Tuning COSMO shallow convection scheme over the Eastern Mediterranean

Pavel Khain, Harel Muskatel, Alon Shtivelman and Yoav Levi

ICCARUS, Offenbach, March 2019

Outline

1. **COSMO-IL OLD scores** *(during ICCARUS 2018)*
2. **Step 1: COSMO 5.1→5.5**
3. **Step 2: Introducing max. updraft threshold in Sh. Conv. scheme**
4. **Step 3: Update of the entrainment rate in Sh. Conv. scheme**
5. **COSMO-IL NEW scores** *(during ICCARUS 2019)*
6. **Conclusions**

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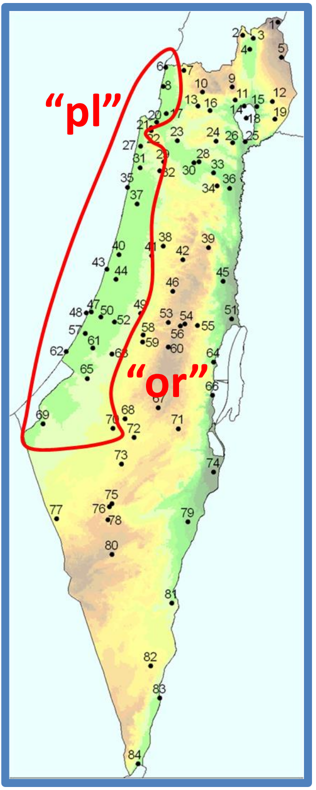
COSMO-IL OLD scores

---> Better score vs. IFS

181 runs (till +78h) during November 2017 – April 2018



		IFS	COSMO-IL **OLD** (version 5.1 shallow convection off)
2m Temp. (K)	TT or_rmse_n	2.08	1.92
	TT or_rmse_d	1.82	1.79
	TT pl_rmse_n	2.1	1.97
	TT pl_rmse_d	1.56	1.6
2m RH (%)	RH or_rmse_n	12.83	13.59
	RH or_rmse_d	9.35	10.5
	RH pl_rmse_n	12.07	13.12
	RH pl_rmse_d	9.42	10.15
10m Wind (m/s)	WV or_rmse_n	2.51	2.65
	WV or_rmse_d	2.47	2.91
	WV pl_rmse_n	2.2	2.34
	WV pl_rmse_d	2.24	2.59
Profiles RMSE	PT 24_48_72	0.88	1.01
	PT 12_36_60	0.71	0.81
	PQ 24_48_72	0.86	0.91
	PQ 12_36_60	0.79	0.89
	PW 24_48_72	2.28	2.53
	PW 12_36_60	2.09	2.28
Rain (1-FSS)	FSS 6	0.38	0.31
	FSS 12	0.46	0.43
	FSS 18	0.43	0.38
	FSS 24	0.45	0.46
	FSS 30	0.45	0.43
	FSS 36	0.47	0.43
	FSS 42	0.47	0.47
	FSS 48	0.52	0.51
	FSS 54	0.48	0.47
	FSS 60	0.52	0.44
	FSS 66	0.55	0.56
	FSS 72	0.52	0.59
	FSS 78	0.5	0.56

?

Color scale:

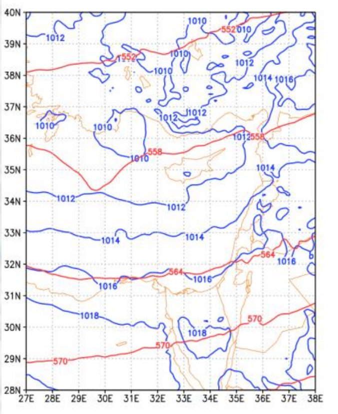
$$S_{thermo} = \frac{1}{N} \sum_{T,RH,Prof} \left[1 - \frac{RMSE_{COSMO}}{RMSE_{IFS}} \right]$$

$$S_{rain} = \frac{1}{N} \sum_{Rain} C \left[FSS_{cosmo} - FSS_{IFS} \right]$$

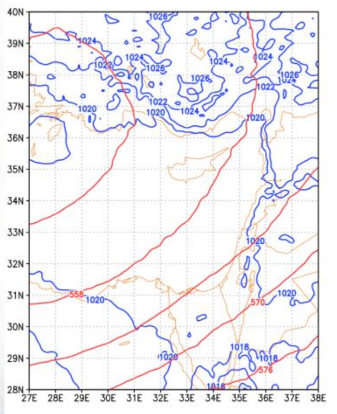
Method: tuning on 10 test-cases

78h forecasts initiated at:
2016121200,2016122300,2017021100,2017021400,2017041200,
2017112000,2017120500,2018010500,2018011800,2018021600

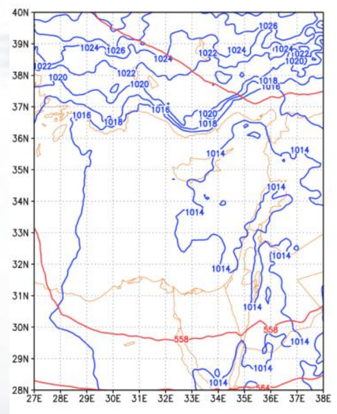
2016121200+24



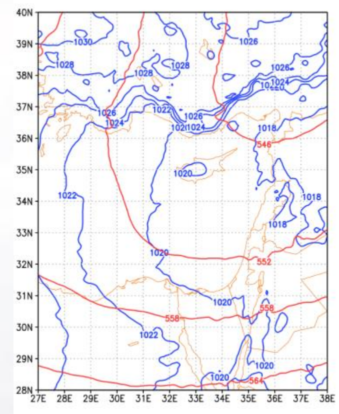
2016122300+24



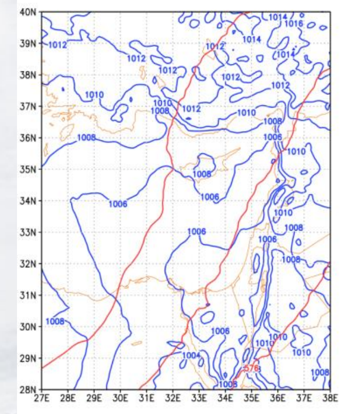
2017021100+24



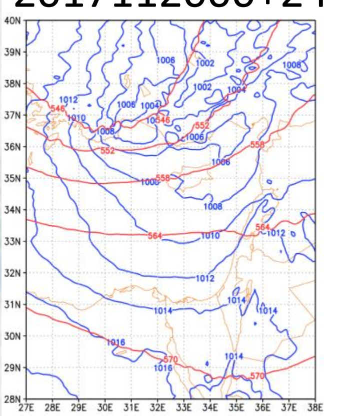
2017021400+24



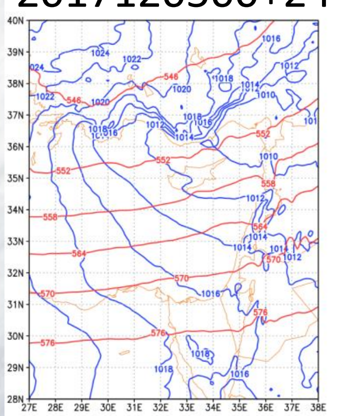
2017041200+24



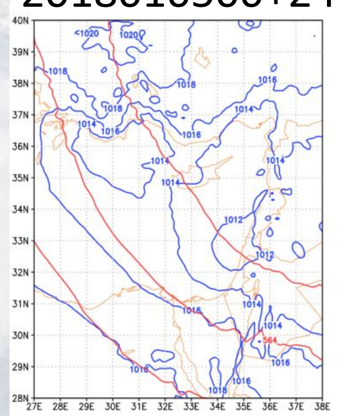
2017112000+24



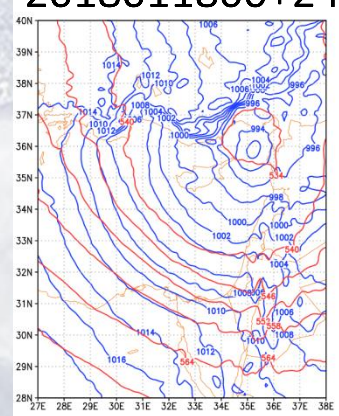
2017120500+24



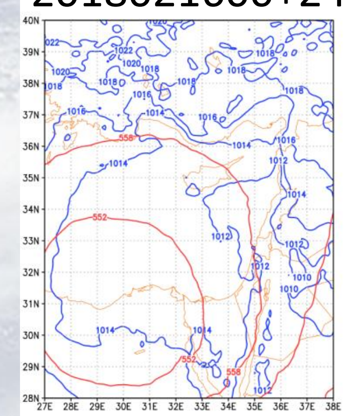
2018010500+24



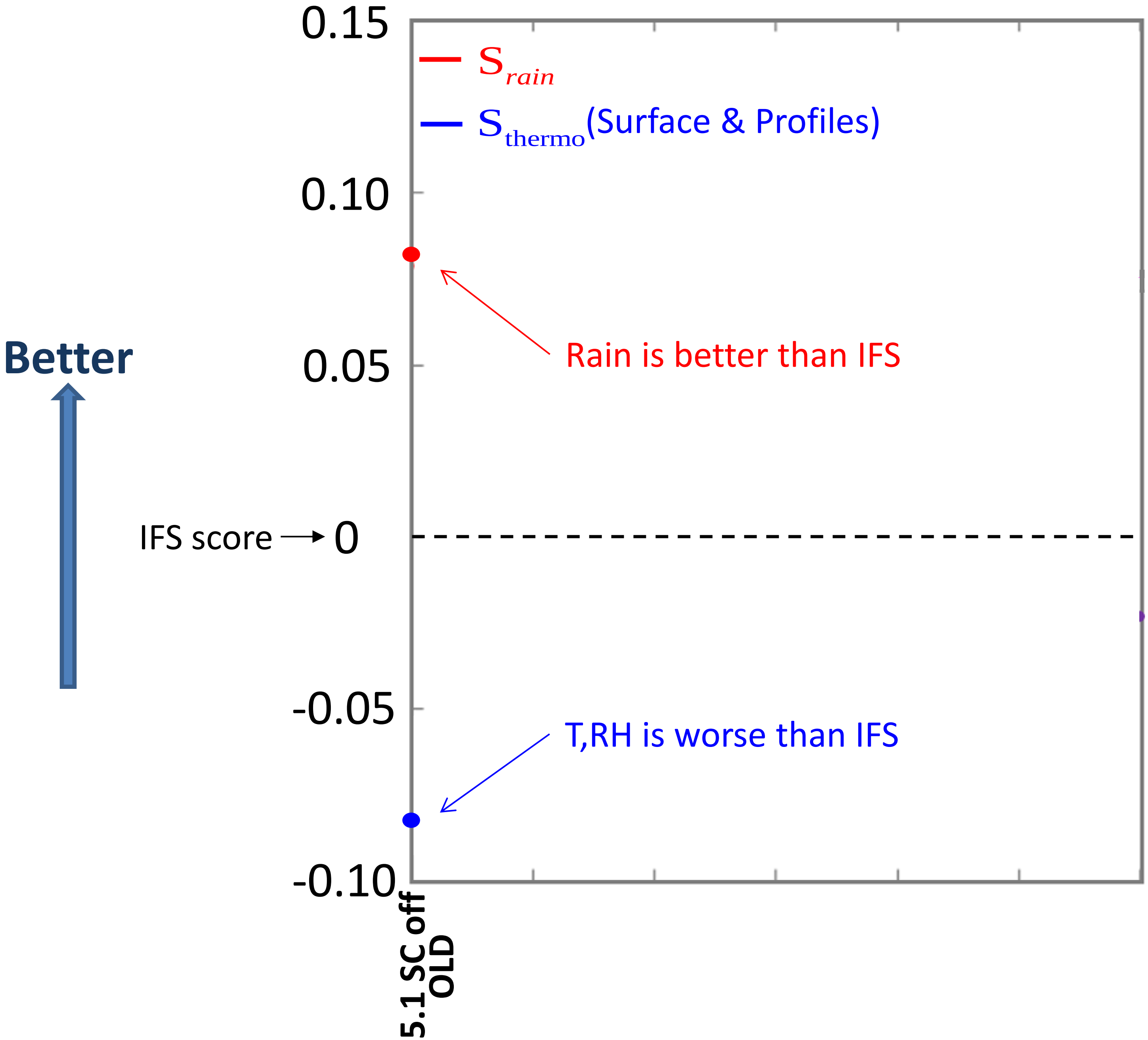
2018011800+24



2018021600+24



COSMO 5.1



Results for 10 "rain" test cases:

Outline

1. **COSMO-IL OLD scores** *(during ICCARUS 2018)*
2. **Step 1: COSMO 5.1→5.5**
3. **Step 2: Introducing max. updraft threshold in Sh. Conv. scheme**
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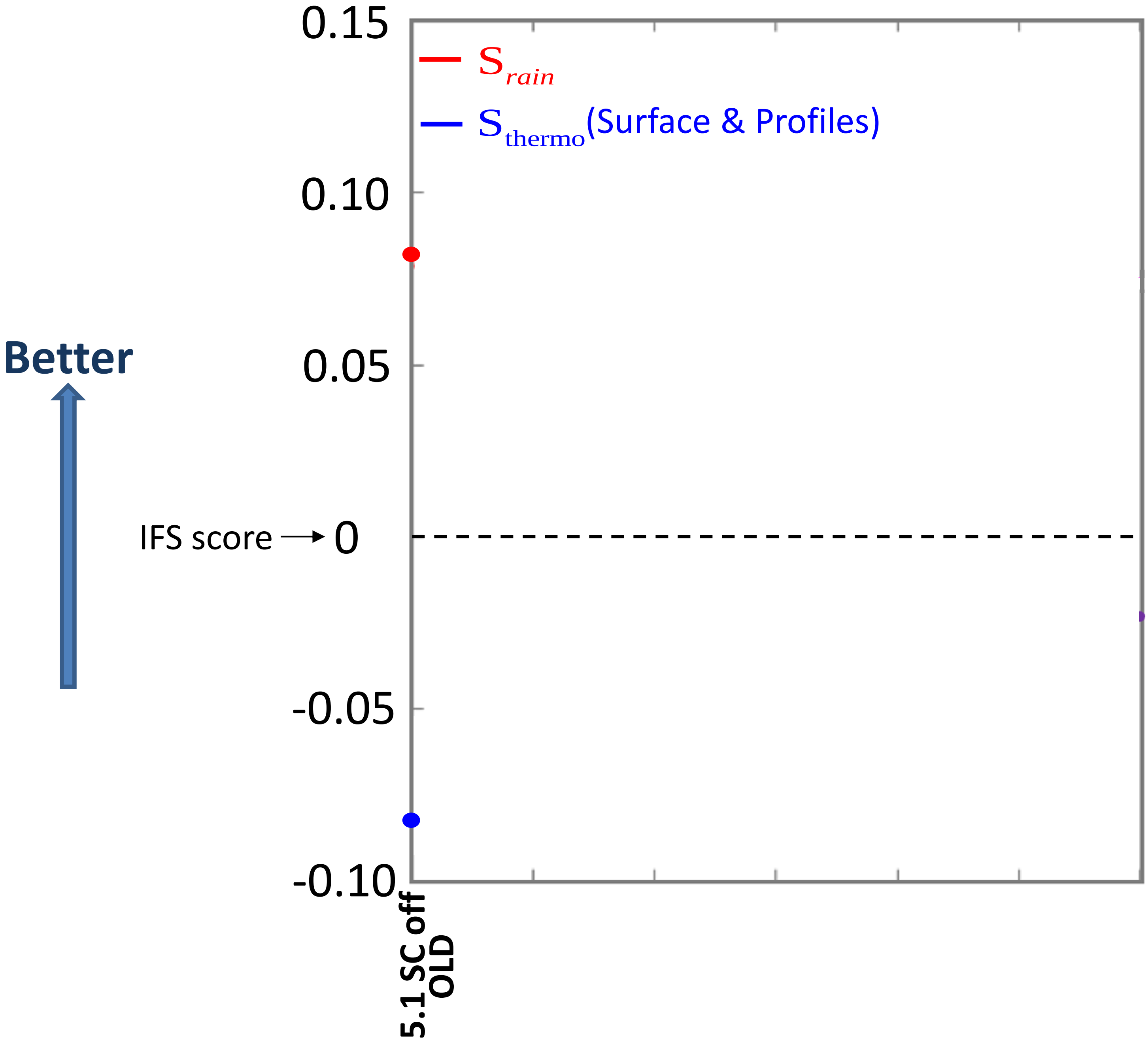
6. **Conclusions**

