



引進Noah-MP LSM至中央氣象署短期氣候預報系統（CWACFS）之模擬與評估

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OUTLINE

- ☁ CWA/CFS 系統大氣模式(T_{Co199})概況
- ☁ NOAH-MP LSM簡介
- ☁ 個案測試結果與調整
- ☁ 結論與未來規劃

將 NOAH 升級至 NOAH-MP 的好處包含：

- 1.物理架構精細化：植被冠層與表層土壤獨立計算，能更精準地分配地表能量與水分。
- 2.多層雪模組升級：導入細緻的積雪壓實力學與相變機制，大幅強化雪水當量 (SWE) 模擬。
- 3.引入動態植被：結合碳循環 (GPP/NPP)，使植被特徵能隨氣候環境真實生長與反饋。
- 4.多物理參數化：提供多種運算選項組合，大幅提升跨地理環境的適應力與實驗調校彈性。

CWA/CFS 系統大氣模式(T_{Co}199)概況

☁ 大氣

模式: CWAGFS-T_{Co}(global)

解析度: 水平約55公里, 72層 (T_{Co}199L72)

☁ 預報長度

12 months

	T _{Co} 199 physics
輻射	RRTMG (Iacono et al., 2008)
邊界層	hybrid EDMF (Han et al., 2016)
陸表	Noah LSM (Chen et al., 1996; Koren et al., 1999; Ek et al., 2003)
地形重力波 拖曳	Kim and Arakawa (1995); Lott and Miller(1997) Stationary convectively forced gravity wave drag (Chun and Baik, 1998)
積雲	scale-aware Simplified Arakawa-Schubert (sa-SAS ; Han et al., 2017)
微物理	GFDL cloud microphysics v2 (Chen and Lin (2013))



NOAH-MP 陸表模式簡介

Noah with Multi-Physics Land Surface Model Overview

NOAH-MP 是一個先進的陸表模式，旨在精確模擬大氣與陸地之間的**水分**、**能量**與**碳循環**交換。其最大的特色在於「多重物理參數化 (Multi-Physics)」框架，允許使用者針對特定的物理過程切換不同的運算方案，以適應全球各種複雜的地理與氣候環境。

核心物理過程

大氣邊界條件與湍流交換

大氣與地表交互作用

接收外部大氣強迫資料
(例如 T_{Co} 模式所產生的氣象場)

Monin-Obukhov
Similarity Theory

動量 (Momentum)
可感熱 (Sensible Heat)
潛熱 (Latent Heat)

植被動力學與冠層物理

動態植被與冠層

透過模擬光合作用的
總初級生產量 (GPP) 與淨初級生
產量 (NPP)

