集合模拟数据可视分析方法进展

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舒清雅[1] **刘日晨**[1] 洪帆[1] 张江[1] 袁晓如[1,2]

1 北京大学 信息科学技术学院 机器感知与智能教育部重点实验室

2 北京大学-奇虎数据可视分析联合研究中心

集合模拟

- 集合模拟：设定不同参数、初始条件后进行多次模拟 (如气候模拟、天气预报、流体力学模拟)
  - “成员 (ensemble member)” ：每一次模拟实验
  - “集合模拟” ：一堆“成员”的集合
- 目的：分析模拟结果的**不确定性**、评估模型**稳定性**、改善模拟结果**可靠性**

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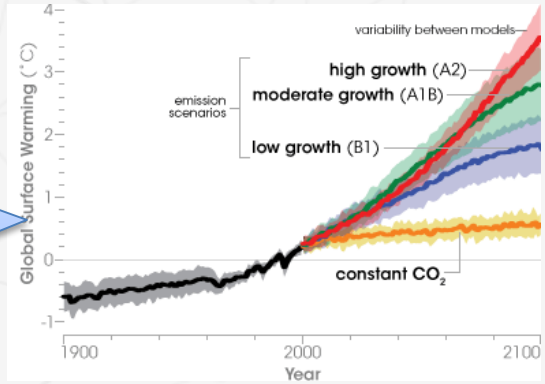
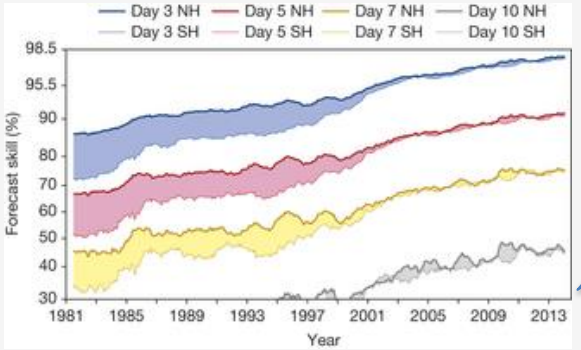
减少一半的空气污染，能否改善气候？

