Surface processes and assimilation of surface variables in operational NWP models: HIRLAM formulation

e.rodriguez@inm.es

Outline

- Why surface parameterization is important?
- Which are the distinct features of surface/atmosphere interaction?
- How important are the different surface parameters?
- Treatment of surface heterogeneity. Aggregation. How big is the impact of tiling?
- How are surface schemes validated?
- Physiographic description. ECOCLIMAP. How big is the impact of physiography?
- Assimilation of surface variables. Case of soil moisture. ELDAS experience. How big is the impact of soil moisture?
- HIRLAM surface analysis. Future plans.
- HIRLAM surface parameterization. Future plans.

Is the Land Surface Important to NWP?

- *"The atmosphere and the upper layers of soil or sea form together a united system. This is evident since the first few meters of ground has a thermal capacity comparable with 1/10 that of the entire atmospheric column standing upon it, and since buried thermometers show that its changes for temperature are considerable. Similar considerations apply to the sea, and to the capacity of the soil for water. "*

  L.F. Richardson, 1922

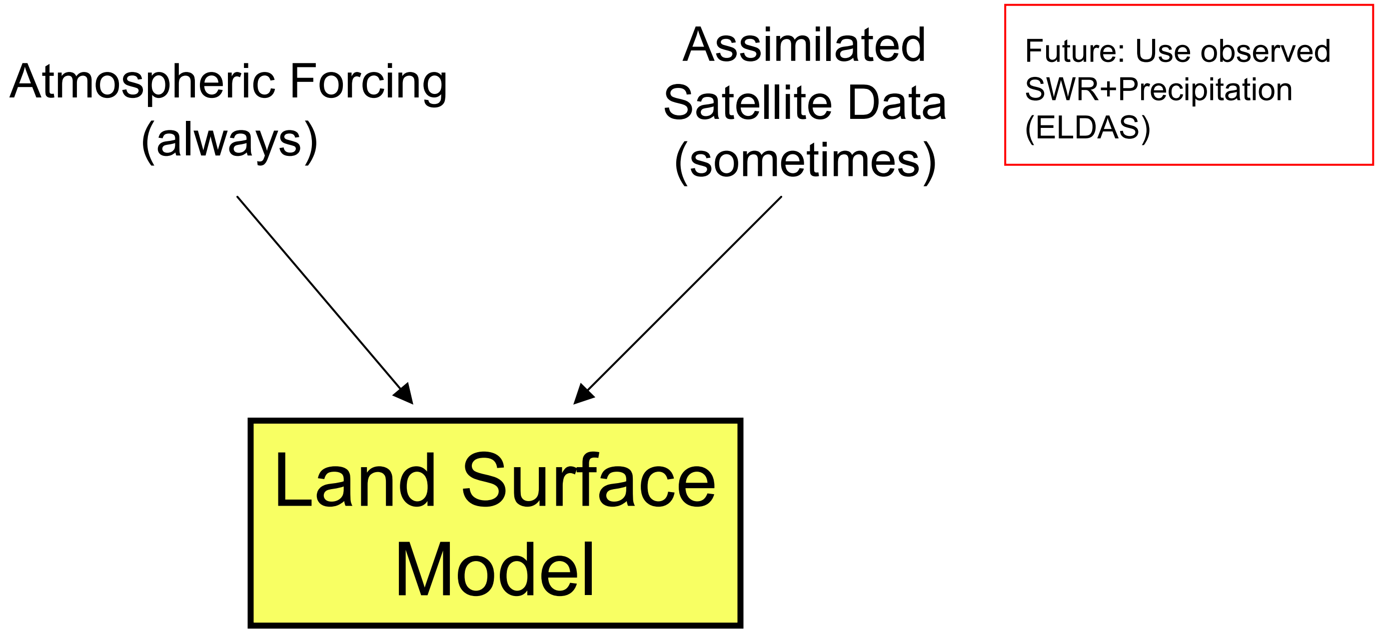
  Weather Prediction by Numerical Processes

- *"Much improved understanding of land-atmosphere interaction and far better measurements of land-surface properties, especially soil moisture, would constitute a major intellectual advancement and may hold the key to dramatic improvements in a number of forecasting problems, including the location and timing of deep convection over land, quantitative precipitation forecasting in general, and seasonal climate prediction."*

  National Research Council, 1996

Why surface parameterization is important?

- Bias detected in climate modelling due, e.g., to the absence of vegetation, incorrect heat fluxes partition, etc.
- NWP models need BC for enthalpy, moisture and momentum equations: fluxes of energy, water and stress at the surface
- Need of consistent budgets of energy and water
- Experimentation and comparison exercises during 80’s and 90’s (HAPEX-MOBILHY 86, FIFE 87, BOREAS 94, EFEDA 91, PILPS, ...) have allowed extensive validation
- Improvement of near surface variables (T2m, RH2m, v10m)



Goal of an LSM: To produce

- Water balance partition (evaporation/runoff/storage)
- Energy balance partition (latent heat, sensible heat, …)
- Carbon balance partition (uptake, respiration, storage,…)
- Evolution of surface and subsurface states (temperature, soil moisture, snow, vegetation phenology, vegetation distribution…)

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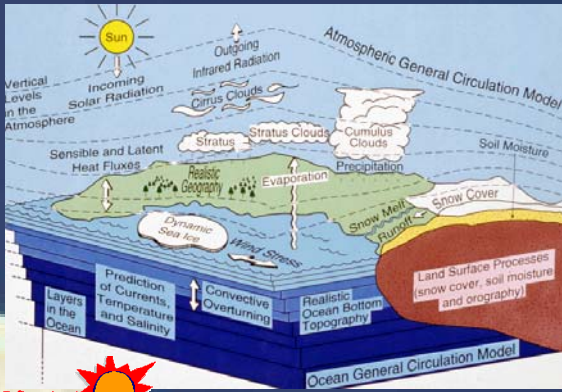
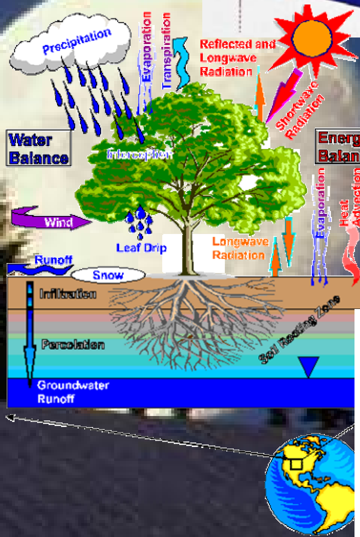
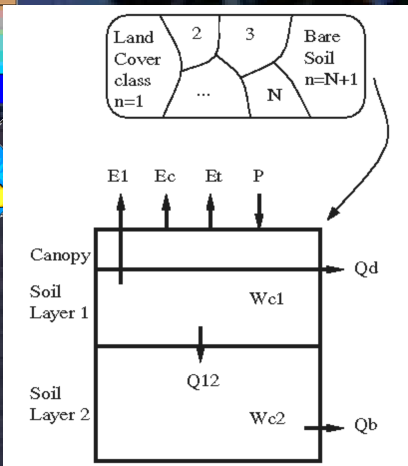
Which are the distinct features of the surface/atmosphere interaction?

- Heterogeneity at all scales. Aggregation issues
- Different physical/biological processes are involved
- Need to initialize surface/subsurface variables
- Many soil and vegetation parameters (10-14) are involved: veg, LAI, emis., albedo, Rsmin, soil texture, ...







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How important are the different surface parameters?

- Use of the Fourier Amplitude Sensitivity Test (FAST).
- General technique for sensitivity analysis of mathematical models. With this technique input parameters are varied simultaneously through their ranges of possible values according to some given PDF. All input parameters are assumed to be independent.
- Each input parameter is assigned a different frequency which determines the number of times that the whole range of the parameter is traversed. This frequency of oscillation different for each parameter is analyzed in the model output to separate the response of the model to every input frequency. Addition of those Fourier coefficients corresponding to a particular input parameter frequency and its harmonics determines the total contribution of that particular input parameter to the model output variances.
- The essence of this method consists of analyzing the spectrum of frequencies of model outputs generated when parameters are forced to oscillate with given linearly independent frequencies. Finally by scaling the relative contribution of the input parameters to the total variance partial variances are obtained which show the sensitivity of the model output parameters to the variation of the individual input parameters in their prescribed range of values.
- The FAST technique is a very powerful technique for general sensitivity analysis in mathematical models though it has also some limitations:
  - Nonlinear algorithms connecting the input parameter and output parameter spaces can distort the real sensitivity caused by some input parameter.
  - The input parameters should be either independent or their dependency in form of covariances between pairs of parameters should be modeled.
  - The FAST technique provides the module of the sensitivity but not its sign
  - The range of variation of the input parameters is usually a critical issue

(Rodríguez & Avissar, 1998)

Table 3: Land-surface parameters used for the ISBA scheme as input to the FAST algorithm. Their maximum and minimum values determine the range of variability of every parameter as it is used in the analysis.

Parameter	Minimum	Maximum
Percentage of sand (s) (%)	10	100
Percentage of clay (c) (%)	10	100
Surface soil wetness (W_s)	0.0	1.0
Total soil wetness (W_d)	0.0	1.0
Roughness length (Z_o) (m)	0.01	2.0
Leaf area index (lai)	0.0	6.0
Minimum stomatal resistance (Rs_{min})	120.	200.
Radiation transpiration factor (R_{st}) (Wm^{-2})	30.	100.
Vapor transpiration factor (e_{st})	0.	0.04
Temperature transpiration factor (T_{st}) (K)	295.	300.
Wetness transpiration factor (W_{st})	0.8	1.0
Albedo (α)	0.14	0.20
Emissivity (ϵ)	0.90	0.99

Table 2: Land-surface parameters used for the LAID scheme as input to the FAST algorithm. Their maximum and minimum values determine the range of variability of every parameter as it is used in the analysis.

Parameter	Minimum	Maximum
Soil Albedo (α_g)	0.05	0.95
Soil emissivity (ϵ_g)	0.80	0.995
Soil texture (t)	1.	11.
Vegetation albedo (α_v)	0.14	0.20
Vegetation emissivity (ϵ_v)	0.90	0.99
Vegetation extinction coefficient (κ_v)	0.30	2.30
Soil surface wetness (W)	0.0	1.0
Surface roughness (Z_o) (m)	0.01	2.0
Leaf area index (lai)	0	6.
Maximum relative conductance ($Csmax$)	0.8	1.0
Temperature factor in conductance (T_{st}) (K)	-2^o[1]	$+2^o$[1]
Radiation factor in conductance (R_{st})	−25%[2]	+25%[2]
Water vapor factor in conductance (e_{st})	−25%[2]	+25%[2]
Moisture potential factor in conductance (W_{st})	−25%[2]	+25%[2]

[1] The variation range is $\pm 2^o$ the model value.

[2] The variation range is ±25% of the model value.

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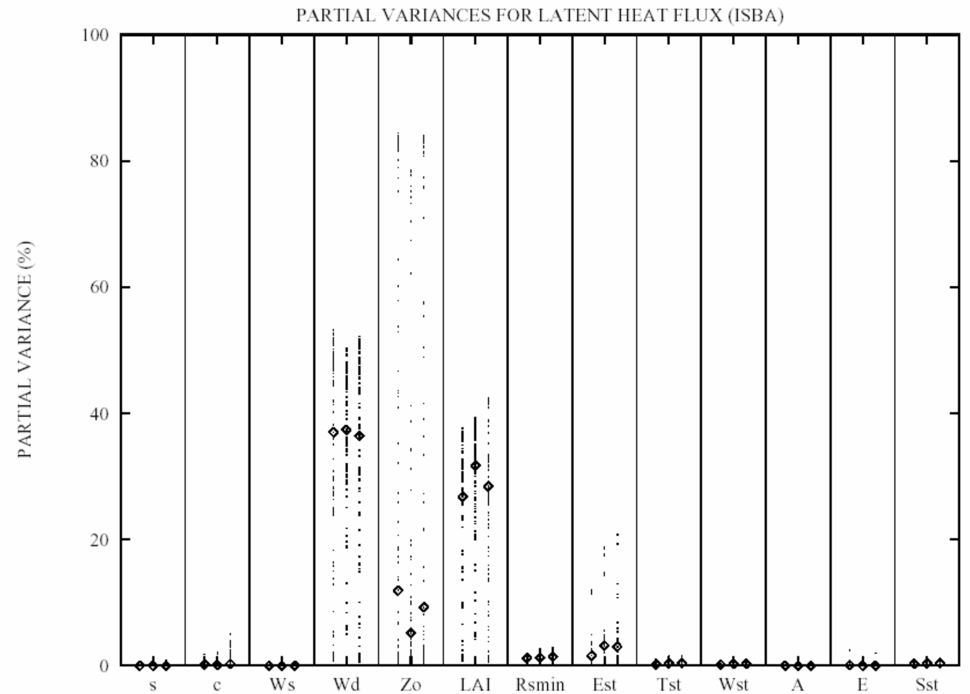
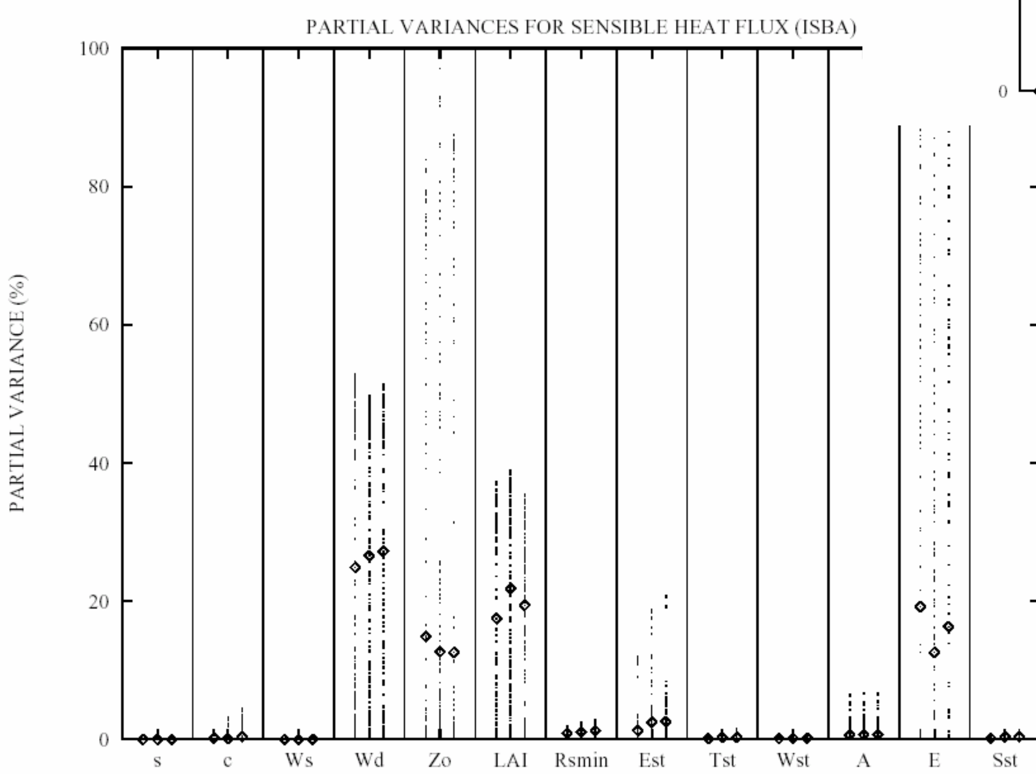
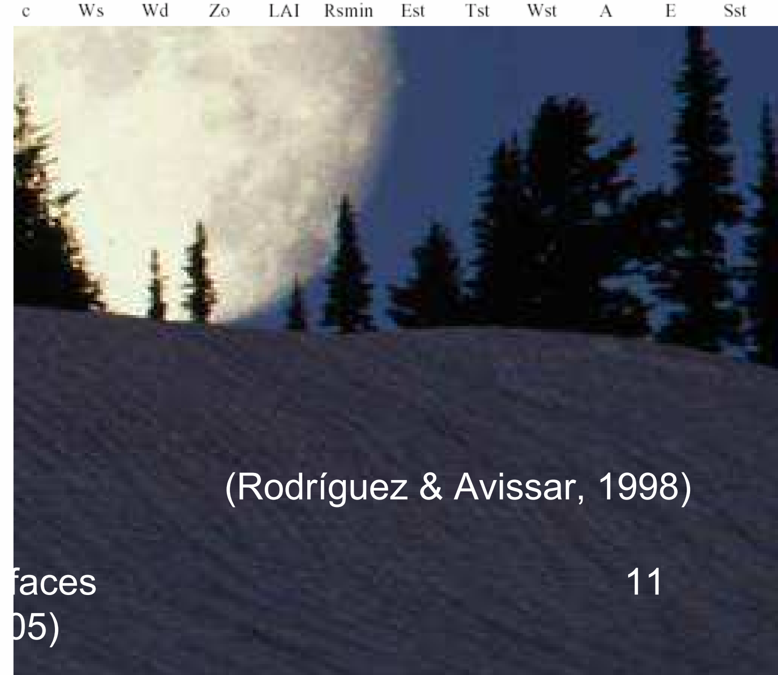
Table 4: Land-surface parameters used for the BATS scheme as input to the FAST algorithm. Their maximum and minimum values determine the range of variability of every parameter as it is used in the analysis.

Parameter	Minimum	Maximum
Surface soil water (W_s) (m)	0.	0.06
Root zone soil water (W_r) (m)	0.	0.66
Soil texture (t)	1	12
Soil color(c)	1	8
Roughness length (Z_o) (m)	0.01	2.0
Minimum stomatal resistance (Rs_{min})	120.	200.
Leaf area index (lai)	0.0	6.0
Stem area index (sai)	0.0	4.0
Vapor transpiration factor (e_{st})	0.	0.04
Temperature transpiration factor (T_{st}) (K)	295.	300.
Light sensitivity factor (R_{st})	0.02	0.06
Reflectance IR (α_{ir})	0.18	0.34
Reflectance VIS (α_{vis})	0.04	0.20







(Rodríguez & Avissar, 1998)

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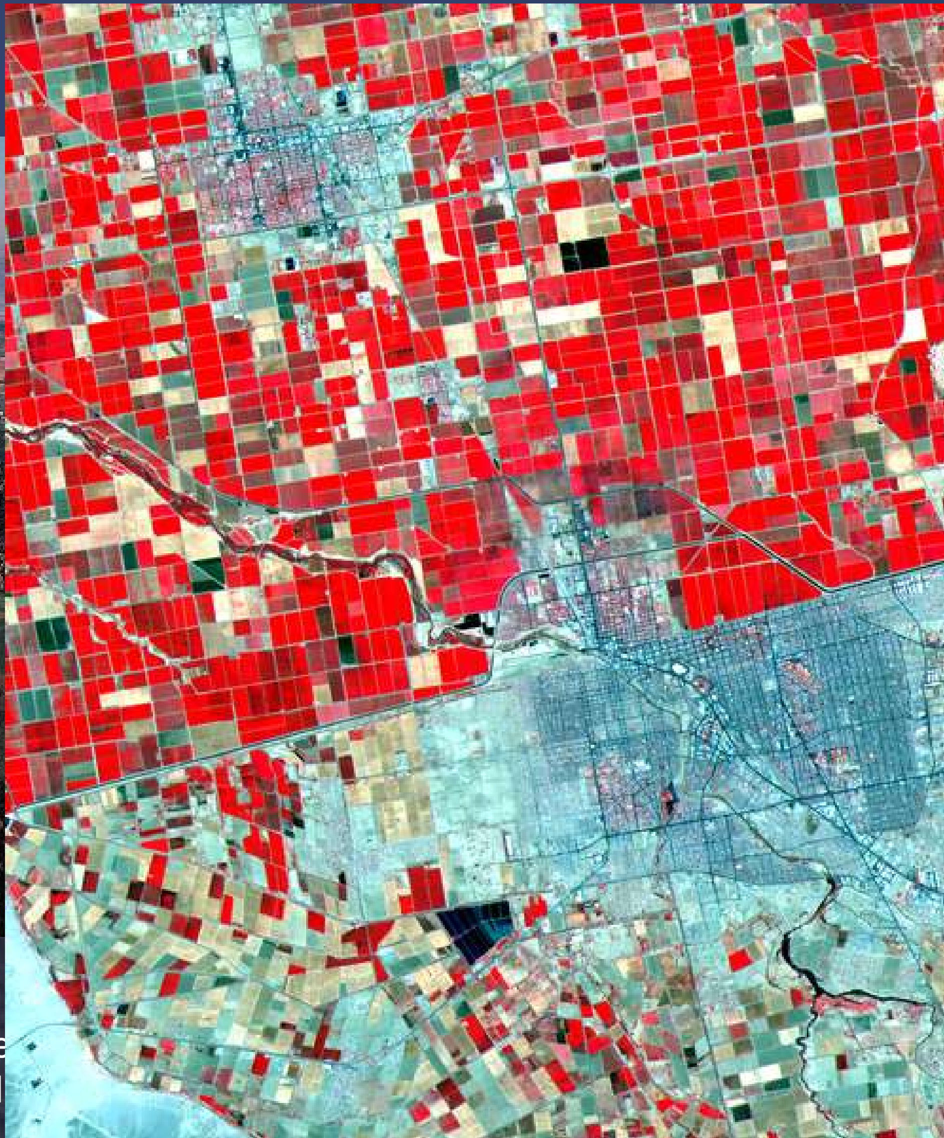
Treatment of surface heterogeneity. Aggregation.



Parameter aggregation (I)

Parameter aggregation is the averaging algorithm used to define effective parameters. Let define f^i as the relative area of one of the M land types within a grid element, Φ^i the corresponding flux from this land type, and $\overline{\Phi}$ the area-averaged flux. If we also define $\{\alpha_k{}^i,\ k = 1, ..., N\}$ as the various parameters of a land type i (N being the total number of parameters), and $\{\alpha_{f_k},\ k = 1, ..., N\}$ as the effective parameters of the grid element, then for a given set of environmental conditions (Ω) and for each type of land, a flux can be expressed as

$$\Phi^i = F(\alpha_k{}^i, \Omega), \quad i = 1, ..., M \qquad (1)$$

and the grid-averaged as:

$$\overline{\Phi} = F(\alpha_{f_k}, \Omega) \qquad (2)$$

where F is the same function relating parameters and fluxes in both expressions.

If, however, the area-averaged flux is assumed to be equal to the weighted average flux calculated from each land type, then it can also be expressed as:

Parameter aggregation (II)

$$\overline{\Phi} = \sum_{i=1}^{M} f^i \Phi^i \qquad (3)$$

If both expressions give the same results, then:

$$F(\alpha_{f_1}, ..., \alpha_{f_k}, ..., \alpha_{f_N}, \Omega) = \sum_{i=1}^{M} f^i F(\alpha_1{}^i, ..., \alpha_k{}^i, ..., \alpha_N{}^i, \Omega) \qquad (4)$$

To estimate the effective parameters, we assume that all land parameters, except the one being aggregated, are identical in all patches of the grid element. If α is the parameter to aggregate, β_j are the other $N-1$ parameters and $\hat{F}$ the corresponding 1-dimensional function ($\hat{F}(\alpha_f) = F(\alpha_f; \beta_j, \Omega)$) then Eq. 4 can be re-written

$$\hat{F}(\alpha_f) = \sum_{i=1}^{M} f^i \hat{F}(\alpha^i) \qquad (5)$$

The effective parameter can be computed from Eq. (5), assuming that $F(\alpha)$ is invertible. Formally,

$$\alpha_f = F^{-1}\left[\sum_{i=1}^{M} f^i \hat{F}(\alpha^i)\right] \qquad (6)$$

Parameter aggregation (III)

Thus, in summary, to calculate an effective parameter associated with a surface flux $\hat{F}$, the following procedure is used:

1. Compute the flux as a function of the parameter α;

2. Compute the inverse $\hat{F}^{-1}(\alpha)$;

3. Compute α_f from Eq.(6).

Because $\hat{F}(\alpha)$ must be a monotonous function of the parameter to be aggregated, the inverse, $\hat{F}^{-1}$, exists. The existence is locally assured if $\partial\hat{F}(\alpha)/\partial\alpha \neq 0$. If $\partial\hat{F}(\alpha)/\partial\alpha = 0$ in some interval of the parameter range, it implies that $\hat{F}$ does not depend on α and, therefore, the effective parameter is not relevant to this particular case. The functional dependency of the flux on the aggregating parameter must be explored to determine the range of validity of these previous assumptions. Likewise, this functional dependency should be considered under different environmental conditions, and under different β_j.

Parameter aggregation (IV)

There is, in principle, one different aggregation algorithm for each surface flux (latent, sensible and radiative) but it is possible that one algorithm is applicable to two or all fluxes. If $\hat{F}$ is a linear function of α, then the effective parameter is simply $\alpha_f = \sum_{i=1}^{M} f^i \alpha^i$. If a sufficiently small range of values is selected for the parameters, then the linear approximation can generally be used. In fact, the entire range of values of the parameter can always be divided into small enough subranges, so that a linear approximation can be applied to calculate the effective parameter within these subranges.

The averaging algorithms for the land surface parameters should be defined according to the dependency of the surface heat fluxes on these parameters, as evident from Eq. 6. This dependency, in principle, could change under different sets of environmental conditions and parameters. Aggregated parameters are well defined only when fluxes computed with them give the same results as fluxes obtained by averaging the contribution of the different patches in a grid element. If the concept of effective parameter is extended to all atmospheric conditions and to all parameters, then the properties of the surface fluxes computed from the effective parameters can be relaxed. Thus, the averaging algorithm can be selected to minimize the mean error in the calculation of the surface fluxes with effective parameters. Furthermore, the surface fluxes must be monotonously dependent on the parameter to aggregate. In fact, to obtain the surface heat fluxes, we need to find an interpolating function, $A(\alpha)$, to estimate the effective parameter, α_f, for each parameter α:

$$\alpha_f = A^{-1}\left[\int_{\alpha_{min}}^{\alpha_{max}} \rho(\alpha)A(\alpha)d\alpha\right] \quad (7)$$

$$\int \rho(\alpha)d\alpha = 1. \quad (8)$$

which results in a flux similar to that obtained when the real distribution of a land-surface parameter, $\rho(\alpha)$, is used explicitly, and such that the difference of surface heat fluxes:

$$\int_{\alpha_{min}}^{\alpha_{max}} \rho(\alpha)F(\alpha;\beta_j,\Omega)d\alpha - F(\alpha_f;\beta_j,\Omega) \quad (9)$$

is minimized when averaged over as many environmental conditions and other land-surface parameters as possible. Since $A(\alpha)$ could vary with different distributions of land-surface parameters, several functions should be evaluated.

Table 1: Prescribed environmental variables used for the experiments

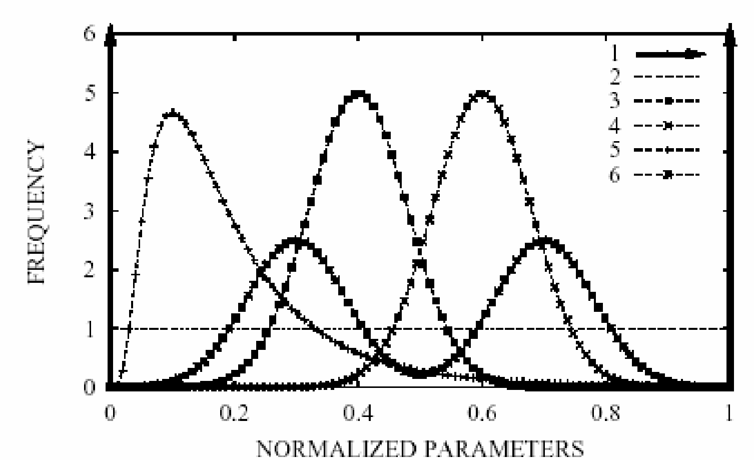
Parameter	Units	Minimum	Maximum
Wind speed	ms^{-1}	1.0	6.0
Relative humidity	%	20	100
Air temperature	K	283	303
Solar radiation	Wm^{-2}	200	1000
Atmospheric radiation	Wm^{-2}	250	350

Table 2: Land-surface parameters used in the ISBA scheme as input to the aggregation algorithm. Maximum and minimum values are given to the most important parameters for land-surface processes. Averaged values are given to the parameters which have less impact on land-surface processes.

Parameter	Units	Minimum	Maximum	Average
Percentage of sand (s)	%			50
Percentage of clay (c)	%			50
Surface soil water content (SWC_s)	m^3m^{-3}	0.0	field capacity	
Total soil water content (SWC_d)	m^3m^{-3}	wilting point	field capacity	
Roughness length (z_0)	m	0.01	2.0	
Leaf area index (LAI)	m^2m^{-2}	0.5	6.0	
Minimum stomatal resistance ($R_{s_{min}}$)	sm^{-1}			140.
Radiation transpiration factor (R_{st})	Wm^{-2}			65.
Vapor transpiration factor (e_{st})				0.02
Temperature transpiration factor (T_{st})	K			298.
Wetness transpiration factor (W_{st})				1.0
Albedo (α)				0.15
Emissivity (ϵ)				1.0

Table 3: Interpolating functions used for aggregating different land-surface parameters.

Aggregated parameter	linear	trigonometric	parabolic	square root	logarithmic
Roughness length (z_0)	x				$1/ln(\frac{a}{z_0})^2$
Soil water content(W)	x	$sin(\frac{\pi}{2}x)$	$-0.7x^2+1.7x$	$1.1\sqrt{x}-0.1x$	
Leaf area index (LAI)	x	$sin(\frac{\pi}{2}x)$	$-x^2+2x$	$1.4\sqrt{x}-0.4x$	



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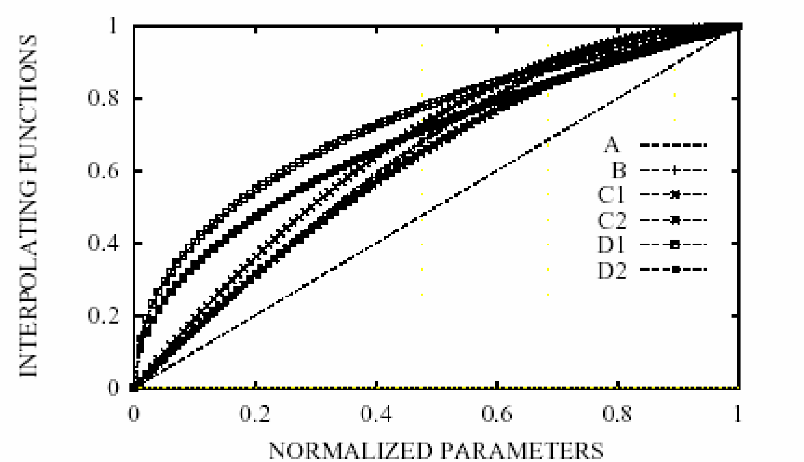
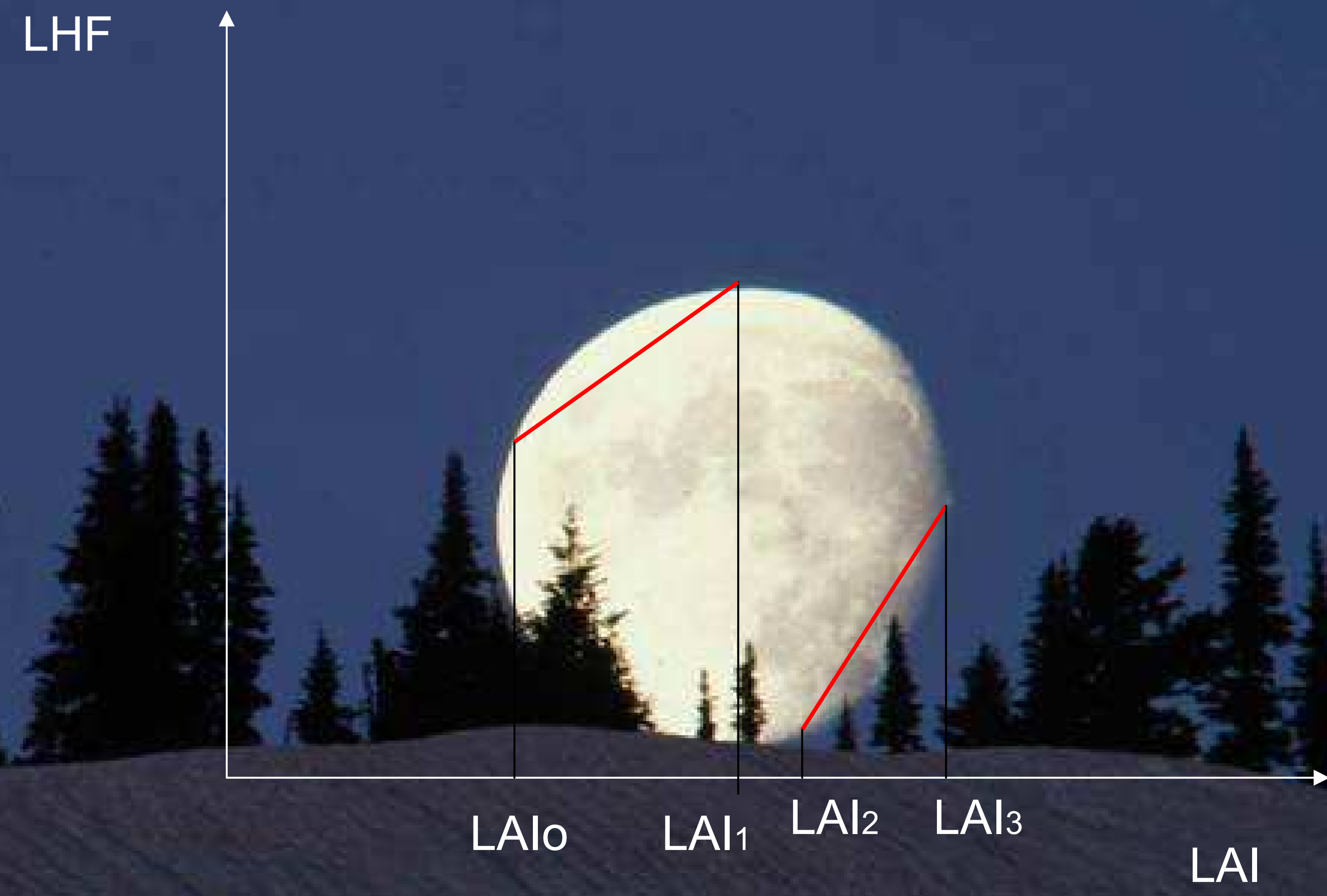
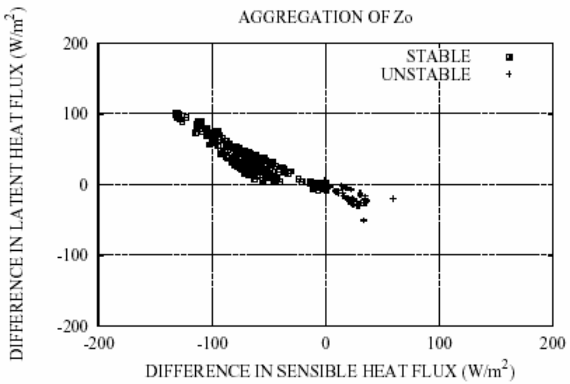
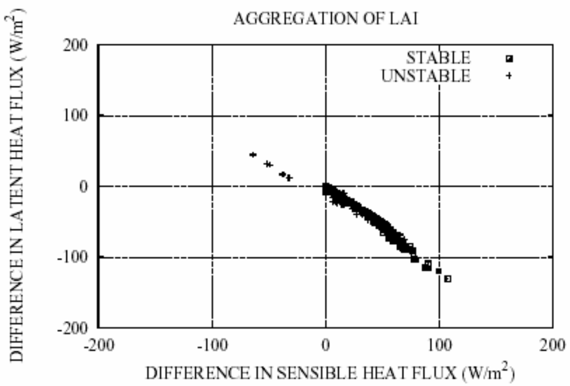


Heuristic approach: concave or convex shape of the surface flux wrt parameter







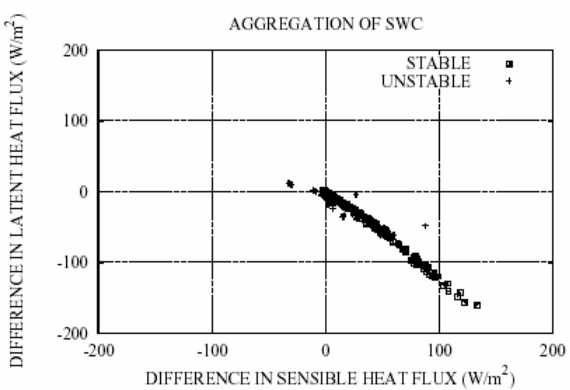


Table 4: Mean (μ) and standard deviation (σ) of differences between aggregated and averaged estimations of sensible heat fluxes (SHF), latent heat fluxes (LHF) and net radiative fluxes (RF) calculated with the different distributions of leaf area index (LAI), total soil water content (SWC_d) and roughness length (z_0) illustrated in Fig. 1. Linear interpolating functions were used to compute the effective parameters. The ground was covered with vegetation. Units are Wm^{-2}.

