Should you dine at ROSETTA's?

UM soil ancillary parameters

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Making Tough Choices

- The Unified Model uses PedoTransfer Functions (PTFs) to derive soil hydraulic properties from soil texture:
  - There are many empirically derived PTFs in the scientific literature and they give wildly different solutions.
  - PTFs determine the water holding capacity of soils.
  - PTFs affect the vertical flow of soil water.
  - PTFs affect the ability of plants to extract water from the soil.
  - PTFs have a big impact on model soil moisture

- Analogy: Choosing a PTF is like choosing a restaurant in an unfamiliar, foreign city.
  - If you don't choose you will be hungry.
  - Any choice may well leave you feeling ill the next day.

UM CH b or VG 1/(n-1) parameters in agreement with ECMWF

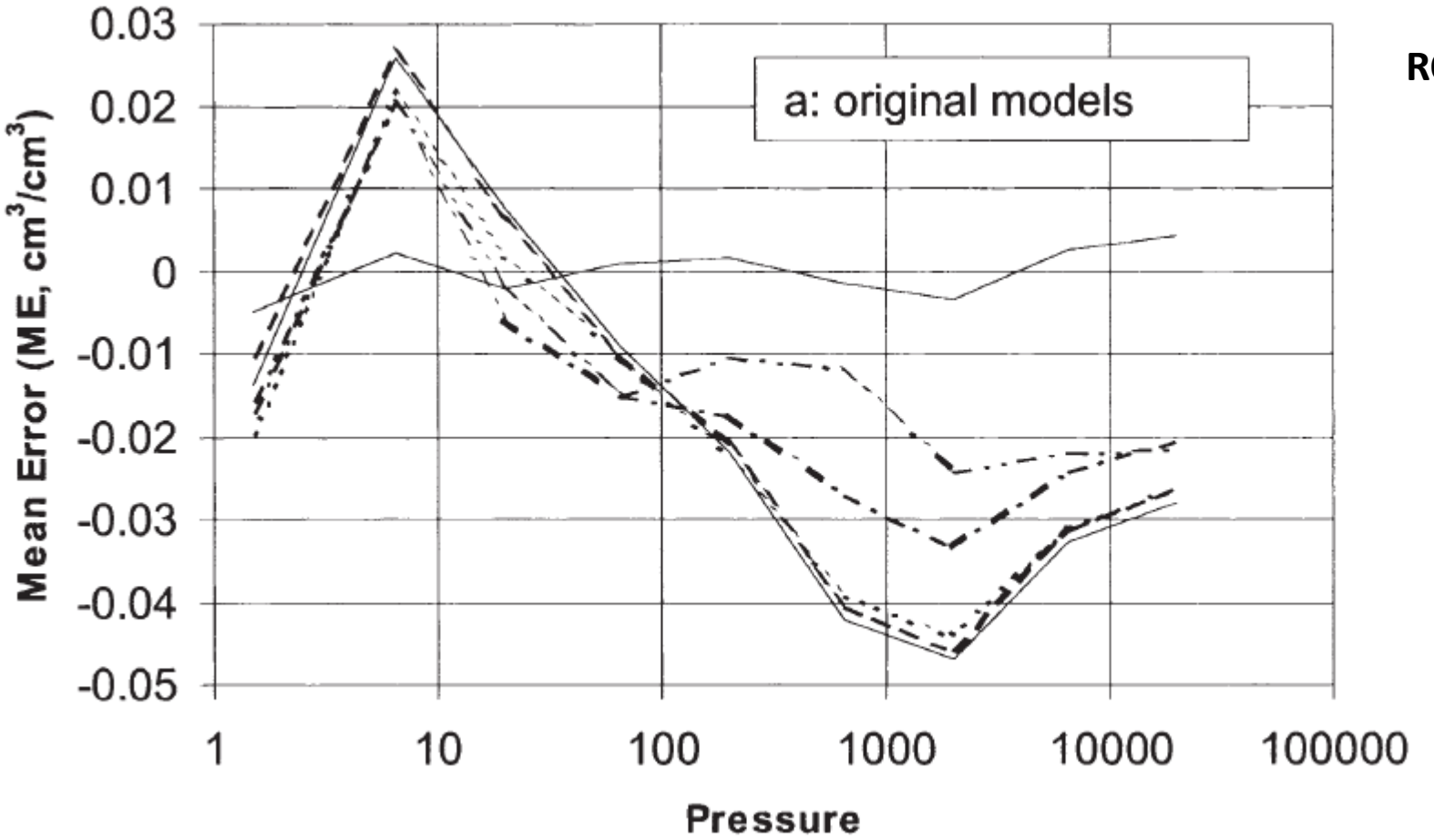
	ROSETTAv1 1998 1/(n-1)	ROSETTAv1 2002 1/(n-1)	COSBY et al 1984 b		TOTH et al 2014 1/(n-1)	Carsel & Parrish 88 1/(n-1)	Rawls et al 1982 1/λ	Woesten et al 1999 1/(n-1)
	IGBP		UM			Orchidee		ECMWF
	Lookup Table	Lookup Table	Lookup Table	Function	Lookup Table	Lookup Table	Lookup Table	Lookup Table
Sand	0.8 ± 1.1	0.6 ± 0.8	2.8 ± 1.4	3.3	1.2	0.6	1.7	2.7 Coarse
Loam	1.8 ±	2.1 ±	5.3 ± 1.7	5.8	5.2	1.8	4.5	5.6 Med *
Clay Loam	2.5 ± 2.3	2.9 ± 2.5	8.2 ± 3.7	8.3	8.6	3.2	5.2	
Sandy Clay Loam	3.3 ± 2.6	3.3 ± 2.7	8.7 ± 4.3	7.2	7.5	2.1	4.0	
Silty Clay		3.5 ± 2.7	10.4 ± 3.9	10.5	9.0	11.0	7.9	
Clay	4.1 ± 2.6	4.3 ± 2.8	11.6 ± 3.9	12.1	8.3	11.0	7.6	9.9 Fine

