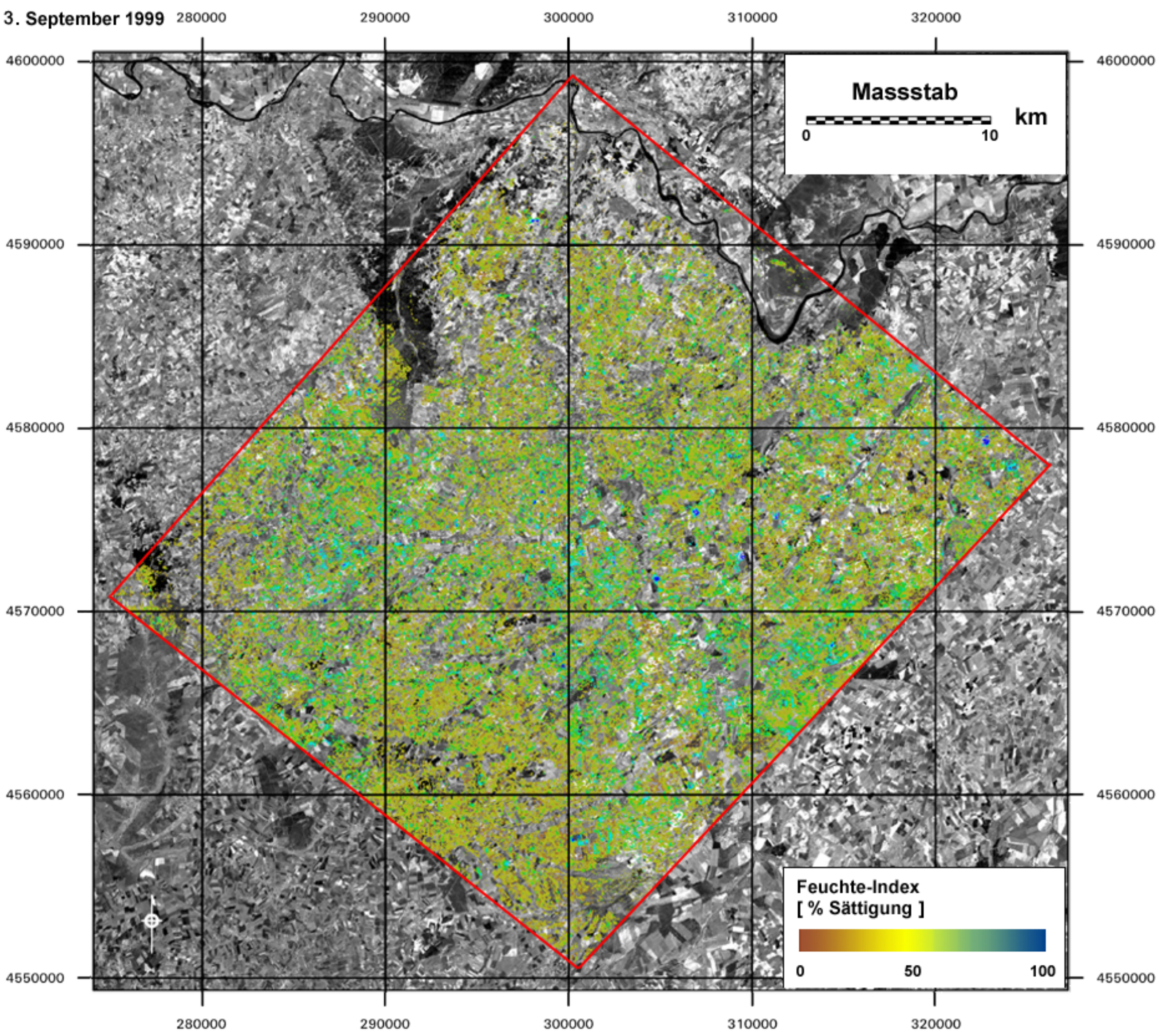
**Masked Areas**
**Water**
**Smooth Surfaces**
**Forest:**
**0-20 m$^3$/ha**
**20-50 m$^3$/ha**
**50-80 m$^3$/ha**
**> 80 m$^3$/ha**

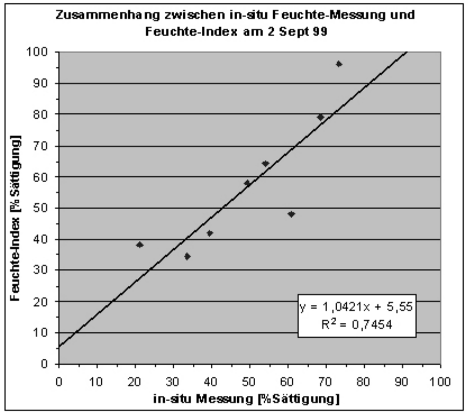
SIBERIA forest map of a 1 Mio. km$^2$ large area from ERS tandem coherence and JERS SAR Data

