ERA report series

10 Forecast drift in ERA-Interim

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1 Introduction

In the ECMWF reanalyses, ERA-15, ERA-40 and ERA-Interim, model-generated estimates of the surface and top-of-atmosphere radiation fluxes, the turbulent fluxes and the hydrological fluxes at the surface were extracted from short-range forecasts. These estimates vary with the forecast length. This drift in the short-range forecasts can be a problem for users of monthly and climatic means. It is often referred to as 'spin-up' or 'spin-down'. Here the spin-up/spin-down properties of ERA-Interim will be summarized and compared to ERA-40. Since the comparisons are best seen directly in the following maps and diagrams, the discussions will be brief. It will be seen that the conflicting requirements of 'stable forecasts' and 'close to the analysis time' can not always be met.

2 Precipitation

The spin-up problem is illustrated in Figures 1 and 2 which show 12-month running means of the monthly precipitation in ERA-40 and ERA-Interim. Forecasts 00h->+12h are blue, +12h->+24h red and +24h->+36h orange. In ERA-40 the 00h ->06h forecasts are green. In Figure 1, independent global precipitation estimates from GPCP (Adler & al.2003) in black, and CMAP (Xie & Arkin 1997) in turquoise are also included.

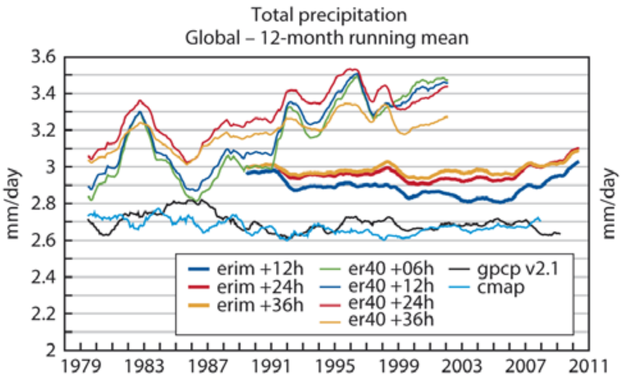

Fig.1: Twelve month running mean of the monthly global precipitation (in mm/day). ERA-Interim with thick curves and ERA-40 with thin curves. 00h → +12 are blue, +12h → +24h are red and +24h → +36h are orange. GPCP and CMAP in black and turquoise.

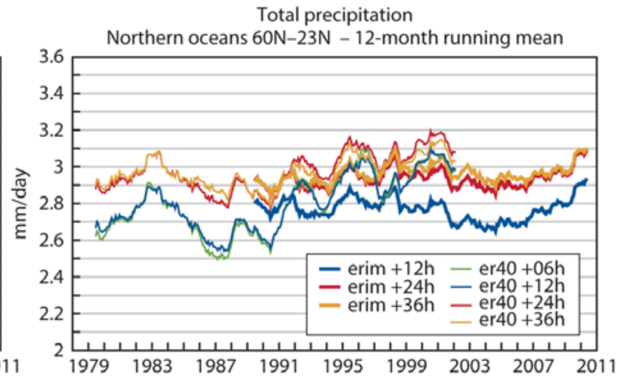

Fig.2: As Figure 1 but for the northern oceans, 23ºN to 60º

The global results demonstrate the huge improvement on going from ERA-40 to ERA-Interim. In ERA-40 the humidity analyses and subsequent precipitation forecasts, especially in the Pacific ITCZ, were too wet. Biases in the use of satellite humidity observations and the choice of control variable for the humidity in the 3D-Var analysis scheme were found to be the causes (Uppala & al. 2005). A revised scheme in ERA-Interim (Dee and Uppala 2009) performed much better; the precipitation is more consistent from year to year and reasonably similar to the independent estimates. There is however a noticeable ‘jump’ down from 1991 on and again a jump up from 2007 on. These jumps are due to an error in the assimilation of rain-affected radiance data from SSM/I, and reflect changes in the availability and use of these data. Dee & al. (2011) give details. The peak in the +24h and +36h precipitation around 1998 is related to the extreme 1998 El Niño event, while the 2009 event is difficult to identify in the global precipitation due to the changes in satellite data use. Just as in ERA-40 the ERA-Interim precipitation forecasts still show a substantial spin-up, especially during the first 24 hours.

