Limitations of Models and Observations

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All Parameterizations are 1-D Column Models

- Stable Clouds and Precipitation
- Deep Cumulus Clouds and Precipitation
- Longwave Radiation/Shortwave Radiation
- Subgrid-Scale Mixing
- Pressure Gradient Force
- Advection
- Gravity

Parameterizations: green boxes
Dynamic Core: red box
All Parameterizations Have Tunable Coefficients and Functions
7.3.3.3 Parameterization Complexity

It is useful to dissect a parameterization algorithm to determine the number of dependent variables and adjustable and universal parameters that are introduced. This dissection can be illustrated through the following simple example. Holtstlag and Boville (1993) and Tjim et al. (1999a) propose the following form for $K_\theta$ above the boundary layer:

$$K_\theta = \frac{I_0^b}{S} F_\theta (Ri),$$  \hspace{1cm} (7-63)

$$\frac{1}{I_0^b} = \frac{1}{kz + \lambda_\theta},$$  \hspace{1cm} (7-64)

$$S = \left| \frac{\partial \bar{V}}{\partial z} \right|,$$  \hspace{1cm} (7-65)

and

$$F_\theta (Ri) = \begin{cases} (1 - 18 \, Ri)^{1/2}, & \text{if } Ri \leq 0 \\ 1/(1 + 10 \, Ri + 80 \, Ri^2), & \text{if } Ri > 0, \end{cases}$$  \hspace{1cm} (7-66)

$$\lambda_\theta = \begin{cases} 300 \, m, & \text{if } z \leq 1 \, km \\ 30 \, m + 270 \exp(1 - (z/1000 \, m)). \end{cases}$$  \hspace{1cm} (7-67)

This formulation for $K_\theta$ includes the following dependent variables, parameters, and prescribed constants:

- In Eq. (7-63), the dependent variables $I_0^b$, $S$, and $F_\theta$ define $K_\theta$.
- In Eq. (7-64), $I_0^b$ is defined with the independent variable $z$, the dependent variable $\lambda_\theta$, and the parameter $k$.
- In Eq. (7-65), $S$ is defined by the vertical gradient of $\bar{V}$.
- In Eq. (7-66), $F_\theta (Ri)$ is defined by the dependent variable $Ri$ [which is defined by Eq. (7-8)] and the constants 18, 10, and 80 and the exponent 1/2.
- In Eq. (7-67), $\lambda_\theta$ is defined by the independent variable $z$ and the constants 300, 30, 270, and 1000.

Therefore, to represent the term $K_\theta$, in addition to the fundamental variables $\bar{u}_i$ and $\theta$, one parameter ($k$) and eight constants (18, 10, 80, 1/2, 300, 30, 270, 1000) must be provided.

A sensitivity analysis can be applied to show how $K_\theta$ responds to slight changes in the dependent variables and constants. For example, in Eq. (7-67), if 100 m were used instead of 300 m when $\lambda_\theta$ dominates in Eq. (7-64), then $K_\theta$ would be 1/9 as large, since $K_\theta$ is proportional to $I_0^b$. Clearly, the form of
All Boundary-Layer Parameterizations Are Tuned From Golden Day Data
Fig. 7-10. Comparison of predictions using (a) higher-order closure (André et al. 1978) for Day 33-34 of the Wangara Experiment, (b) first-order closure (McNider and Pielke 1981), and (c) observational data presented by André et al. (1978). The solid and dashed lines correspond to 1200 LST and 1800 LST on Day 33; the dotted line corresponds to 0300 LST on Day 34.
Boundary-Layer Data For The Parameterizations Are Developed For Horizontally Homogeneous (Including Flat) Landscape, And For Near-Steady Or Slowly Changing Atmospheric Conditions
Fig. 7-11. Schematic illustration of the growth of an internal boundary layer with a neutrally stratified surface layer as airflow advects (a) from a smooth (small $z_0$) to a rough surface (large $z_0$); and (b) from a rough (large $z_0$) to a smoother (small $z_0$) surface. Note that for (a), eventually only one planetary boundary layer remains, whereas for (b), two levels of $z_i$ remain, with separate and distinct regions of turbulence that last until the turbulent kinetic energy in the upper layer decays by dissipation.
Fig. 7-12. Schematic illustration of the growth of an internal boundary layer as air advects (a) from a stably stratified surface to a region with an unstably stratified surface layer, and (b) from one unstably stratified region to another in which the equilibrium height of $z_i$ over the new surface is lower.
Location of Field Campaigns

- Hays, Kansas
- Wangara, Australia
Basic Terms Are Ignored In
The Model Equations
\[
\frac{\partial}{\partial t} \overline{u''_k u''_i} = -\tilde{u}_j \frac{\partial}{\partial x_j} \overline{u''_k u''_i} - u''_j \frac{\partial}{\partial x_j} \overline{u''_k u''_i} - \overline{u''_i u''_j} \frac{\partial \tilde{u}_k}{\partial x_j} - u''_i \frac{\partial \tilde{u}_i}{\partial x_j}
\]

\[
- \theta_0 u''_i \frac{\partial \overline{\pi''}}{\partial x_k} - \theta_0 u''_i \frac{\partial \overline{\pi''}}{\partial x_i} + \frac{\delta}{\theta_0} \delta_{k3} \overline{u''_i \theta''} + \frac{\delta}{\theta_0} \delta_{i3} \overline{u''_k \theta''}.
\]