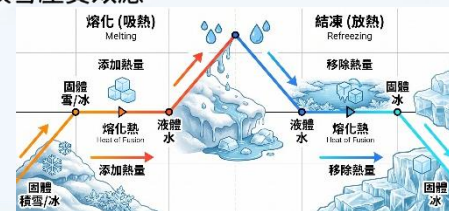


多層雪物理過程

精準積雪模型

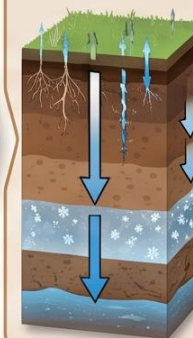
最高三層的積雪模型

- 相變 (融化與再結凍)
- 反照率 (Albedo) 動態衰減
- 積雪壓實效應



多層土壤與水文傳輸

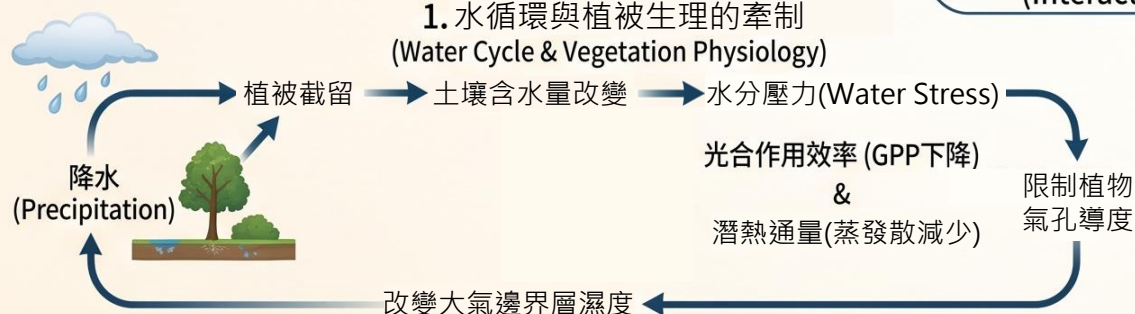
土壤與水文傳輸



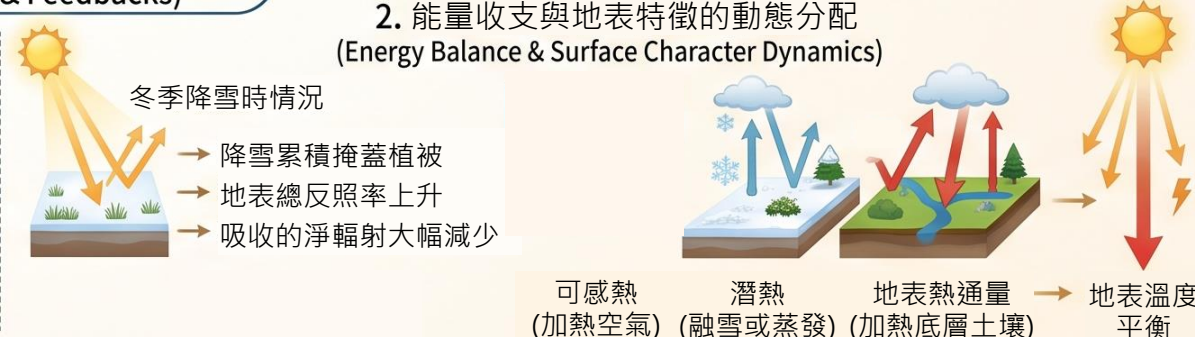
模擬深層土壤的熱傳導與水分下滲，包含凍土的透水性限制、地下水位變化與基流產生。
特定參數如地表阻抗 (Ground Surface Resistance) 與土壤熱傳導係數，更是控制乾燥地區或熱帶雨林局地日夜地表溫度偏差的關鍵因子。

過程間的交互作用與反饋 (Interactions & Feedbacks)

1. 水循環與植被生理的牽制 (Water Cycle & Vegetation Physiology)



2. 能量收支與地表特徵的動態分配 (Energy Balance & Surface Character Dynamics)



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Edit from Nano Banana 2

NOAH-MP 陸表模式簡介

Noah with Multi-Physics Land Surface Model Overview

☁ 物理過程選項

● Vegetation and near surface

iopt_dveg	dynamic vegetation
iopt_crs	canopy stomatal resistance
iopt_sfc	surface layer exchange coeff.
iopt_diag	thermal roughness
iopt_trs	thermal roughness

● Surface

iopt_rad	radiation transfer
iopt_alb	snow surface albedo
iopt_snf	rainfall & snowfall
iopt_run	runoff and groundwater

● Soil

iopt_btr	soil moisture factor for stomatal resistance
iopt_inf	frozen soil permeability
iopt_frz	supercooled liquid water
iopt_tbot	lower boundary of soil temperature
iopt_stc	1 st layer snow/soil temperature time scheme



個案測試結果與調整

☁ 初始時間：2025.01.01.00Z

☁ 模擬時長：365days

陸表模式	實驗名稱	描述
Noah LSM	NOAH	目前所使用之陸表模式設定
Noah-MP LSM	NOAHMP	更新為Noah-MP LSM
	NOAHMP_res	修改陸冰反照率之Noah-MP LSM
	NOAHMP_res_bare	修改陸冰反照率與裸地及稀疏灌木叢的地表參數之Noah-MP LSM
	NOAHMP_res_mix	基於上述修改再調整其他參數之Noah-MP LSM

