GPS derived water vapor in aLMo: status and outlook

Jean-Marie Bettems, MeteoSwiss

With contributions from:
Guergana Guerova, IAP, EPFL (GPS ZTD)
Martin Zingg, MeteoSwiss/ETHZ (GPS ZTD)
Marc Troller, Geodesy and Photogrammetry, ETHZ (GPS tomography)

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Motivation

- Water vapor plays obviously a key role in the correct simulation of atmospheric processes (e.g. hydrological cycle, atmospheric radiation, atmospheric stability,…)
- Quantitative precipitation forecast with explicit convection at kilometric scale are very sensitive to temperature and humidity structures [Ducrocq, 2002]

- Humidity structures show a high temporal and spatial variability
- Water vapor observations are rare compared to other quantities; currently the main sources of information over land are
  - radiosoundings (poor spatial and temporal resolution)
  - 2m level humidity (representativity is problematic)
- Water vapor observations by GPS network is promising
  - all weather system
  - high temporal resolution (better than 1 hour)
  - good spatial resolution in some regions (e.g. Swiss net with 50km spacing)

Quality of GPS ZTD data

- Integrated water vapor (IWV) can be retrieved by ground based GPS with the same level of accuracy as radiosondes and microwave radiometers
  - both post-processed and near real time data, with occasional smoothing in the latter case

- For the period January to June 2003, an intercomparison of GPS with radiosonde and radiometer produced the following results [Guergana]:

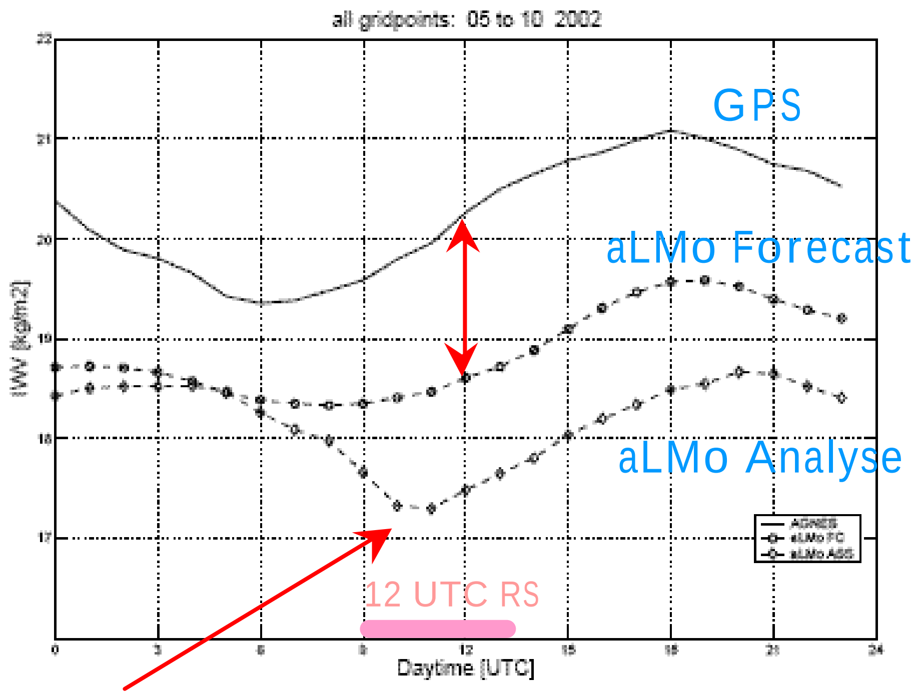
	IWV 00 UTC		IWV 12 UTC	
	Bias [mm]	Std [mm]	Bias [mm]	Std [mm]
GPS vs. radiometer (Bern)	0.34	1.36	0.59	1.65
GPS vs. radiosonde (Payerne)	-0.57	1.47	0.89	2.11

Summer bimodal day/night distribution of gps-radiosonde bias (~1mm) has been documented elsewhere [Ohtani, 2000 / Haase, 2002], as a radiosonde midday dry bias

jean-marie.bettems@meteoswiss.ch

Quality of GPS ZTD data

- IWV Daily cycle,
  May – October 2002
- 14 Swiss GPS sites, within ± 50m of model topography
- Only conventional observations assimilated in aLMo
- GPS or model bias ?



