Recent tests of proposed revisions to the STRACO cloud scheme

Bent H. Sass and Xiaohua Yang

Danish Meteorological Institute

1. Introduction

Modifications to the STRACO convection scheme have been developed and tested recently. The goal is to better predict the observed spectrum of surface precipitation intensity and to produce a realistic vertical structure of the heating and moistening due to the condensation and evaporation processes. Previously, the scheme has suffered to some extent from the prediction of too frequent small precipitation amounts and perhaps a too little occurrence of heavy summertime precipitation. The main points of the update are summarized below, followed by a presentation of validation results for month-long model integrations. A detailed description of the entire cloud scheme is in progress (Sass, 2002).

a) Convective cloud model

The convective 'cloud parcel ascent' has been modified to better describe the vertical extent of convection. A lateral mixing process between cloud and environment is described, e.g., including effects of wind shear. Test results show that the diurnal cycle of precipitation release over land will be delayed statistically, occasionally by several hours. Since most convection schemes suffer from a problem of a too early convection during the day this deficiency is likely to be improved with the present update. Furthermore, the update makes it more difficult to generate 'active' convection with precipitation in weak forcing situations. This feature should contribute to reduce further a deficiency of the previous version of the scheme to release small precipitation amounts too frequently.

b) Shallow convection

A dependency of the 'shallow convection' parameterization on the model's turbulent kinetic energy (TKE) near the top of shallow convective clouds has been eliminated. This has been done in order to avoid a too strong dependency on the prediction of TKE by the turbulence scheme. The modification has been achievied by 'buoyancy'-considerations in the shallow convection scheme, without giving up the basic principles of the parameterization (Sass, 2001). The proposed modification behaves as expected and removes the previous explicit link to the TKE field.

c) Microphysics

Precipitation release following the ideas of Sundqvist (1993), is strongly governed by two parameters, namely a threshold cloud condensate value where precipitation release becomes efficient, and a parameter defining the intensity of the precipitation release (Sundqvist, 1993). Separate fixed parameters have been used in the past, for convective conditions and 'resolved' scale precipitation.

When approaching high resolution models it becomes artificial to keep fixed coefficients, since the resolved scale precipitation release should approach 'convective' precipitation release. To make the current precipitation release more realistic the threshold parameters mentioned above have been modified to depend on the resolved scale vertical velocity. In this way 'resolved scales' can retain more cloud water before efficient precipitation sets in, in case that a large upward vertical velocity exists. Also the evaporation rate of very small precipitation intensities at a given level has been increased. The argument is that the previous formulation does not adequately take into account the longer time that small drops have to stay in the atmosphere due to a small fall velocity, since the scheme assumes that precipitation reaches the surface in one time step.

d) Sub-grid scale condensation and cloud cover

Uncertainties exist in the formulation of subgrid scale condensation and cloud cover. The dimensionless amplitude defining the magnitude of fluctuations in total specific humidity has been modified. The main idea is to describe that precipitation release will primarily lead to a less dense cloud (less cloud volumetric condensate) and not to substantial changes in cloud cover. In addition, the convective cloud cover has been modified to better describe conditions near saturation. The convective cloud cover field is no longer stored separately. The field previously used to store convective cloud cover is instead used to carry the time dependent amplitude of the moisture fluctuations. The 3D-cloud cover is stored by one field only ('totcov').

2. Validation setup and results

The revisions to the cloud scheme as proposed above is validated with data assimilation runs for two month-long periods, covering respectively 20020115 - 20020215 (winter case) and 19950825-19950925 (summer case). In general the chosen winter period has been rather active and stormy, but also exceptionally mild over Northern Europe. The summer period includes several episodes of heavy precipitation over Europe.

In the test setup, the proposed STRACO revisions are implemented on top of the latest Beta-version of the reference HIRLAM model 5.1.4, which features the new surface analysis and forecast scheme ISBA, as well as the recent revisions to the turbulence scheme. The results are then compared to the parallel test runs previously performed for the reference versions 5.1.0 and 5.1.4. These experiments, all performed on ECMWF Fujitsu VPP5000, are configured on the reference 'Delayed Mode Run (DMR)' setup,

Table 1: Contingency table for accumulated precipitation, 20020115-20020215 (6-18 hour forecasts)

