How ARM/ASR observations have contributed to ECMWF model development

Maike Ahlgrimm, Richard Forbes, **Irina Sandu**

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ECMWF

ASR Atmospheric System Research

ARM/ASR have funded collaboration with ECMWF for over a decade

- Fixed sites and mobile facilities on observational campaigns
- Covered many climatic regimes
- We have looked at:
  - Maritime warm boundary layer clouds
  - BL cloud over land
  - Arctic mixed-phase clouds
  - Tropical deep convection

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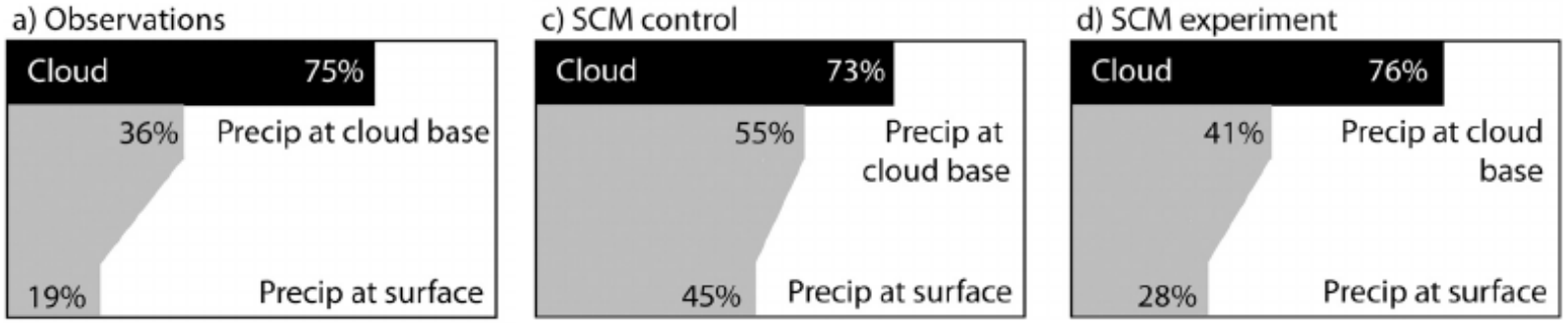
ASR Atmospheric System Research

Tackling the ‘light rain’ problem that many global models have

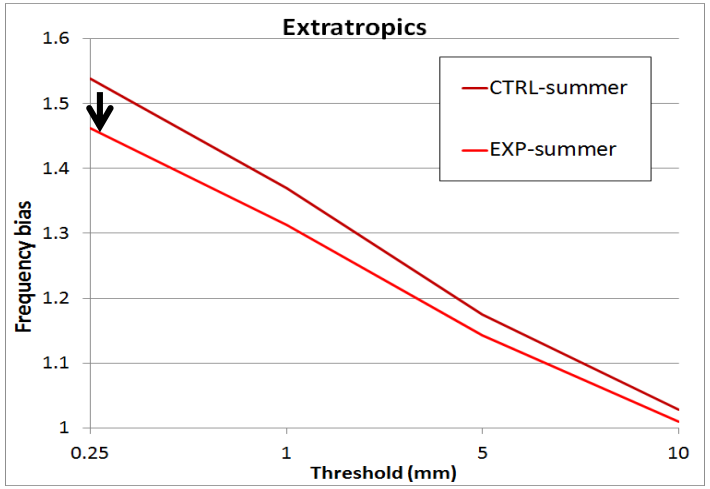
CAP-MBL campaign on Graciosa island, now Eastern North Atlantic site

- Qualitative indication that autoconversion/accretion too efficient (drizzle produced too frequently), and evaporation insufficient (not enough drizzle evaporates below cloud base)
- Changes to autoconversion/accretion improve drizzle occurrence, but evaporation remains too weak (2015)



Ahlgrimm and Forbes (2014, MWR)

Reduction in precipitation frequency bias in CY41R1 (2015)