* For UM Medium soil type [sand=27%, silt=50%, clay=23%] the Cosby CH b parameter = 6.6
* Averaged over all 6 USDA loam types the average Cosby CH b parameter = 6.5

Large biases in ROSETTAv1

Schaap, M.G., Nemes, A. and Van Genuchten, M.T., 2004. Comparison of models for indirect estimation of water retention and available water in surface soils. *Vadose Zone Journal*, *3*(4), pp. 1455-1463.

- "the mean errors of H1 through H4 before modification were considerable"
- "By far the strongest effect is seen for the parameter *n*"



ROSETTA models

H1
H2
H3
H4
H5
Fit

IGBP uses H3

H4 and H5 use additional information we don't have

Comparison of Ks (cm/day) *

Typical uncertainty in PTF derived Log10(Ks) is about 0.5 to 1 (uncertainty in Ks is about half to one order of magnitude).

	ROSETTAv1 1998	ROSETTAv1 2002	COSBY et al 1984		TOTH et al 2014	Carsel & Parrish 88	Rawls et al 1982	Woesten et al 1999
	IGBP		UM					ECMWF
	Lookup Table	Lookup Table	Lookup Table	Function	Lookup Table	Lookup Table	Lookup Table	Lookup Table
Sand	512	642	403	211	8	713	504	60 Cors
Loam	10	12	29	41	14	25	32	12 Med
Clay Loam	5	8	21	23	195	6	6	
Sandy Clay Loam	19	13	39	55	44	31	4	
Silty Clay		10	12	9	0.01	0.48	2	
Clay	13	15	8	12	17	5	1	25 Fine

* UM ancillaries use units of mm/s for Ks

Comparison of Θ_s-Θ_r (m3/m3)

Typical uncertainty in PTF derived values is 0.05 to 0.1 m3/m3.

