# Satellite cloud assimilation and preprocessing stratocumulus cloud fields based on mixed-layer theory in WRF

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## Introduction

- Marine layer stratocumulus is commonly found in coastal regions, and their lifetime and inland spatial coverage are notoriously difficult to predict.
- The presence of stratocumulus greatly attenuates solar irradiance at the surface, so accurate prediction is vital to the integration of solar power onto the electric grid.
- To improve WRF simulations of coastal stratocumulus, a two-part preprocessing procedure was implemented, consisting of:

1. A direct satellite cloud assimilation package which immediately populates cloud fields rather than relying on the microphysics scheme to develop clouds from outdated assimilated variables, and
2. An algorithm which provides an initial guess of cloud liquid water based solely on mixed-layer theory, thereby shortening the initial "spin-up" period. This allows greater flexibility in initialization data set selection.

## Methodology

### R1 – Cloud data assimilation (CLDDA)

1. Latitude/longitude of low clouds are obtained from GOES imagery.
2. Cloud tops are defined at temperature inversion base.
3. Cloud base height is determined from an empirical function of cloud top height.
4. Relative humidity (RH) is adjusted to a maximum of 75% in clear columns.
5. Relative humidity is adjusted to 110% within cloudy columns, and all previous liquid water is zeroed.
6. Microphysics heating is turned off to prevent intense subsequent latent heating.

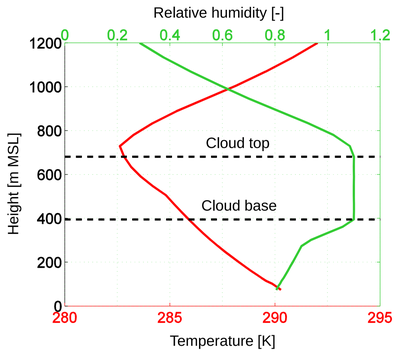


**Figure 1** – Adjusted temperature and relative humidity profiles at initialization

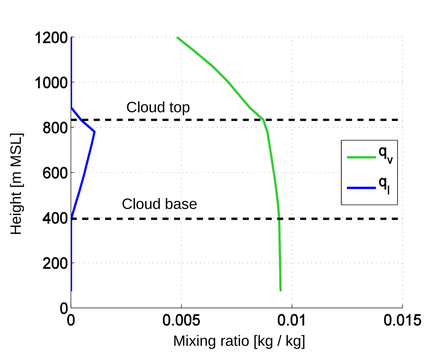


**Figure 2** – Moisture profiles 15 minutes after initialization.

### R2 – Well-mixed preprocessor (WEMPP)

1. Cloud tops in columns with temperature inversion under 3 km are determined (RH > 95%).
2. Mass-weighted averages of RH are computed downwards until layer average < 95%.
3. Cloud base is defined at the bottom-most point in cloud layer.
4. Water vapor mixing ratio $q_v$ is set to $q_{sat}$ at cloud base, and total water mixing ratio $q_t$ is assumed equivalent to $q_{sat}$ at cloud base.
5. Lastly, $q_v$ is set to $q_{sat}$ within cloud layer and the excess is partitioned into $q_l$.

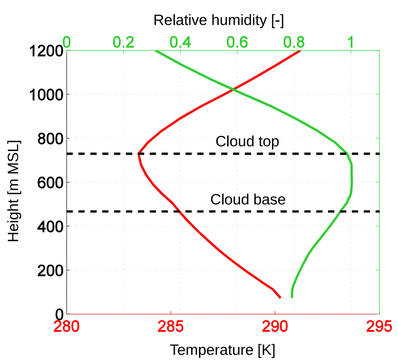


**Figure 3** – Unadjusted temperature and relative humidity profiles at initialization.

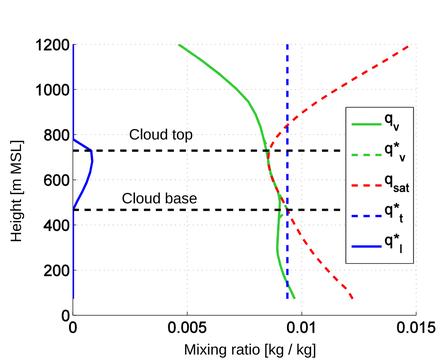


**Figure 4** – Adjusted moisture profiles at initialization.

## Acknowledgements

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## Setup

- The two nested domains, at 8.1 km and 2.7 km resolution, respectively, are shown in Figure 5.
- Simulations were initialized at 12 UTC (5 a.m. local time) from 0th hour forecast of 12 UTC initialized NAM on 218 AWIPS CONUS grid at 12 km resolution.
- Four simulations were run, and are summarized in Table 1.

**Table 1 - Summary of WRF runs for intercomparison.**

| Name | WRF-Vanilla | WRF-R1 | WRF-R2 | WRF-Combination |
|---|---|---|---|---|
| **Preprocessing** | None | CLDDA | WEMPP | CLDDA+WEMPP |

- The water vapor and liquid water fields from WRF-R1 and WRF-R2 were combined 15 minutes after initialization, taking values from the run with greatest liquid water path, to form the WRF-Combination run. A diagram is shown in Figure 6.
- All WRF simulations were validated against SolarAnywhere satellite-derived irradiance.
- Errors were computed from the clear sky index $kt \equiv \frac{\mathrm{GHI}}{\mathrm{GHI}_{\mathrm{clear,Kasten}}}$, where $\mathrm{GHI}_{\mathrm{clear,Kasten}}$ is obtained from the Kasten clear sky model, as modified by Ineichen and Perez.

