MOLECULAR PROFILES AT THE CTA SITES

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THE CURRENT MODEL

- MAGIC Winter (MW) model, based on NRLMSISE-00 data:
  - Diploma thesis, written in German, from Marijke Haffke who left MAGIC right afterwards.
  - Tabulated densities used in CORSIKA
  - Fitted integrated optical depth ("thickness") used in reflector.
  - Studied mainly the atmospheric extinction while the location of the shower maximum, together with the opening of the Cherenkov cone at that position, are much more important.
  - NRLMSISE-00 is not the best model for the troposphere (they say it themselves on their webpage!).

THE MOLECULAR PROFILE

- Has effects on size of Cherenkov light pool (via shower altitude and Cherenkov angle) and transmission of Cherenkov light
- Optical transmission, i.e. integrated density from the emission point to the ground, has an approximately linear effect on E_{rec}
- E_{rec} scales approximately with central light density:

  $\rho_c \approx (h_{med} - h_{obs})^{-2}$

  because of the modulation of the Cherenkov angle and median shower height (h_{med}) (Bernlöhr, Astrop. Phys. 12 (2000), 255)
- A_{eff} more complicated, needs simulations

THE MOLECULAR PROFILE

- We have excellent Data Assimilation models for La Palma and for Chile (for free) for temperature and pressure (and hence, density):
- The NRLMSISE-00 model for 20 to 100 km a.s.l. (MW based on it)
  - http://ccmc.gsfc.nasa.gov/modelweb/atmos/nrlmsise00.html
- Global Data Assimilation System (GDAS) from ground to 25 km a.s.l.
  - ftp://arlftp.arlhq.noaa.gov/pub/archives/gdas1/
- The ECMWF has been tested by INFN Torino with very encouraging results
  - http://weather.unisys.com/ecmwf/index.php
- The IG2 model has been tested as well, but does not agree well at these altitude ranges (at least for temperature).
- The WRF model (based on GDAS). We will look into it in the near future

CHECKS ON THE NRLMSISE-00 MODEL

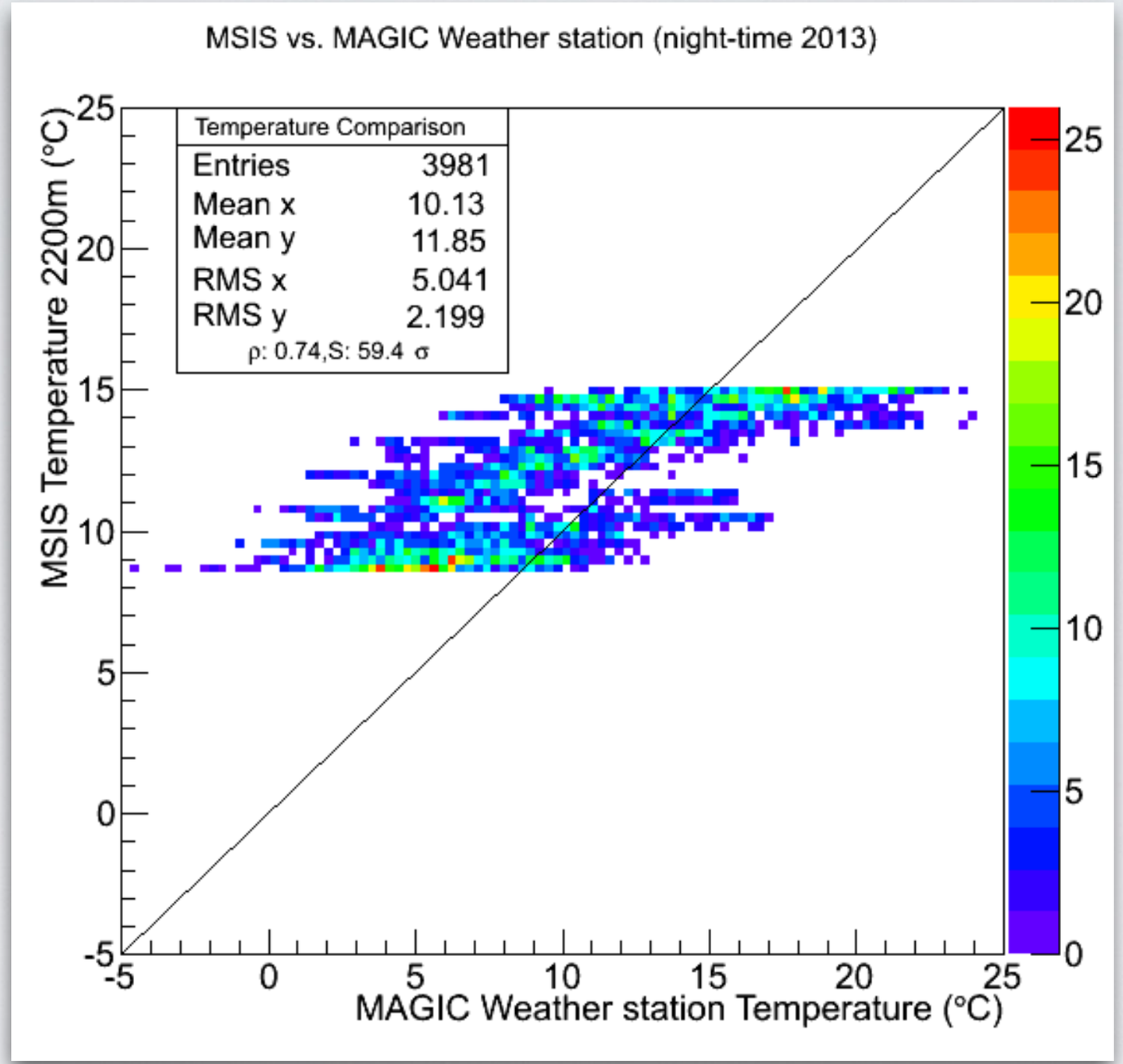
- The NRLMSISE-00 models can be downloaded from the web: http://ccmc.gsfc.nasa.gov/modelweb/atmos/nrlmsise00.html