- Discrepency between GPS data and aLMo could be related to:
  - Vaissala RS dry bias due to chemical contamination of sensor [MAP – up to 15% IWV]
  - RS dry bias during summer day time

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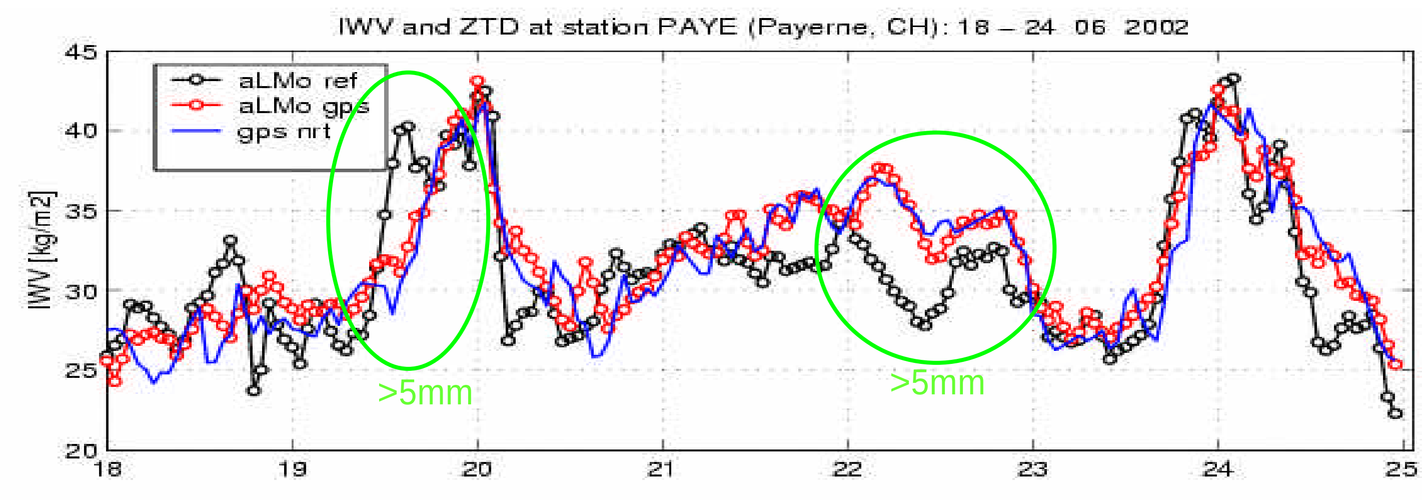
Impact of GPS ZTD on humidity field

- Dependent on weather regime and season;
  typical maximal impact on IWV aLMo analysis is
  - January: ±10% (average IWV 10mm)
  - September: ±20% (average IWV 20mm)
  - June: ±30% (average IWV 32mm)
    ±20% up to +30h forecast

- The implemented scheme corrects a large part of IWV deficiencies observed in the reference experiment



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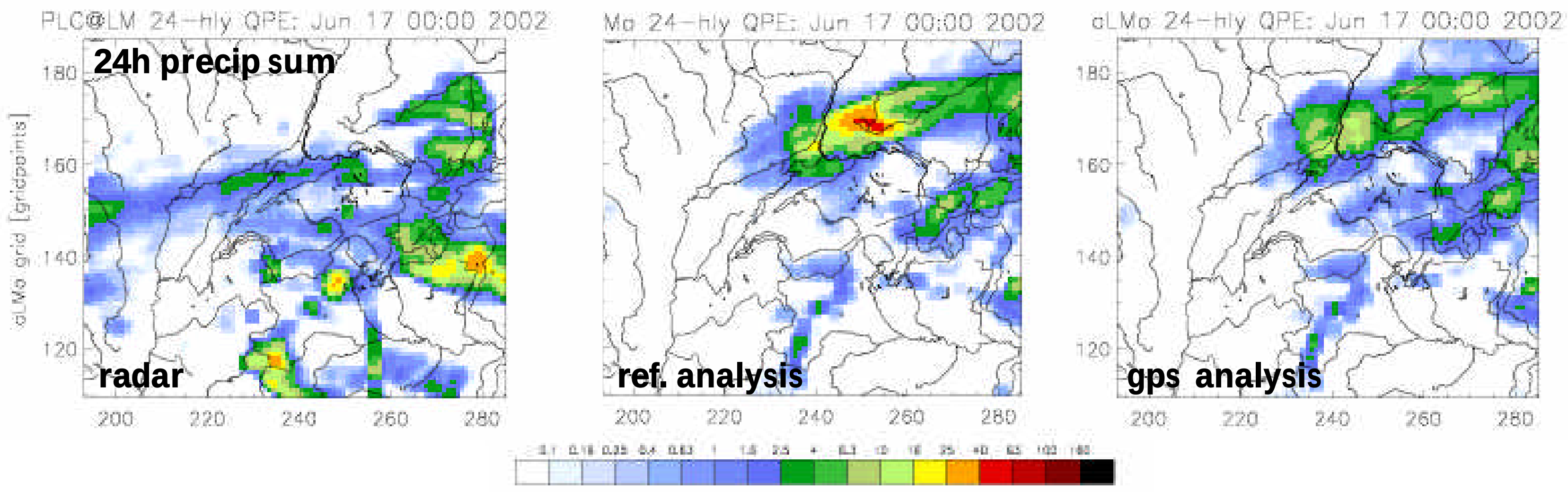
Impact of GPS ZTD on precipitation