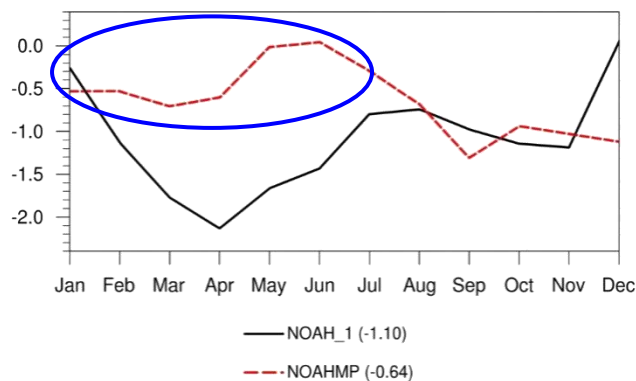


個案測試結果與調整

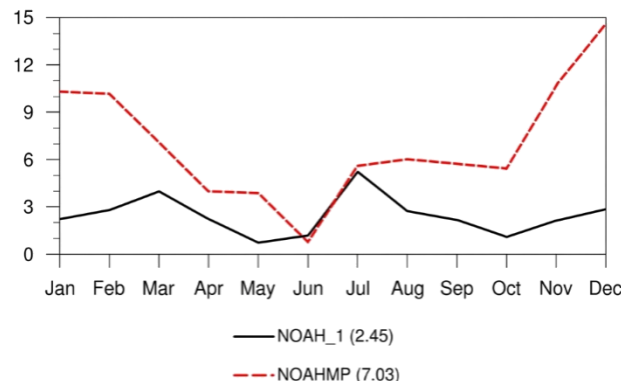
Noah-MP LSM與Noah LSM地面溫度預報差異

1. Noah LSM在夏季地面溫度預報表現較佳
2. Noah-MP LSM在前半年的地面溫度誤差較低
3. Noah-MP LSM在南極大陸夏季有明顯地面溫度正偏差

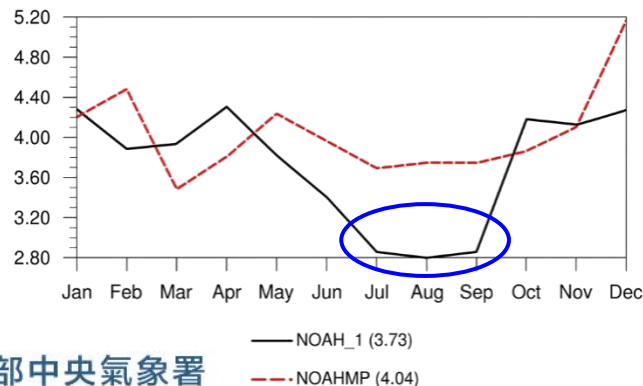
SKT BIAS (to ERA5, 60S-80N)



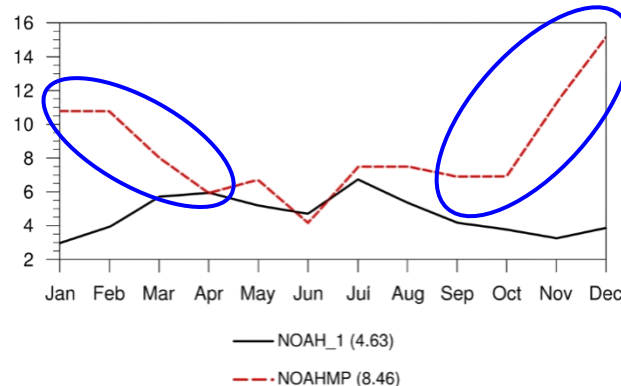
SKT BIAS (to ERA5, 90S-60S)



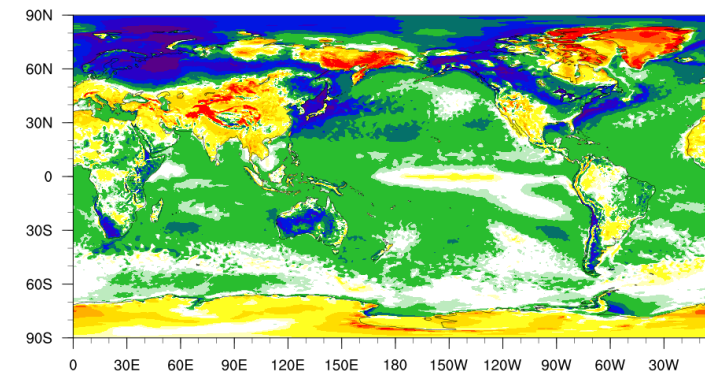
SKT RMSE (to ERA5, 60S-80N)



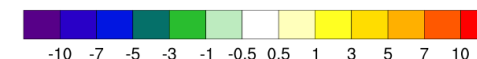
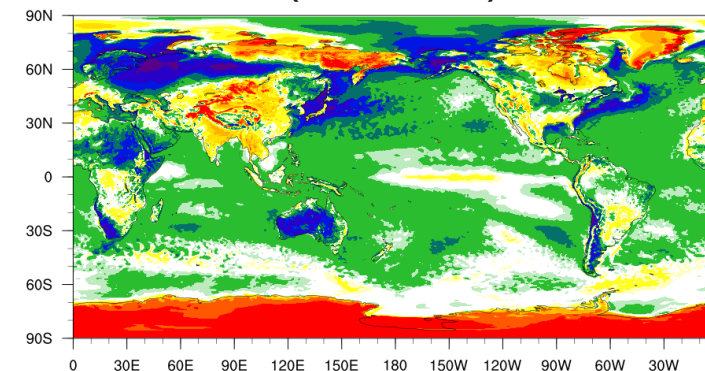
SKT RMSE (to ERA5, 90S-60S)



[Jan] Mean Surface Temp Diff
(NOAH - ERA5)