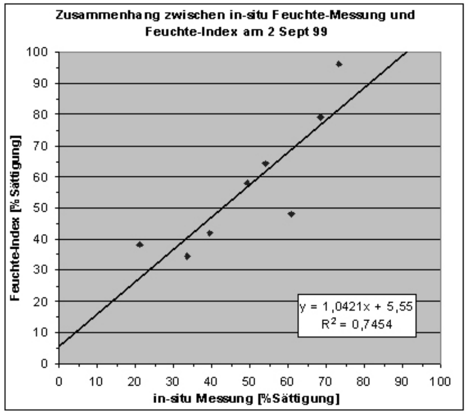
# Soil Moisture

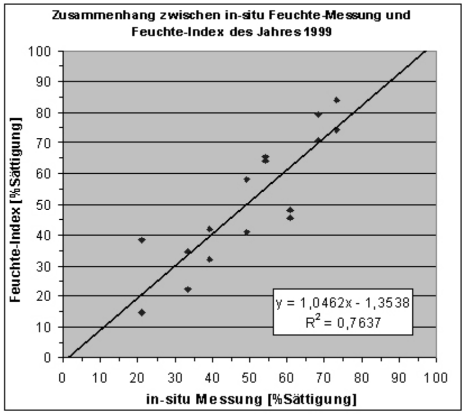
- **Local-scale soil moisture (< 1 km)**
  - Synthetic Aperture Radar (SAR)
  - Still in an experimental stage, no operational products
  - All satellite SAR systems are multi-purpose missions, i.e. not well suited for the task of soil moisture monitoring
- **Large-scale soil moisture (> 10 km): 2005-2015 Decade of Soil Moisture Remote Sensing**
  - Dedicated, experimental soil moisture missions
    - SMOS: ESA Earth Explorer Opportunity Mission (2007)
    - HYDROS: NASA Hydrosphere State Mission (2010)
  - Operational "soil moisture" missions
    - METOP
    - AMSR, CMIS
  - First experimental products are becoming now available

