Comparison of model-generated boundary-layer clouds to observations from space-borne lidar

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The Integrated Forecasting System's (IFS) boundary layer and convective parameterizations have evolved significantly over the past few years. These new developments are based on observations such as those collected during the ARM project. This poster illustrates the improved ability of the IFS to forecast marine stratocumulus clouds by comparing model-generated clouds to space-borne lidar observations.

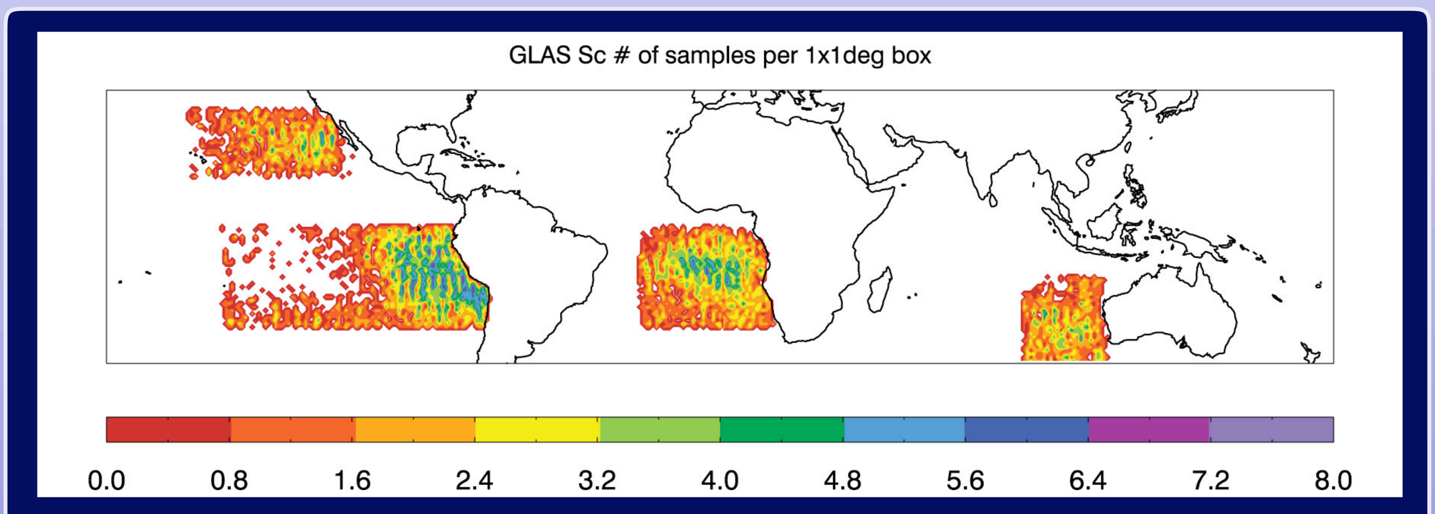

Fig 1a

⇑Shown above is the ***frequency of occurrence*** of stratocumulus clouds in the lidar observations for all 54 days. As expected, the majority of samples identified as marine stratocumulus are located in the eastern ocean basins, close to the coast.