- Previous experiments at MeteoSwiss [Guergana]
  - Weak impact both on January and September experiments (5 days each)
  - Both positive and negative impact on the June experiment (7 days, 6h sum); 15% positive, 25% negative, 60% neutral / increased positive precipitation bias
- New experiment at MeteoSwiss, June 2002, with latest model version and reduced horizontal scale [Zingg]
  - free soil humidity (3 days, 6h sum): 15% positive, 8% negative, 75% neutral
  - soil humidity constraints by IFS (30 days, 24h sum): mainly neutral impact, 1 clear positive case



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GPS ZTD - Summary

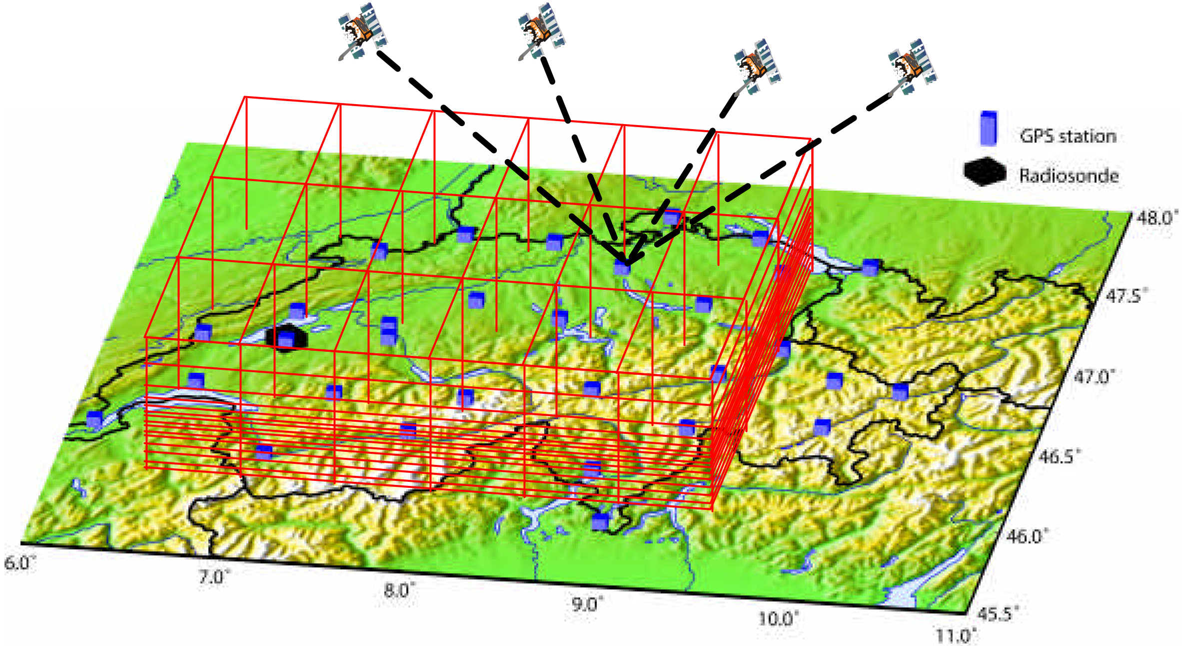
- Data quality and data impact
  - Data quality comparable to radiosonde
  - Large impact on humidity field
  - Cases with remarkable positive impact on precipitation fields, but also negative impact observed
  - Mainly neutral statistical scores
  - Similar conclusions by others, e.g. Japan [Nakamura] and the US [Gutman]