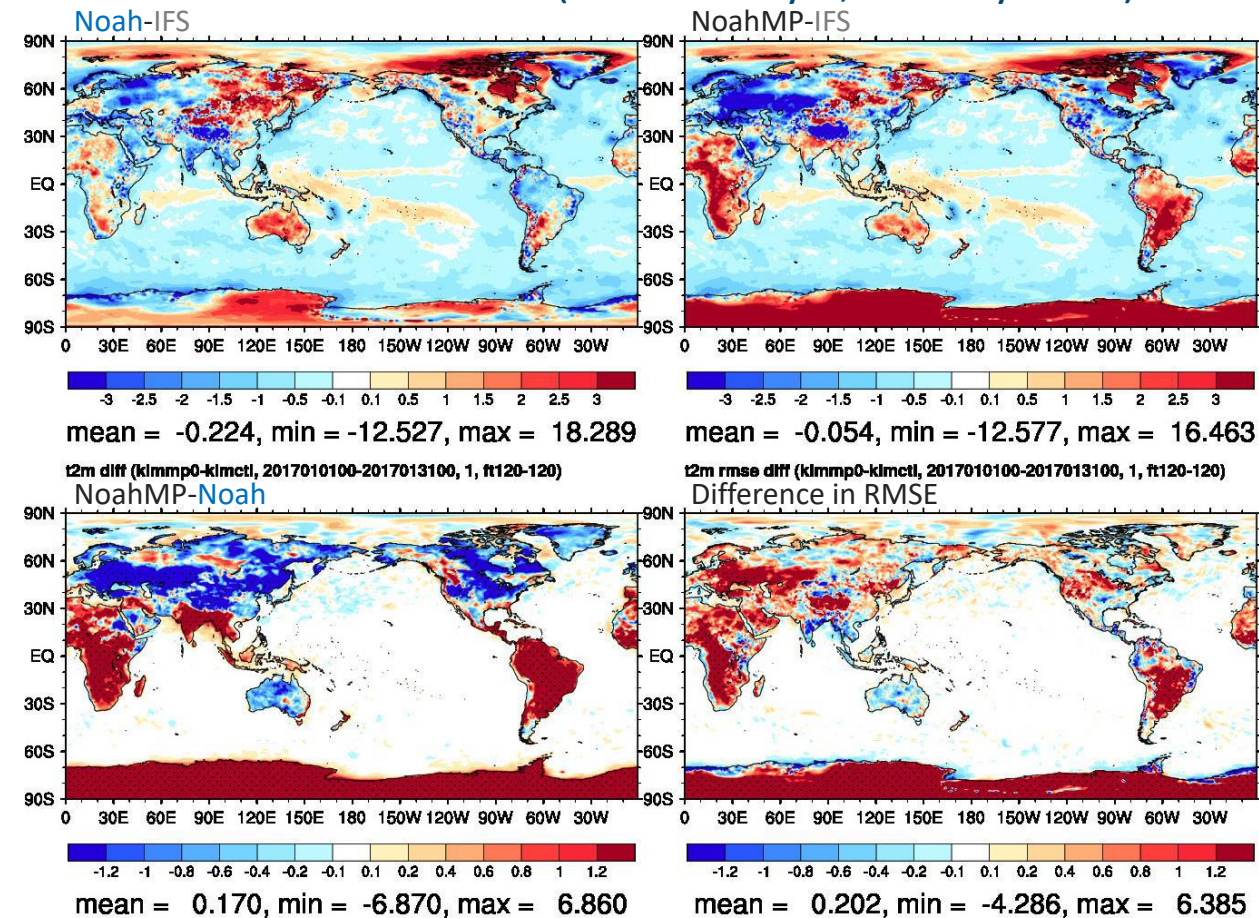
[Jan] Mean Surface Temp Diff
(NOAHMP - ERA5)



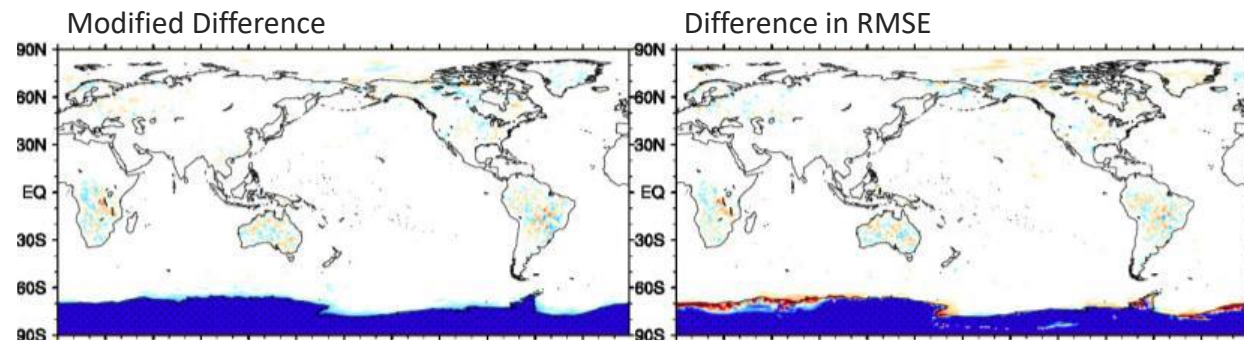
個案測試結果與調整

Noah-MP LSM在南極大陸的地面溫度預報修正

Noah vs. Noah-MP in KIM (forecast day 5, January 2017)



根據 [Korea Institute of Atmospheric Prediction Systems \(KIAPS\)](#) 研究顯示，南極大陸在南半球夏季有嚴重暖偏差(iopt_alb=1 (BATS scheme))
KIAPS解決方法：將glacier ice上的snow albedo固定為0.82(與NOAH設定相同)



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個案測試結果與調整

Noah-MP LSM在南極大陸的地面溫度預報修正

1. 測試過兩種雪反照率參數化，均有明顯地面溫度正偏差
2. 選用CLASS scheme(iopt_alb=2)能直接調整參考雪反照率值
3. 明顯改善南極大陸夏季地表溫度過高問題