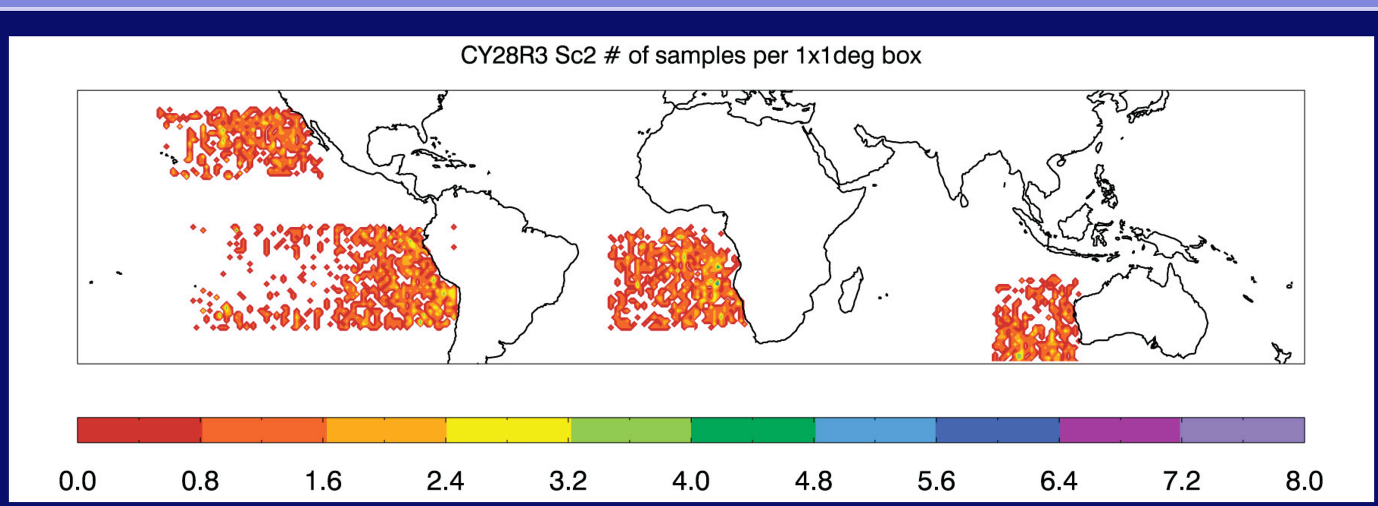

Fig 2a

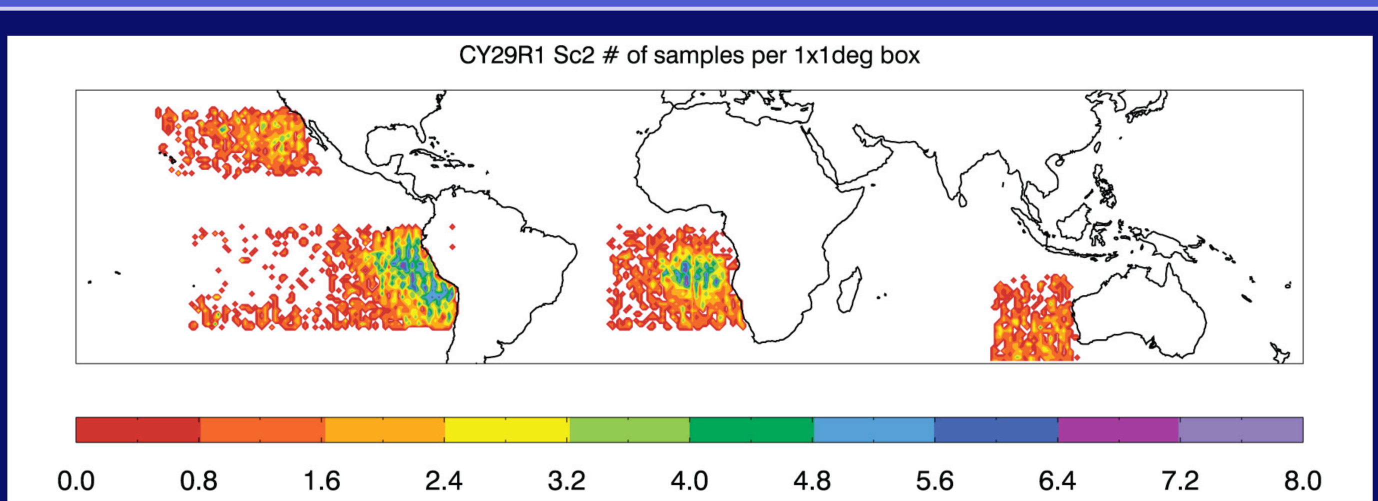

Fig 3a

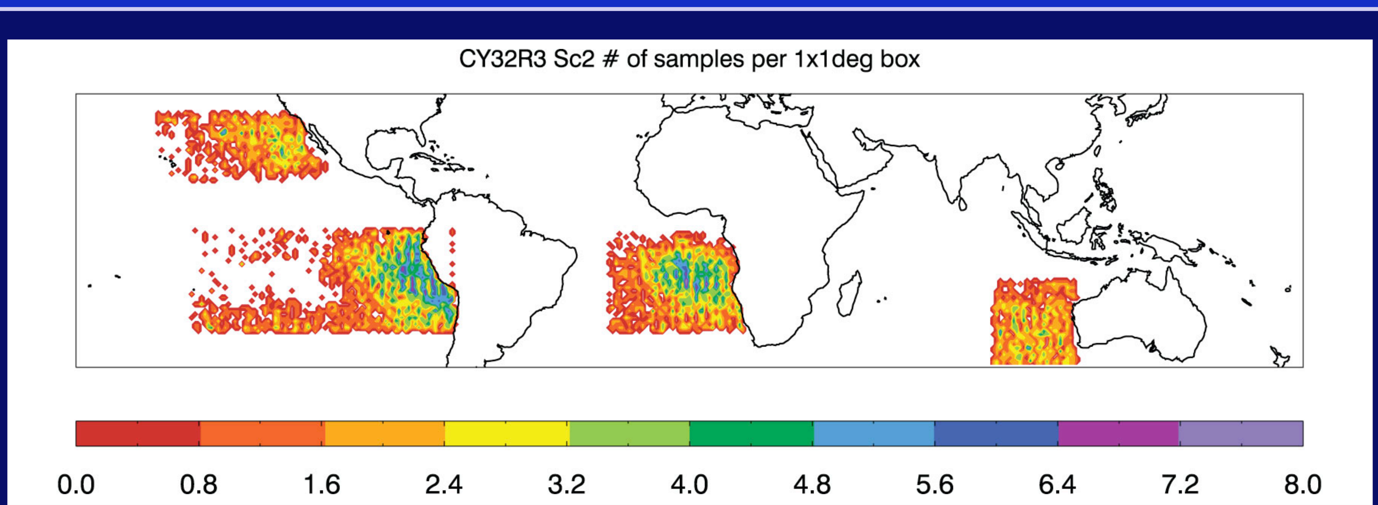

Fig 4a

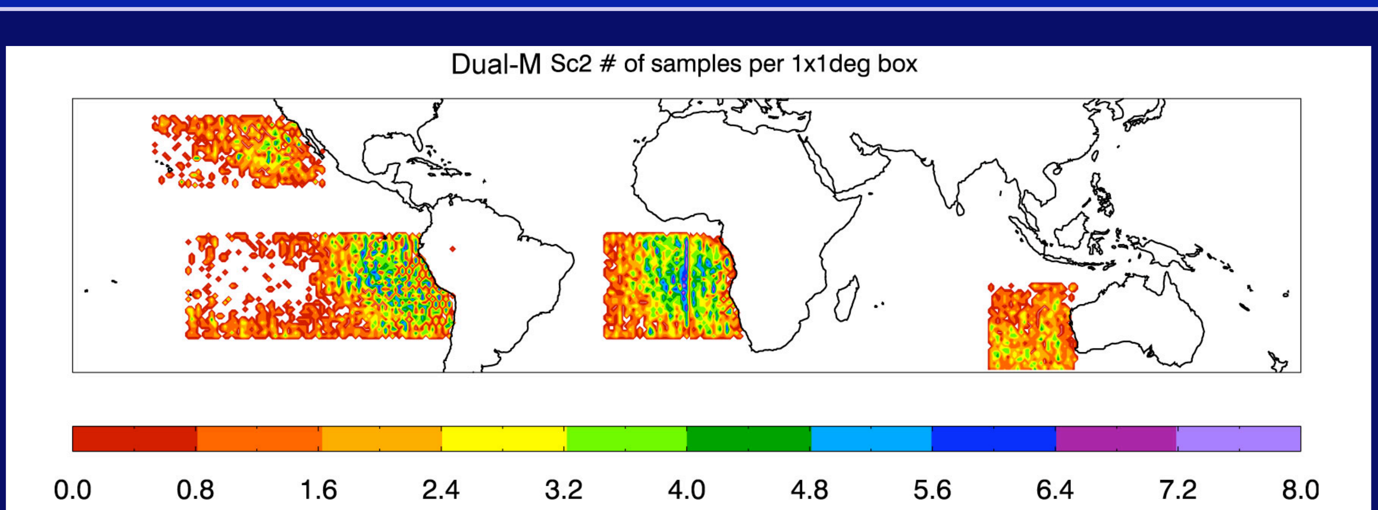

Fig 5a

The latest development is an extension of the EDMF, the **dual mass flux scheme** (**Dual-M**)[4]. Here, the mass-flux component of the EDMF is split into two variable area partitions for dry updrafts and moist updrafts. A smooth transition between dry boundary layer, stratocumulus and shallow cumulus is thereby possible.