- Main problems, possible solutions
  - vertical distribution of observation increments (e.g. [Tomasini])
    - tomographic approach
    - same problem with a 4D Var system [Nakamura]
  - isotropic horizontal weight, for largely anisotropic structures (e.g. front)
    - anisotropic weights, defined according to measured or model humidity gradient
  - better humidity does not necessarily produces better |
    - shall one tune the model for specific applications?

jean-marie.bettems@meteoswiss.ch

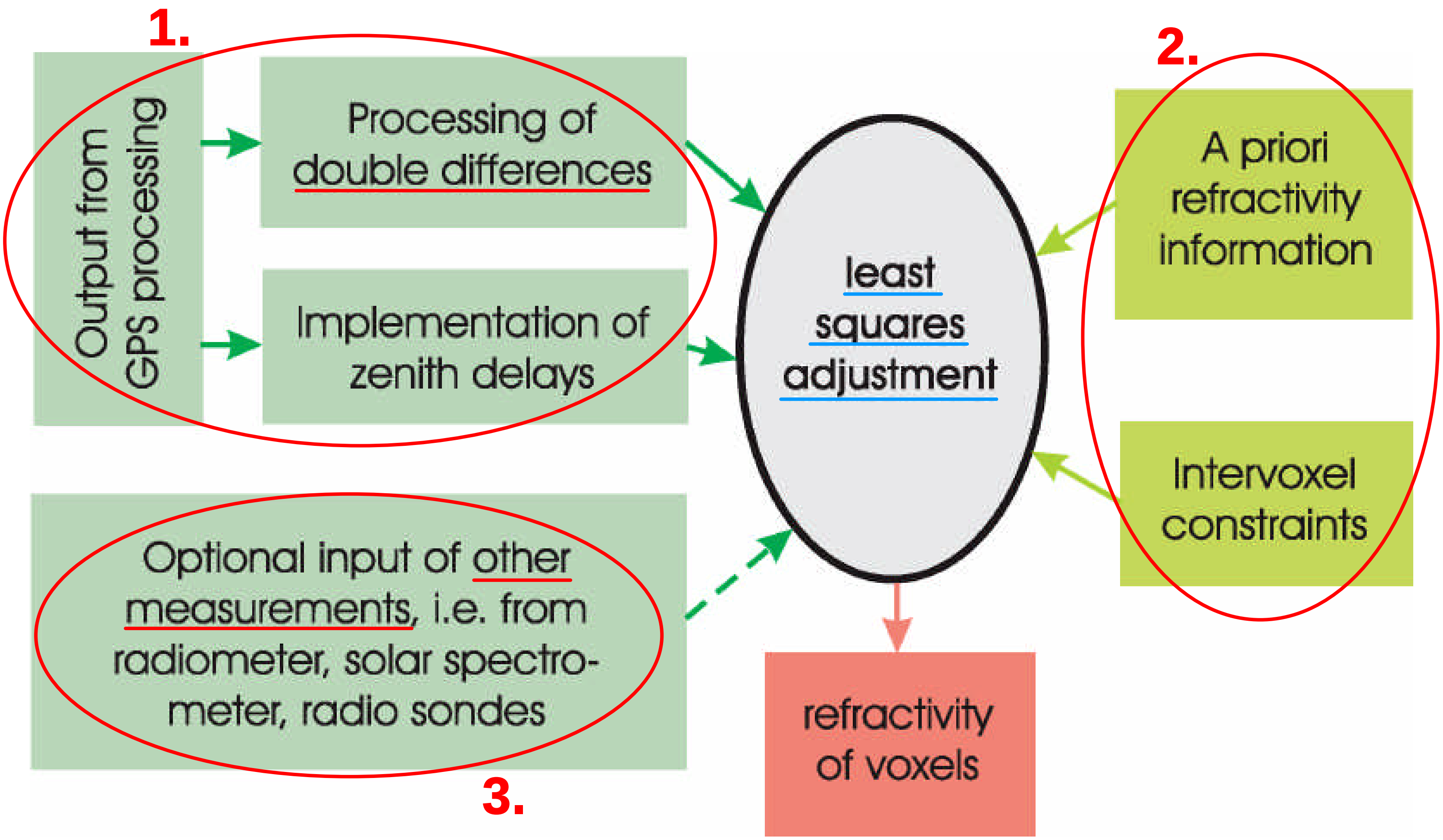
GPS Tomography – Voxel Model

- Based on Swiss AGNES GPS network (30 sites, 50km mean spacing)
  - 3x6 mesh elements, open elements at the boundaries
  - 15 levels between 0 and 8000 meters; 1 more level aloft