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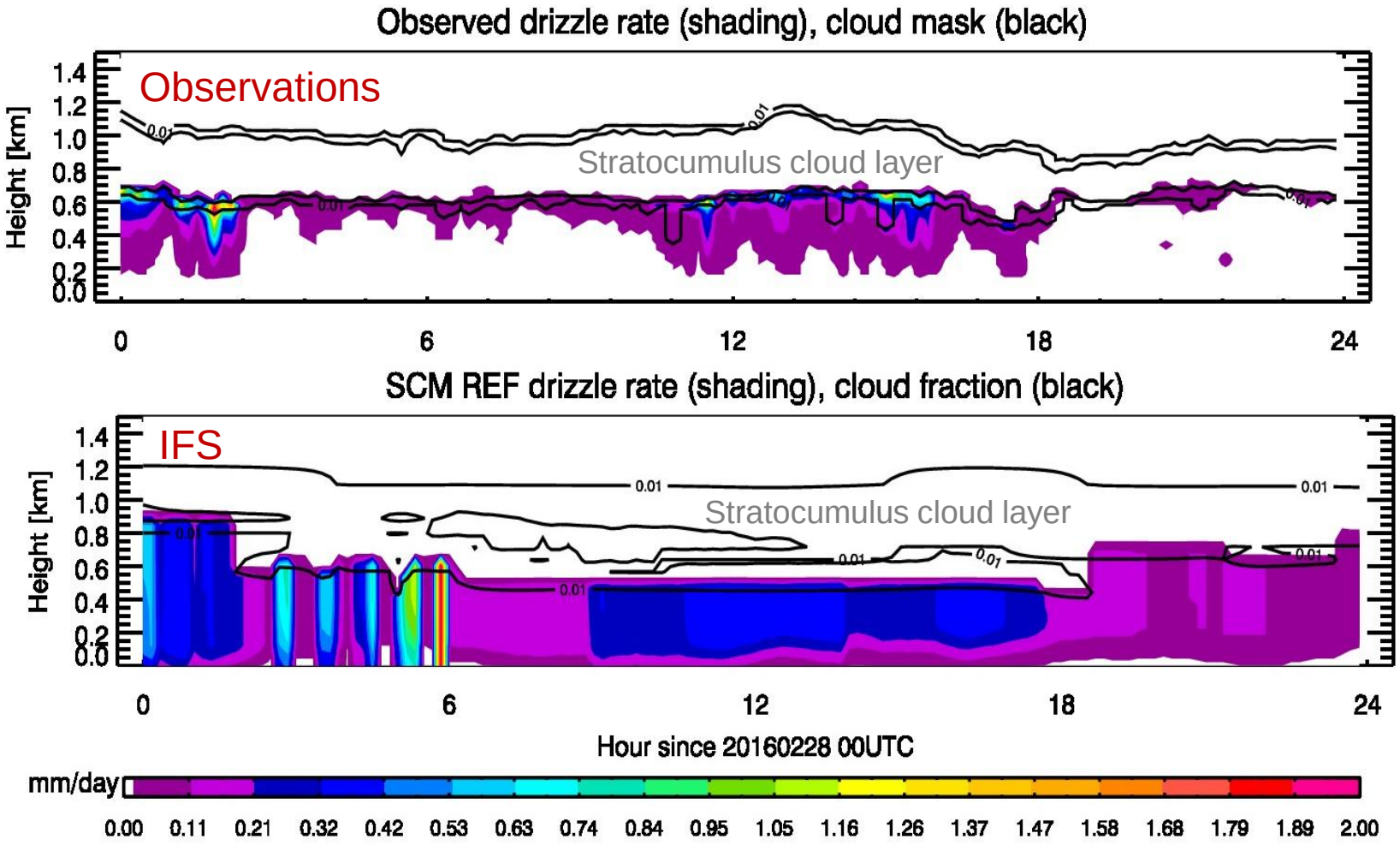
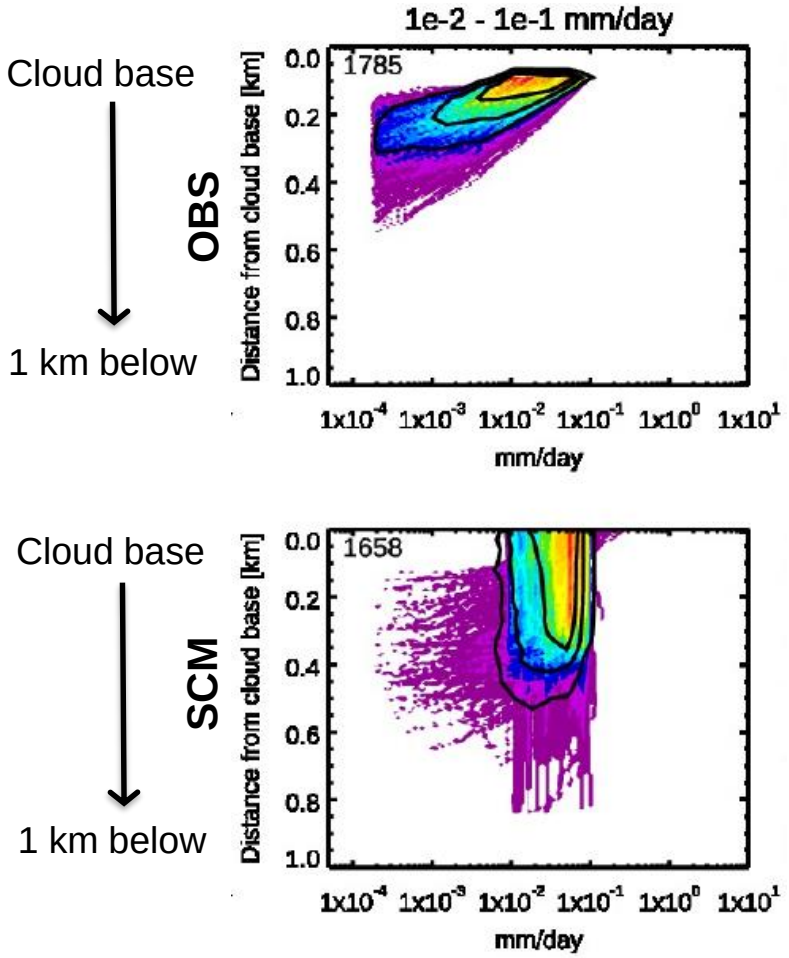
Tackling the ‘light rain’ problem that many global models have

Vertically resolved drizzle rates at the Eastern North Atlantic site



Drizzle rate vs distance from cloud base (18 months of data)