	ROSETTAv1 1998	ROSETTAv1 2002	COSBY et al 1984		TOTH et al 2014	Carsel & Parrish 88	Rawls et al 1982	Woesten et al 1999
	IGBP		UM					ECMWF
	Lookup Table	Lookup Table	Lookup Table	Function	Lookup Table	Lookup Table	Lookup Table	Lookup Table
Sand	0.37	0.32	0.34	0.37	0.35	0.39	0.42	0.38 Cors
Loam	0.30	0.34	0.44	0.44	0.49	0.35	0.43	0.43 Med
Clay Loam	0.35	0.36	0.47	0.45	0.47	0.32	0.39	
Sandy Clay Loam	0.30	0.39	0.40	0.41	0.41	0.29	0.33	
Silty Clay	0.31	0.37	0.47	0.48	0.46	0.29	0.42	
Clay	0.36	0.36	0.47	0.45	0.50	0.31	0.39	0.51 Fine

Comparison of CH Ψ_s or VG $1/\alpha$ (m)

Typical uncertainty in PTF derived Log10(Ψ_s) is about 0.5 to 1 (so uncertainty in Ψ_s or $1/\alpha$ is about half to one order of magnitude).

	ROSETTAv1 1998 $1/\alpha$	ROSETTAv1 2002 $1/\alpha$	COSBY et al 1984 Ψ_s		TOTH et al 2014 $1/\alpha$	Carsel & Parrish 88 $1/\alpha$	Rawls et al 1982 Ψ_s	Woesten et al 1999 $1/\alpha$
	IGBP		UM					ECMWF
	Lookup Table	Lookup Table	Lookup Table	Function	Lookup Table	Lookup Table	Lookup Table	Lookup Table
Sand	0.37	0.28	0.07	0.05	0.39		0.07	0.26 Cors
Loam	1.29	0.90	0.35	0.24	0.29		0.11	0.32 Med
Clay Loam	0.89	0.63	0.26	0.28	0.08		0.26	
Sandy Clay Loam	0.63	0.47	0.13	0.12	0.14		0.28	
Silty Clay		0.62	0.32	0.60	0.32		0.34	
Clay	0.78	0.67	0.47	0.29	0.43		0.37	0.27 Fine

Validation of model predicted un-saturated hydraulic conductivity

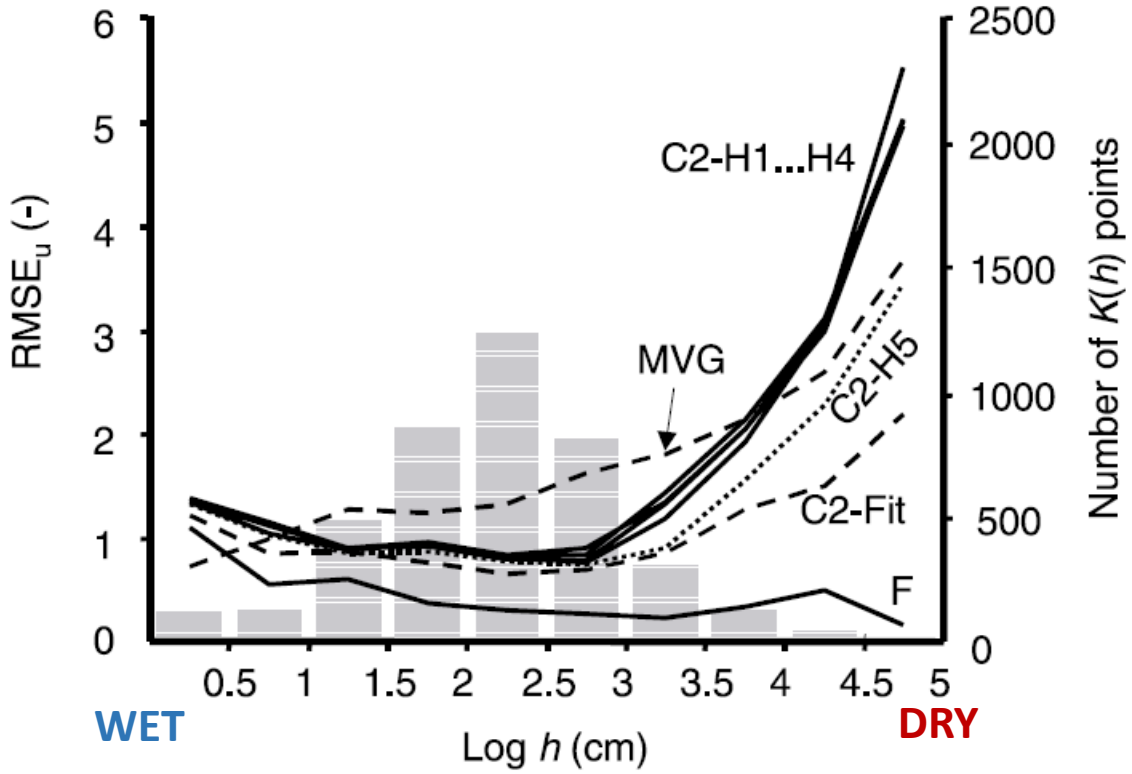
Source: Vereecken, H., Weynants, M., Javaux, M., Pachepsky, Y., Schaap, M.G. and Genuchten, M.T., 2010. Using pedotransfer functions to estimate the van Genuchten–Mualem soil hydraulic properties: A review. Vadose Zone Journal, 9(4), pp.795-820.