# Soil Moisture from SAR



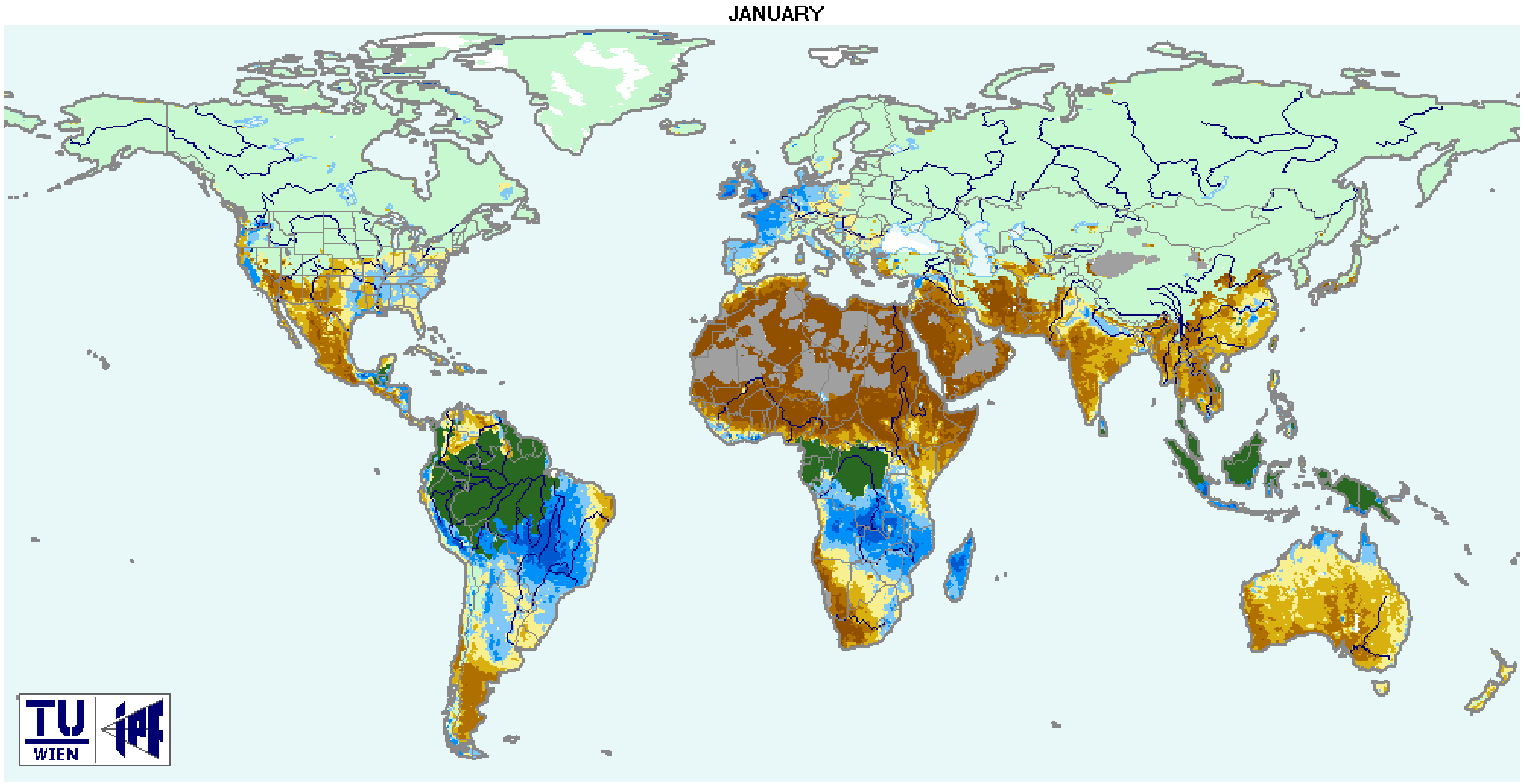




Soil moisture derived from SAR using a change detection approach

# Seasonal Soil Moisture Dynamics




Closed Forest Cover

Azimuthal Effects

Frozen Soil/Snow Cover

SWI

0.0 12.5 25.0 37.5 50.0 62.5 75.0 87.5 100.0%

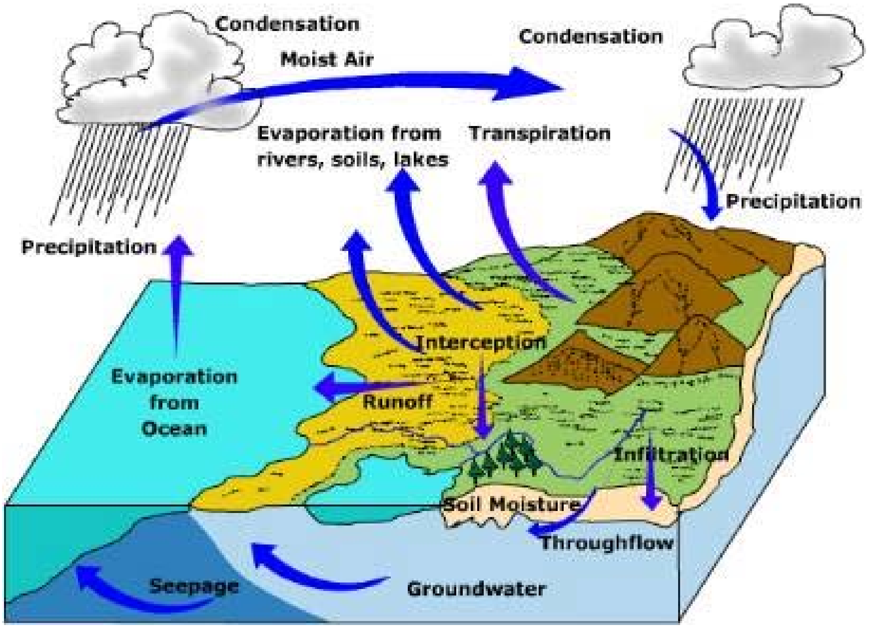
Dry Soil
Wilting Point

Wet Soil
Field Capacity

TU VIENNA

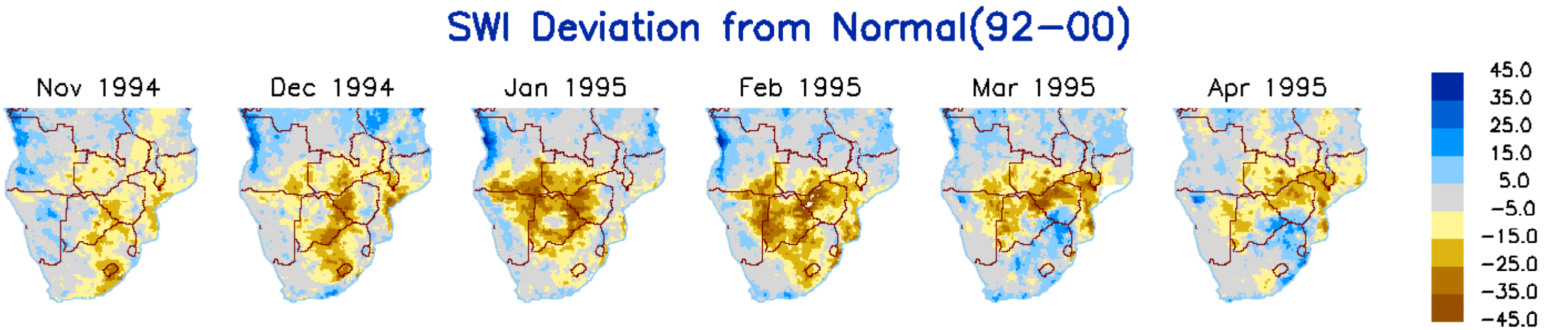
# Integrated Data-Modelling Approaches

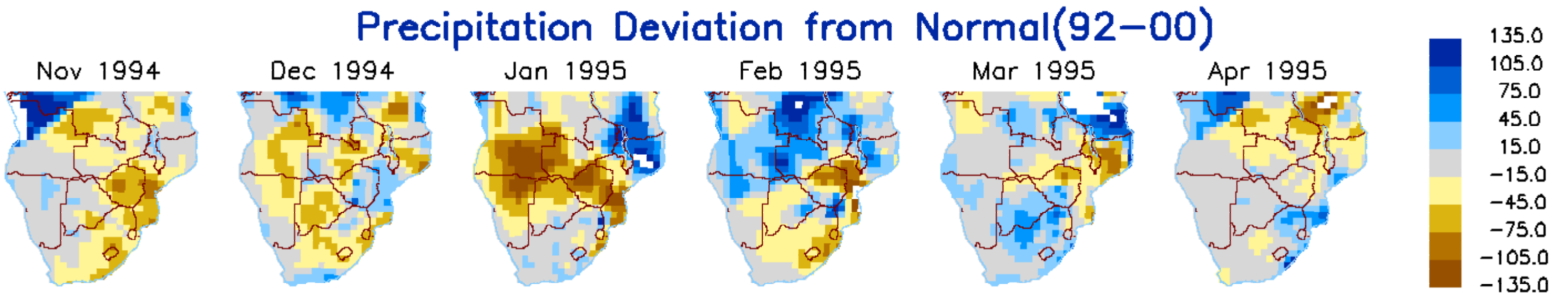