The frequency of occurrence of Sc samples is similar to CY32R3, but **cloud top heights are now in better agreement with observations.** (Figs 5a&b)

The **Geoscience Laser Altimeter System** (**GLAS**) provided a first two-month record of space-borne lidar observations from Sept. 26th to Nov. 18th 2003. Similar observations are now available from CALIPSO and CloudSat.

The IFS is run for this period at T511L60 resolution, initialized every other day. Days two and three of the forecast are then used. The model data are remapped onto a 1°x1° latitude-longitude grid using nearest-neighbor sampling.

The lidar tracks are compared to model data by co-locating each track with the model columns intercepted, and calculating an average cloud top height and a cloud fraction from the lidar observations falling into each individual model grid box. Cloud fraction and top height from observations and the model are then used to identify a cloud type.

Shown here are results for cloud type **marine stratocumulus** (***Sc***). A sample is classified as *Sc* when its cloud fraction is at least 80%, and its cloud top height does not exceed 2 km. Samples also have to be located over ocean and within the four regions shown on the figures to the left. (Figs 1a&b)

In **CY28R3**, the boundary layer is represented by simple K-diffusion using dry-conserved variables. Hence, the scheme has no information about the state of saturation in the boundary layer. All boundary layer clouds are generated with the shallow convective scheme.

The number of *Sc* samples is much lower than observed. The scheme compensates by producing an overabundance of shallow clouds with low cloud fraction (not shown here). The cloud top height is **200 m to 300 m too low**. (Figs 2a&b)

In **CY29R1**, the Eddy Diffusivity Mass Flux scheme (**EDMF**) is introduced[1,2]. It splits the boundary layer transport into a diffusive component and a mass flux component. This allows the direct representation of boundary-layer-size eddies, as well as simple down-gradient diffusion. The scheme also uses moist-conserved variables, thus keeping track of the saturation state of the air. The EDMF will produce stratocumulus clouds if the boundary layer is moist enough for a lifted parcel to reach the LCL before it reaches a level of zero vertical velocity. Also required for cloud generation is strong lower level stability (Klein and Hartmann stability criterion[3]).

The introduction of the EDMF leads to a much improved representation of marine stratocumulus clouds, with more samples being classified *Sc*. However, the cloud top heights are now even lower than before, with the peak of the distribution **400 m to 500 m lower than observed.** (Figs 3a&b)

CY32R3 improves the stratocumulus top entrainment by using a more realistic lower amount of free tropospheric diffusion.

The test parcel used in the EDMF to determine the boundary layer height entrains environmental air during its ascent. This entrainment has been reduced in CY32R3 compared to CY29R1, also contributing to a slightly deeper boundary layer.

CY32R3 includes several changes that are not related to the boundary layer scheme. The distinction between shallow and deep convection via test parcel ascent has been adjusted to allow a more consistent treatment of both convection types. This has a small impact in the results shown here, as shallow convection still contributes to the samples classified as *Sc*.

The frequency of occurrence, as well as the location of Sc samples is now in very good agreement with observations. Cloud tops remain too low, however. (Figs 4a&b)

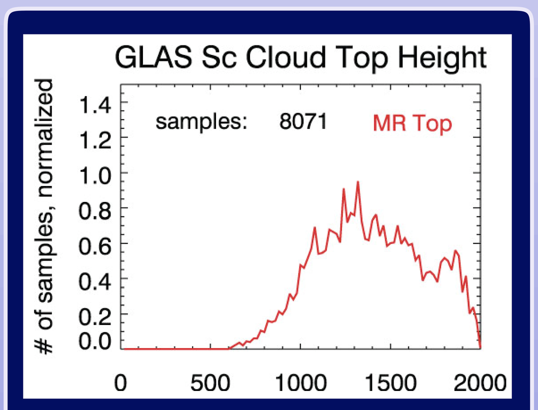

Fig 1b

⇑The cloud top height distribution for the lidar samples identified as *Sc* shows a broad peak in cloud top height between 1200 m and 1500 m.