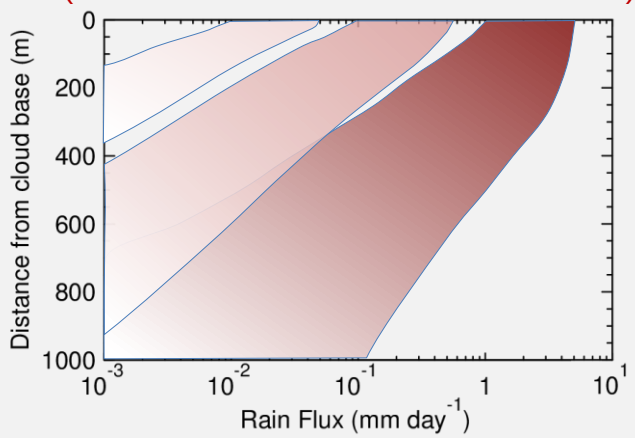
ECMWF

Tackling the ‘light rain’ problem that many global models have

Tests with 1D evaporation model with different droplet size distribution options

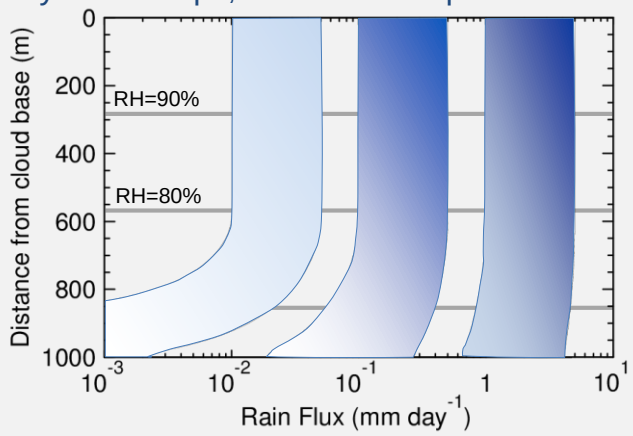
Observed distributions of drizzle flux profiles

(based on 18 months of data from ENA site)



Abel-Boutle DSD, 1-mom, RH threshold

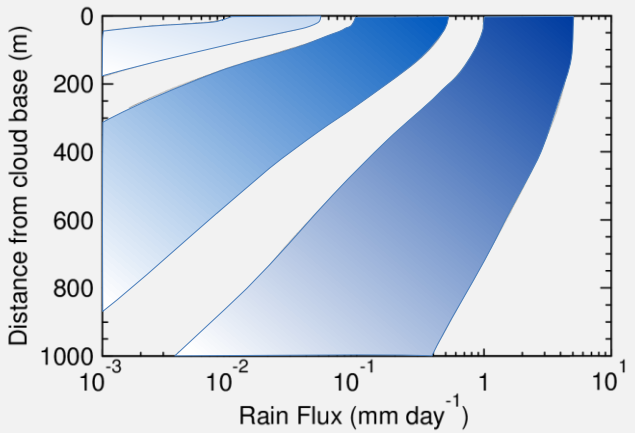
Many small drops, threshold compensates for rapid evap



Current IFS

Abel-Boutle DSD, 2-moment

Many small drops, but size sorting reduces evap



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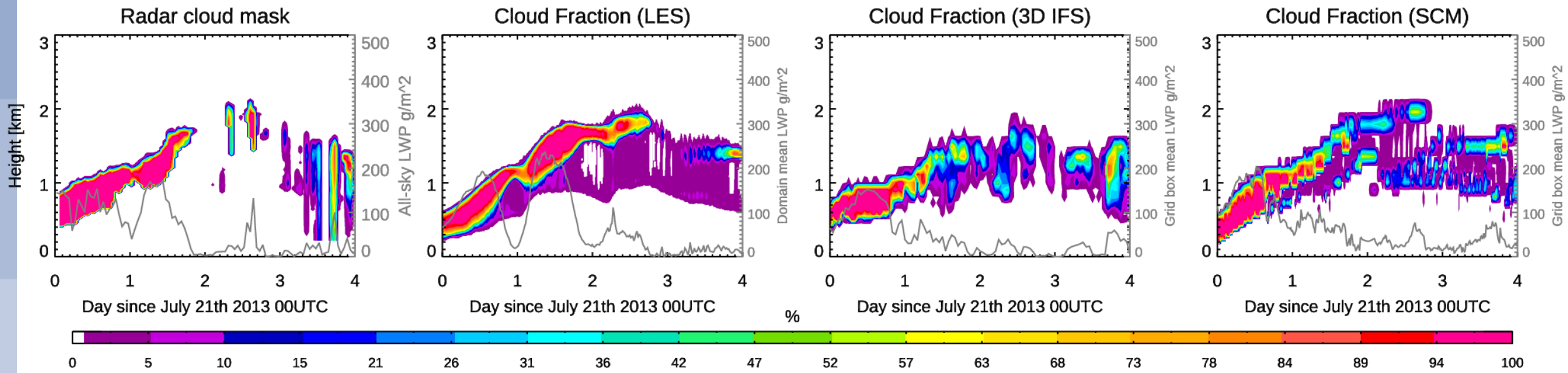
Forbes et al. (2019, in prep)