- **Remote sensing can provide spatial data products**
  for hydrologic model validation, calibration or input
- **Only a limited number of geophysical parameters can be derived**
- **Integration of**
  - In-situ observation
    i.e synoptic observations
  - Remotely sensed geophysical products
  - Modelling approaches




What parameters can be measured using RS?

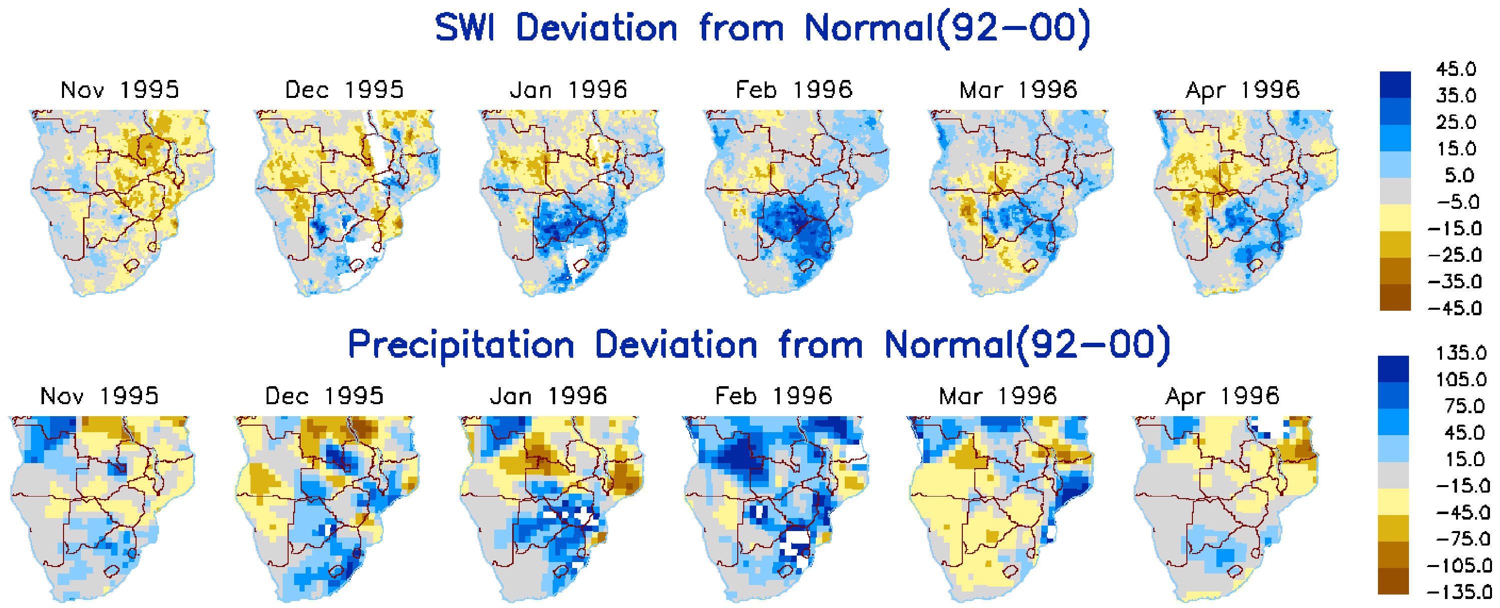
# Droughts in South Africa 1994/95




During the 1994/95 season, a blocking high-pressure system related to warm El Niño events kept southern Africa dry. Most of southern African countries suffered from severe droughts. In the north-western part of Zimbabwe, rainfall during the 1994/1995 season was near the lowest ever recorded. Cereal production fell to 45 percent of the long-term average. USAID reported that over six million people needed emergency assistance because of crop failures and food shortages throughout southern Africa.