	PDF	μ^A_{LAI}	σ^A_{LAI}	$\mu^A_{SWC_d}$	$\sigma^A_{SWC_d}$	$\mu^A_{z_0}$	$\sigma^A_{z_0}$
SHF	1	21.3	34.0	21.4	34.9	-36.6	43.0
	2	8.2	13.3	8.3	13.8	-9.4	11.7
	3	0.7	1.7	0.8	1.4	-0.3	2.2
	4	0.5	1.9	0.6	1.7	-0.3	2.1
	5	4.4	10.1	3.3	8.8	-2.6	3.2
	6	4.1	6.8	4.2	7.3	-1.8	3.8
LHF	1	-23.8	35.5	-24.0	37.6	20.2	31.5
	2	-9.0	13.4	-9.3	14.3	5.3	8.6
	3	-0.8	1.3	-0.9	1.5	0.2	1.3
	4	-0.5	2.7	-0.6	1.4	0.2	1.4
	5	-5.3	10.1	-3.7	8.9	1.5	2.8
	6	-4.4	6.8	-4.6	7.0	1.1	2.6
RF	1	2.6	5.0	2.4	6.2	16.2	16.8
	2	1.0	2.0	0.9	2.3	4.1	4.5
	3	0.2	0.7	0.1	0.2	0.1	1.3
	4	0.0	1.0	0.0	0.5	0.1	0.8
	5	0.7	2.5	0.2	3.0	1.1	1.1
	6	0.4	1.3	0.4	1.1	0.7	1.6

Table 5: Mean (μ) and standard deviation (σ) of differences between aggregated and averaged estimations of sensible heat fluxes (SHF), latent heat fluxes (LHF) and radiative fluxes (RF) calculated with different distributions illustrated in Fig.1 and different interpolating functions (A-linear, B-trigonometric, C1-parabolic, D1-square root) for the leaf area index (LAI). The ground was covered with vegetation. Units are Wm^{-2}.

	PDF	μ^A_{LAI}	σ^A_{LAI}	μ^B_{LAI}	σ^B_{LAI}	μ^{C1}_{LAI}	σ^{C1}_{LAI}	μ^{D1}_{LAI}	σ^{D1}_{LAI}
SHF	1	21.3	34.0	3.4	17.8	-0.7	16.5	-1.4	16.4
	2	8.2	13.3	1.0	7.0	-0.7	6.7	-0.1	6.8
	3	0.7	1.7	0.0	1.2	-0.1	1.2	0.1	1.2
	4	0.5	1.9	-0.5	2.1	-0.6	2.1	0.2	1.8
	5	4.4	10.1	2.7	8.5	1.6	7.7	-1.0	6.7
	6	4.1	6.8	-1.0	4.1	-1.9	4.3	0.5	4.0
LHF	1	-23.7	35.5	-4.3	18.5	0.3	17.2	1.0	17.5
	2	-9.0	13.4	-1.2	6.8	0.7	6.6	0.0	6.7
	3	-0.8	1.3	0.0	0.7	0.2	0.8	-0.1	0.7
	4	-0.5	2.7	0.6	2.2	0.7	2.2	-0.2	2.3
	5	-5.3	10.1	-3.4	8.2	-2.1	7.0	0.9	5.7
	6	-4.4	6.8	1.3	3.7	2.2	3.8	-0.5	3.5
RF	1	2.6	5.0	1.0	3.5	0.6	3.2	0.5	3.2
	2	1.0	2.0	0.2	1.5	0.6	1.6	0.2	1.5
	3	0.1	0.7	0.0	0.7	0.0	0.7	0.0	0.7
	4	0.0	1.0	-0.1	1.0	-0.1	1.0	0.0	1.0
	5	0.7	2.5	0.6	2.3	0.4	2.2	0.1	1.8
	6	0.4	1.3	-0.1	1.1	0.0	1.3	0.1	1.2

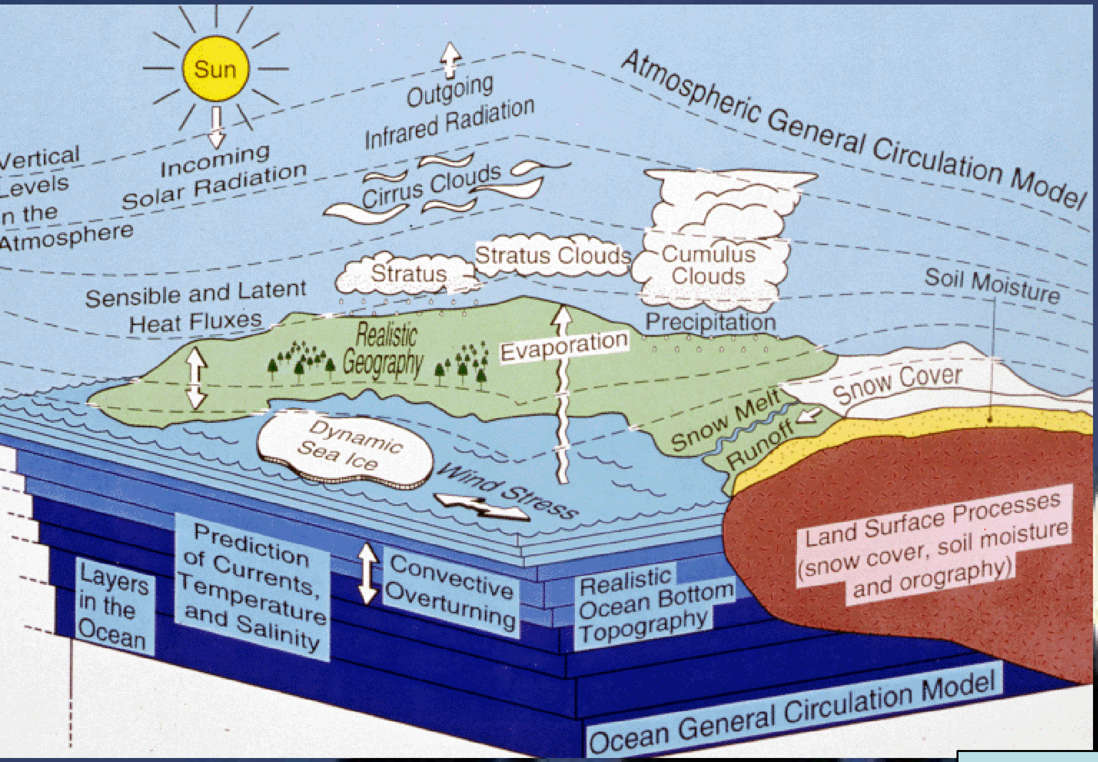
More in (Rodriguez and Avissar, 1999)

Conclusions on parameter aggregation

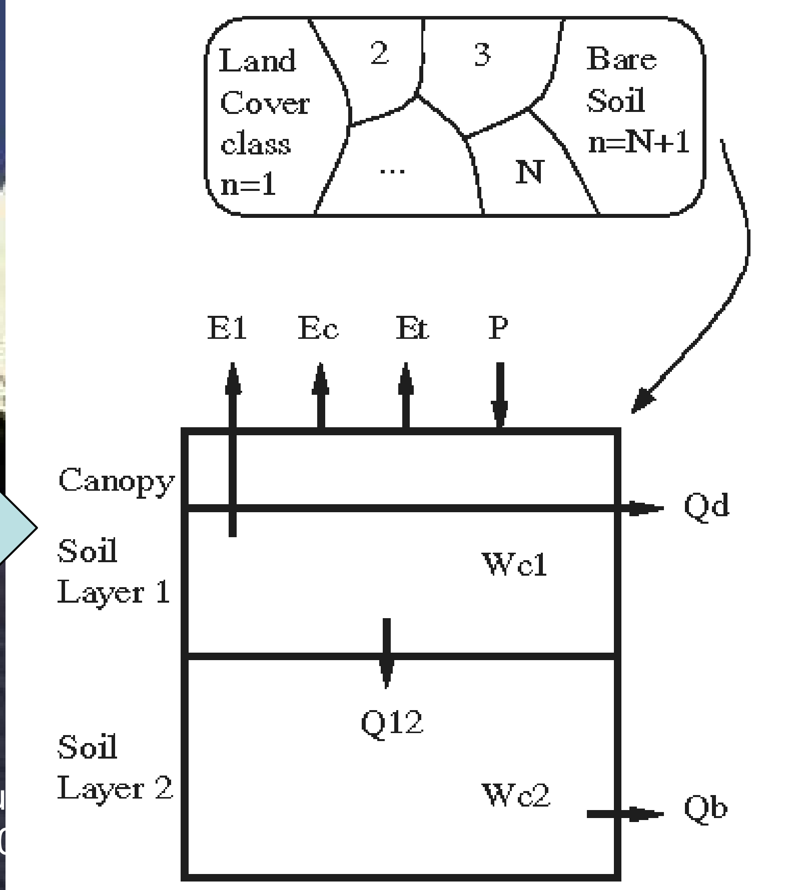
- Relation between most land-surface parameters and heat fluxes is non-linear.
- Thus, not surprisingly, when a linear function is used to aggregate these parameters for the calculation of mean land-surface heat fluxes, a relatively large error can be generated.
- The process of linear aggregation of, e.g., LAI and SWC enhances/ decreases latent/sensible heat fluxes. This is general for all PDFs studied in this work (more distributions not shown here confirm this point), being the upper limit for differences the extreme case of the double Dirac's delta distribution.

- Using non-linear functions for that purpose can, in most cases, significantly reduce this error. This is particularly true for those parameters which relate to the fluxes independently of the atmospheric stability, LAI and soil water content. However, finding a non-linear function for the roughness length, which has a different impact on the surface heat fluxes under stable and unstable atmospheric conditions, is more complicated.
- Validations, however, are restricted to the particular conditions of the site under study. Some atmospheric conditions result to be more sensitive than others to the procedure for computing surface heat fluxes.
- While the type of aggregating function used for the various parameters is typically independent of the magnitude of the surface fluxes, it is nevertheless important to calibrate these functions under those environmental conditions resulting in strong heat fluxes (e.g. high solar radiation). This is because the non-linear effects then become more important.

Surface as mosaic of tiles (Avissar & Pielke, 1989)



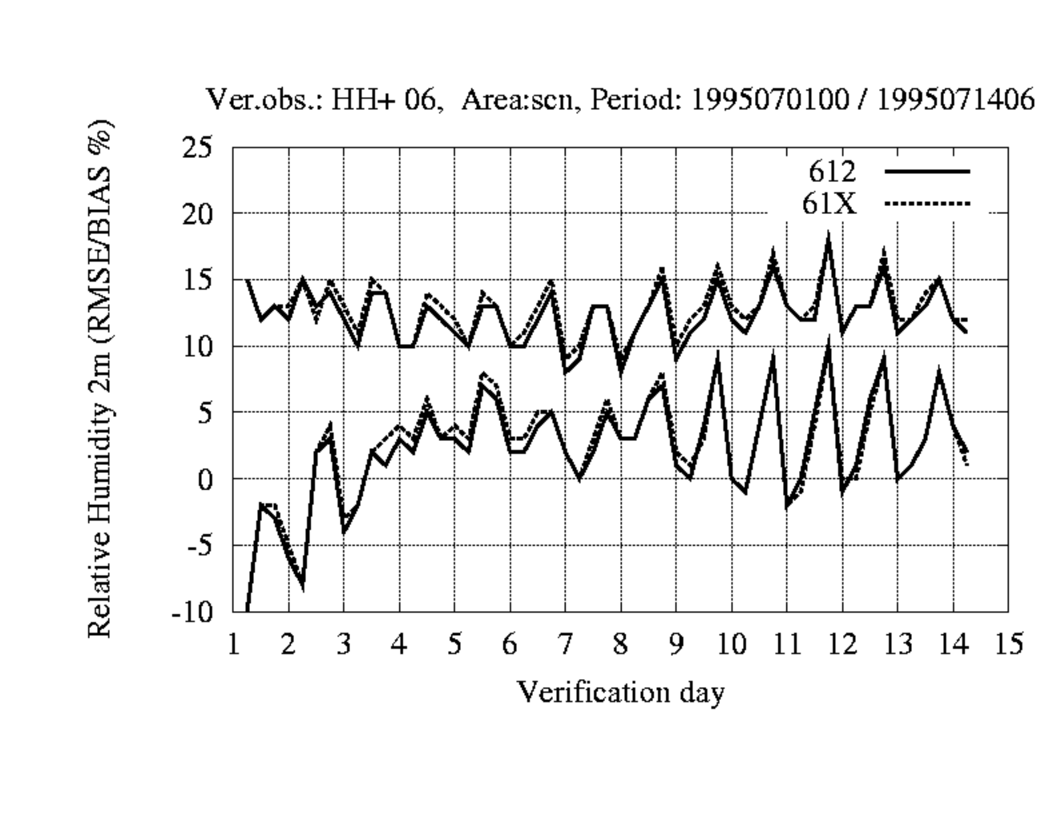
The rest of the physics only "sees" averaged surface fluxes

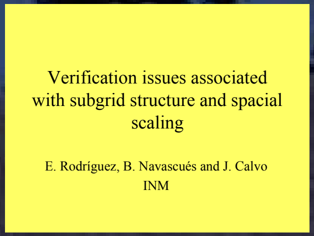


Each tile only interact with the lowest model layer: no horizontal interaction between tiles

How big is the impact of tiling?

- In general small in term of scores of screen variables
- However, it can be very relevant when verifying!





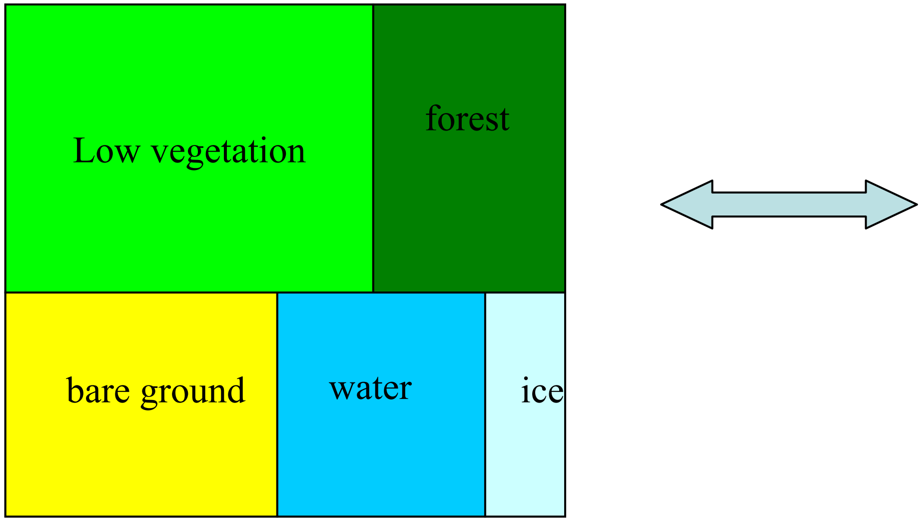
Scales of model forecasts and observation networks (I)

- Verification of deterministic forecasts against observations is very much **conditioned by the represented spacial scales** of both forecasts and observation network.
- Model output is usually supplied in the form of grid-point values. However, those values should be considered as a grid box areal quantities when dealing with **variables that area implicitly areal** (Skelly and Henderson-Sellers, 1996). This is the case of variables resulting from subgrid parameterizations like precipitation, radiation, etc.
- Observations, on the other hand, are frequently affected by the **problem of representativeness**. Some observed variables are representative of large areas and are not very much influenced by local conditions, whereas others show a remarkable horizontal variability.
- Usually, the variables close to the ground (like 2-metre temperature, 10-metre wind) inherit their big **horizontal variability from the high heterogeneity of the land surface**. Other variables, like precipitation, inherit their high horizontal variability from the scales of the intervening precipitating clouds.

Ideal verification of model output against conventional observations should consist of:

- The model variable is horizontally interpolated to the observation point.
- The model variable should be vertically corrected to account for the difference between model orography and the real height of the station.
- Some quality control should be performed to disregard disparate values coming from incorrect observations.
- Approaching of model and observation scales

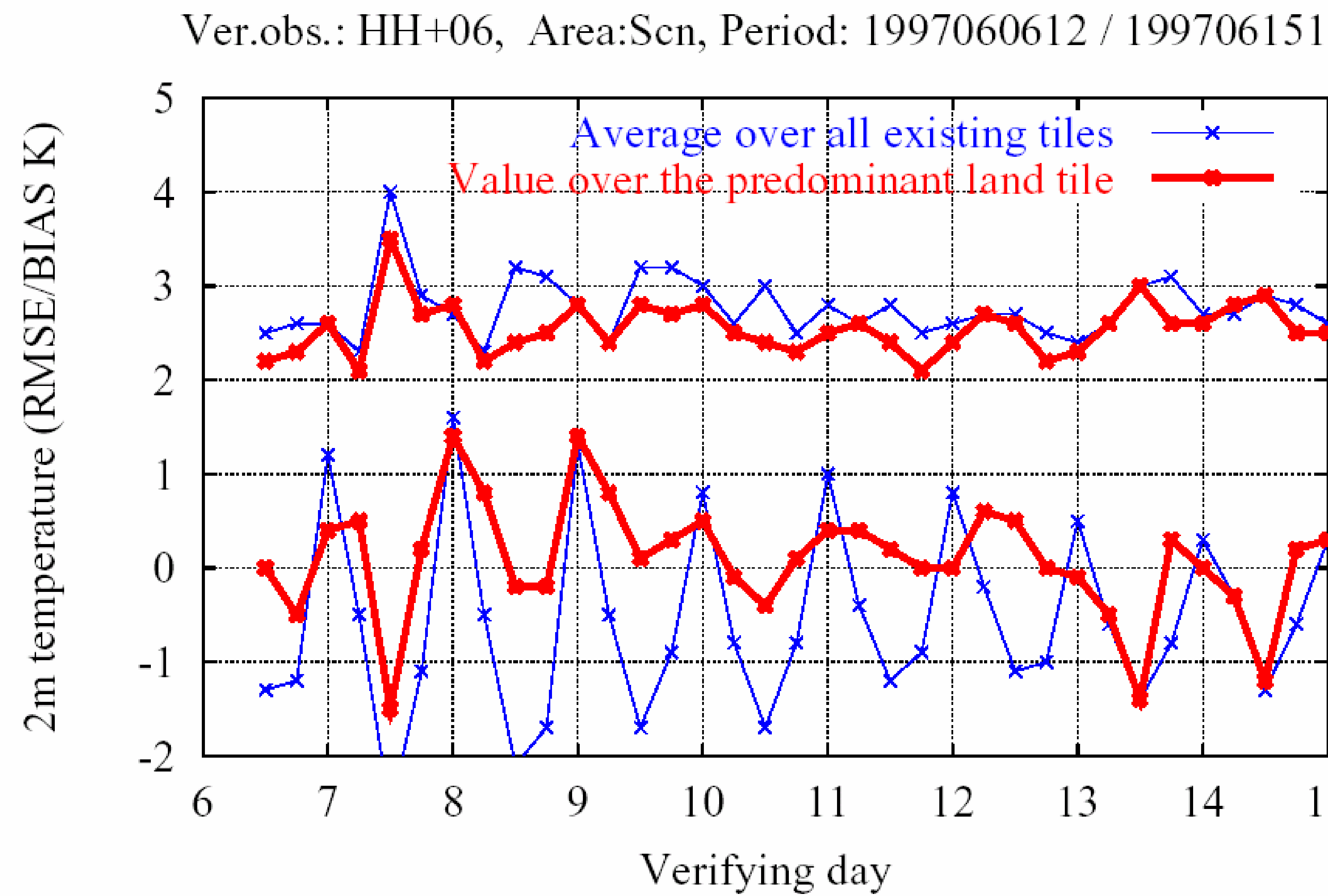
Subgrid structure in the surface model treatment



Which T2m?: $T_{2m} = \sum_{I=3}^{5} f_i T_{i2m}$ $T_{2m} = \sum_{I=1}^{5} f_i T_{i2m}$ $T_{2m} = T_{4_{2m}}$

Postprocessing and verification of T2m and RH2m

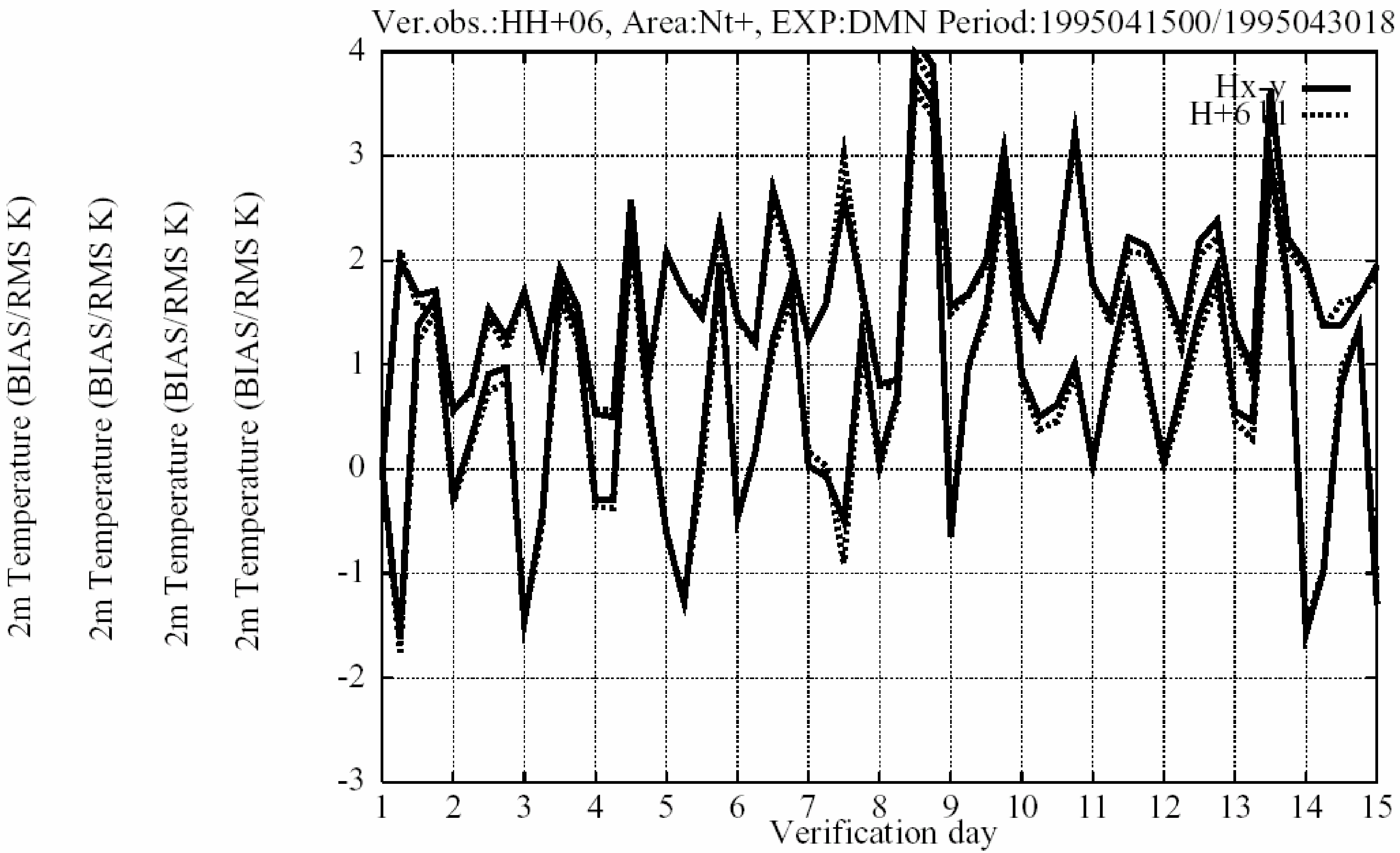
- The complexity of the surface scheme allows many possibilities for postprocessing and verifying against obs.
- Surface analysis: compare observations against output of observation operator (vertical correction+average over land tiles)

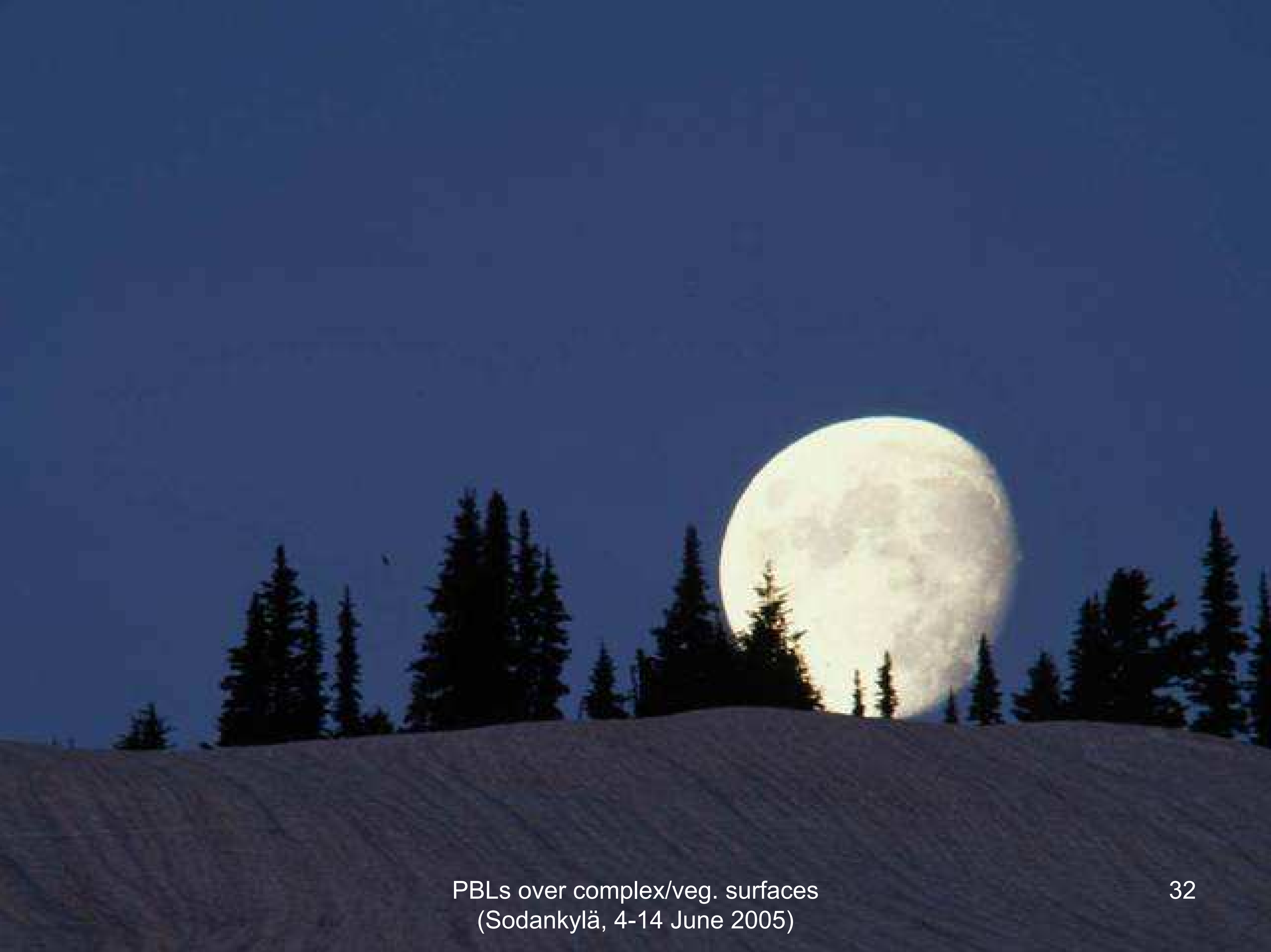


Ver.obs.: HH+06, Area:Scn, Period: 1997060612 / 199706151
2m temperature (RMSE/BIAS K)
Average over all existing tiles
Value over the predominant land tile
Verifying day
5
4
3
2
1
0
-1
-2
6
7
8
9
10
11
12
13
14

Verification of T2m and RH2m

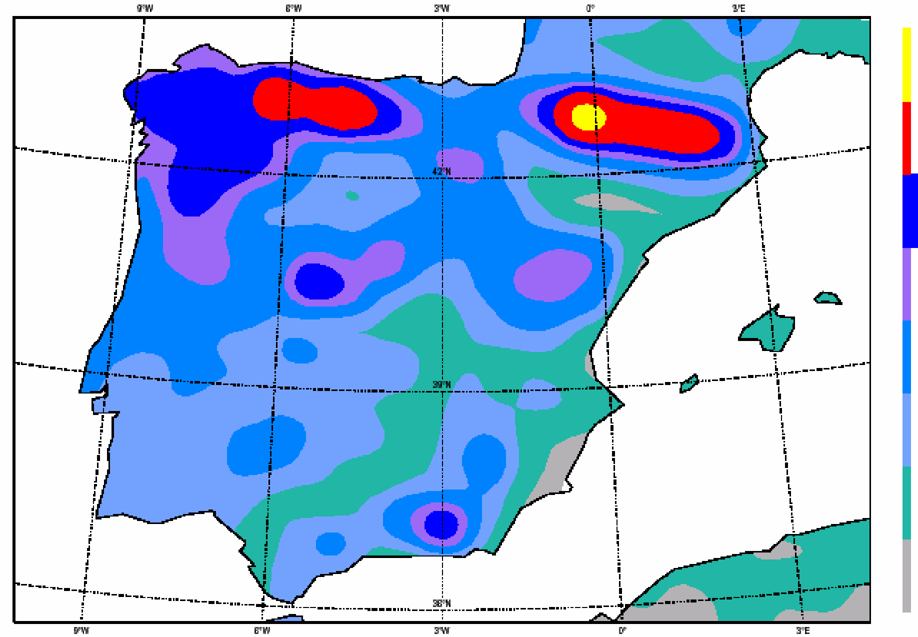
(vertical correction)



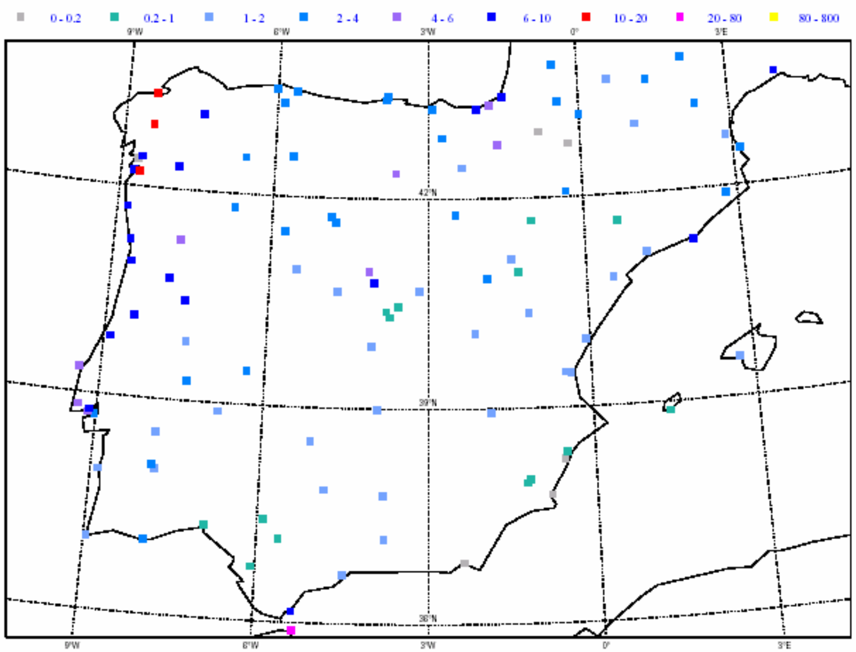


Verification of precipitation using synoptic stations

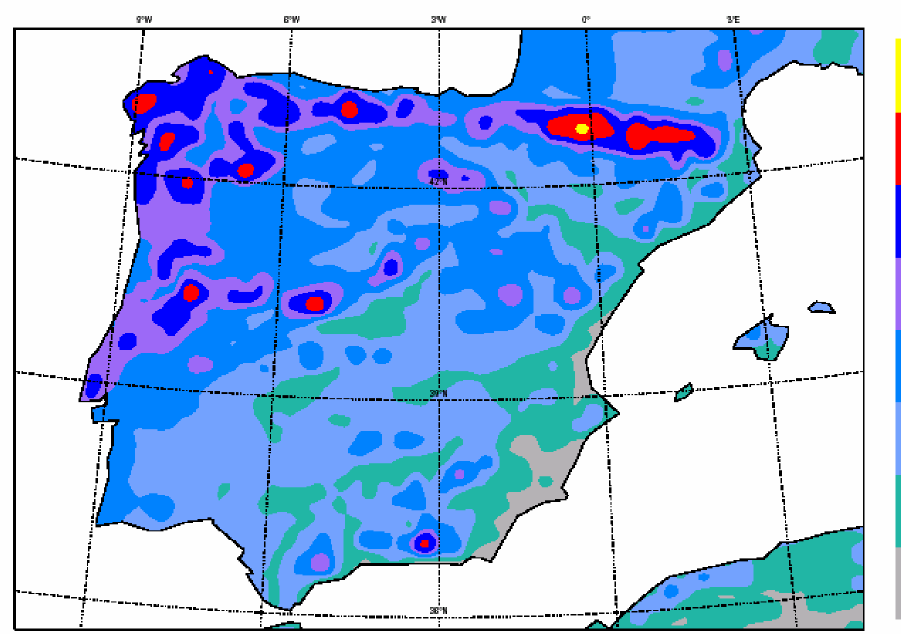
31/10/2002 00z HIRLAM H+ 24 Valid: 01/11/2002 00z
OPA Total precipitation-Oct 2002 mean (mm/day