Marine boundary layer cloud transitions

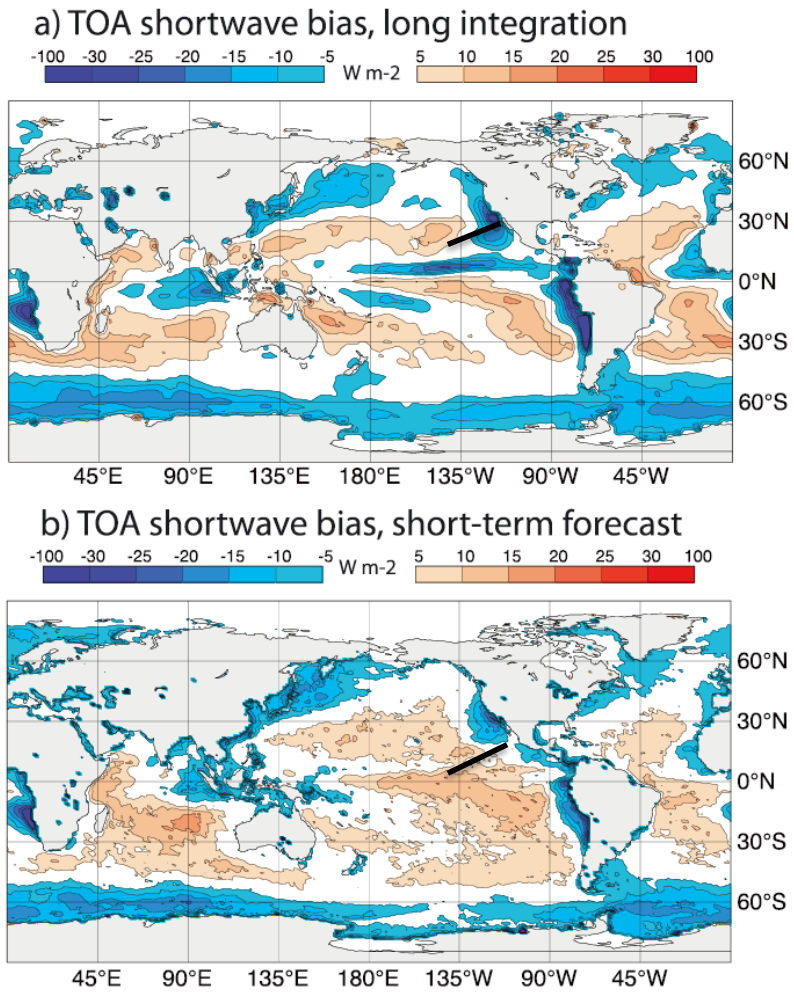
MAGIC campaign – from LA to Hawaii along the north Pacific transect

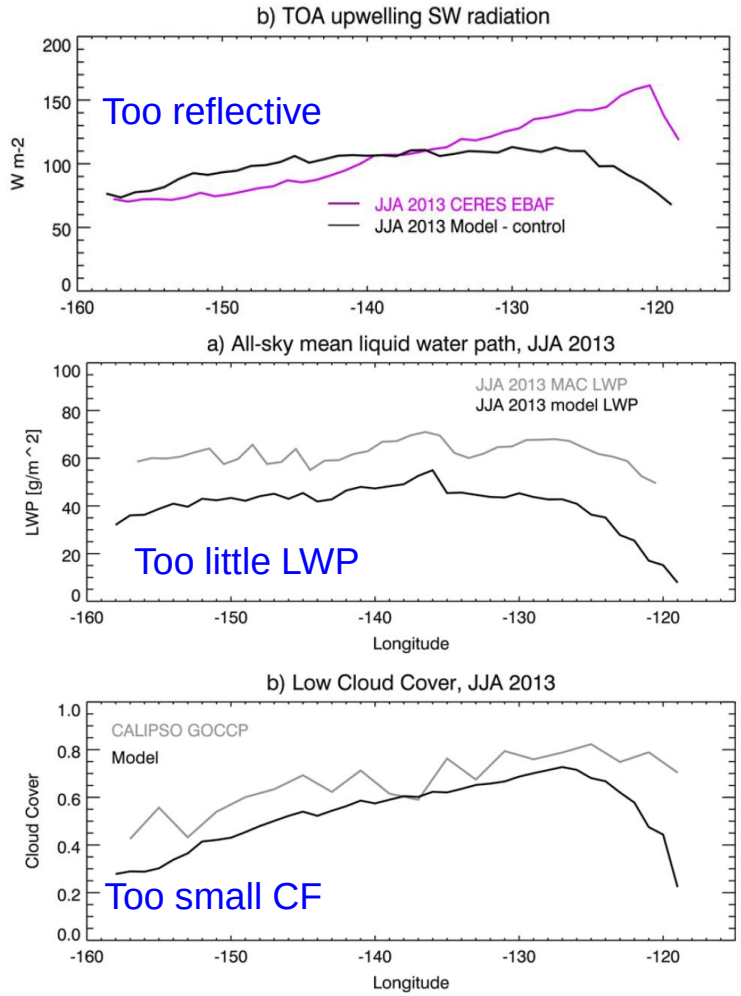
- Observations – ship-following LES simulations – ship-following SCM simulations – 3D model
- Use successful (i.e. reproducing observations) LES to provide benchmark for parameterized quantities (e.g. massflux transport, higher order moments)
- Similar use of CSET / NARVAL campaigns data