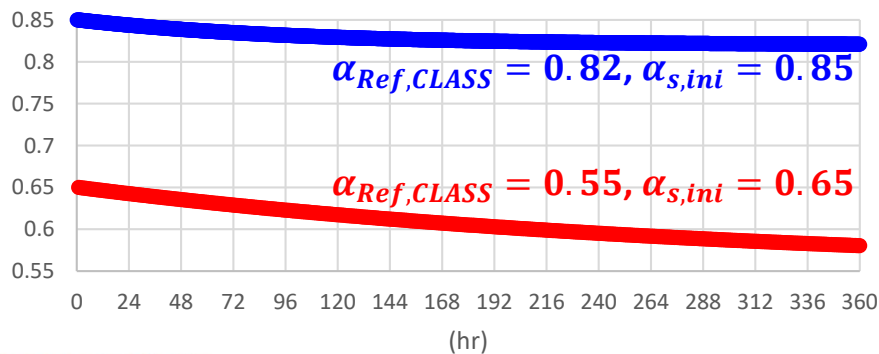
CLASS scheme (Verseghy, 1991) (iopt_alb=2)
雪反照率(α_s) :

$$\alpha_s = \alpha_{Ref,CLASS} + (\alpha_{s,p} - \alpha_{Ref,CLASS}) \times e^{\frac{-0.01 \times \Delta t}{S_{a,c}}}$$

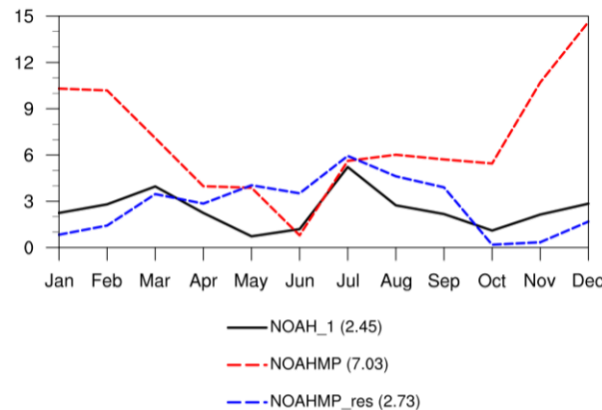
當地表降雪率(Q_{snow} [mm/s])大於零時 :

$$\alpha_s = \alpha_s + \min\left(Q_{snow}, \frac{m_{snow, mx}}{\Delta t}\right) \times (\alpha_{s,CLASS} - \alpha_s)$$

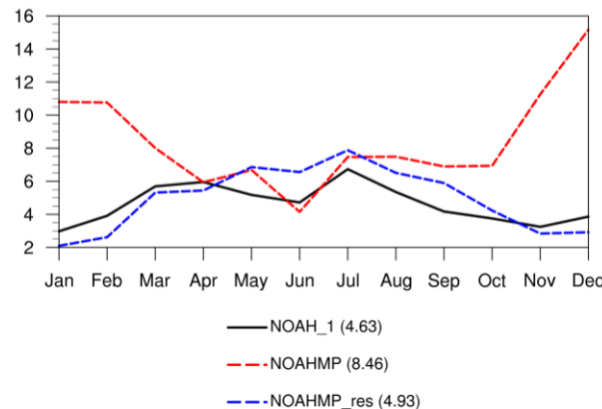
在無新降雪狀態下snow albedo隨時間變化



SKT BIAS (to ERA5, 90S-60S)



SKT RMSE (to ERA5, 90S-60S)



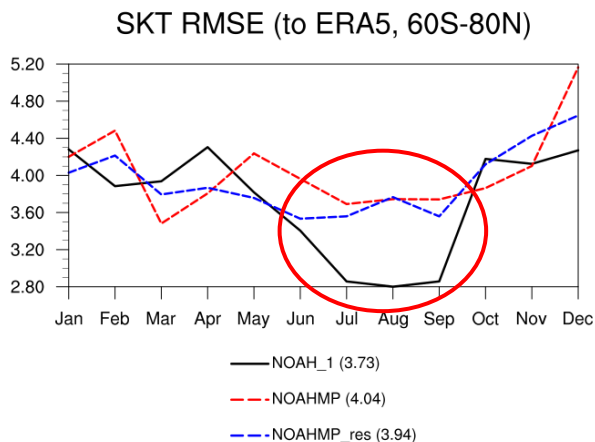
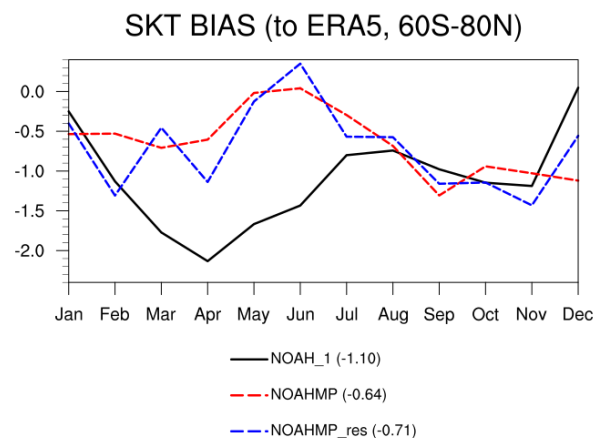
$\alpha_{Ref,CLASS}$: reference snow albedo in the CLASS scheme
 $\alpha_{s,p} / \alpha_{s,ini}$: snow albedo from previous/initial time step
 $S_{a,c}$: snow aging e-folding time in the CLASS scheme [s] (3600)
 $m_{snow, mx}$: new snow mass to fully cover old snow [mm] (1.0)
 $\alpha_{s,CLASS}$: fresh snow albedo in the CLASS scheme (0.84)



