Downscaling general circulation model output: a review of methods and limitations

R.L. Wilby and T.M.L. Wigley

本文综述了目前常用的四种降尺度方法——Regression methods(回归方法), weather pattern(circulation)-based approaches(基于天气特征的方法)[——这里的'circulation'并不是很清楚含义], stochastic weather generators(随即天气发生器), limited-area climate models(局地天气模型). 并通过RMSE（均方根误差）分析比较几种不同降尺度方法的优劣。

图1很直观的给出降尺度和聚合的关系。GCMs和水温模型在参数化过程中最大的误差出现在天气和陆地相互影响的界面尺度上

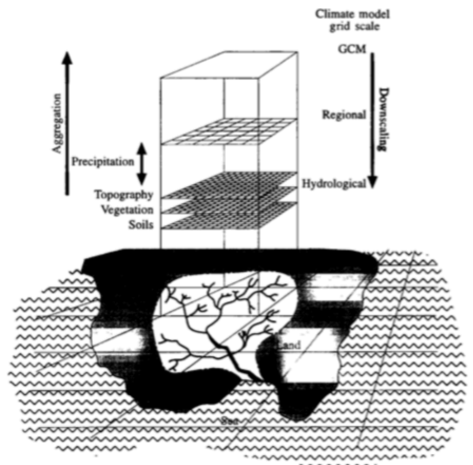

Figure 1 Conceptualization of downscaling and aggregation between atmospheric and hydrologic models
Source: Modified after Hostetler (1994)

1 Regression methods

回归方法通常是在子网格尺度（单站点）参数和较粗糙分辨率（网格尺度）的预报变量之间建立线性或非线性的关系。对这个方法的延伸可以参考Burger的expanded downscaling模型；还可以通过训练一个ANN来讲观测到的局部和区域天气联系起来，这样的话方程可能需要通过使用GCM中的区域尺度天气数据来强迫。

海岸和山（地形）和季节性大气特征对美国西北部有很大的影响。

方法拓展：从区域到本地尺度，或跨多个尺度回归相同的参数。一些应用（尝试）：Carbone and Bramante对美国东南部的多个站点，针对相同变量的空间月平均最高温和最低温做了回归。

2 Weather pattern approaches

该方法通常使用统计方法将观测的站点或区域平均气象数据和一个给定的天气归类方法（weather classification scheme）建立联系，这样的方法可以是主观的也可以是客观的。天气归类过程包括以下几个步骤：principal components(重要组成部分), canonical correlation analyses(典型相关分析), fuzzy rules(模糊规则), compositing(合成), neural networks(神经网络), correlation-based pattern recognition techniques(基于相关的特征识别技术) and analogue procedures(模拟程序).

当已经选好一个分类方案后，就有必要在对应的（日变化）天气特征上训练局部表面变量，比如降水。这可以通过推导观测数据（如，一个潮湿天气随后而来的潮湿天气的可能性或与一个给定的大气循环特征有关的潮湿天气的平均数）的概率分布获得；降水序列可以进一步通过月或季节或主要降水机制来分解。

Table 2 Notations for precipitation models used in the comparison exercise

Notation	Description	References
HadCM2	Hadley Centre coupled ocean–atmosphere model forced by combined CO_2 and sulfate aerosol forcing. Two 20-year periods were selected: present climate (1980–99) and a perturbed, future climate (2080–99)	Mitchell *et al.* (1995), Johns *et al.* (1997), Mitchell and Johns (1997)
ANN1	Artificial neural network calibrated against observed single-site and area-average precipitation, and forced using daily 700 and 500 hpa heights obtained from the two HadCM2 periods	Hewitson and Crane (1992a; 1992b; 1994; 1996)
ANN2	Artificial neural network calibrated against observed single-site and area-average precipitation, and forced using daily 700 and 500 hpa heights and temperatures obtained from the two HadCM2 periods	Hewitson and Crane (1992a; 1992b;1994; 1996)
WGEN	First-order, two-state Markov process of daily rainfall occurrence. Wet-day precipitation amounts are modelled using gamma distributions. Downscaled future precipitation was produced by perturbing WGEN parameters in proportion to the changes in model parameters calibrated using the HadCM2 present and future data	Richardson (1981), Wilks (1989; 1992), Gregory *et al.* (1993), Wilby *et al.* (1996b)
SPEL	An alternating negative binomial recurrence process for wet- and dry-spell lengths. Wet-day precipitation amounts are modelled using gamma distributions. Downscaled future precipitation was produced by perturbing SPEL parameters in proportion to the changes in model parameters calibrated using the HadCM2 present and future data	Wilby *et al.* (1996b)
CRU	Binned vorticity method of resampling observed daily rainfall sets. Downscaled precipitation is modelled by sampling rainfall occurrence and amounts from discrete vorticity classes. Only the distribution of daily vorticity values is assumed to change between the present and future climate	Conway *et al.* (1996), Conway and Jones (1996; in press)
UD	Semi-stochastic precipitation occurrence and intensity drived by vorticity. Downscaled precipitation is modelled using nonlinear empirical relationships between wet-day occurrence/persistence/mean amounts and vorticity. Only the distribution of daily vorticity values is assumed to change between the present and future climate	Conway *et al.* (1996), Wilby *et al.* (1996a; 1996b)

3 Stochastic weather generators

该方法和传统的基于循环的降尺度模型有许多共同之处，但在对未来天气条件的应用上有很大差异。其中，最普遍使用的是Richardson的WGEN模型。该模型最初用于模拟当前气候的每日时间序列如降水量、最高温和最低温以及太阳辐射。除了受循环模式的限制之外，Richardson模型中的所有变量都是以降水发生为条件进行模拟的。模型的核心是一阶或多阶Markov更新过程——对于每个连续的一天，降水的发生（以及可能的数量）由前几天的结果控制。

4 Limited-area climate models

该方法主要是在GCM中嵌入更高分辨率的有限区域气候模型（LAM），并使用GCM定义（随时间变化的）边界条件。LAMs可以很好的模拟小尺度大气特征，比如地形降水等。

A comparison of statistical downscaling methods

P.S. 可以从本文中较好的学习英文文献书写的技巧，比如在同时将4种方法时，可以在最后一种方法的描述上简单采用先抑后扬的方法。同时，要注意时态的多变——having done的用法。但我认为本文的逻辑有一些不清晰，对四种方法的描述很概括且最后得到结论（就是在判断GCM对降水的可靠性）的过程很不直接，让我有些迷茫。