Table 6. Validation of pedotransfer functions (PTFs) expressed as the root mean squared residual (RMSR) for the van Genuchten–Mualem model to predict hydraulic conductivity curve using independent data.

Study	PTF validated, type†	Database	No. of data points	RMSR
Schaap and Leij (1998b)	Schaap and Leij (1998b), $l = -1$	UNSODA		1.65–1.77‡
Schaap and Leij (1998b)	Schaap and Leij (1998b), $l = 0.5$	UNSODA		1.24–1.37‡
Weynants et al. (2009)	HYPRES, Wösten et al. (1999)	Vereecken et al. (1989)	136	2.54§
Weynants et al. (2009)	ROSETTA, Schaap et al. (2001)	Vereecken et al. (1989)	136	3.01§

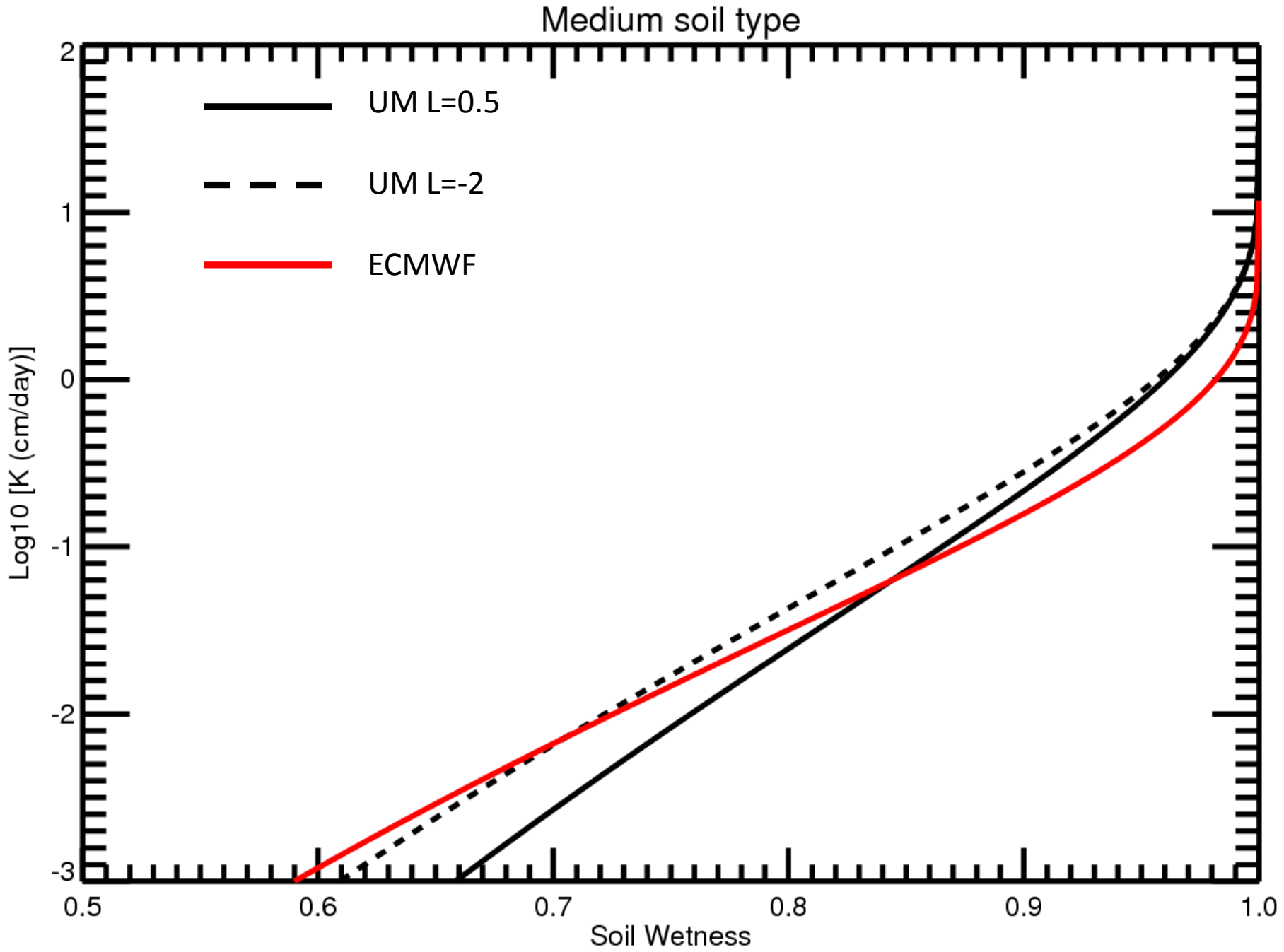
- The RMSR is for the $\log_{10}$ of the un-saturated hydraulic conductivity. Therefore, the error in ROSETTA is about 3 orders of magnitude!
- The Woesten PTF appears to be less inaccurate than ROSETTA.