	5.1.0 - winter				5.1.4 - winter				5.1.5 - winter			
obs→ ↓for	O1	O2	O3	O4	O1	O2	O3	O4	O1	O2	O3	O4
F1	2991	78	29	11	4497	156	52	12	5228	207	76	19
F2	6449	2409	749	77	4971	2403	740	83	4220	2311	713	75
F3	290	766	1784	119	263	691	1776	115	283	736	1789	116
F4	8	14	124	78	7	17	118	75	7	13	108	75

Table 2: Contingency table for accumulated precipitation, 19950825-19950925 (6-18 hour forecasts)

	5.1.0 - summer				5.1.4 - summer				5.1.5 - summer			
obs→ ↓for	O1	O2	O3	O4	O1	O2	O3	O4	O1	O2	O3	O4
F1	6022	262	197	67	5711	243	201	68	7012	362	270	100
F2	5102	1733	760	157	5318	1713	749	167	4088	1593	652	128
F3	379	512	1224	154	470	548	1239	165	401	545	1246	135
F4	27	34	202	307	31	37	194	285	29	41	215	322

with a resolution of 0.5 degrees and a grid mesh of 166*130*31 points, using semi-lagrangian advection scheme and Digital Filtering Initialization (DFI). The analysis is made with the reference OI scheme. The assimilation interval is 6 hours, each followed by a 48 hour forecast. The forecasts generated by the above parallel experiments are verified against EWGLAM synoptic and sounding data. In the following text, we use 5.1.0, 5.1.4 and 5.1.5 to denote, respectively, the results from forecast models based on Hirlam 5.1.0, 5.1.4 and the revised 5.1.4 with the STRACO update, as discussed in previous section.

Results of precipitation verification are shown in the contingency tables 1 and 2. Table 1 applies to the winter period from 20020115 - 20020215 and table 2 shows the results for the summer period (19950825 - 19950925). Verification of 12 hour accumulated precipitation R is done in four classes representing, respectively, the intervals $R < 0.1\text{mm}$, $0.1\text{mm} \leq R < 2.0\text{mm}$, $2.0\text{mm} \leq R < 10\text{mm}$ and $10\text{mm} \leq R$. We present here only the contingency tables for the forecast period between 6 hours and 18 hours. Corresponding tables for other periods up to a 48 hour forecast range are very similar (not shown).

The results presented in table 1 and table 2 show clearly that version 5.1.5 has a considerably higher score for precipitation class 1 (no or very little precipitation) as compared to 5.1.4 and 5.1.0. A similar reduction of cases occurs in block F2/O1 of 5.1.5. On the other hand, the frequency of predicted high precipitation amounts has not decreased.

Qualitatively these features can be expected to show up on forecast charts as more distinctly confined precipitation areas in the horizontal, as compared to previously. The new version 5.1.5 gives rise to a large improvement of the diagonal sums of the precipitation tables. The relative improvement of the diagonal sum is 'dramatic' (about 30 %) as regards the comparison with 5.1.0 for the winter period. Moreover, the improvement of the diagonal sum of 5.1.5 is significant for both periods as compared to the alternative model versions. On the contrary, the precipitation score of 5.1.4 relative to 5.1.0 is only improved for the winter period.

It turns out that the produced rain rate as computed from an area average intensity over all grid points is 5 -10 % lower in 5.1.5 compared to the other versions. For the winter period this comparison agrees qualitatively with a simple precipitation bias computation from the verification over EWGLAM stations. The bias with 5.1.5 is slightly smaller than for the other versions. However, for the summer period, a slightly negative bias, common for all model versions, is closer to zero for 5.1.5 (more precipitation) in spite of the smaller model averaged rain rate. Since EWGLAM stations are situated over land this suggests that precipitation over land areas in summer (including the EWGLAM stations) has increased in version 5.1.5 whereas precipitation in other areas, e.g. over oceans, has become smaller. This is qualitatively a desirable result since experience in the past with earlier versions of the scheme has indicated that pecipitation over land in summer is somewhat too small when running with a rather coarse model resolution as is done here.

Traditional verification scores for other parameters have also been computed for both periods and for the different model versions. A subjective assessment of these results (5.1.5 versus 5.1.4) is given in table 3. A '+' means that version 5.1.5 performs better than 5.1.4 and ' - ' means that 5.1.5 performs poorer than 5.1.4. A '0' means a neutral result. These values are subjectively assessed from the full set of results. Verification results of surface and upper air parameters up to a level of 500 hPa are presented in Fig.1 and Fig.2.

