Climate change impact on water resources in several regions of the world. A European, Asian and African case study using CHyM hydrological model. Problems and challenges

E. Coppola <sup>(1)</sup>

L. Mariotti <sup>(1,2)</sup>, X. Gao <sup>(3)</sup>, ES.Im <sup>(1)</sup>, and F. Giorgi <sup>(1)</sup>

(1) The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy
(2) National Climate Center of CMA, China,
(3) CETEMPS, University of L'Aquila, Italy
(coppolae@ictp.it)







#### Temperature and Precipitation mean change









•Accurate assessment of the potential impacts of climate change on societies and ecosystems requires regional- to local-scale climate change information

•However, information about fine-scale climate change and its uncertainties is currently very sparse due to the lack of a coordinating framework

•Fine-scale climate factors (topography and land cover) modulate regional and local climate changes and dictate impacts on various sectors, including water resources

•We are starting the framework using the ICTP-based RegCNET network (Giorgi et al, 2006), the RegCM3 RCM (Pal et al. 2007), and the CMIP3 AOGCM ensemble (Meehl et al. 2007). We cover the geographic uncertainty dimension with six continental-scale domains (North and Central America, South America, Europe, Africa, Central Asia, and South and East Asia) at 25 km grid spacing, a state-of-the-art resolution for long-term RCM experiments. Regional Climate Change (RCC) Hyper-Matrix framework (Giorgi et al., EOS, 2008)