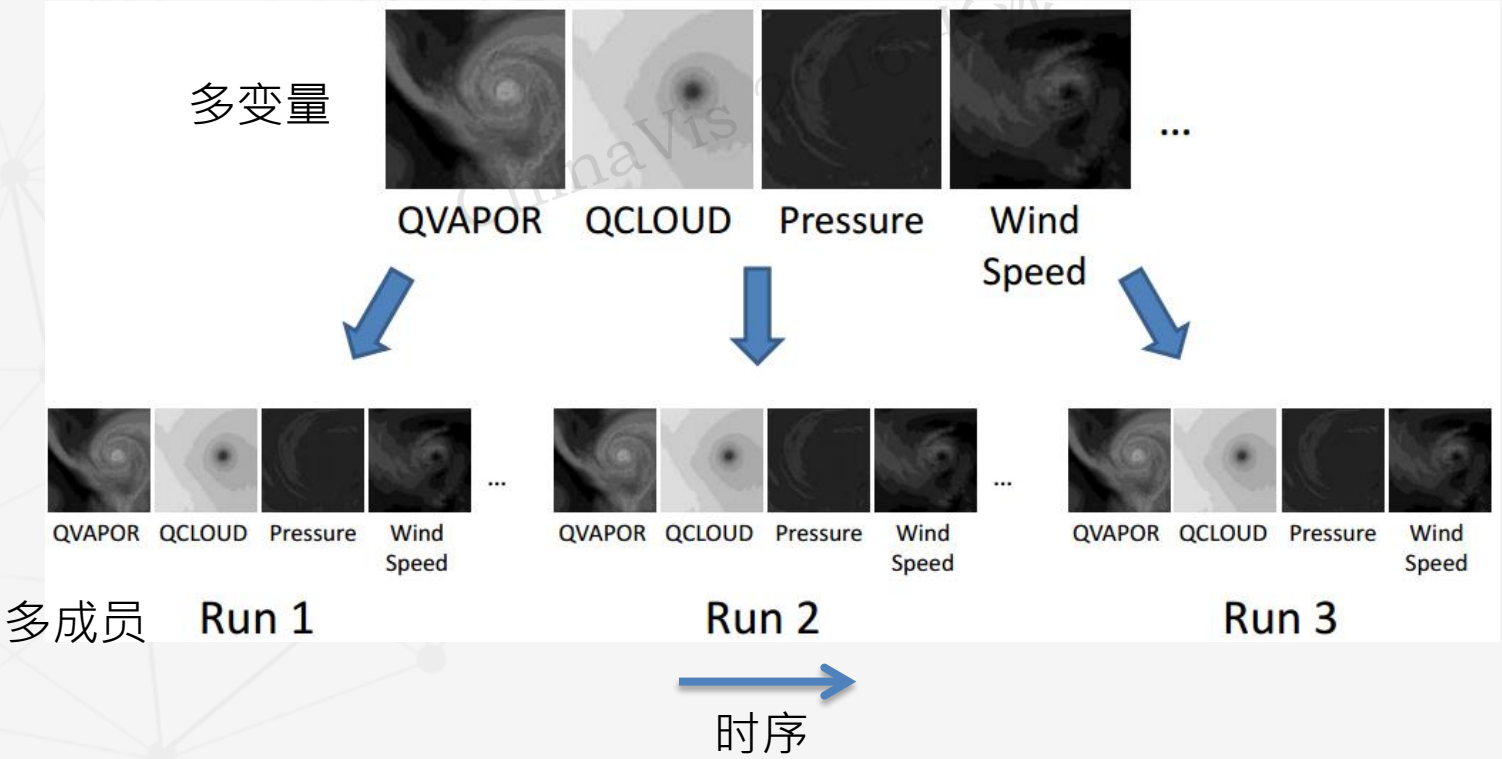




明天下雨么？可信度高吗？

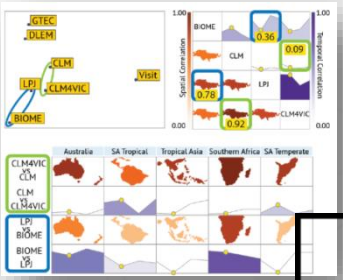
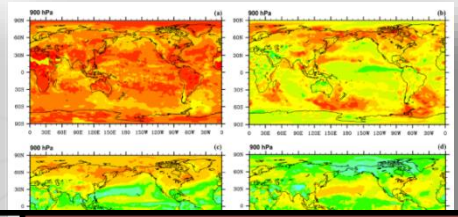
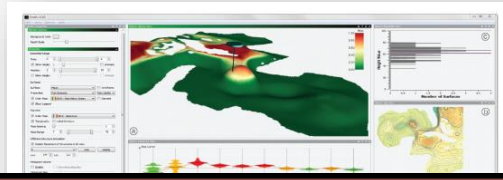
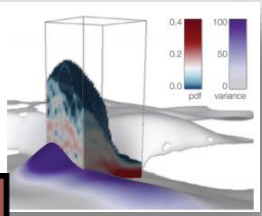
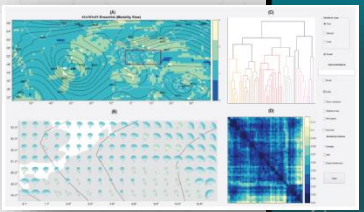
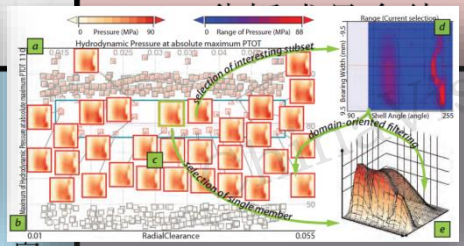
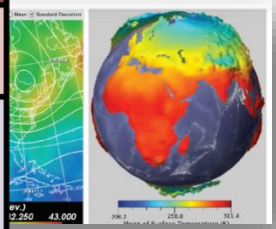
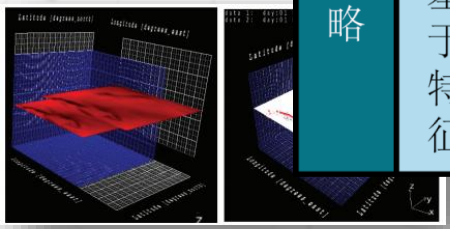
集合模拟数据