- They provide data below 20 km, but are not reliable

- It can be read in Mars with the class MSISFileRead

- The output will be stored in tree with branches of type MSISEntry

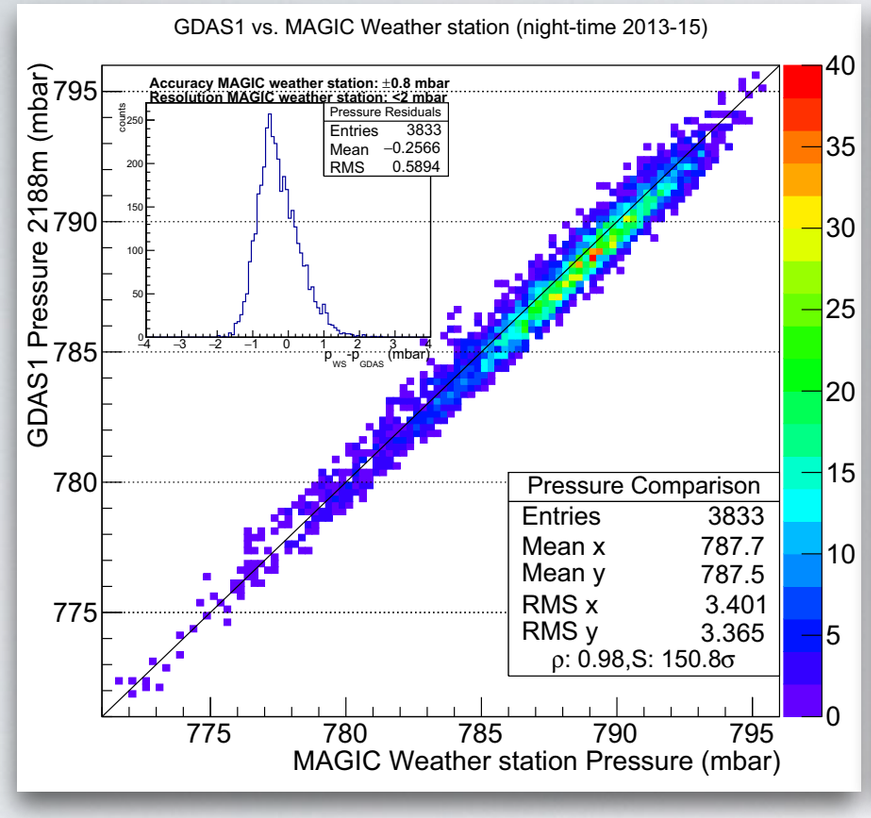
CORRELATION OF MAGIC TEMPERATURE WITH NRLMSISE-00 TEMPERATURE

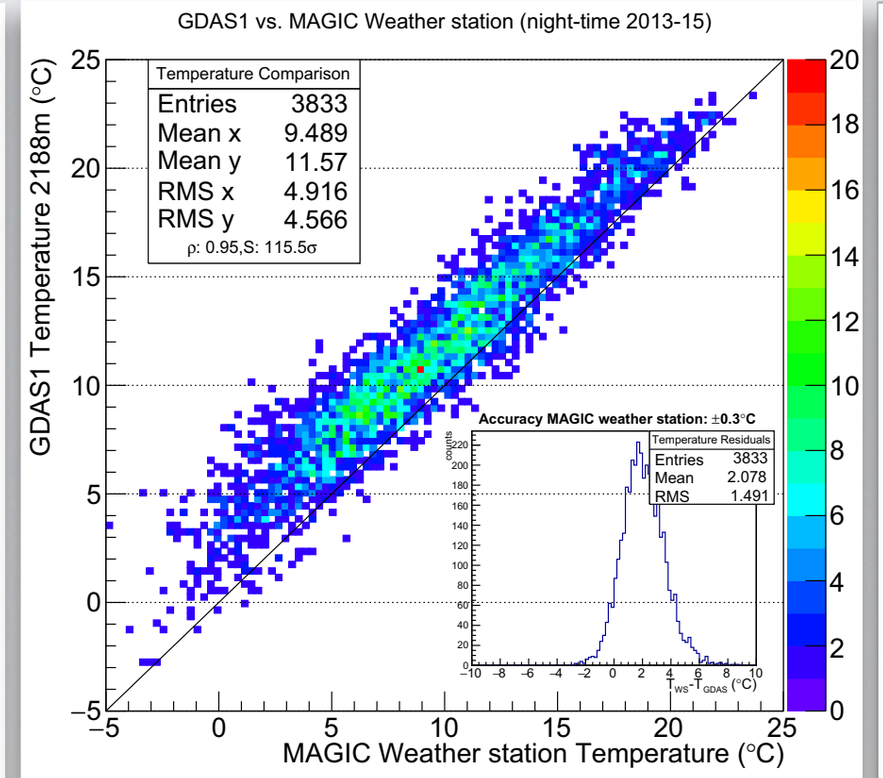


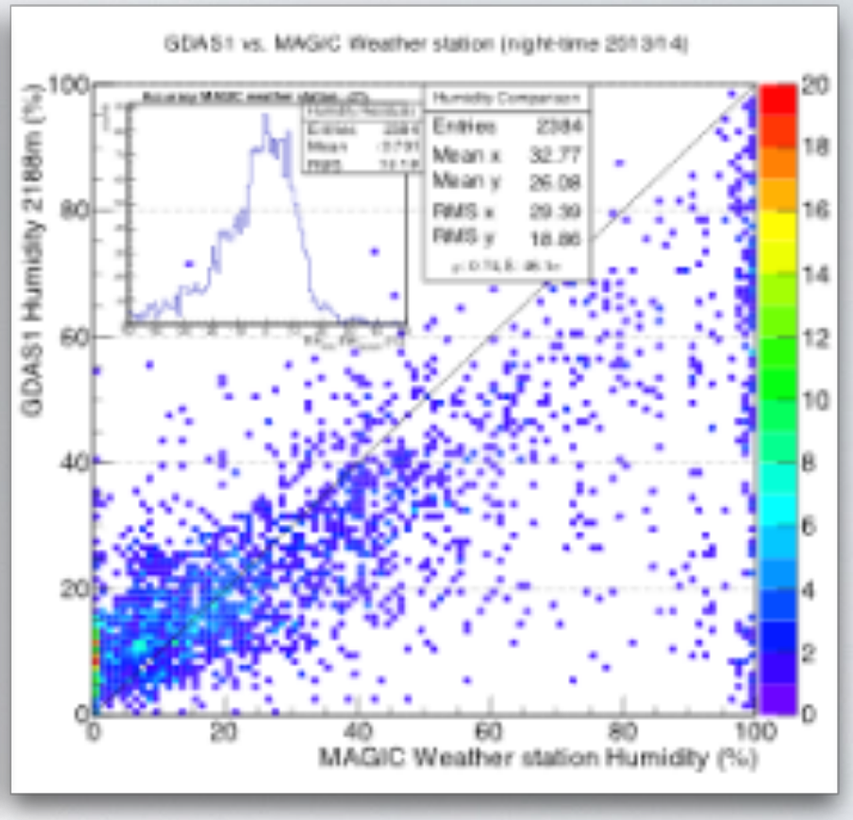
CHECKS ON THE GDAS MODEL

- The GDAS models can be downloaded from the web:
  ftp://arlftp.arlhq.noaa.gov/pub/archives/gdas1/
- Downloading all data means about 2.4 GB per month
- A fortran code then allows to pick the corresponding grid point (on a 1° grid)
- Model goes from 0 to 25 km only (MW up to 40 km) with 24 pressure levels
- GDAS files can be read in Mars with the class MGDASFileRead
- Output will be stored in tree with branches of type MGDASEntry

CORRELATION OF THE MAGIC WEATHER STATION DATA WITH GDAS







Gaug et al (2016)

Cross-correlation with MAGIC weather station

- GDAS combined with NRLMSISE-00 (above 25km)
- Perfect match for pressure comparison
- Systematic shift for temperatures can be explained by local ground effects (inverse for day-time data)
- Even correlation for humidity is good (difficult because of very local variation)

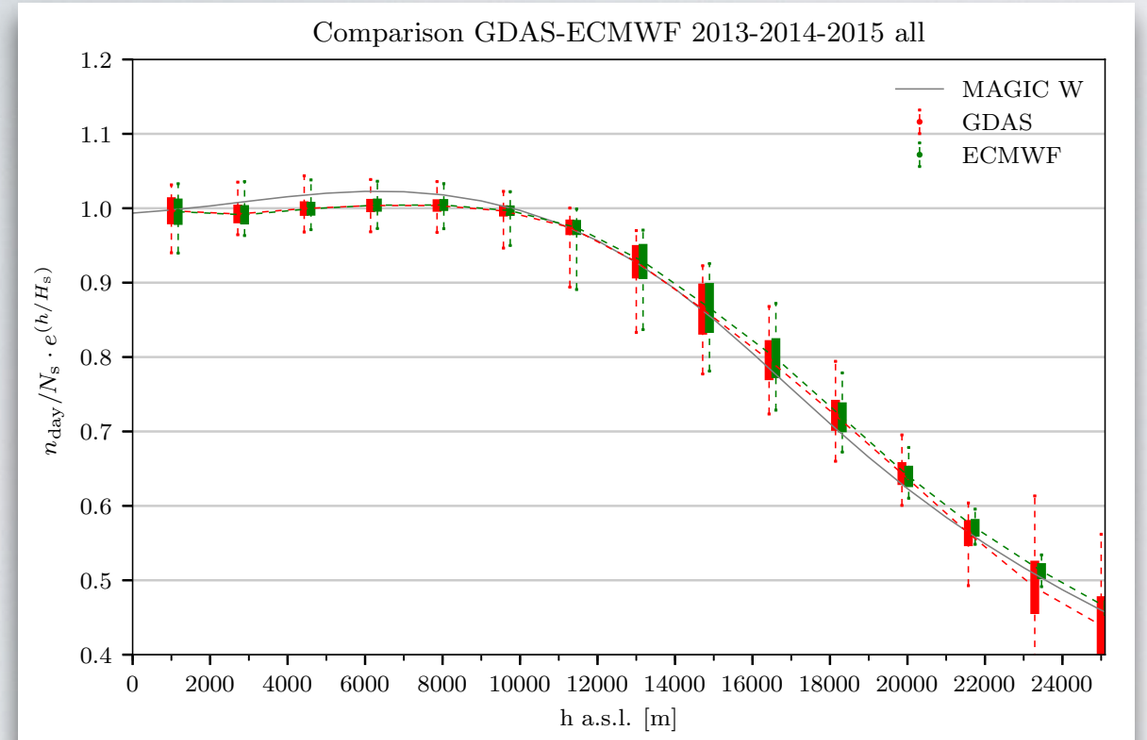
CHECKS ON THE ECMWF MODEL

- The ECMWF ERA Interim data can be downloaded from:
  - https://www.ecmwf.int/en/research/climate-reanalysis/era-interim
- Registration on ECMWF needed
- The web server allows to pick the corresponding grid point (on a 0.75° grid)
- Downloading, once selected for La Palma or Chile site, means about 200 Mb per year
- Model goes from 0 to 50 km with 37 pressure levels and many parameters available (wind dir., rel. humidity, vorticity…)
- ECMWF files read with a python code using pygrib (quite slow to read for yearly data files!)
  - Grib files need to be read just once.

CHECKS ON THE MODELS

- North site
  - Compared GDAS and ECMWF
    - with the MW model
    - between them
- South site
  - Compared MW and ECMWF
- Compared North and South sites density at 15 km a.s.l.

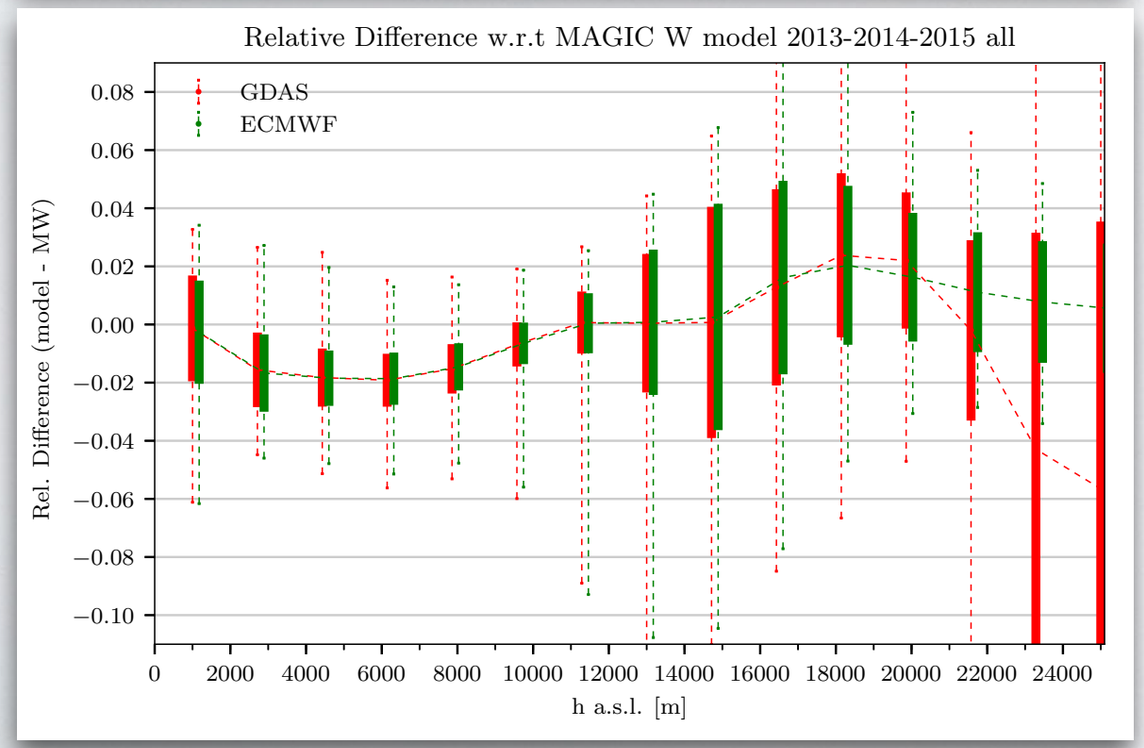
GDAS vs ECMWF (NORTH SITE)

