Using ARM data to explore post-cold-frontal clouds and their representation in models

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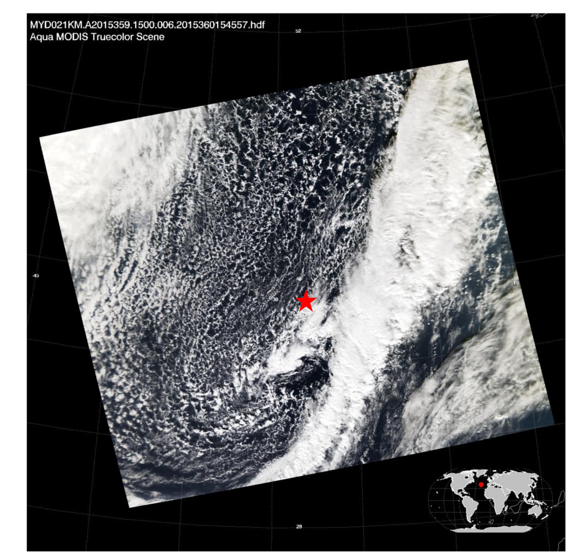
Goal: Improve understanding of cloud physics and atmospheric dynamics interactions in the sector of extratropical cyclones behind the cold fronts

Motivation

- One major issue with GCMs: representation of low level clouds.
- Statrocumulus dominate cloudiness in post-cold frontal clouds => large model bias

Methods

1. Study properties of clouds using ENA + CAP-MBL observations and their dependency on local and large scale conditions. Do the same using MICRE
2. Test configurations of WRF + CAM models to evaluate relative importance of PBL, microphysics and convection for representation of post-cold frontal clouds

