Representation of Planetary Boundary Layer Climatology over Europe and US in ERA-Interim

Dian J. Seidel, NOAA Air Resources Laboratory, Silver Spring, Maryland, USA
Yehui Zhang, Applied Hydrometeorological Research Inst., Nanjing Univ. of Information Science & Technology, China
Anton Beljaars, European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom
Andrew R. Jacobson, University of Colorado and NOAA Earth System Research Laboratory, Boulder, Colorado, USA

Motivation

Planetary boundary layer (PBL) information from reanalyses is used in important practical applications, such as:

- air quality forecasting and development of air pollution regulations
- modeling dispersion of atmospheric releases of hazardous materials
- inverse modeling of biogeochemical budgets, including the carbon cycle

Reanalysis representations of the PBL may be used in lieu of observations for:

- evaluation of free-running climate models
- detection of long-term climate trends

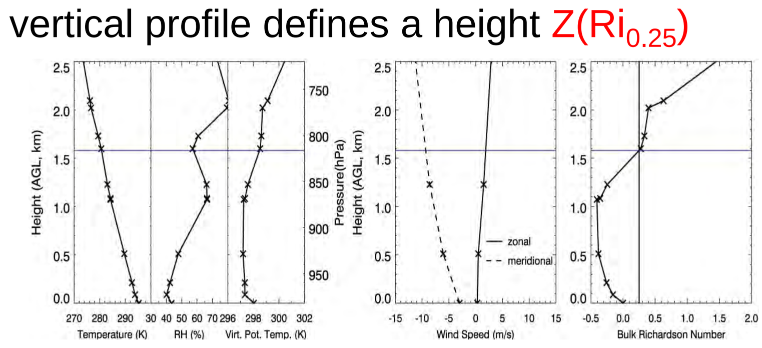
But representation of the PBL in ERA-Interim, or other reanalyses, has not be evaluated against long-term global observations to identify potential temporal and spatial patterns of bias. This study evaluates ERA-Interim representations of PBL climatology using radiosonde observations.

Methodology

We employ a PBL "mixing height" metric based on Bulk Richardson number

Threshold value of Ri=0.25 in Ri vertical profile defines a height Z($Ri_{0.25}$)

$$Ri_z = \frac{(g/\theta_{vs})(\theta_{vz}-\theta_{vs})(z-z_s)}{(u_z-u_s)^2+(v_z-v_s)^2}$$



Example: 0000 UTC 28 June 2006 radiosonde observation of T, RH, and wind profiles at Minneapolis, Minnesota (45 N, 94 W) is used to compute virtual potential temperature and bulk Richardson number, for location of Z($Ri_{0.25}$).

For this study, we

• Computed Z($Ri_{0.25}$) from radiosonde station data (2x/day) and ERA-Interim gridded (8x/day) data for continental United States and Europe

• Created climatological seasonal values for 25-yr period 1981-2005. Diurnal cycle analysis is based on data for 2000 only.

Challenges

1. Complex vertical structure, diurnal variability, and spatial heterogeneity of the PBL are unlikely to be fully represented in radiosonde or ERA-Interim data
2. Subtle distinctions in PBL type are lost when applying automated algorithms to large datasets
3. Limitations of radiosonde data (vertical resolution, lack of u*, lack of surface winds) require adjustments to Z($Ri_{0.25}$) algorithm. We set b=0, u_s=v_s=0, and take z_s and θ_{vs} as 2-meter values.
4. Limitations of ERA-Interim (mainly gridding/spatial resolution) compromise direct comparison with radiosonde data

Related Studies

An analysis of PBL height algorithms suitable for application to large datasets:

Seidel, D.J., C.O. Ao, and K. Li, 2010: **Estimating climatological planetary boundary layer heights from radiosonde observations: Comparison of methods and uncertainty analysis**. *J. Geophys. Res.*, 115, D16113, doi:10.1029/2009JD013680.