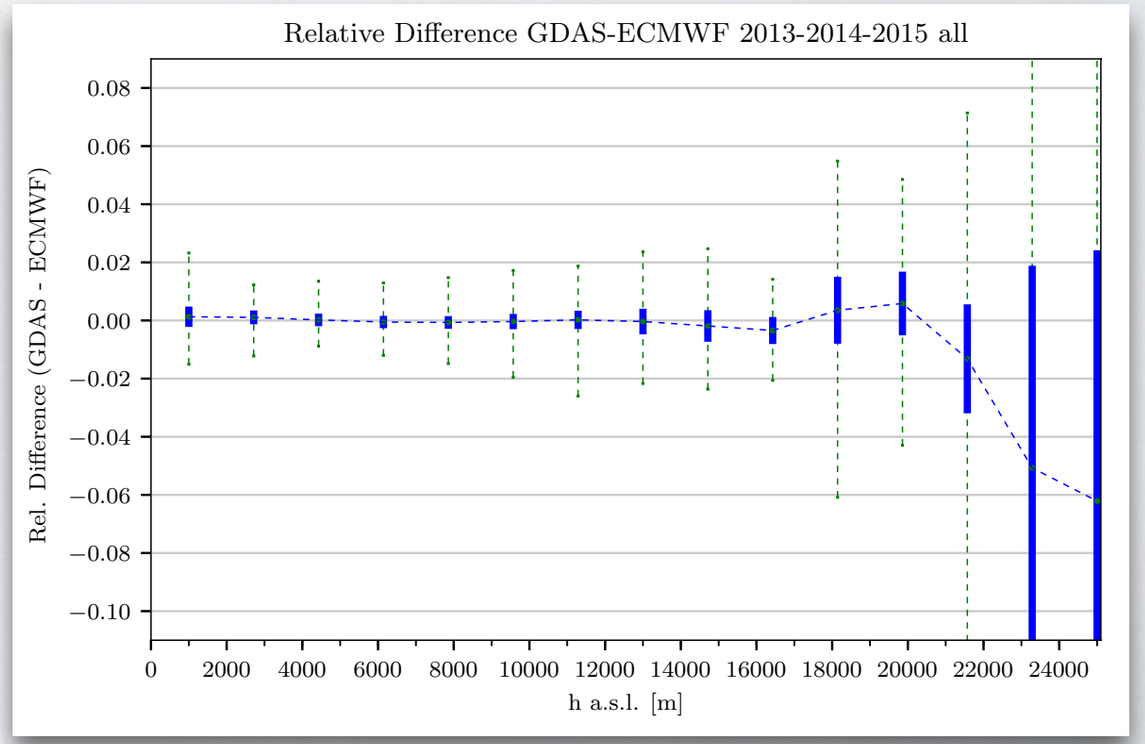


2013 - 2014 - 2015 data

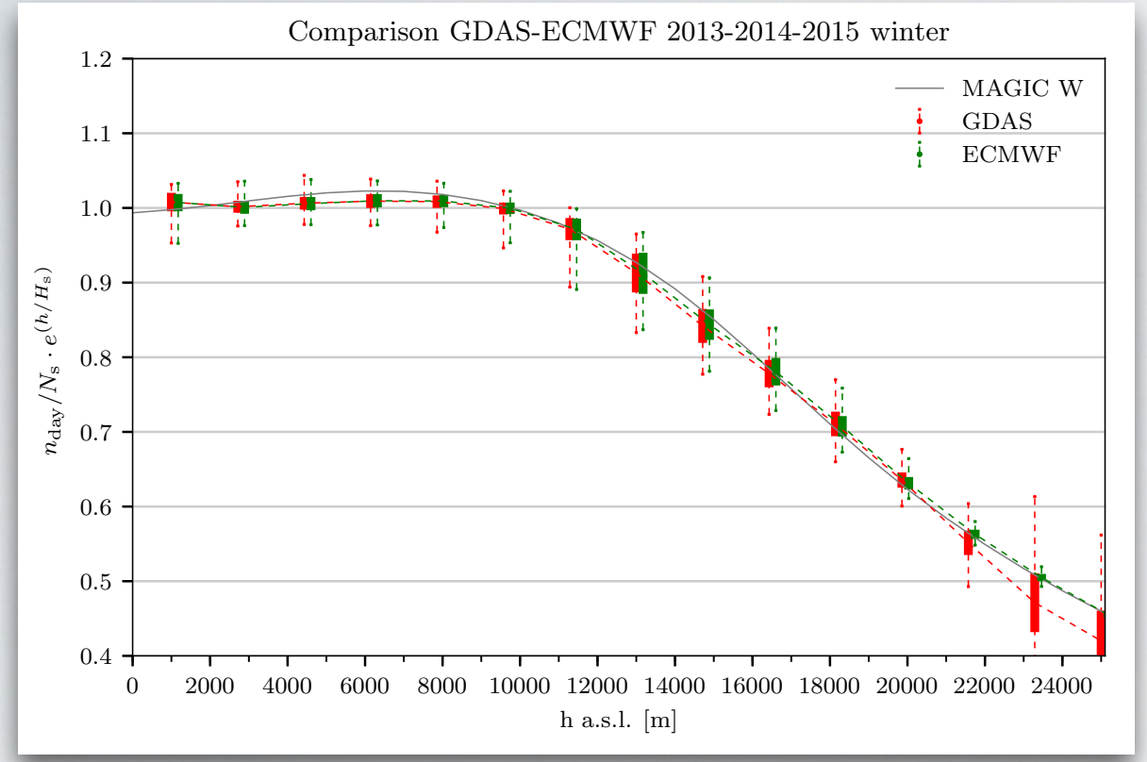
All months

Compared to MW model





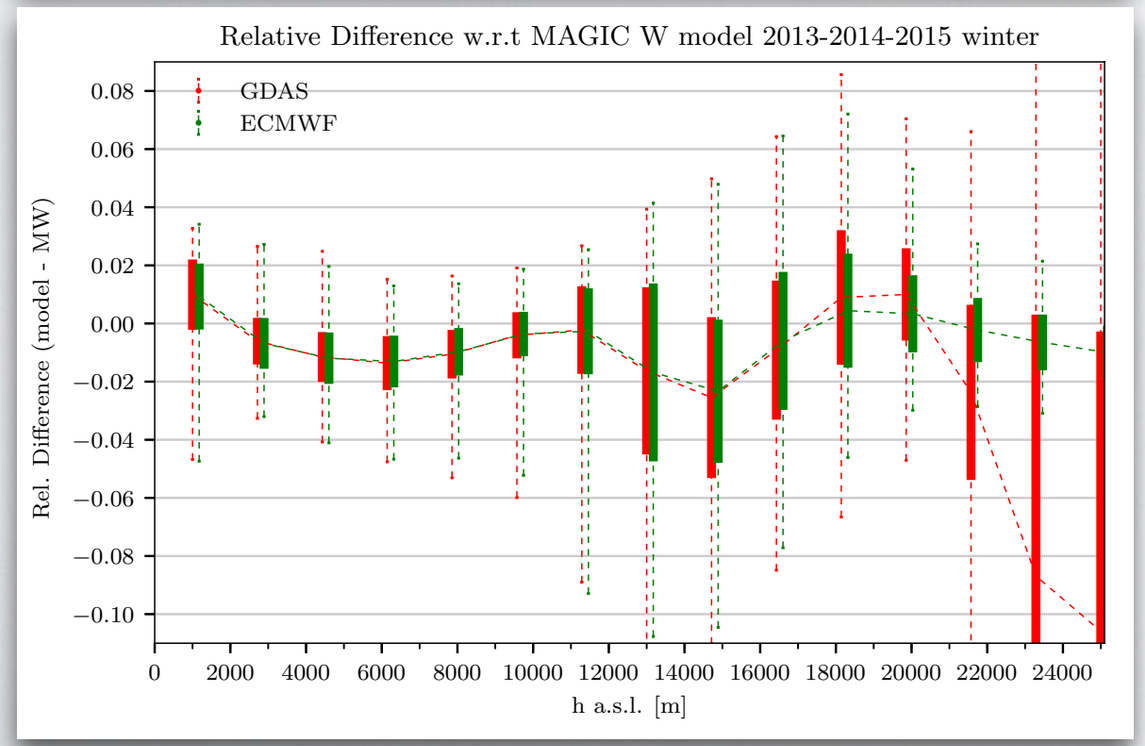
GDAS vs ECMWF (NORTH SITE)