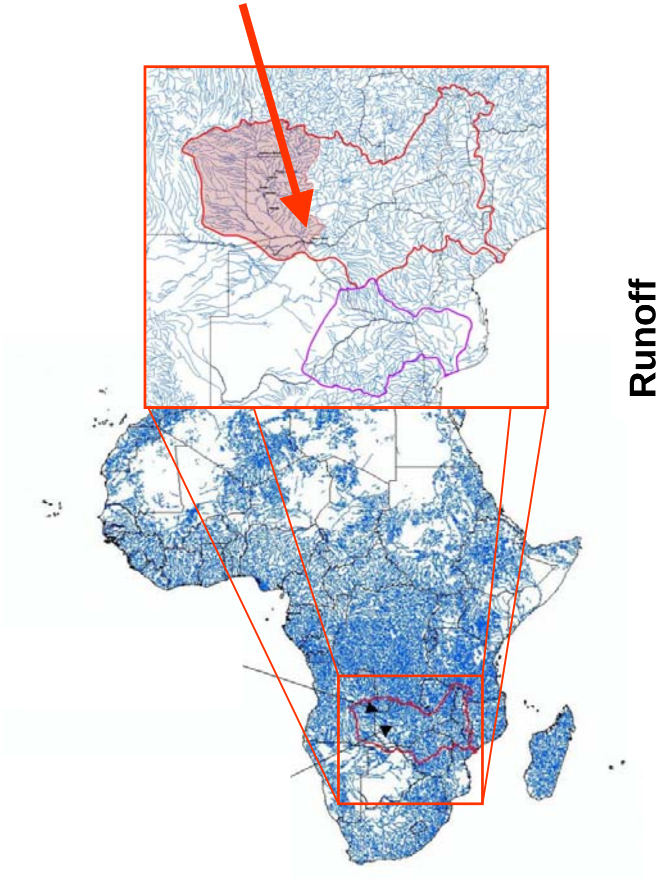
# Floods in South Africa 1995/96



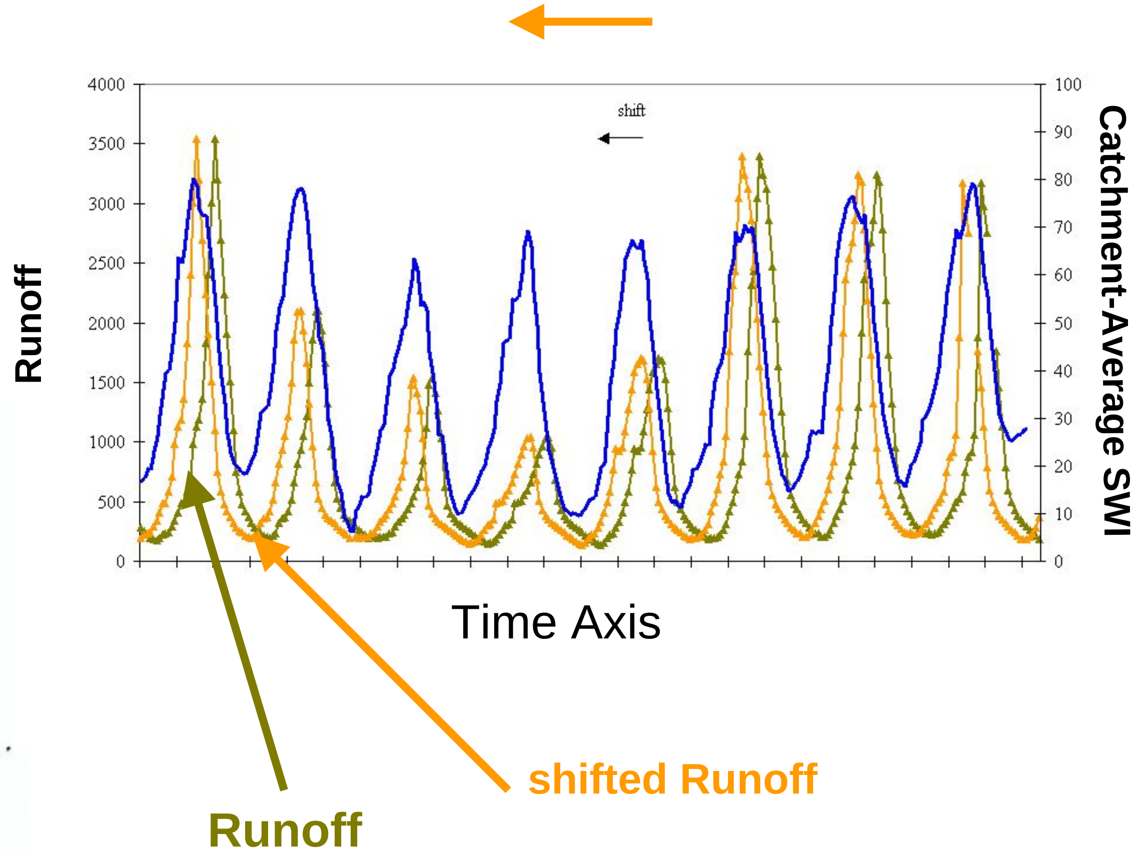

Contrary to the season 1994/95 in the season 1995/96, a progression of Atlantic lows led to a series of storms, bringing heavy rainfall to the area.. According to USAID the excessive rainfalls resulted in floods and consequently in damage to crops and property in the South African areas of Northern Transval and Eastern Cape Provinces and in Mozambique.