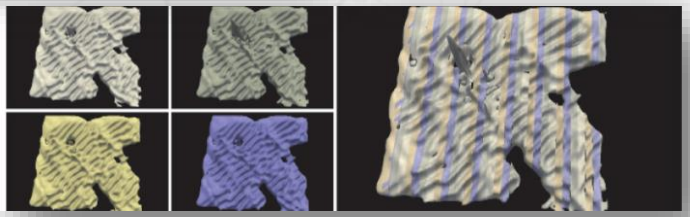
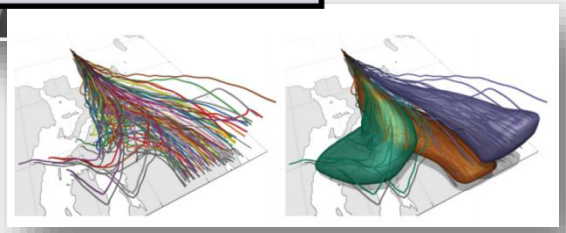
- 数据特点：多变量、多成员、时序、高维
- 数据量大



近年来集合模拟可视化相关文章数量趋势

集合模拟可视化分类

按位置

分析任务

概括全体模拟

基于位置的
不确定性可视化

比较单个成员

总结全体成员

分析策略

基于特征

基于特征的
比较可视化

基于特征的
不确定性可视化

按特征

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集合模拟数据的比较可视化

- 基于位置：研究不同成员在相同空间位置上的差异
- 基于特征：比较各成员的特征 (等值线、等值面、旋涡等)

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[1] H. Obermaier and K. I. Joy. Future challenges for ensemble visualization. IEEE CG&A, 2014

集合模拟数据的比较可视化

- 基于位置
  - 问题一：并排 (juxtaposition) 不容易定位差异的位置和大小
  - 解决一：重叠 (superposition) 或显示编码 (explicit encoding) 定位成员之间差异的位置和大小

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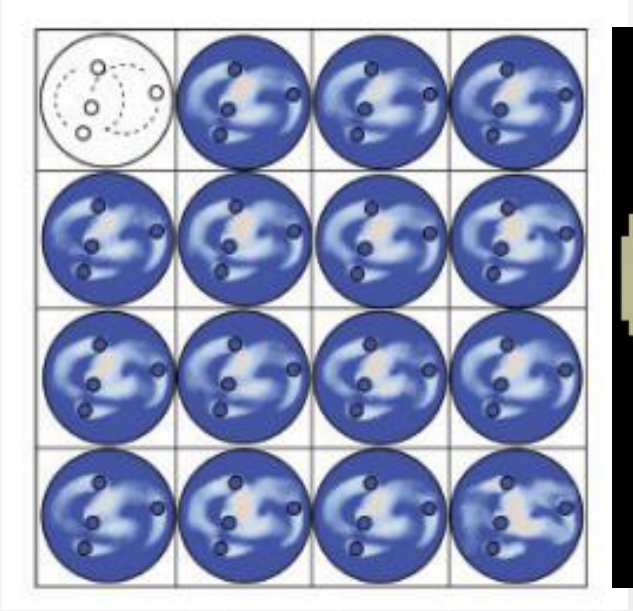
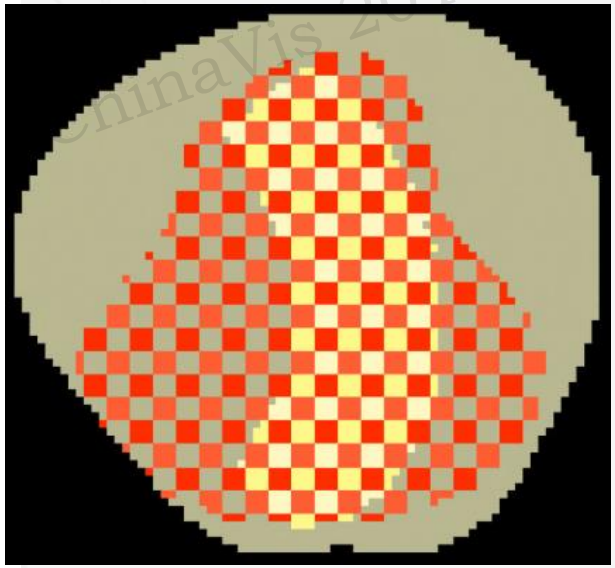
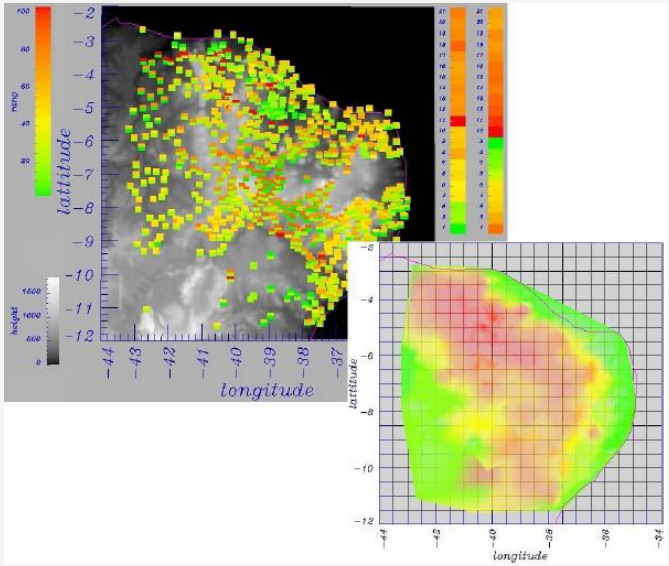