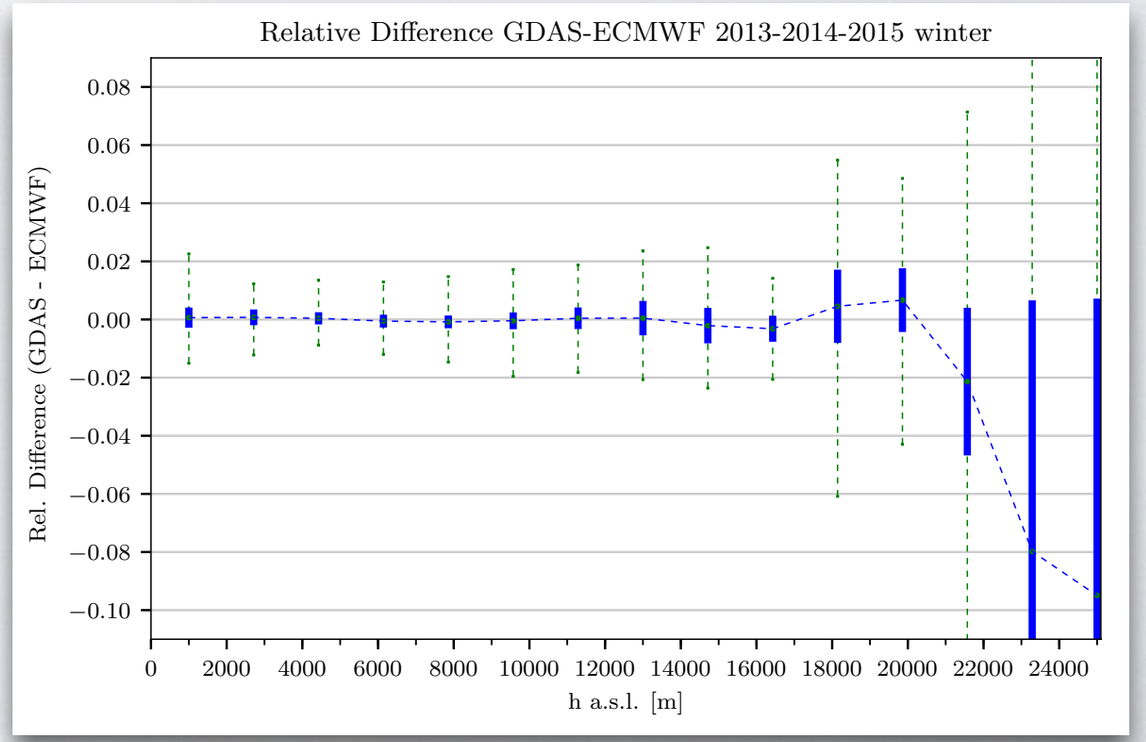


2013 - 2014 - 2015 data

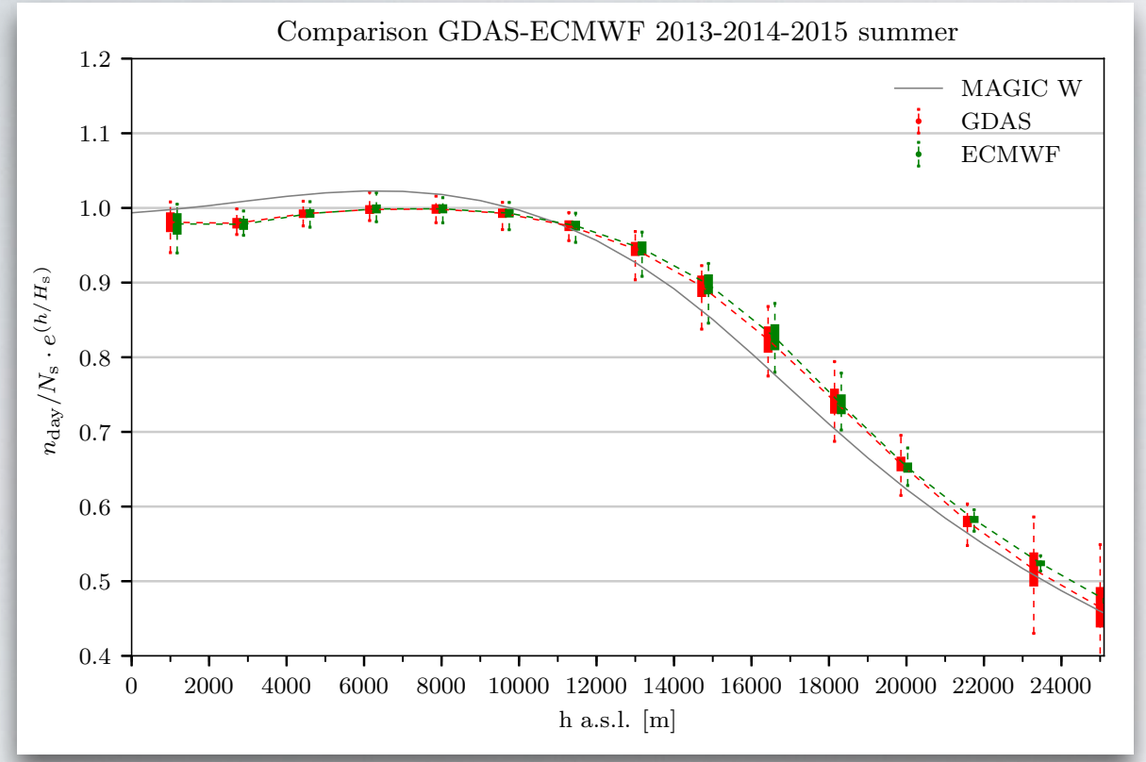
Winter (Dec, Jan, Feb, Mar, Apr)

Compared to MW model





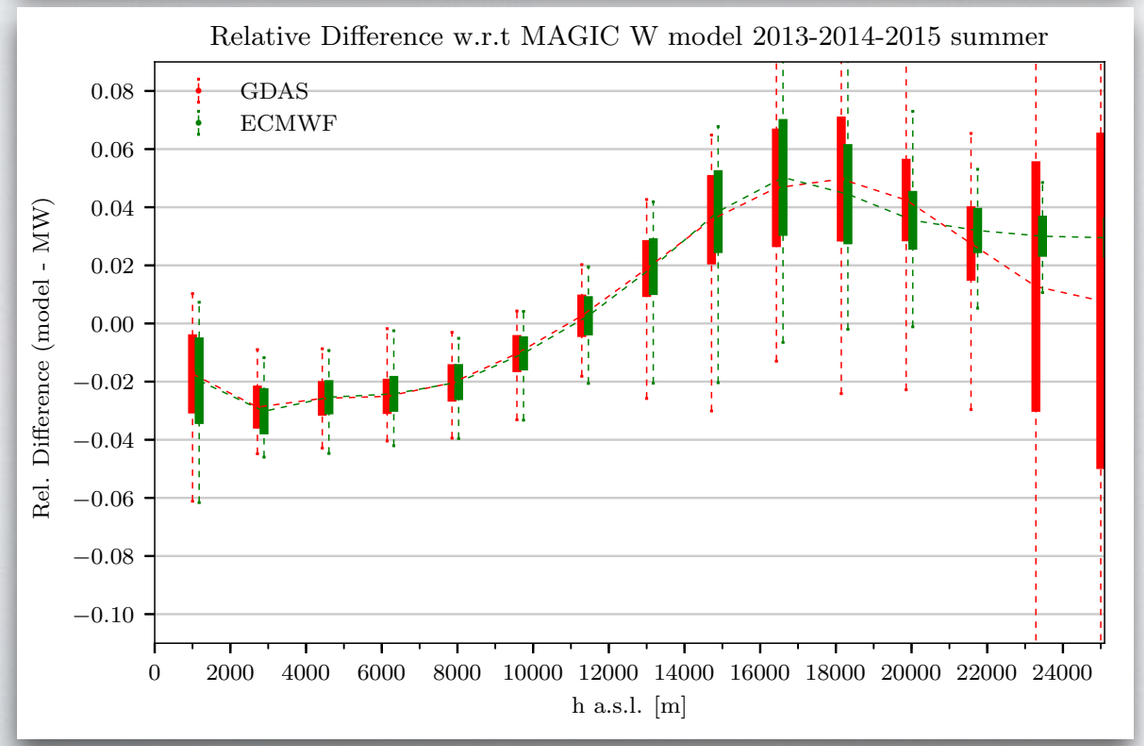
GDAS vs ECMWF (NORTH SITE)

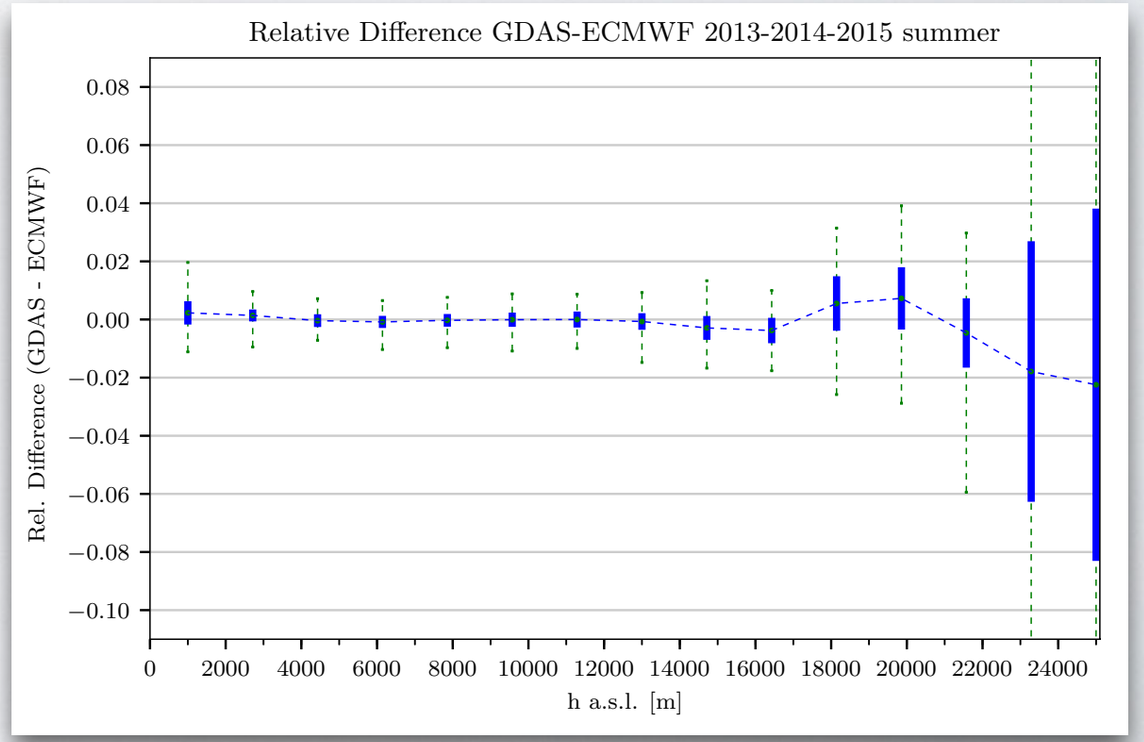


2013 - 2014 - 2015 data

Summer (Jul, Aug, Sep)