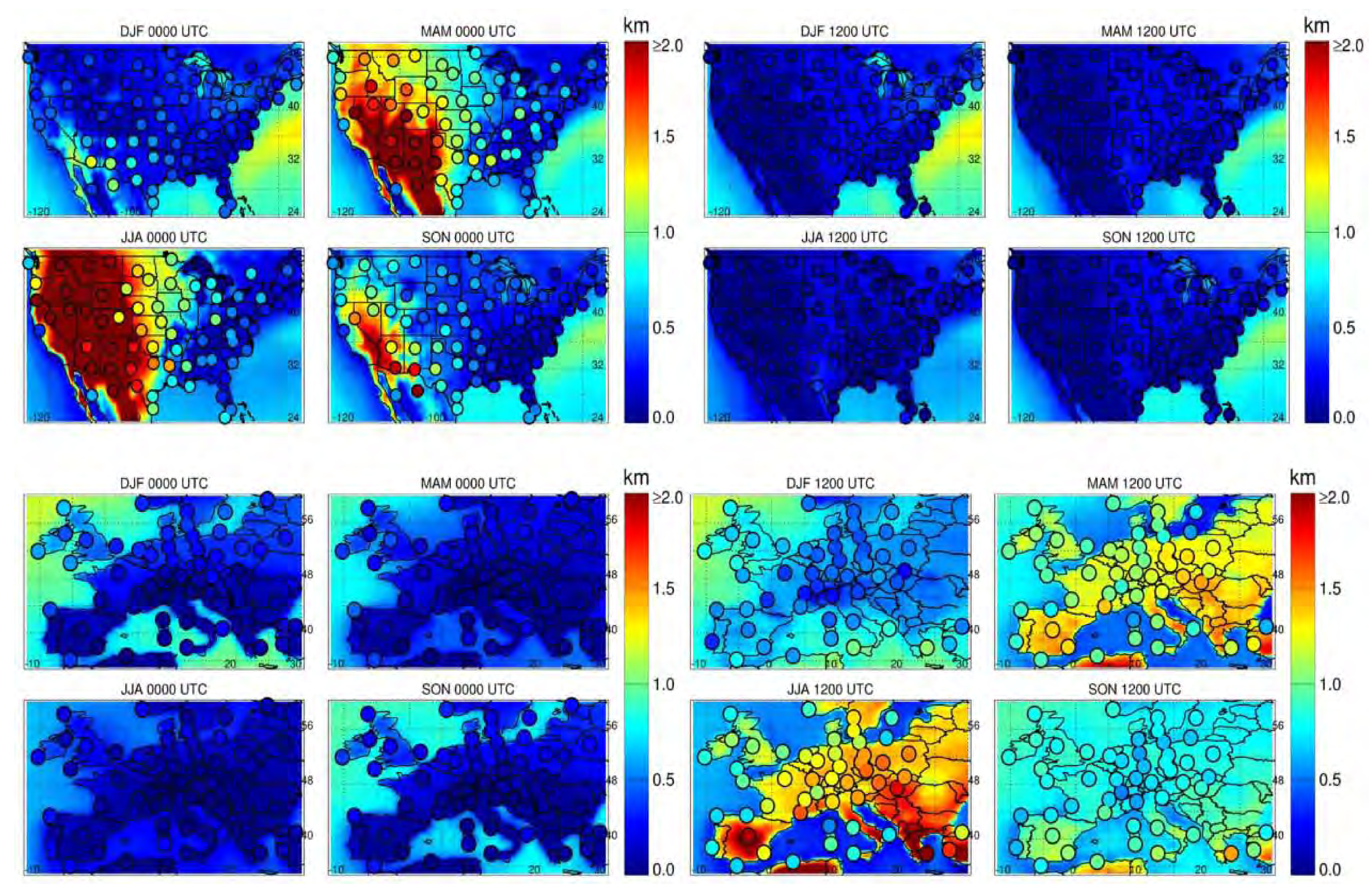
A comparison of ERA-Interim, radiosonde, and climate model representations of the polar PBL, specifically surface-based inversions.

Zhang, Y., D.J. Seidel, J.-C. Golaz, C. Deser, and R.A. Thomas, **Climatological characteristics of Arctic and Antarctic surface-based inversions**, *J. Climate,* 24, 5167-5186, doi: 10.1175/2011JCLI4004.1.