(7-11)

\[
\frac{\partial}{\partial t} \overline{u''_i \theta''} = -\tilde{u}_j \frac{\partial}{\partial x_j} \overline{u''_i \theta''} - u''_j \frac{\partial \overline{\theta}}{\partial x_j} - \overline{u''_i \theta''} \frac{\partial \tilde{u}_l}{\partial x_j} - u''_i \frac{\partial \overline{\theta''}}{\partial x_j}
\]

\[
- \theta'' u''_j \frac{\partial \overline{u''_i}}{\partial x_j} - \theta_0 \theta'' \frac{\partial \overline{\pi''}}{\partial x_i} + \frac{\delta}{\theta_0} \delta_{i3} \overline{\theta''^2} + \overline{u''_i S''_\theta}.
\]

(7-14)
\[
\overline{w''u''} = -K_m \frac{\partial \bar{u}}{\partial z} = -u_*^2 \cos \mu
\]

\[
\overline{w''v''} = -K_m \frac{\partial \bar{v}}{\partial z} = -u_*^2 \sin \mu,
\]

(7-16)

with

\[
\arctan(\bar{v}/\bar{u}) = \mu \quad \text{and} \quad \bar{\rho} u_*^2 = \tau.
\]
\[
\overline{w'' \theta''} = -K_\theta \frac{\partial \theta}{\partial z} = -u_* \theta_* ,
\]
\[
\overline{w'' q_n''} = -K_q \frac{\partial q_n}{\partial z} = -u_* q_{n_*} ,
\]
\[
\overline{w'' \chi_m''} = -K_\chi \frac{\partial \chi_m}{\partial z} = -u_* \chi_{m_*} .
\]  (7-29)
Fig. 7-3. Plot of $\phi_m$ against $(z - d)/L$ in log-log representation for unstable stratification. The small dots are data from Högström (1988). The other symbols have been derived from modified expressions from the sources listed in the key. (From Högström 1996 with kind permission from Kluwer Academic Publishers.)
Fig. 7-5. As in Figure 7-3 except for $\phi_h$. (From Högström 1996 with kind permission from Kluwer Academic Publishers.)
Models Provide Grid Volume Information. Observations Provide Point, Line, Area, or Volume-Average Information.

Thus a Mismatch Exists Between Models And Observations.
Fig. 4-1. A schematic of a grid volume. Dependent variables are defined at the corners of the rectangular solid.
Meteorological monitoring aircraft from NCAR.
R-274 http://blue.atmos.colostate.edu/publications/reviewedpublications.shtml
and
R-254 http://blue.atmos.colostate.edu/publications/reviewedpublications.shtml
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Eads, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Holly, CO. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Trinidad, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Cheyenne Wells, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Lamar, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Wray, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.
Photographs of the temperature sensor exposure characteristics of the NWS COOP station at Las Animas, Colorado. Panel a) shows the temperature sensor, while panels b)-e) illustrate the exposures viewed from the temperature sensor looking N, E, S, and W, respectively.
Maximum-minimum temperature sensor (MMTS) installation near Lindon, Colorado.
MMTS installation near John Martin Reservoir, Colorado.
Figure 11: Fort Morgan site, showing images of the cardinal directions from the sensor.
Role of Surface Forcing
Regional Land-Use Change Effects on Climate in the Winter

R-277 at http://blue.atmos.colostate.edu/publications/reviewedpublications.shtml
Fig. 2. Outer and inner grid configurations for RAMS domain centered on south Florida.
Fig. 1. Number of citrus trees per county and principle areas of winter fresh vegetable production. Figure adapted from Florida Agriculture Facts Directory 2002.
Fig. 2. Observations of minimum temperature from the National Weather Service Cooperative Observer Network on the morning of January 19, 1997.
Fig. 3. U.S. Geological Survey land cover classes for pre-1900s natural conditions (left) and 1993 land use patterns.
Fig. 4. Model simulated 2 meter minimum temperatures on the morning of January 19, 1997 for the pre-1900s scenario (top panel), the 1993 scenario (middle panel), and the difference of the two (1993 minus pre-1900s scenario; bottom panel).
Fig. 5. Time spent below freezing (minutes) for the night prior to the morning of January 19, 1997, for the pre-1900s land cover scenario (top), the 1993 land cover scenario (middle) and the difference of the two (bottom).
Fig. 7. Time series of 2 meter temperature for a model grid point located just south of Lake Okeechobee for the pre-1900s land cover scenario (filled circles) and the 1993 land cover scenario (open circles).
Regional Land-Use Change Effects on Climate in the Summer


R-272 at http://blue.atmos.colostate.edu/publications/reviewedpublications.shtml
FIG. 25. Regional average time series of accumulated convective rainfall (cm) from 1924 to 2000, with corresponding trend based on linear regression of all July-August amounts. The vertical bars overlain on the raw time series indicate the value of the standard error of the July-August regional mean.
FIG. 26. Same as in Figure 25, except for daily (a) maximum and (b) minimum shelter-level temperature (°C).
FIG. 4. Accumulated convective rainfall (mm) from the model simulations of July-August 1973 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).
FIG. 5. Same as in Figure 4, except for July-August 1989.
FIG. 6. Same as in Figure 4, except for July-August 1994.
Two-month average of the surface latent heat flux (W m\(^{-2}\)) from the model simulations of July and August 1994 with pre-1900s land cover (top), 1994 land use (middle), and the difference field for the two (bottom; 1994 minus pre-1900s case).
FIG. 13. Two-month average of the daily maximum shelter-level temperature from the model simulations of July-August 1989 with pre-1900s land cover (top), 1993 land use (middle), and the difference field for the two (bottom panel; 1993 minus pre-1900s case).
FIG. 17. Difference (1993 minus pre-1900s case) of the fields shown in Figure 16.
Conclusions