Compared to MW model



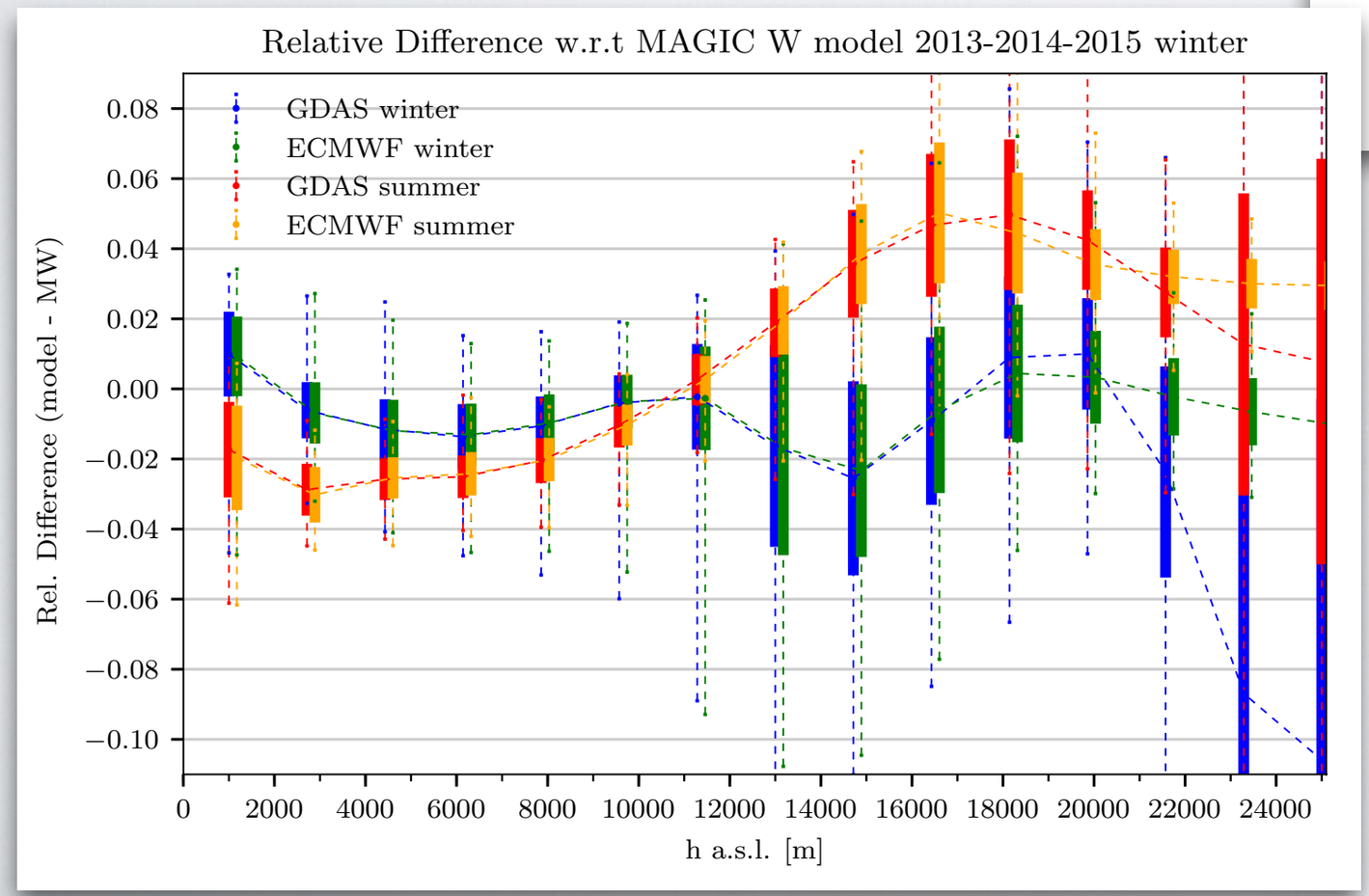


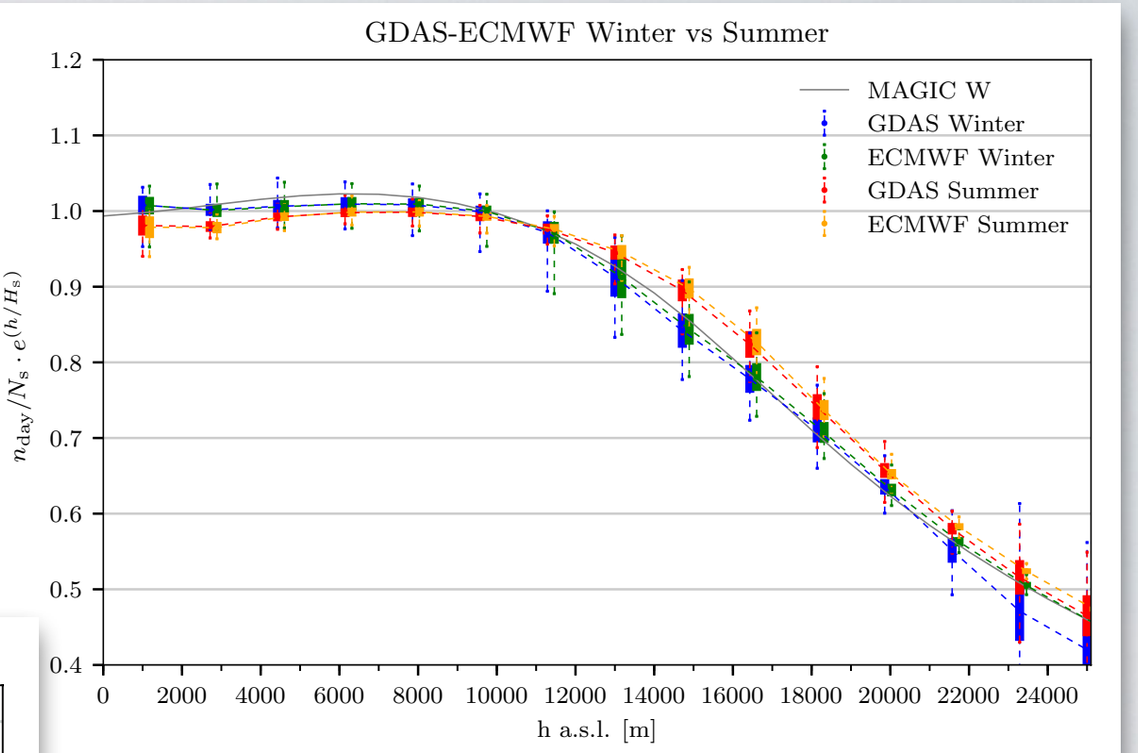
GDAS vs ECMWF (NORTH SITE)