The results from the standard station verification shows generally neutral impact of 5.1.5 for the winter period, and a clear positive impact for the summer period. The verification shows a neutral impact for wind at different elevations, and a positive impact for both relative humidity and geopotential heights.

A somewhat increased bias in 2 metre temperature has been diagnosed for the winter period. The cloud cover diagnosis shows a significant reduction of low level cloud cover in version 5.1.5 relative to the other versions. The negative bias increase of 2 metre temperature (up to 0.4 °C) in 5.1.5 is consistent with the significant cloud cover reduction of almost 10 % which might be excessive. A negative cloud cover bias in mid- and high latitude winter is likely to be associated with lower surface temperatures due to a high significance of net outgoing longwave radiation in the surface energy budget. The somewhat increased negative bias of 2 metre temperature for the winter period is not considered to be a serious shortcoming (see next section). Time series of bias and standard deviation for the entire period (not shown) confirm that the benefit in 2 metre temperature prediction obtained in 5.1.4 relative to 5.1.0 is to a large extent retained, e.g. reducing a sometimes quite substantial diurnal variation of the 2 metre temperature bias. The standard deviation of 2 metre temperature for 5.1.5 is neutral for the the winter period and slightly lower (improved) for the summer period, compared to 5.1.4.

Table 3: Subjective comparison of standard objective scores for HIRLAM version 5.1.5 versus 5.1.4, based on standard EWGLAM list (see text)

Measure	Bias (W)	Stdev (W)	Bias (S)	Stdev (S)
Mslp	+	0	+	0
10m wind	0	0	0	0
2m temperature	-	0	-	+
2m relative hum.	-	0	-	+
850 hPa geopot.	+	0	+	0
850 hPa temp.	-	0	+	+
850 hPa relative hum.	+	0	+	+
850 hPa wind speed	0	0	0	0
700 hPa geopot.	0	0	+	0
700 hPa temp.	-	0	0	-
700 hPa relative hum.	+	0	0	0
700 hPa wind speed	0	0	0	0
500 hPa geopot.	-	0	0	+
500 hPa temp.	+	-	0	-
500 hPa relative hum.	0	0	0	+
500 hPa wind speed	0	0	0	0
300 hPa geopot.	-	0	-	+
300 hPa temp.	0	0	0	0
300 hPa relative hum.	+	+	+	+
300 hPa wind speed	0	0	0	+
200 hPa geopot.	-	-	-	+
200 hPa temp.	0	-	0	0
200 hPa relative hum.	0	+	-	+
200 hPa wind speed	0	0	+	0

3. Concluding remarks

The impact of recently proposed modifications to the STRACO cloud scheme has been studied. Model integrations have been carried out for a month long winter period and a summer period, respectively. By running three different model versions it has been possible to investigate the impact of recently suggested modifications in the physical parameterizations. In particular, the specific impact of the proposed modifications (5.1.5) to the cloud scheme can be evaluated on top of the most recently proposed upgrade 5.1.4 including the ISBA surface scheme.

The primary goal of the suggested modifications to the convection scheme , that is, to obtain a better verification fit of model precipitation to observed precipitation, has been achieved. The results clearly indicate that the suggested modifications are able to improve on the occurrence of small precipitation amounts in the scheme without reducing