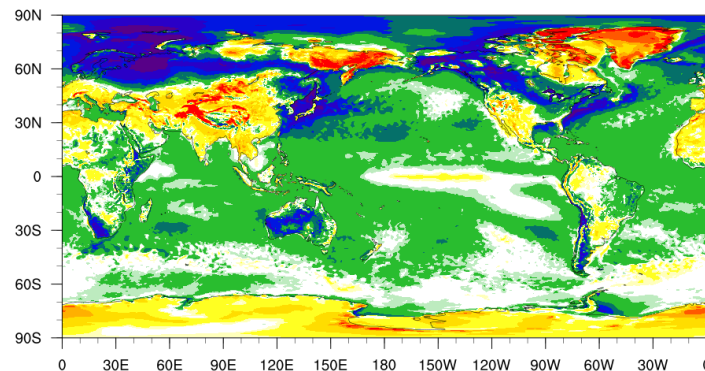
個案測試結果與調整

Noah MP LSM與Noah LSM地面溫度預報差異

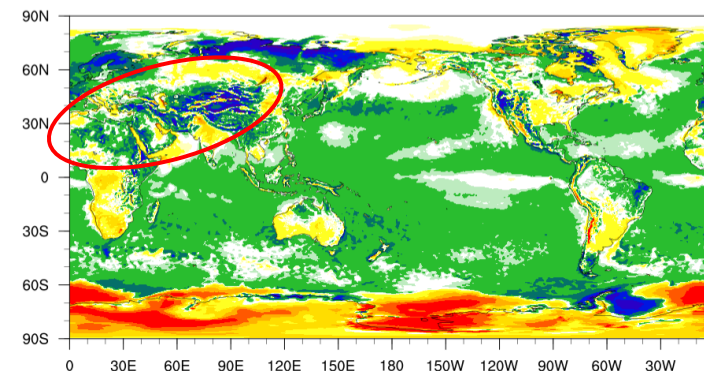
1. Noah-MP LSM在夏季有明顯地面溫度負偏差，主要來自於裸地與稀疏灌木叢



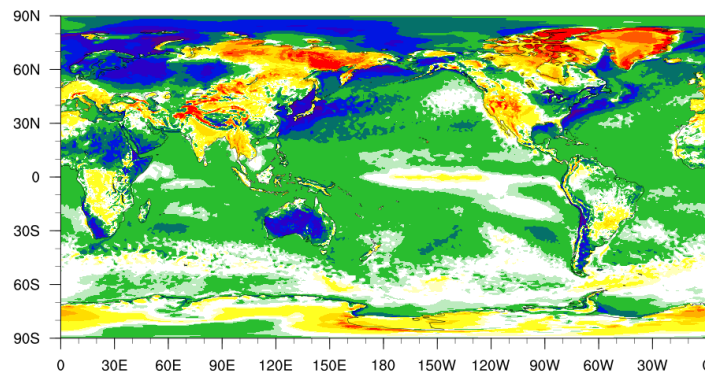
[Jan] Mean Surface Temp Diff
(NOAH - ERA5)



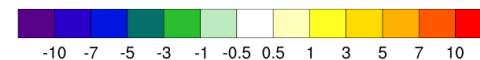
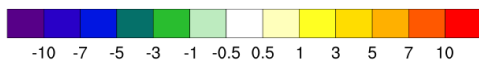
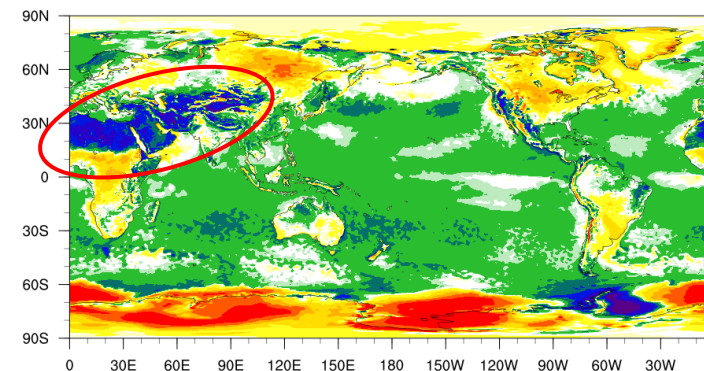
[Jul] Mean Surface Temp Diff
(NOAH - ERA5)