2013 - 2014 - 2015 data

Winter vs Summer

Compared to MW model

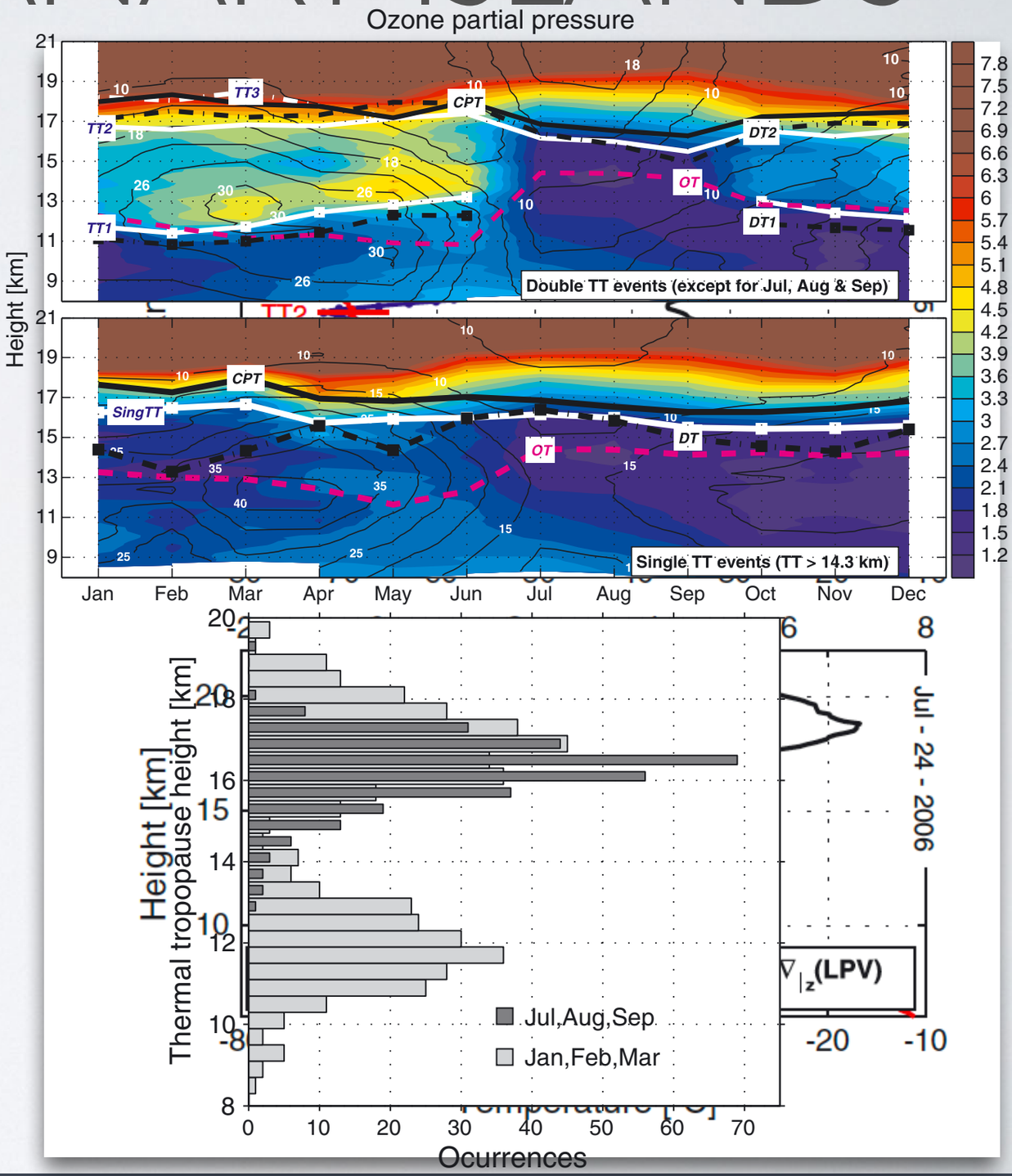




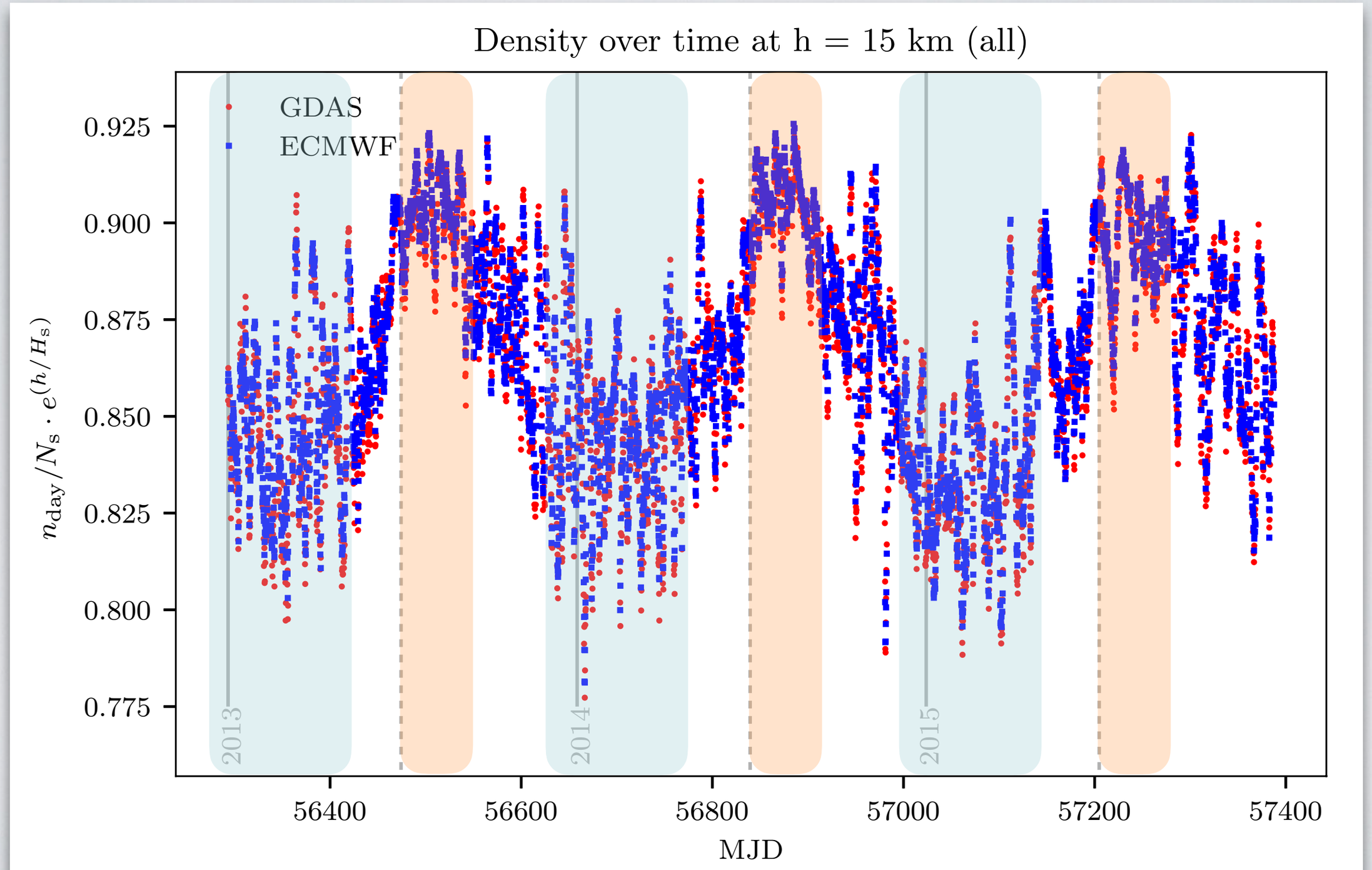
THE COMPLICATED TROPOPAUSE ABOVE THE CANARY ISLANDS

- Winter tropopause (DEC,JAN,FEB,MAR, APR) characterized by multiple thermal tropopauses, which are several kilometers thick and can reach extremely high altitudes of up to 20 km a.s.l..
- Influenced by the sub-tropical jet stream (STJ) centered at lower latitudes.
- The Summer tropopause (JUL,AUG,SEP) is characterized by only one thermal tropopause, typical for a tropical upper troposphere, with the STJ having moved northwards of the Canary Islands.
- Intermediate months (MAY,JUN,OCT, NOV) show transition behavior between both scenarios.

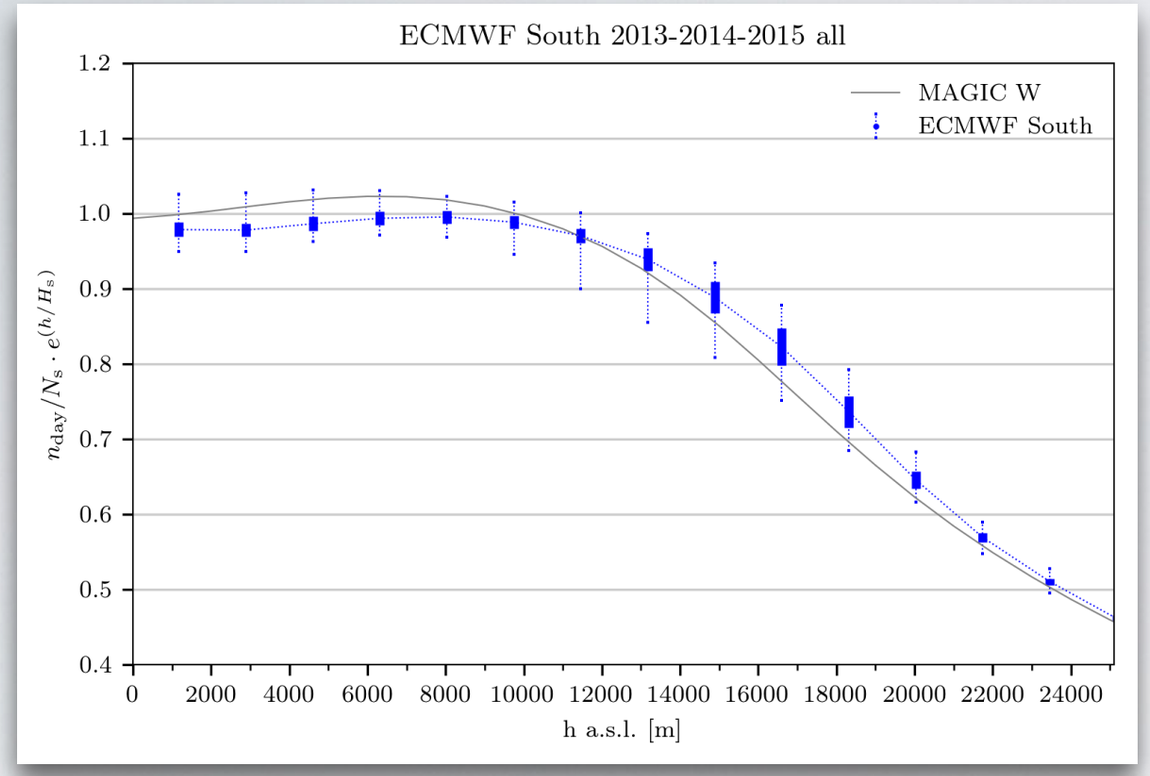
- J. J. Rodriguez-Franco & E. Cuevas,. J. Geophys. Res.: Atmospheres 118 (19) 10754 (2013)