并列 [Obermaier et al., CG&A'14]



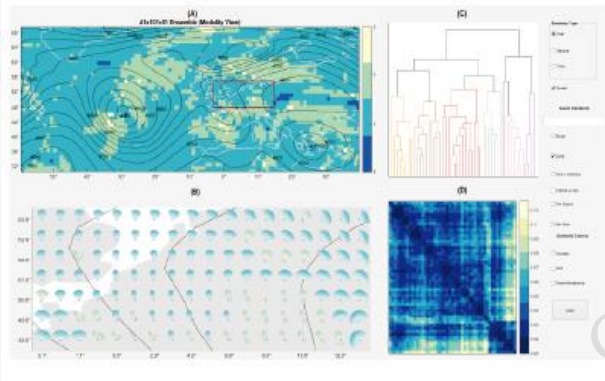
百叶窗叠加镶嵌 [Phadke et al., VDA'12]



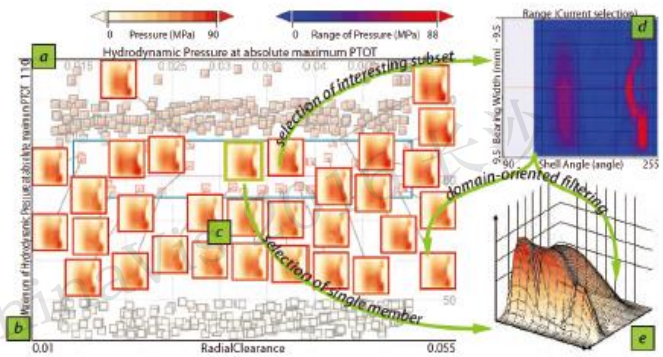
显示编码 [Nocke et al., 2007]

集合模拟数据的比较可视化

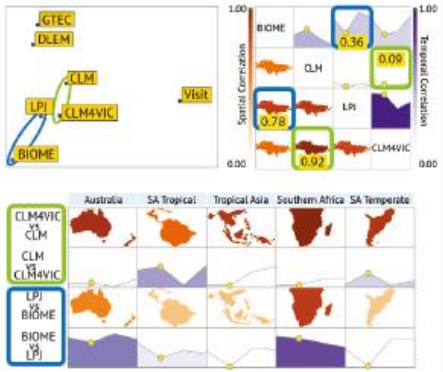
- 基于位置
  - 问题二：并排 (juxtaposition) 每次只能同时比较两个成员，不适合成员数很多的情形
  - 解决二：先计算成员之间相似性或使用降维聚类等，最后显示编码 (explicit encoding)



图标(glyph)编码相似性
[Jarema et al., VAST'15]

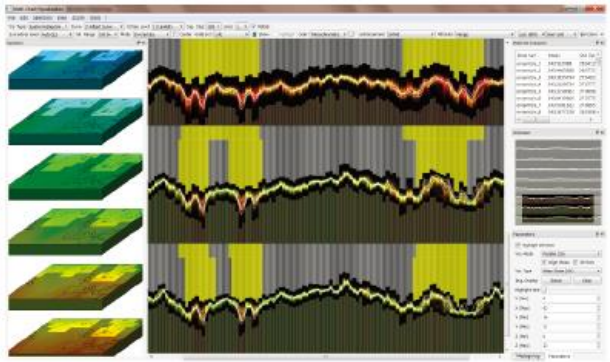


投影到2D分析相似性
[Piringer et al. CGF'12]

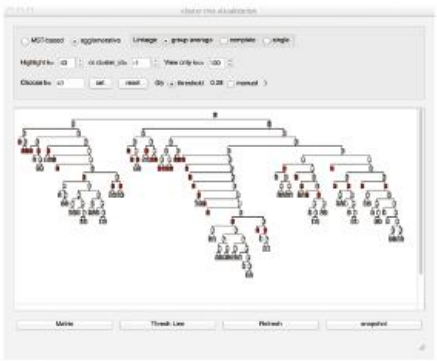


投影2D、矩阵视图相似性
[Poco et al., CGF'14]