Over the extratropical oceans – Figure 2 - ERA-40 produced a more realistic precipitation but again spinning up during the first 24 hours. The same behaviour is also seen in ERA-Interim.

The precipitation spin-up/spin-down patterns in ERA-Interim vary geographically, as shown in Figure 3. The 20-year average difference between the +24h->+36h and the 00h->12h precipitation forecasts varies from a spin-up of up to 0.5 mm/day in the mid-latitude storm-tracks and up to 1 mm/day in parts of the Pacific ITCZ to a spin-down with up to 2 mm/day over tropical land, particularly the rain-forests. For reference the ERA-Interim 20-year average precipitation (from the 00h->12h accumulation) is shown in Figure 4.

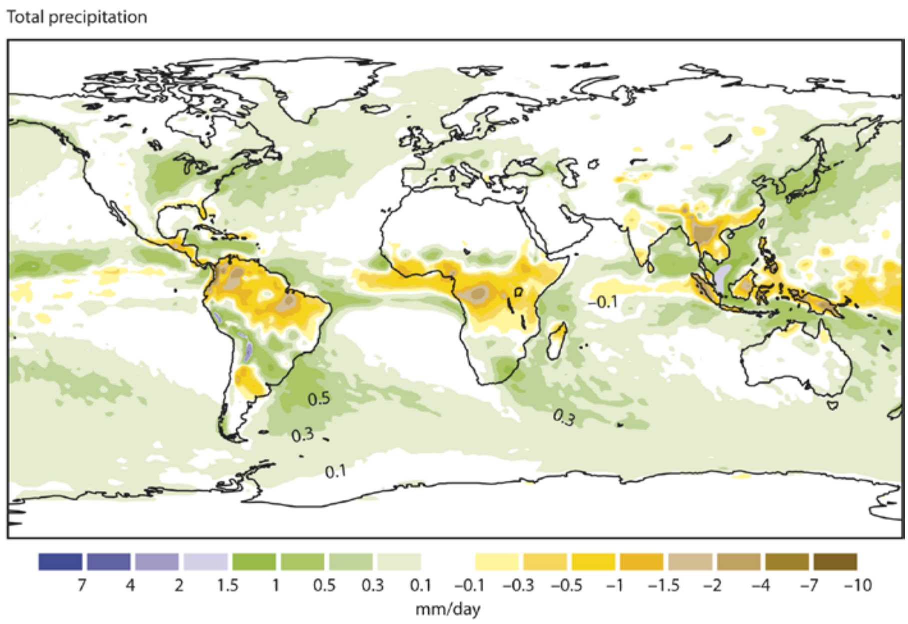

Fig 3. 20 year average of the difference between the precipitation forecasts +24h → +36h and 00h → +12, in mm/day.

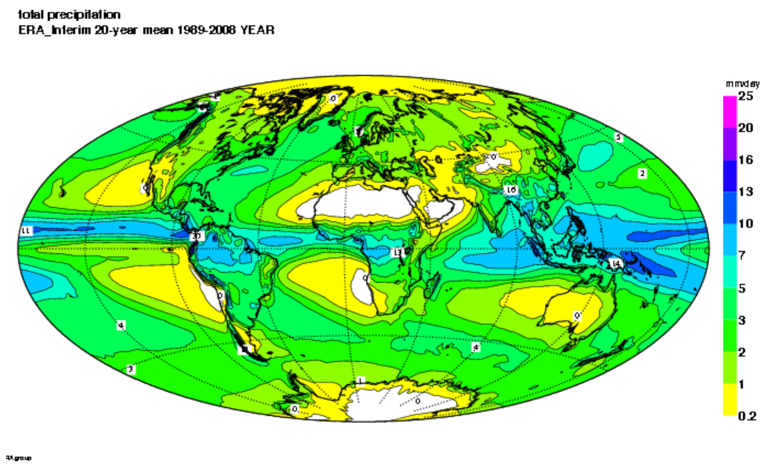

Fig 4:. 20 year average of the global precipitation in ERA-Interim, in mm/day.

There is no marked difference between the spin-up/spin-down properties of the stratiform (left) and convective (right) parametrizations, as seen in Figures 5 and 6.