LIFE





## CHyM: Drainage network test



ÎM

# CHyM: Drainage network test

| N.F.         | 35 147                 | Ø 1368              | 1390 | 1522 | 1365 | 1413  | 1437 | 1437 | 1498 | 153Ø | 1561         | 1729 | 179Ø | 181Ø | 181Ø | 185Ø | 1813  | 1906 | 193Ø |       |
|--------------|------------------------|---------------------|------|------|------|-------|------|------|------|------|--------------|------|------|------|------|------|-------|------|------|-------|
| TA 3         | 1630 <mark>154</mark>  | Ø 1425              | 1347 | 1290 | 133  | 1406  | 1415 |      | 1435 |      |              |      | 1637 |      | 1678 | 1756 | 1766  | 1840 | 1895 |       |
| The second   | 1577 <mark>157</mark>  | 7 1480              | 1384 | 1273 | 1316 |       |      | 14Ø9 | 14Ø9 | 1453 | 1474         |      |      |      | 1630 | 1630 | 158Ø  |      | 1825 | 14    |
| anon:        | 1568 <mark>15</mark> 6 | 8 1488              |      | 1310 | 1289 | 1325  |      | 1360 |      | 1385 | 1 297        |      |      | 1579 | 156Ø |      | 1537  |      | 1611 |       |
| 12           | 1524 144               | 3 1443              |      |      |      | 1285  | 1325 |      |      | 1344 | 1349         | 1 81 |      | 1470 |      |      | 15 17 | 1528 | 1595 |       |
| 190          | 1440 141               | 2 14 2              | 1397 | 1388 |      | 1/2   | 1286 |      |      | 1350 | 1346         | 136  |      |      |      |      | 15    | 1557 | 1570 |       |
| 5            | , 125 145              | 453                 | 1453 | 1362 | 1263 | 1 199 | 1279 |      |      |      | 1381         | 1360 | 1371 |      | 1490 | 1602 | 1604  | 16Ø4 | 1580 | 12 19 |
| and a second | 1445 <mark>14</mark> 3 | 2 1401              | 1325 | 1325 | 1285 | 14    | 1279 | 1280 | 1326 |      |              | 139  | 1375 |      | 1453 | 1588 | 1596  | 1550 | 1550 | - Th  |
| a            | 1380 138               | 233                 | 1292 | 292  | 1290 | 1287  |      | 1279 | 129Ø | 1348 |              | 1414 | 1395 | 1386 | 1375 | 1410 |       | 1423 | 1439 | 21/2  |
| Re l         | 1437 131               | 11298               | 1298 | 195  | 1295 | 1292  | 1288 |      | 1277 | 1300 | 1078<br>1078 | 1368 | 1395 | 1393 | 1351 | 1074 | 1360  |      | 1310 |       |
|              | 1003 136               | 0 1424              | 1351 | 1318 | 1297 | 1297  | 1292 | 1286 |      |      |              | 1268 | 1265 |      | 1295 | 1274 | 1289  | 1224 | 1307 |       |
|              | 1450 145               | 0 1521              | 1487 | 1399 | 1270 | 1204  | 1290 |      |      |      |              | 1261 | 1257 | 1257 | 1252 | 1247 | 1251  |      | 1365 |       |
| -1           | 1435 147               |                     |      | 1473 | 1360 | 1320  |      |      |      |      |              | 1257 | 1255 | 1251 | 1251 | 1248 | 1244  | 1276 | 1370 |       |
| -            | 1580 <mark>160</mark>  | 7 1619              |      | 1552 | 145  |       | 112  |      |      |      |              | 1252 | 1249 |      | 1245 | 215  | 1244  | 1252 | 1300 |       |
| A.           | 1545 162               | 2                   | 1645 | 1587 | 1548 | 1508  | 1462 |      |      | 1295 |              | 1255 | 1246 |      | 1744 | 1244 | 1244  | 1243 | 127Ø |       |
| 2            | 1570 <mark>157</mark>  | <mark>Ø</mark> 1646 | 1690 |      |      | 1548  |      | 1457 | 144Ø | 1360 | 1344         |      |      |      | 243  | 1243 | 1243  | 1243 | 1251 |       |
|              | 1591 162               | 8 1628              | 1676 | 1715 | 1697 | 1638  | 1545 |      | 15Ø9 |      |              | 1354 | 1289 | 1246 | 1244 | 1243 | 1243  | 1242 | 1242 |       |
| .6.6         | 1656 <mark>17</mark> 8 | 2 1702              | 1690 | 1700 | 1759 | 1714  | 1657 | 1581 | 1512 | 1512 | 1458         | 142Ø | 1379 | 1348 | 1745 | 1244 | 1245  | 1245 | 1242 |       |
|              | 1676 171               | 3 1726              | 1726 | 17ØØ | 1714 | 1742  | 1723 | 1648 | 1552 | 1552 | 15Ø8         | 1462 | 1437 | 1428 | 137, | 1282 | 1266  | 1266 | 1244 |       |
|              | ทห                     |                     | N    |      |      | NE    |      | E    |      |      | SE           |      | S    |      |      | รห   |       | v    |      |       |
|              |                        |                     |      | -    |      | 1     | 19   |      | 4    |      |              |      |      |      | 6    |      |       |      |      | 9     |

IIII

P







DEM Smooting Algorithm 1 (DSA1)

DEM Smooting Algorithm 2 (DSA2)





## CHyM: DEM pit correction



CETEMPS Hydrological Model Preprocessor



Flow Direction Map - 6633 of 6633 no-flow points were corrected.





## CHyM: DEM pit correction

CETEMPS Hydrological Model Preprocessor

1367 1367 -4434 1467 1463 1468 1475 1467 1467 1465 1363 1352 1368 +4 🛯 🖌 🖓 🖓 🖓 🖓 🖓 🖓 1390 1408 1465 1464 1461 1475 1485 1485 1500 1516 1522 1525 1458 1318 26 4300 1300 4328-4395-1440 1482 1482 1489 +## 1296 4997 1297 4980 1408 1412 1427 1388> 1268 1368 1398 1298 1298 1298 4860 1879 4840-1860-1870 1870 1870 4868 1876 1366 1468 1465 1467 1368 1363 1363 <del>4982 4984</del> 1468 1465 1469 1362 <del>488</del> बिद्ध फिर्ड 19हर 18हर 17हर 17हर 17हर 17हर 18हर 18हर 17हर 17हर 18हर 18हर 18हर 18हर 18हर 18 1560 1983 19/2 1744 1787 1784 1784 1903 1935 1986 1988 1988 1990 1890 1980 4102 1565 1662 1765 4727 4700 4797 1727 1680 1367 1617 4920 1853 1955 1986 1985 