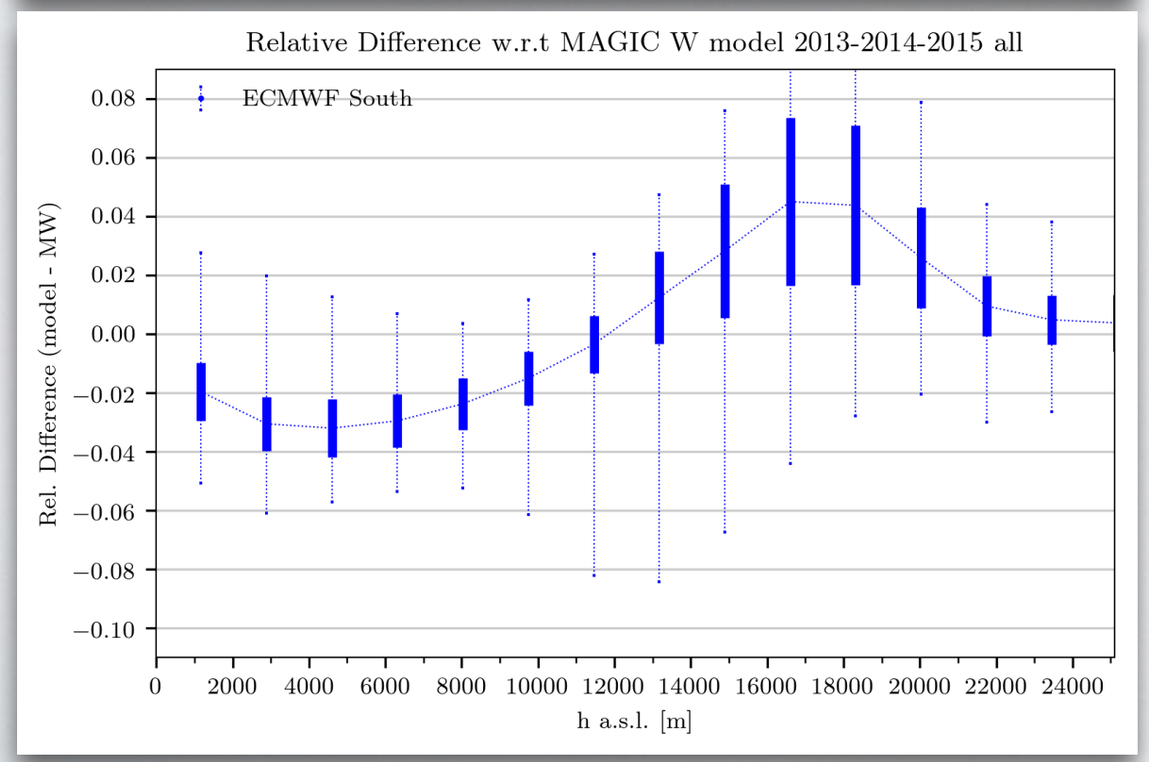


GDAS vs ECMWF (NORTH SITE)



ECMWF (SOUTH SITE)



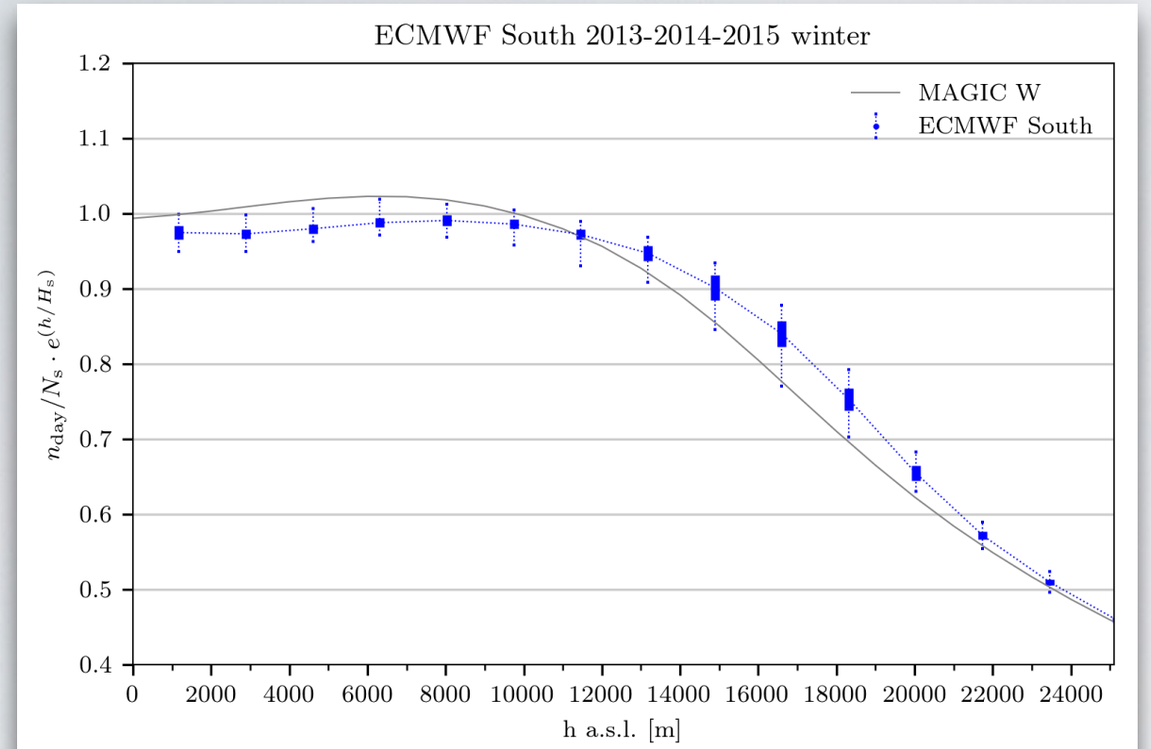


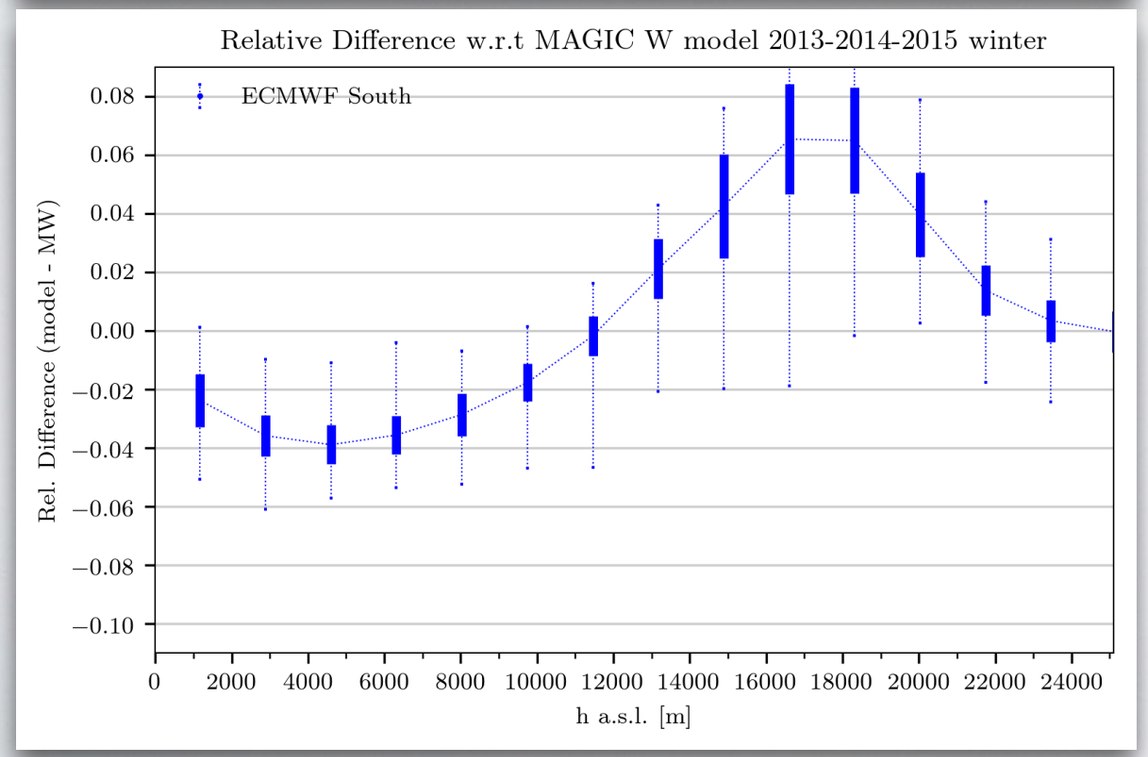
2013 - 2014 - 2015 data

All months

Compared to MW model

ECMWF (SOUTH SITE)