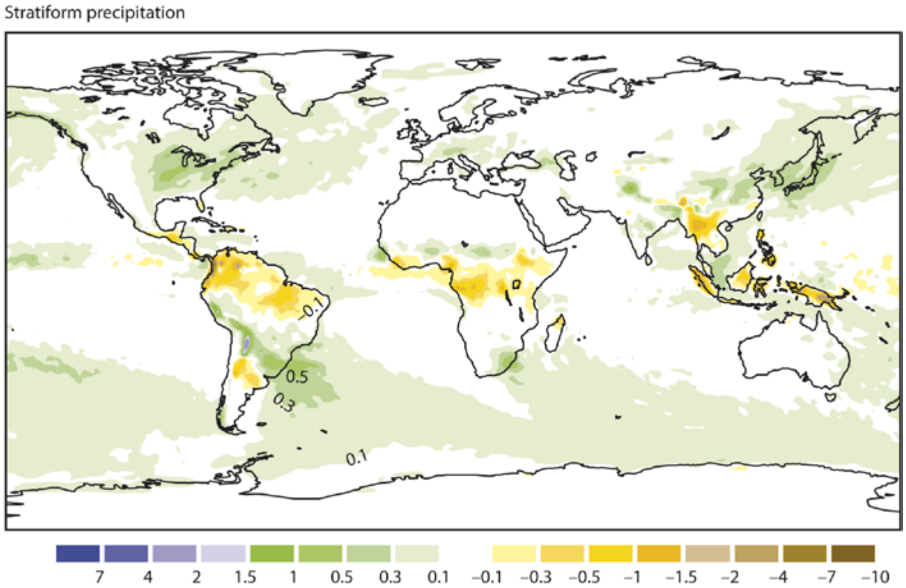

Fig 5: As fig.3, but for the stratiform component of the precipitation.

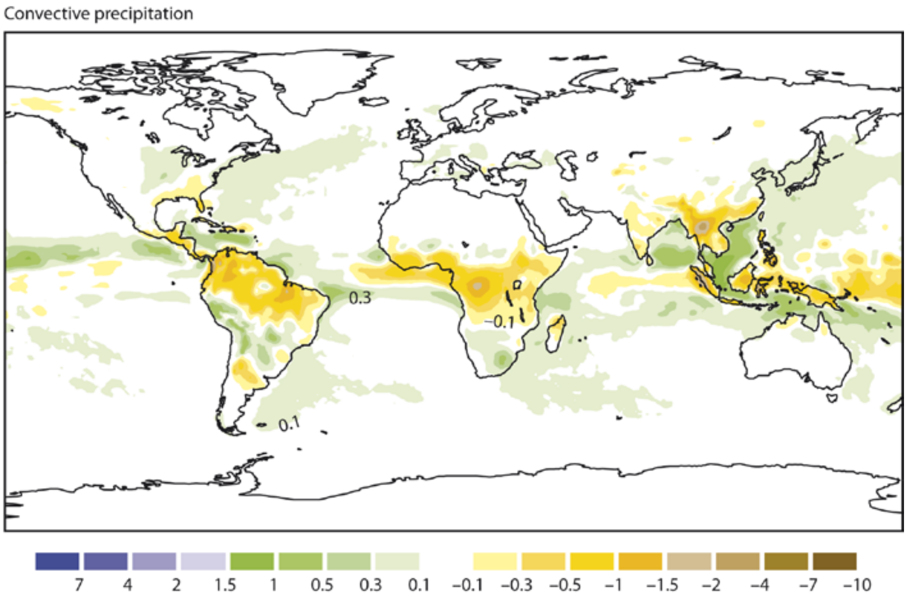

Fig 6: As fig 3, but for the convective component of the precipitation.

Twice daily 10-day forecasts made during the ERA-Interim production give some further insight. They have been averaged into annual means for two years, 2000 and 2008. 2000 is in the middle of the period where the annual precipitation stays fairly constant (excepting the El Niño events), while 2008 is after the upward jump due to changes in satellite data usage. The daily mean precipitation summed from two 12h accumulations each day (from 00Z and 12Z) is seen in Figures 7 and 8 for 2000 (full lines) and 2008 (dashed). For reference the GPCP estimates for 2000 are included as dotted lines.