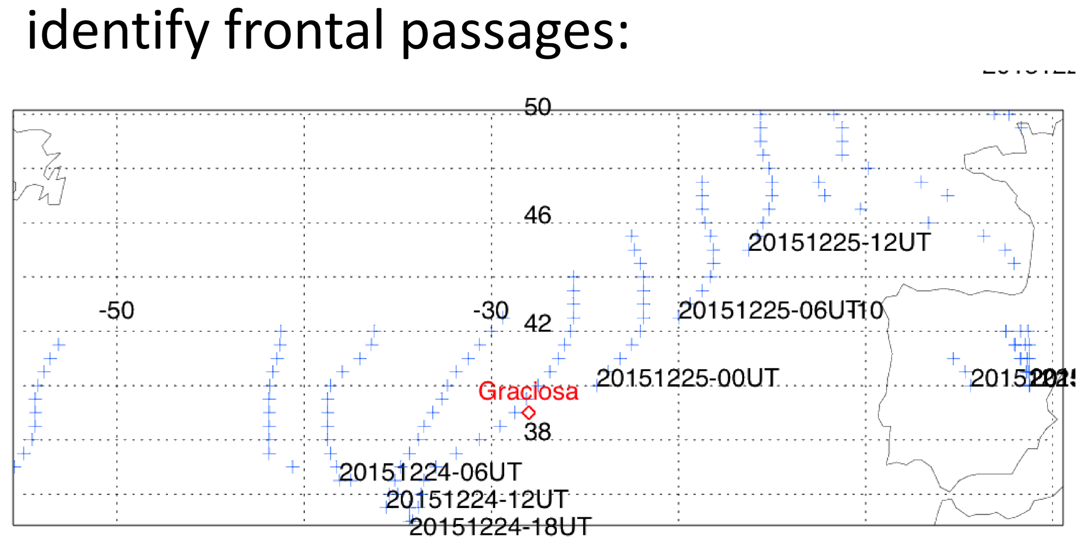


Post cold frontal cloud example. Red dot is ENA Site MODIS-Aqua 2015-12-25 15UT

I. Identify frontal passages during CAP-MBL and since 2013 at ENA:

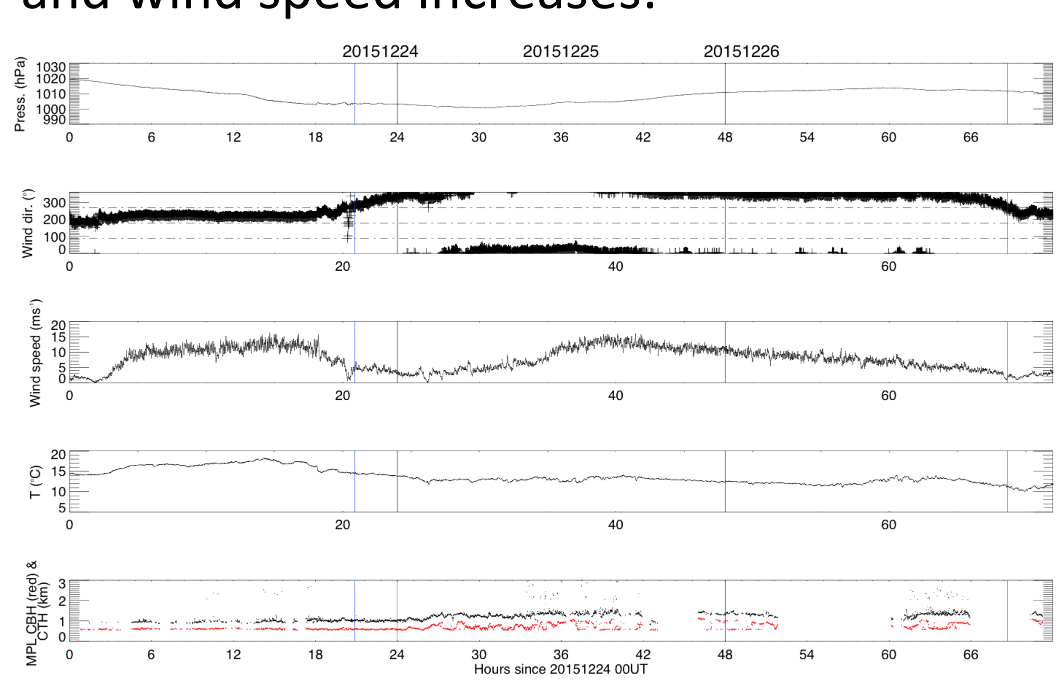
Automated detection:

Condition 1. Use cyclone tracking database (MCMS Bauer et al., 2016) and cold front detection (Naud et al., 2016) to identify frontal passages:



Example of automated front detection over Graciosa around 2015-12-25

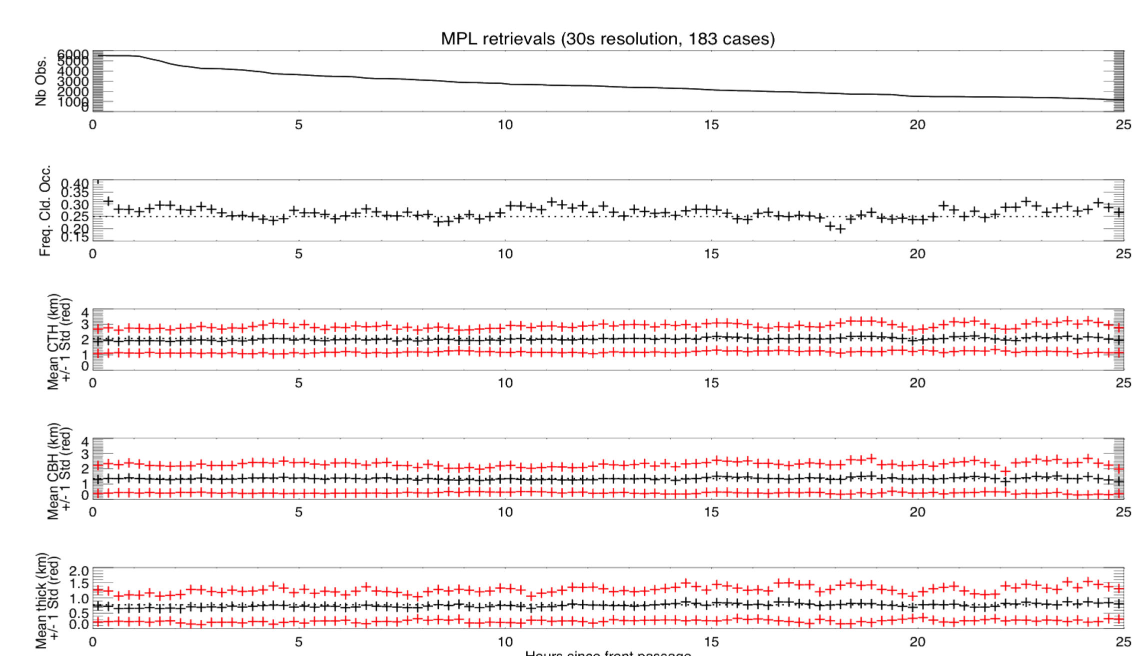
Condition 2. Use ground-based wind measurements: frontal passage if wind direction jumps from southerly to northerly and wind speed increases:



Time series of ENA meteorological observations for the 2015-12-25 case

For entire period: 32 "golden" cases, and 80 potential cases.