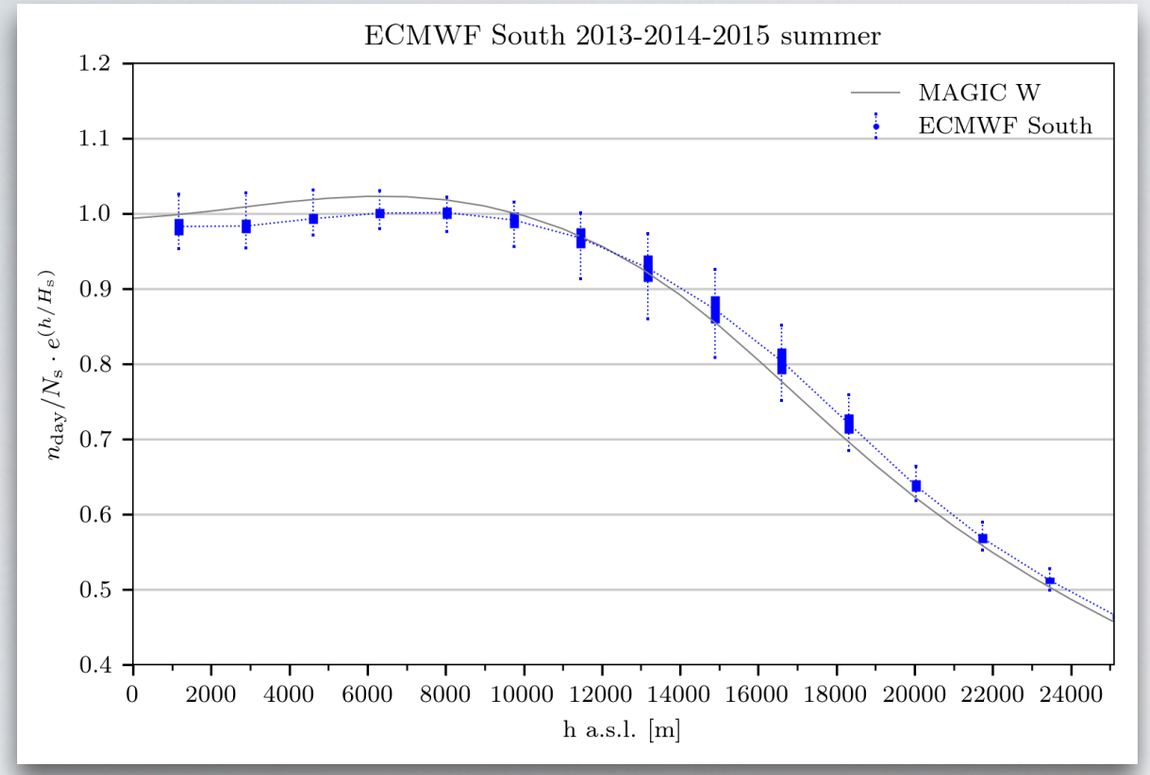


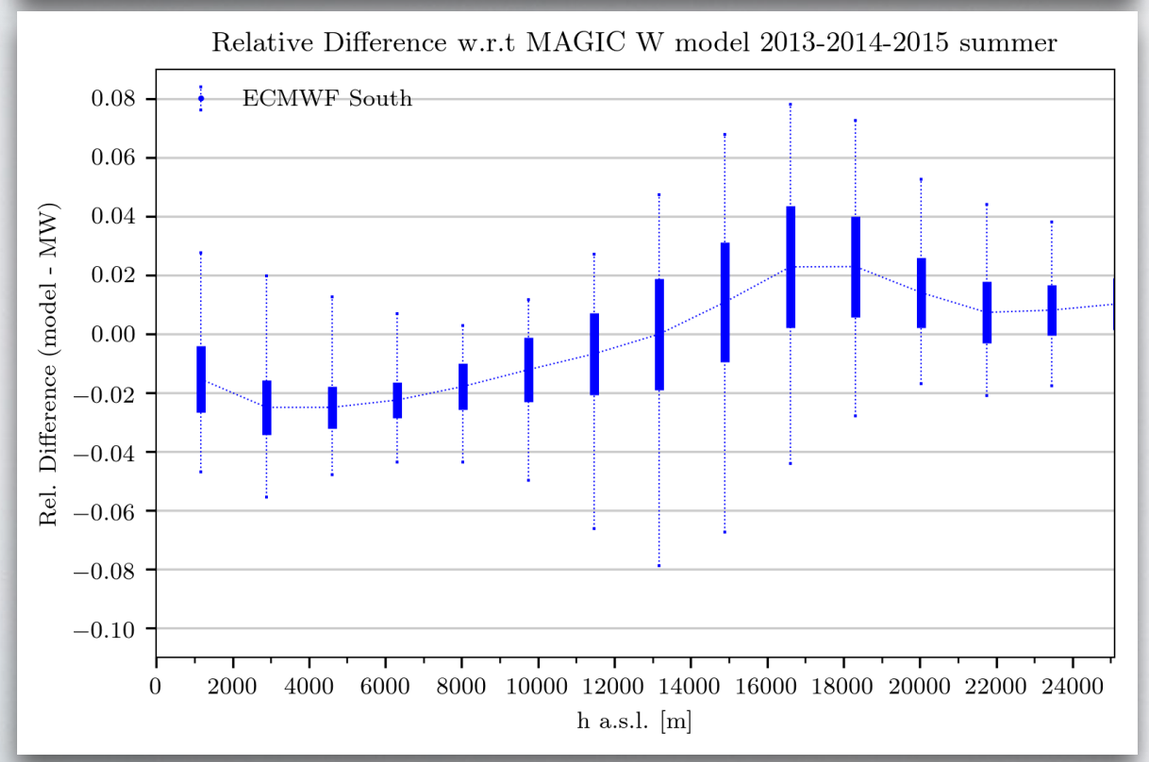
2013 - 2014 - 2015 data

Summer south months

Compared to MW model

ECMWF (SOUTH SITE)



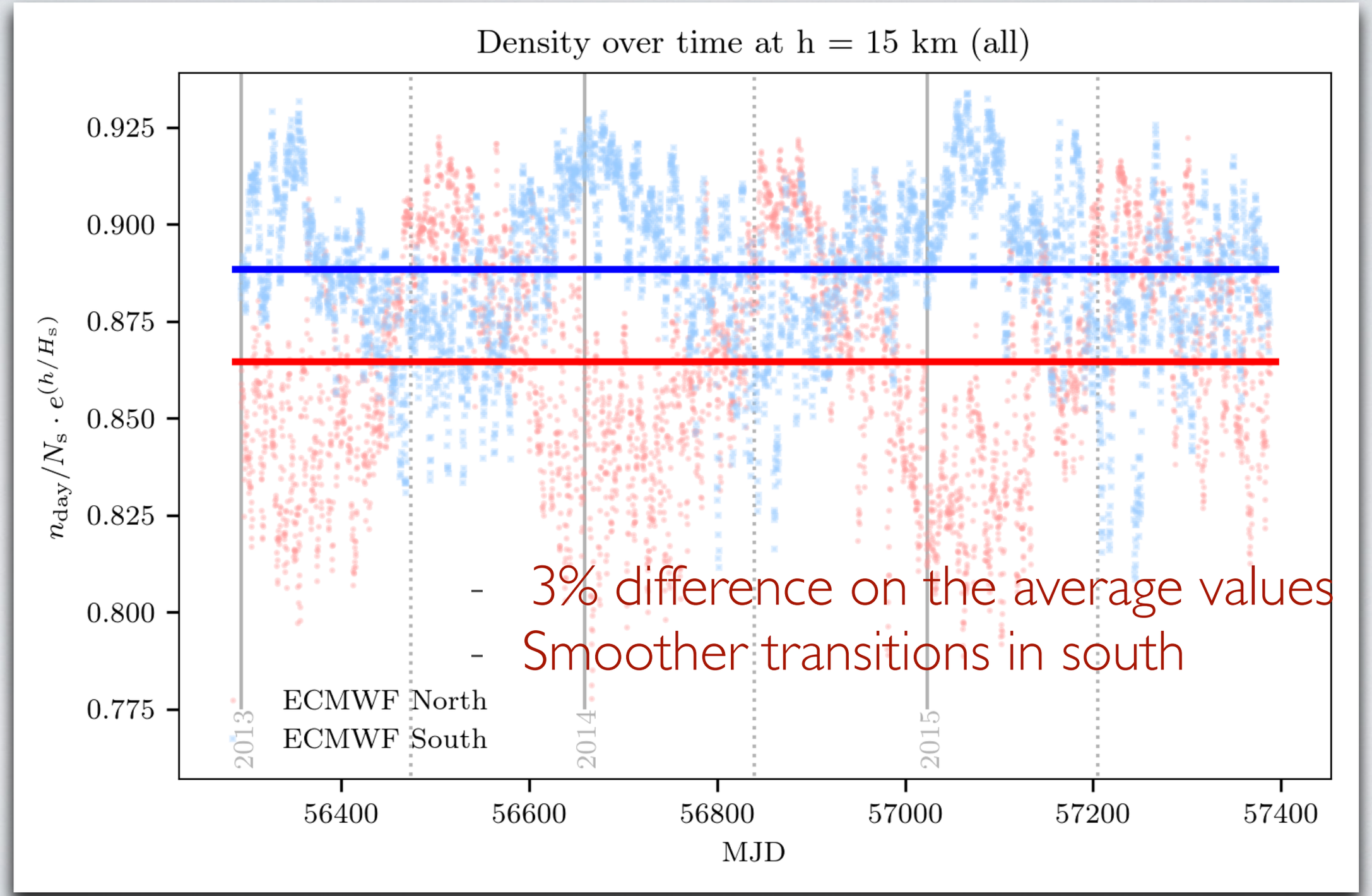


2013 - 2014 - 2015 data

Winter south months

Compared to MW model

ECMWF NORTH vs SOUTH



CONCLUSIONS

- We compared GDAS and ECMWF data for the North site
  - Differences between GDAS and ECMWF are of a ~%
  - Differences w.r.t. the current MW model up to ~10%
  - Evident differences in inter-year periods. Single model may not describe well the atmosphere
- We studied ECMWF data for the South site:
  - Compared to MW model
    - Same order of difference between models, a bit higher for South
    - Comparison to North site density at 15 km
      - 3% difference between sites. South has higher density on average
      - Smoother transitions between seasons in South

Future prospects:

- Study WRF model with GDAS data and compare with other servers
- Ground validation with weather station and LIDAR data
- Propose new average models. Probably 3
  - winter, summer, intermediate
- Implement to CTApipe