EnsembleGraph [Shu et al., Pvis'16]



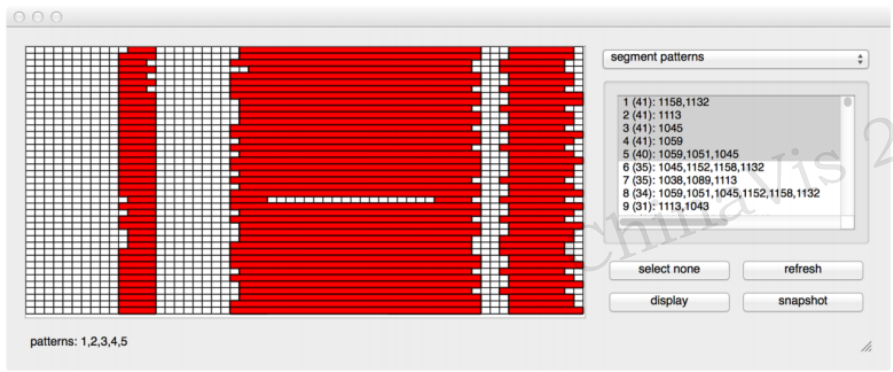
Multi-Charts [Demir et al., TVCG'14]



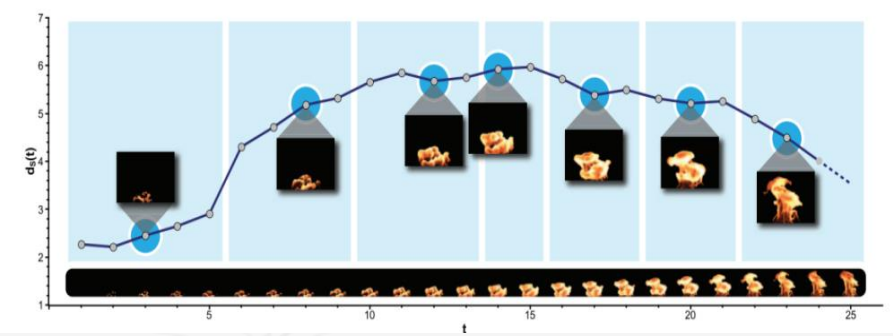
树形图 [Hao et al., TVCG'16]

集合模拟数据的比较可视化

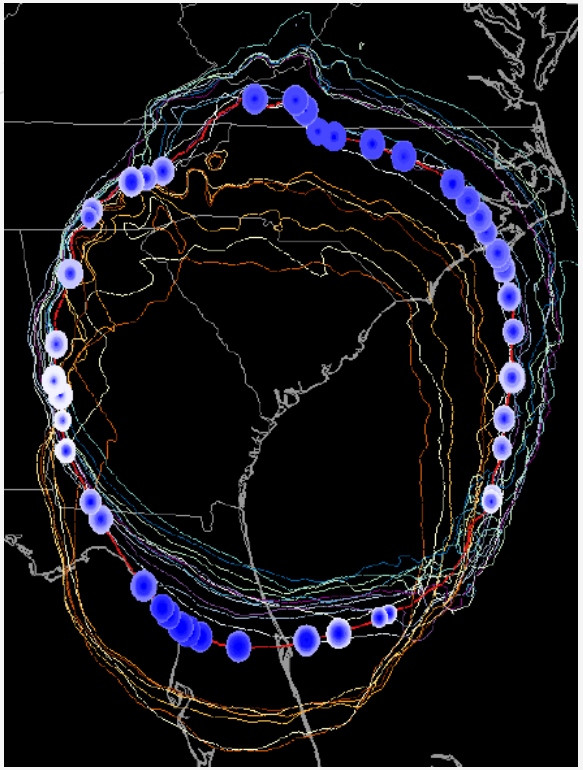
- 基于位置
  - 问题三：考虑时间维度后信息更庞大，比较难度大大增加
  - 解决三：针对时序的集合模拟数据的研究，比如从时间维度的聚集、从空间维度的聚集、和同时从时间和空间两个维度的聚集



时间上聚集 [Hao et al., TVCG'16]