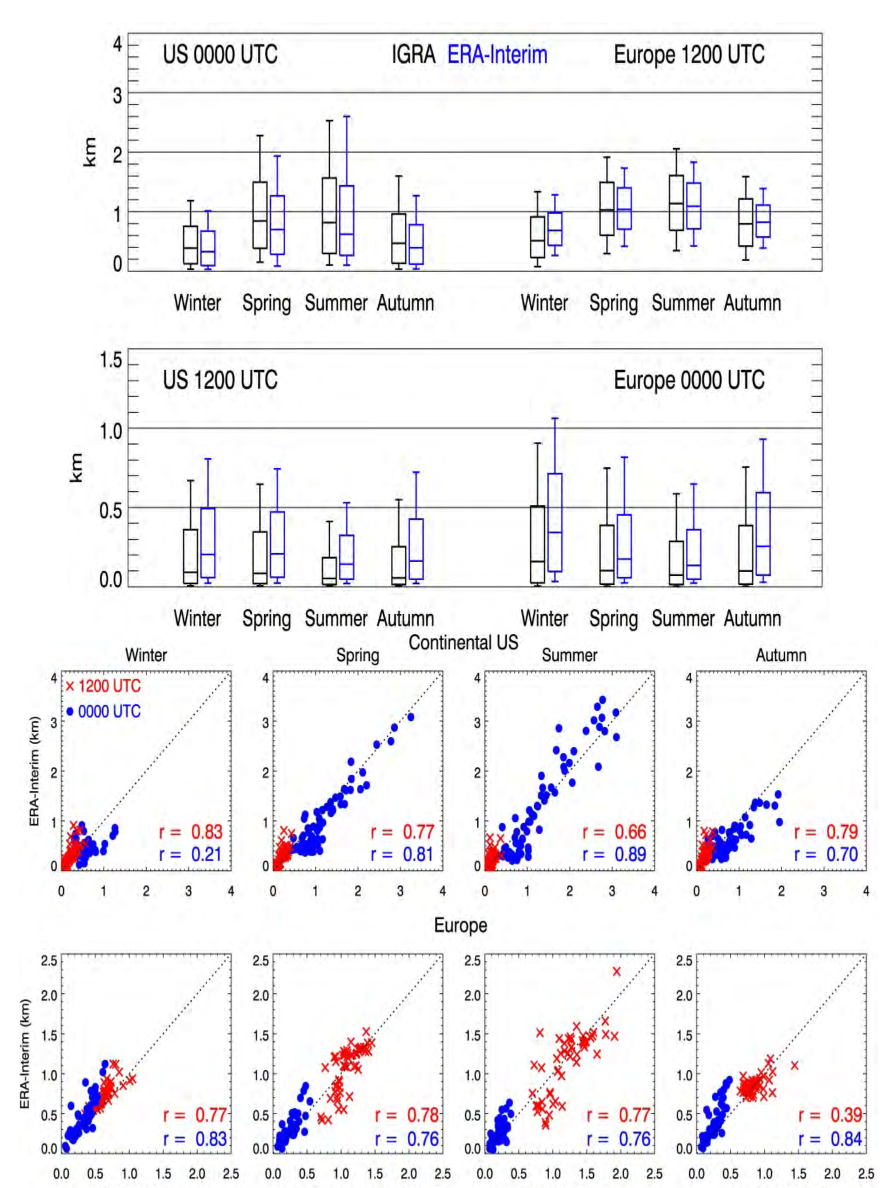
Results: Representation of the Seasonal Cycle

Climatological Seasonal Cycles at 0000 and 1200 UTC

Maps show median Z($Ri_{0.25}$) values for each season for 1981-2005, with radiosonde values plotted over ERA-Interim values.



Box-and-whisker plots, and scatter plots, show distributions of station values for each region and observation time.

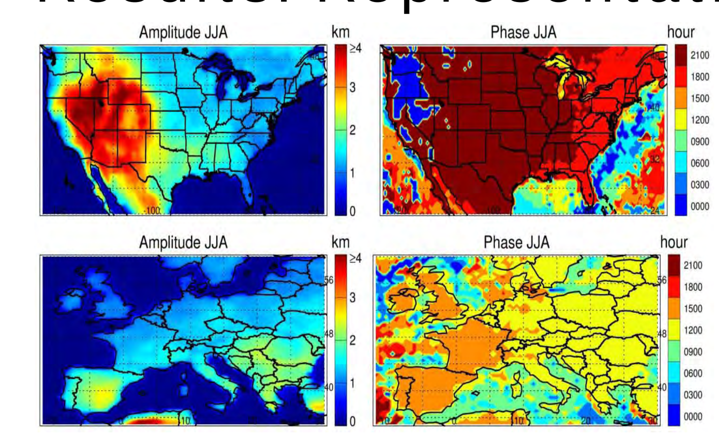


Main Findings - Seasonal Cycle

Basic features of seasonal cycle are similar in both datasets.
Both datasets show seasonal variations larger for daytime than nighttime.
Daytime: summer Z($Ri_{0.25}$) exceed winter values
Nighttime: winter Z($Ri_{0.25}$) exceed summer values

ERA-Interim provides Z($Ri_{0.25}$) over ocean areas not sampled by radiosondes. Ocean PBL shows smaller seasonal variation than over land. Results may be strongly influenced by treatment of near-surface winds in our Ri computations.