Marine boundary layer cloud transitions – The ‘too few - too bright’ problem

MAGIC campaign – from LA to Hawaii along the north Pacific transect



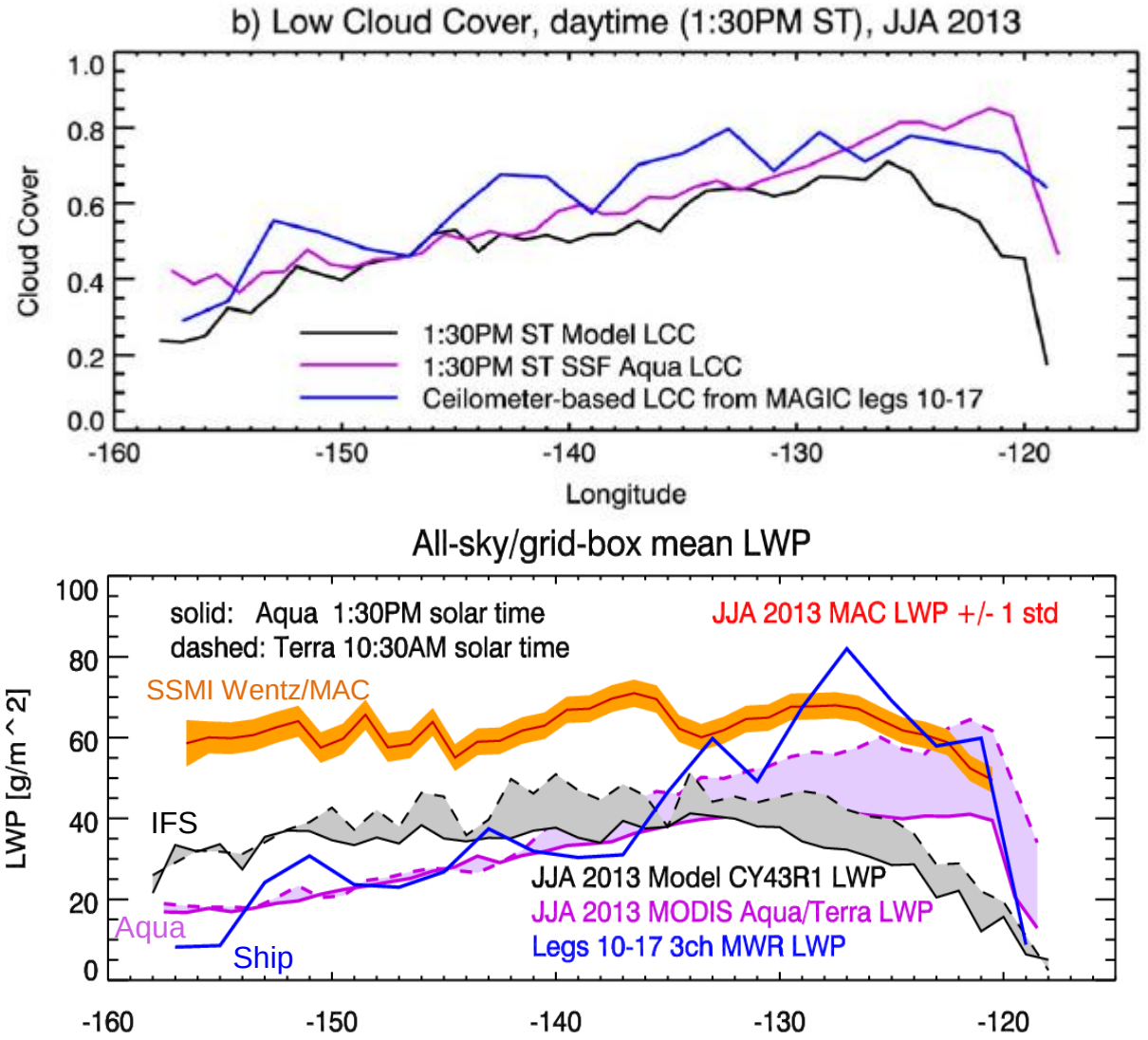


Hawaii - TCu Sc - Los Angeles

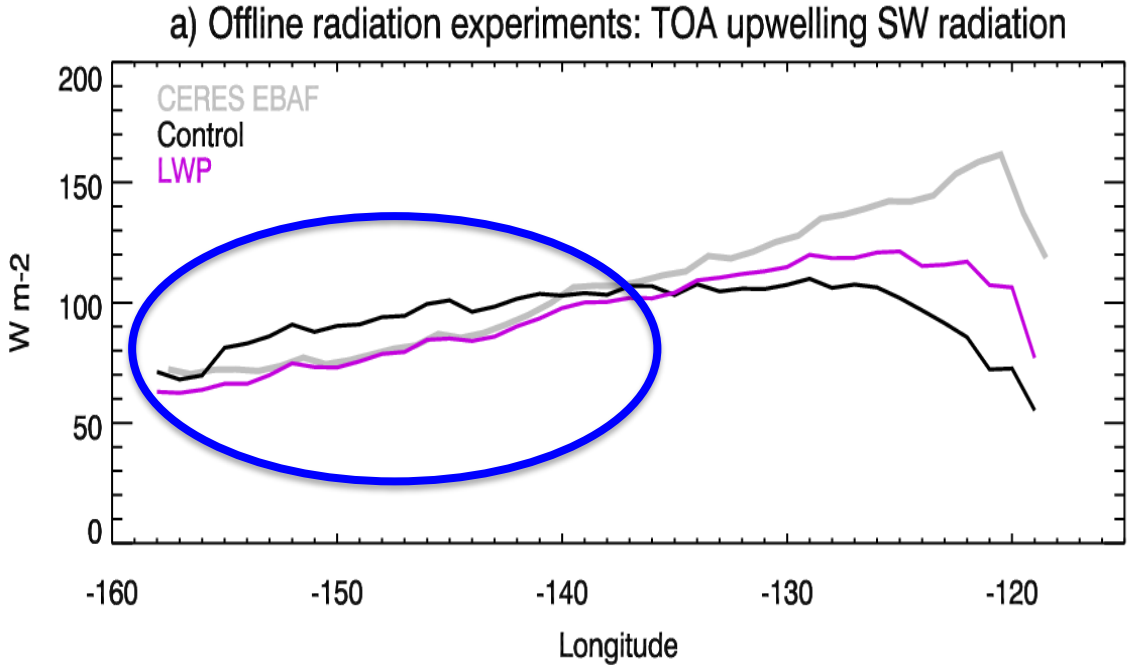
ECMWF

Ahlgrimm et al (2018, JAMES)