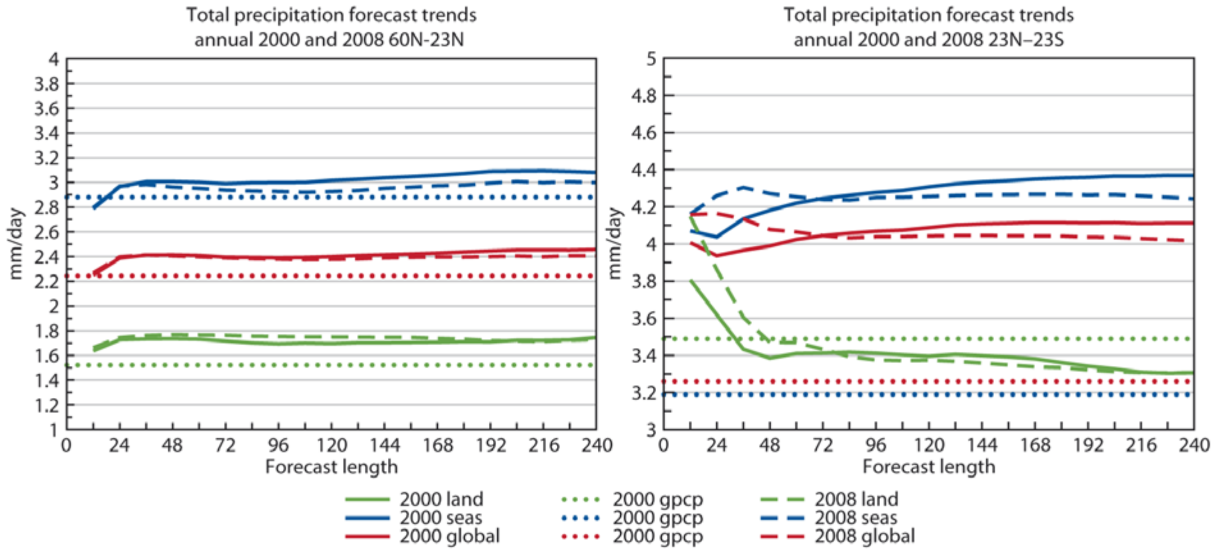

Fig 7: Trends in precipitation in 10-day forecasts, averaged for the years 2000 and 2008. Northern midlatitudes (23ºN to 60ºN).

Fig 8: As Fig. 7, but for the tropics (23ºS to 23ºN).

In the extratropics (Figure 7) the oceanic precipitation (blue curves) increases rapidly over the first 36 hours, followed by a slow but steady further increase. The continental precipitation (green) behaves similarly but less pronounced. The red curves show the global sums. There are only minor differences between the two years.

In the tropics (Figure 8) the 2000 and 2008 forecasts both show a marked spin-down over land, which reflects the rain forest spin-down already mentioned. The two years are interestingly different over the tropical oceans. In 2000 (full lines) there is first a weak decrease from +12h->+24h whereafter there is a steady increase (~0.23mm/day) all the way to day 10. In 2008 (dashed lines) the tropical ocean rain spins up rapidly initially and peaks at +36h whereafter the rainrate flattens out at a somewhat smaller value. The reason for these differences have not been examined in detail, but the changes in satellite usage already mentioned are likely.

3 Hydrological balance

The global hydrological balance in ERA-40 suffered severely from the problem of overestimation of the humidity in the oceanic ITCZ, which lead to imbalances in the global P-E of the order +0.3mm/day. ‘Fictitious’ water vapour was added to the atmosphere in every analysis cycle. The revised 4D-Var analysis scheme in ERA-Interim has eliminated the problem, and the global hydrological balance is now very good, on average over 1991-2010 it is at its best at +12h with -0.001 mm/day, increasing to +0.094 mm/day at +36h, (Figure 9). The P-E balance varies over the years, related to the availability and use of observation systems over the 20 years. During most years (1992-2006) the +12h->+24h balance is close to zero.