Results: Representation of the Diurnal Cycle



Main Findings: Diurnal Cycle

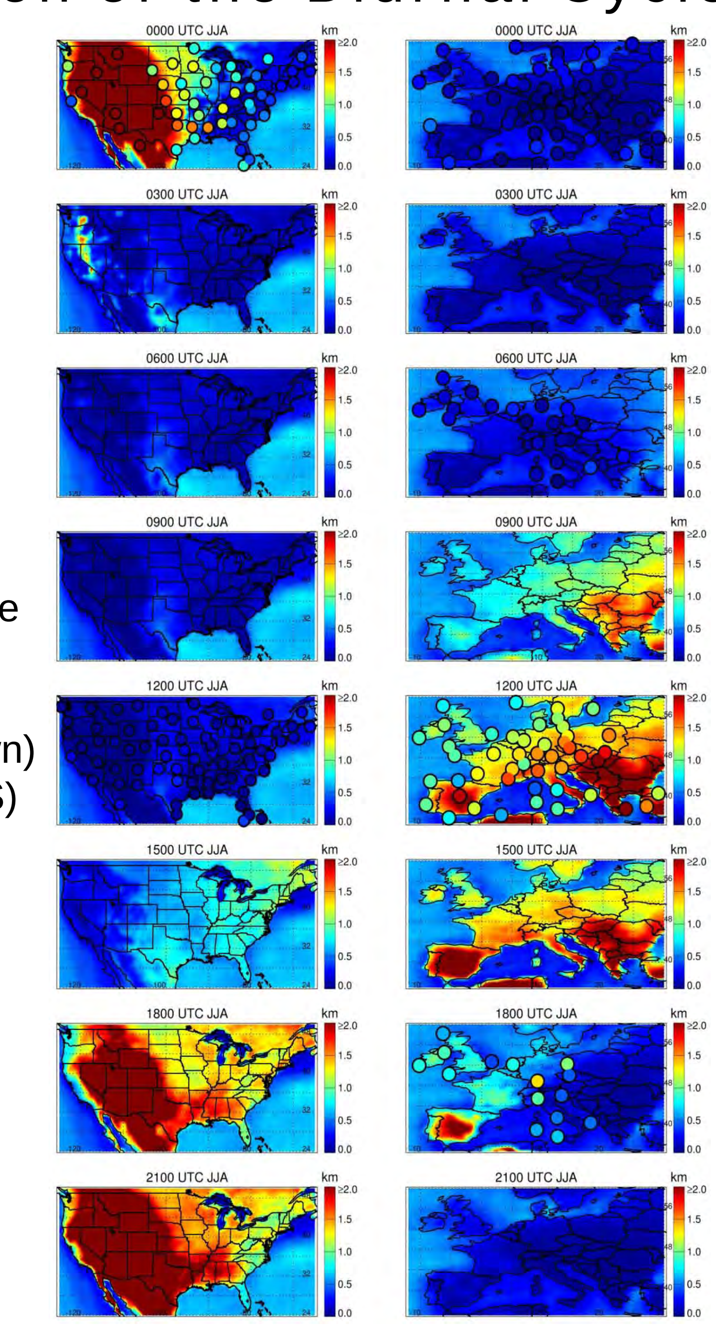
ERA-Interim (8x/day) shows diurnal cycle **amplitude** (maximum minus minimum):

- is larger in JJA (shown here) and MAM than in DJF and SON (not shown)
- is larger in US (especially western US) than Europe

phase (time of maximum):

- has peak in early afternoon
- shows expected longitudinal variation

Radiosonde data (2x/day) capture full cycle well for Europe, poorly for US.



Results: Uncertainties and Biases

Uncertainties: (Not shown on poster.)

Several factors contribute to uncertainties in Z($Ri_{0.25}$).

Relative uncertainty can exceed 50 % when the PBL is shallow (Z($Ri_{0.25}$) < 1 km) but is generally < 20 % for deeper PBLs.

Biases:

Z($Ri_{0.25}$) in ERA-Interim vs Radiosondes: (Shown at left)
ERA-Interim tends to overestimate nighttime climatological median Z($Ri_{0.25}$) determined from radiosonde observations, and to show a smaller range of daytime values, despite assimilation of radiosonde data.

ERA-Interim Mixing Height Product vs Calculated Z($Ri_{0.25}$): (Not on poster.)
The ERA-Interim product shows higher heights especially over high elevation regions, than the algorithm used in this study. The difference is larger over ocean than over land. Differences are < 100 at night and several 100 m during daytime.

Future Directions

TransCom: The Atmospheric Tracer Transport Model Intercomparison Project

Transcom is a project to quantify and diagnose the uncertainty in inversion calculations of the global carbon budget that result from errors in simulated atmospheric transport.

We are comparing these ERA-Interim and radiosonde results with results from ECMWF forecasts and MERRA, with applications to carbon cycle models

Climate model evaluation study

We are comparing these ERA-Interim and radiosonde results with simulated PBL structure in two state-of-the-art atmospheric climate models (GFDL AM3 and NCAR CAM5). Unlike the reanalyses, the climate models do not assimilate upper-air data, and the PBL representation is the result of parameterizations of mixing processes.

Other applications of these datasets?

Please contact us with ideas for potential collaborative research projects.
Dian.Seidel@noaa.gov
+1-301-713-0295 x 126

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