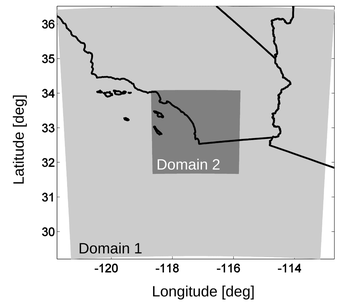
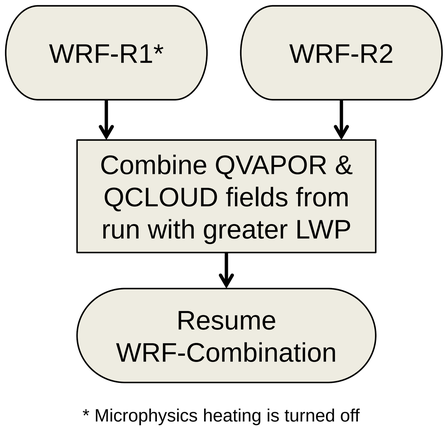



**Figure 5** – Domain setup.




* Microphysics heating is turned off

**Figure 6** – Diagram of WRF-Combination run.

## Results (June 1 – June 30, 2013)

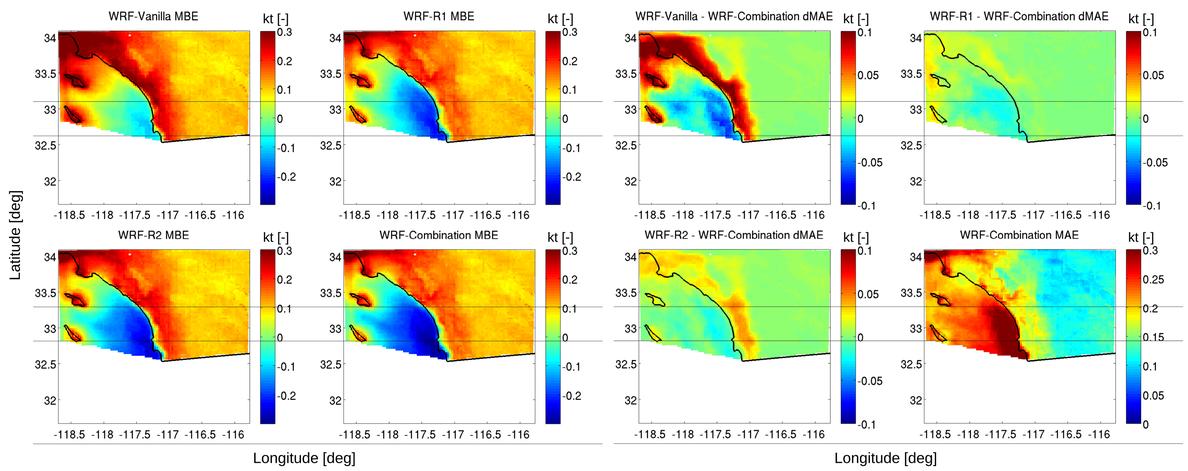



**Figure 7** – Monthly-averaged mean bias error.

**Figure 8** – Monthly-averaged mean absolute error relative to WRF-Combination.

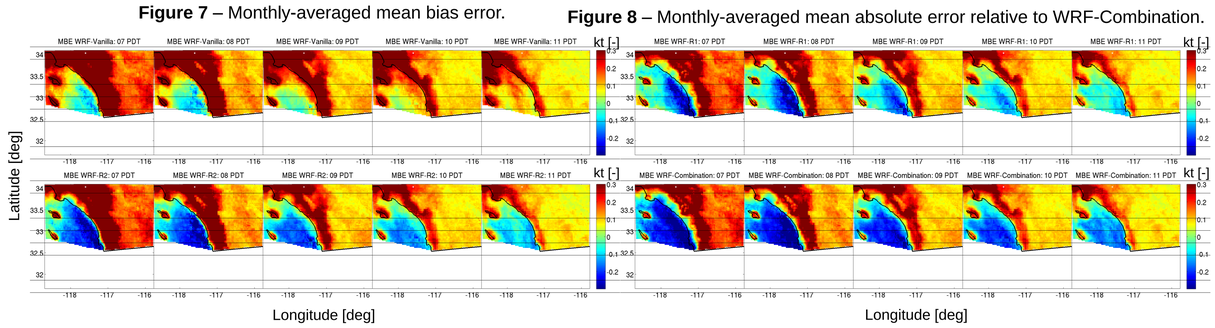



**Figure 9** – Monthly-averaged mean bias error by hour for each run.

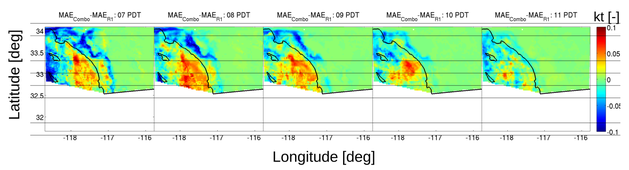



**Figure 10** – Monthly-averaged mean absolute error by hour of WRF-R1 relative to WRF-Combination.

## Conclusions

- All simulations show positive bias over land and negative bias over ocean (see Figure 7).
- A clear sky GHI bias is evident in all simulations (see session **6a.11**: Resolving WRF surface clear sky irradiance bias in the New Goddard Shortwave scheme. Zhong, Xiaohui and Jan Kleissl, *UCSD*).
- WRF-Combination shows least bias over land, and greatest over ocean.
- Improvement in prediction of both spatial coverage and lifetime of coastal stratocumulus was achieved (see Figure 8).

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