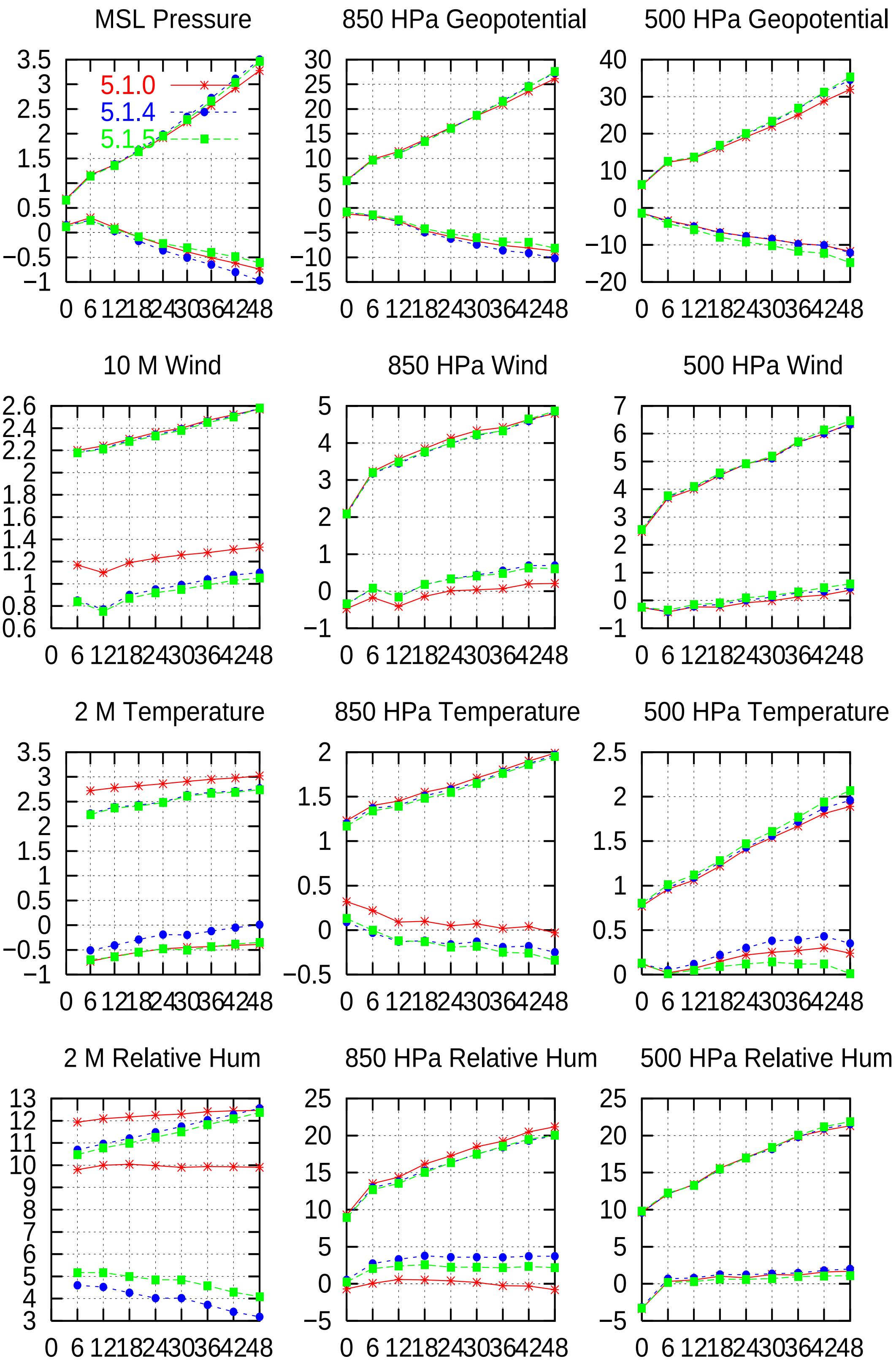

Figure 1: Obs-verification (bias and standard deviation) of surface parameters and upper air geopotential, wind, temperature and relative humidity at 850 hPa and 500 hPa respectively (winter period)