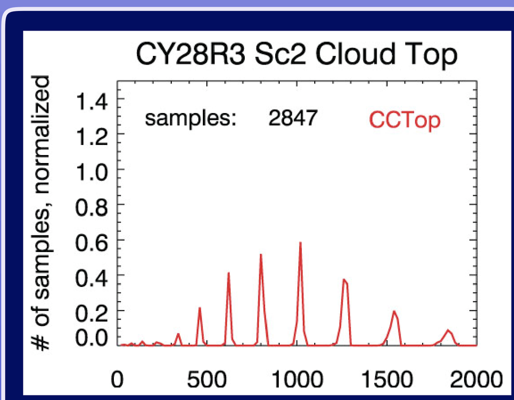

Fig 2b

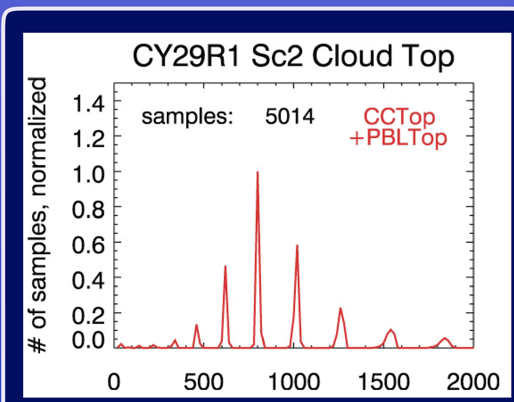

Fig 3b

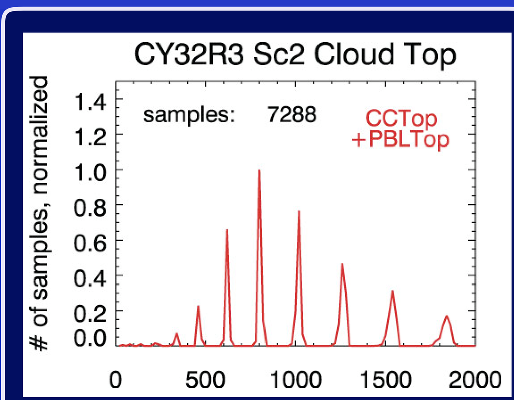

Fig 4b

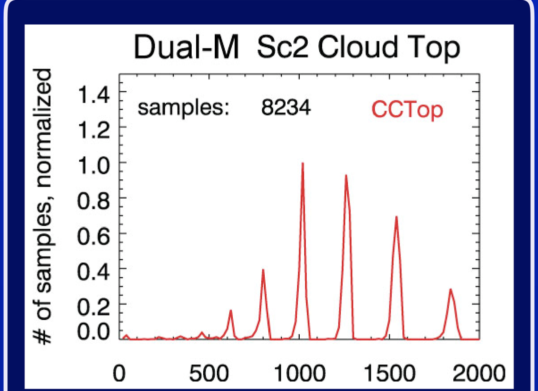

Fig 5b

References:
1: Köhler, M., 2005: Improved prediction of boundary layer clouds. ECMWF newsletter No. 104 - Summer 2005
2: Tompkins, A.M., P. Bechthold, A.C.M. Beljaars, A. Benedetti, S. Cheinet, M. Janiskova, M. Köhler, P. Lopez, J.-J. Morcrette, 2004: Moist physical processes in the IFS: Progress and Plans, ECMWF Technical Memo 452
3: Klein, S. A. and D. L. Hartmann, 1993: The seasonal cycle of low stratiform cloud, J. Climate, 6, 1587–1606.
4: Neggers, R.A.J., 2006: Extending the EDMF into the statistical modeling of boundary layer clouds. ECMWF workshop on the Parameterization of Clouds in Large-Scale-Models, 13-15 Nov 2006

Outlook: The Dual-M scheme is currently undergoing further evaluation. The results shown here are only a first glance at the latest results.
The lidar evaluation tool is being extended for use with CALIPSO and CloudSat observations, and to interface with the existing CFMIP ISCCIP/CloudSat/CALIPSO Simulator (CICCS).

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