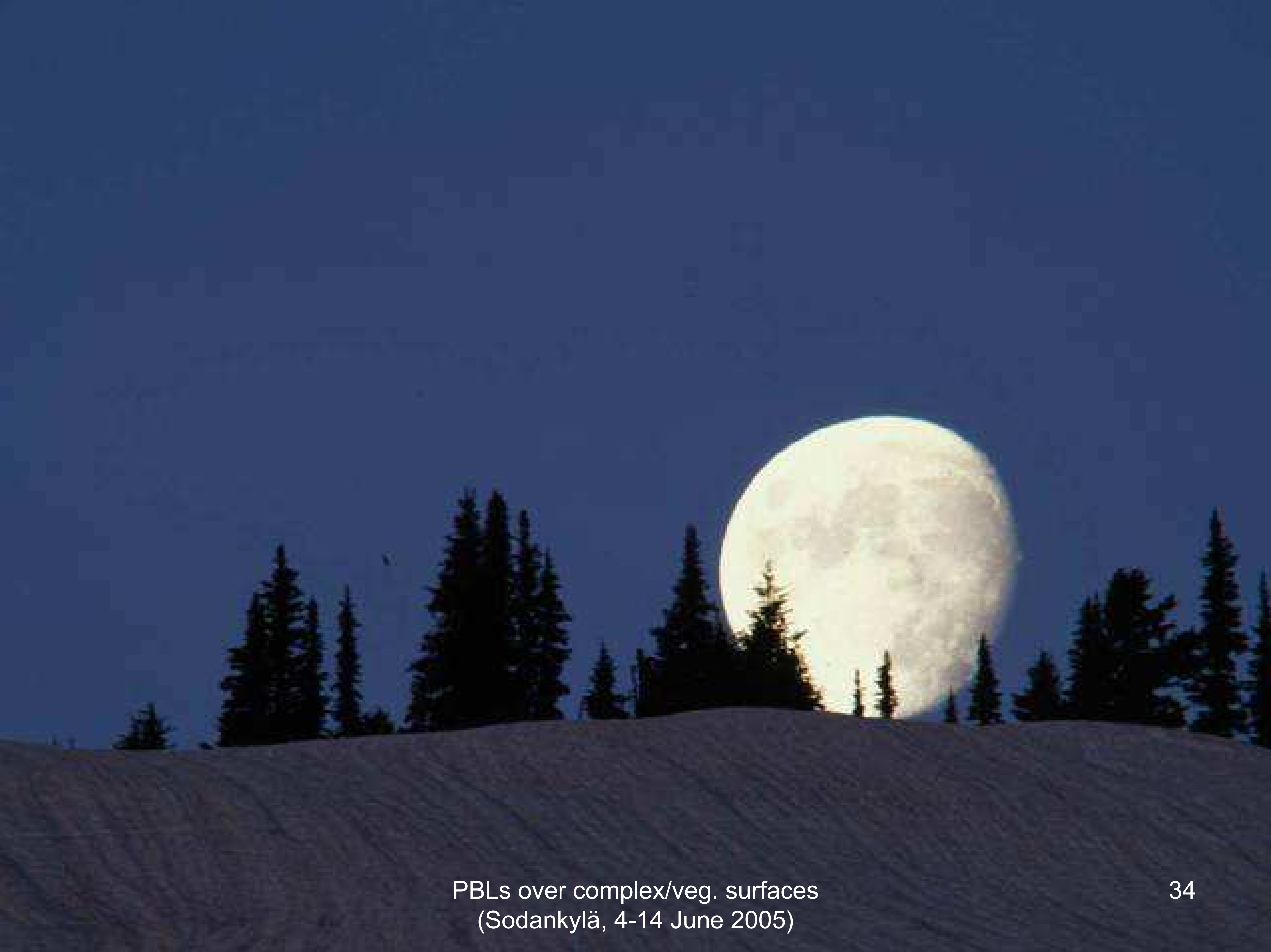


GTS SYNOP obs - Oct 2002 mean

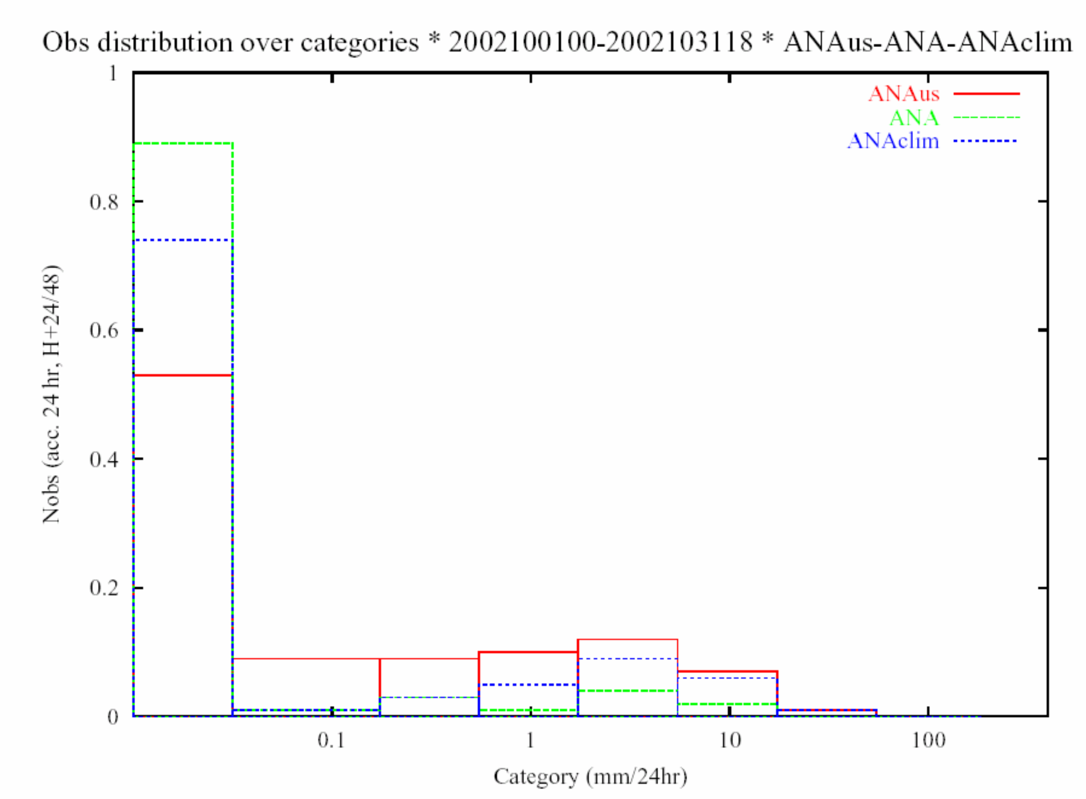


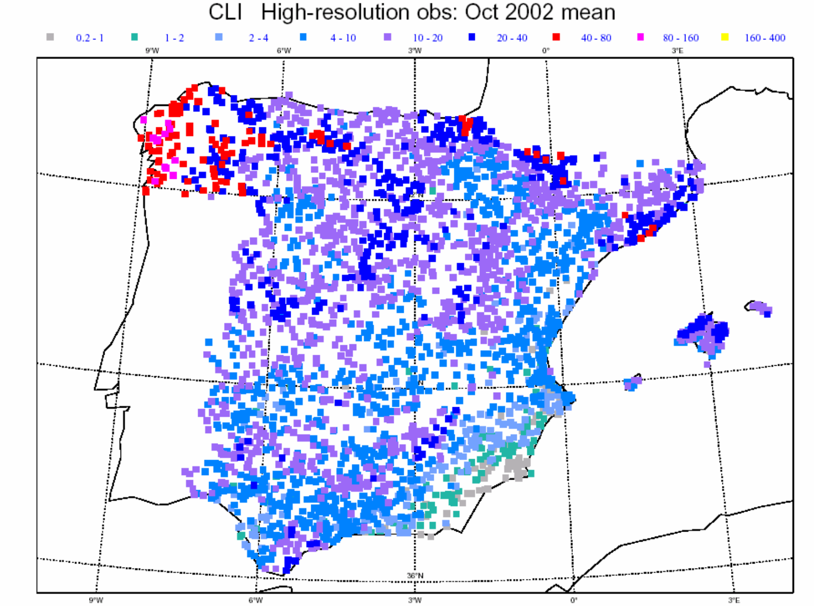
31/10/2002 00z HIRLAM H+ 24 Valid: 01/11/2002 00z
H62 Total precipitation-Oct 2002 mean (mm/day

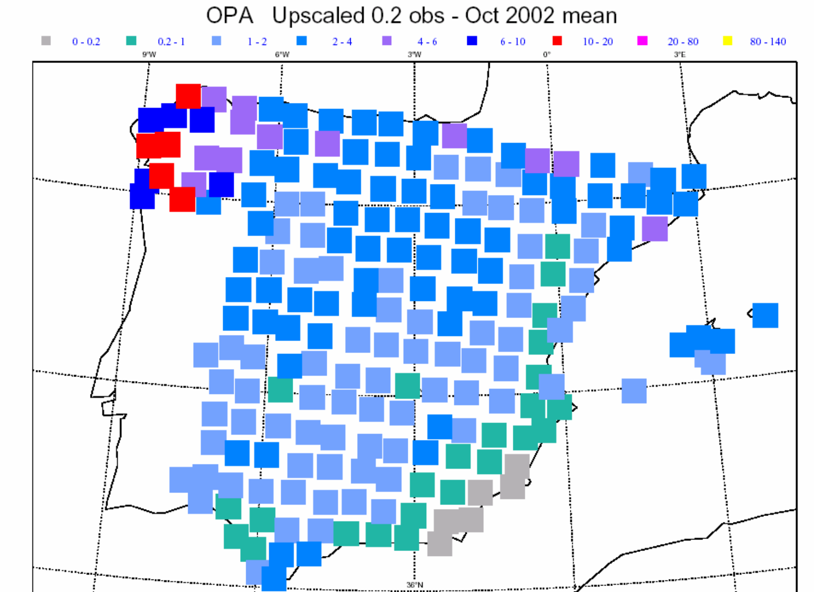


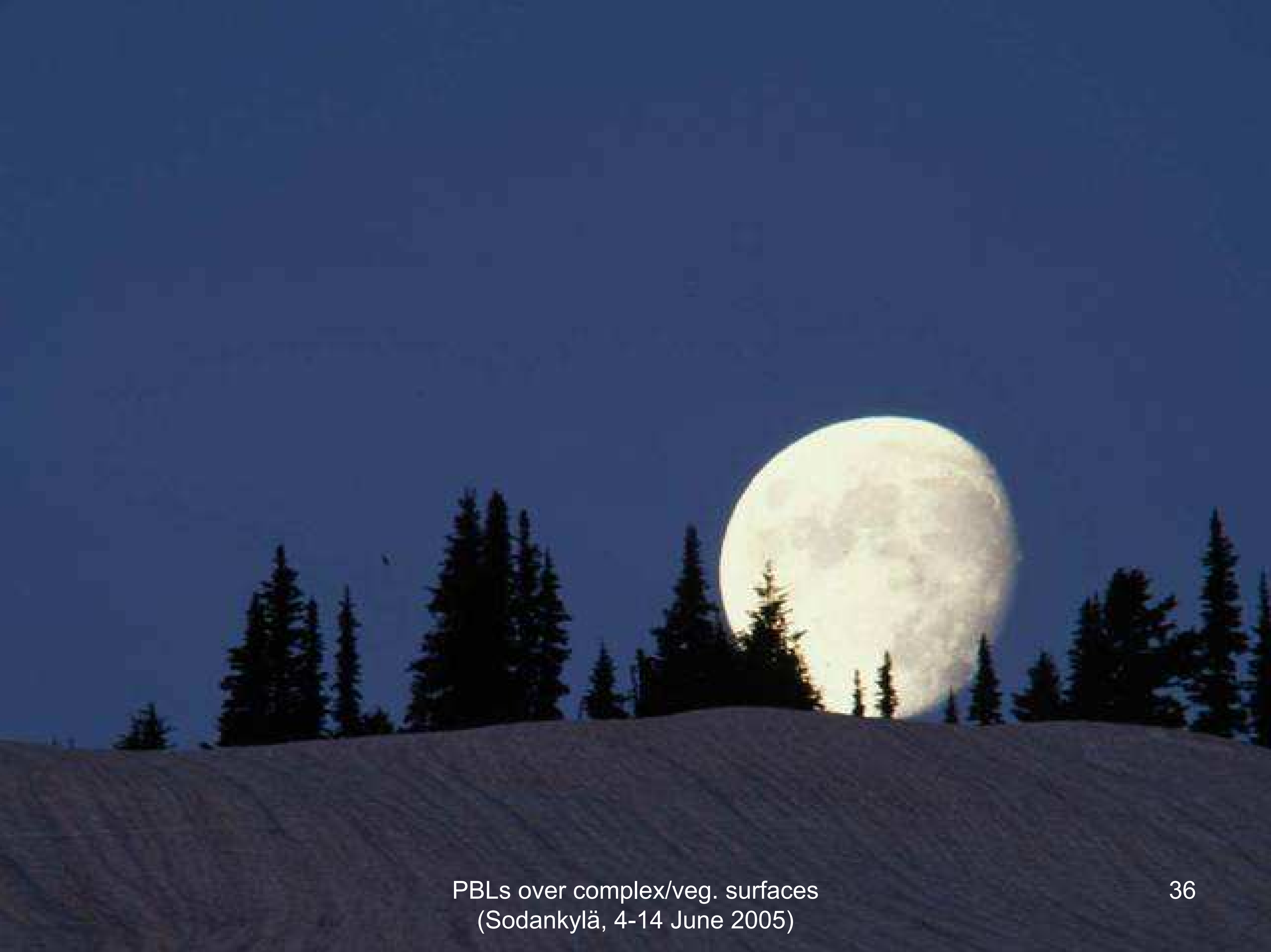


Verification of precipitation by scaling a very dense observation network (I)







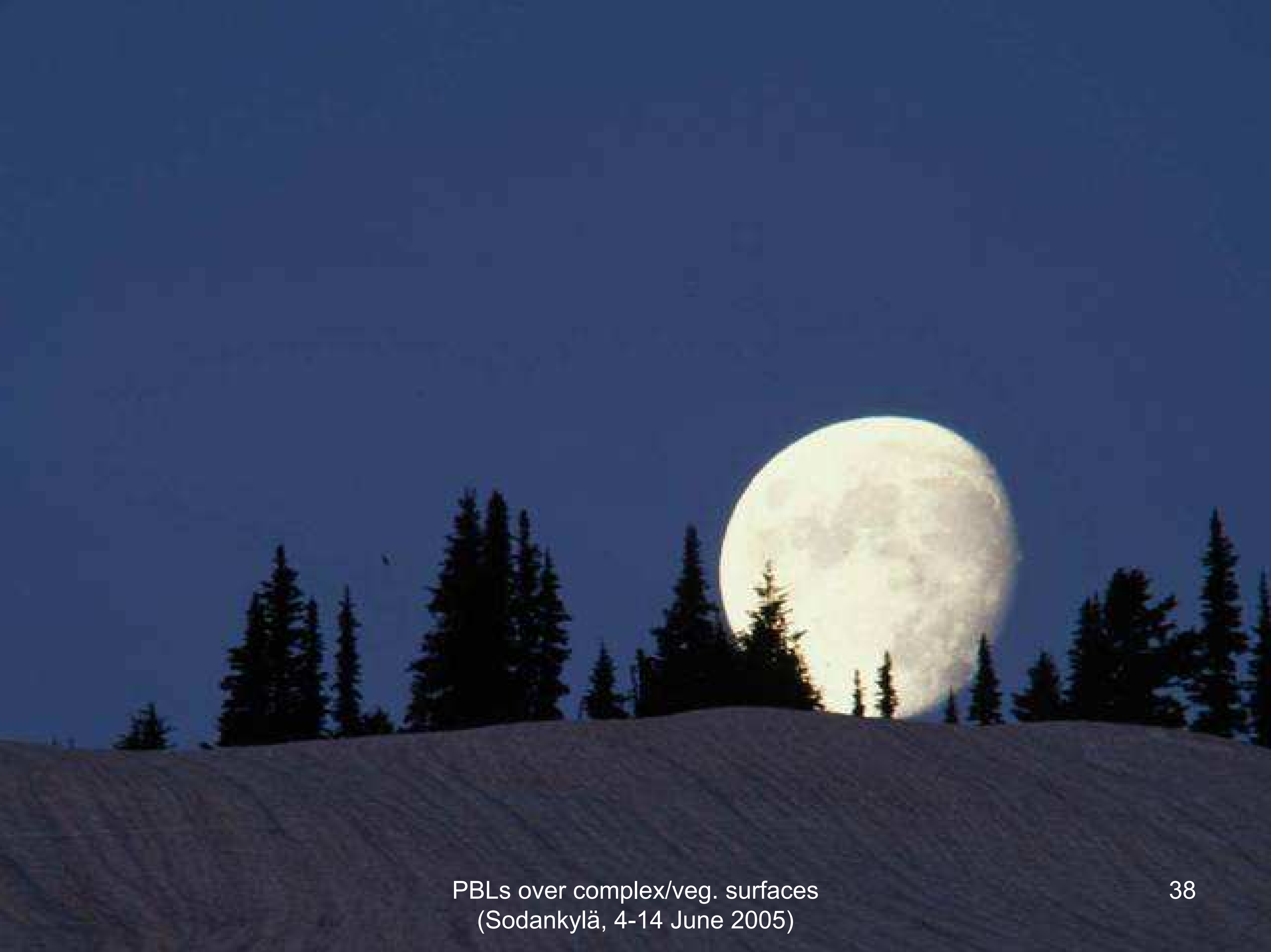


Verification of precipitation by scaling a very dense observation network (II)

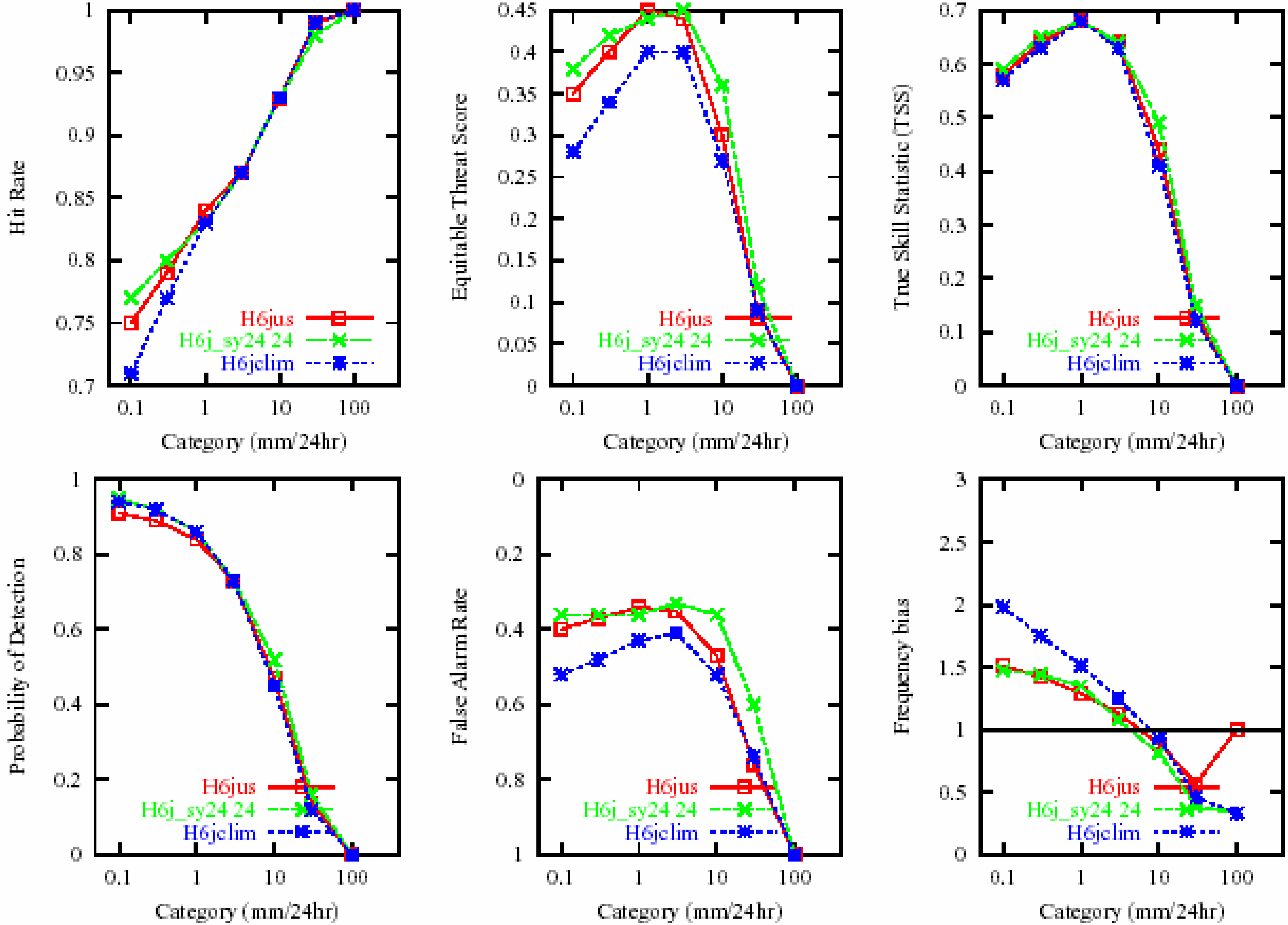
- Frequency Bias Index (FBI) =(a+b)/(c+d). It measures the event frequency and has value one for a perfect forecast, and larger (smaller) than one if the system is over (under)forecasting. Bias alone conveys no information about skill.
- Equitable Threat Score (ETS) is the TS rendered equitable by taking away the random forecast R(a)= (a+b)\cdot(a+c)/(a+b+c+d). ETS=(a-R(a))/(a-R(a)+b+c). It ranges from 1 (perfect forecast) to 0 (chance and constant forecast).
- True Statistics Skill (TSS)=(ad-bc)/(a+c)(b+d). The TSS can also be written as the probability of detection (H=a/(a+c)) minus the probability of false detection (F=b/(b+d)): TSS=H-F. It ranges from 1 (perfect forecast) to -1.

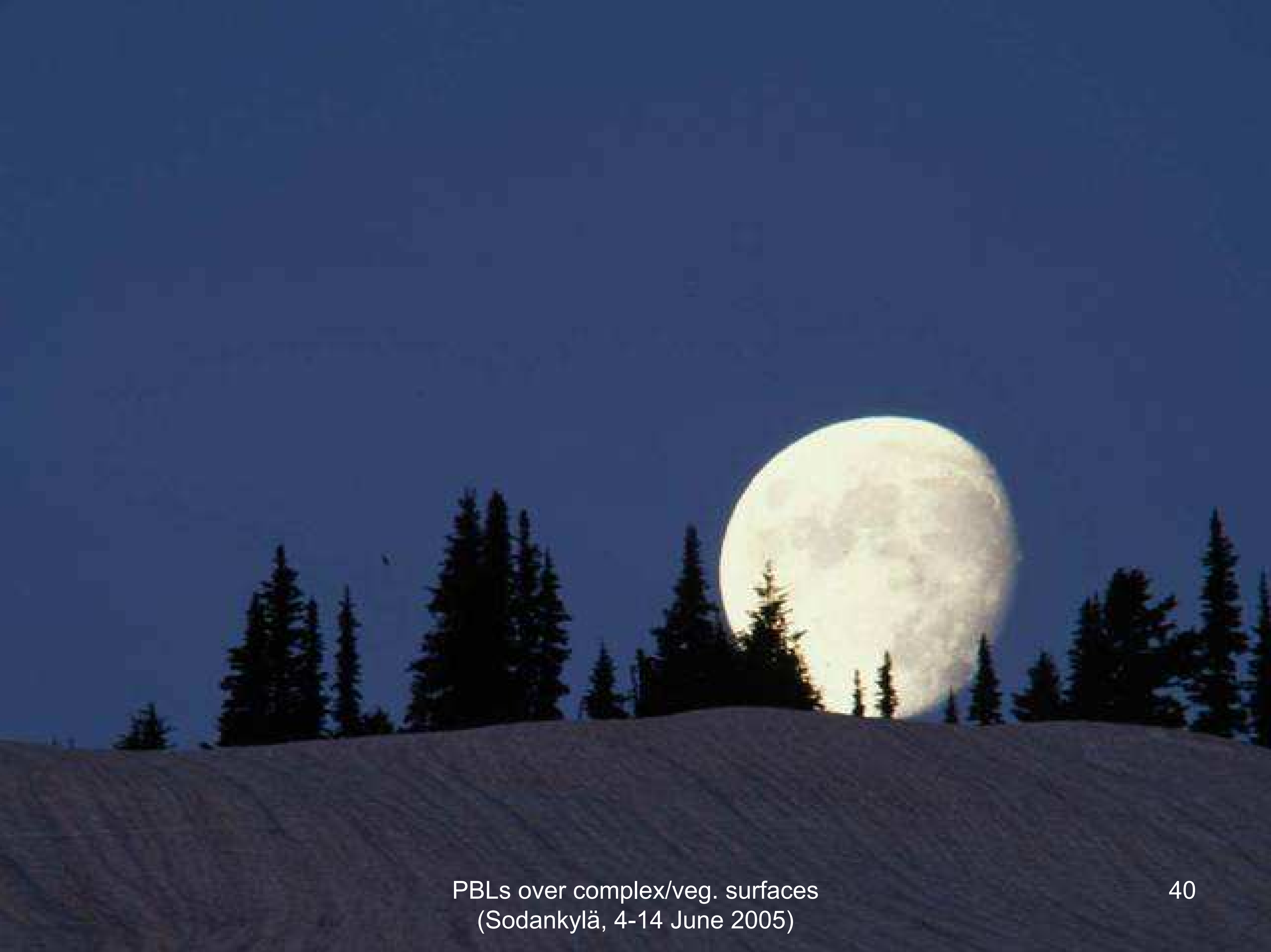
Table 1: Contingency table for observed and forecasted precipitation categories

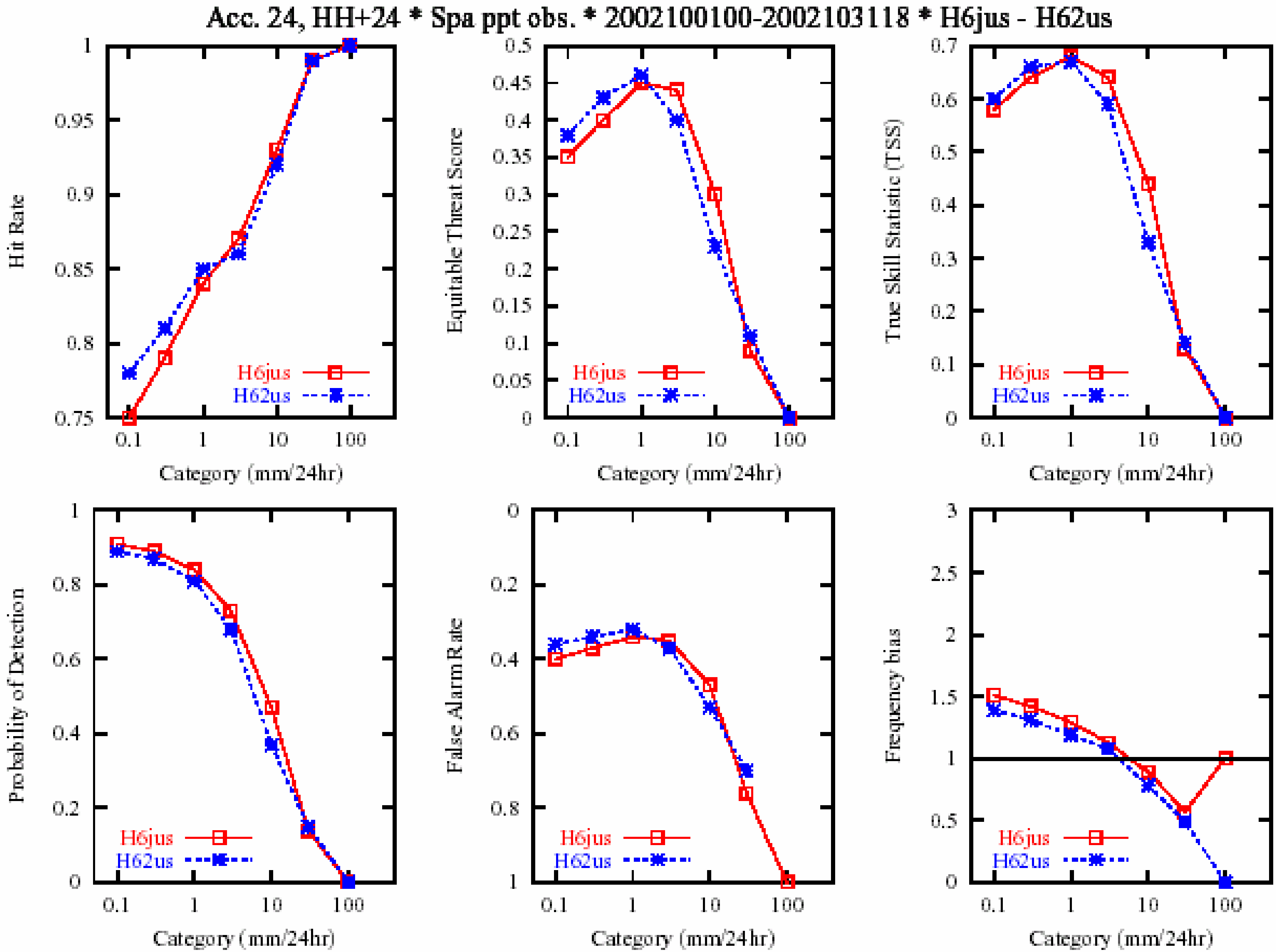
	Observed YES	Observed NO	Total
Forecasted YES	a (hit)	b (false alarm)	a+b
Forecasted NO	c (miss)	d (correct rejection)	c+d
Total	a+c	b+d	a+b+c+d=n



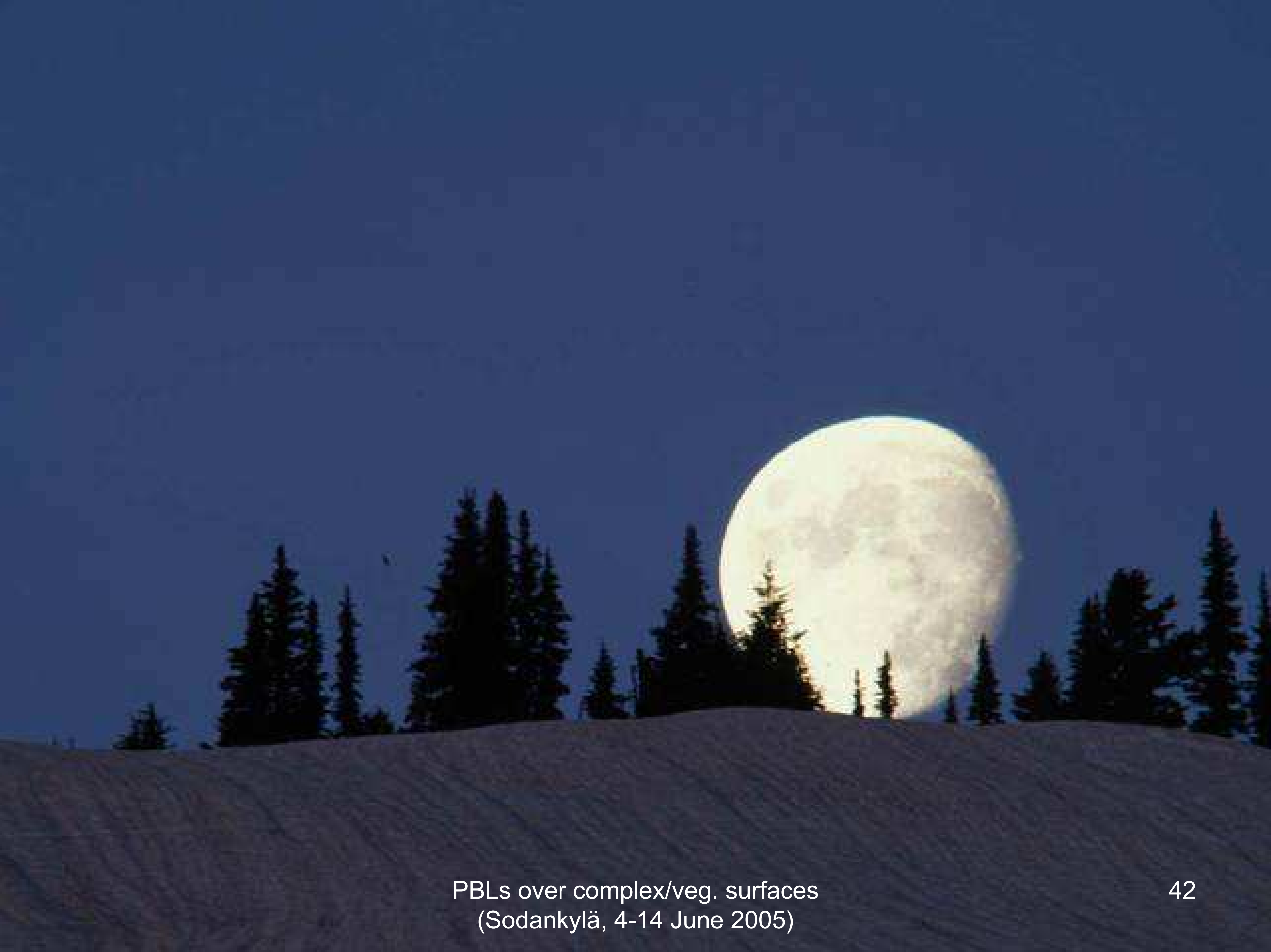
Acc. 24, HH+24 * Spa ppt obs. * 2002100100-2002103118 * H6jus-H6j_sy24-H6jclim