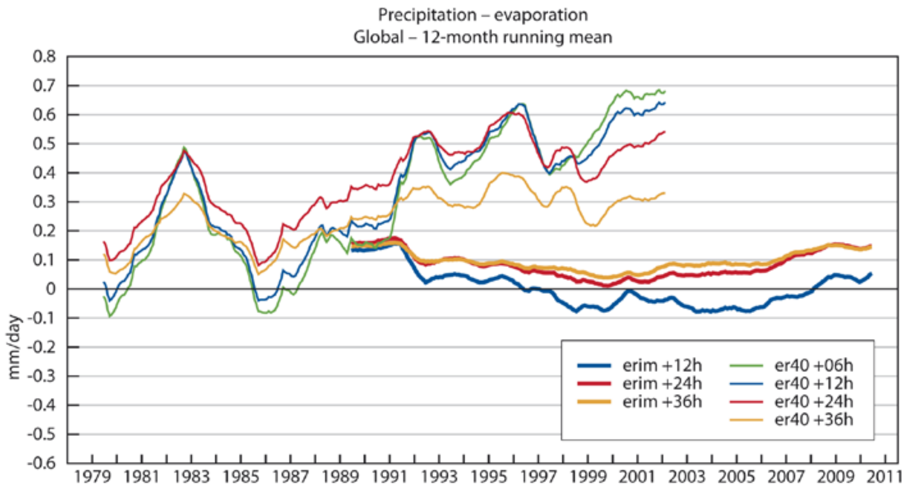

Fig 9: : Twelve month running mean of the monthly global precipitation minus evaporation(in mm/day). ERA-Interim with thick curves and ERA-40 with thin curves. 00h → +12 are blue, +12h → +24h are red and +24h → +36h are orange.

4 Surface energy exchange

In ERA-Interim the surface net energy balance is actually worse than it was in ERA-40, (Figure 10). Ideally it should be very close to 0 W/m² but in ERA-Interim it approaches +5 to +7 W/m² (downwards, into the sea). The two major El Niño events encountered during ERA-Interim are clearly seen in the energy balance and, interestingly, also on the spinup properties. Up to about 2007 the global net flux imbalance diminishes from +12h to +36h while later on the three forecast lengths are very similar in this respect. This is also so during the 2009 El Niño event while in 1998 there was a marked spin-down in the net flux.

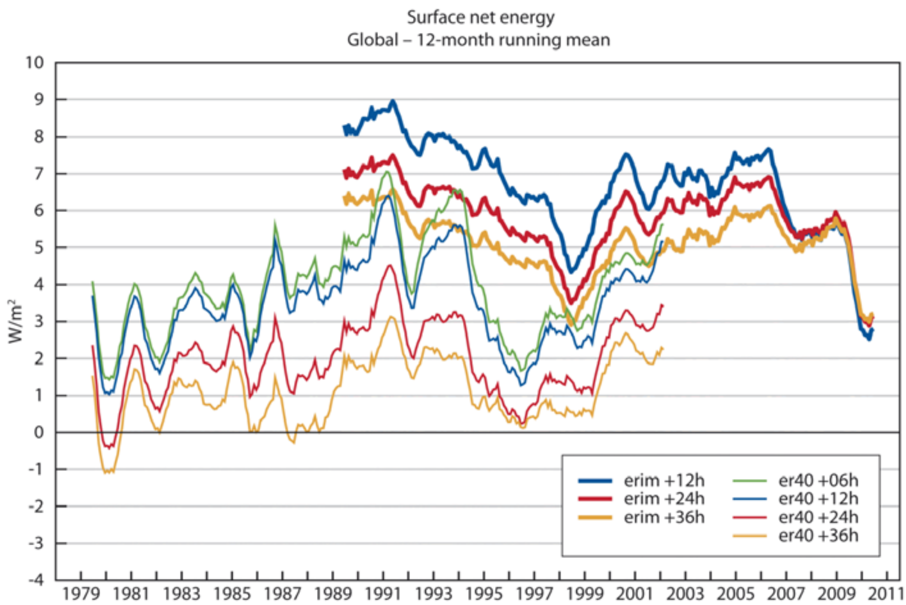

Fig 10: Twelve month running mean of the monthly surface net energy balanc in W/m². ERA-Interim with thick curves and ERA-40 with thin curves. 00h → +12 are blue, +12h → +24h are red and +24h → +36h are orange.

The anomalous Pacific SST during the 1998 and 2009 El Niño events are reflected (as peaks or dips) in the latent heat flux and long- and short-wave radiation components of the surface energy exchange. All four components are shown in Figures 11-14.