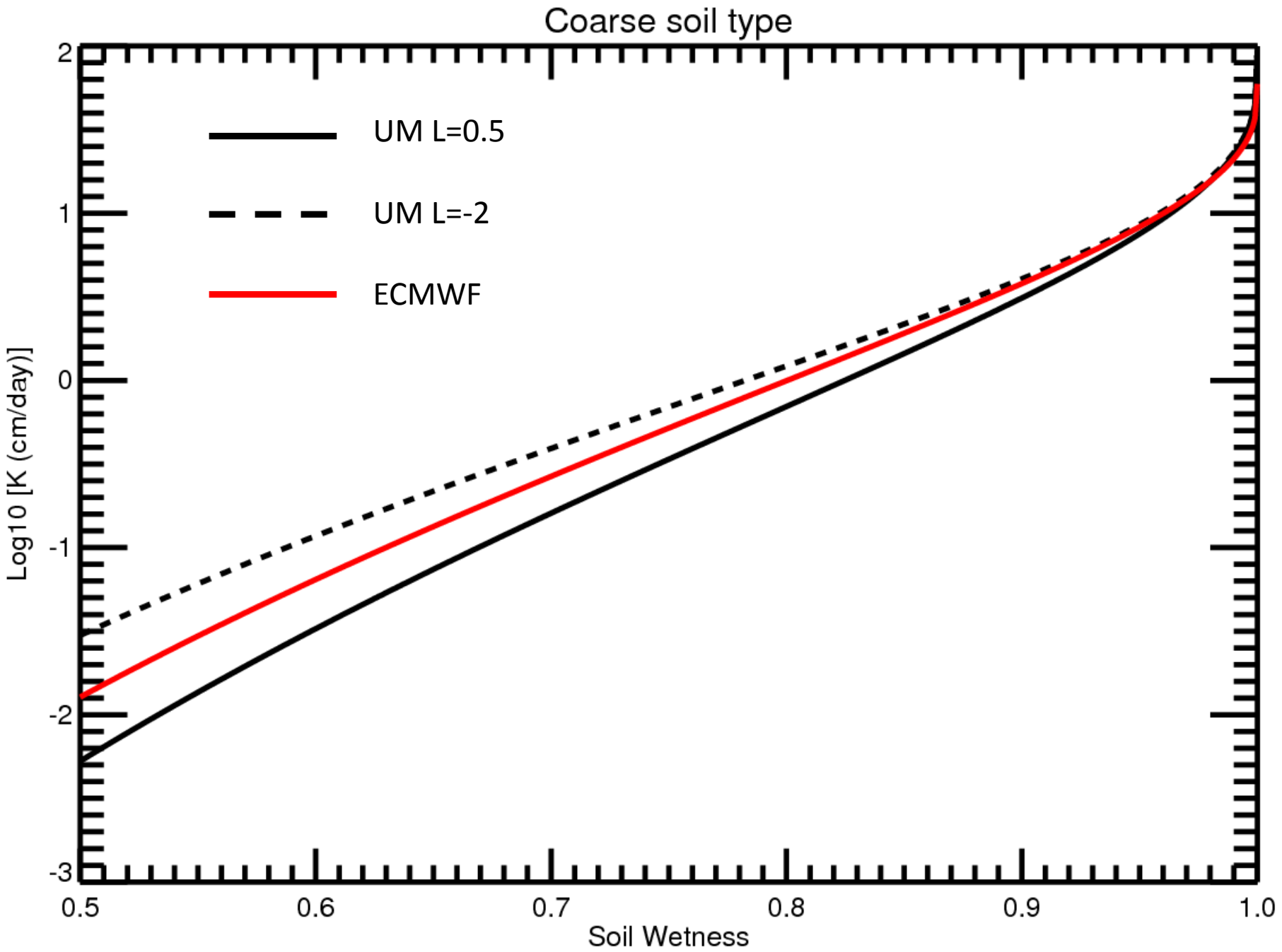
RMSD between ROSETTAv1 derived and observed hydraulic conductivity (MVG curve)