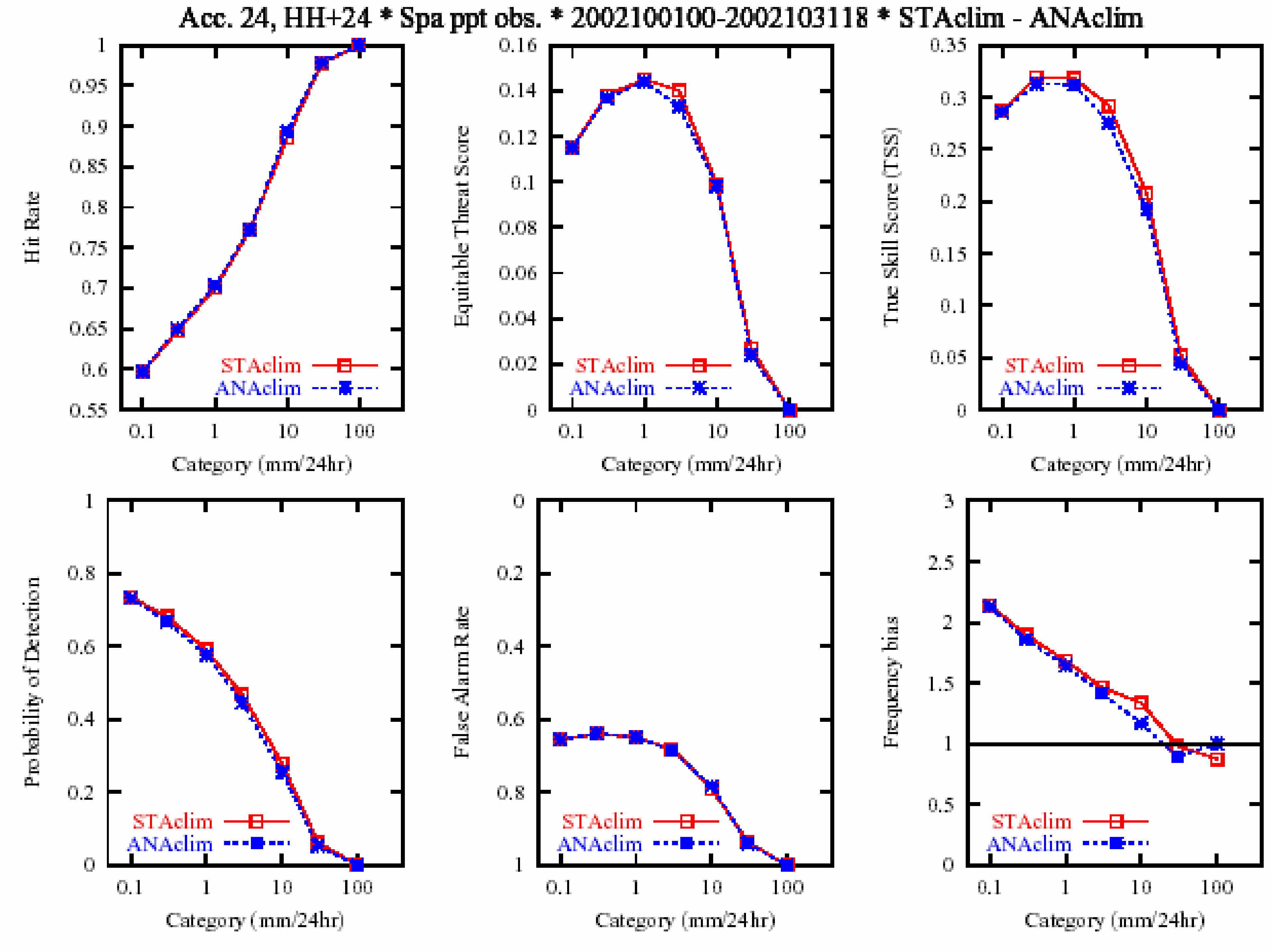


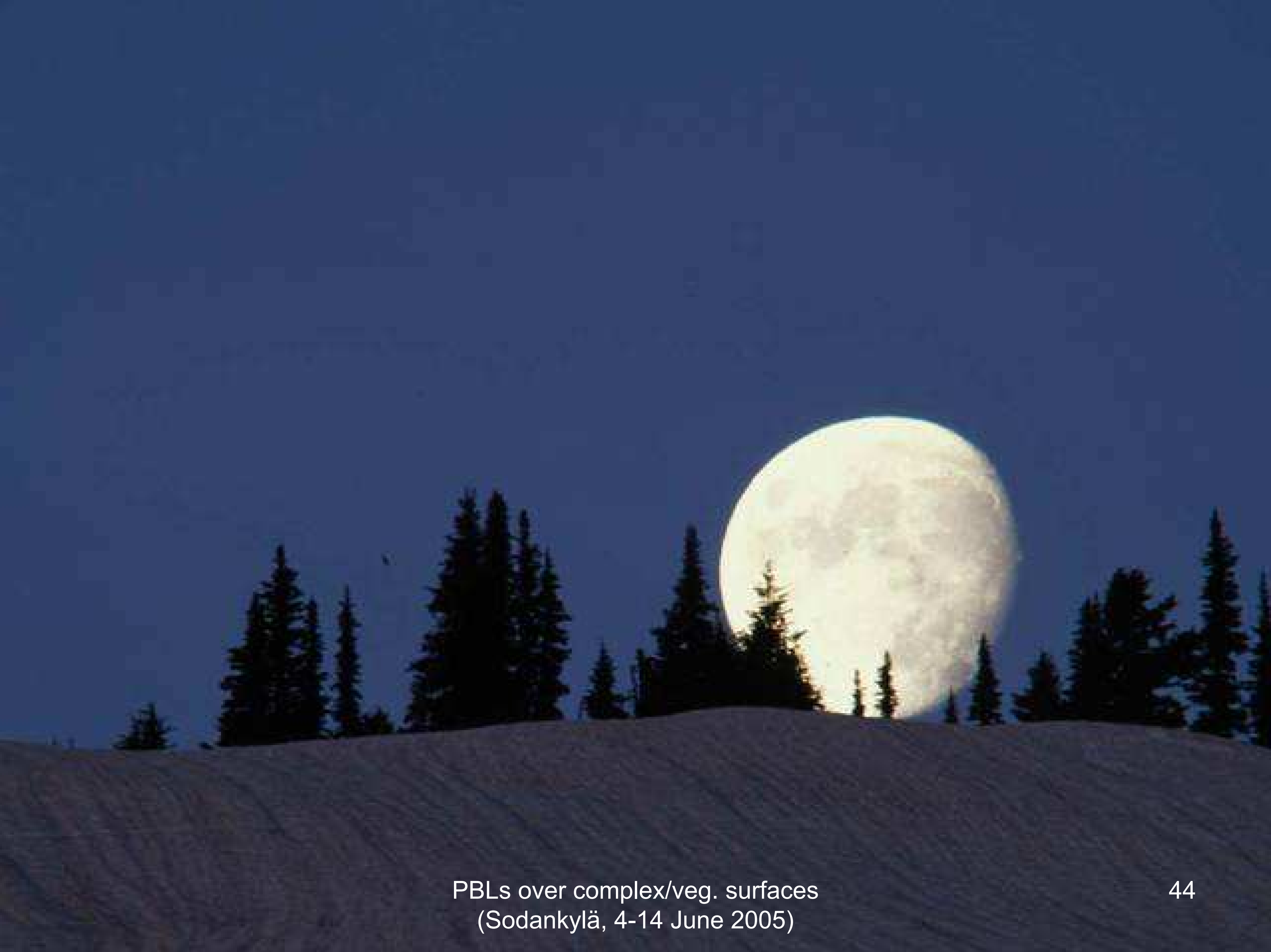




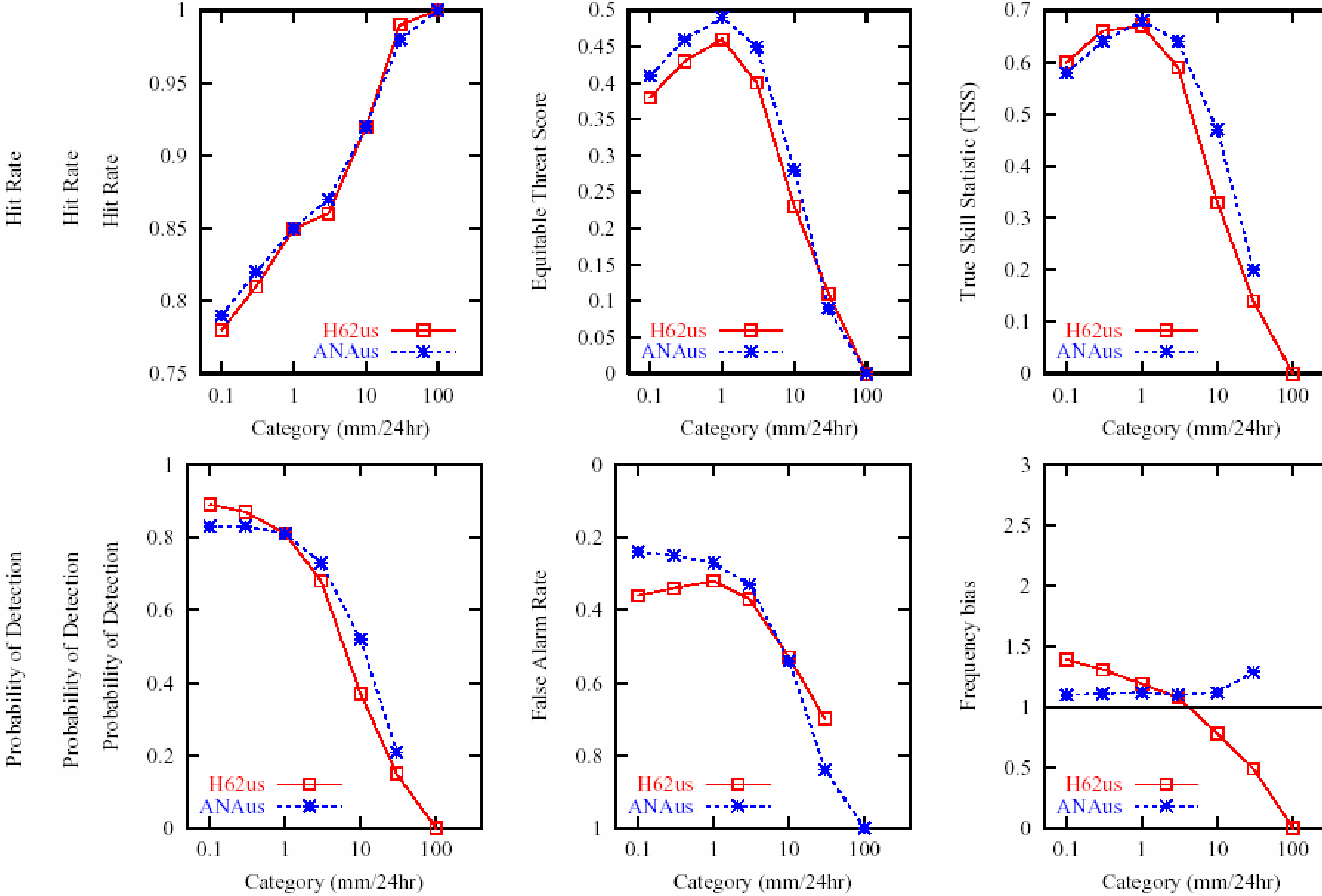
Acc. 24, HH+24 * Spa ppt obs. * 2002100100-2002103118 * H6jus - H62us
Hit Rate
Equitable Threat Score
True Skill Statistic (TSS)
Probability of Detection
False Alarm Rate
Frequency bias
Category (mm/24hr)
H6jus
H62us




Acc. 24, HH+24 * Spa ppt obs. * 2002100100-2002103118 * STAclim - ANAclim
Hit Rate
Equitable Threat Score
True Skill Score (TSS)
Probability of Detection
False Alarm Rate
Frequency bias
Category (mm/24hr)
STAclim
ANAclim



Acc. 24, HH+24 * Spa ppt obs. * 2002100100-2002103118 * H62us - ANAus



CONCLUSIONS

- The new surface scheme has a complexity which is lost during the postprocessing/ verification: (i) Vertical correction and (ii) distinction between grid average (over all/land tiles) screen variables.
- Approaching of model/obs scales → upscaling of precipitation data when a dense obs. network is used
- Usage of very dense observation network to validate new code updates. The usage of only synoptic stations could be misleading.

Outline

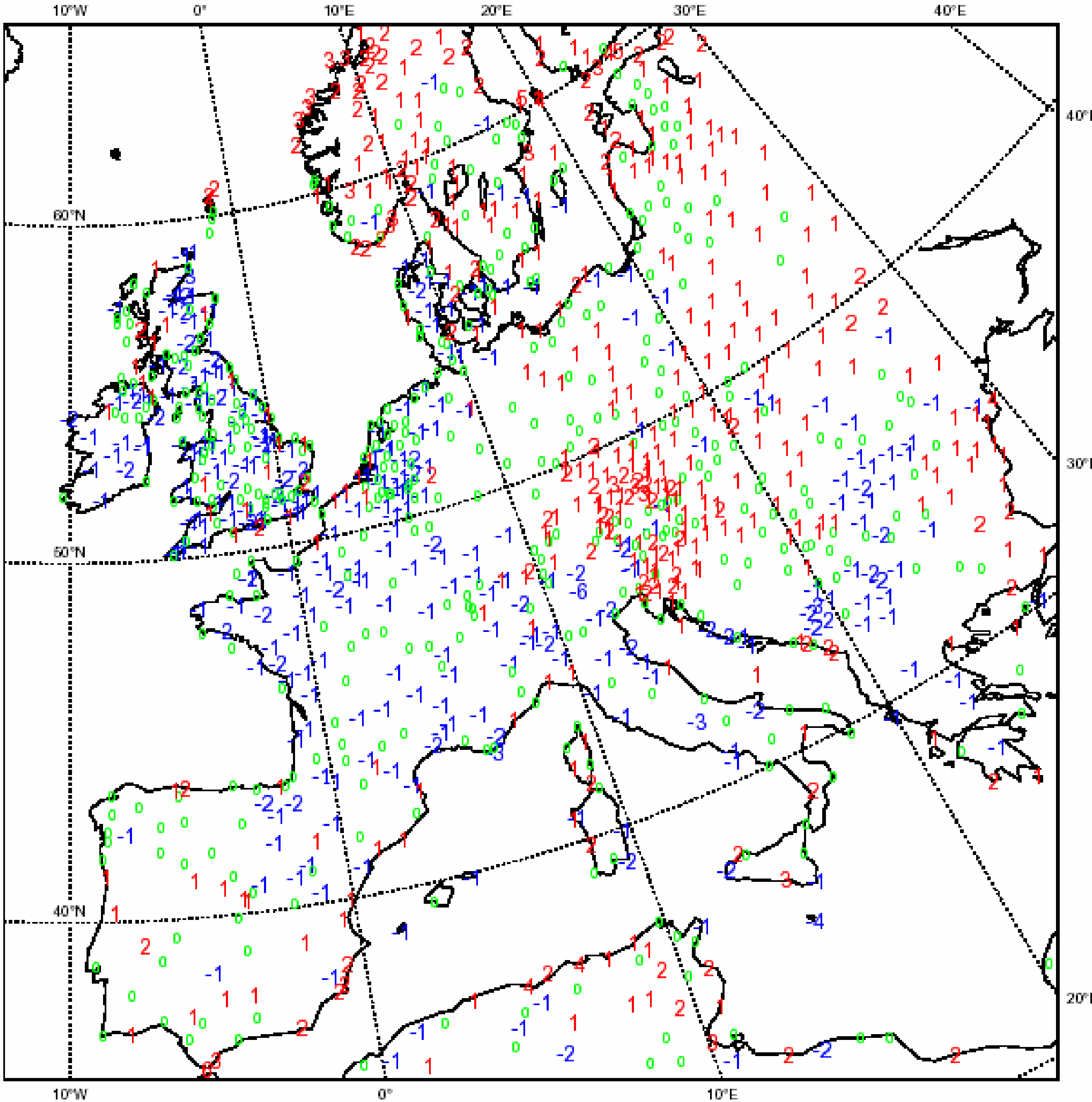
- Why surface parameterization is important?
- Which are the distinct features of surface/atmosphere interaction?
- How important are the different surface parameters?
- Treatment of surface heterogeneity. Aggregation. How big is the impact of tiling?
- How are surface schemes validated?
- Physiographic description. ECOCLIMAP. How big is the impact of physiography?
- Assimilation of surface variables. Case of soil moisture. ELDAS experience. How big is the impact of soil moisture?
- HIRLAM surface analysis. Future plans.
- HIRLAM surface parameterization. Future plans.

How are surface schemes validated?

- Operational model (3D) results vs observations: T2m, RH2, low level cloudiness
- Identification of missing/misrepresented physical mechanisms (e.g., soil water freezing, thawing). Evaluation of energy and water budget terms.
- Changing the model formulation. Sensitivity experiments.
- Comparison exercises with other schemes (e.g., PILPS, RhoneAggr, ELDAS).
- Identification of potential validation data sets and methodology for controlled validation (e.g., FIFE, NOPEX, EFEDA, HAPEX-MOBILHY, BOREAS, ...)
- Testing in “controlled” mode (ie, cutting most feedbacks)
  - 1-column 1-2 day integrations
  - Surface only integrations, 1 month to several years, forced to obs
  - 1-column integrations with data assimilation emulation, months/years
  - 3D relaxation integrations: A cheap proxy for data assimilation
- 3D testing with model and model/assimilation
- 3D testing with idealised configurations for further identification of feedback mechanisms
- Testing in seasonal/yearly experiments

(Thanks to P. Viterbo)

620 T2m BIAS(K) H+24 (against 140 105 2)



(Boone et al. 2003)

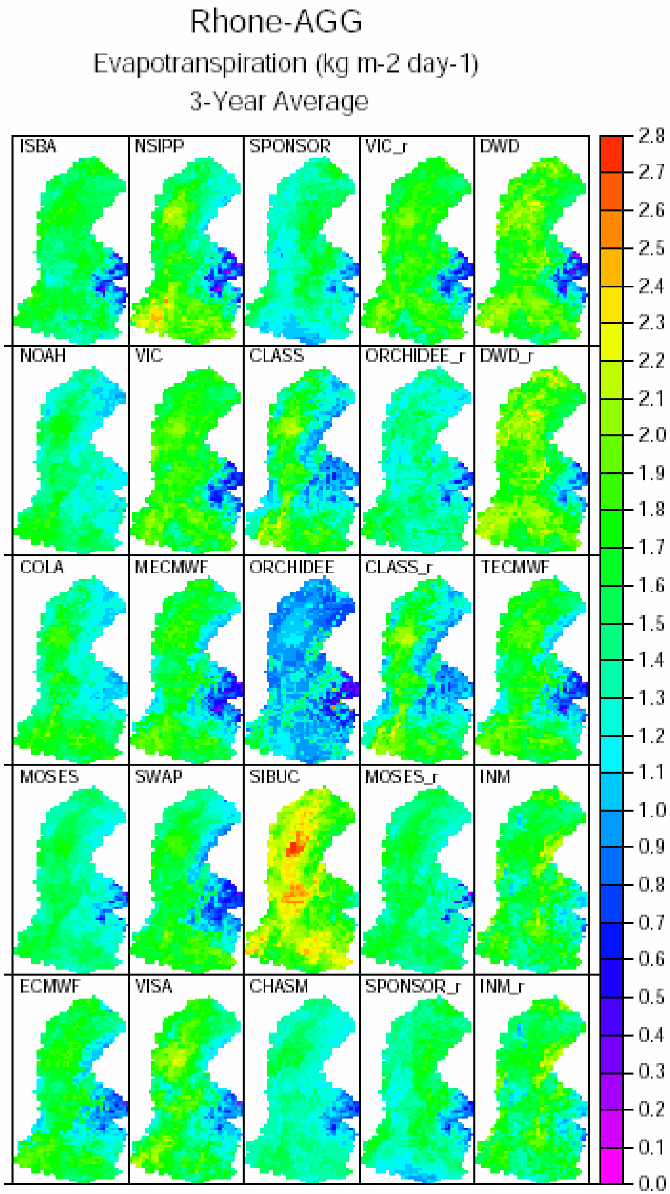


FIG. 3.2. The three-year average evapotranspiration (Evap).

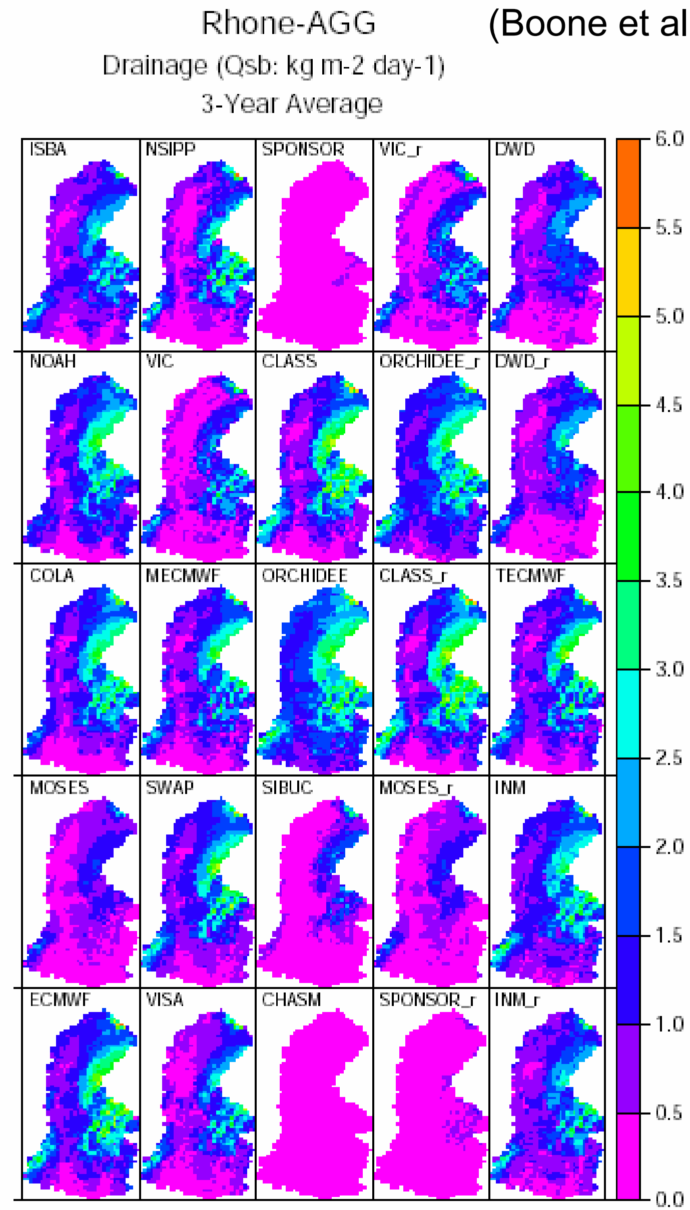
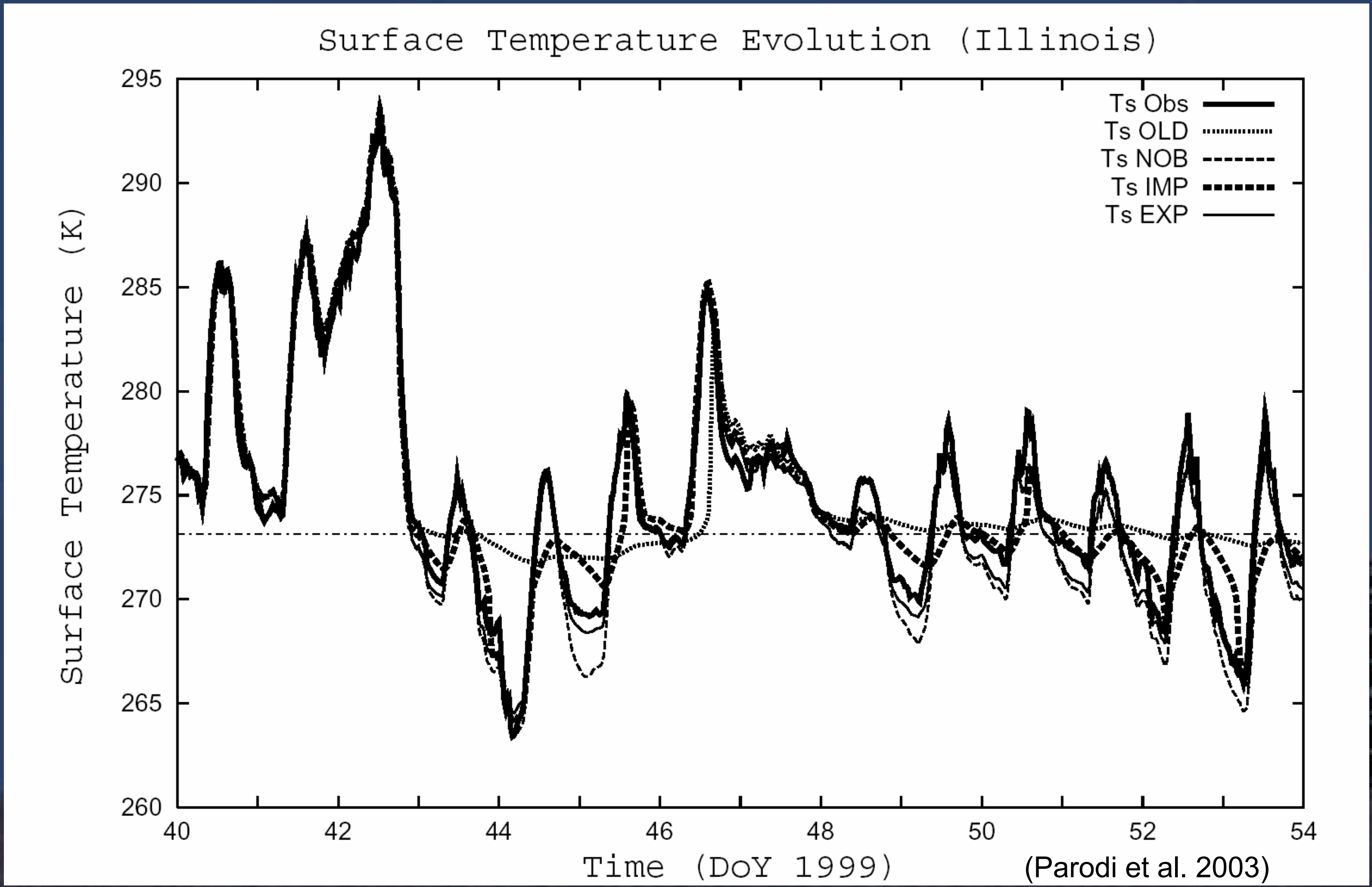
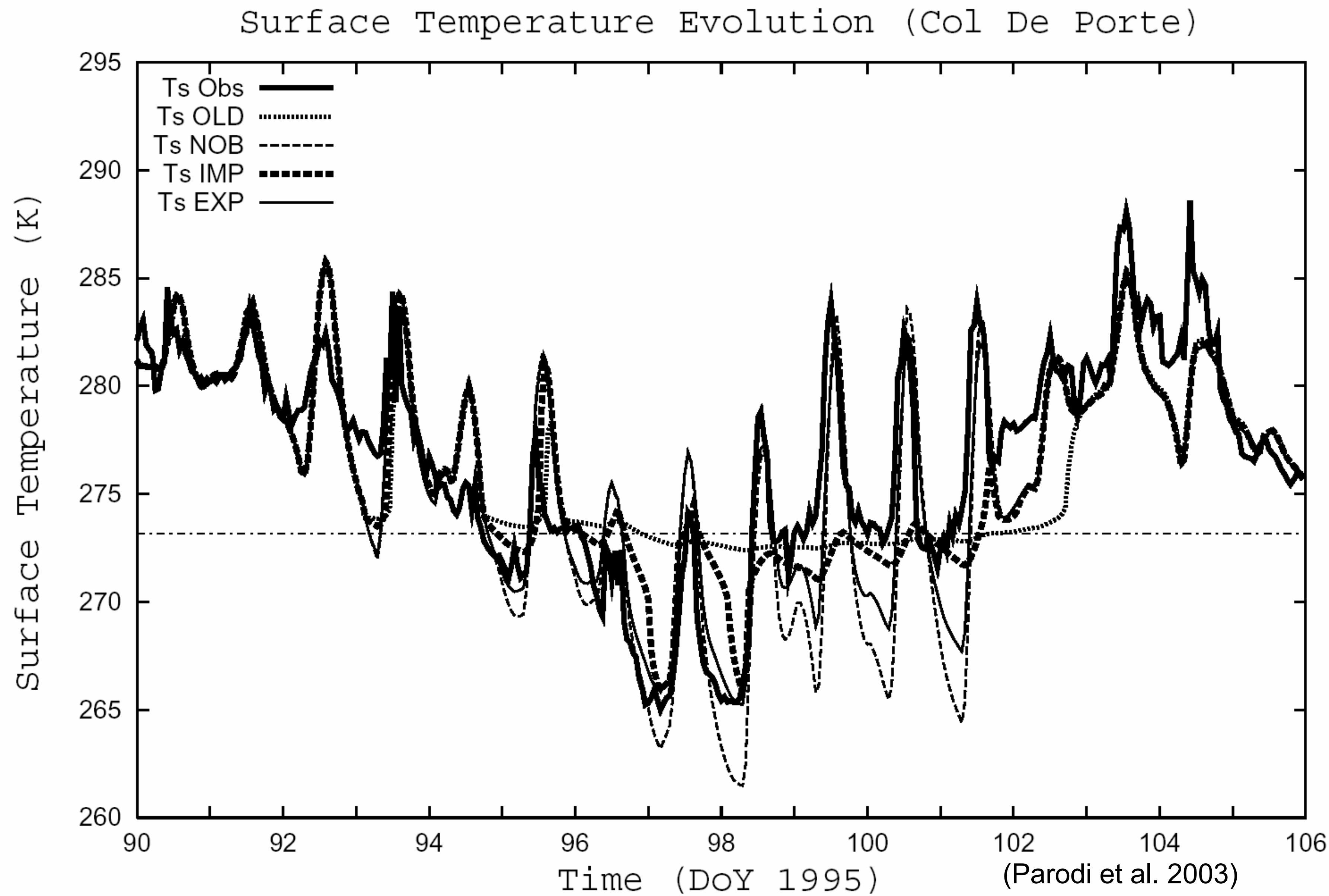
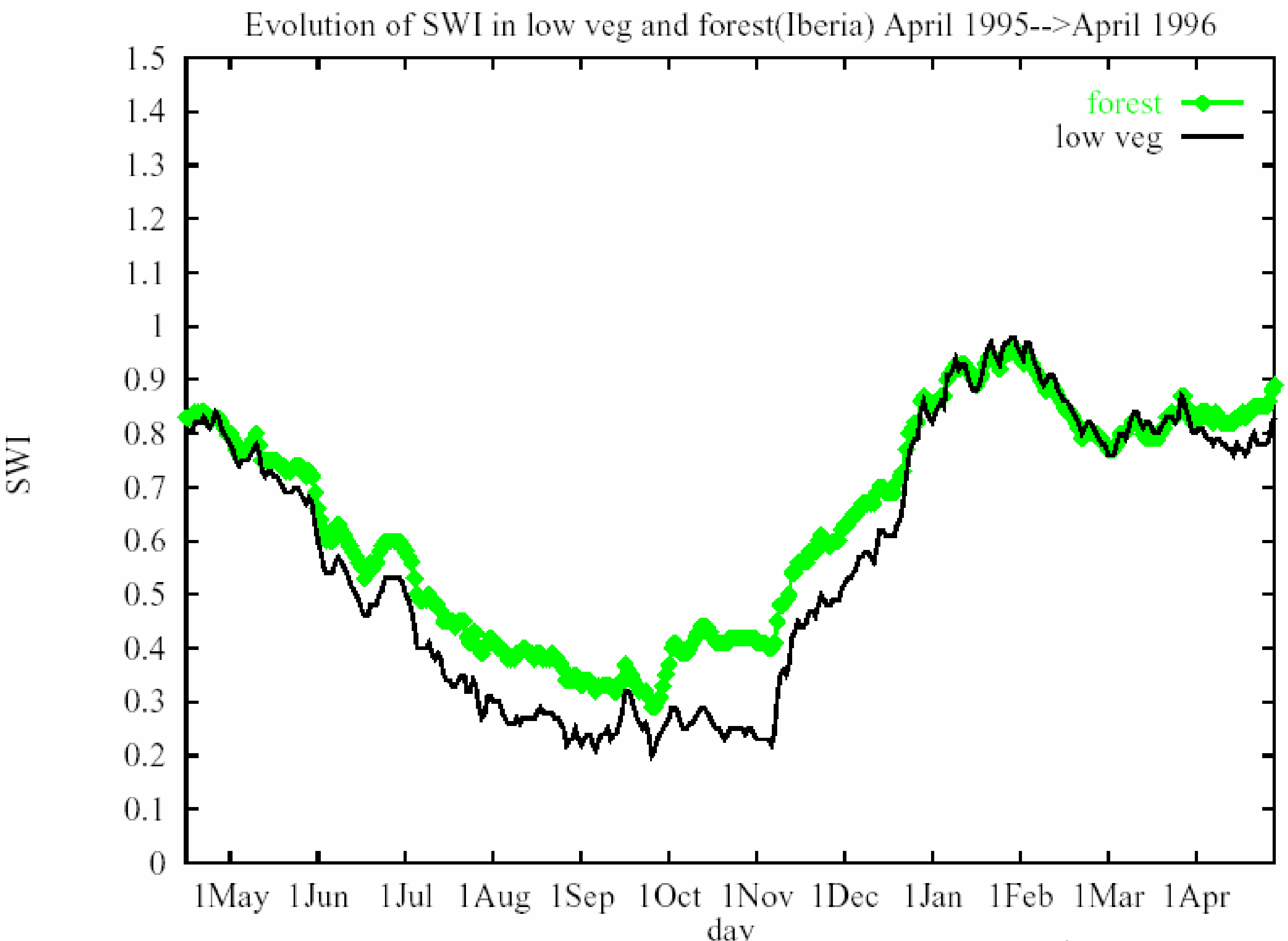


FIG. 3.4. The three-year average drainage or baseflow runoff (Qsb).


Surface Temperature Evolution (Illinois)
Surface Temperature (K)
295
290
285
280
275
270
265
260
40
42
44
46
48
50
52
54
Time (DoY 1999)
Ts Obs
Ts OLD
Ts NOB
Ts IMP
Ts EXP
(Parodi et al. 2003)

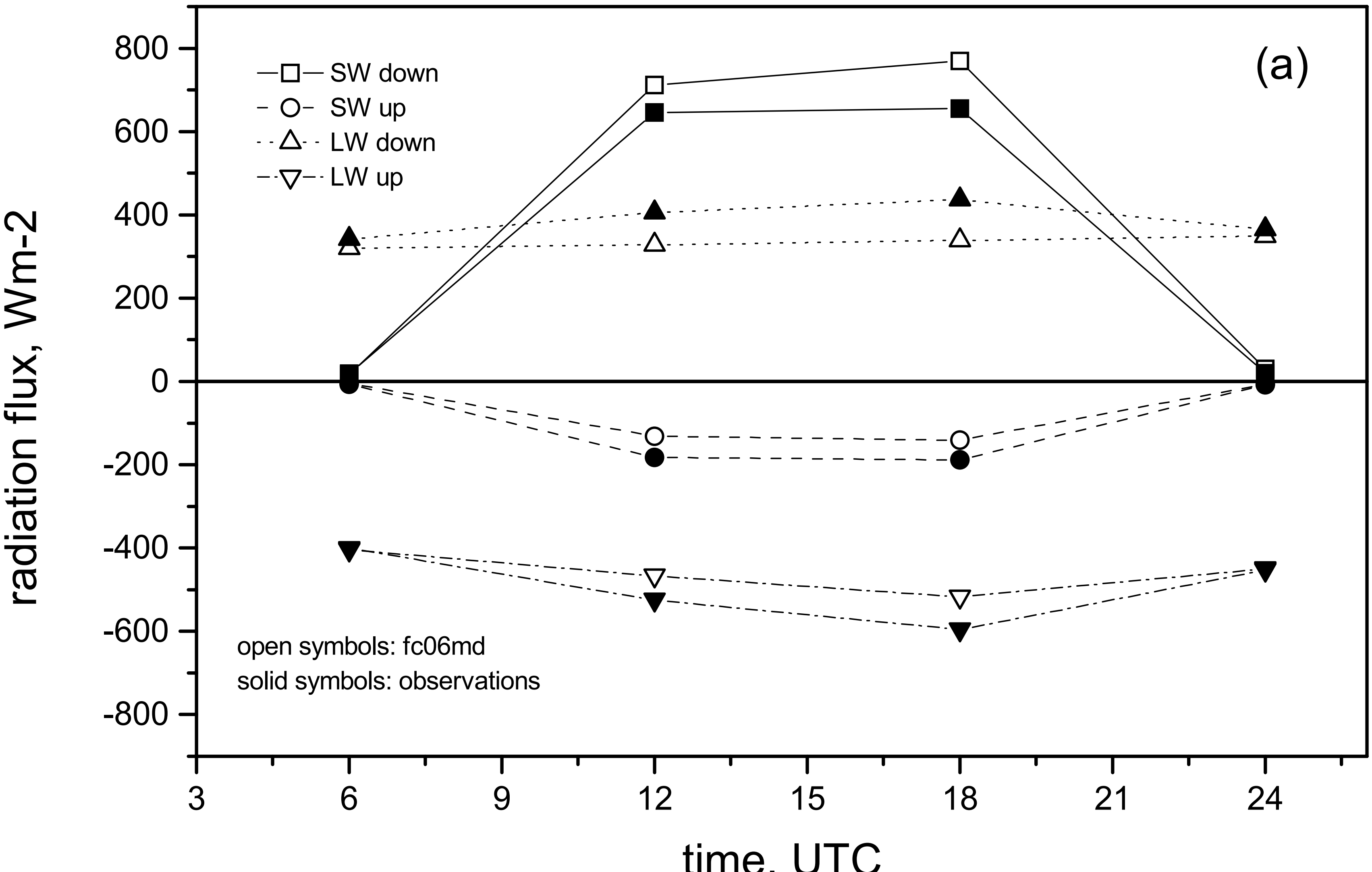


(Parodi et al. 2003)

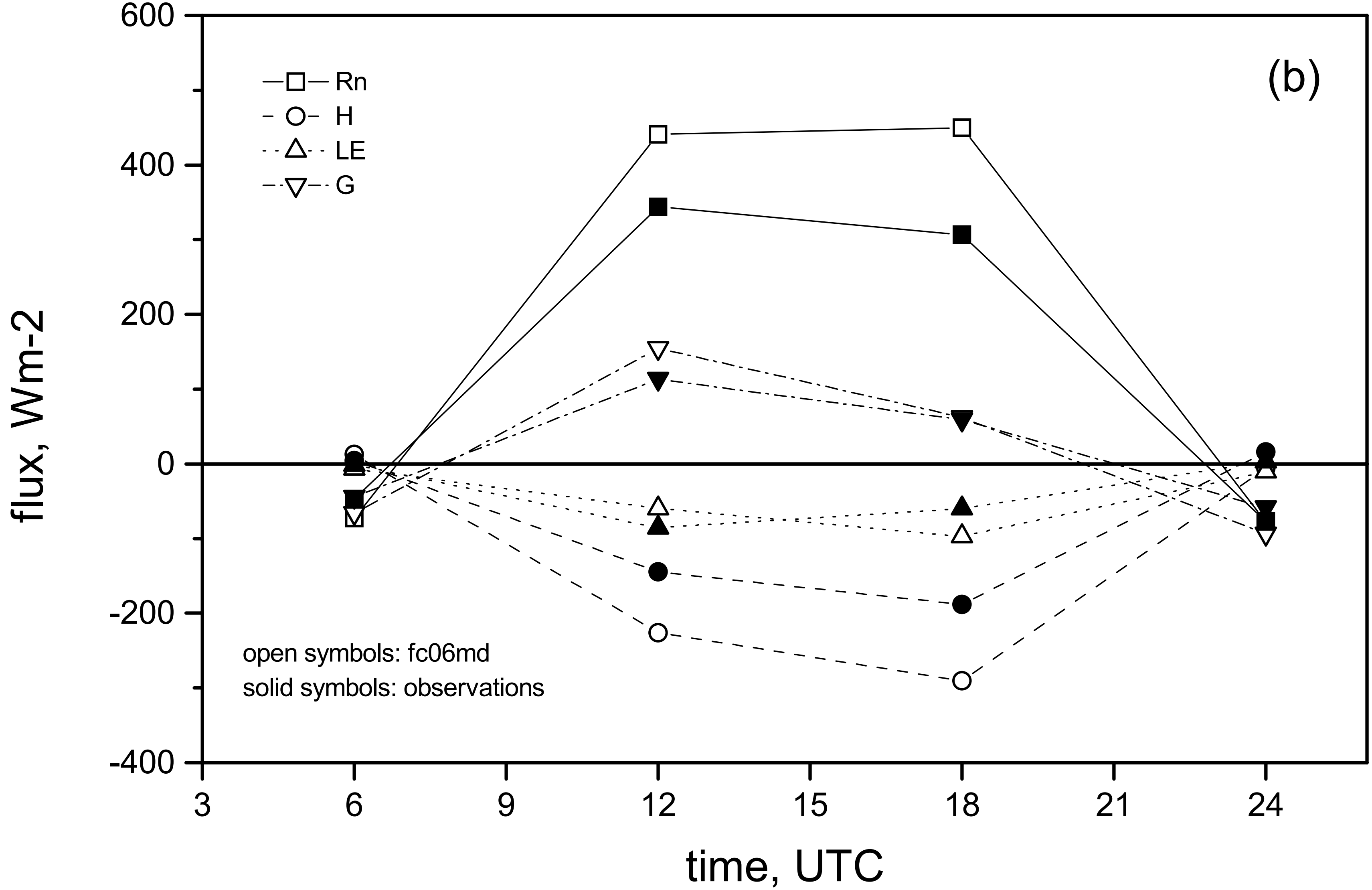


(Navascues et al. ,2003)

Figure 23: Daily evolution of total layer soil wetness index averaged for all grid points over the Iberian Peninsula. Values of low vegetation and forest fractions are represented separately.