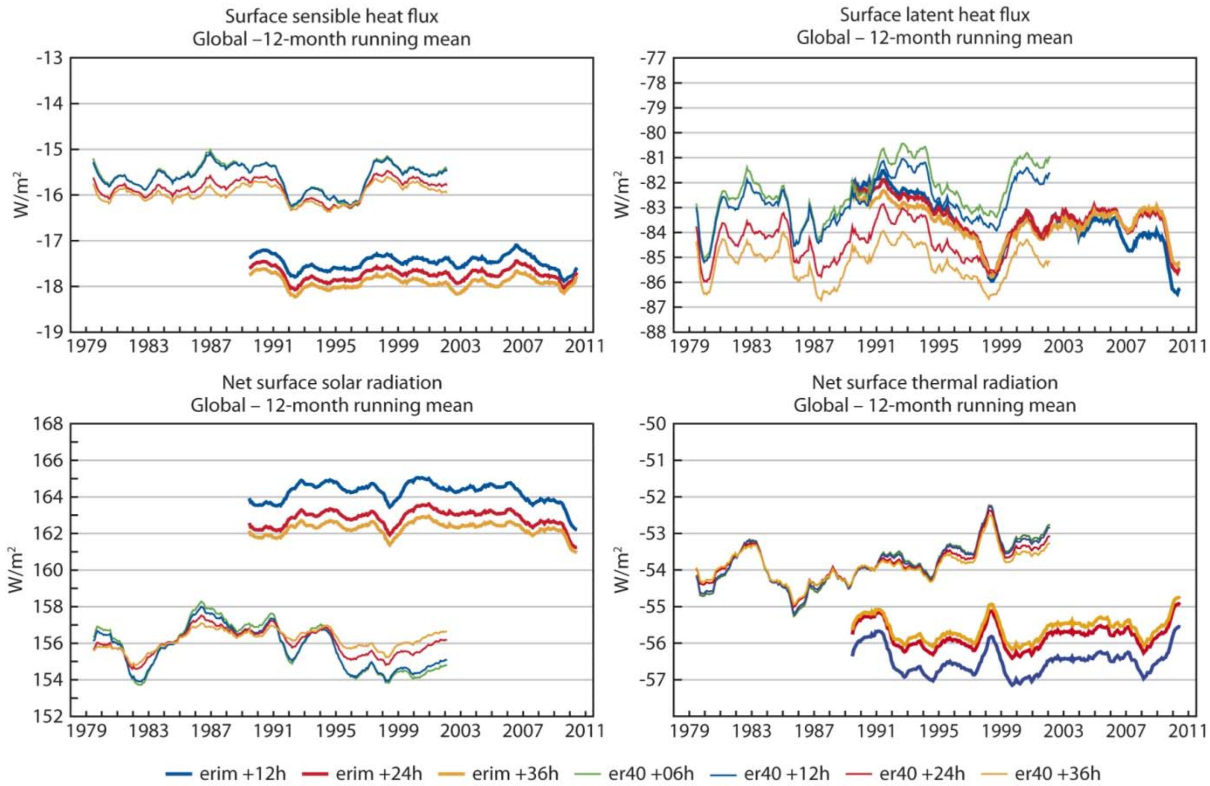

Fig 11 (top left): As fig 10, but for surface sensible heat flux.
Fig 12 (top right): As fig 10, but for surface latent heat flux.
Fig 13 (bottom left): As fig 10, but for surface net shortwave radiation.
Fig 14 (bottom right): As fig 10, but for surface net thermal radiation.

The common cause for the drift in radiation and latent heat is the increase or decrease of cloud cover during the first 24 hours of the forecasts. Forecasts from 00Z (Figure 15) and from 12Z (Figure 16) indicate the 24-hour increase (grey) or decrease (blue) in the total cloud cover. The clouds have a tendency to increase almost everywhere over the oceans, except over the subtropical upwelling areas where in particular the low clouds (stratocumulus) decrease. The clouds also increase over the extra tropical continents, while over the ‘rain-forests’ the tendency in cloudiness is different whether the forecasts are initialized at 00Z or at 12Z.