STEP 1 COSMO 5.1 → 5.5

		OLD	TEST 1
Parameter	**Meaning**	**“Dry” / “Rain” versions**	**5.5 “icon” version with fixed SST and strong SSO, Tegen, reduced evaporation, old heat conductivity**
	COSMO version	**5.4/5.1**	**5.5**
lconv	Shallow convection	on/off	off
loldtur	Old/New turbulence	Old	New
SST	Sea Surface Temperature	bug	from ICON
lsso	Subgrid Scale Orography	bug (false)	true
gkwake	SSO friction strength. Reduced wind speed	-	1.0
itype_ aerosol	Aerosol climatology	1	2
c_soil	fraction (out of 2) of evaporating grid points. Increases RH2m, reduces T2m	1	1 (not 1.75)
itype_ heatcond	1- use average soil moisture, 3- account for soil moisture and vegetation. Bad effect	1/-	1 (not 3)

STEP 1 COSMO 5.1 → 5.5



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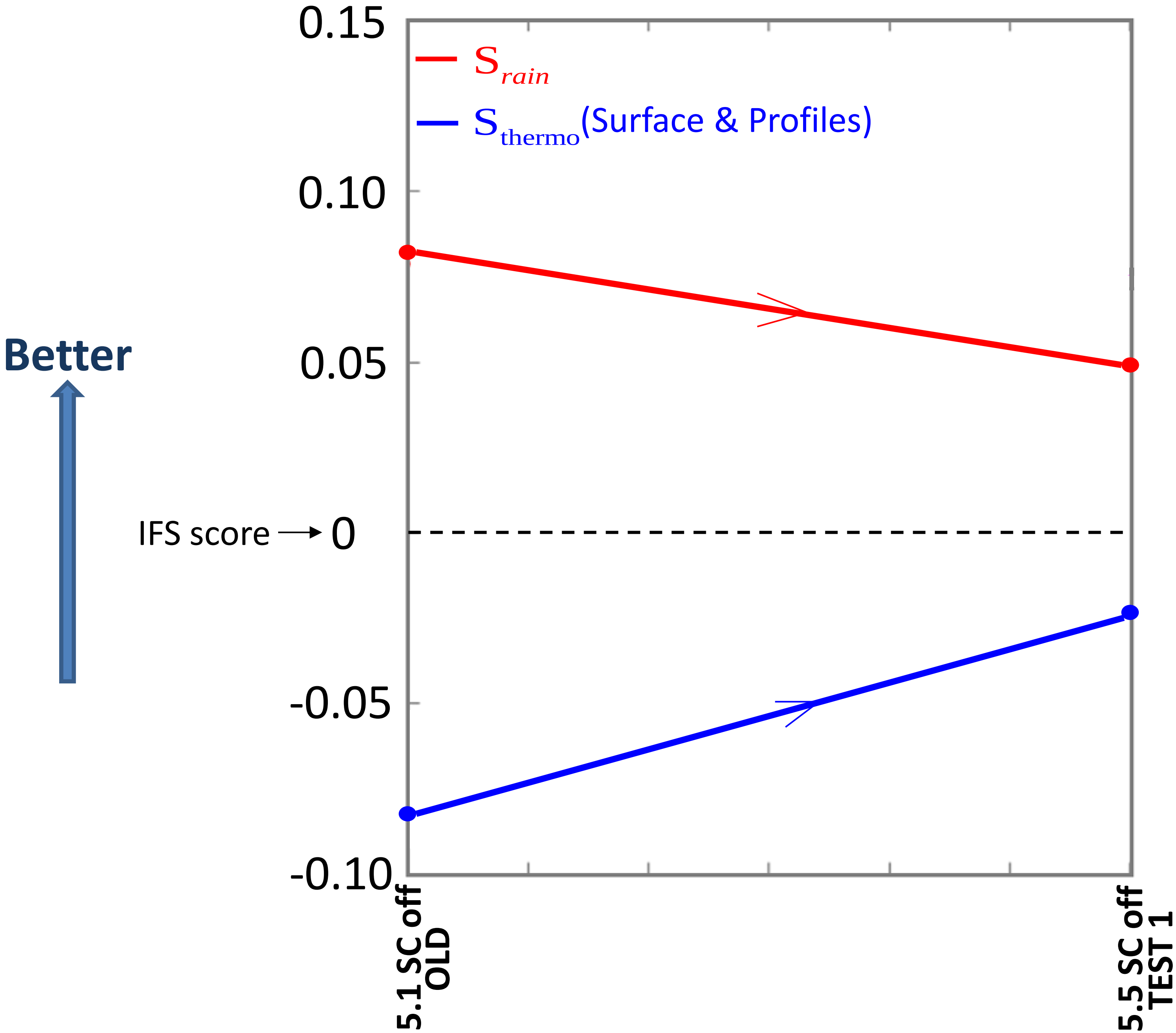


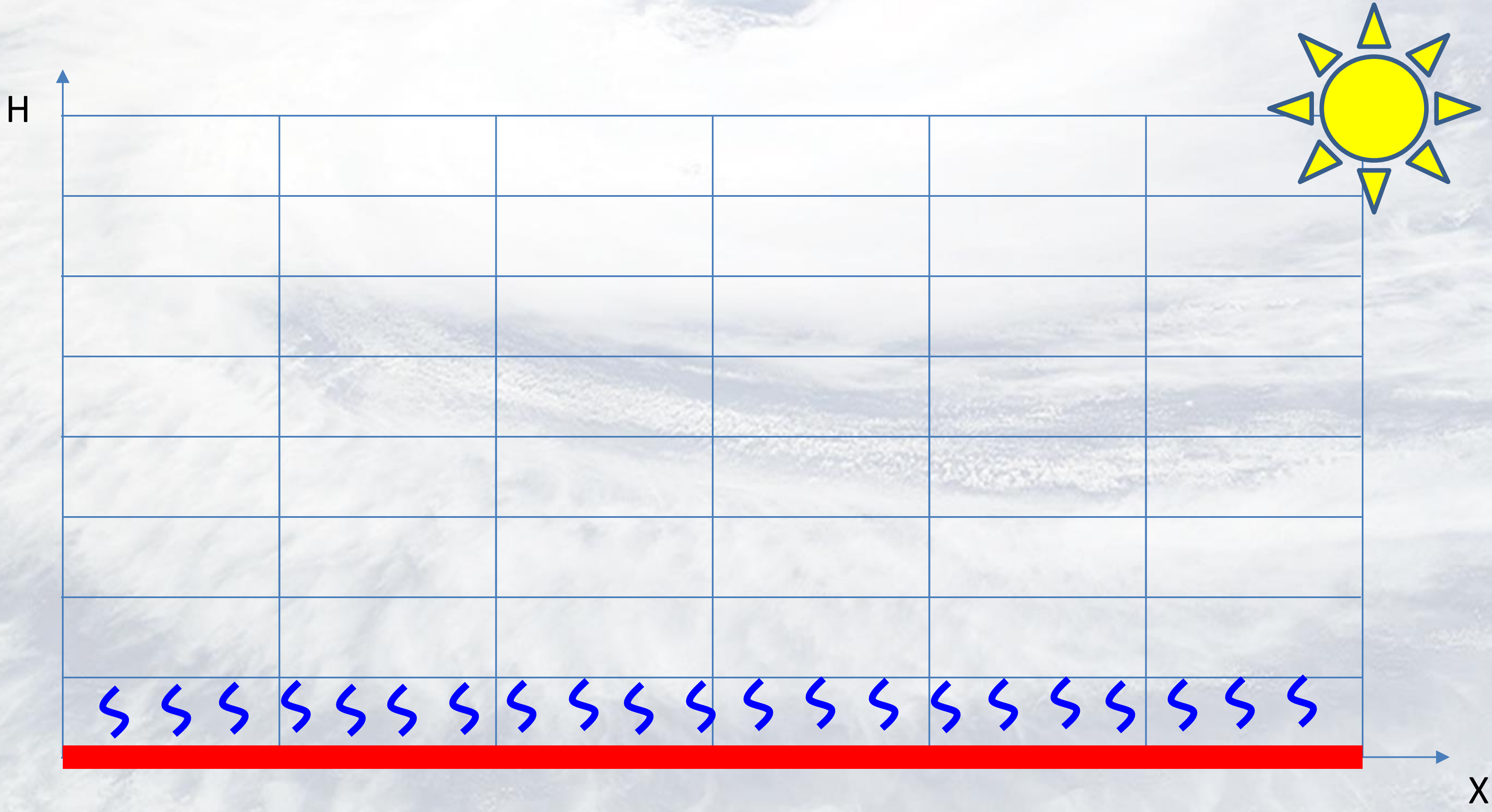
Results for 10 "rain" test cases:

Better sfc & profiles

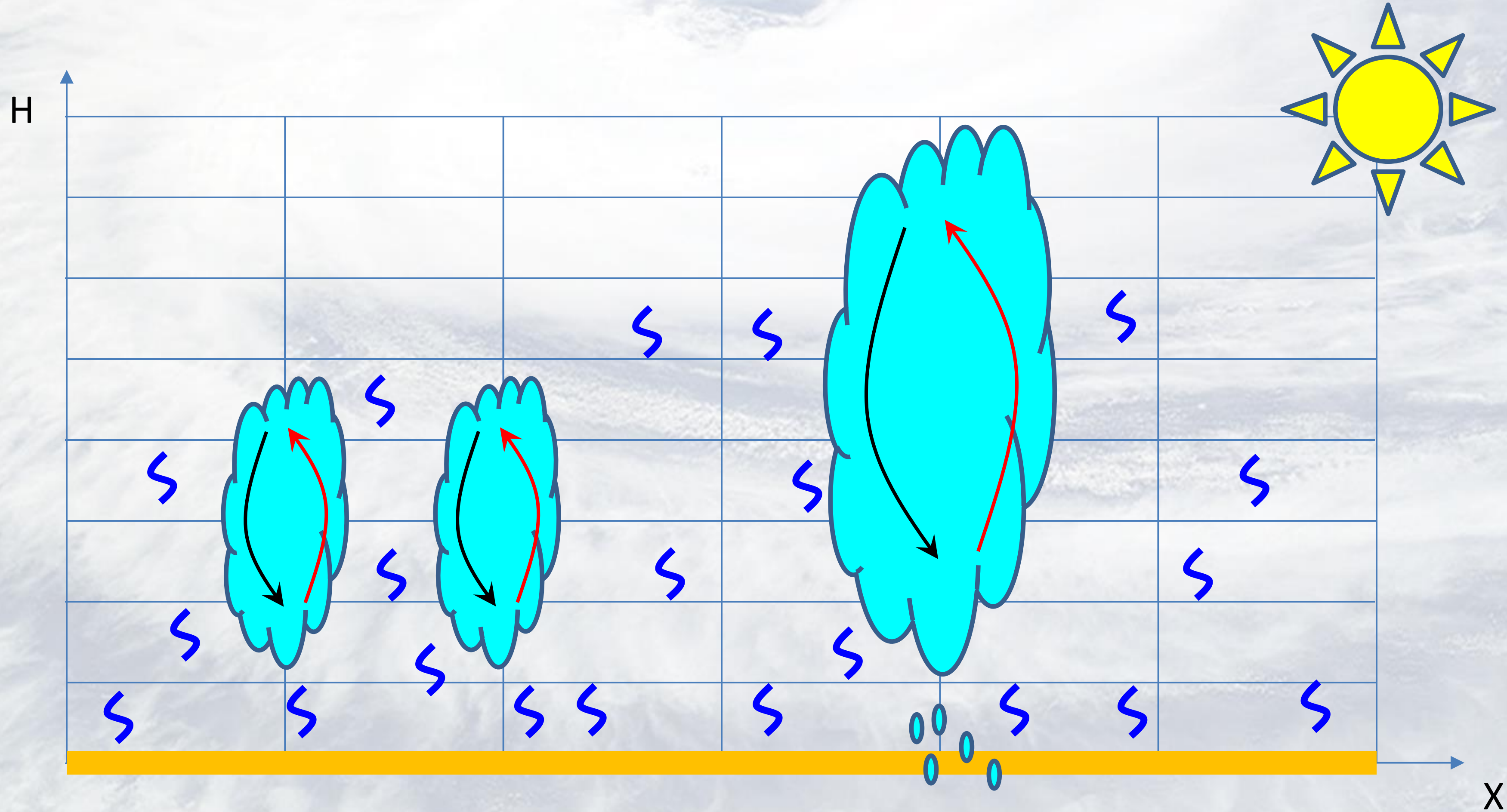
How to further improve the forecasts?