- Under-determined system, needs additional information
  - inter-voxels constraints between contiguous voxels
  - a-priori values for uppermost layer, option for lowest layers values from ANETZ data
- Output 18 hourly humidity profiles over Switzerland

GPS Tomography – Data flow



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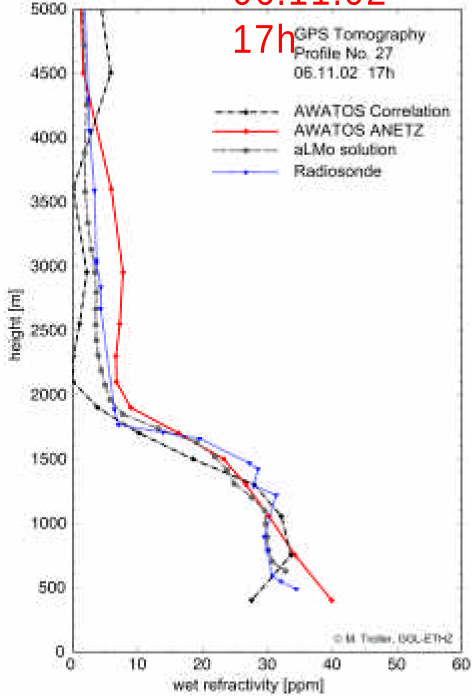
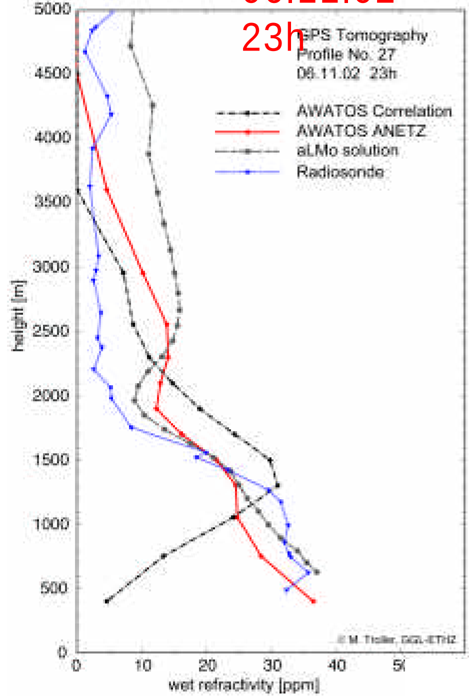
GPS Tomography – Some results

06.11.02 17h



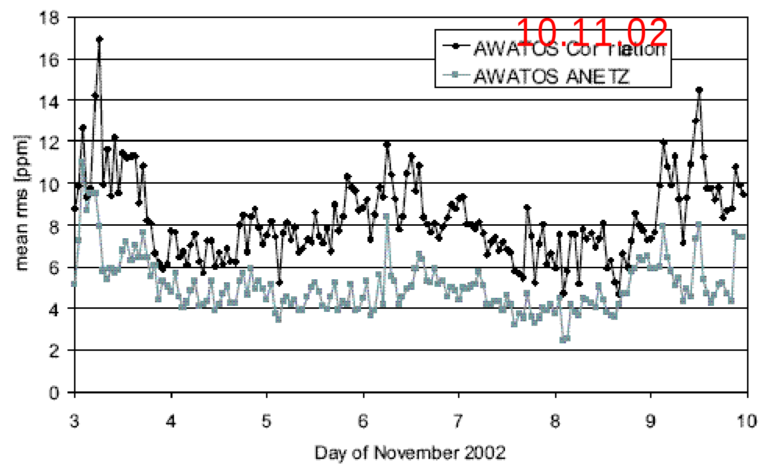
06.11.02 23h



Humidity profiles at Payerne; tomographic solutions compared with radiosonde and aLMo.

Improved solution when taking into account additional data (ANETZ).

03-10.11.02



Comparison of all 12 tomographic profiles with aLMo analysis:
time serie of rms.