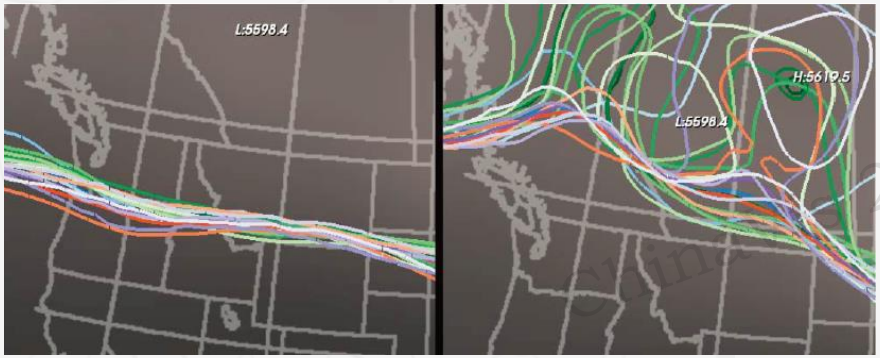
Clustering timeline: 时间空间聚集 [Bruckner et al., TVCG'10]



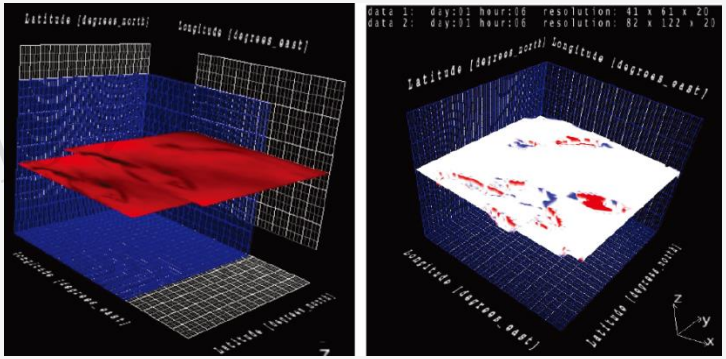
Noodles: 空间上聚集 [Sanyal et al., TVCG'10]

集合模拟数据的比较可视化

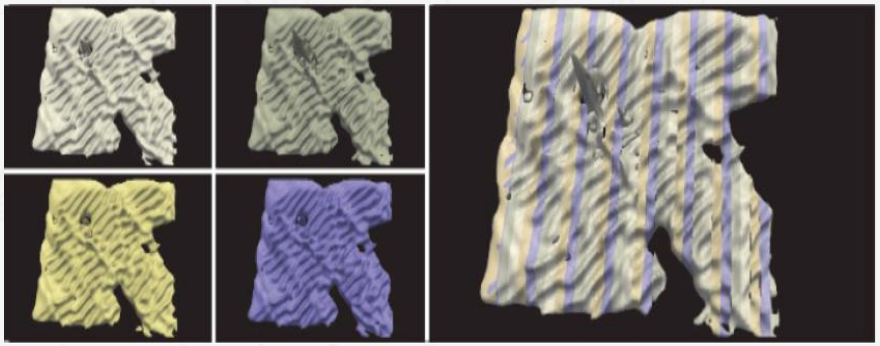
- 基于特征 (等高线、等值线、等值面、旋涡等)
  - 难点：怎样更好地提取特征，怎样呈现成员特征的差异
  - 解决：利用颜色、形状差异、切片重叠、交互等方法提取特征并比较



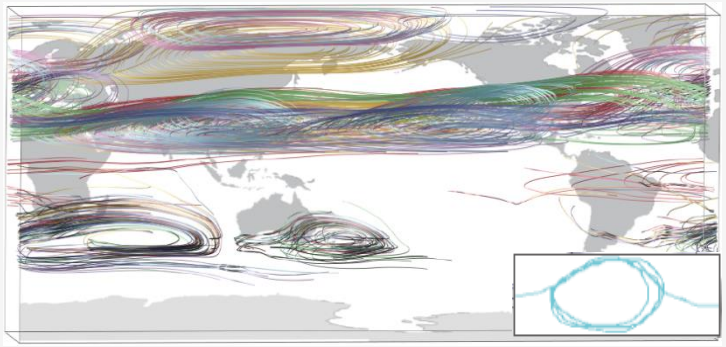
意大利面 (spagetti plot) [Silva et al., ISMRM 2000]



意大利面 (spagetti plot) [Nocke et al. 07]



切片等值曲 [Alabi et al., VDA'12]



基于手绘的旋涡提取比较可视化 [Liu et al., VHPC'15]