[Jan] Mean Surface Temp Diff
(NOAHMP_res - ERA5)



[Jul] Mean Surface Temp Diff
(NOAHMP_res - ERA5)

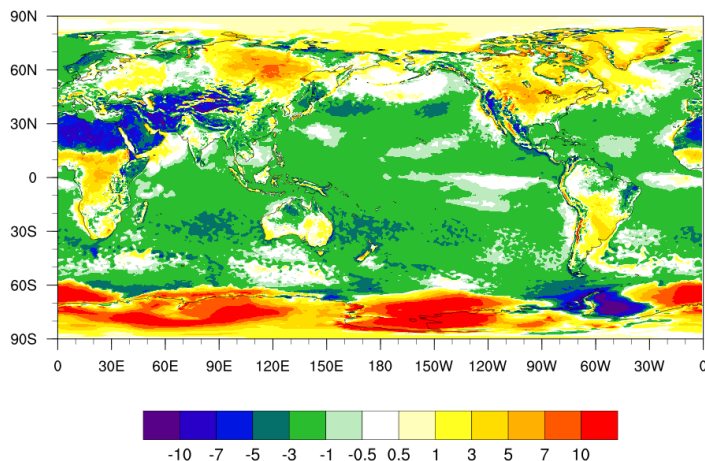


個案測試結果與調整

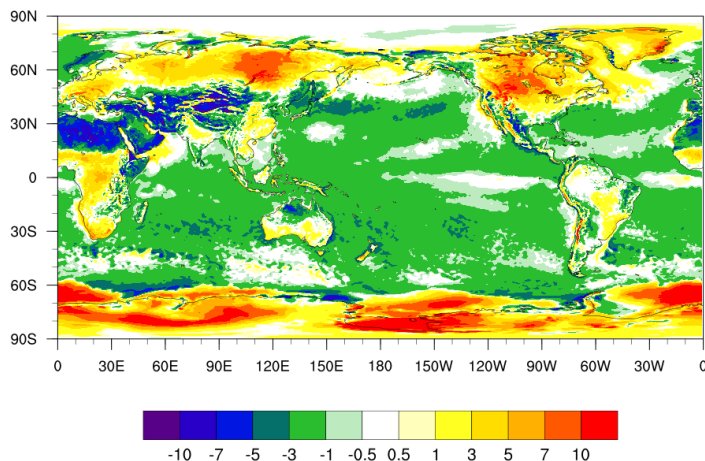
Noah-MP LSM在裸地與稀疏灌木叢的地面溫度預報修正

1. 將裸地與稀疏灌木叢的地表發射率由0.97降至0.90，減少能量以長波形式逸散至大氣
2. 稀疏灌木叢的LAI(leaf area index)與SAI(steam area index)減半，減少植物對地表溫度的影響
3. 將淺色土壤處(沙地、含水量較少的土地)的反照率降低，減少短波輻射反射回大氣

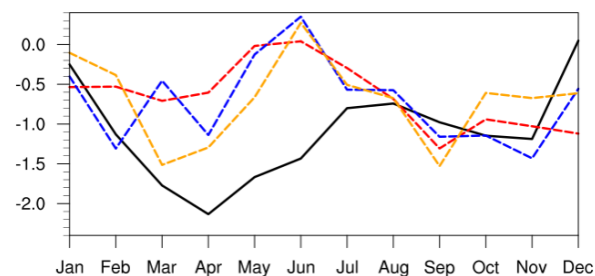
[Jul] Mean Surface Temp Diff
(NOAHMP_res - ERA5)



[Jul] Mean Surface Temp Diff
(NOAHMP_res_bare - ERA5)

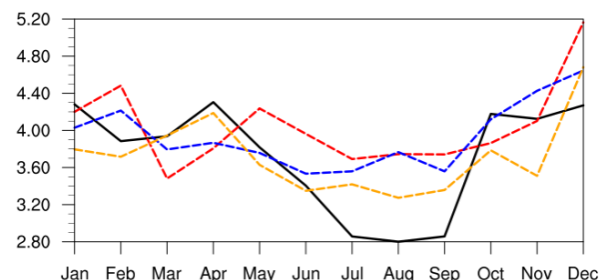


SKT BIAS (to ERA5, 60S-80N)



— NOAH (-1.10) - - - NOAHMP_res (-0.71)
- - - NOAHMP (-0.64) - - - NOAHMP_res_bare (-0.69)

SKT RMSE (to ERA5, 60S-80N)



— NOAH (3.73) - - - NOAHMP_res (3.94)
- - - NOAHMP (4.04) - - - NOAHMP_res_bare (3.72)

