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Key Eco-Hydrological Parameters Retrieval and Land Data Assimilation System Development in a Typical Inland River Basin of China¡¯s Arid Region

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In this presentation, we primarily report the results regarding land surface parameters inversion and progresses on the development of a catchment scale land data assimilation by using multi-source remote sensing data in the Heihe River Basin (HRB), China. Satellite observations are widely utilized in our project, and these abundant data sets paved the way for carrying out lots of dedicated and novel studies related to land surface parameters. A two-step retrieval scheme was proposed to acquire surface roughness and soil moisture (SM) based solely on multi-angular ENVISAT-ASAR data without ancillary information. And, the impact of SM dynamics on radar observed backscatters and its spatial variability were evaluated in the upstream of the HRB by using time series of ASAR data. To investigate the 3D heterogeneity of land surface and convective boundary layer, ENVISAT-AATSR data were used to derive land surface temperature (LST) and air temperature at the height of planetary boundary layer over the whole HRB. Besides, higher surface temperature was observed at nadir view than at off-nadir view by using the angular information from AATSR images, indicating anisotropy of the thermal emittance of the land surface, which is helpful to obtain a clear separation between soil and vegetation component temperatures. In addition, heat fluxes estimated from AATSR data were compared against in situ large aperture scintillometer (LAS) measurements to gain more insight of the error features between pixel sale and footprint. For the utilization of Chinese satellite remote sensing observations, works of time series analysis and gap filling LST records were performed towards FY 2 data. Within the TPM data group, based on the hybrid canopy reflectance model, a new hyperspectral directional second derivative method was proposed by using PROBA- CHRIS data. Another attempt was to assimilate regional LAI estimates that extracted from a CHRIS image that can contribute to remarkably improve the accuracy of simulated corn yields. And, a case study took place in the middle stream of the HRB demonstrated that soil moisture can be reliably estimated by combining the observations of K-band airborne passive radiometer and ALOS-PALSAR. By using other platforms (truck-mounted, ground station, aircraft etc.), fruitful observations were acquired to estimate/derive eco-hydrological parameters, e.g. precipitation, snow properties, evapotranspiration, canopy resistance, leaf chlorophyll content, bi-directional reflectance, albedo, effective LAI, vegetation coverage, land surface temperature and drought index. We have developed the Heihe data assimilation system (HDAS) to make use of these multi-source observations at the catchment scale in a land data assimilation framework for improved estimation of SM, soil temperature, ET, snow and streamflow on a 1 km grid basis with a temporal resolution of 1 hour. HDAS was developed in Python and C++ programming language and the time manager of Python was used to control the HDAS flow. Each module of the HDAS is designed separately and the external module can be easily integrated. The features of HDAS are as follows: evaluate different data assimilation algorithms, evaluate the strategies and impacts of the multi-source observations assimilation, the new version of model can be adapted with little modification to keep up to date and the high performance computation. The design goals of HDAS are off-line, high-resolution (up to 1km), catchment scale data assimilation system executed on highly parallel computing platforms, with well-defined standard conforming interfaces and data structures to interface and inter-operate with other Earth system models. HDAS contains eight key components: (1) Assimilation methodologies: from the direct insertion, the optimal interpolation, the variational method, the ensemble Kalman filter to the particle filter were implemented; (2) Parameters and forcing data perturbation: different perturbation methods can be used in the ensemble generation of model parameters and atmospheric forcing data, such as additive noise and multiplicative noise; (3) Sensitivity analysis: to identify the sensitive model parameters and model initial states for model calibration and assimilation; (4) Model operator: the Community Land Model CLM and NOAH were chosen because of their full capabilities in modeling of the land water and the energy cycles; (5) Observation operator: multi-source in situ observations, remote sensing observations and several microwave radiative transfer models were integrated; (6) Parallel computing: two different parallel approaches were implemented to meet the challenge of the high performance computation because of the detailed model spatial delineation; (7) Input and output: the NetCDF file format was used to manage all the input and output data efficiently; (8) Visualization: to present the scientific data in different plot manners (1D, 2D or 3D).