Worse results by rapidly changing weather situation (3, 6, 9.11)

jean-marie.bettems@meteoswiss.ch

GPS derived water vapor - Outlook

- Tomography is a promising method for regions with dense GPS network
  - All weather, high spatial and temporal resolution, humidity profiles over land

- Tomography should be completed with additional data source to produce consistent quality profiles
  - GPS occultation (transverse data)
  - Satellite aloft cloud cover, in the upper part of the atmosphere
  - Lidar and other operational humidity data where available
  - Model analysis could possibly be used as first guess data (iterative procedure)

- The tomography technique developed at ETHZ can be seen as a pre-processing tool to integrate different sources of humidity information and provide humidity profiles directly usable by the LM nudging scheme

- A proposal for a European project on this topic is being evaluated by the ETHZ (Institute of Geodesy and Photogrammetry)

aLMo snow analysis:
Meteosat-8 snow map as additional ingredient

Jean-Marie Bettems, MeteoSwiss

Work done by:

Martijn de Ruyter de Wildt, EUMETSAT Fellowship, ETHZ

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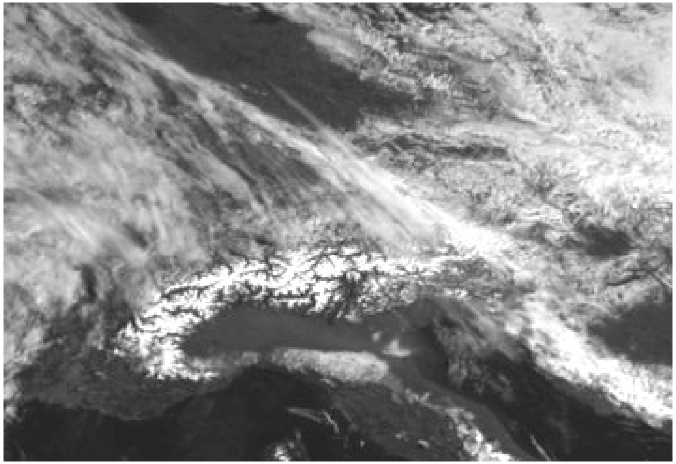
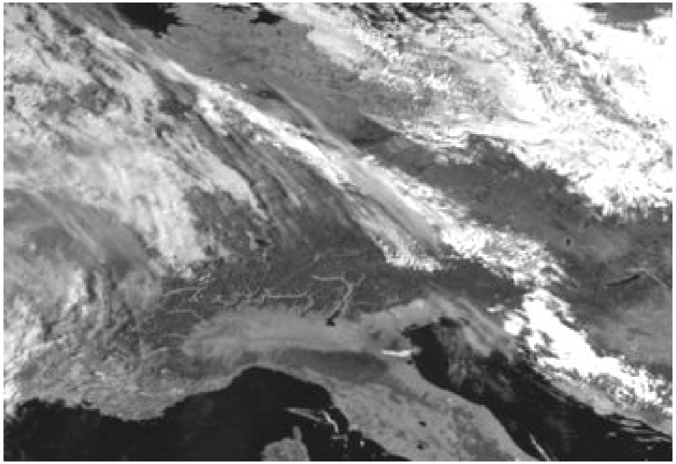
Snow analysis – Image classification

04.03.2004 09h



- Main problem: separation of snow and clouds,
  e.g. in the visible channels, but this can also occur in the infrared channels



- Fortunately: around 1.6 μm, snow and ice have a low albedo, and water a high albedo

- … but even in the 1.6 μm channel some clouds look the same as snow ⇒ use contextual information to improve classification

jean-marie.bettems@meteoswiss.ch

Snow analysis – Contextual classification

- <u>At the moment</u>
  In a sequence of images, the image with the most cloud-clear view of a certain pixel (spectral features furthest away from overcast situation) is considered to reflect the surface conditions for that pixel.

- Possible other classification features:
  - homogeneity in (x, y, t) data space ⇒ clouds less homogeneous than surface snow
  - consistency in (x, y, t) data space ⇒ no snow at unlikely locations / moments
  - displacement of patterns ⇒ must be clouds

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Snow analysis – Plan at MeteoSwiss

- Combine in-situ information with satellite data
  - adapt LM snow analysis algorithm (start summer 2005)
- Consider both Meteosat8 [EUMETSAT Fellowship] and NOAA [Uni Bern]
  - with emphasis on mountainous regions
  - main product is snow/ice cover for each element of aLMo/7 and aLMo/2 mesh
  - additional products such as snow surface temperature and albedo will also be considered

jean-marie.bettems@meteoswiss.ch