Let's look at the **shallow convection** scheme

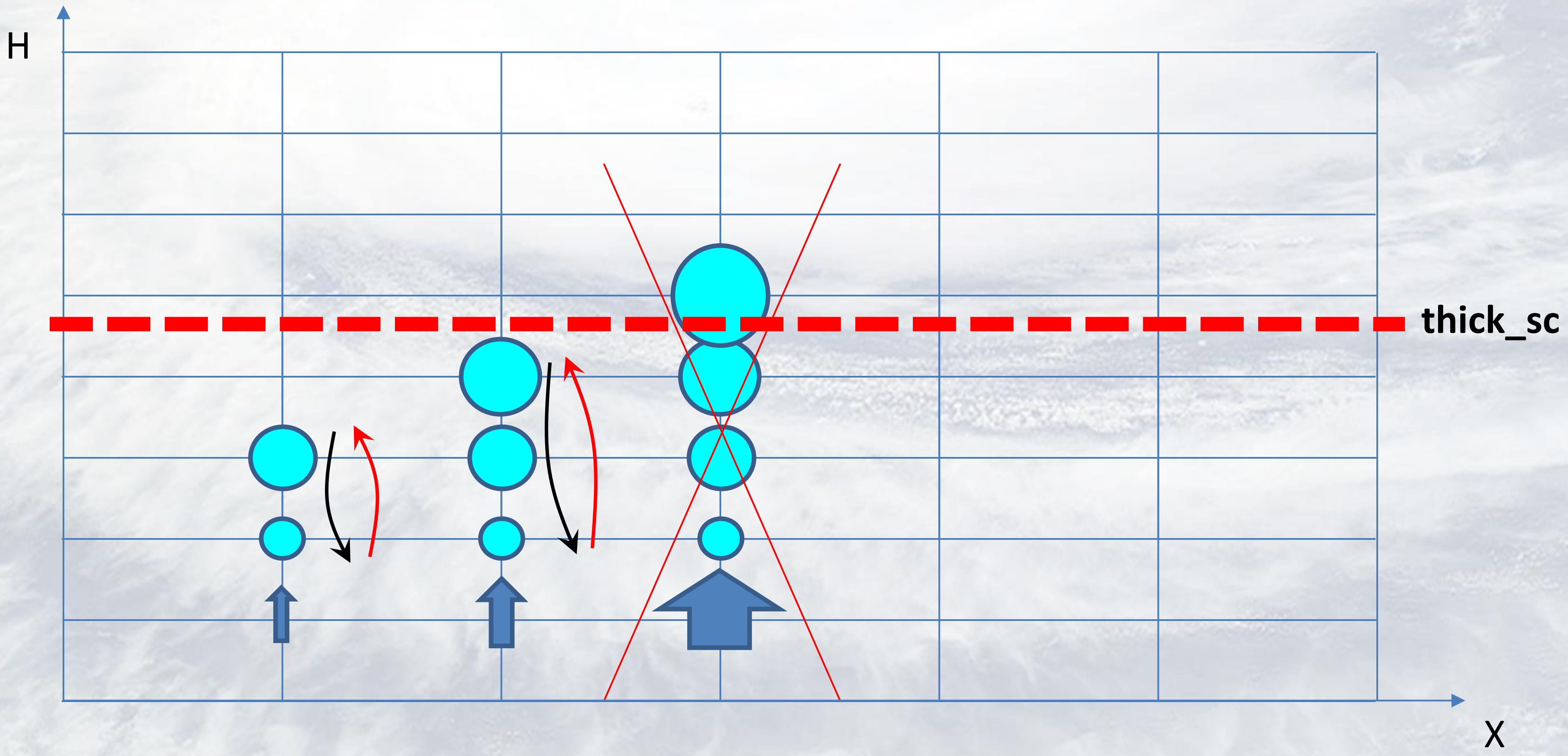
The role of shallow convection



The role of shallow convection



Description of shallow convection in the model



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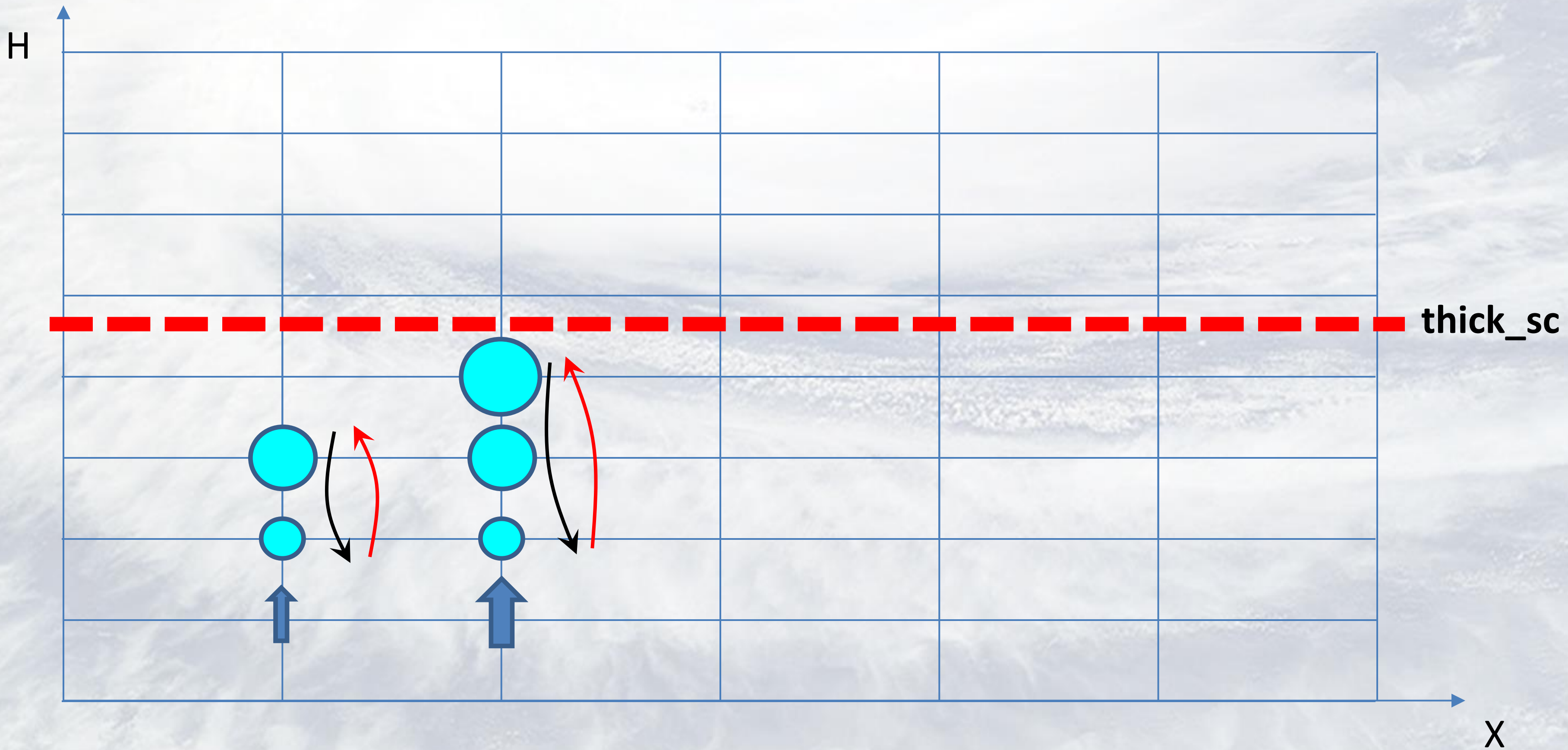

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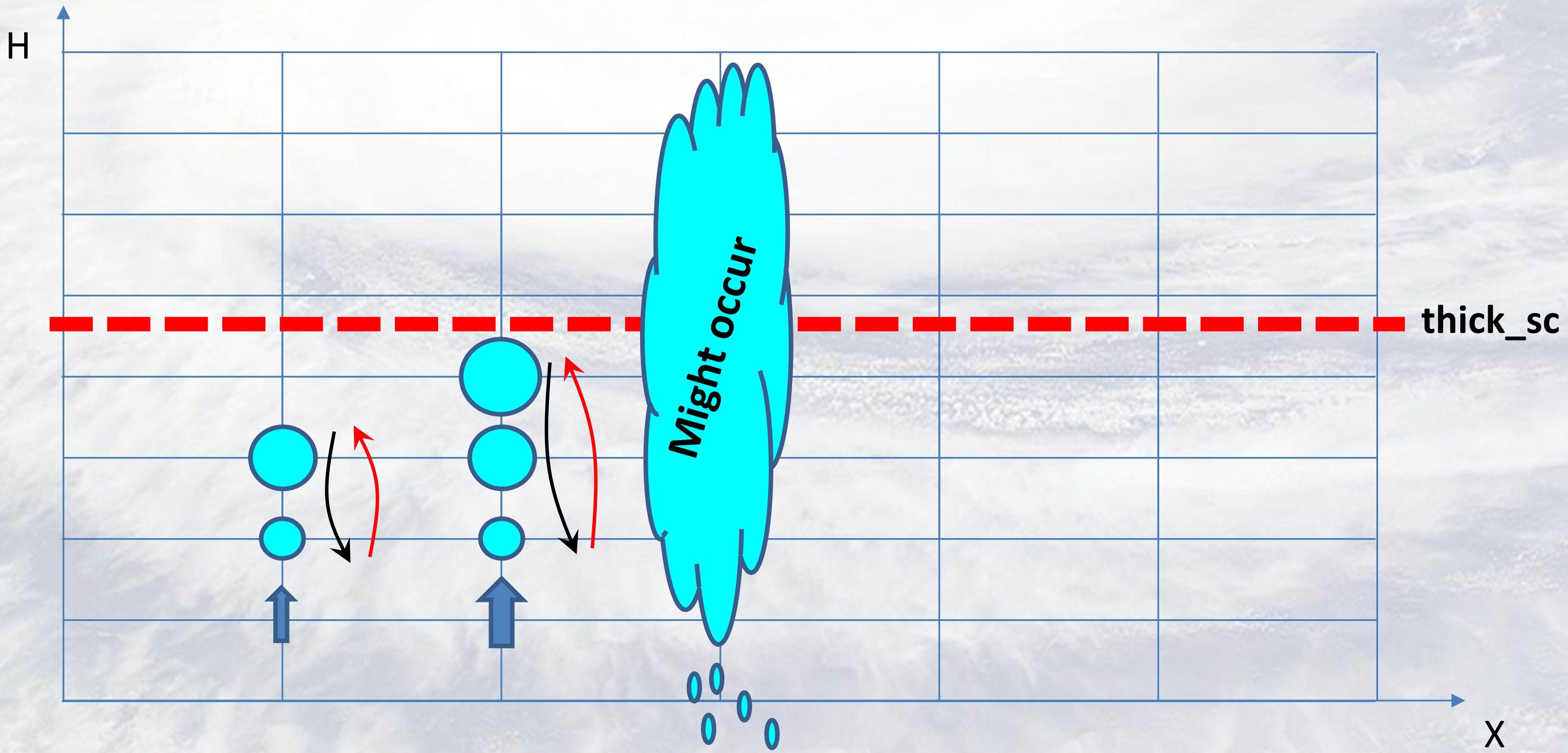
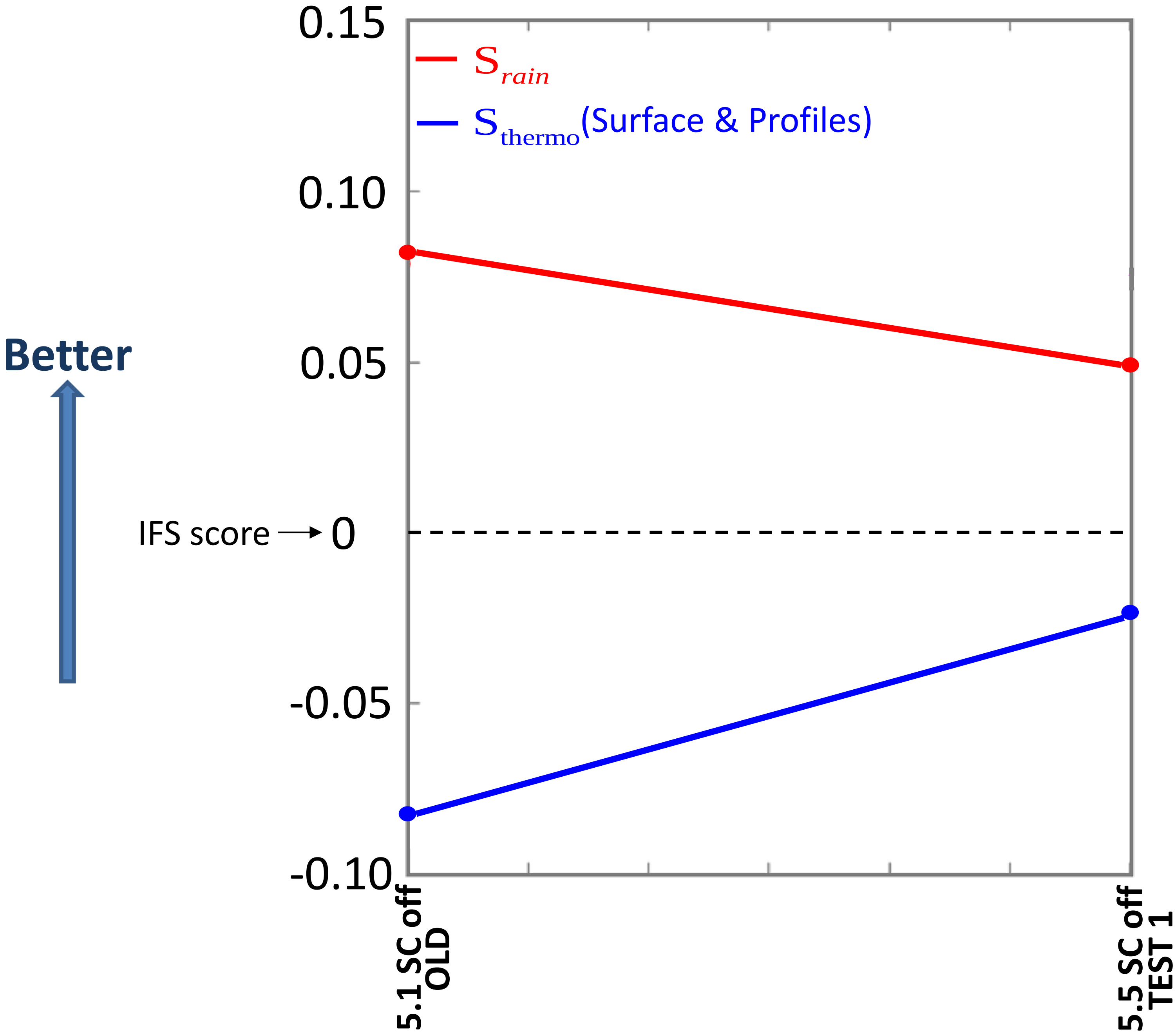


Switching shallow convection on ?