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中国干旱地区典型内陆河流域关键生态－水文参数的反演与陆面同化系统研究

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本文主要介绍了本项目在黑河流域利用多源遥感数据取得的有关陆面参数反演和流域数据同化系统研建方面的进展和结果。

卫星数据得到了广泛的应用，并为发展陆表参数反演方法提供了丰富的数据源。例如采用多角度的ENVISAT-ASAR数据，提出了两步骤的反演算法，从而可以不依赖其他辅助数据获得区域尺度的地表土壤水分和粗糙度分布信息。 利用时序ASAR数据，评估了黑河上游研究区内雷达后向散射系数对土壤水分变化及其空间变化特征的响应。为了更好地理解地表3维方向的异质性和边界层信息，利用ENVISAT-AATSR数据获得了全流域的地表温度和行星边界层高度的空气温度。此外，通过分析多角度的AATSR的影像发现天底方向观测得到的地表温度要高于非天底方向的观测，显示出了地表发射的各向异性，从而有助于明确地分离地表和植被层的组分温度。通过比较大孔径闪烁仪（LAS）的观测和从AATSR影像估算得到的感热通量，可以更加深入的了解地面观测足迹与遥感像元之间的误差特征。对国产的风云2号卫星数据，我们也开展了时间序列分析和对地表温度产品的补缺的工作。对第三方（TPM）数据的应用也有较多进展，如针对现有二阶微分方法反演LAI时对遥感数据中的随机噪声敏感，精度不高的现状，利用PROBA-CHRIS数据，发展了一个新的高光谱方向性二阶微分方法，通过分析冠层的异质性来提高LAI的反演精度。此外，我们也尝试了将从CHRIS影像反演得到的区域尺度的LAI产品同化到作物生产力模型中，从而显著改善了估产的准确性。在黑河中游，通过结合K波段机载微波辐射计和ALOS-PALSAR的观测可以有效地获得地表土壤水分的准确估计。

通过其他平台的遥感观测（如车载、站点和航空），亦获得了丰富的观测数据，从而促进了大量针对生态-水文参数的反演/估算工作的开展，如降水、积雪特性、蒸散发、冠层阻抗、叶绿素含量、二向反射特性、反照率、有效LAI、植被覆盖度、地表温度和干旱指数。

在"黑河综合遥感联合观测试验"的支持下，利用多源遥感数据，我们发展了黑河数据同化系统（HDAS）。该系统的目标是获得更加可靠的地表参数、水文循环变量（如土壤温度与水分、蒸散发、地表径流和雪水当量等）的估算，以期更好的支持流域水资源管理和高效利用。该系统设计空间分辨率为1 km，时间分辨率为1小时，基于Python和C++语言。

HDAS是灵活的模块化设计，每个模块都是独立的，而且外部的模块可以很容易的集成到整个系统中。HDAS可以评估不同的同化算法、多源数据同化策略及其影响；能够适应新模型的不断融入和不断提高的计算效能。HDAS的总体设计目标是离线、高分辨率、流域尺度、并行计算、并提供标准化的接口以便与其他地学模型关联/互操作。

HDAS包括八个关键组成部分：（1）数据同化方法：采用连续修正、优化插值、变分、集合卡尔曼滤波和粒子滤波；（2）参数和大气驱动扰动：在模型参数和驱动数据的集合生成过程中施以不同的扰动影响，如加性和乘性噪声；（3）敏感性分析：寻找在模型标定和同化过程中最为敏感的模型参数和初始状态变量；（4）模型算子：考虑到对陆地能水循环的综合模拟能力

选用CLM和NOAH模型；（5）观测算子：多种微波辐射传输模型以针对多源的地面和遥感观测；（6）并行计算：对因高时空分辨率带来的高性能计算需求采用两种不用的并行计算方法；（7）输入输出数据：采用NETCDF格式以保证较高的输入输出效率；（8）可视化：通过不同样式的图表生动的展示计算、数据分析过程和运行结果（1D，2D和3D）。