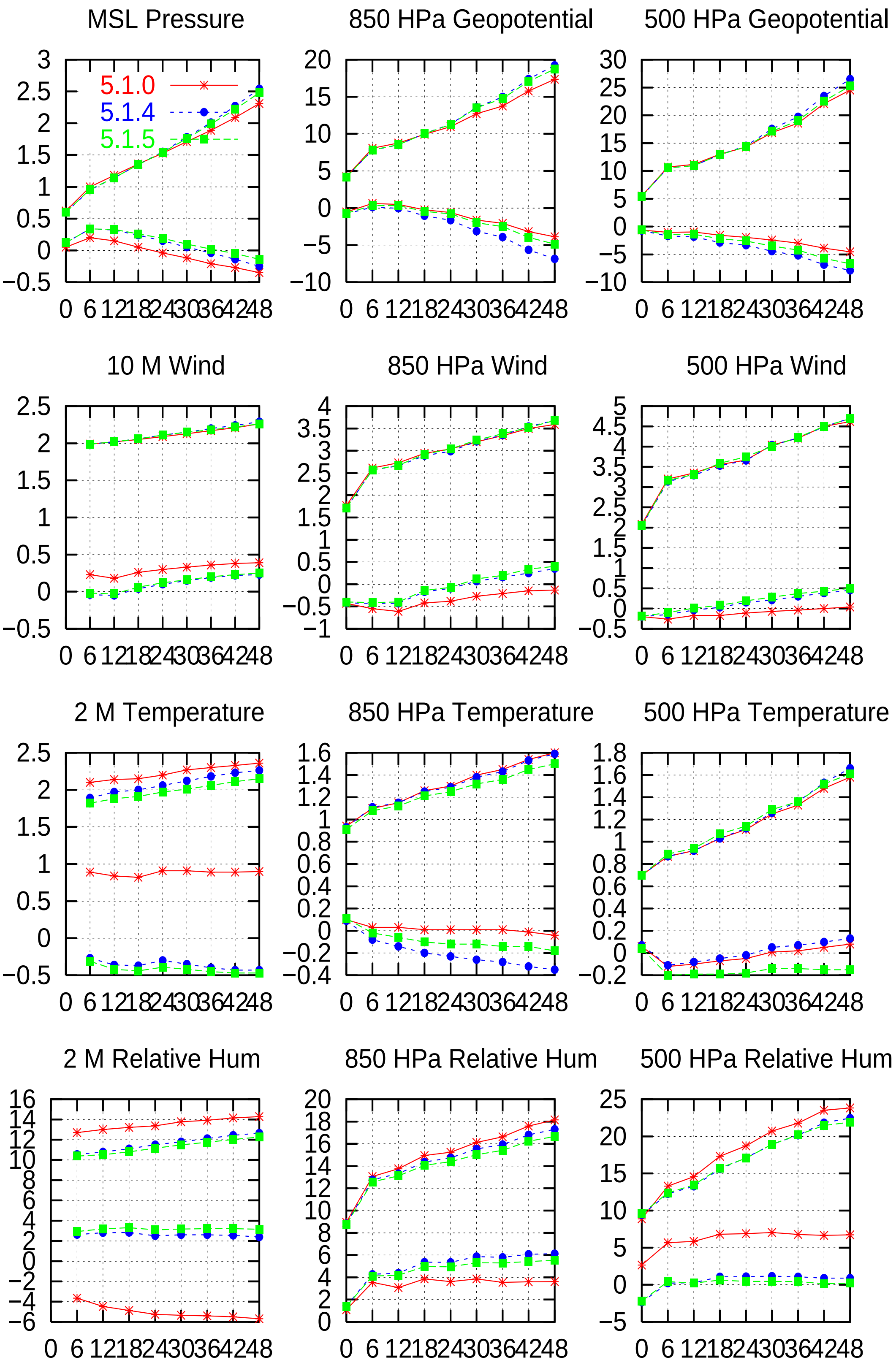

Figure 2: Obs-verification (bias and standard deviation) of surface parameters and upper air geopotential, wind, temperature and relative humidity at 850 hPa and 500 hPa respectively (summer period)

or degrading the prediction of large amounts. There is also some indication that summer time precipitation over land in 5.1.5 is slightly increased compared to previous versions. This statement, however, has not yet been confirmed for a high model resolution.

As regards other parameters than precipitation, the results from standard station verification package shows generally neutral impact of 5.1.5 for the winter period, and a clear positive impact for the summer period. Since the summer period is characterized by significant convective activity there is some reason to believe that the improvements are linked to a more realistic treatment of convection.

It thus appears that the ISBA scheme plus the suggested modifications to the turbulence scheme and cloud scheme generally work well together.

As regards the detected bias increase of 2 metre temperature for the winter period, a slight tuning of one or few coefficients in the cloud cover parameterization can most likely reduce or eliminate this feature without having undesirable side effects.

Some spinup features of the model, essentially during the first 6 hours, have been identified in the present experiments using OI analysis and DFI. The results of additional experiments (not shown) indicate that these spinup features can be substantially reduced when using instead 3D-Var analysis and incremental DFI. Minor tuning and application of 3D-Var plus incremental DFI is therefore expected to provide more optimal results than presented in the present report.

The output from the condensation and convection scheme should be seen as a combined effect of the model dynamics, turbulence and cloud scheme. Hence the need for some tuning of parameters in the cloud scheme is not surprising when used together with a specific turbulence scheme and model dynamics. Tests with the suggested modifications to the cloud scheme at high model resolution is another issue for further studies since the modifications have been designed for possible use at high model resolution.

References

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