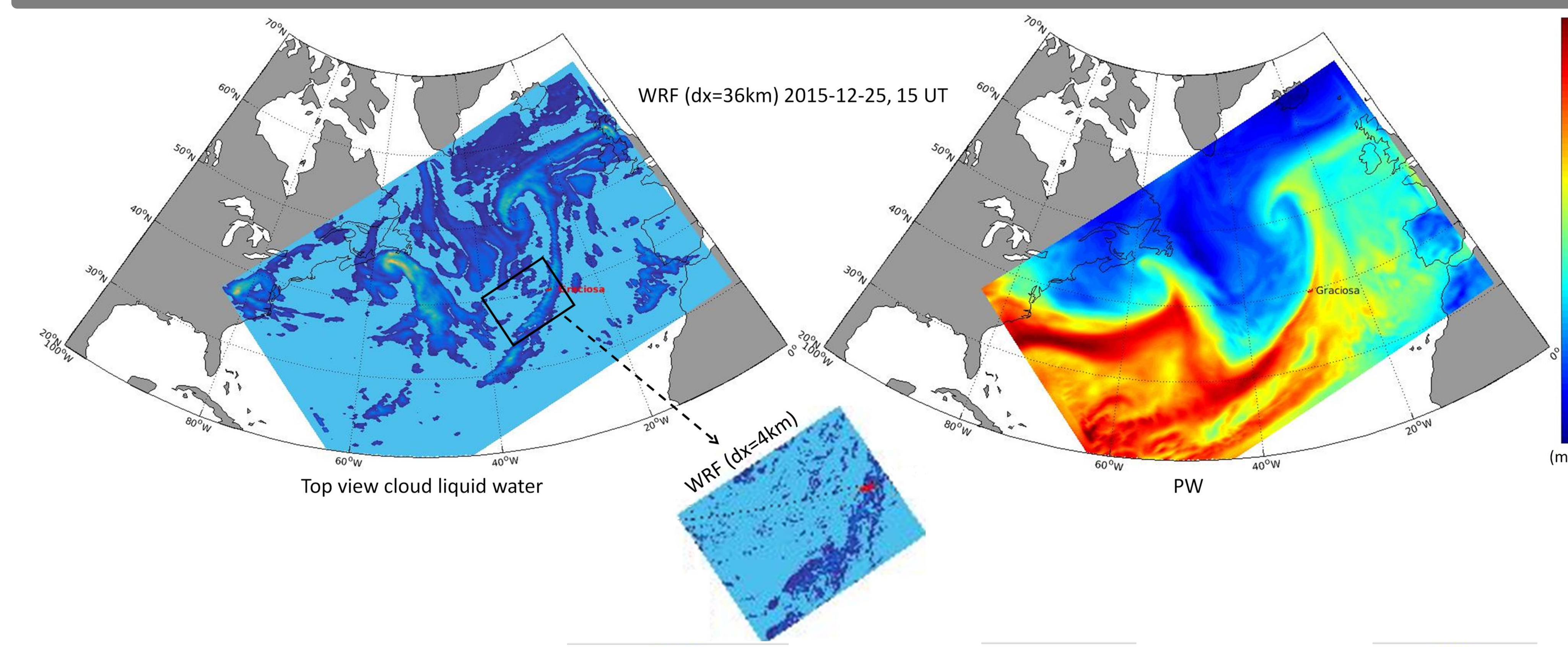
2. Statistical analysis of cloud properties