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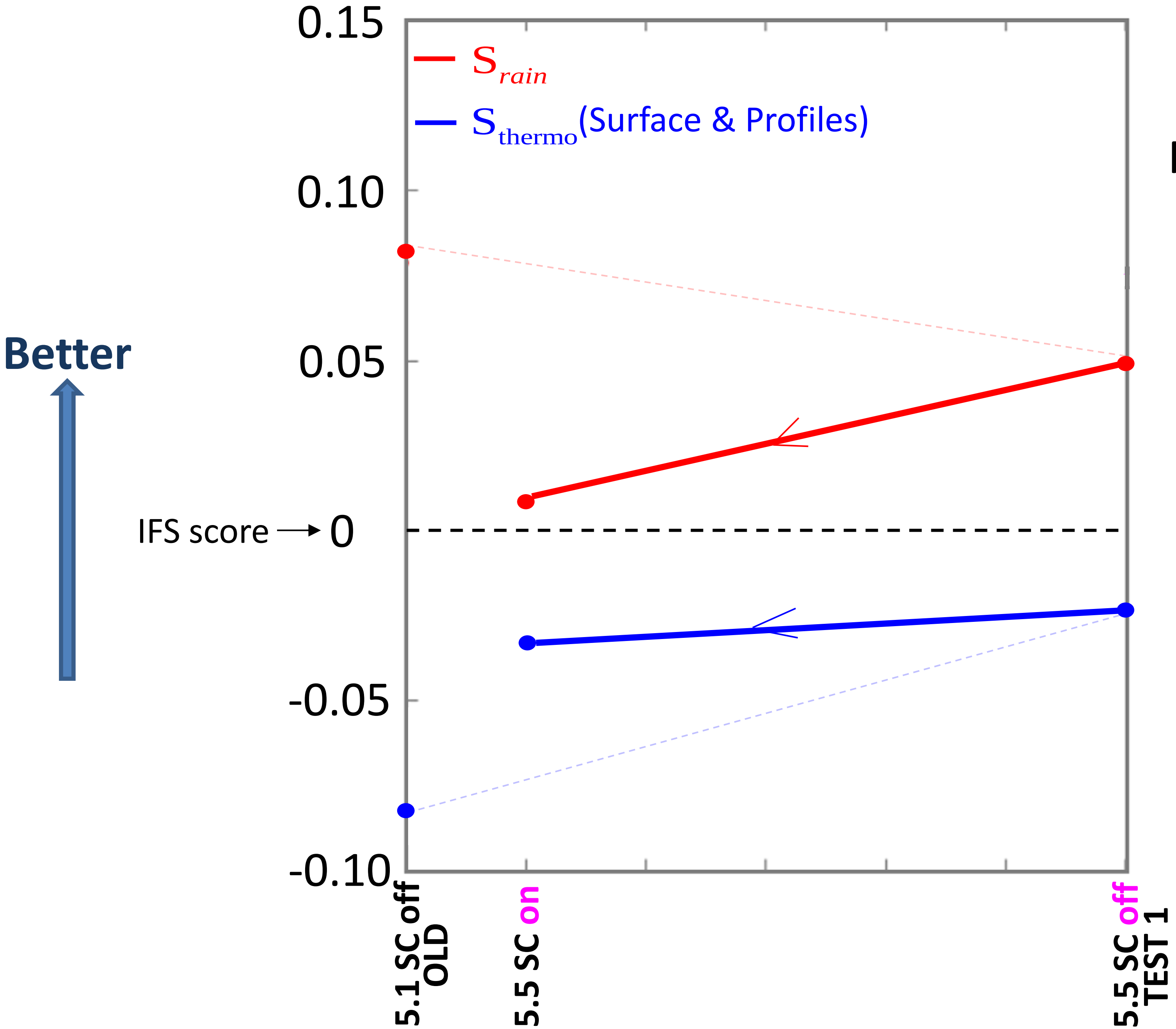
Switching shallow convection on ?



Results for 10 "rain" test cases:

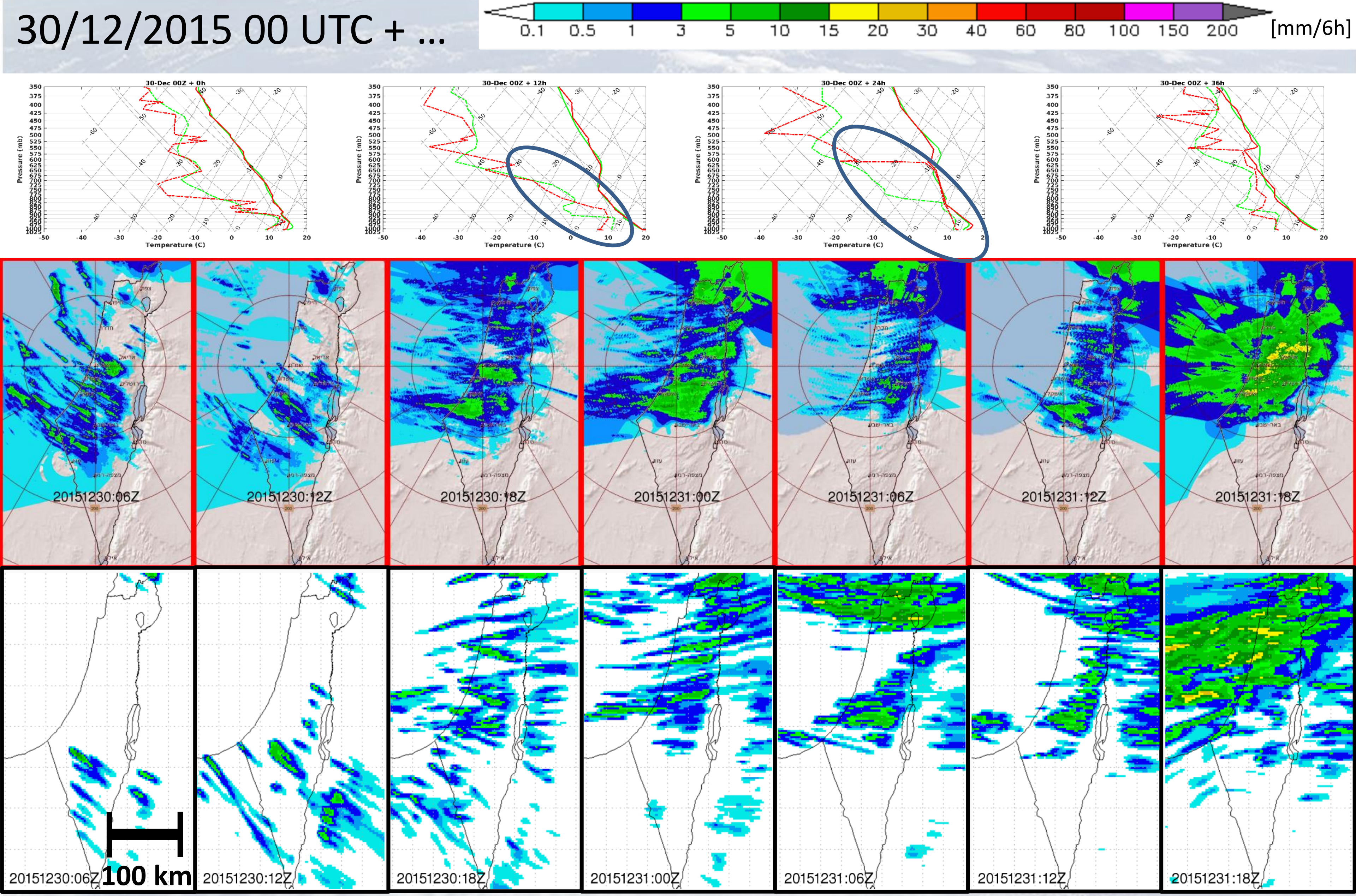
Worse rain forecast

Shallow convection ON → Worse rain forecast

Why?

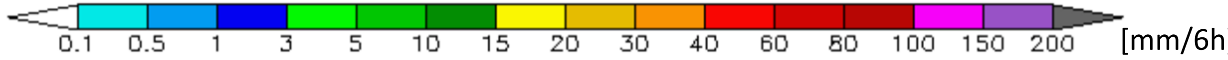
Example …

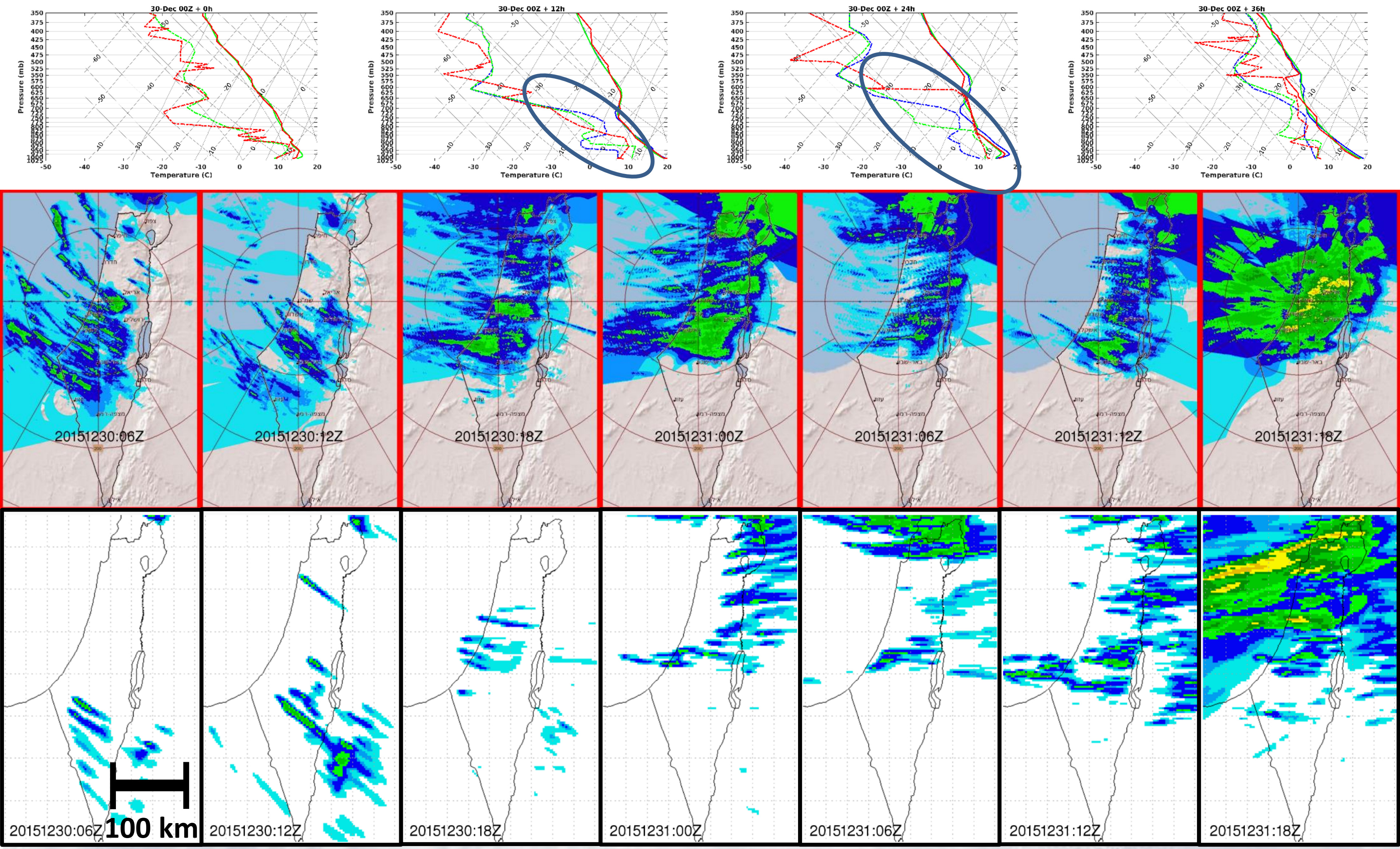
30/12/2015 00 UTC + ...



Shallow Convection OFF

30/12/2015 00 UTC + ...