"The MVG model provides … an average RMSE of 1.4 (i.e. 1.4 order of magnitude)"

Fig. 4. RMSE$_u$ (lines, left axis) for the direct fit to conductivity data (F), for model C2 using fitted retention parameters (denoted as C2-Fit), model C2 using estimated retention parameters from the hierarchical approach (C2-H1–C2-H5). The MVG model with $K_0 = K_s$ and $L = 0.5$ is shown as MVG. The number of conductivity points per suction class is also shown (bars, right axis).


Medium soil type
UM L=0.5
UM L=-2
ECMWF
Log10 [K (cm/day)]
2
1
0
-1
-2
-3
0.5
0.6
0.7
0.8
0.9
1.0
Soil Wetness


Coarse soil type
UM L=0.5
UM L=-2
ECMWF
Log10 [K (cm/day)]
2
1
0
-1
-2
-3
0.5
0.6
0.7
0.8
0.9
1.0
Soil Wetness

Conclusions

- A number of PTFs have been compared and shown to give very different soil hydraulic parameter values.
- The ROSETTAv1 parameters have been shown to have biases (Schaap et al 2004).
  - We shouldn't use the ROSETTAv1 PTF as a proxy for the truth.
  - ROSETTAv3 was released in 2017 and may be much better.
- UM soil hydraulic ancillary parameters agree quite well with the parameters used by ECMWF and the parameters provided by Toth et al.
- There are other soil parameters hard wired in the UM which could be causing problems …
  - They aren't ancillary parameters but maybe they should be (VG L and Θ_r)

Possible Future Work

- Work with Anne Verhoef and Pier Luigi Vidale at Reading university
  - Anne is part of a GEWEX-ISMC initiative to test and compare PTFs
- Use an ensemble approach
- Make the UM VG L parameter flexible
  - This change would bring UM soil properties closer to ECMWF
  - Run UM/Jules tests with empirically derived values of VG L
- Do something about tropical soils
  - Tropical soils have very different parameters from mid-latitude soils
  - But, very few PTFs for tropical soils