(Jochum et al., 2004)



(Jochum et al., 2004)

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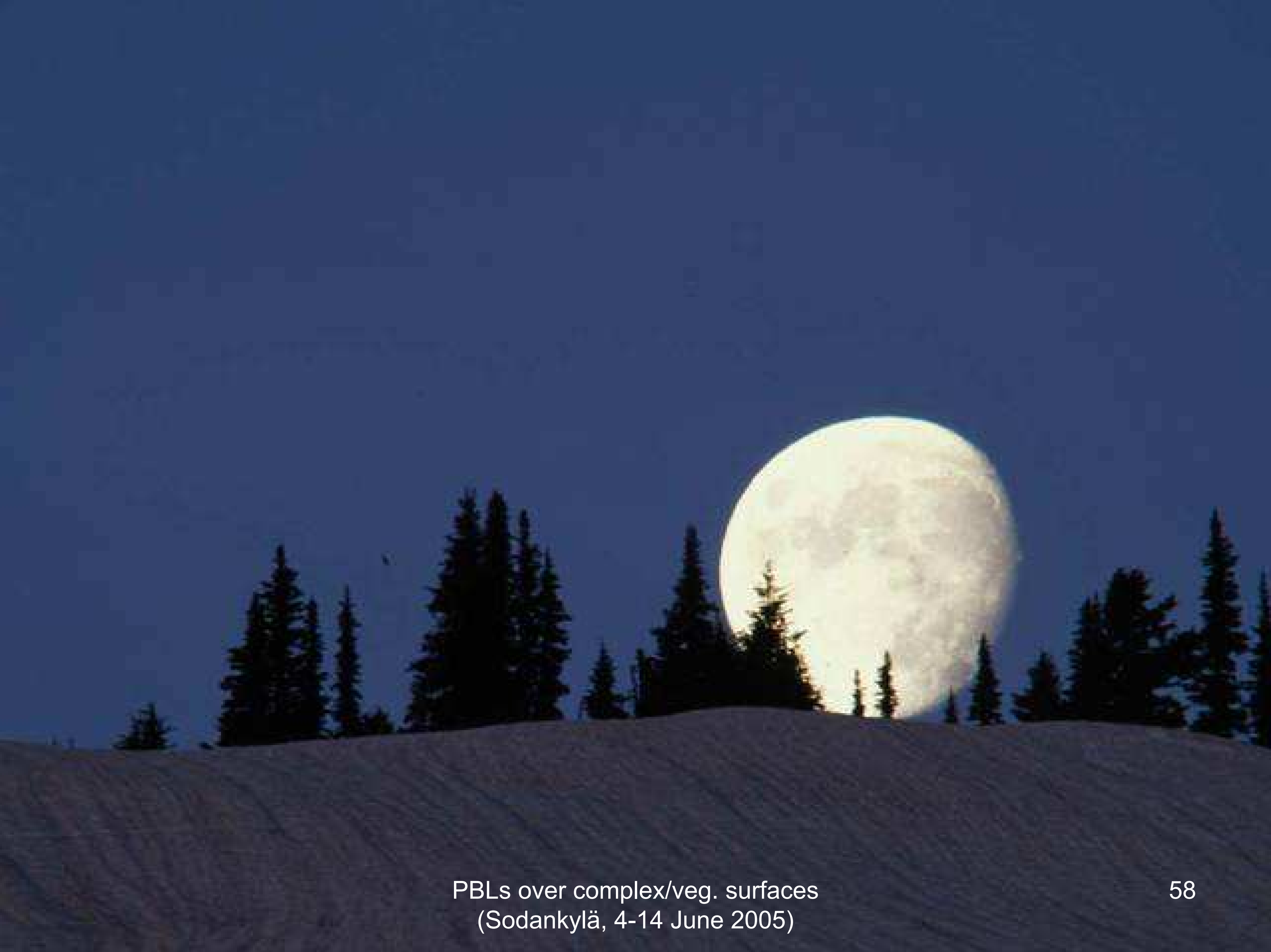
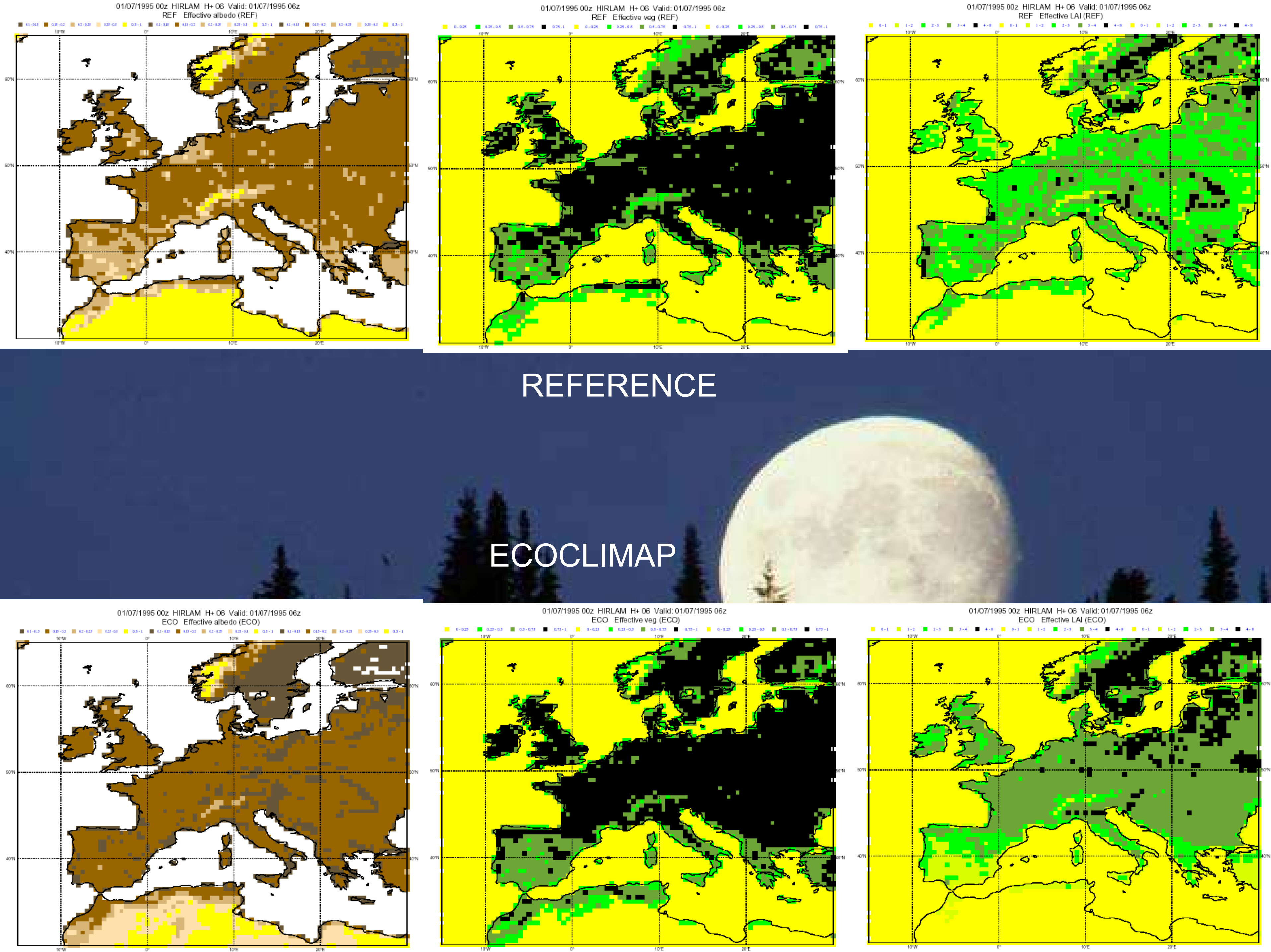
- HIRLAM surface parameterization. Future plans.

How big is the impact of physiography?

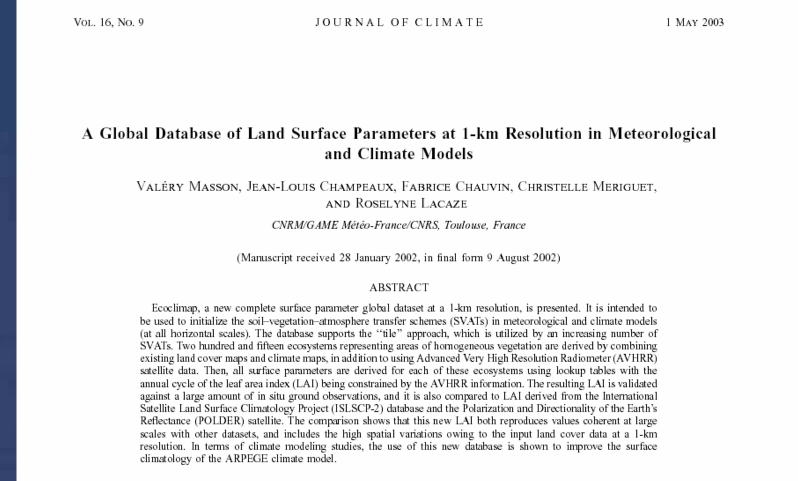


How to assess a physiographic database

- Most straightforward way: compare against **point measurements** or estimations of vegetation and soil features. (i) comparison is restricted only to certain landuses and climate conditions; (ii) representativeness problem.
- Another way of evaluating a physiographic database is to **introduce it in a forecasting model** and to compare the forecasted relevant parameters against the corresponding observations using the standard scores. Advantage: globality. Drawback: models are usually tuned to their climatic fields and a new physiographic database would be in clear disadvantage
- By **comparing with other databases and by looking at the raw data** (either using satellite information, direct terrain inspection, or both) used to arrive to the vegetation maps. Also the comparison of the algorithms used to classify ecosystems and the aggregation rules (to upscale from the original database resolution to the resolution used by the forecast model) can shed some light on the quality of the database
- When a weather forecasting model is used to evaluate a vegetation database it must be born in mind that models have usually **compensation mechanisms to minimize errors**. This is the case of the assimilation of soil water content based on the optimal interpolation method used by the HIRLAM model.The soil water content is corrected at every assimilation cycle to minimize errors of H+6 T2m and RH2m. The method is not able to improve simultaneously turbulent fluxes and soil moisture if the vegetation parameters are poorly specified


01/07/1995 00z HIRLAM H+ 06 Valid: 01/07/1995 06z
REF Effective albedo (REF)
01/07/1995 00z HIRLAM H+ 06 Valid: 01/07/1995 06z
REF Effective veg (REF)
01/07/1995 00z HIRLAM H+ 06 Valid: 01/07/1995 06z
REF Effective LAI (REF)
REFERENCE
ECOCLIMAP
01/07/1995 00z HIRLAM H+ 06 Valid: 01/07/1995 06z
ECO Effective albedo (ECO)
01/07/1995 00z HIRLAM H+ 06 Valid: 01/07/1995 06z
ECO Effective veg (ECO)
01/07/1995 00z HIRLAM H+ 06 Valid: 01/07/1995 06z
ECO Effective LAI (ECO)

ECOCLIMAP database (Masson et al., 2003)


VOL. 16, NO. 9 JOURNAL OF CLIMATE 1 MAY 2003

A Global Database of Land Surface Parameters at 1-km Resolution in Meteorological and Climate Models

VALÉRY MASSON, JEAN-LOUIS CHAMPEAUX, FABRICE CHAUVIN, CHRISTELLE MERIGUET, AND ROSELYNE LACAZE

CNRM/GAME Météo-France/CNRS, Toulouse, France

(Manuscript received 28 January 2002, in final form 9 August 2002)

ABSTRACT

Ecoclimap, a new complete surface parameter global dataset at a 1-km resolution, is presented. It is intended to be used to initialize the soil–vegetation–atmosphere transfer schemes (SVATs) in meteorological and climate models (at all horizontal scales). The database supports the "tile" approach, which is utilized by an increasing number of SVATs. Two hundred and fifteen ecosystems representing areas of homogeneous vegetation are derived by combining existing land cover maps and climate maps, in addition to using Advanced Very High Resolution Radiometer (AVHRR) satellite data. Then, all surface parameters are derived for each of these ecosystems using lookup tables with the annual cycle of the leaf area index (LAI) being constrained by the AVHRR information. The resulting LAI is validated against a large amount of in situ ground observations, and it is also compared to LAI derived from the International Satellite Land Surface Climatology Project (ISLSCP-2) database and the Polarization and Directionality of the Earth's Reflectance (POLDER) satellite. The comparison shows that this new LAI both reproduces values coherent at large scales with other datasets, and includes the high spatial variations owing to the input land cover data at a 1-km resolution. In terms of climate modeling studies, the use of this new database is shown to improve the surface climatology of the ARPEGE climate model.

- Global and high resolution dataset (1-km).
- Detailed information over Europe coming from CORINE and PELCOM projects.
- Use of full resolution maps of the vegetation index NDVI to provide the appropiate temporal and spatial scales.
- 215 ecosystems allowing a better assignement of vegetation parameter sets. (90 over Europe)
- Use of aggregation rules to derive surface parameters at the desired model resolution and for mixed ecosystem pixels.
- It allows the tiling approach, as used by the HIRLAM surface scheme.
- It is highly sophisticated as compared with the current HIRLAM physiographic description and it allows many possible choices
- Vegetation parameters (veg, lai, Zoh, Zom, alb, Rsmin, frac, emis, ...) with monthly or decennial (10 days) frequency.
- Under testing in HIRLAM system.
- Straightforward usage for lat/lon coordinates.

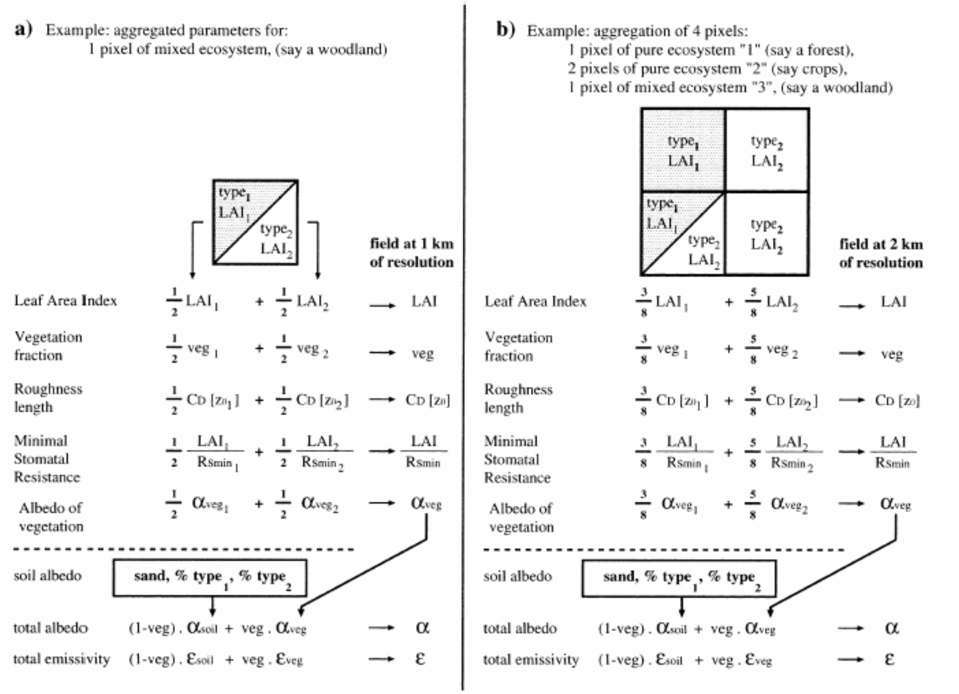


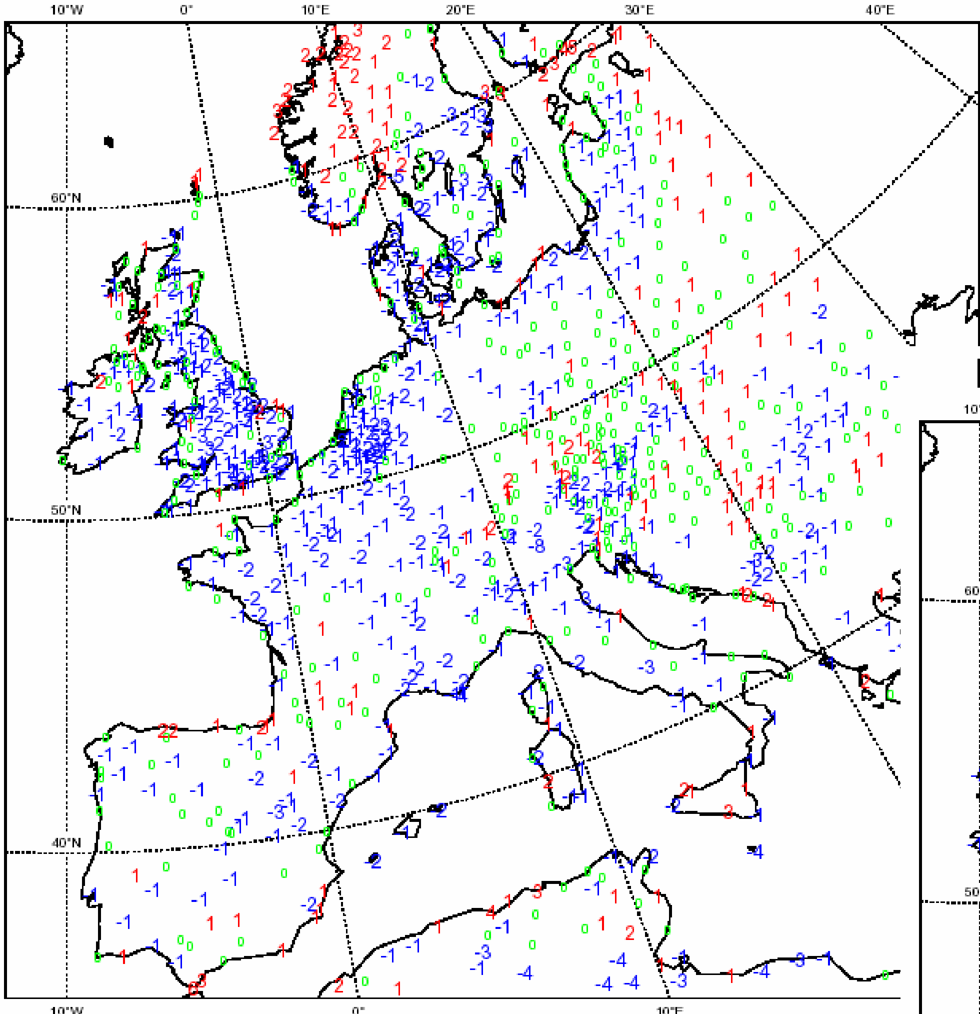
FIG. 5. Aggregation rules used to derive surface parameters: (a) aggregation of the surface characteristics of a mixed ecosystem pixel, and (b) aggregation toward a coarser resolution of the surface characteristics of several pixels, whether they are mixed or not. Here C_D is the neutral drag coefficient at 10 m, equal to $\kappa^2/\ln^2(10/z_0)$, where κ is the von Karman constant and z_0 is in meters. The Veg_1, $Rs_{\min1}$, z_{01}, α_1 (Veg_2, $Rs_{\min2}$, z_{02}, α_2) are estimated from LAI_1 (LAI_2) and the vegetation type 1 (2) according to Table 2.

1) PURE ECOSYSTEMS

Each pure ecosystem includes a single vegetation type with a corresponding LAI. Note that the understory LAI is incorporated for the forests. Due to the lack of a unique relationship between LAI and NDVI, this NDVI information serves to make a dynamic adaptation of the LAI from the minimum and maximum values found in the literature:

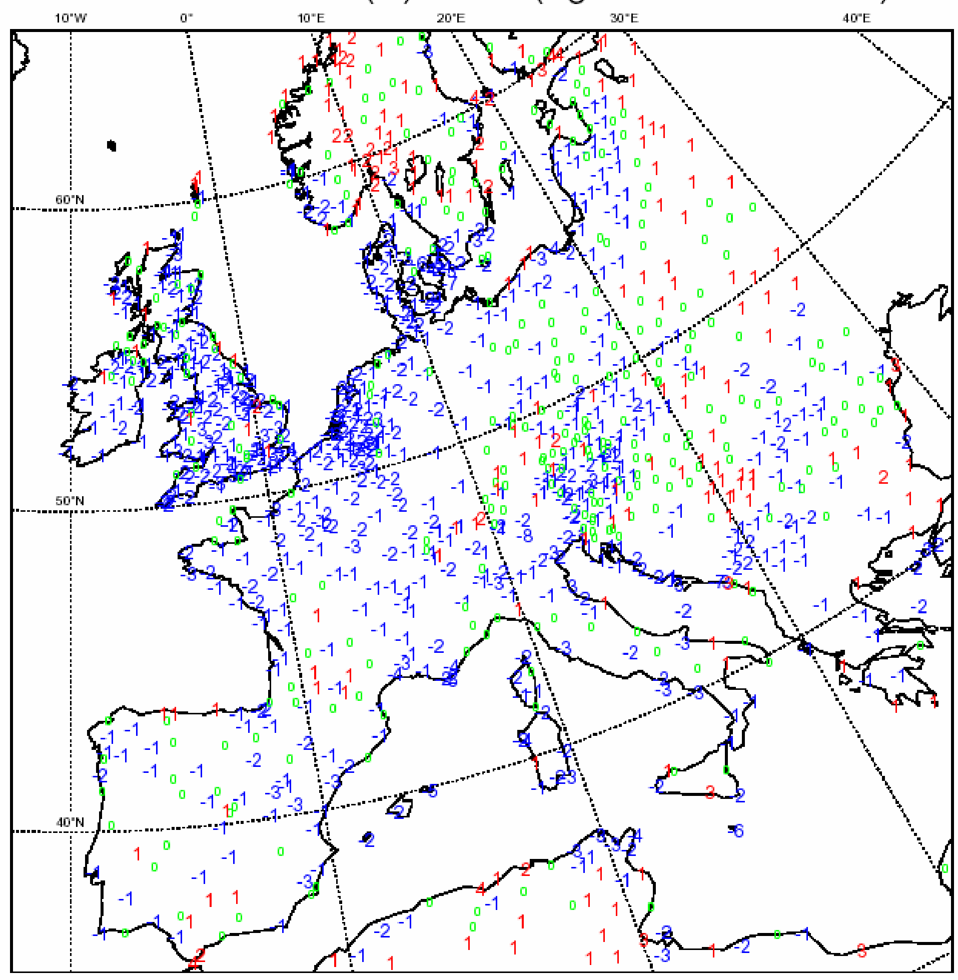
$$\mathrm{LAI} = \mathrm{LAI}_{\min} + (\mathrm{LAI}_{\max} - \mathrm{LAI}_{\min})\frac{\mathrm{NDVI} - \mathrm{NDVI}_{\min}}{\mathrm{NDVI}_{\max} - \mathrm{NDVI}_{\min}}. \quad (2)$$

620 T2m BIAS(K) H+48 (against 11 105 804)



PBLs over con
(Sodankylä,

ECO T2m BIAS(K) H+48 (against 11 105 804)



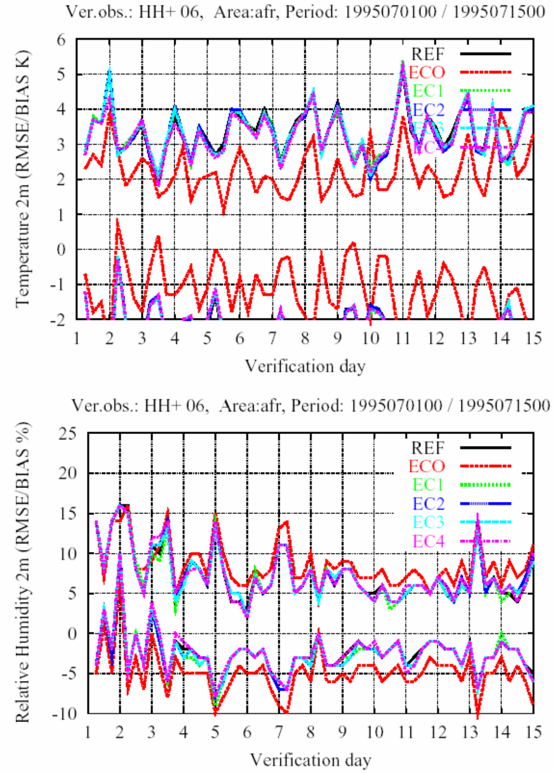


Figure 2: The same as Fig. 1, but for the African region (30^0N, 30^0E, 20^0N, 10^0W)

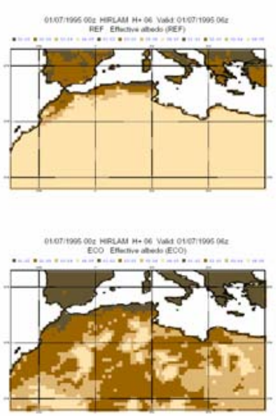


Figure 3: Effective albedo for the REF (top) and ECO (bottom) experiments over the African region (30^0N, 30^0E, 20^0N, 10^0W)

Parameter	REF (bare soil)	ECO (bare soil)
albedo	0.48	0.27

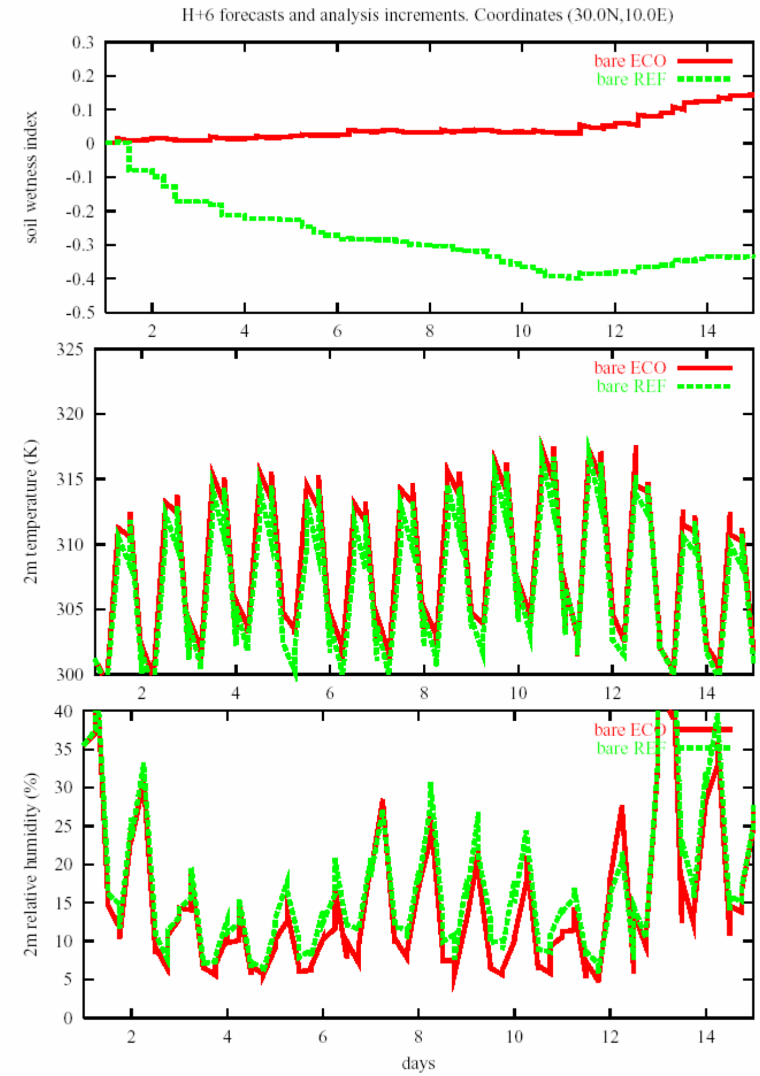


Figure 8: The same as Fig. 4 but for the point (30.0^0N, 10.0^0E). The values correspond here only to the bare ground fraccion, which is the predominant one over the considered grid square.

PBLs over compl
(Sodankylä, 4-14 June 2005)

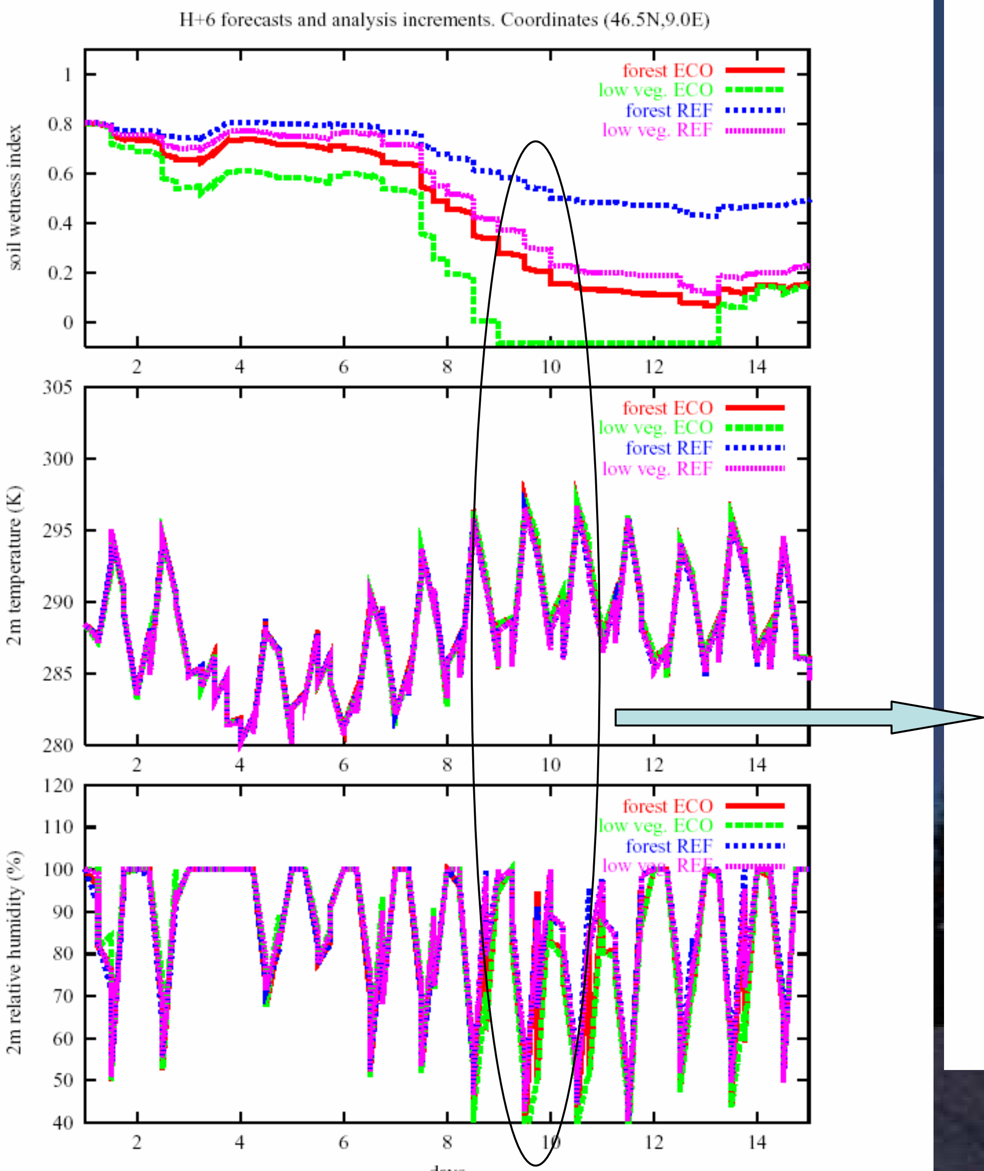


Figure 4: Evolution of total soil wetness index (top), 2-metre temperature (middle) and 2-metre relative humidity (bottom) for the grid point ($46.5^0N, 9.0^0E$). The values corresponding to the forested and low vegetation tiles are plotted for the ECO and REF experiments. Both first guess (H+6) values and analysis increments (vertical lines) are represented. Evolution period: 1-15 July 1995

13

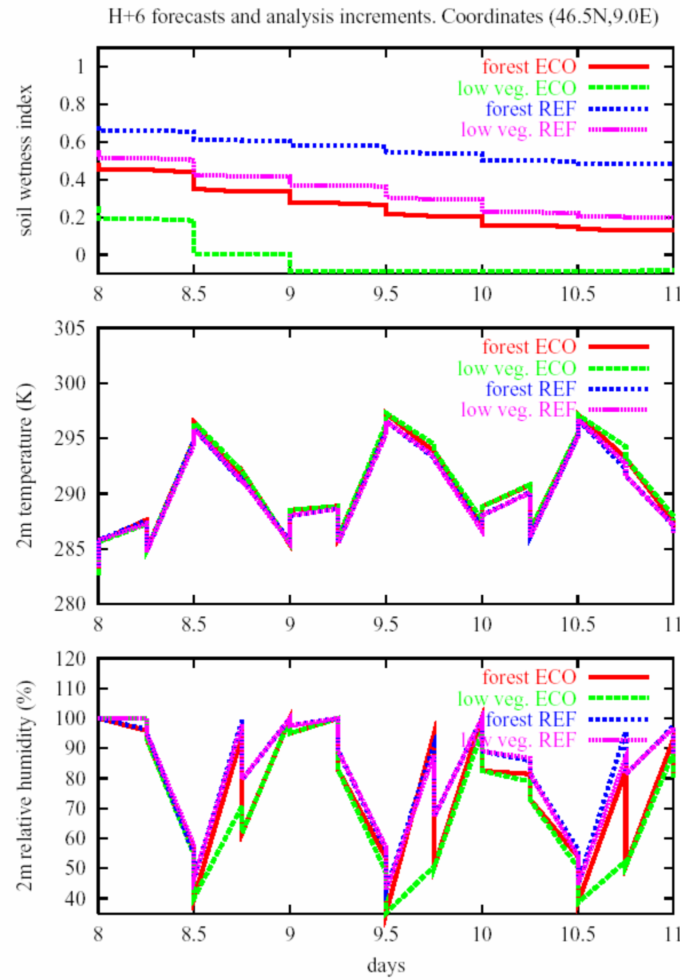


Figure 5: The same as Fig. 4 but zooming between days 8 and 11 July 1995.