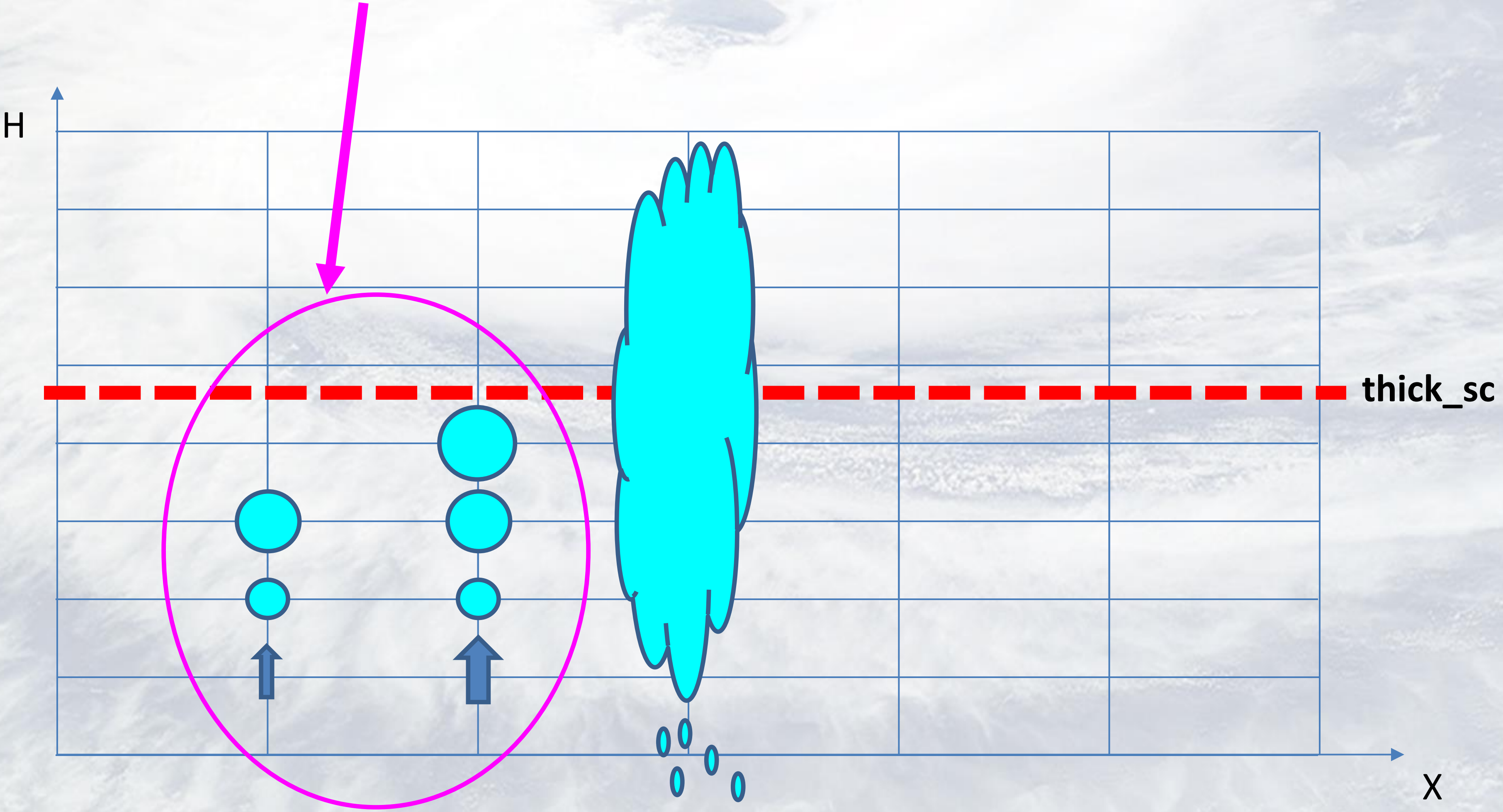




Shallow Convection ON

Description of shallow convection in the model

Drying the lower layers → prevents grid-scale rain



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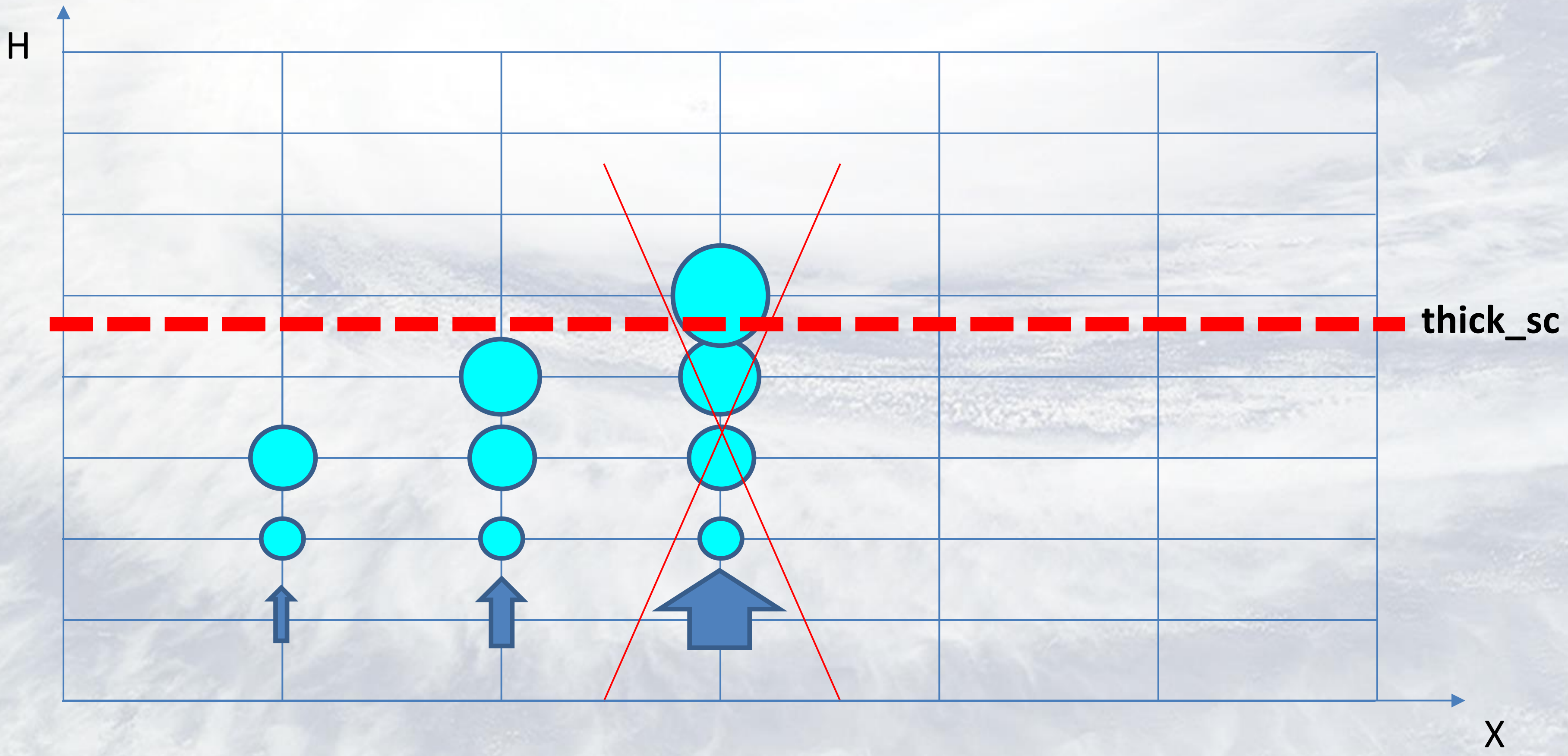
Change A in shallow convection



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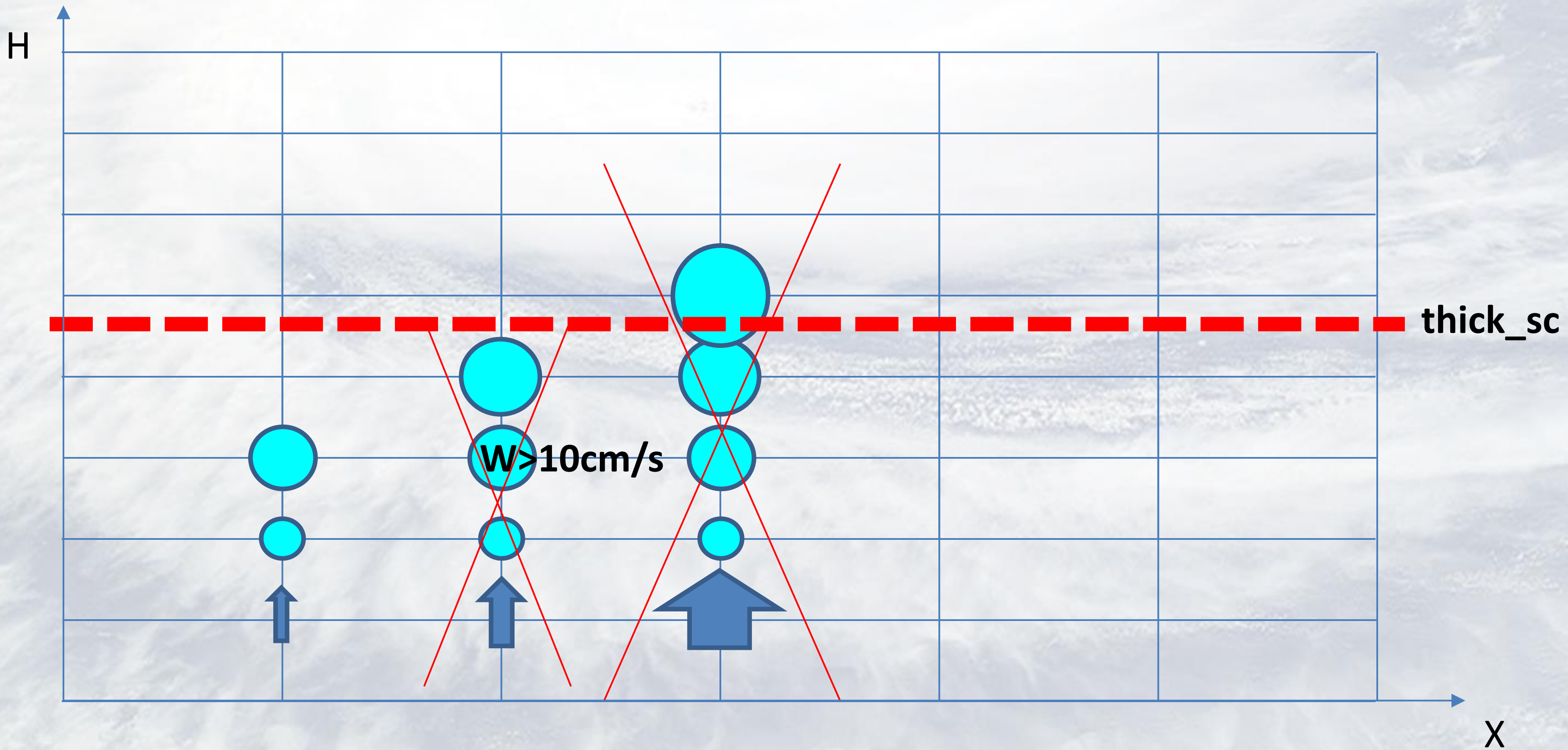

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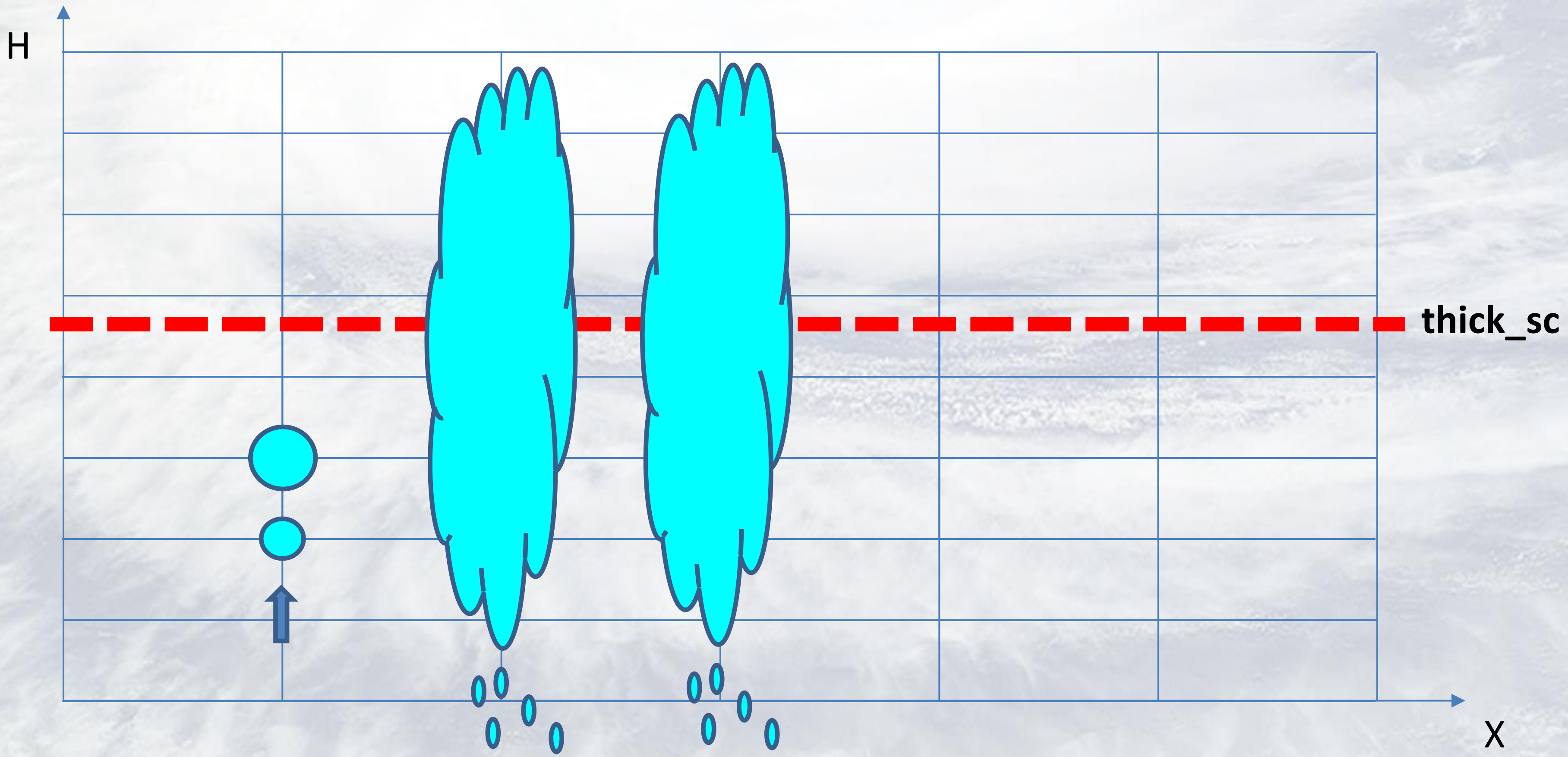
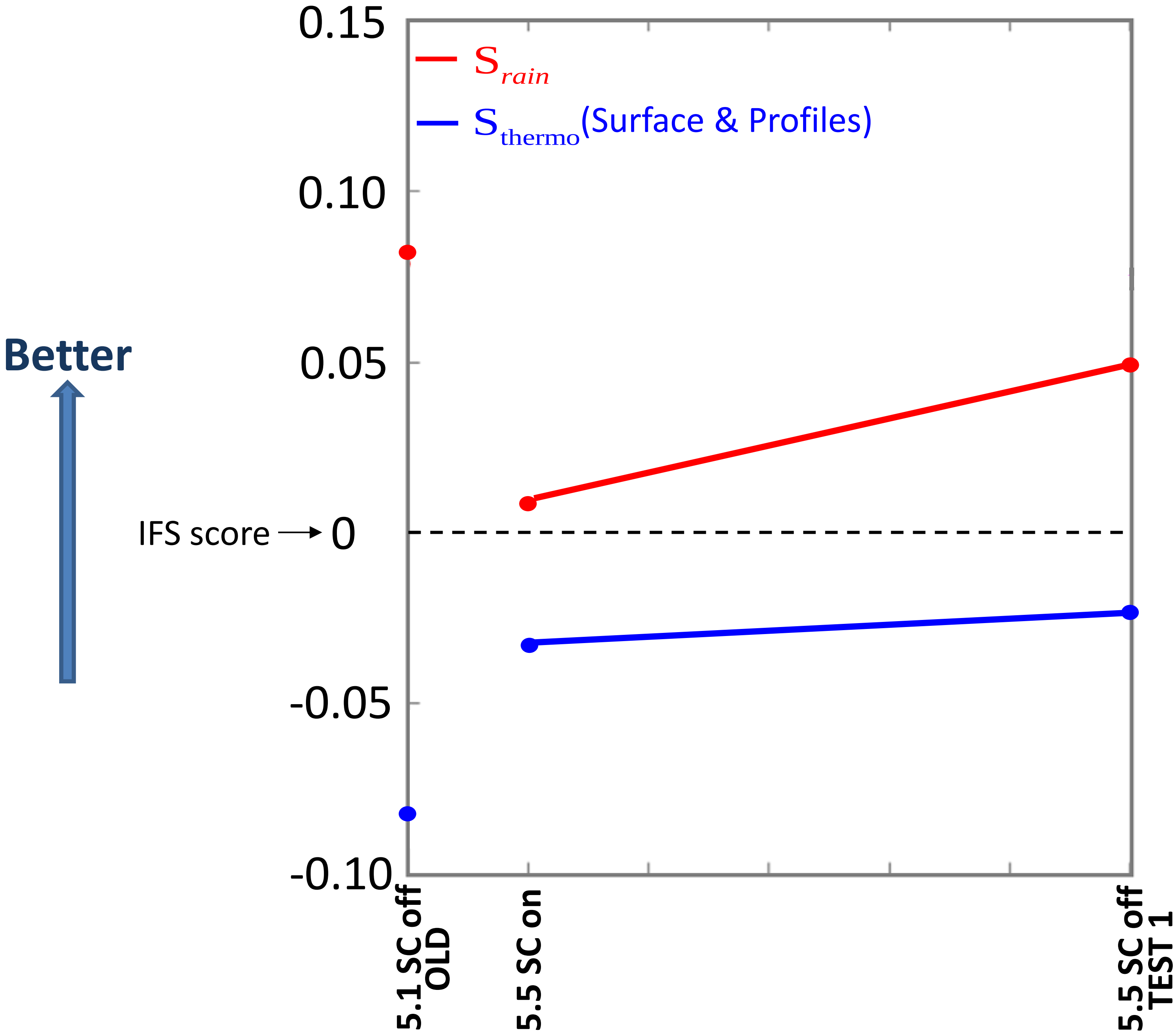