Marine boundary layer cloud transitions – The ‘too few - too bright’ problem



Hawaii - TCu Sc - Los Angeles



In fact too bright, but too much LWP
Errors in shortwave driven by errors in LWP

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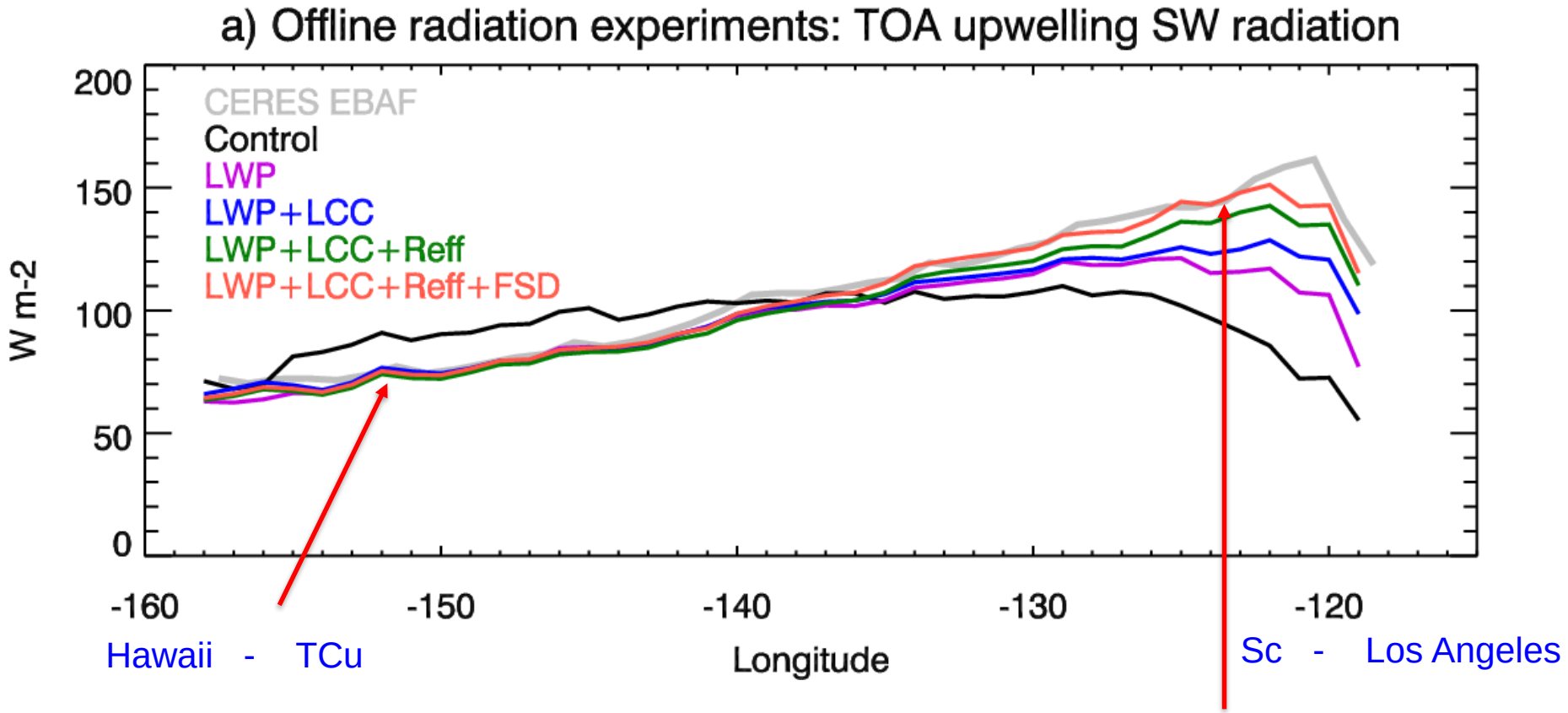
Ahlgrimm et al (2018, JAMES)

Marine boundary layer cloud transitions – The ‘too few - too bright’ problem



Error driven by errors in LWP

Error also due to errors in CF/ effective radius, inhomogeneity

Ahlgrimm et al (2018, JAMES)

Mixed phase clouds: how to maintain supercooled liquid water in the cloud?

OBS

PROG

(36R4 -2010)