# Potential for Large-Scale Hydrologic Models

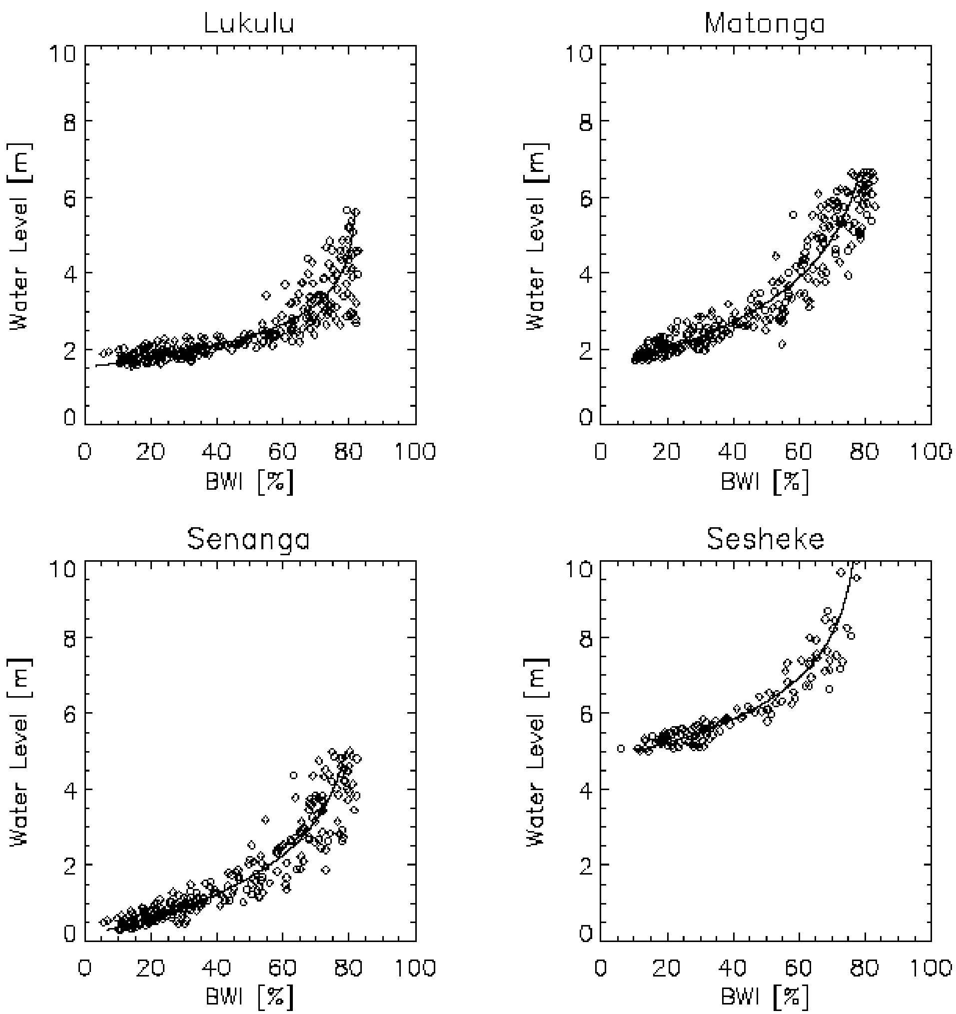
Sambesi – Nana's Farm

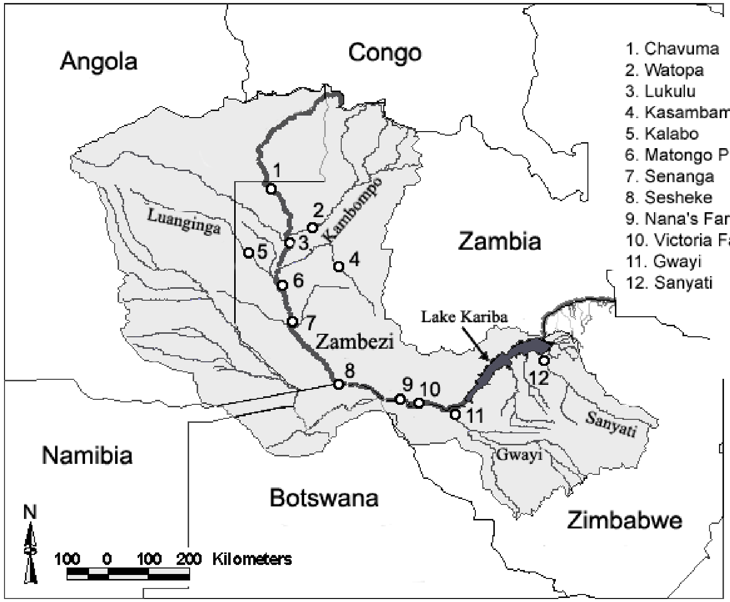


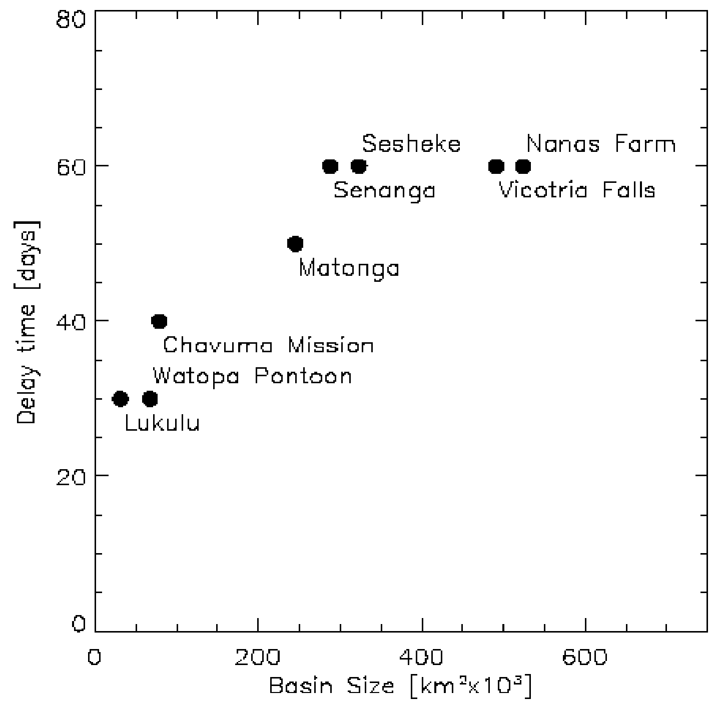
60 days shift



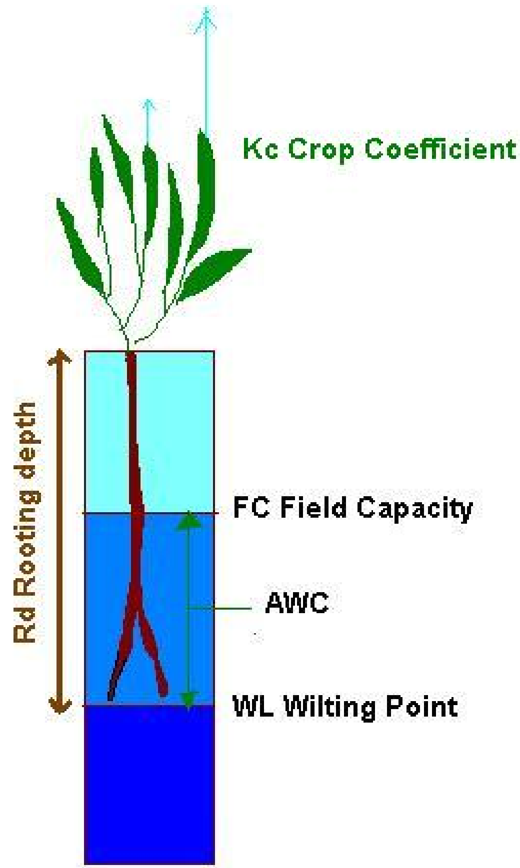
# Catchment Modelling – Case Study Zambezi River