STEP 2 Adding updraft threshold W_{sc}



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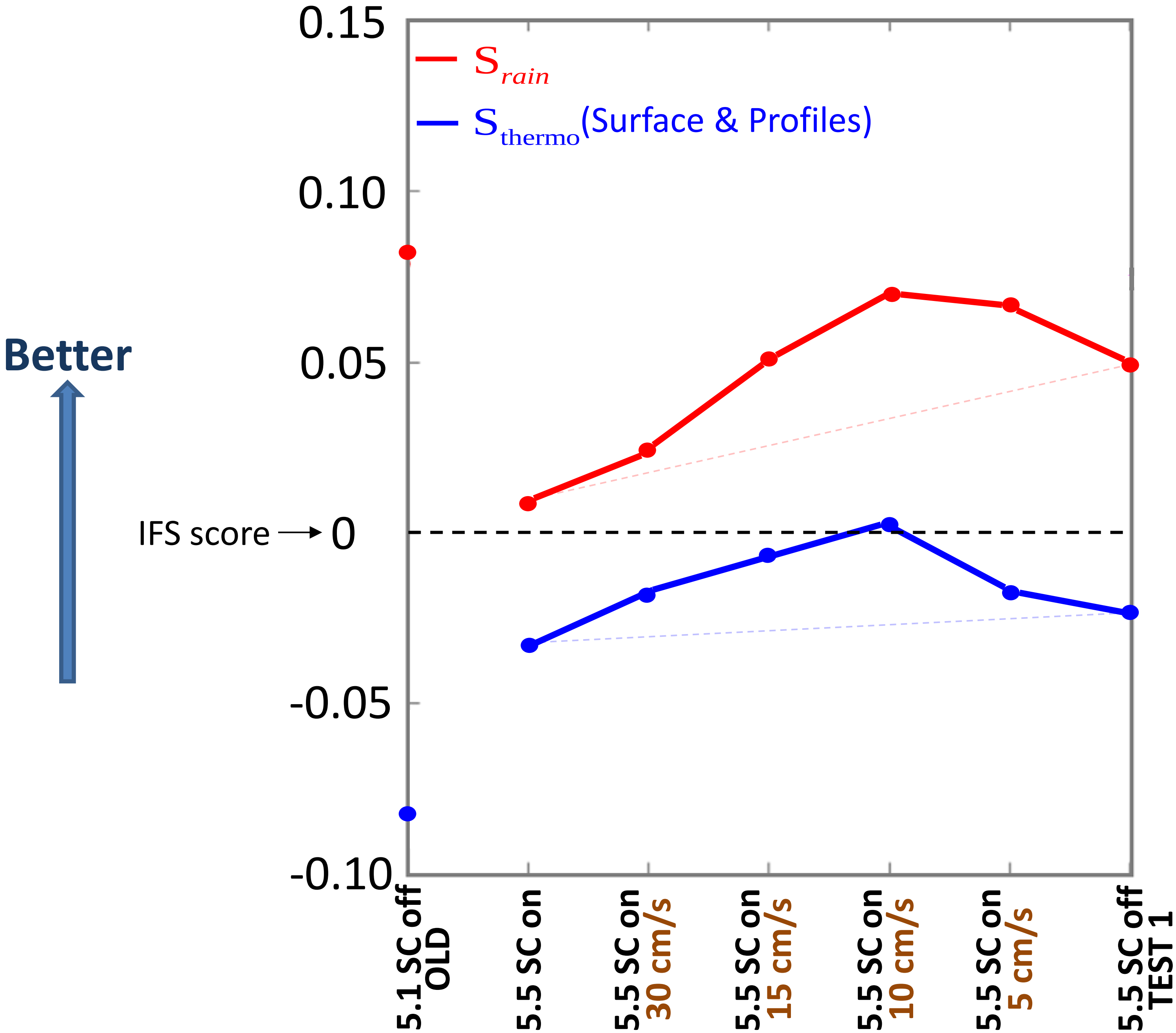

Results for 10 “rain” test cases:

Better rain forecast

Better sfc & profiles

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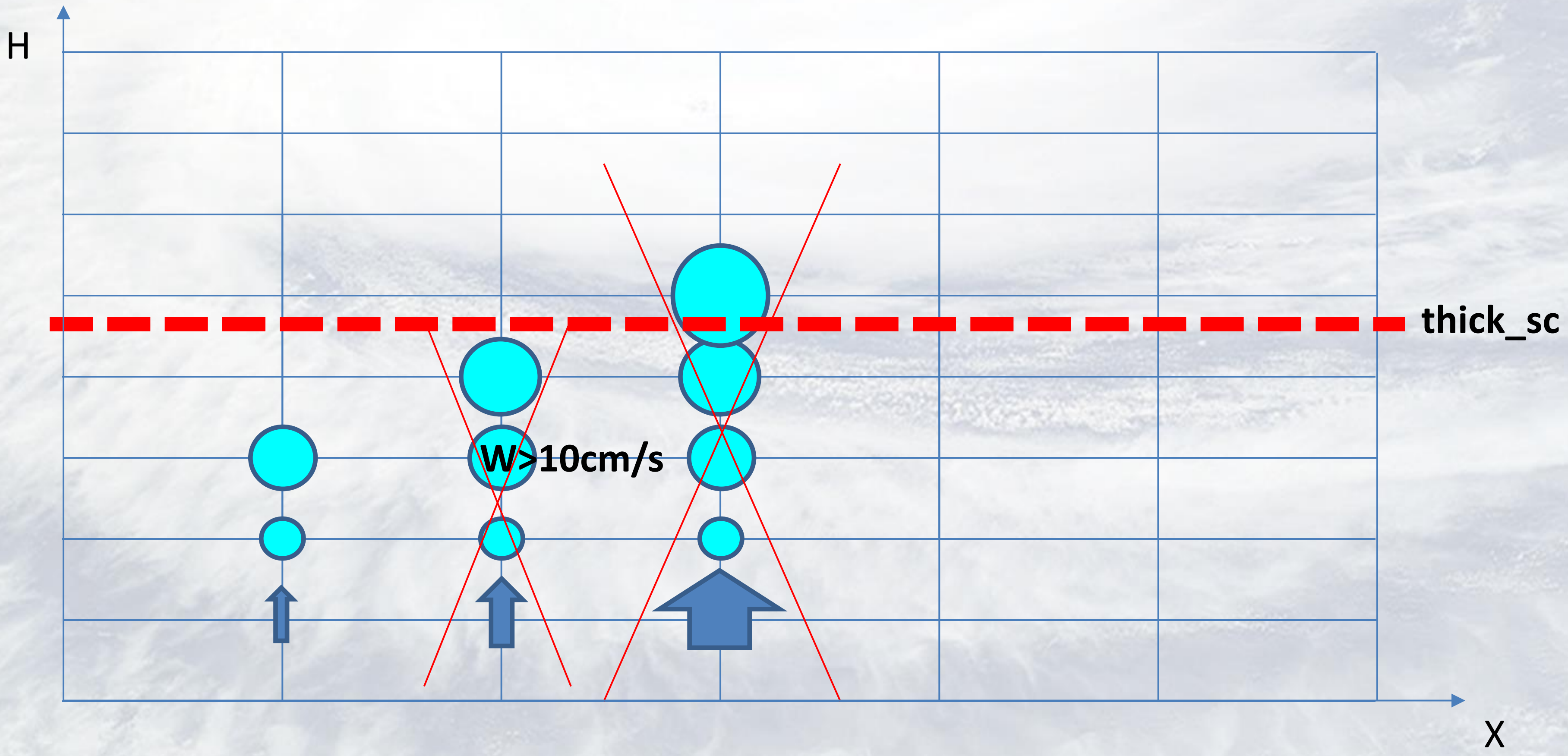
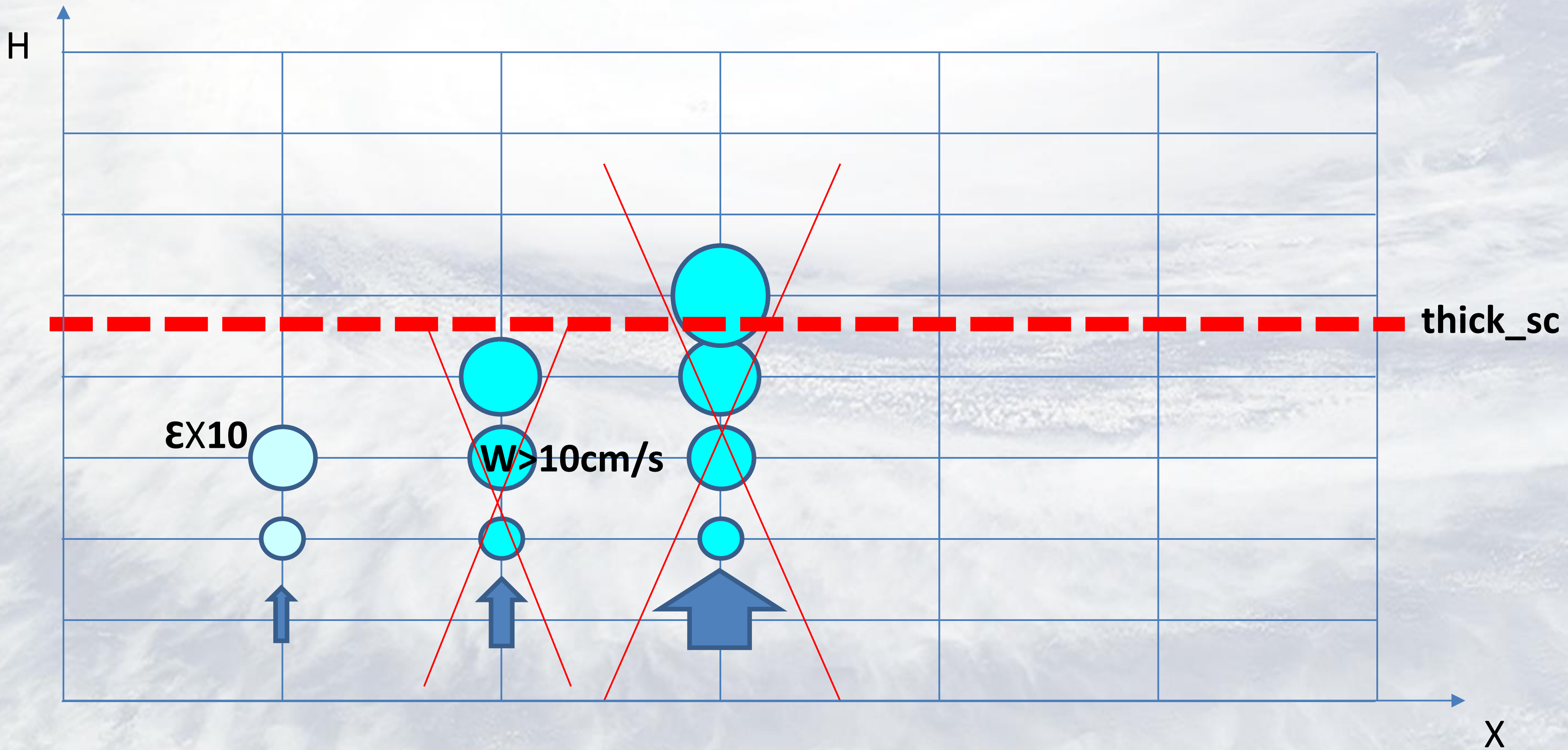
Change B in shallow convection



Change B in shallow convection



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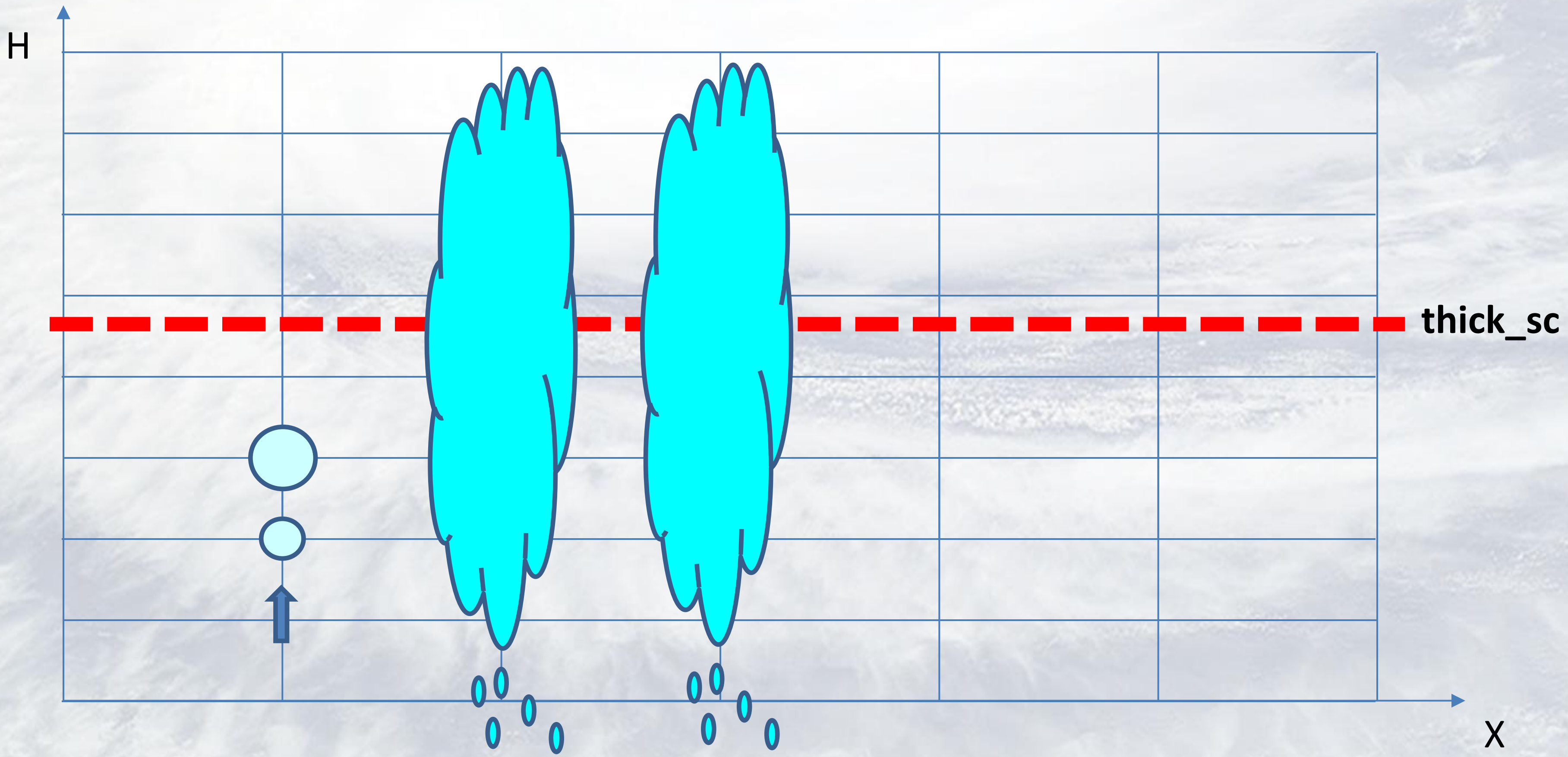


LWC for shallow convection (SGS)

Parameterization for LWC profile, obtained using LES simulations:

$$\overline{LWC}(z) \approx \frac{4}{3}\pi\rho_w\beta N_{d_{ad}}\left(\frac{\alpha(z)r_{e_{ad}}(z)}{1.15}\right)^3 = \boxed{\beta[0.95 - 1.2\cdot 10^{-4}(z - z_{cb})]LWC_{ad}(z)} \qquad (*)$$

Khain, P., R. Heiblum, U. Blahak, Y. Levi, H. Muskatel, E. Vadislavsky, O. Altaratz, I. Koren, G. Dagan, J. Shpund, and A. Khain, 2019: Parameterization of Vertical Profiles of Governing Microphysical Parameters of Shallow Cumulus Cloud Ensembles Using LES with Bin Microphysics. *J. Atmos. Sci.*, **76**, 533–560, https://doi.org/10.1175/JAS-D-18-0046.1

In COSMO Shallow-Convection scheme, an ascending parcel with entrainment rate “entr_sc” approximates an ensemble of shallow Cu in the grid-box.