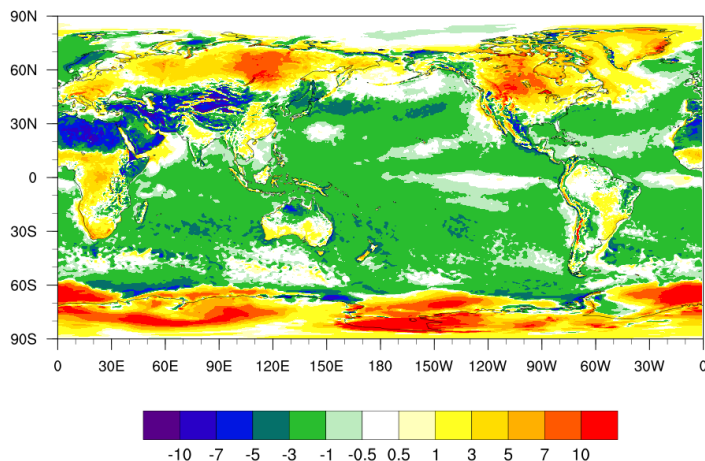


個案測試結果與調整

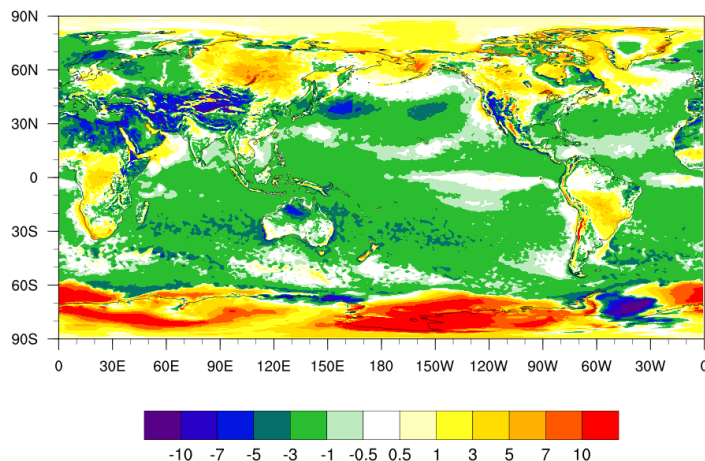
Noah-MP LSM整體參數調整對地面溫度預報修正

1. 提升乾燥土壤地區土壤熱導率、動力粗糙長度(針對裸地與稀疏灌木叢的地表溫度冷偏差)
2. 增加森林地區LAI、動力粗糙長度、雪衰減效應、植物氣孔光照敏感度、植物氣孔最小阻力(針對高緯度地區雪融期及夏季地表溫度暖偏差)

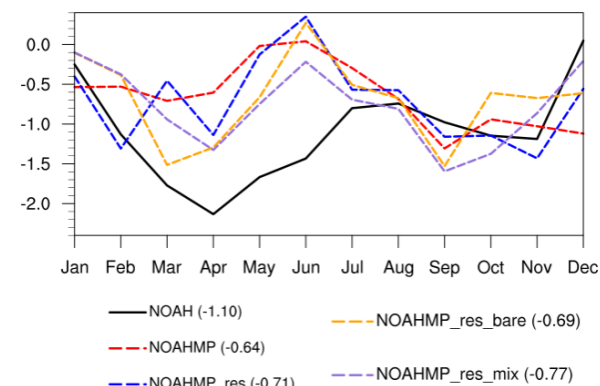
[Jul] Mean Surface Temp Diff
(NOAHMP_res_bare - ERA5)



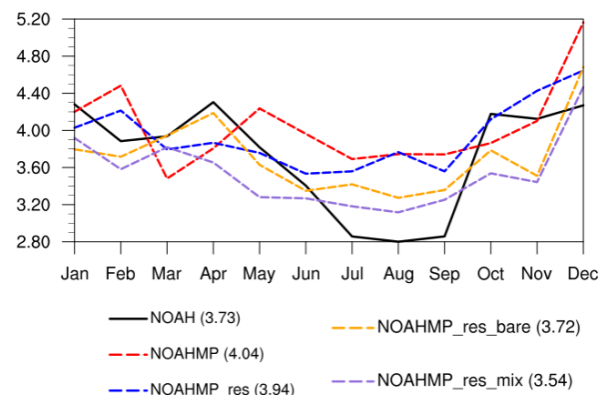
[Jul] Mean Surface Temp Diff
(NOAHMP_res_mix - ERA5)



SKT BIAS (to ERA5, 60S-80N)



SKT RMSE (to ERA5, 60S-80N)



結論與未來規劃

- ☁ 原版本Noah-MP LSM在南極大陸有明顯地表溫度高估、在裸地與稀疏灌木叢區有明顯地表溫度低估的情況。
- ☁ 透過改變雪反照率、土壤反照率、地表發射率、葉/樹幹面積指數、動力粗糙長度、雪衰減效應、植物氣孔光照敏感度、植物氣孔最小阻力等，有效降低地表溫度預報偏差。
- ☁ 進行整月預報以確認修改方向無誤。
- ☁ 更新Noah-MP LSM版本至v5.x。



END



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