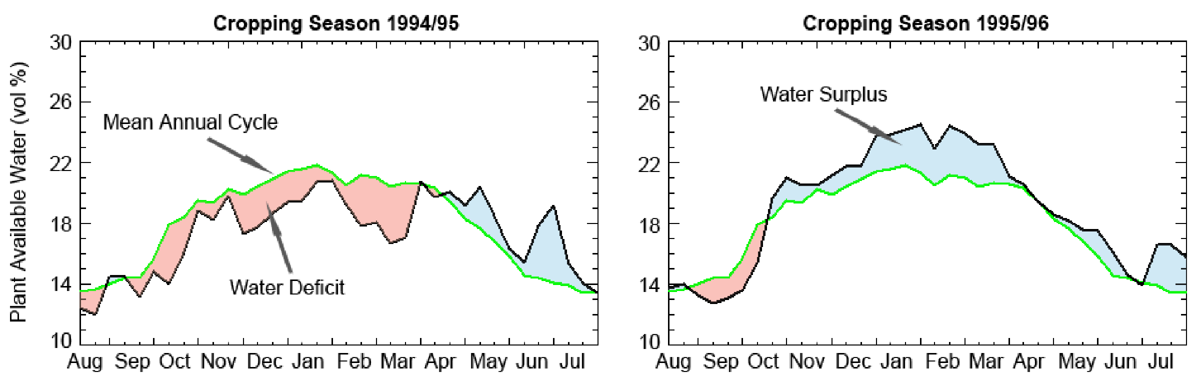
# Crop Performance Index




| Water | Plant Parameters | Soil Parameters |
| --- | --- | --- |
| Soil Moisture Trend SWI | Rooting Depth Rd<br>Evaporation Coeff. Kc | Available Water Coeff.<br>AWC=FC-WL |

## Crop Performance Index

CPI (%) = ((*SWI** Rd * AWC) – (Kc * AWC))/ (Kc * AWC)) * 100

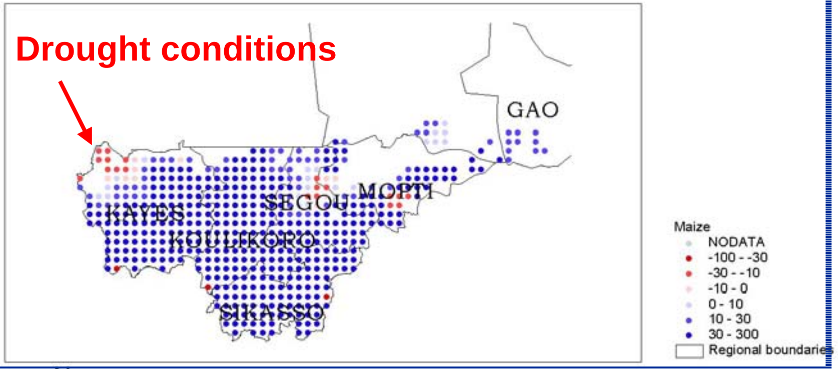


# Drought Indicators for Africa and China

## Mali

**Drought conditions were confirmed by Malinese experts**

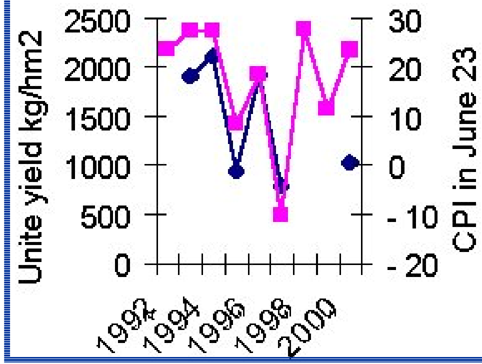
Plant growth conditions for Maize for the period 29-07 to 05-08



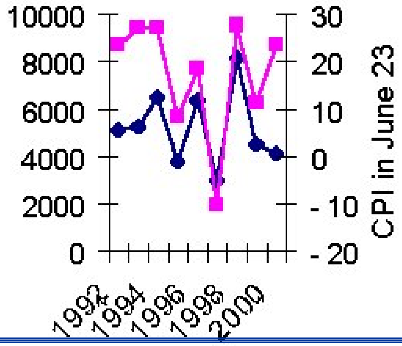

## China

**Drought conditions were confirmed by statistics**

Relation of proso millet yield with CPI in Ansai




Relation of corn yield with CPI in Ansai




**CONCLUSIONS:**

- Simple yet powerful method
- CPI and actual yield correlate well
- Water shortage must be yield dominating factor
- Not applicable for irrigated crops

# Conclusions

- **Remote sensing is not just about land cover classification**
  - it is tool for monitoring geophysical parameters/processes
    - soil moisture, topography, vegetation height, biomass, evapotranspiration, etc.
- **Despite there has been yet few commercial success stories for satellite remote sensing, major advances are being made**
  - It is not always spatial resolution that counts
  - tremendous potential in hydrologic and agronomic applications
  - In collaboration with the user communities, new modelling approaches must be developed
    - Integration with in-situ observations and models (hydrology, agronomy, etc.)