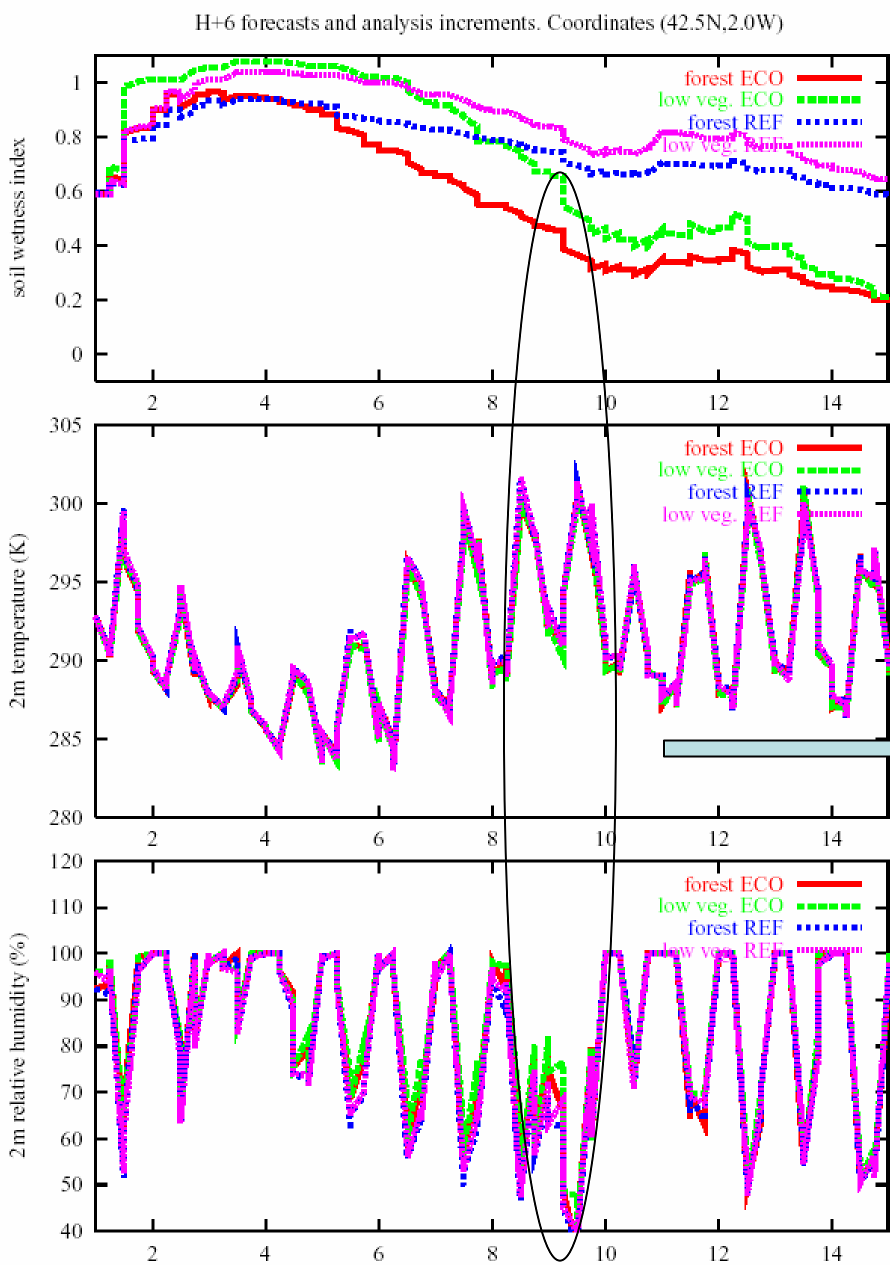


Figure 6: The same as Fig. 4 but for the point ($42.5^0 N, 2.0^0 W$)

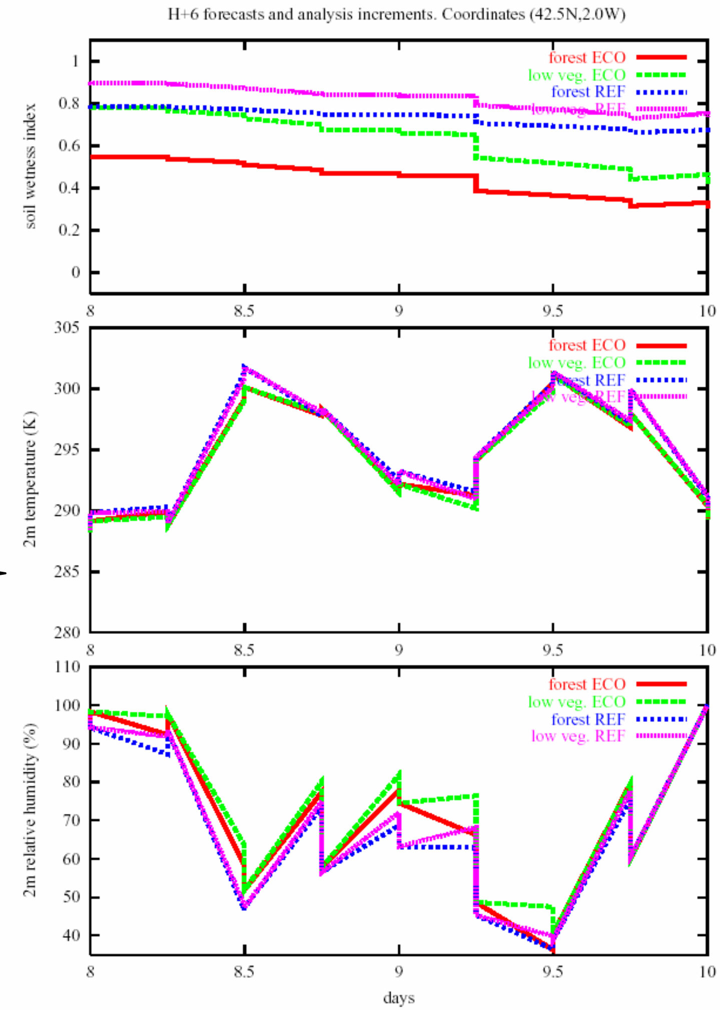


Figure 7: The same as Fig. 6, but zooming between days 8 and 10 July 1995.

urfaces
005)

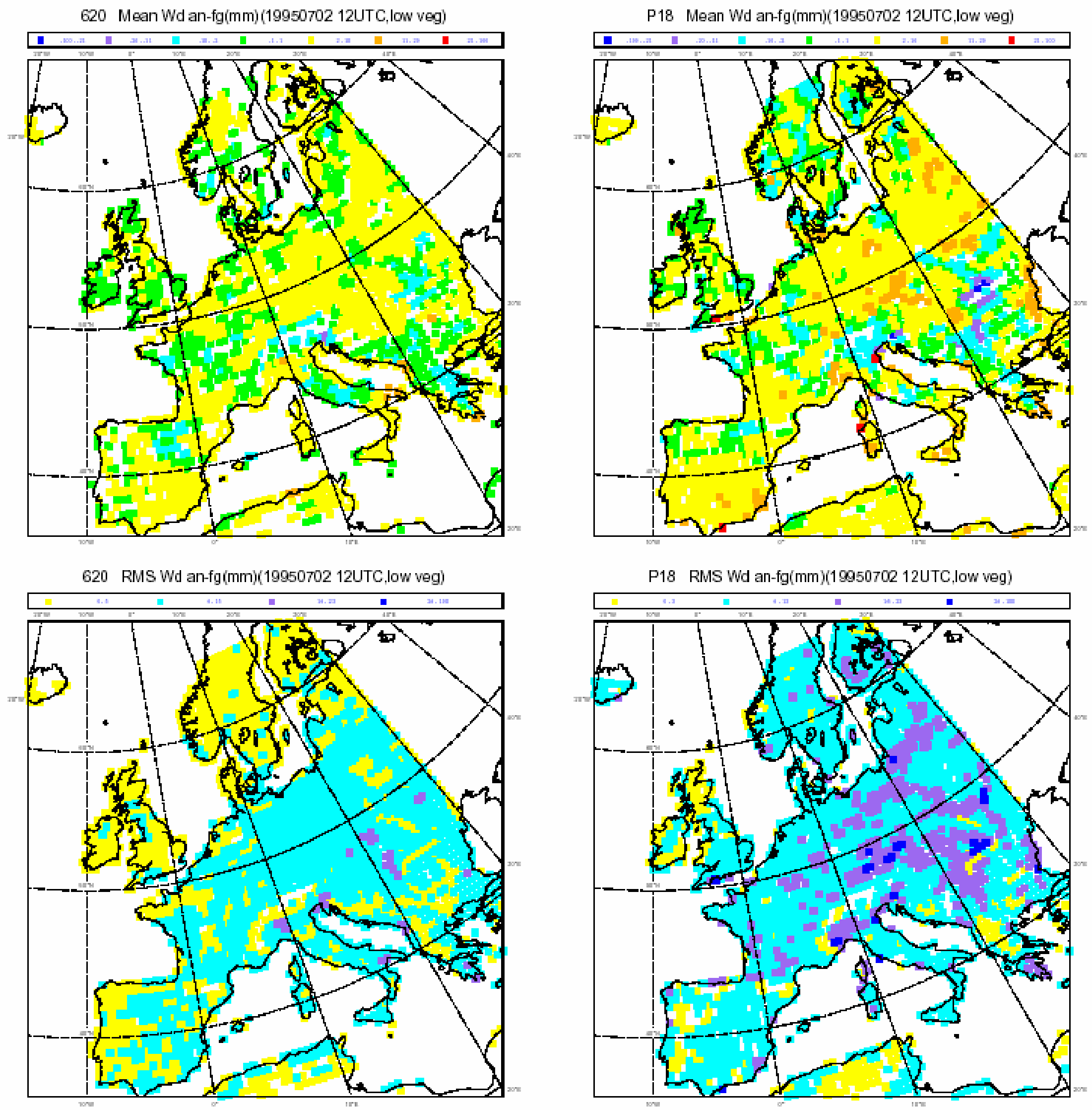


Figure 3: Mean (top) and rms error (bottom) of soil water increments at the 12 UTC assimilation step for experiments 620 (left) and (ECO) averaged for the period 1-15 July 1995. The increments here shown were computed only for the low vegetation tiles

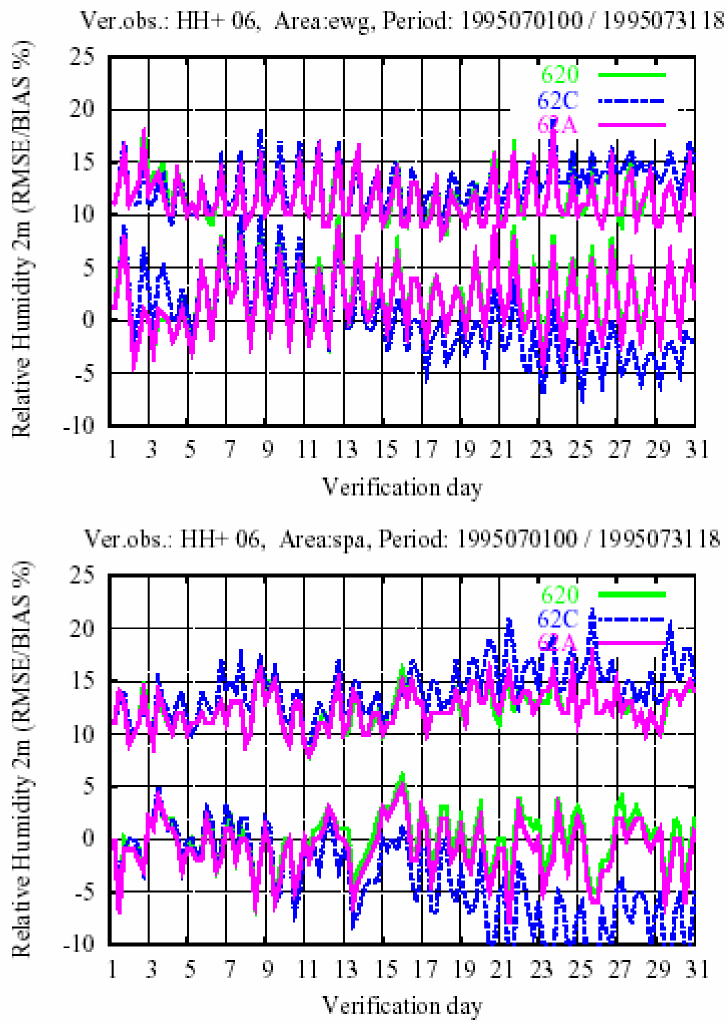
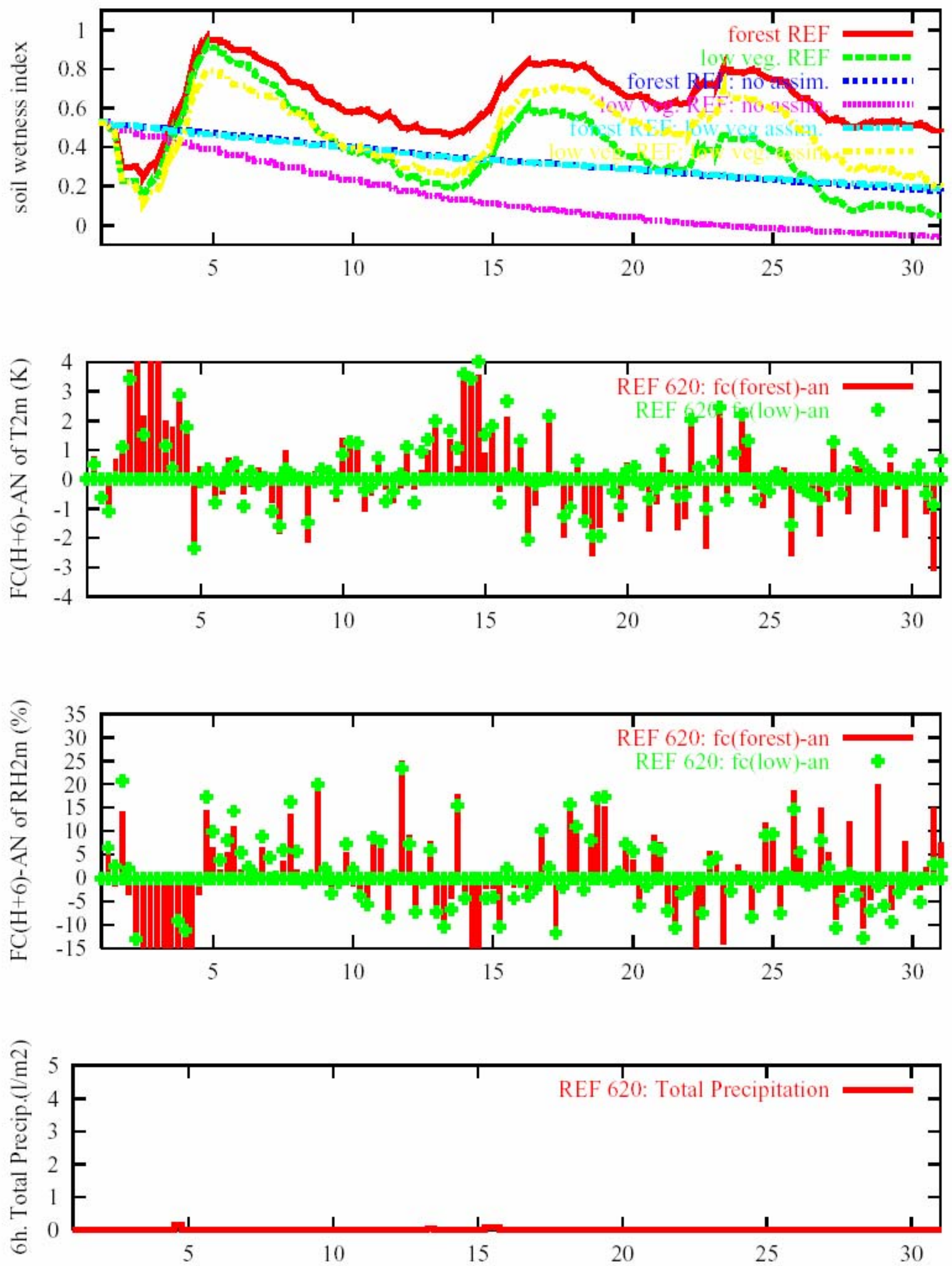


Figure 5: H+6 verification against observations of 2-metre relative humidity for the EWGLAM (top) and the Iberian peninsula (bottom) stations for the experiments 620, 62C, 62A (see the text for further details). Period: 1-15 July 1995

H+6 forecasts and analysis increments. Coordinates (48.0N,20.5E)



How big is the impact of physiography?

- **The effect of the vegetation parameters change is frequently offset by soil moisture assimilation, which is able to compensate differences in vegetation parameters by adding/removing soil water.**

- **Of course, if vegetation parameters are wrongly specified, it cannot be expected that soil moisture values are realistic.**

- **The soil moisture assimilation is a rather robust approach, preserving surface heat fluxes rather well against changes in vegetation parameters by minimizing errors of forecasted 2-metre temperature and humidity. The possible errors or misspecification of vegetation parameters is therefore translated to the soil water content.**

Outline

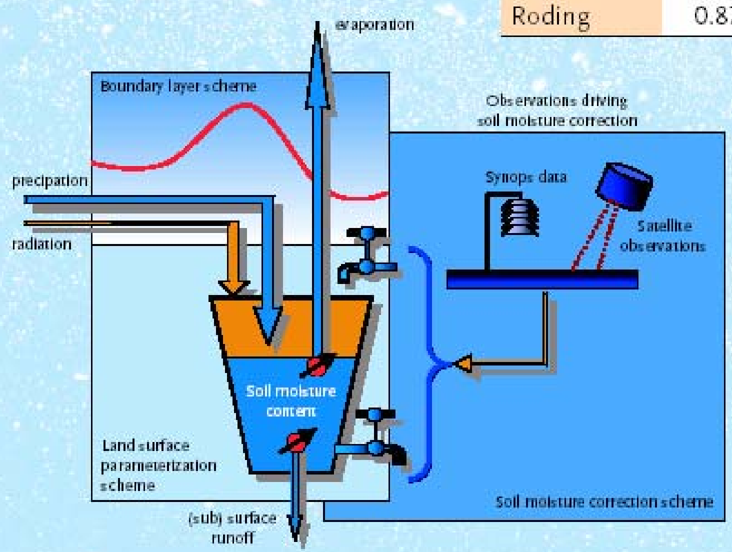
- Why surface parameterization is important?
- Which are the distinct features of surface/atmosphere interaction?
- How important are the different surface parameters?
- Treatment of surface heterogeneity. Aggregation. How big is the impact of tiling?
- How are surface schemes validated?
- Physiographic description. ECOCLIMAP. How big is the impact of physiography?
- Assimilation of surface variables. Case of soil moisture. ELDAS experience. How big is the impact of soil moisture?
- HIRLAM surface analysis. Future plans.
- HIRLAM surface parameterization. Future plans.

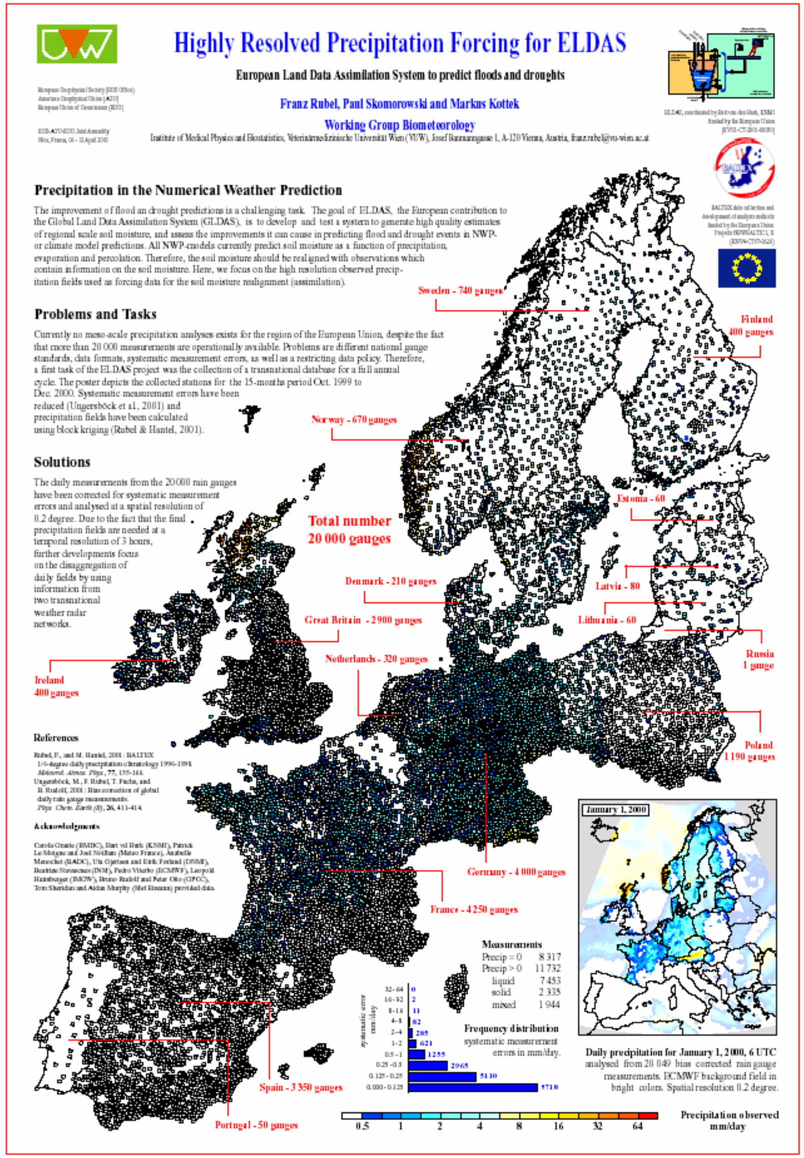
ELDAS project

The ELDAS project

In the context of the Fifth Framework program of the European Commission, a project called ELDAS (Development of a European Land Data Assimilation System to predict floods and droughts) was launched on 1 December 2001. In ELDAS scientists from 10 European institutes combined their expertise on soil moisture assimilation and related topics. The project resulted in a set of accurate databases of precipitation, radiation and surface heating rates at high spatial and temporal resolution, a number of soil moisture assimilation systems developed and tested at various European weather institutes, and a collection of validation and demonstration studies using the forcing data and soil moisture estimates. Before presenting the ELDAS databases and system design, an overview is given of some applications where ELDAS products have been evaluated.

Roding	0.87



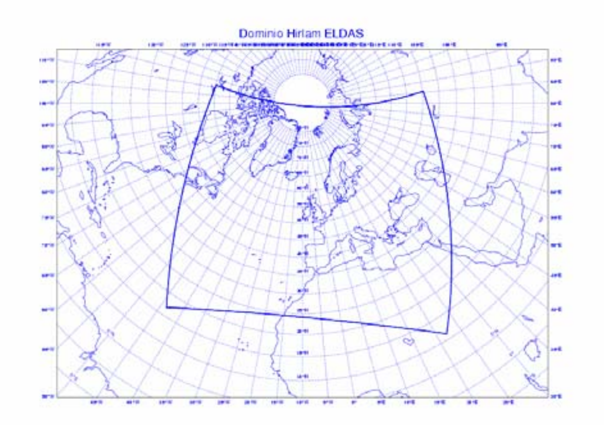


ELDAS: What have we learnt? (I)

- ELDAS was EU funded project (ended Nov 2004)
- Aims: To deliver a soil moisture data assimilation system, validate its products and explore the potential improvements in meteorological and hydrological applications
- INM participation: comparison of three soil moisture assimilation methods (REF, VAR, ELD) using HIRLAM 6.2.0, one (predominant) land-tile only and ECOCLIMAP.

June→Oct. 2000

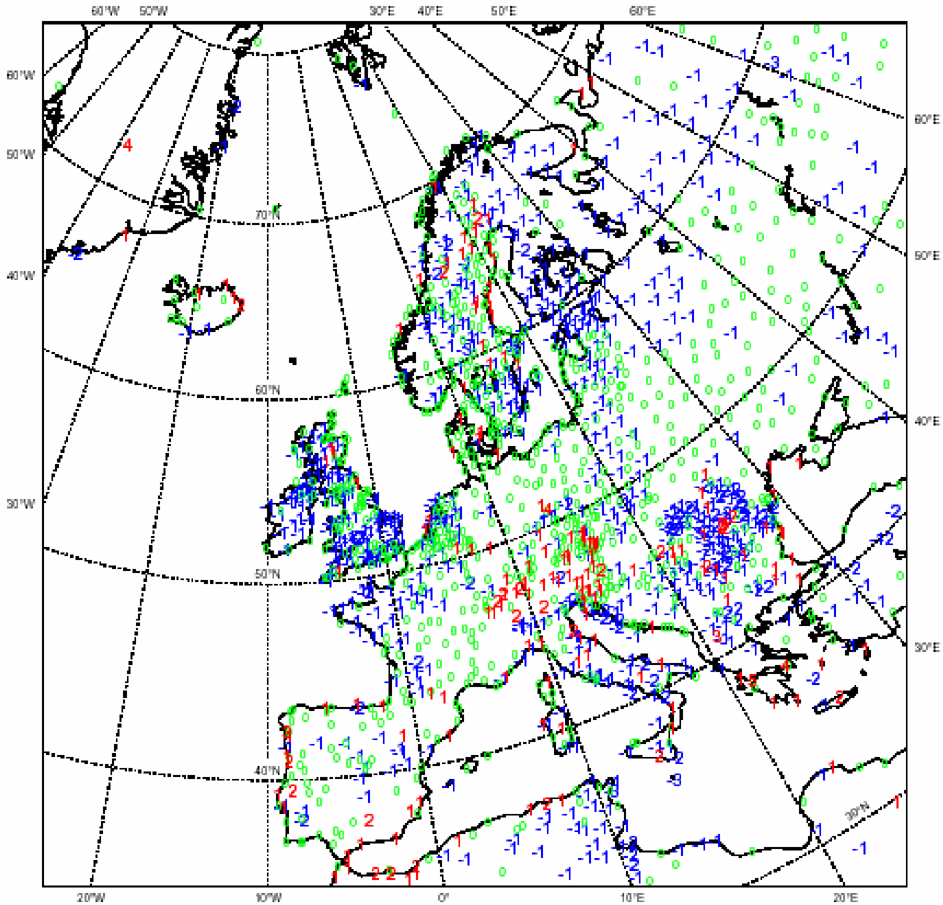
PBLs over complex/veg. surfaces
(Sodankylä, 4-14 June 2005)



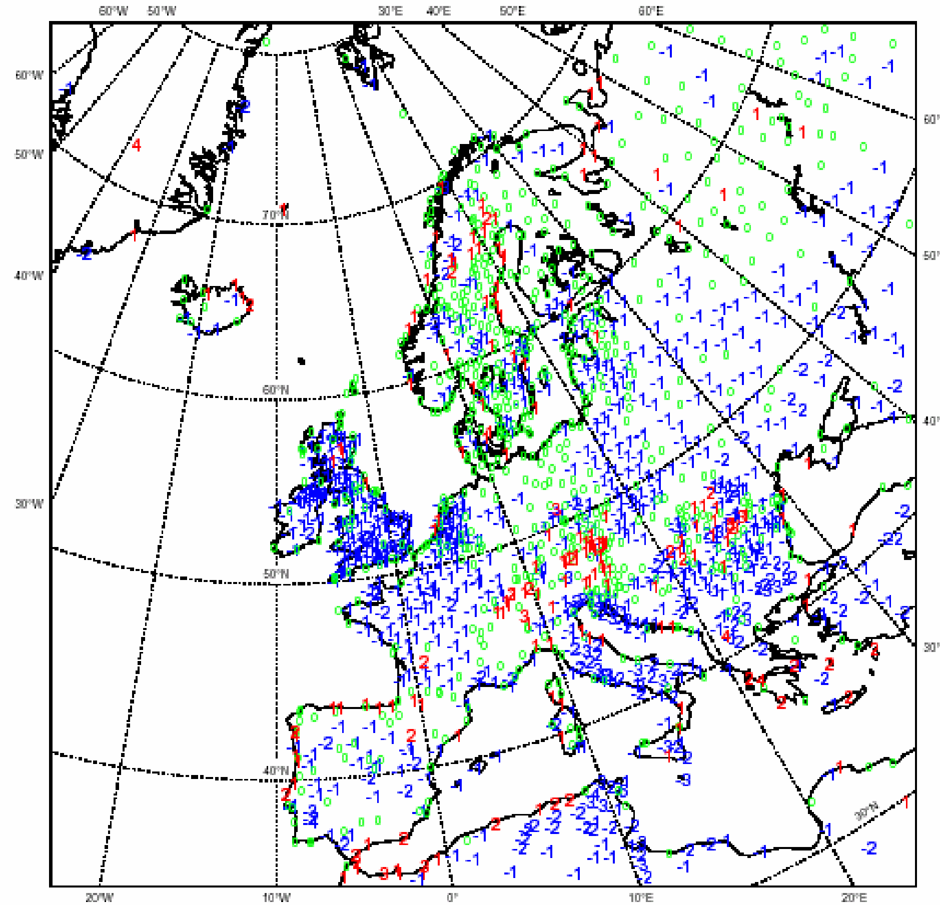
Three approaches to SM assimilation

REF	VAR	ELD
OI based on HIRLAM ref	2D-VAR assim (Balsamo et al. 2004)	SM assim switched-off. SM from ARPEGE based also on (Balsamo el al. 2004)
It assimilates T2m and RH2m	It assimilates T2m and RH2m.	It assimilates T2m and RH2m + precip. correct.
Opt. Coeff. fixed depending on LST and veg/soil features	Extra integration needed to estimate TL obs. oper. Dyn. corrections adapted to met and surf conditions	Two extra integrations to estimate TL obs. oper.
6 h cycling	6 h cycling	24 h assim. window
Masking	Masking: No assim. over threshold values of differences in precipitation, wind, cloud cover..., also no corrections when ΔT2m and ΔWp are positively correlated or when ΔRH2m and ΔWp are negatively correlated)	