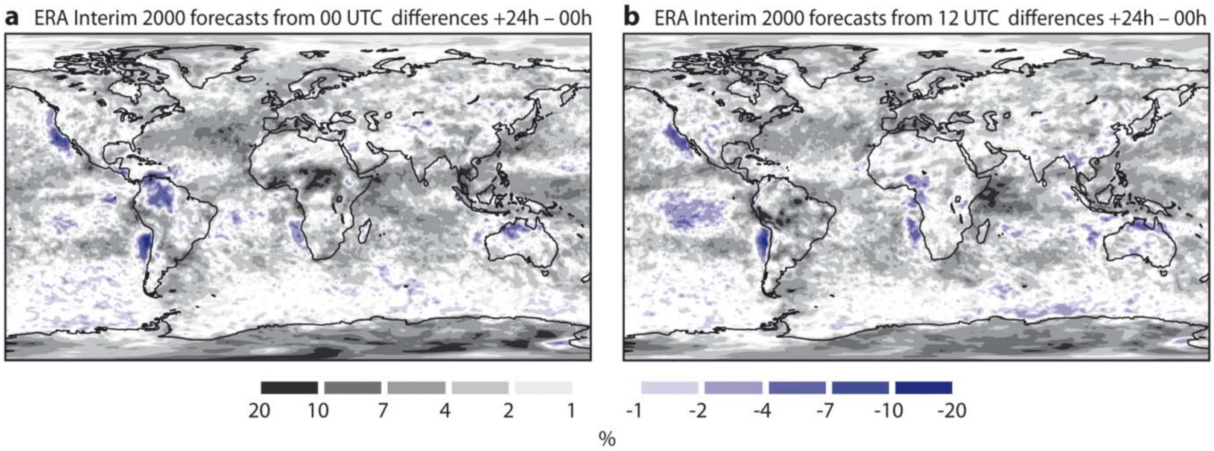

Fig 15: Annual mean of the 'spinup/spindown' of the total cloud cover over the first 24 hours in 2000 from forecasts from 00UTC. Increasing clouds in grey, decreasing blue, in %.

Fig 16: Annual mean of the 'spinup/spindown' of the total cloud cover over the first 24 hours in 2000 from forecasts from 12UTC. Increasing clouds in grey, decreasing blue, in %.

The cloud spin-up/spin-down is clearly reflected in the surface net energy balance in Figure 17. Over the subtropical 'up-welling' areas, the Atlantic ITCZ, the Arabian Sea and also over the high latitude southern oceans the downward energy flux increases over the 24 hours (red colours). The good correspondence between the cloud spin-up/spin-down and the net energy flux indicates that the model clouds are the major contributor to the imbalance in the surface energy

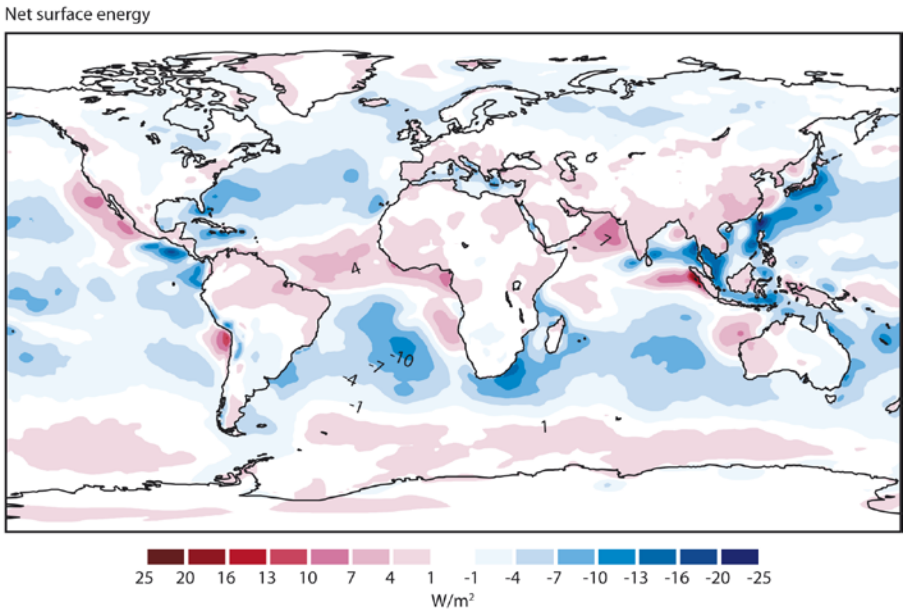

Fig 17. 20 year average of the difference between the net surface energy flux from forecasts +24h +36h and 00h → +12, in W/m².