Flow Direction Map - 6633 of 6633 no-flow points were corrected.

movie

## CHyM: DEM pit correction

CETEMPS Hydrological Model Preprocessor



Flow Direction Map - 6633 of 6633 no-flow points were corrected.

movie

11644





Î













E. Coppola, B. Tomassetti, L. Mariotti, M. Verdecchia and G. Visconti, Cellular automata algorithms for drainage network extraction and rainfall data assimilation, Hydrological Science Journal, 52(3), 2007

TIRI

Earth System Physics, The Abdus Salam International Centre for Theoretical Physics

17 89677 48337 47096 60866 54616 68375 62136 65896



Po river (Italy) (1 km resolution; 110945.0 km2 drained area) 5 years RegCM-ERA40 simulation 1995-2000 3 years RegCM-ECHAM5 A1B scenario simulation 1980/82 -2080/82

Niger - Volta river (West-Africa)(9.5 km; Niger 2494084 km2, Volta 434235 km2 drained area)

3 years RegCM-ECHAM5 A1B scenario simulation 1980/82 -2080/82

Han-Kum-Nakdong river (Korea)(740 m; Han 19678 km2, Nakdong 15848 km2, Kum 6769 km2 drained area)

3 years RegCM-ECHAM5 A1B scenario simulation 1980/82 -2080/82

Yellow – Yangtze river (China)(5.7 km, Yellow river 360431km2, Yangtze 564594 km2)

1 years RegCM-ECHAM5 A1B scenario simulation 1961-2071



#### RegCM-ERA40





#### RegCM-ECHAM 25km A1B scenario 1950-2100









#### **Temperature**



PREC RegCM ECHAM (2071/2100- 1961/90) change % (MAM)PREC RegCM ECHAM (2071/2100- 1961/90) change % (SON)





**Precipitation** 

Earth System Physics, The Abdus Salam International Centre for Theoretical Physics

PREC ReaCM ECHAM (2071/2100- 1961/90) change % (DJF) PREC ReaCM ECHAM (2071/2100- 1961/90) change % (JJA)

#### A1B scenario simulation



-100

-75 -50

movie



-100 -75

-50

-25



#### Station annual discharge cycle

•Shift of the spring peak toward the early part of the season

•Decrease of runoff during the summer months (Jul. and Aug.)

Increase of the autumn runoff



#### RegCM-ECHAM 50km A1B scenario 1950-2100



Precipitation



-20 -40 -60 -20 -40 -60

-80

20 10 5

> -10 -20 -40 -60

#### A1B scenario simulation





#### Annual discharge at the river mouth



•Decrease of runoff during in the second rainy season



#### RegCM-ECHAM 20km A1B scenario 1950-2100





#### A1B scenario simulation



movie



#### Annual discharge cycle at the river mouth



No big change is found neither in the annual mean discharge nor in the discharge timing

#### RegCM-fvGCM 20km A2 scenario 1950-2100

#### China







#### A2 scenario simulation





MJJAS precipitation change 2071-1961



movie



#### Annual discharge at the river mouth



Shift of the OCT-NOV peak toward the early part of the summer for the Yellow river and from summer to spring for the Yangtze river



### **Summary**

Effects of climate change on precipitation are reflected in runoff changes in a highly non-linear way

Snow dominated climate change scenarios seem to show a shift in the peak discharge toward the early part of the year

Western African monsoon dominated areas seem to show an increase of runoff during the first rainy season

Runoff change in monsoon regions like Korea is weak



# Thanks !

Sun and the

Laizhou Wan

2 May

m