集合模拟数据的不确定性可视化

- 基于位置：描述空间位置上数据不确定性
- 基于特征：描述成员特征的不确定信息

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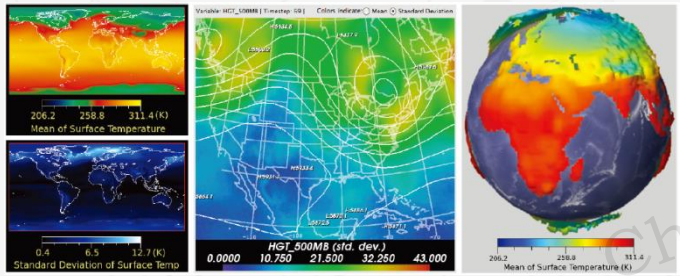
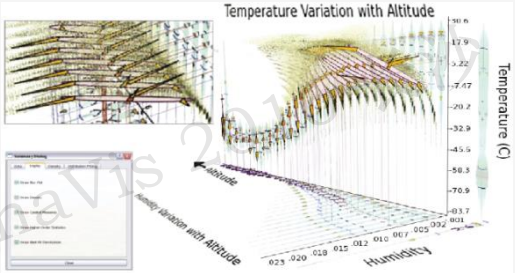
集合模拟数据的不确定性可视化

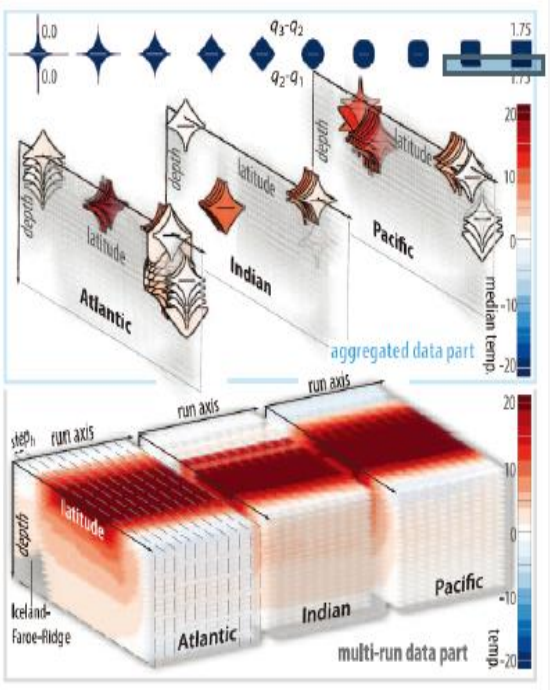
- 基于位置 (同一位置上多值数据的不同描述方法)
  - 统计值 (均值、方差、四分位数、置信区间)
  - 分布

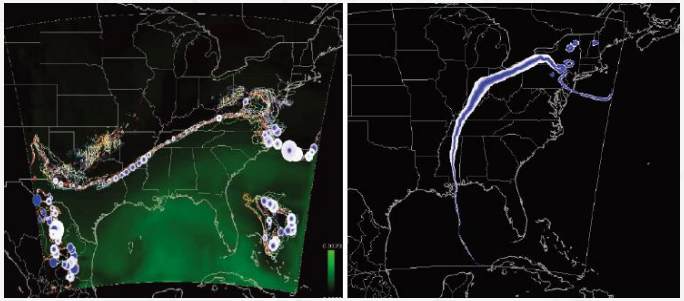


Ensemble-Vis [Potter et al., ICDM'09]

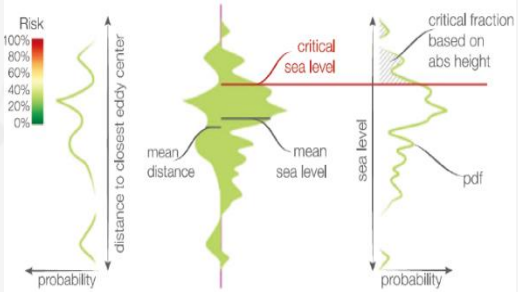


概括图 [Potter et al., CGF'10]





Noodles:基于图标与条带 [Sanyal et al., TVCG'09]