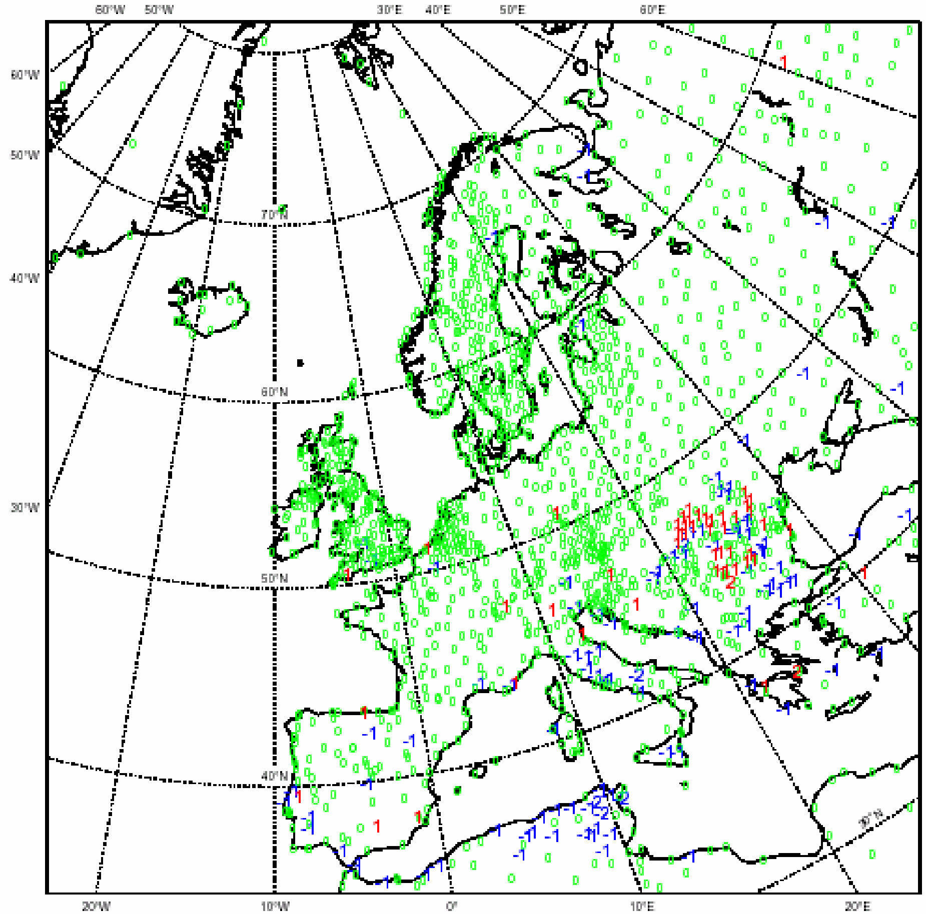
REF T2m BIAS(K)_JUN_to_OCT2000 H+36



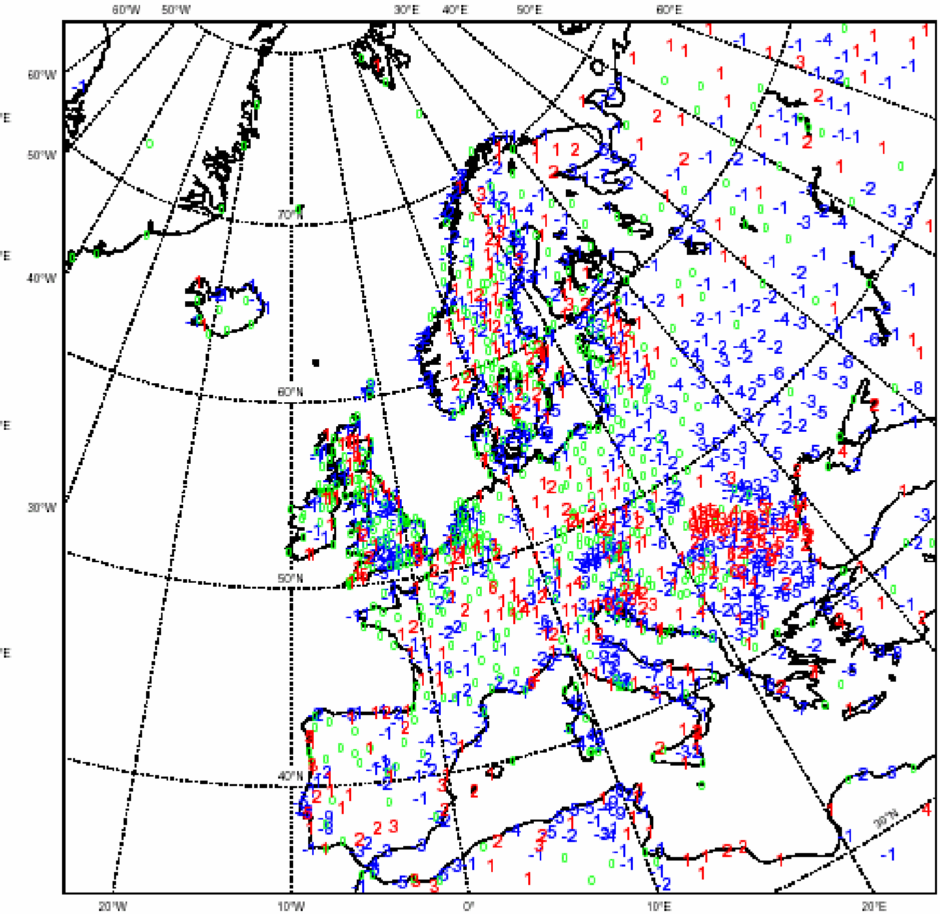
ELD T2m BIAS(K)_JUN_to_OCT2000 H+36



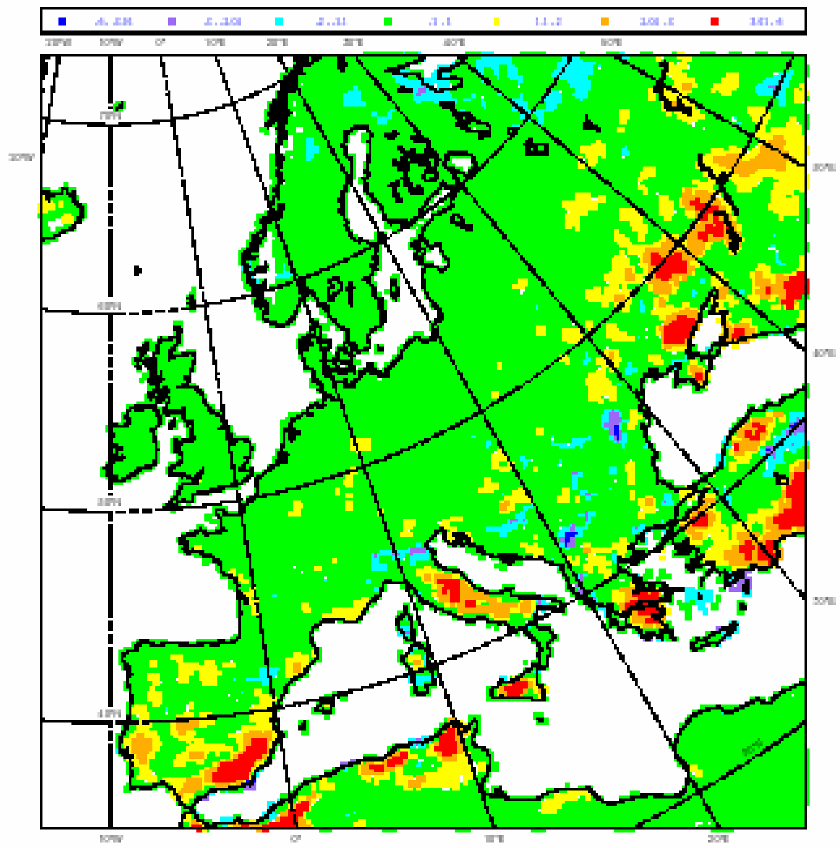
RMS diffs T2m(K) JUNtoOCT2000 H+36 REF-ELD



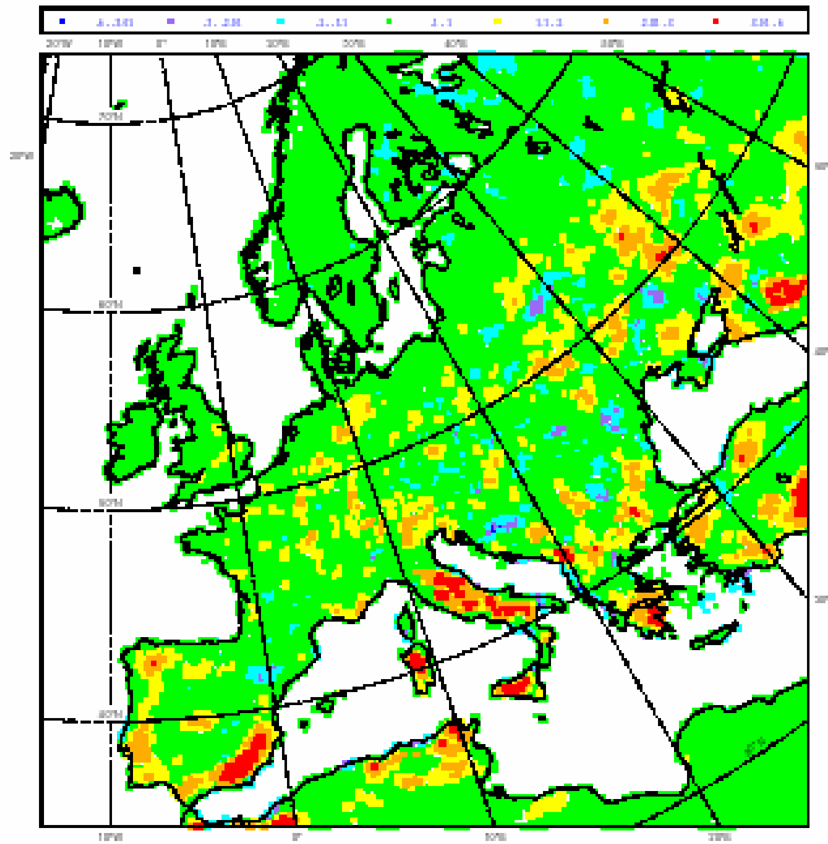
RMS diffs RH2m(%) JUNtoOCT2000 H+36 REF-ELD



DIF   T2 REF-ELD bias(20000702 00UTC)

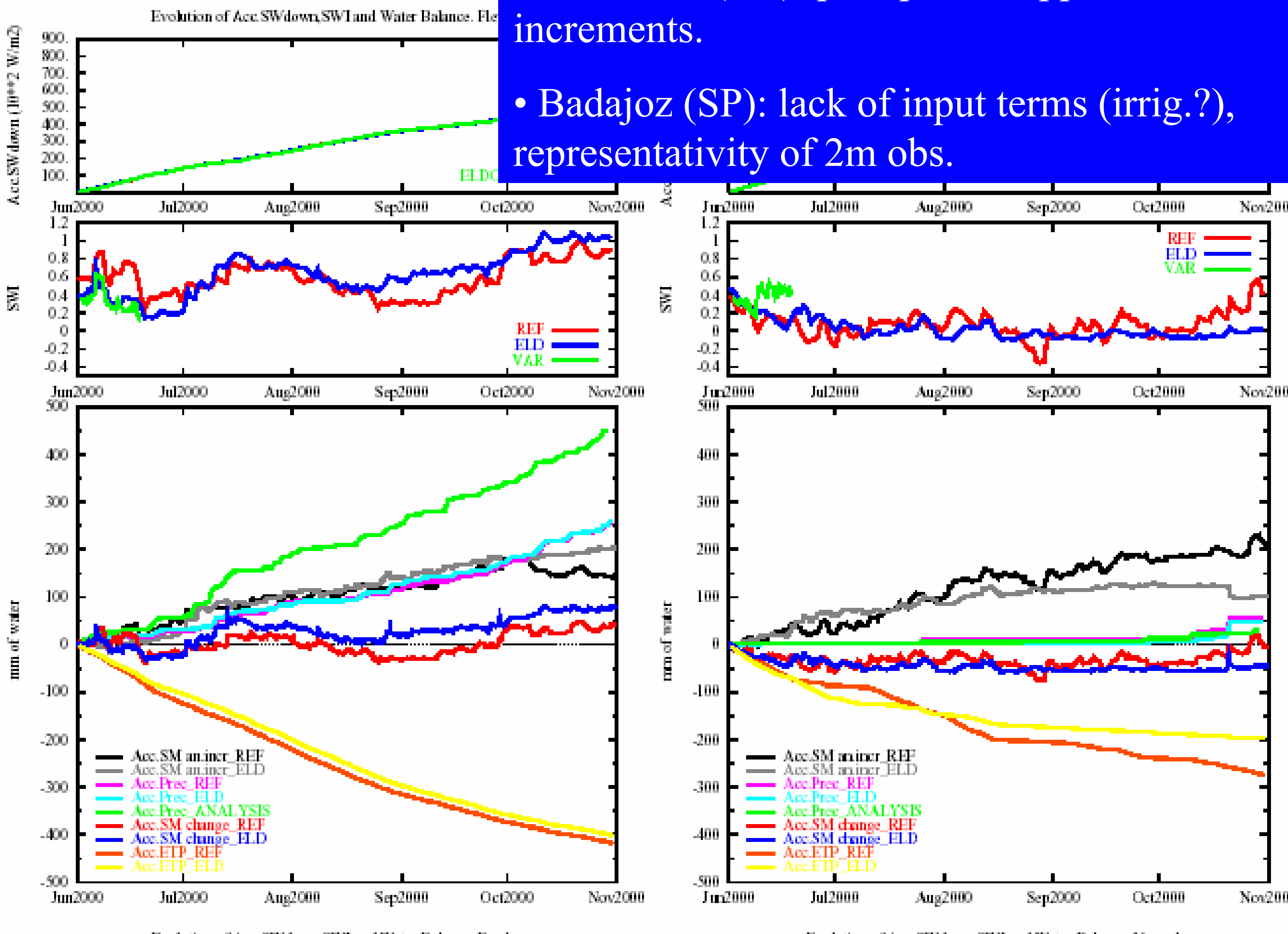


DIF   T2 REF-ELD bias(20000802 00UTC)



A few p

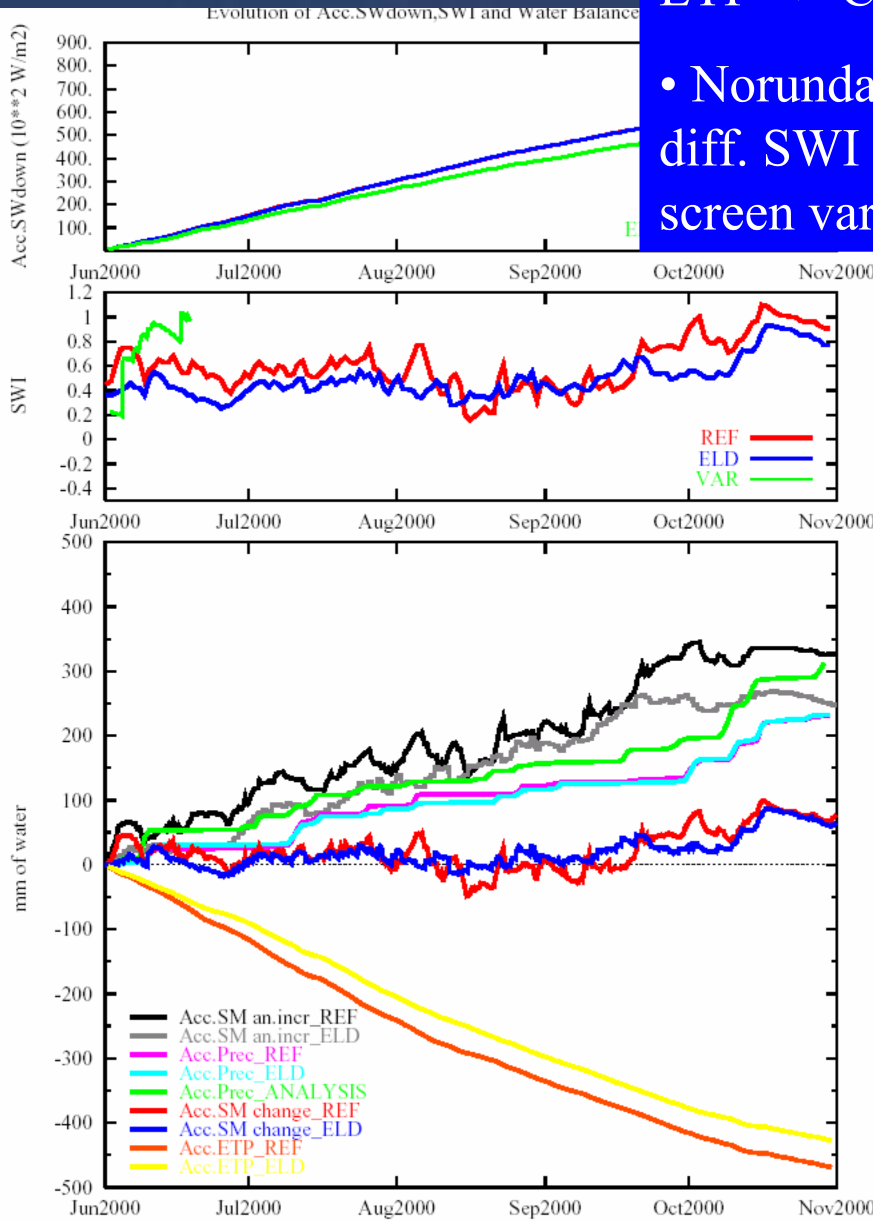
- Too big SM corrections, also experienced by other model and implementations.
- Flevoland (NL): precip.error approx. SM increments.
- Badajoz (SP): lack of input terms (irrig.?), representativity of 2m obs.

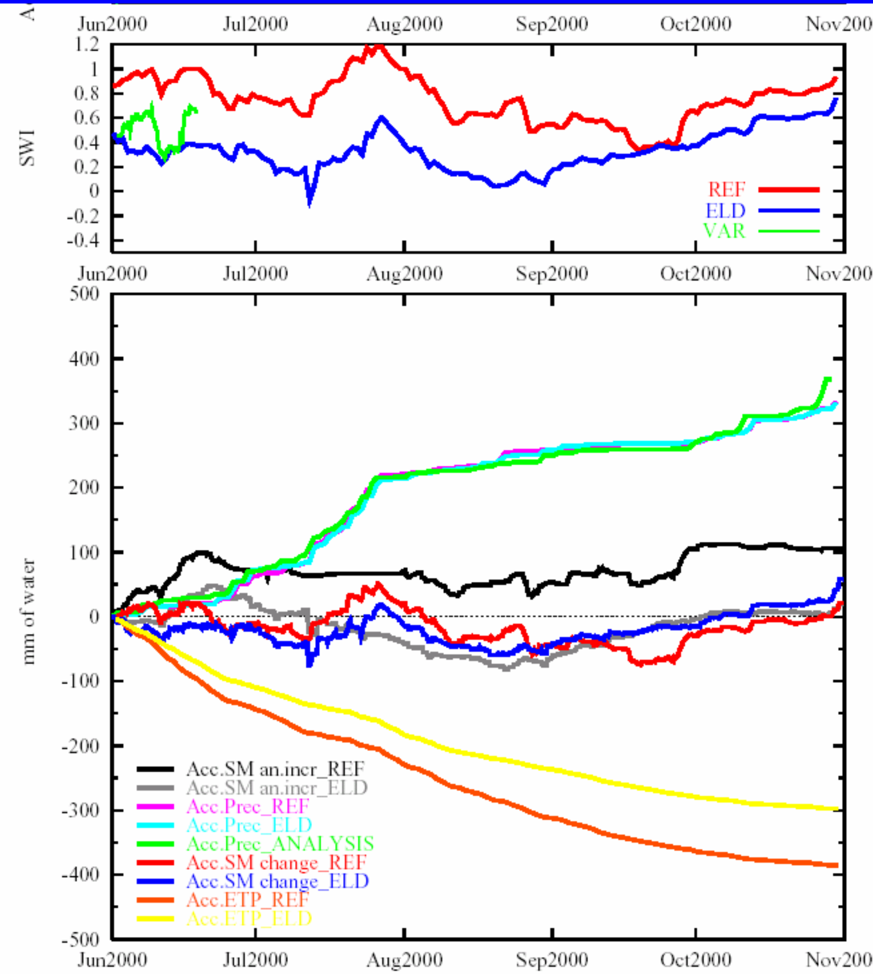


A few po

• Bordeaux (FR): SM incr. is the main positive contributor. Model SWD > Obs. SWD => Too much ETP => Compensated by SM incr.

• Norunda (SE): ETP and precip. major terms. Big diff. SWI => diff IC and poor coupling btw SM and screen variables => few SM corrections.





REF produces bigger SM increments than ELD

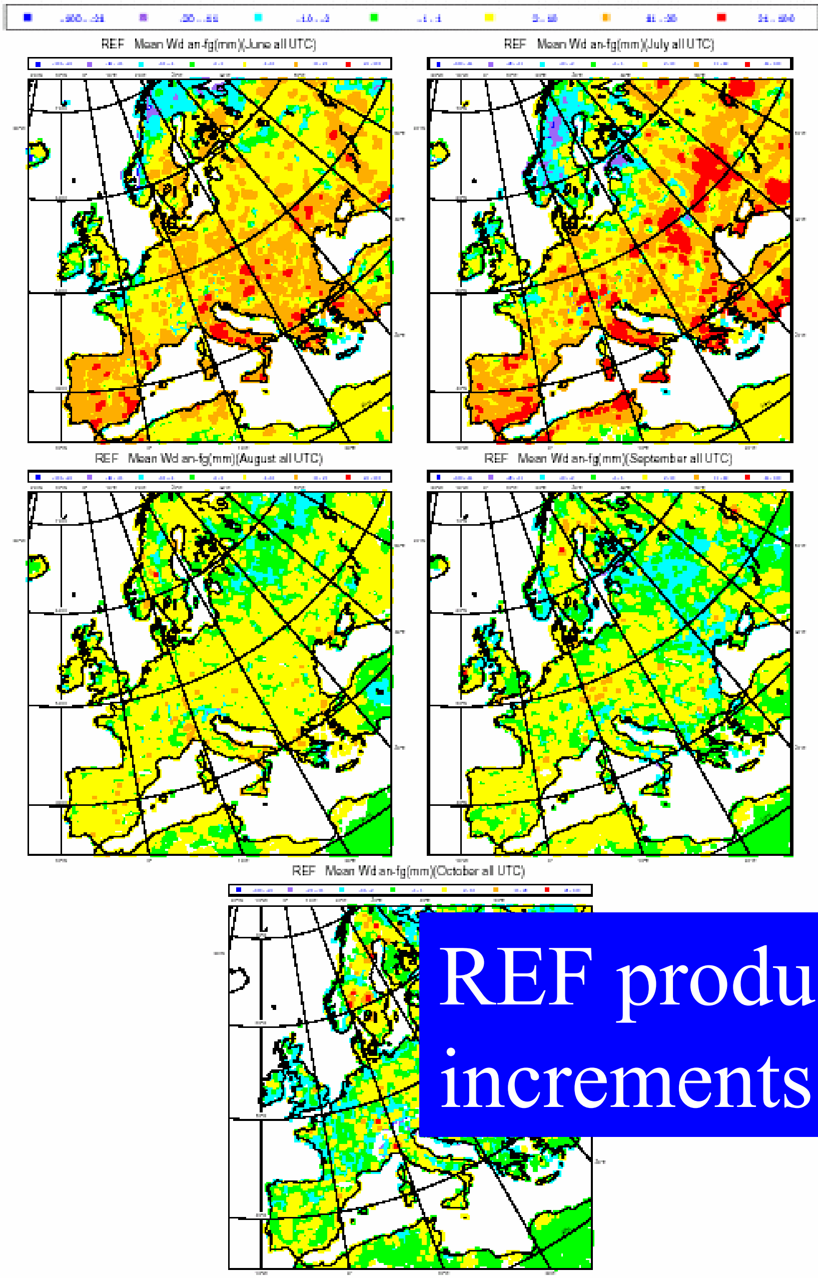


Figure 3: Monthly averaged (from June to October 2000) soil moisture increments (analysis minus first guess, expressed in mm) for the REF experiment.

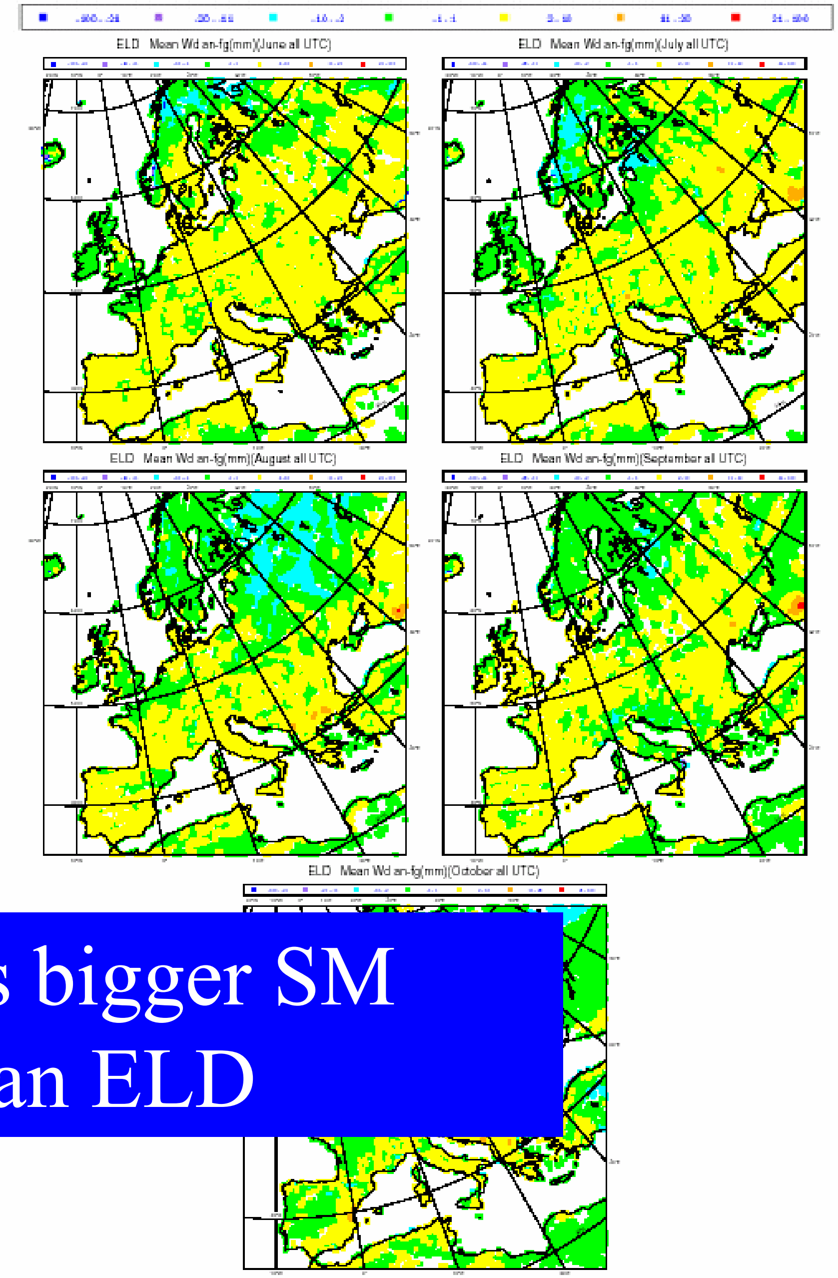


Figure 4: Monthly averaged (from June to October 2000) soil moisture increments (analysis minus HIRLAM first guess, expressed in mm) for the ELD experiment.

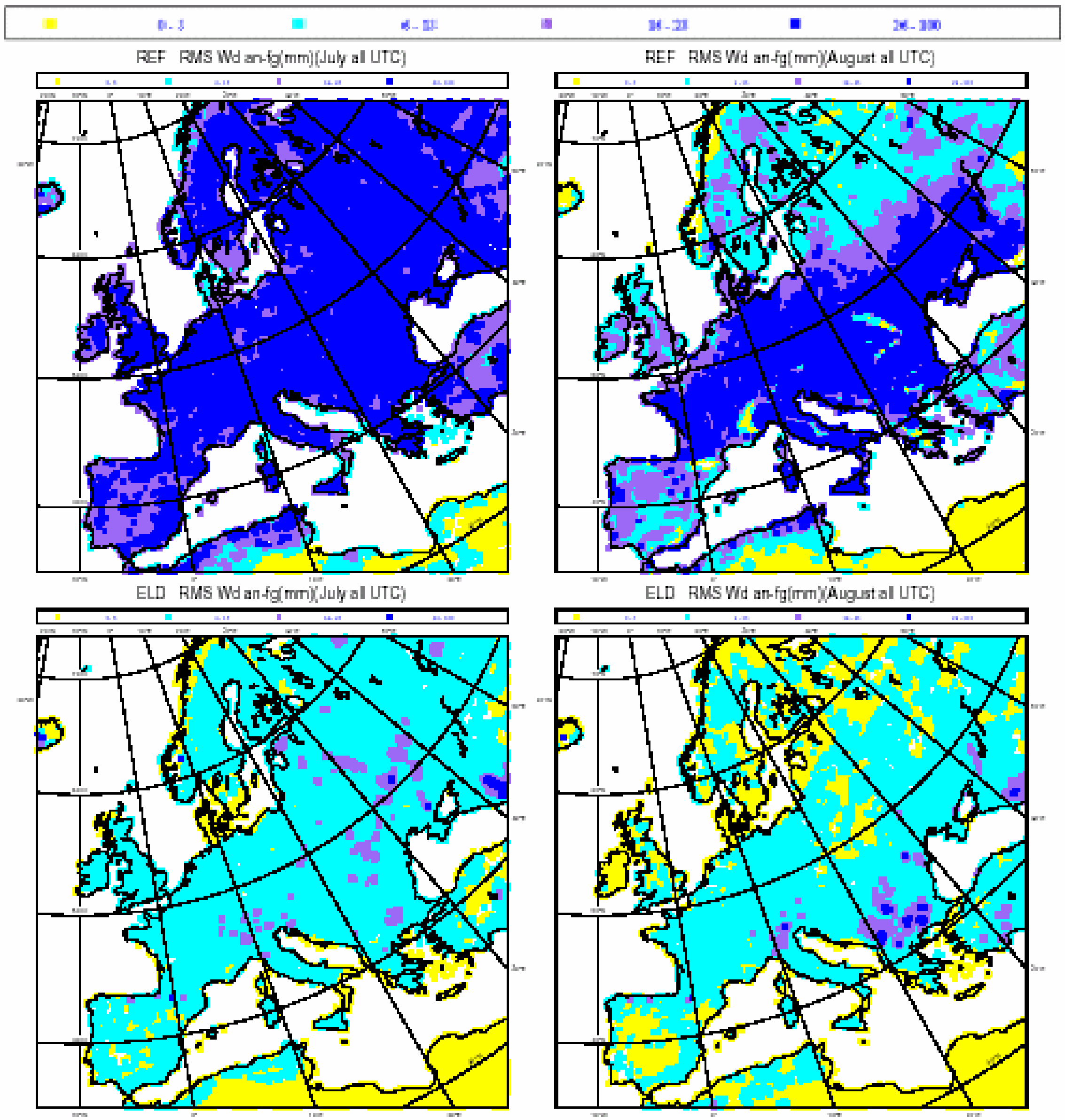
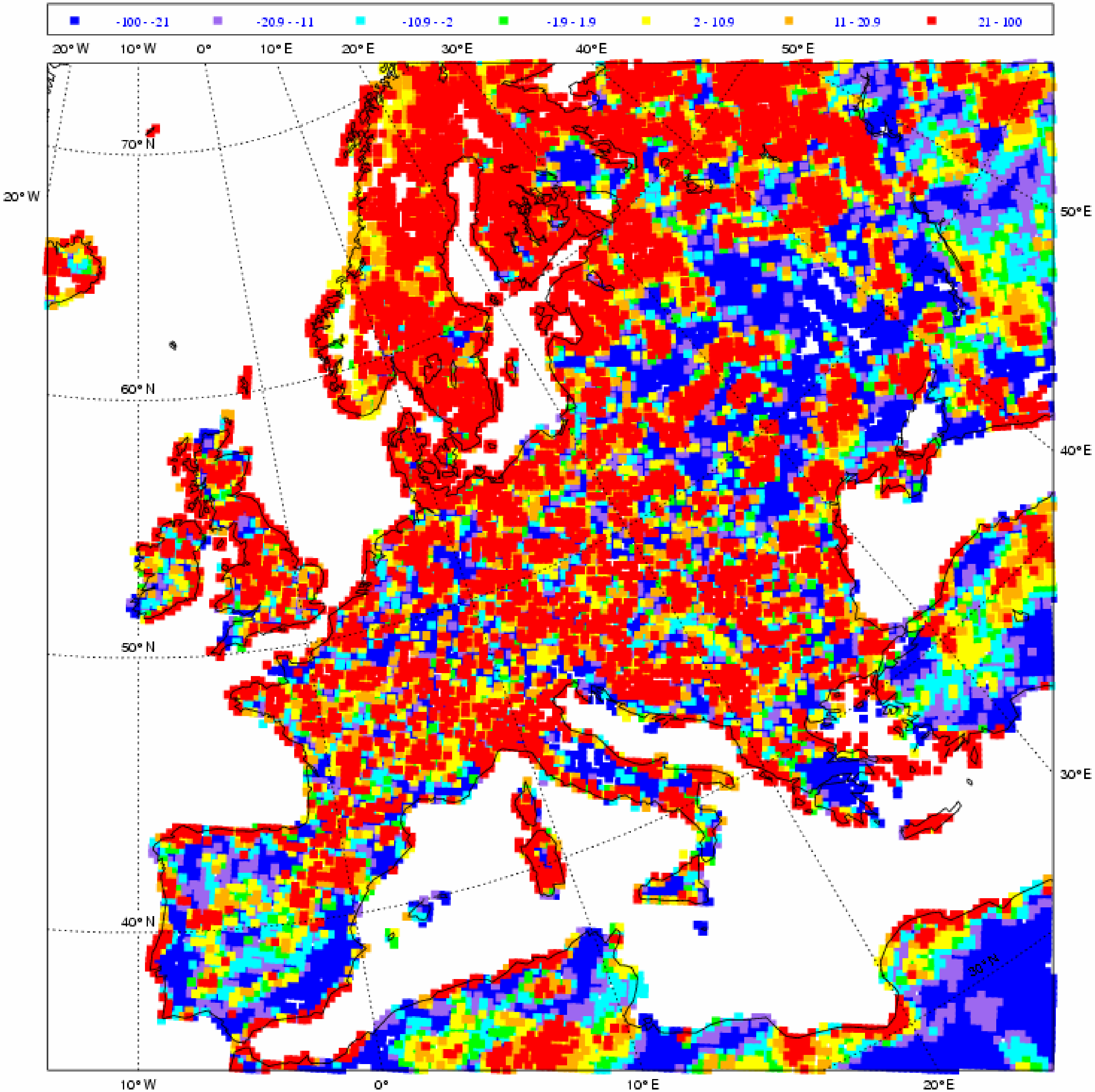


Figure 5: Monthly averaged (July and August) rms error of soil moisture increments (analysis minus HIRLAM first guess, expressed in mm) for REF (top) and ELD (bottom) experiments.

DIF Mean Wd REF-ELD(mm)(20000702 00UTC)



Conclusions from ELDAS (I)

- The comparison of 3 SM assim. schemes covering a whole growing season from June to October 2000 shows no big differences in terms of impact on screen level temperature and relative humidity.
- The default OI scheme in the HIRLAM system (REF experiment) showed a marked tendency to overcorrect soil moisture. The ELDAS generated soil moisture field (ELD experiment) showed a more realistic soil moisture evolution and soil moisture analysis increments. The variational method (VAR experiment) implemented for soil moisture assimilation within the HIRLAM system also showed overcorrection due to the excessively large soil moisture perturbations used by the computation of the pertubed integration.
- The analysis of water balance and of forcing terms (precipitation and short wave radiation) for the studied specific points seems to indicate that no substantial differences appear between REF and ELD experiments. The accumulated soil moisture increments and their assignation to the different hydrological terms show big similarities between both experiments.
- Net contribution of soil moisture coming from the analysis increments (general to most models). Some systematic behaviour requiring further study has been observed over certain regions, *e.g.*, the huge demand of water supplied by the soil moisture analysis and converted directly to the evapotranspiration. This behaviour suggests the existance of water sources not contemplated by the model (irrigation) or problems of representativeness.

More from ELDAS in
http://www.knmi.nl/samenw/eldas/

Conclusions from ELDAS (II)

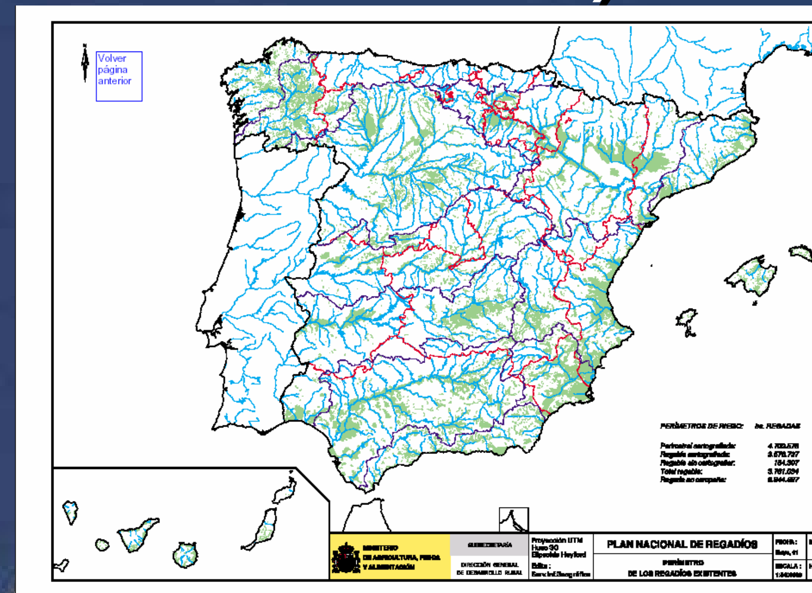
- General problem: excessive SM corrections. Needed: (i) better models, (ii) better assim. procedures, (iii) assim. of diverse set obs. sampling physical space in complementary directions, avoiding aliasing, e.g., use of SM informative sat. data (IR, MW).
- Approx. neutral impact in term of scores of screen variables.
- Size of SM increments gives some hints on the quality of the SM assim. Procedure.
- Recommedations: Start to use SM products in applications, e.g., agriculture, hydrology, forest fires risk, etc.
- Start assimilation of vegetation properties (LAI, veg, Zoheat) using satellite information.
- ELDAS has allowed to implement and test the 1D surface variational code (Balsamo et al., 2004) in the HIRLAM framework. This code is the suitable frame for extending the SM informative data from screen variables only to satellite information. Also the ECOCLIMAP database has been used and tested.