DIAG

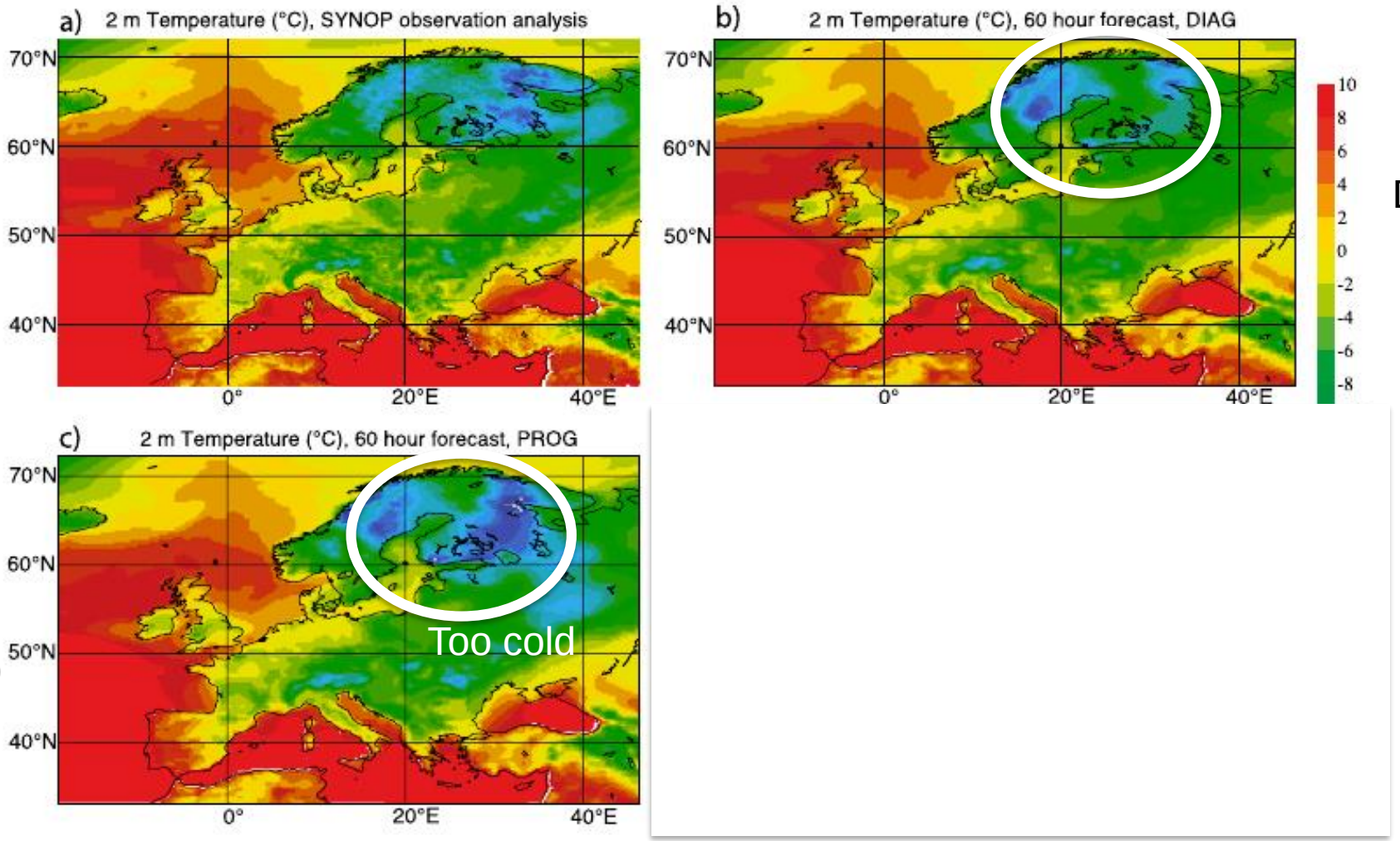


FIG. 10. 2-m temperature (°C) over northern Europe at 0000 UTC 4 Jan 2011 for (a) SYNOP observation analysis, and 60-h forecasts for (b) DIAG simulation, (c) PROG simulation, and (d) PROG+ simulation.

Forbes and Ahlgrimm, 2014.

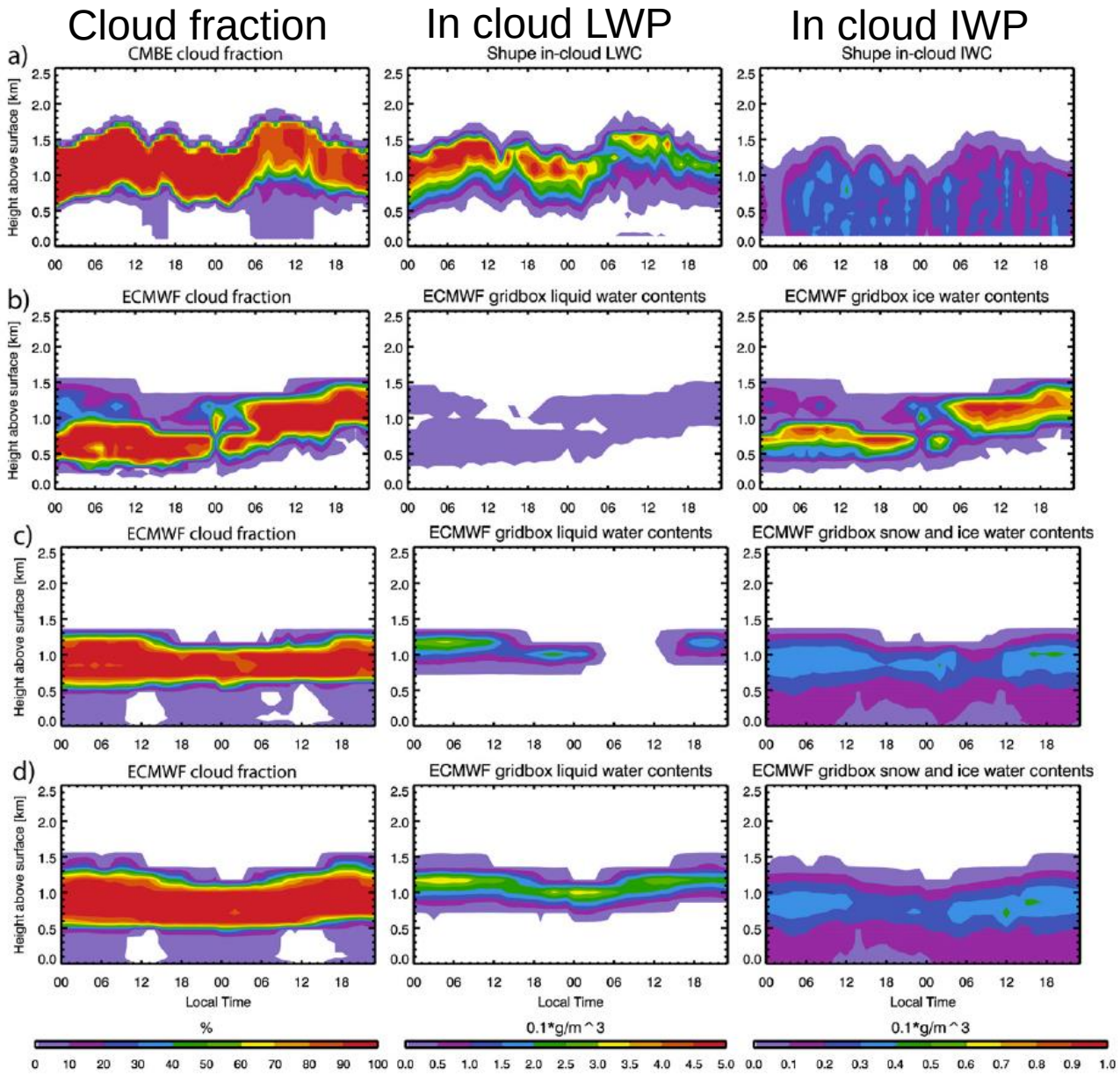
Mixed phase clouds: how to maintain supercooled liquid water in the cloud?