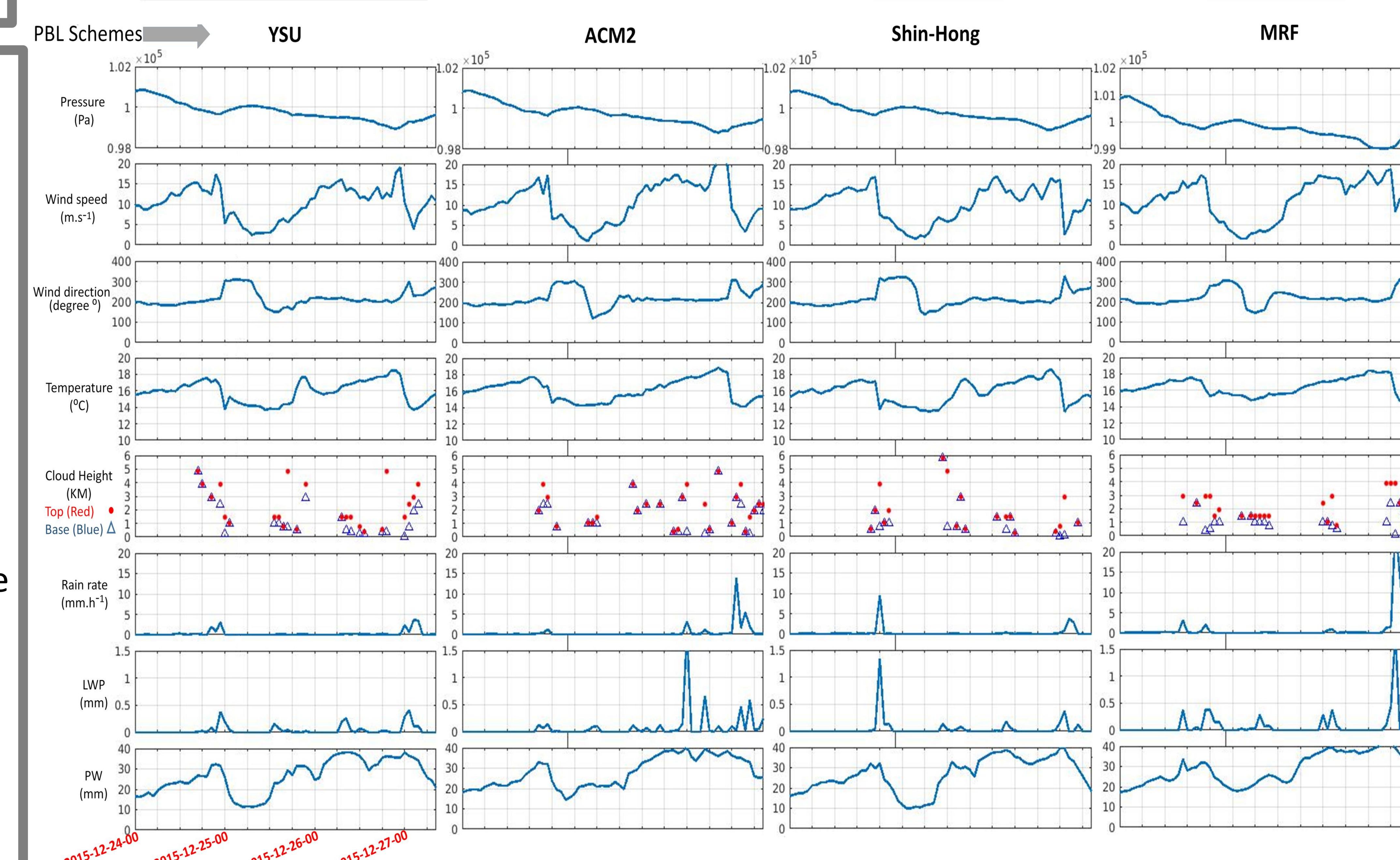
MPL retrievals of cloud boundary: 15 min average from time of frontal passage until wind turns southerly- Red: ± 1 Std. Dev.

Dong et al. PI product during CAP-MBL

3. Case study: WRF simulations for 2015-12-25



YSU *Hong et al. (2006)*	**ACM2** *Pleim (2007)*	**Shin-Hong** Shin and Hong (2015)	**MRF** *Hong and Pan (1996)*
• nonlocal • First-order closure • Depth of PBL determined from thermal profile • Explicit representation of entrainment at the top of the PBL	• Hybrid (local &–nonlocal) • First-order closure • Upward fluxes -> represented as interactions between the surface layer and each and every layer above (with local eddy diffusion also included) • Downward fluxes-> extend from each layer to each immediately underlying layer	• Scale-aware non-local PBL scheme • Nonlocal transport via strong updrafts and local transport via the remaining small-scale eddies are separately calculated • More robust for gray zone runs	• nonlocal • First-order closure; incorporates a countergradient correction term into downgradient diffusion expressed by local mixing
• More accurately simulates deeper vertical mixing in buoyancy-driven PBLs with shallower mixing in strong-wind regimes compared to MRF	• The profile of potential temperature and velocity through the PBL are depicted with greater accuracy.		• Simulates accurately the deeper mixing within an unstable PBL where larger eddies entrain higher potential temperatures above the PBL into the PBL
• Overdeepens the PBL for springtime deep convective environments, resulting in too much dry air near the surface and underestimation of MLCAPE related to environments of deep convection	• Too-deep PBLs represented by ACM2		• Too deep PBL, especially in strong-wind regimes at night; too deep of mixing results in overerosion of convective initiation



Conclusions:

1. Cloud properties on average fairly stable during entire post-cold frontal (PCF) region: very scattered, 1km or less thick, below 2 km.
2. Largest differences occur when comparing different products.
3. WRF simulations (dx=4km) Vs Observation (Graciosa Island – ENA site):
   3.1. Delayed detection and shorter duration of cold front passage.
   3.2. The frequency of PCF clouds is slightly higher with MRF compared to other PBL schemes.
   3.3. PCF clouds are mainly non-precipitating convective shallow cumulus.