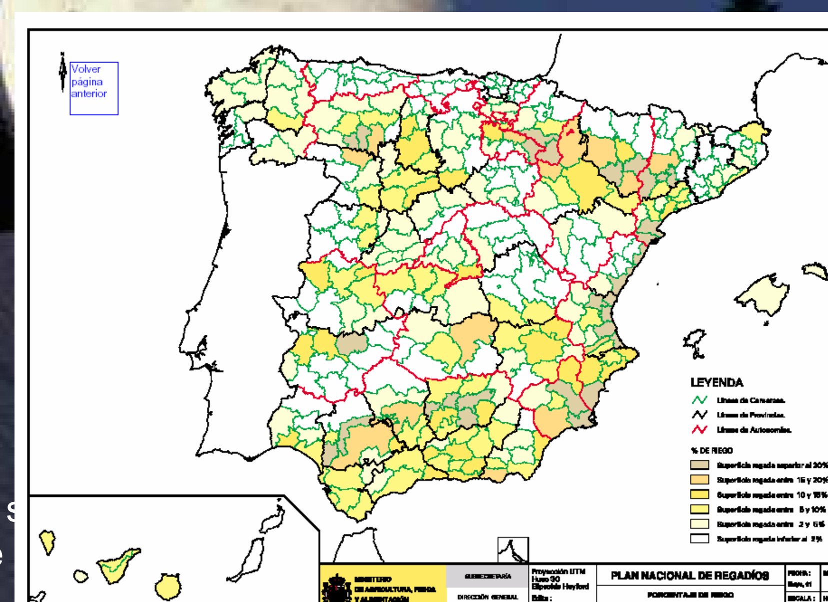
More from ELDAS in
http://www.knmi.nl/samenw/eldas/

Irrigation (not a Nordic issue!)

Table 1. Countries having more than 1% of the global irrigated area according to FAOSTAT 1998.

Country	Area (km^2)	% of total irrigated area
World	2,714,320	100.0
India	590,000	21.7
China	525,820	19.4
United States of America	214,000	7.9
Pakistan	180,000	6.6
Iran	75,620	2.8
Mexico	65,000	2.4
Indonesia	48,150	1.8
Thailand	47,490	1.7
Russian Federation	46,630	1.7
Uzbekistan	42,810	1.6
Turkey	42,000	1.5
Bangladesh	38,440	1.4
Spain	36,400	1.3
Iraq	35,250	1.3
Egypt	33,000	1.2
Viet Nam	30,000	1.1
Romania	28,800	1.1
Italy	26,980	1.0
Japan	26,790	1.0
Brazil	26,560	1.0
Sri Lanka	6,510	0.2

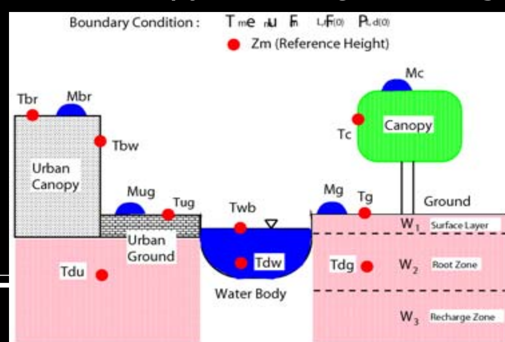




Treatment of irrigation by SiBUC (Yoruzu et al. 2005) (I)

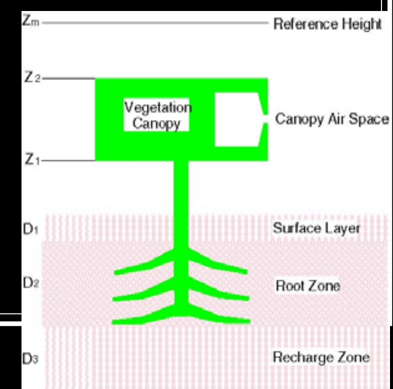
Land Surface Scheme (SiBUC)

- Grid box is divided into three land use categories
  (1) Green Area (Canopy, ground)
  green area can be further divided (10classes)
  (2) Urban Area (urban canopy, urban ground)
  (3) Water Body
- Fractional Area
  (Vga, Vua, Vwb)
- Canopy Coverage
  (Vc, Vuc)



Vegetation scheme (SiB)

- Prognostic variables
  temperature (canopy, ground, deep soil)
  intercepted water/snow (canopy, ground)
  soil moisture (surface, root zone, recharge)
- Time-invariant parameter
  morphological
  optical
  physiological
- Time-varying parameter
- Soil physical properties



Vegetation type

- 1. Broadleaf-evergreen trees
- 2. Broadleaf-deciduous trees
- 3. Broadleaf and needle leaf trees
- 4. Needle leaf-e
- 5. Needle leaf-d
- 6. Short vegeta
- 7. Broadleaf shr
- 8. Dwarf trees a
- 9. Agriculture/C
- 10. Paddy field

9. farmland (non-irrigated)
10. paddy field (non-irrigated)
11. paddy field (irrigated)
12. spring wheat (irrigated)
13. Winter wheat (irrigated)
14. Corn (irrigated)
15. Other crops (irrigated)

To activate irrigation in LSS

- The irrigation rules are based on at least four parameters:
  1. Planting date
  2. Harvesting date
  3. Periods of each growing stage
  4. Minimum water depth / soil moisture for each growing stage

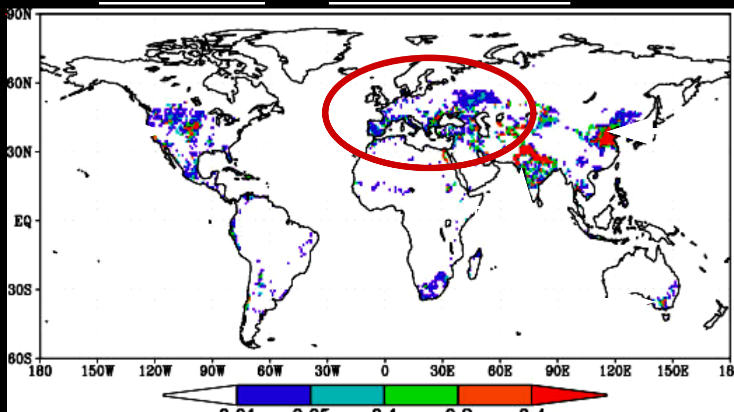
Table. 1 The period of each growing stage (Unit:%) and the low level of water depth (Unit:mm) or soil wetness at the root zone

crop type	growing stage	1	2	3	4	5
spring wheat	period	23	14	14	14	35
	soil moisture	70	60	80	80	55
winter wheat	period	26	20	22	13	19
	soil moisture	70	70	80	80	55
corn	period	8	48	6	14	24
	soil moisture	75	65	70	75	65
rice	period	25	13	33	13	16
	water depth (mm)	20-50	none	20-60	moistening	intermittent
soy bean	period	4	25	16	28	27
	soil moisture	75	65	65	70	65

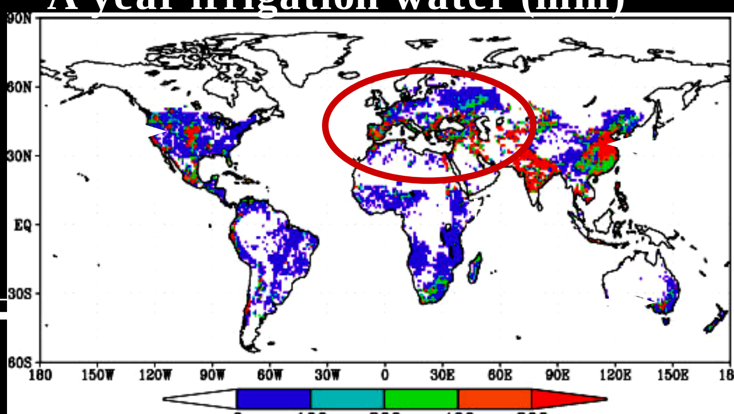
Treatment of irrigation by SiBUC (Yoruzu et al. 2005) (II)

Irrigation effects

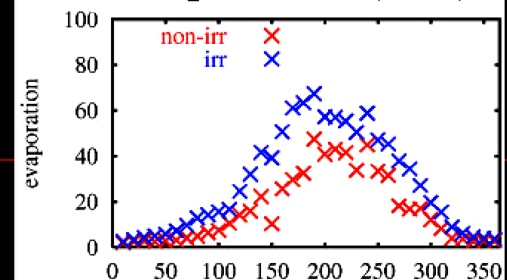
The increase in soil wetness of root zone



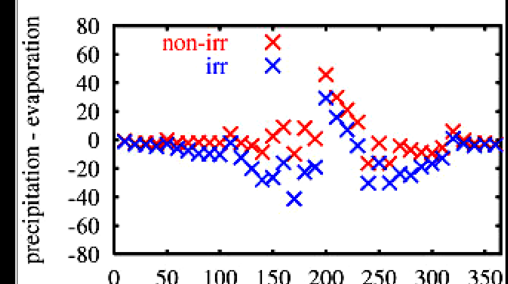
A year irrigation water (mm)



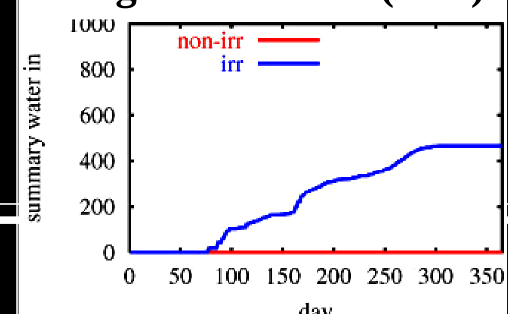
Evaporation (mm)



Precip-Evap (mm)



Irrigation water (mm)



Outline

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- HIRLAM surface parameterization. Future plans.

Main features of new surface

- New climate files: REF+vegetation+texture+tiling
- Fully re-coded surface analysis package: SST, Ice and water fractions, Sn, T2m, RH2m, SSM, DSM, Ts, Td
- ISBA for 3 land fractions
- Mods in postprocessing: surface fields (T2m,RH2m,W10m,...) over tiles and averaged over all tiles.

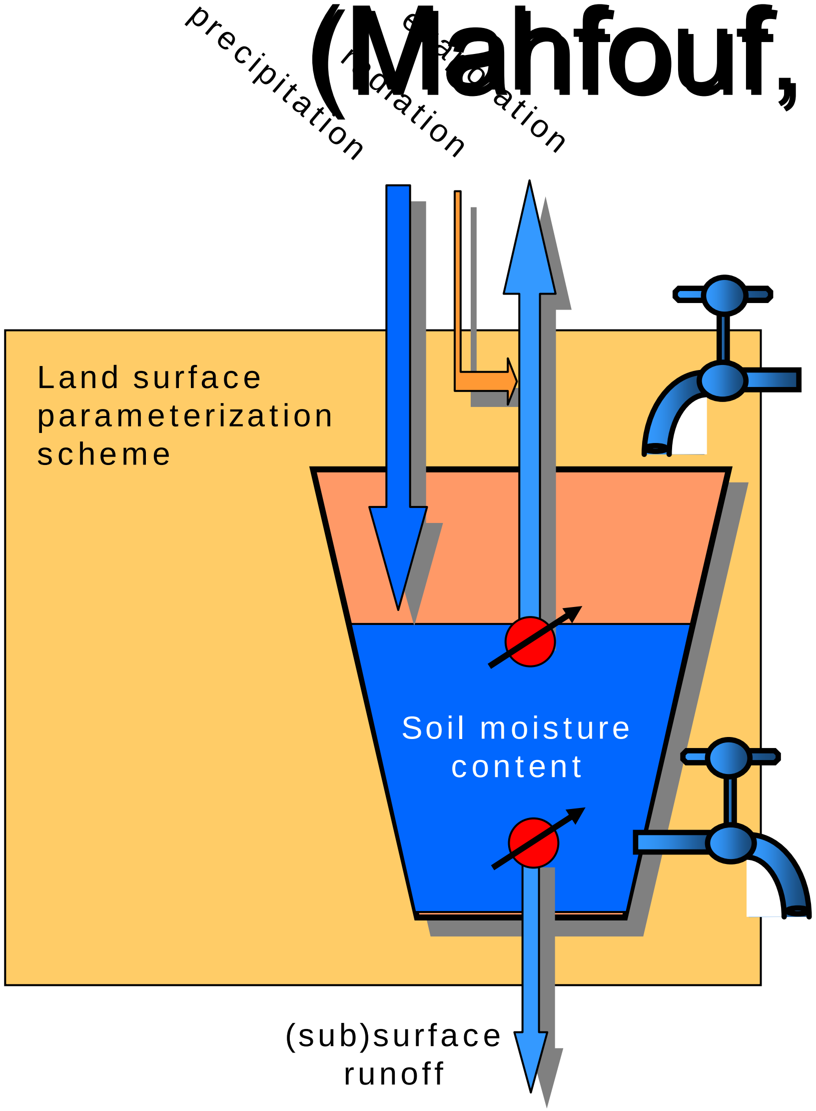
Surface Analysis(I)

- SST, Snow depth based on Succesive Corrections
- T2m, RH2m based on OI
- SSM, DSM based on sequential assim. (Mahfouf 91, Bouttier et al. 93, Giard & Bazile 00):

$$\Delta w_s = \alpha_s^T \Delta T_{2m} + \alpha_s^H \Delta H_{2m}$$

$$\Delta w_d = \alpha_d^T \Delta T_{2m} + \alpha_d^H \Delta H_{2m}$$

Soil moisture assimilation (Mahfouf, 1991)



$$\Delta T_{2m} > 0;$$
$$\Delta RH_{2m} < 0$$

$$\Delta T_{2m} < 0;$$
$$\Delta RH_{2m} > 0$$

Surface Analysis(II)

- Coefficients $\alpha = F(time, veg, LAI, R_{s\min}, texture)$
- Constraints for soil moisture corrections: low 10m wind, no precip., no snow, low cloudiness, day length, etc.
- Surface and mean soil temperature corrections:

$$\Delta T_d = \Delta T_{2m} / 2\pi$$

$$\Delta T_s = \Delta T_{2m}$$

Surface Analysis(III)

- Main weakness of SM corrections: T2m and RH2m errors coming from other physical processes (or numerics) different from incorrect SM specification.
- Bias in precipitation is easier to handle (it affects to SM only) than bias in radiation (it affects T2m and RH2m independent of SM) (Douville et al.,2000).

Surface analysis (IV): new snow depth analysis based on OI

- Modifications of the background field computation accounting for a very simplified snow metamorphism: snow aging
- Second order autoregressive (SOAR) function structure function to model background errors:

$$\alpha(r) = (1 + c\,r)\exp(-c\,r)$$

- Bias correction: all observations from the previous 5 days to calculate the bias in a given station.

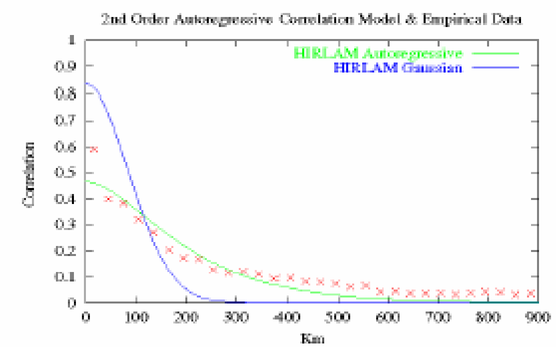
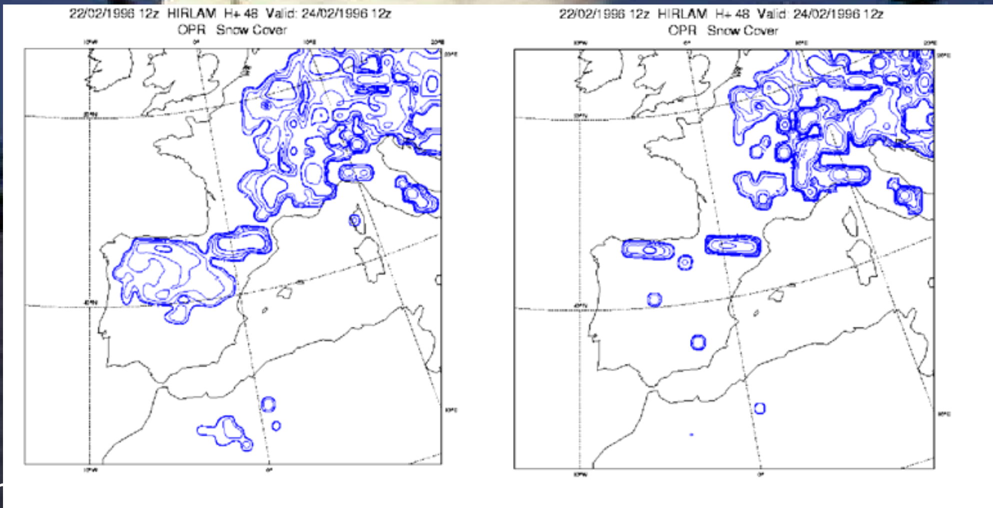


Fig. 3. Structure Functions of the analysis

SC:
* noisier snow depth
• more spread, specially in Southern Europe
• not satisfactory QC

OI:
• it solves "bull eye"
• more realistic patchy snow cover distribution.
• errors in model precipitation produce spureous snow cover (specially over mountain ranges)
• the model is not still able to follow the rapid thawings that sometimes happen.



(Cansado et al. 2004)

Surface analysis (V): new snow depth analisis based on OI

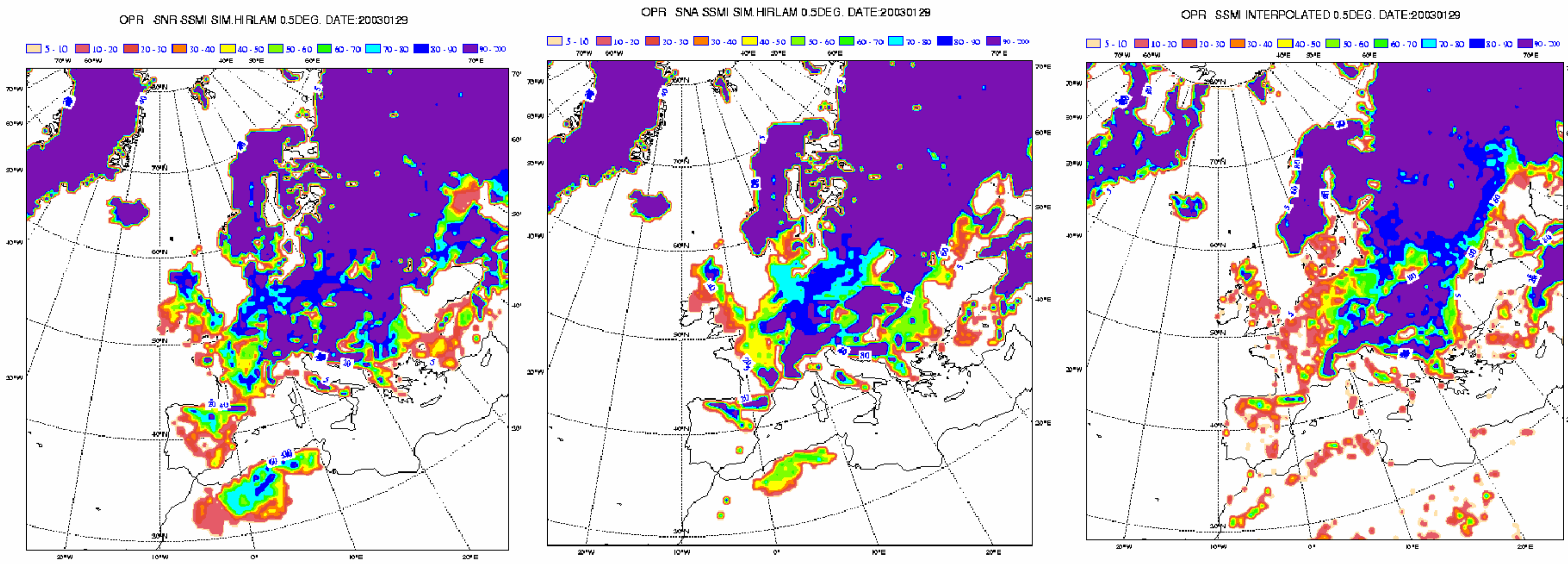


Fig. 4. Comparison between SNR (left), SNA (center) and SSMI derived data (right)

(Cansado et al. 2004)

Surface analysis (VI): new snow depth analisis based on OI

Two different satellite derived snow cover information sources have been tested (*both satellite products are not available in real time*):

- SSMI derived NESDIS global snow cover product, 1/3 degree resolution, updated once a week (if snow has been observed 0 per cent of time during a week, a 0 cm snow cover pseudobservation is introduced in the analysis every day of the considered week).
- MODIS TERRA global snow cover information, 0.05 degrees spatial resolution, updated daily.

(Cansado et al. 2004)

Future plans (I): Data requirements

* Precipitation:
  * European Rain Radar Network –OPERA
  * National gauge online
* Thermal IR
* MW: Precip. over land, SM, snow
* Radiative forcing
* ECOCLIMAP:
  · Static data (land cover classif.[based on GLC2000 and CORINE 2000])
  · Semistatic data (soil/veg param 10d updated based on SPOT/VEGETATION, MODIS data)
  · Irrigation
* Hydro-meteorological observations
* Discharge

Future plans (II): data assimilation methodology

- Use of off-line 1D VAR technique forced by observed precipitation and SW radiation (feasibility demonstared during ELDAS (prototypes at ECMWF, DWD, MF, HIRLAM))
- Combination of multiple time scales: GEOLAND (1d for SM; 2-3 weeks for LAI)

Outline

- Why surface parameterization is important?
- Which are the distinct features of surface/atmosphere interaction?
- How important are the different surface parameters?
- Treatment of surface heterogeneity. Aggregation. How big is the impact of tiling?
- How are surface schemes validated?
- Physiographic description. ECOCLIMAP. How big is the impact of physiography?
- Assimilation of surface variables. Case of soil moisture. ELDAS experience. How big is the impact of soil moisture?
- HIRLAM surface analysis. Future plans.
- HIRLAM surface parameterization. Future plans.

Land fractions: ISBA scheme (Noilhan & Planton, 1989)

$$\frac{\partial T_s}{\partial t} = C_t G + \frac{2\pi}{\tau}(T_s - T_2)$$

$$\frac{\partial T_2}{\partial t} = \frac{T_s - T_2}{\tau}$$

$$\frac{\partial w_s}{\partial t} = \frac{C_1}{\rho_w d_1}(P_g - E_g) + \frac{C_2}{\tau}(w_s - w_{geq})$$

$$\frac{\partial w_2}{\partial t} = \frac{1}{\rho_w d_2}(P_g - E_g - E_{tr}) + \frac{C_3}{d_2 \tau}\max[0, (w_2 - w_{fc})]$$

$$\frac{\partial w_r}{\partial t} = veg \cdot P - E_r, w_r \leq w_{r\,\max}$$

$$\frac{\partial W_{si}}{\partial t} = {F^s}_f - {F^s}_m$$

$$\frac{\partial W_{pi}}{\partial t} = +({F^s}_f - {F^s}_m) + ({F^p}_f - {F^p}_m)$$

$$\left(\frac{\partial T_s}{\partial t}\right)_{f/m} = C_t L_f ({F^s}_f - {F^s}_m)$$

$$\left(\frac{\partial T_p}{\partial t}\right)_{f/m} = C_t L_f ({F^p}_f - {F^p}_m)$$

$$ {F^p}_f = \frac{K_p}{\tau_p} \cdot \left(\frac{W_{pl}}{W_{sat}}\right) \cdot \frac{max(0, T_t - {T^+}_p)}{C_i L_f}$$

$$ {F^s}_f = \frac{K_s}{\tau_s} \cdot \left(\frac{W_{sl}}{W_{sat}}\right) \cdot \frac{max(0, T_t - {T^+}_s)}{C_i L_f}$$

$$ {F^p}_m = \frac{K_p}{\tau_p} \cdot \left(\frac{W_{pi}}{W_{sat}}\right) \cdot \frac{max(0, {T^+}_p - T_t)}{C_i L_f}$$

$$ {F^s}_m = \frac{K_s}{\tau_s} \cdot \left(\frac{W_{si}}{W_{sat}}\right) \cdot \frac{max(0, {T^+}_s - T_t)}{C_i L_f}$$

Noilhan & Planton (1989)

Giard & Bazile (2000)

Rodríguez et al. (2003)

Bazile and Giard (1999)

Parodi et al. (2003)

New surface scheme for HIRLAM (Gollvik) (I)

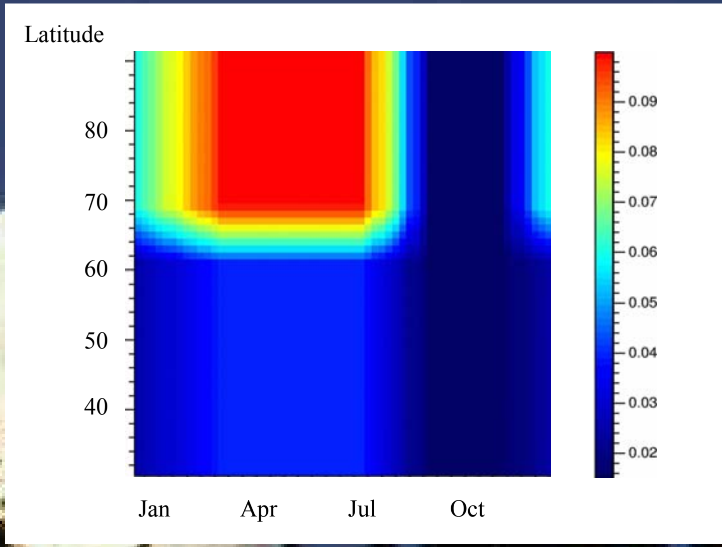
- Force-restore formulation replaced by heat conduction formulation for temperature
- Force-restore formulation for soil moisture
- Energy budget for snow and canopy
- 7 tiles: water, sea ice, snowfree bare land, snowfree low vegetation, snowfree forest, snowed openland and snowed forest.
- For all land tiles: 3 prog. soil temperatures with depths: 1.0, 7.2 and 43.2 cm + bottom clim. layer
- The forest tile has a common canopy layer for snowed and snowfree forest.
- Both snowed tiles also have evolving albedo, density and liquid water content

Snowfraction

It is simply estimated by

$$frsn(x,y,t) = sn(x,y,t)/sncrit(x,y,t), \quad frsn \leq 1$$

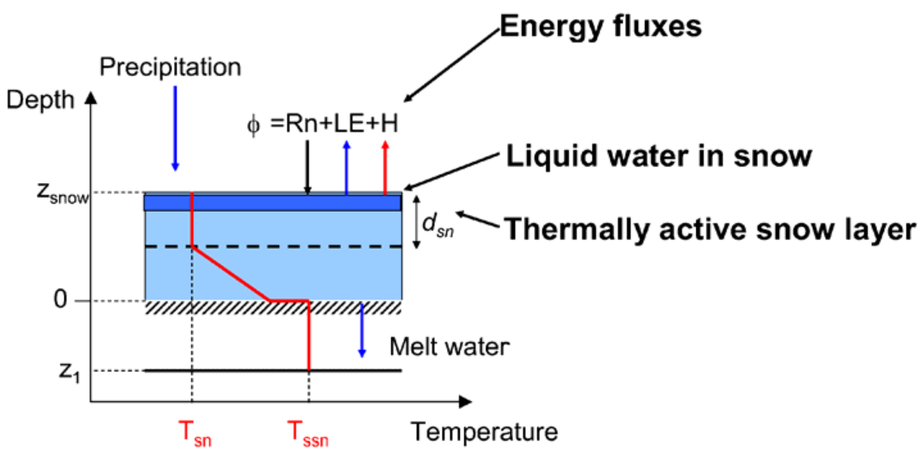
- One of the biggest problems in all snow schemes.
- Observations indicate an hysteresis effect, such that the melting phase is more patchy than the growing phase. In order to be able to use observations of snow we use this simple formulation.
- By analysing both snow depth and snow coverage *sncrit* can be calculated. This is not ready yet, so for the time being we use an ad hoc *sncrit* as a function of time of the year and latitude:



Heat conduction

- Snow described by 1 layer: Tsn
- Thermally active snow layer
- Heat conduction btw snow and Ts is function of snow depth
- Snow thawing starts when Tsn reach 0ºC
- Melted snow starts draining when SnWsat is reached (4-12% depending on snow density).
- Dry snow density (snow at old time step – liquid water) increases with time (Douville et al., 1995) (e-folding time about 4 days). Density at the new step is then modified by liquid water and frozen liquid water.

Here we use only one layer of snow, the depth of which is Z_{snow} [m snow]. Only the upper part is thermally active in cases of deep snow:



$$\frac{dT_{sn}}{dt} = \frac{1}{c_{snow} * MIN(Z_{snow}, d_{sn})}[\Phi - \alpha_{snow}(T_{sn} - T_{ssn})]$$

$$c_{snow} = vhice * \rho_{sn}/\rho_{ice}$$

Here the coefficient α_{snow} (formulation from ERA 40) is parameterizing a "fictive" profile through the snow, since the isolation is a function of the snowdepth:

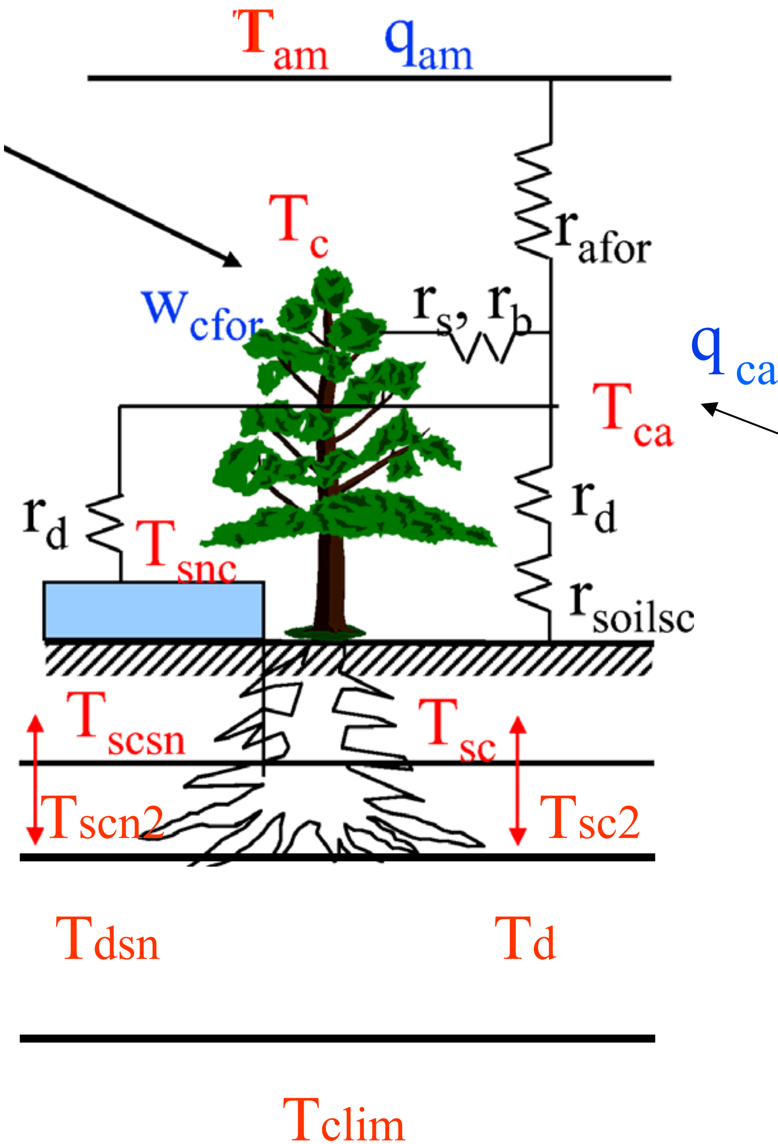
$$\alpha_{snow}^{-1} = 0.5\frac{Z_{snow}}{\lambda_{sn}} + 0.5\frac{Z_1}{\lambda_{soil}} \; ; \quad \lambda_{sn} = \lambda_{ice}\left(\frac{\rho_{sn}}{\rho_{ice}}\right)^{1.88}$$

MELTING/FREEZING

* Melted water is kept in the snow, until it reaches a saturation value *swsat* varying linearly with snow density between 12% for low density snow, and 4% for dense snow (simulating that the snow gradually transforms to ice)

* Freezing of the water in the snow, is less straightforward, since negative energy flux must be partitioned between freezing and cooling of the snow pack. This fraction is parameterized as *freezefrac*, which is a function of snow depth and liquid water in the snow. Technically the timestep is split between a phase shift part and a warming/cooling part.

The forest tile



$$H_{for} = \rho c_p \frac{T_{ca} - T_{am}}{r_{afor}} =$$

$$= H_c + frsn * H_{snc} + (1 - frsn) H_{sc}$$

Canopy air temperature (assuming no heat capacity) and humidity

Calculations of r_b and r_d follows Choudbury and Monteith, 1988

- Within the forest, the snow pack is treated as in openland
- A view factor defines how much of the incoming SWD is reaching the forest floor

New surface scheme for HIRLAM (Gollvik) (IV). Changes in the surface analysis

- The two snow temperatures are adjusted in the same way as the other surface temperatures, based on the 2m-analysis.
- The soil temperature changes under the snow are neglected in the analysis.
- Below the snowfree tiles, the soil temperatures are updated by solving the heat conduction

Future plans

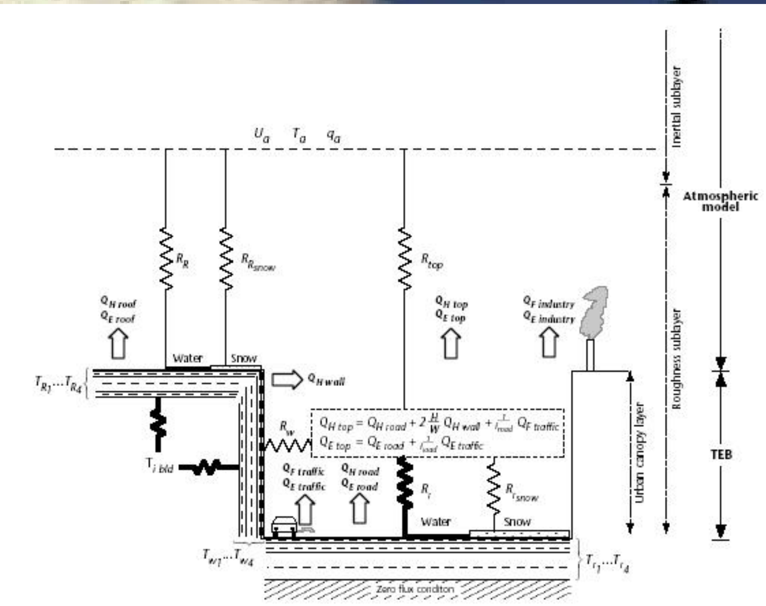
- Concept of externalized code for assimilation and parametrization of surface processes to separate surf schemes from atm model (in line with MF, ECMWF)
- As some soil/surface variables increase their accuracy, new applications of e.g. SM can be envisaged: hydrological, crop yield, fire risk, irrigation management, etc.
- Incorporation of carbon/green biomass processes
- The ELDAS project has posed the problem of the very large systematic SM increments, probably coming from incorrect land surface modelling (but not only!). Need to revise:

  * Parameters responsible for s increments, such as hydraulic conductivity, s stress formulation, etc.

  * For the snow treatment, introd bands and param. of snow cover fraction as f hysteresis effect.

  * For the proper assim of TIT, r coupling of surf/atm, possibly by adopting a ca

  * Modelling of urban terrain (TE al. 2002)



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