Obs

Diagnostic

Prognostic

Prognostic +



MPACE - 2004

Forbes and Ahlgrimm, 2014.

Mixed phase clouds: how to maintain supercooled liquid water in the cloud?

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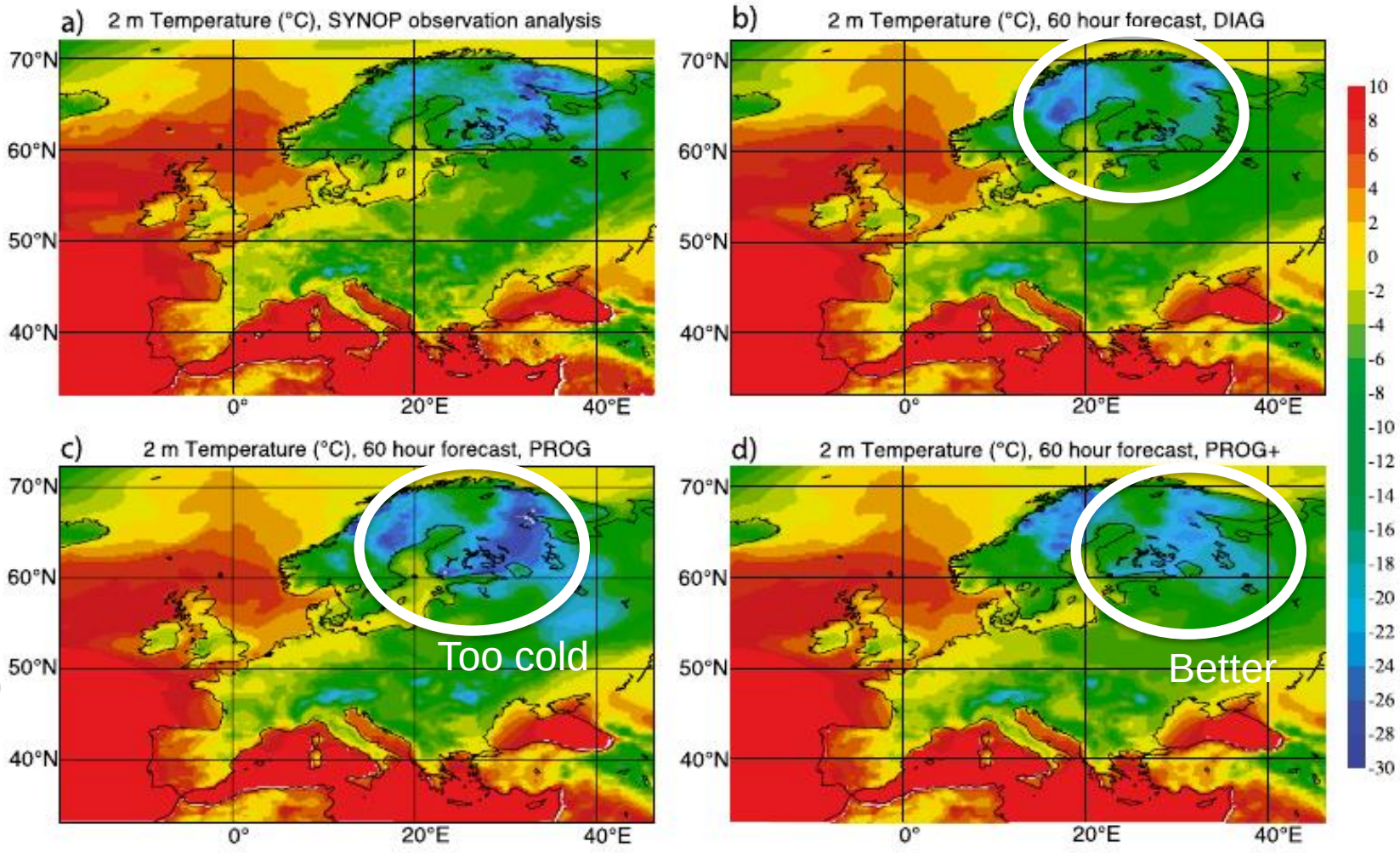

DIAG

PROG+

(37R3 - 2011)

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ECMWF

Forbes and Ahlgrimm, 2014.

A few lessons learned from using ARM/ASR data…..& from physics development at ECMWF

- Helpful to have mature data products (retrievals) with good QC. Very important to convey to modellers how to interpret measured/retrieved variables, and if/when limitations apply e.g. due to weather conditions (Example: LWP in raining conditions). Interaction between observationalists and modellers is key!
- A lot of data still unexplored!
- Balance between “golden days” to study specific processes, and continuous/all-day observations – models need to cope with intermediate weather conditions that are not easily classified
- Short range biases often representative of long range biases: NWP is powerful for disentangling sources of error
- Combined SCM/3D short + long range testing is a very powerful and efficient approach & so is the GCSS/GASS approach (obs – LES – SCM – 3D)