5 Top-of-atmosphere radiation balance.

The radiative balance at the top of the atmosphere (TOA) in ERA-40 was not very good with a net cooling of the atmosphere/earth system of between 7 and 8 W/m². Figure 18 shows that in ERA-Interim the balance is much better, still with some net cooling but now reduced to between 1 and 2 W/m² with the 'best' balance at +12h.

Just as with the surface net energy exchange, the 1989 and 2009 El Niño events stand out as peaks also at the T.O.A. The anomalous SST during these periods seem to be the major contributor to the imbalance also at the top of the atmosphere due to the impact of the cloud amounts.

Both ERA-Interim and ERA-40 show similar spin-up properties in the TOA radiative balance and the increasing total cloud amount seen in Figures 15 and 16 is a possible cause of this problem, at least in ERA-Interim.

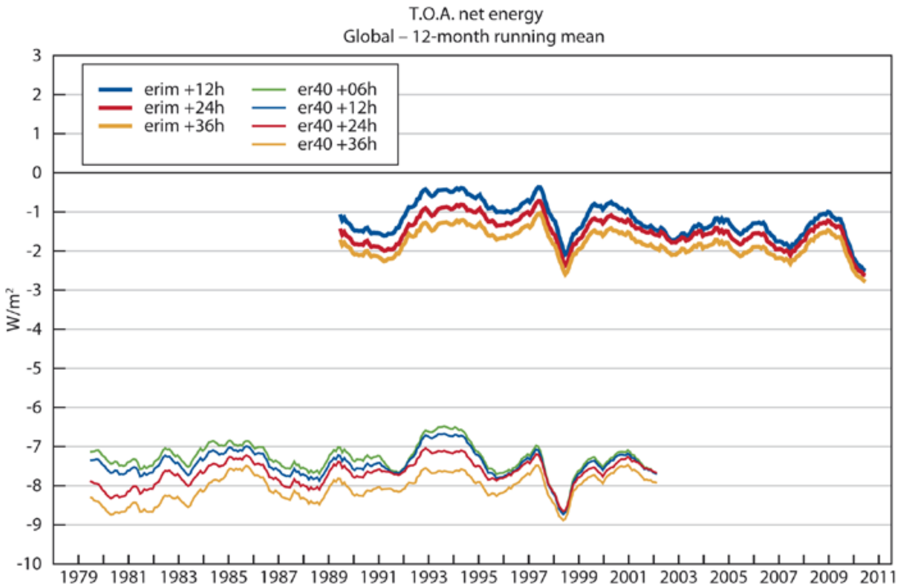

Fig 18: Twelve month running mean of the monthly top-of-atmosphere energy balance in W/m². ERA-Interim with thick curves and ERA-40 with thin curves. 00h → +12 are blue, +12h → +24h are red and +24h → +36h are orange.

6 Conclusions and recommendations:

Just as in ERA-40 there is some drift in short-range forecasts of various model-generated variables in ERA-Interim. The most striking feature is the geographical inhomogeneity with precipitation spin-down over rain-forested areas and spin-up over the mid-latitude ocean stormtracks. There is a fairly large imbalance in the net surface energy flux, due primarily to problems in the cloud distribution. Still, running mean timeseries of the monthly mean fluxes indicate that the 00h->+12h forecasts generally are the better.

The conclusions can be summarized in a table.

Diagnostic variable	Best choice of forecast length
Total precipitation	Large geographical variations, +12h closest to GPCP and CMAP globally
Hydrological balance 'P-E'	Varies with time, +12h best average over 20 years.
Net surface energy exchange	+36h but varies with time
Net top-of-atmosphere radiation balance	+12h

An additional aspect is that the 00h->+12h forecasts obviously are synoptically closest to the analyses. So, in short, it is recommended that the 00h->+12h forecasts are used for the extraction of precipitation and energy fluxes from ERA-Interim.

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