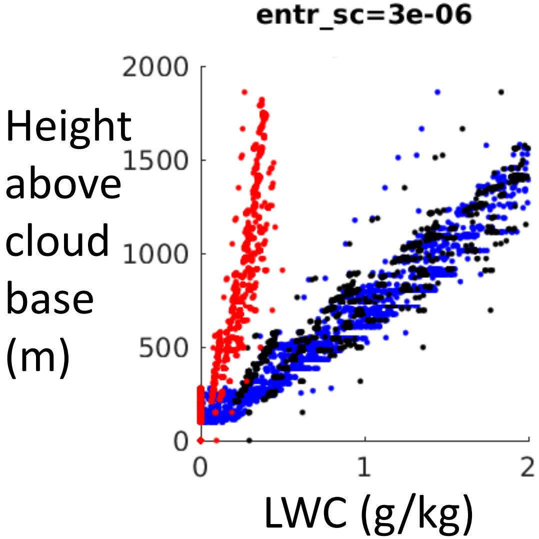
During the ascend, the parcel saturates and produces **LWC_{sc}** which is not used further in the model

The parametrization (*) was obtained for a real ensemble of shallow cumulus with detailed description of mixing.

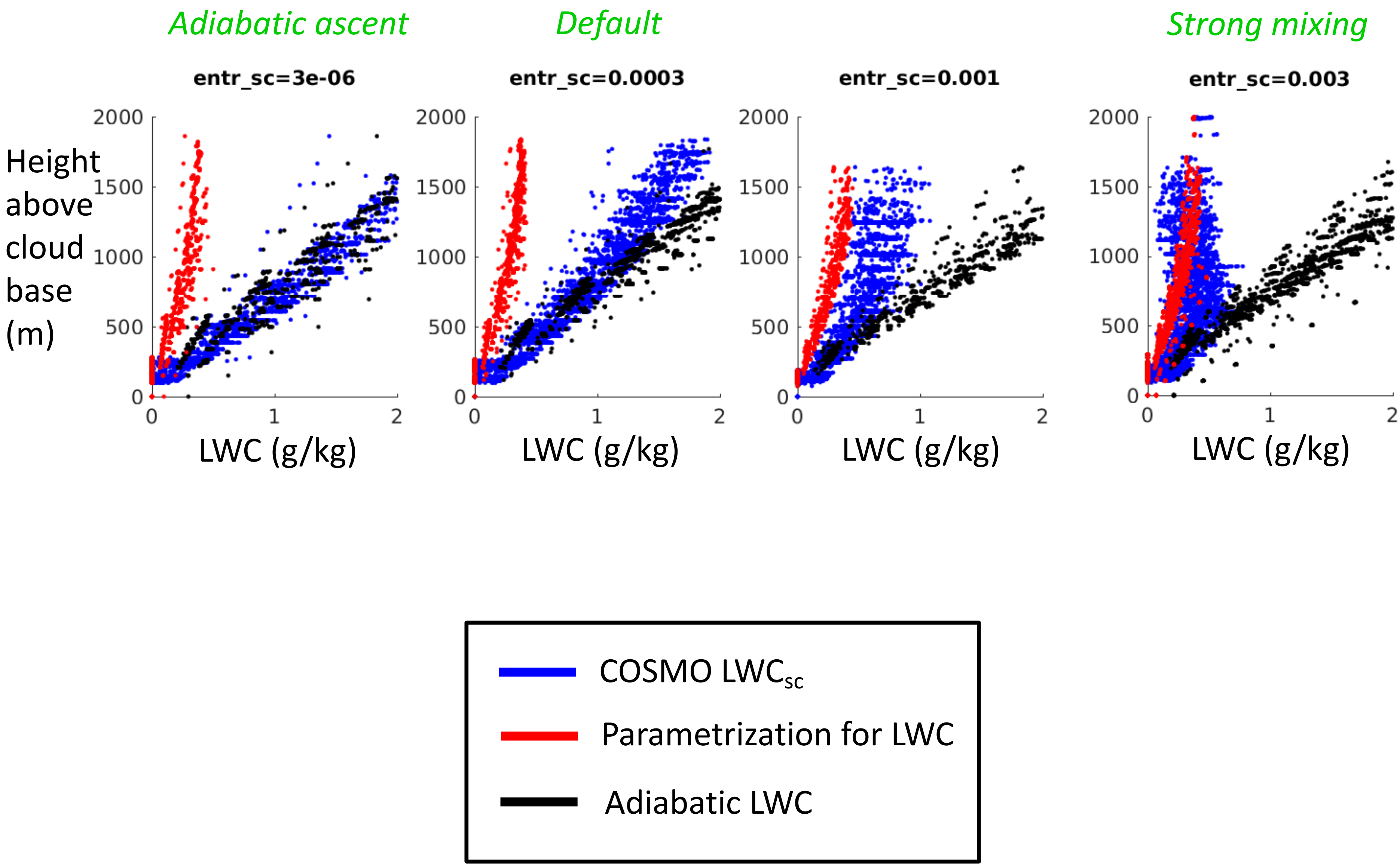
Do they agree ?

Example: 23/2/2018 12 UTC

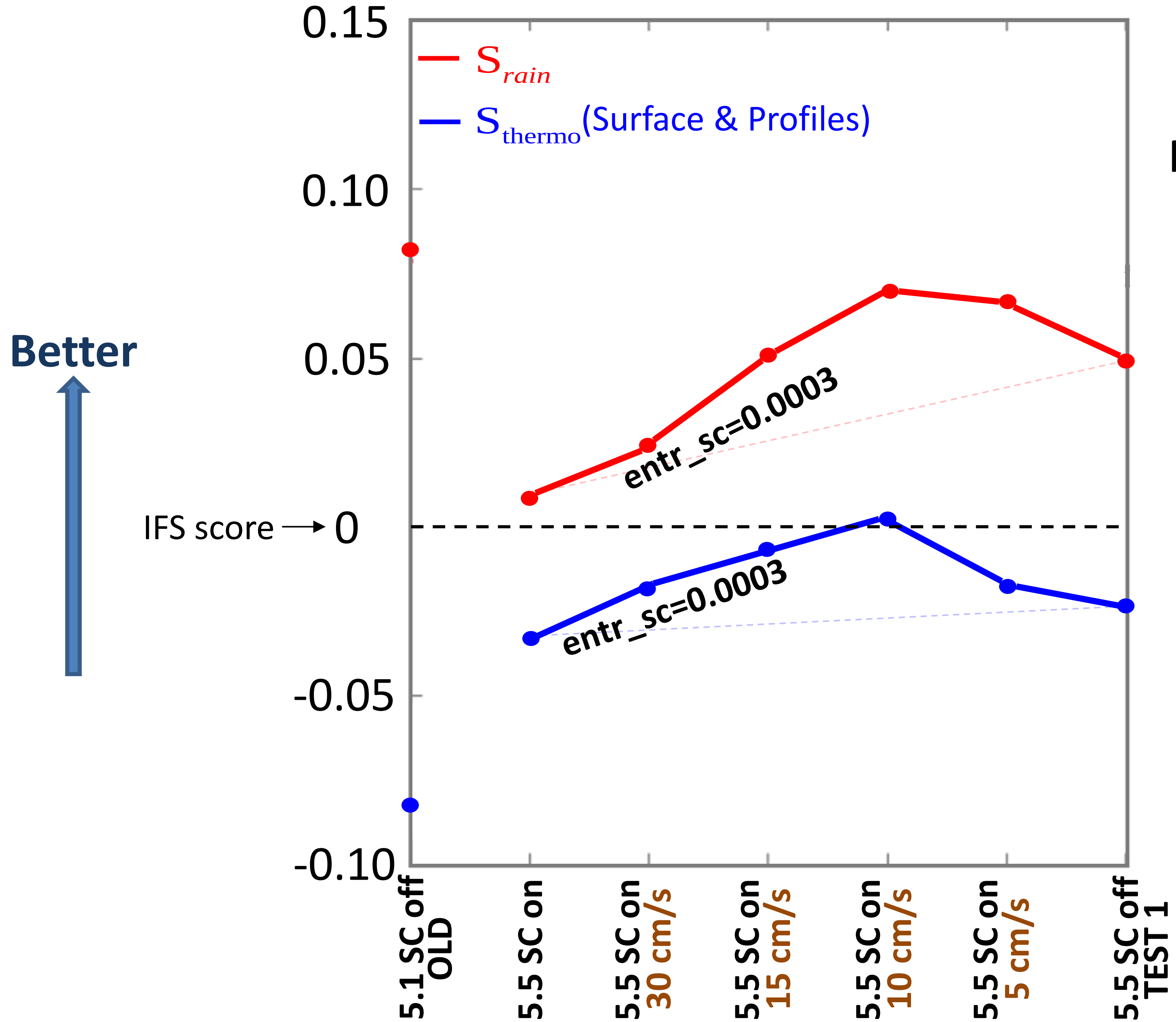
Adiabatic ascent



Example: 23/2/2018 12 UTC



STEP 3 Increasing entrainment rate **entr_sc**



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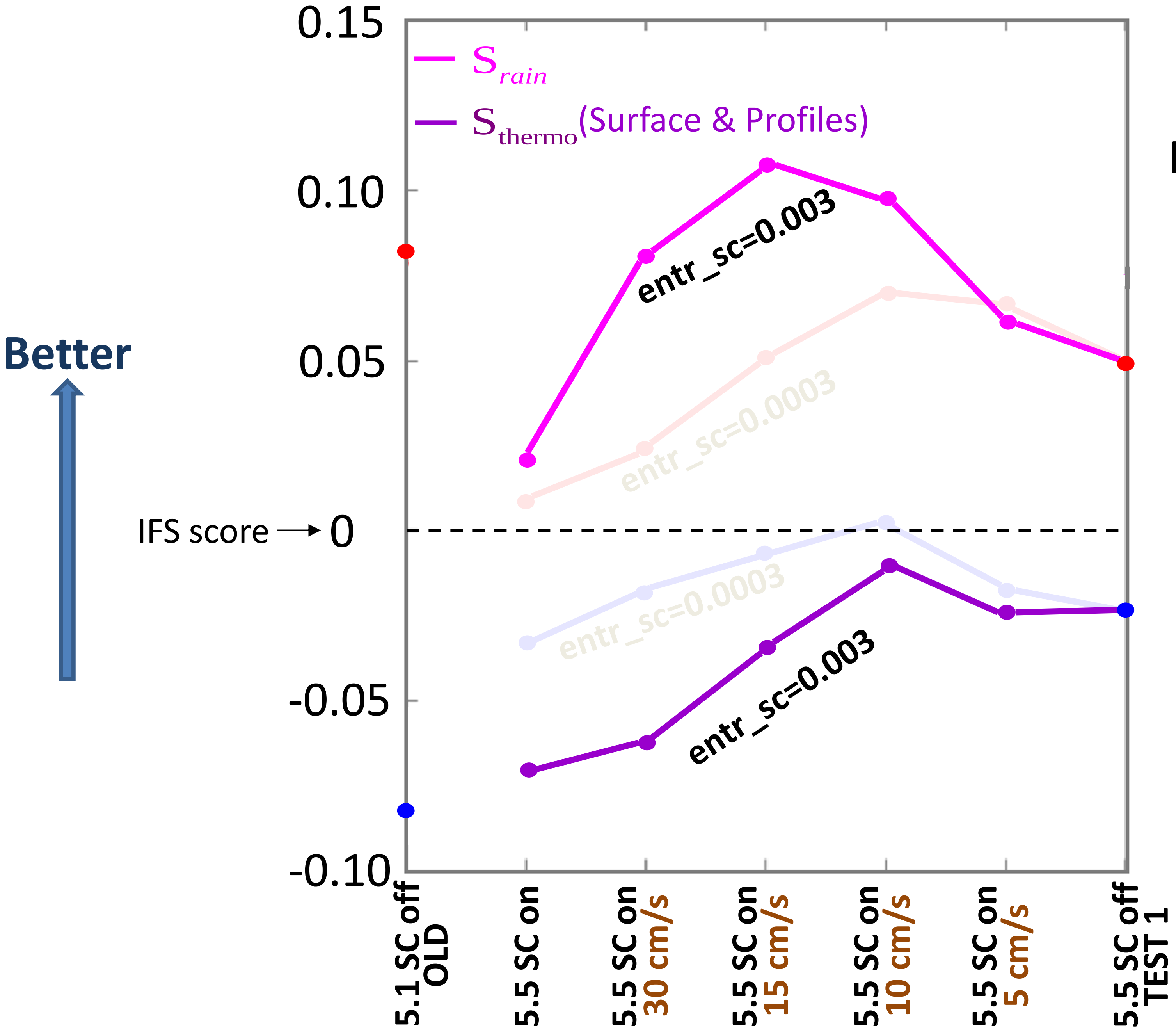