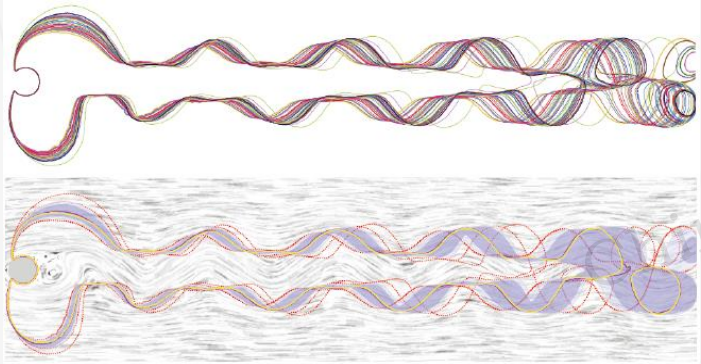


小提琴图[Hollt et al. TVCG'14]

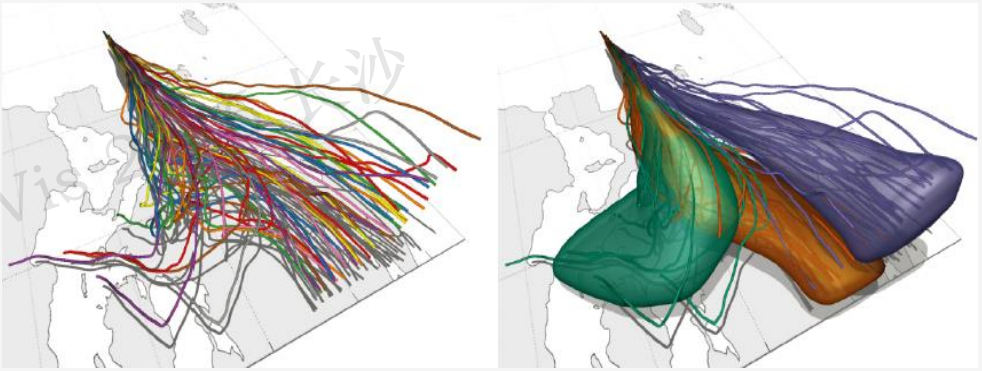
星状图图标不确定性可视化
[Kehrer et al. TVCG'11]

集合模拟数据的不确定性可视化

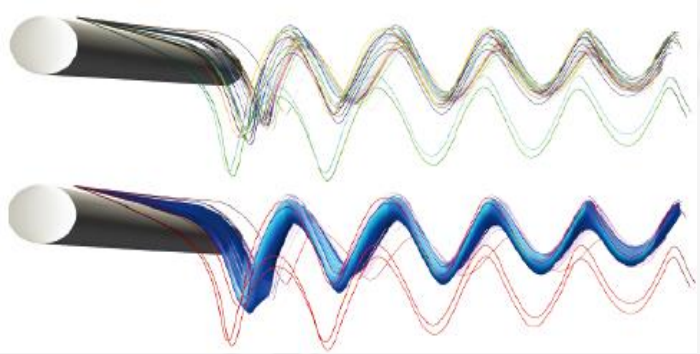
- 基于特征
  - 问题：有限的屏幕空间容纳过多的图形导致视觉混乱
  - 解决：借用盒图(boxplot) 表示成员平均趋势、异常值，或利用聚类方法概括集合成员



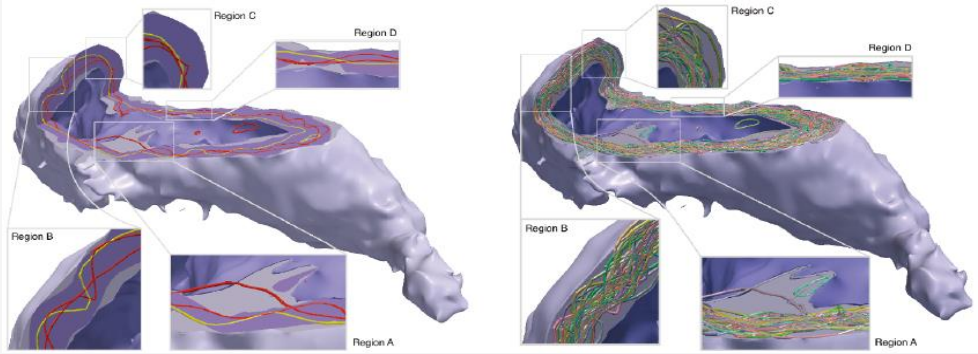
Contour boxplot, [Whitaker et al.,TVCG'13]



Streamline variability plots, [Mirzargar et al., TVCG'14]



Curve boxplot, [Ferstl et al., TVCG'16]



3D contour iso-surface, [Raj et al., CG&A'15]

总结

- 从比较可视化与不确定性度量两个角度调研了近年来集合模拟数据可视化方法
- 分别从基于位置与基于特征的两个角度总结

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Papers

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