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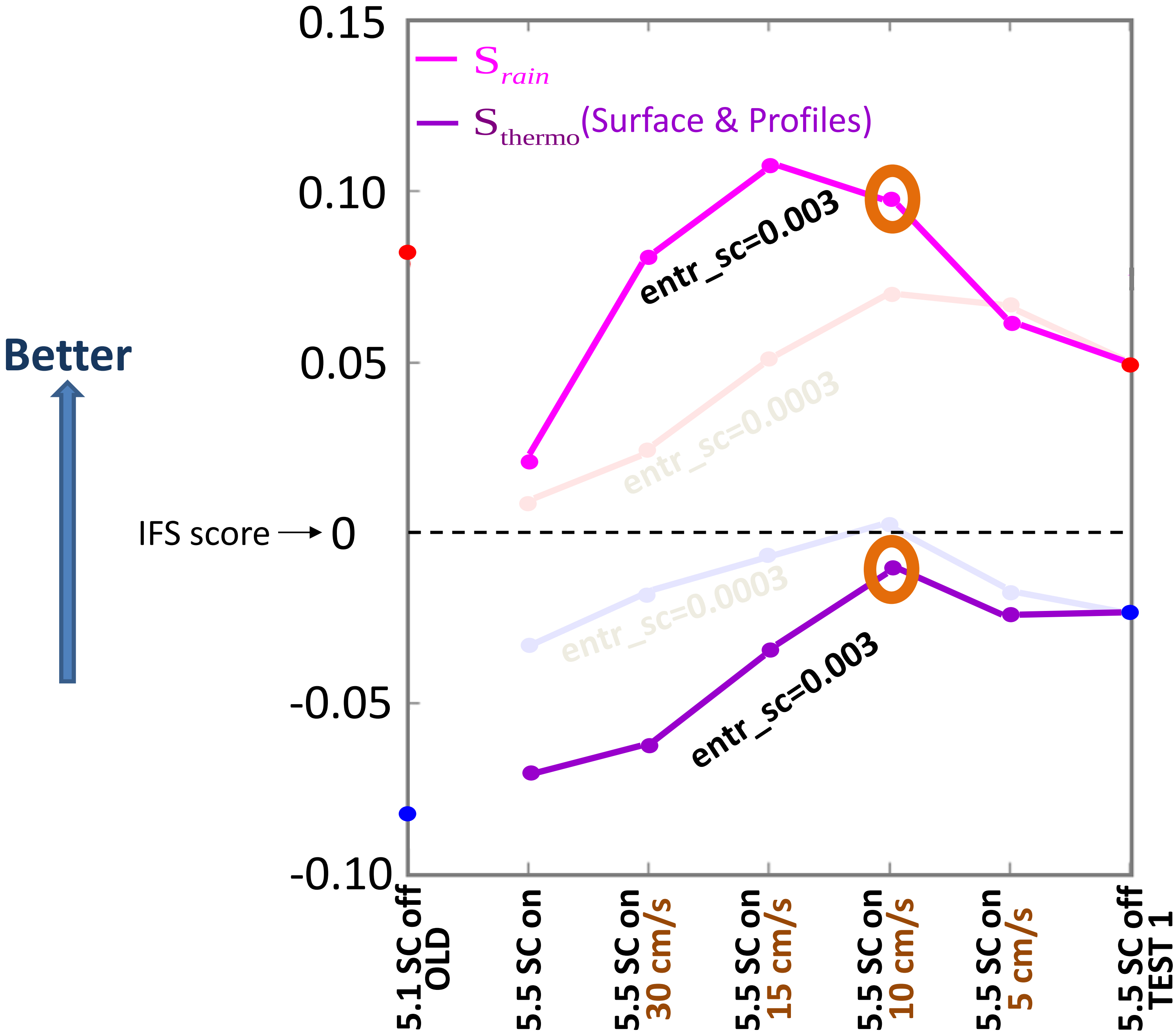

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	TT or_rmse_d	1.82	1.79
	TT pl_rmse_n	2.1	1.97
	TT pl_rmse_d	1.56	1.6
2m RH	RH or_rmse_n	12.83	13.59
	RH or_rmse_d	9.35	10.5
	RH pl_rmse_n	12.07	13.12
	RH pl_rmse_d	9.42	10.15
10m Wind	WV or_rmse_n	2.51	2.65
	WV or_rmse_d	2.47	2.91
	WV pl_rmse_n	2.2	2.34
	WV pl_rmse_d	2.24	2.59
Profiles	PT 24_48_72	0.88	1.01
	PT 12_36_60	0.71	0.81
	PQ 24_48_72	0.86	0.91
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	FSS 48	0.52	0.51
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	FSS 66	0.55	0.56
	FSS 72	0.52	0.59
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---> Better score vs. IFS

COSMO-IL OLD & NEW scores

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	RH pl_rmse_d	9.42	10.15	9.36
10m Wind	WV or_rmse_n	2.51	2.65	2.37
	WV or_rmse_d	2.47	2.91	2.78
	WV pl_rmse_n	2.2	2.34	2.1
	WV pl_rmse_d	2.24	2.59	2.47
Profiles	PT 24_48_72	0.88	1.01	0.94
	PT 12_36_60	0.71	0.81	0.74
	PQ 24_48_72	0.86	0.91	0.86
	PQ 12_36_60	0.79	0.89	0.85
	PW 24_48_72	2.28	2.53	2.36
	PW 12_36_60	2.09	2.28	2.21
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	FSS 24	0.45	0.46	0.41
	FSS 30	0.45	0.43	0.42
	FSS 36	0.47	0.43	0.43
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	WV pl_rmse_d	2.24	2.59	2.47
Profiles	PT 24_48_72	0.88	1.01	0.94
	PT 12_36_60	0.71	0.81	0.74
	PQ 24_48_72	0.86	0.91	0.86
	PQ 12_36_60	0.79	0.89	0.85
	PW 24_48_72	2.28	2.53	2.36
	PW 12_36_60	2.09	2.28	2.21
Rain	FSS 6	0.38	0.31	0.43
	FSS 12	0.46	0.43	0.42
	FSS 18	0.43	0.38	0.39
	FSS 24	0.45	0.46	0.41
	FSS 30	0.45	0.43	0.42
	FSS 36	0.47	0.43	0.43
	FSS 42	0.47	0.47	0.46
	FSS 48	0.52	0.51	0.52
	FSS 54	0.48	0.47	0.46
	FSS 60	0.52	0.44	0.49
	FSS 66	0.55	0.56	0.56
	FSS 72	0.52	0.59	0.56
	FSS 78	0.5	0.56	0.54

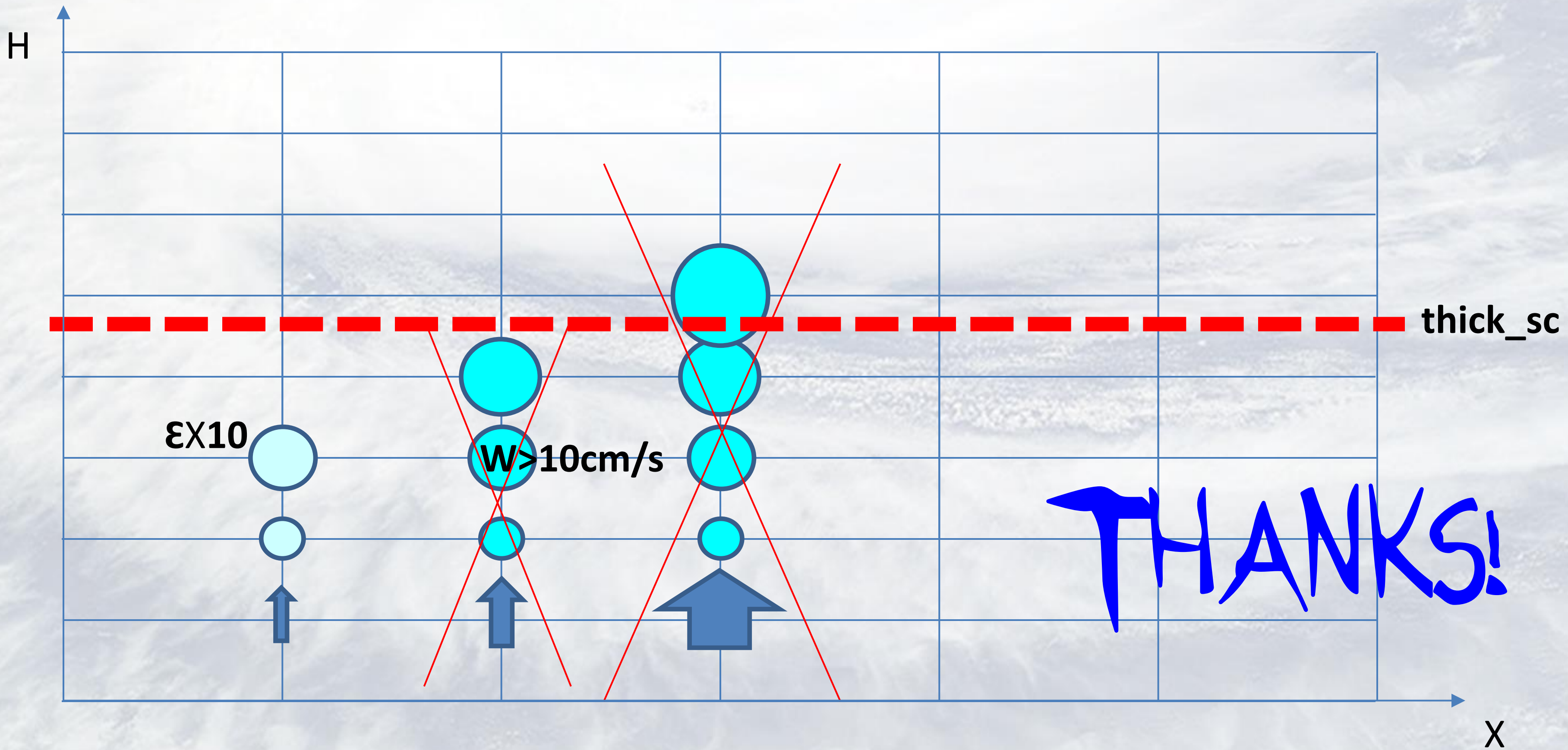
---> Better score vs. IFS

Outline

1. **COSMO-IL OLD scores** *(during ICCARUS 2018)*
2. **Step 1: COSMO 5.1→5.5**
3. **Step 2: Introducing max. updraft threshold in Sh. Conv. scheme**
4. **Step 3: Update of the entrainment rate in Sh. Conv. scheme**
5. **COSMO-IL NEW scores** *(during ICCARUS 2019)*
6. **Conclusions**

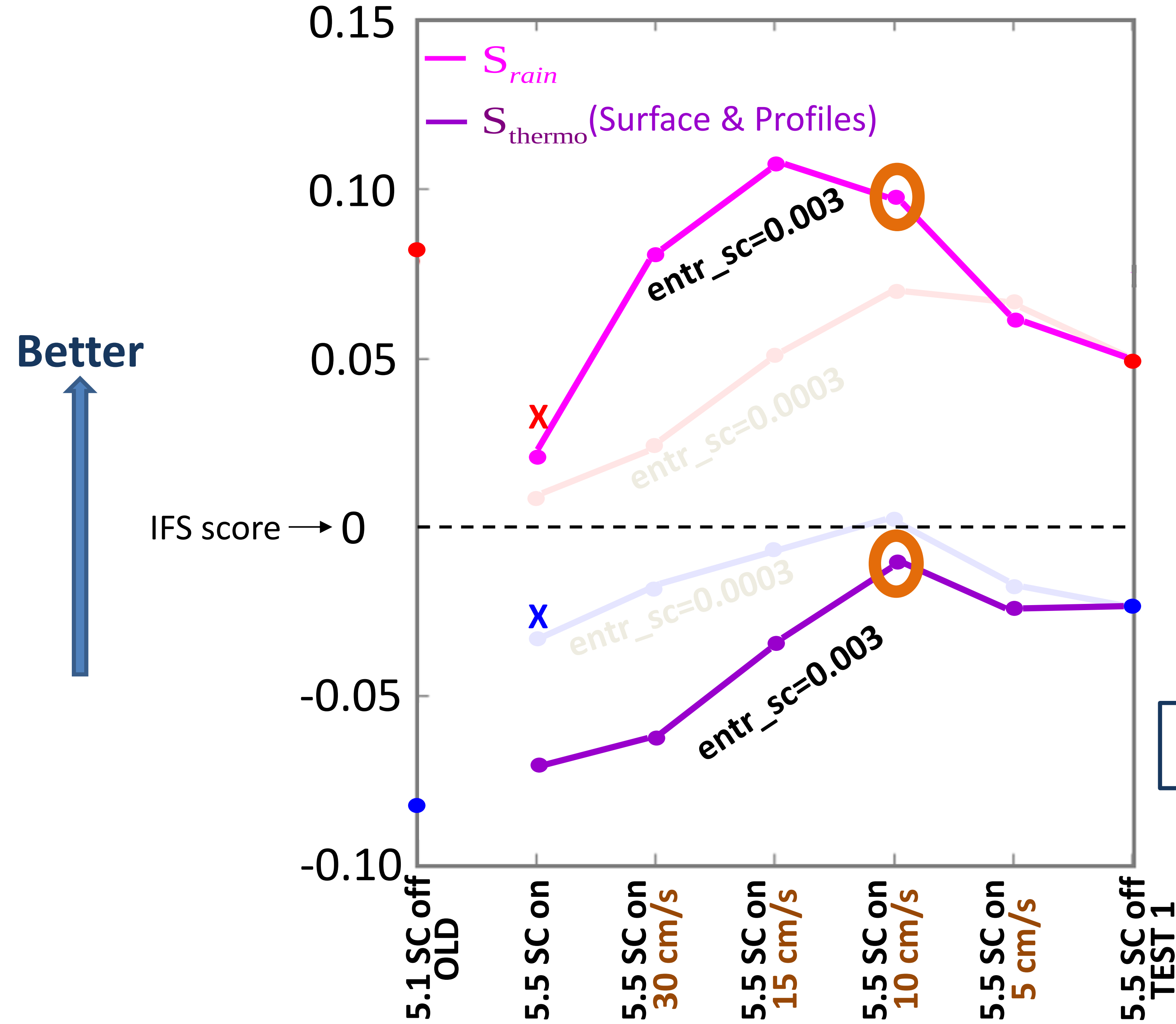
Conclusions

- COSMO 5.5 version was tuned for winter time over Israel
- It was shown that the forecast improved for “reduced” shallow convection scheme. Namely, the entrainment rate was strongly increased, and a threshold on the maximum updraft was introduced



Additional slides:

Attempt with Tiedtke-Bechthold Shallow Convection



Results for 10 "rain" test cases:

XX Tiedtke-Bechthold Shallow Convection